American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)
ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Physico-chemical Analysis of Groundwater Around Mai-Bela, Asmara, Eritrea

Nahom Tesfalem[a*], Aron Tesfamariam[b], Abel Okbaslasie[c], Kibrom Tesfay[d]

[a,b,c,d]*Eritrea Institute of Technology, Asmara, Eritrea*
[a]*Email: nahomtesfalem6@gmail.com*
[b]*Email: arontesfamariam34@gmail.com*
[c]*Email: abelokbaslasie@gmail.com*
[d]*Email: ktesfay206@gmail.com*

Abstract

Groundwater quality studies were carried out inAsmaraaround Mai-Belaan area having a long history of waste water irrigation. The objective of this study is to identify the quality of groundwater where groundwater is used for domestic and agricultural purposes in Mai-Bela area. Samples from five locations were collected and analyzed. The present investigation is focused on the determination of Physico-Chemical parameters such as temperature, electrical conductivity, pH, hardness, total dissolved solids (TDS), alkalinity, salinity,sodium, potassium, calcium, magnesium, iron, manganese, bicarbonate, chloride, sulphate, nitrate, nitrite, ammonia, chemical oxygen demand (COD)and toxic metal determinations. Groundwater suitability for domestic and irrigation purposes was compared with World Health Organization (WHO) and Food and Agriculture Organization (FAO) standards. Most of the physico-chemical parameters were found above the permissible limit and so do the toxic metals except for COD, pH, temperature, Al, Cd, Cr, Cu and Zn which were found slightly lower than the standard limit which indicate the groundwater in most of the study sites were not suitable for drinking and irrigation purposes. This therefore, calls for appropriate treatment measures before the consumption of these waters by the populace to avoid long term accumulated health problems of these pollutants.

Keywords: Groundwater; Physico-Chemical parameters; pollutants; toxic metals.

----

* Corresponding author.

1. Introduction

Water is an important constituent of the ecosystem which is essential component of life. On earth 97.2% of water is salty and 2.8% is fresh water from which about 20% constitutesgroundwater [1]. Rapid growth of industrialization, population, and urbanization spoil the groundwater. The term groundwater pollution was defined in the International glossary of hydrology as: “Addition of pollutant to water.”(Pollutant was defined in the International glossary as: “A substance which impairs the suitability of water for a considered purpose ”[2]. Groundwater is used for domestic and industrial water supply and also for irrigation purposes in all over the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization. However, groundwater could be chemically, physically or microbiologically contaminated. According to WHO, about 80% of all the diseases in human beings are water borne diseases [3]. Ground water contamination is nearly always the result of human activity. There are many possible sources of chemical contamination. These include wastes from industrial chemical production, metal plating operations, domestic wastewater and pesticide runoff from agricultural lands. It is known that wastewater, depending on its source, contains dissolved salts, organic matter, oil, grease, detergents, essential minerals and toxic heavy metals…etc [4]. Asmara is the capital city and largest settlement of Eritrea. Home to a population of around 800,000 inhabitants, it sits at an elevation of 2,325 meters. The city is located at the tip of an escarpment that is both the north western edge of the Eritrean highlands and the Great Rift Valley in neighboringEthiopia. Whereas Mai-Bela is a river with a long history of wastewater drainage which originates from the heart of Asmara, containing the house hold and industrial effluents, and flows through the western escarpment which is a major tributary of the Anseba river. Finally Anseba river after flowing for 346 Km it merges with the Barka river near the border of Sudan and flow to Sudan altogether. The area around the waste water drainage of Asmara is called Mai-Bela which is well known for the agricultural practices, the waste water is the main source of water, and its characteristic unpleasant smell evolved from the effluent. It is expected that since the wells are located near the wastewater drainage in Mai-Bela, Asmara for long time; the ground water may be contaminated with inorganic and organic pollutants. Therefore, attention is paid to investigate the effect of domestic wastewater seepage on the physical and chemical properties of groundwater around Mai-Bela, Asmara. The sources of groundwater contamination are many and varied because, in addition to natural processes, practically every type of facility or structure installed by man and each and every human physical activity may eventually cause groundwater quality problems (Figure 1).The vulnerability of groundwater, especially of groundwater supplies, to existing or potential sources of contamination underscores the need for a systematic, detailed process by which these potential threats can be recorded and evaluated.

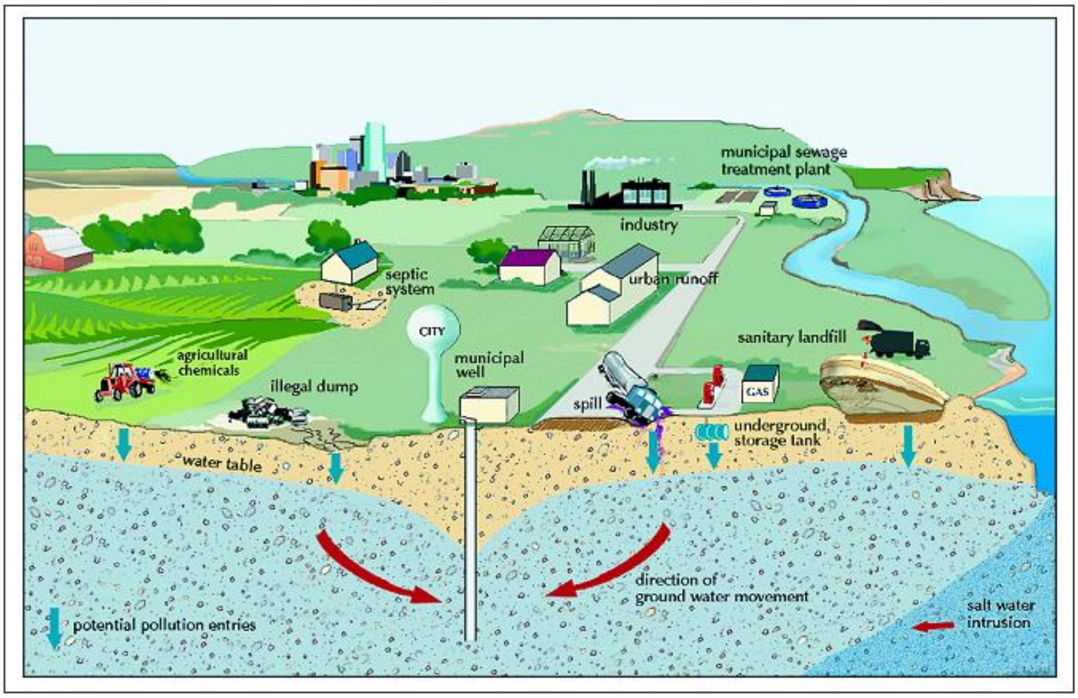

Figure 1: Some potential sources of groundwater contamination taken from[2]

In this study, groundwater samples were collected from five wells around Mai-Bela, Asmara. Various physico-chemical parameterswereanalyzed and compared with the WHO guideline values set for potable and other purposes of water. Based on the results of the analysis, the recommendations were made.

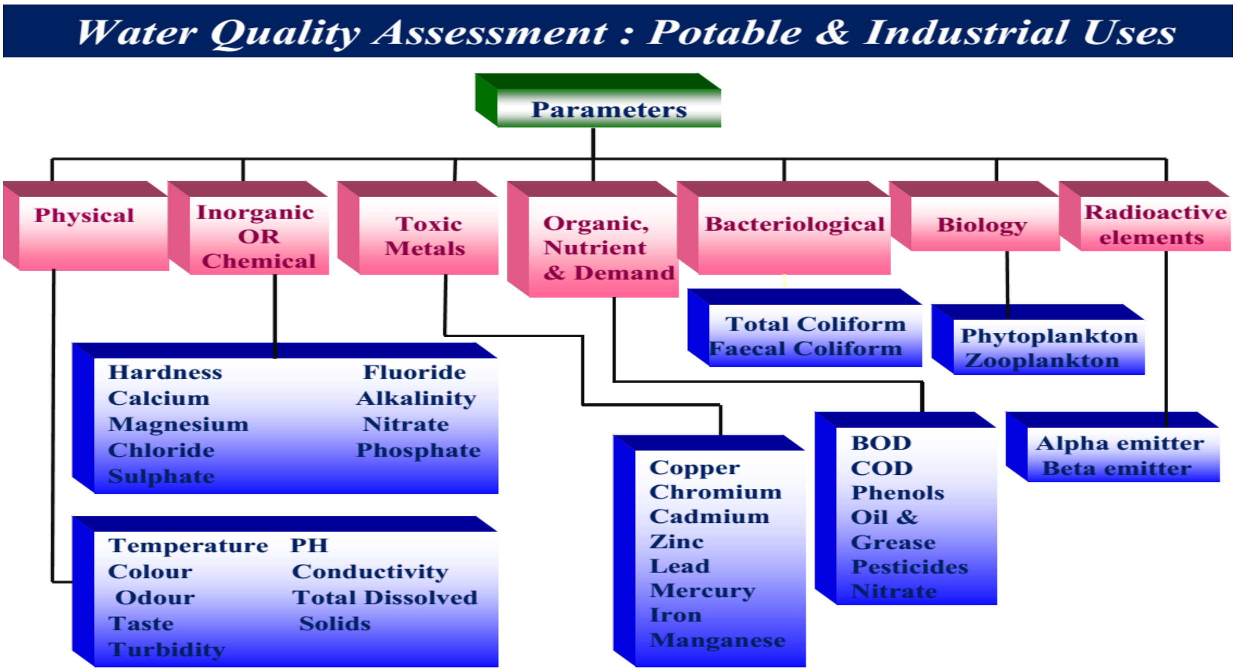

Figure 2: Flow chart of water quality assessment parameters[5].

2. Literature review

2.1 International status

Several research papers were referred on Physico-chemical analysis of ground water as well as surface water of different districts, cities and countries. Different Physico-chemical parameters were compared with WHO standards to determine the quality of water if it is suitable for drinking, irrigation and other domestic purposes [4]. carried out studies on domestic wastewater effect on the pollution of the ground water in rural areas in Egypt. The main aim was to analyze groundwater pollution as a consequence of wastewater discharging into permeable underground septic tanks. In the study, groundwater (from a well used for irrigation and drinking) samples were taken at the pumping level. A series of chemical analysis was carried out for water samples at different periods of time. Harmful effects of wastewater on the chemical compositions of groundwater were detected. In addition it was explained that, toxicity and chemistry of heavy metals increases in groundwater. Groundwater quality studies were carried out [6] in and around Namakkal District, Tamilnadu, India. The objective of the study was to identify the quality of groundwater especially in the town and rural areas where groundwater is used for domestic and agricultural purposes. Groundwater suitability for domestic and irrigation purposes was examined by using WHO standards, which indicates the groundwater of few areas, were not much suitable for drinking purposes. The work aimed to assess the quality of drinking water in some of local commercial water treatment plants in Jeddah city, five samples were taken from different water plants subjected to physical, chemical and biological analysis. The parameters Theseresults were compared with the maximum level of the World Health Organization (WHO), Saudi Specification and Standardization organization (SASO) and Gulf Countries Standards for drinking water (GCS). The results showed a compliance with the water quality standards regarding the physical, chemical and biological characteristics. Statistical tools such as average, standard deviation and the correlation coefficient (r), were also calculated for these water quality characteristics [7]. The assessment of the groundwater quality was carried out in the different wards of Indore City. The analysis was aimed at assessing the water qualityindex (WQI) for the ground water of Indore City and its industrial area .The ground water samples of all the selected stations from the wards were collected for a physiochemical analysis. The obtained results were compared with Indian Standard Drinking Water specification IS: 10500-2012. The study of physico-chemical and biological characteristics of this ground water sample suggests that the evaluation of water quality parameters as well as water quality management practices should be carried out periodically to protect the water resources [3]. The physico-chemical parameters of water from 12 boreholes in 12 different communities in Umuahia North Local Government Area, Abia State, Nigeria were determined [8] within the period of six months (February to July, 2011) to investigate their quality. The results of the study indicated that the water sources were contaminated and unfit for human consumption. It showed that, appropriate treatment measures before the consumption of the water should be done by the populace to avoid long term accumulative health problems of the pollutants present. Recommendations on the strategies to reduce/eliminate some of the pollutants were made [9], carried out the correlation and regression analysis on 12 physico-chemical parameters of groundwater revealed that all the parameters were more or less correlated with one another. A linear regression analysis technique has been proven to be a very useful tool for monitoring groundwater and has a good accuracy. The linear correlation is very useful to get fairly accurate idea of the quality of the groundwater by determining just a few examples experimentally and then predicting the remaining from correlation equation.[10] presented the levels of physico-chemical parameters in the well water samples collected from Dass, Kaltungo and Langtang North in Nigeria. The results showed that most of the parameters determined did not exceed the permissible limit of the WHO. The groundwater and river water from Lagbe town in Benin Republic were collected and analyzed [11] for physico-chemical and microbiological parameters. The surface water samples were treated with alum, *Moringa oleifera* seeds powder and the combination of alum and *Moringa oleifera* seeds. The groundwater samples analyzed were contaminated by nitrate due to the proximity of septic tanks next to wells for which the waters were sampled. The surface water turbidities were high in some places and mostly rich of organic matter. The groundwater and surface water presented a microbial pollution of faecal origin. It was recommended that those waters are not potable and cannot be consumed without adequate treatment. All standard permissible limits were adopted from WHO permissible limits [12].

2.2 Physical Aspects of Water

2.2.1 Temperature

Temperature is one of the important factors in an aquatic environment for its effects in chemical and biological reactions in organisms. The change in atmospheric temperature with change in season brought corresponding changes in water temperature. The difference in atmospheric temperature and groundwater temperature are under the influence of high specific heat of water. According to WHO standards temperature of groundwater should not exceed 25^{o}C to use it for drinking purpose [13,14]

2.2.2 pH

The pH is a measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. It has no direct adverse effect on health, however, a slight low value, below 6.5 will produce sour taste and slight higher value above 8.5 shows bitter taste. A pH range of 6.5 – 8.5 is normally acceptable as per guidelines suggested by WHO. As the pH value of water goes far apart from the suggested guideline it shows corrosive nature [3,10,13,14,15,16].

2.2.3 Electrical Conductivity (EC)

Electrical Conductivity is the measure of capacity of a substance or solution to conduct electric current. It is a useful toolto evaluate the purity of water. It is an excellent indicator of Total Dissolved Solids (TDS) andsalinity that affects the taste of potable water. The variation in electrical conductivity is based on sedimentary structure and composition of rock. Chemically pure water does not conduct electricity. Any rise in the electrical conductivity of water indicates pollution. It is a good and rapid measurementof contamination. Groundwater contamination often shows higher values of ECdue to the presence of ions like OH^{-}, $CO3^{-2}$, Cl^{-}, Ca^{+2}etc. As per the WHO and FAO standards the maximum permissible limits are 1000µS/cm, for drinking, and 3000µS/cm, for irrigation, purposes respectively [3,10,13,14].

2.2.4Total Dissolved Solids (TDS)

Total Dissolved Solids is a measure of the combined content of all inorganic and organic substances contained in waterTotal Dissolved Solids may be considered as salinity indicator forclassification of groundwater. The TDS in groundwater is due to the presence ofCalcium, Magnesium, Sodium, Potassium, Bicarbonate, Chloride and Sulphate ions.Primary sources for higher TDS in the groundwater might be due to agricultural runoff, discharge of waste from industries and other human activities. According to WHO permissible limit for TDS is 500 mg/L [3,10,13,14,16].

2.3 Chemical aspects of water

2.3.1 Total Hardness (TH)

Hardness is caused by multivalent metallic cations. The principal hardness causing cations are the divalent calcium and magnesium ions. The hardness in water is derived largely from contact with the soiland rock formations. Calcium and magnesium are the greatest portion of the hardnessoccurring in natural waters. Hardness of water is objectionable from the point ofviewwater use for laundry and domestic purposes since it consumes a large quantity of soap. Classification of groundwater Hardness is given in Table.1 whereas the maximum permissible limit of WHO is 500 mg/L.

Table 1: Classification of groundwater Hardness

TH Concentration (mg/L)	Classification
0-60	Soft
61-120	Moderately Hard
121-180	Hard
>180	Very Hard

2.3.2Total Alkalinity

The alkalinity of water is a measure of its capacity to neutralize acids. Alkalinity values provide guidance in applying proper dose of chemicals in water and wastewater treatment processes particularly in coagulation and softening. The alkalinity in natural water is caused by bicarbonates, carbonates and hydroxides and can be ranked in order of their association with high pH values. However, bicarbonates represent the major form since they are formed in considerable amounts due to the action of carbonates with the basic materials in the water. Maximum permissible limit for the total alkalinity is 250 mg/L[3,14].

2.3.3 Chloride

Naturally, chlorides are found as salts such as sodium chloride (NaCl), potassium chloride (KCl), and calcium chloride ($CaCl_2$). Chlorides are leached from different rocks into soil and water due to weathering. The chloride concentration can be used as an important parameter for detection of contamination by sewage. High chloride content in watermay harmmetallic pipes and structures aswell as growing plants. Chlorides in excess impart the salty taste to water and people not accustomed to high chloride are subjected to laxative effect. Chloride as anion occurs in all natural waters in widely varying concentrations. The origin of chloride in ground water is from weathering and leaching of sedimentary rocks, domestic and industrials wastes discharge, municipal effluences etc. It is advisable to use water withchloride concentration less than 600 mg/Land 350 mg/L for drinking and irrigation purpose respectively as per the WHO and FAO standard limits [3,10,14,15,16].

2.3.4Sulphate

Naturally, Sulphates are found in various minerals, such as epsomite ($MgSO_4 \cdot 7H_2O$), gypsum ($CaSO_4 \cdot 2H_2O$) and barite ($BaSO_4$). Such dissolved mineral constituents increases the mineral content in drinking water. Sulphates find their way into water through smelters in mines, also from Kraft pulp in paper mills, tanneries and textile mills. Sulphate of potassium, magnesium and sodium are highly soluble in water, while barium, calcium and various other heavy metal sulphates are less soluble. Sulphur dioxide & Sulphur trioxide also contribute to the Sulphate content of water to some extent. Cathartic effects are commonly reported to be experienced by people consuming drinking water containing sulphate with higher concentrations. Dehydration is another common side effect resulted by the ingestion of large amounts of sodium or magnesium sulphate containing water. So water with concentration above 400 mg/L is unfavourable for drinking [3,14,15].

2.3.5Nitrate

Relatively little amount of the nitrate found in natural waters is of mineral origin, most of it coming from organic and inorganic sources, the former includes waste discharges and the latter comprises chiefly artificial fertilizers. However, bacterial oxidation and fixing ofnitrogen by plants can both produce nitrate. Interest is centered on nitrate concentrations forvarious reasons. Most importantly, high nitrate level in water to be used for drinking will render it hazardous to infants as it induce the "blue baby" syndrome (methaemoglobinaemia). The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite [see also below] which reacts with blood hemoglobin to cause methaemoglobinaemia. As per the WHO guidelines the nitrate concentration of potable groundwater should not exceed 50 mg/L [3,10,14,16,17].

2.3.6 Nitrite

Nitrite ion exists normally in very low concentrations and even in waste treatment plant effluents levels are relatively low, principally because the nitrogen will tend to exist in the more reduced (ammonia; NH_3) or more oxidized (nitrate; NO_3^-) forms. Because nitrite is an intermediate in the oxidization of ammonia to nitrate, because such oxidation can proceed in soil, and because sewage is a rich source of ammonia nitrogen, waters which show any appreciable amounts of nitrite are regarded as being of highly questionable quality. Levels in unpolluted water is normally low, below 0.03 mg/L. Values greater than this may indicate sewage pollution. The significance of nitrite (at the low levels often found in surface waters) is mainly as an indicator of possible sewage pollution rather than as a hazard itself although, as mentioned above, under "Nitrate”, it is nitrite rather than nitrate which is the direct toxicant. There is, accordingly, a stricter limit for nitrite in drinking waters which is 0.5 mg/L. Concentration above this limit can cause methaemoglobinaemia. In addition, nitrites can give rise to the presence of nitrosamines by reaction with organic compounds and there may be carcinogenic effects [14].

2.3.7Chemical Oxygen Demand (COD)

COD is the oxygen required by the organic substances in water to oxidize them by a strong chemical oxidant. COD is related to organic and inorganic pollutants which causes unfavorable conditions for the growth of microorganisms. It is originated by natural or, more probably, added organic matter. COD measurement is useful as it gives a good figure about the water quality, it is applicable to wastewater and also heavily polluted waters. It has no direct hazard implication. The ideal value of the COD for drinking is 75 mg/L according to [14].

2.4.8 Ammonia

Ammonia is generally present in natural waters, though in very small amounts, as a result of microbiological activity which causes the reduction of nitrogen-containing compounds. When present in levels above 0.1 mg/L N, sewage or industrial contamination may be indicated. From the viewpoint of human health the significance of ammonia is marked because it indicates the possibility of sewage pollution and the consequent possible presence of pathogenic micro-organisms [14,18]

2.4.9 Salinity

Salinity is the saltiness or dissolved salt content (such as sodium chloride, magnesium and calcium sulfates, and bicarbonates) of a body of water. Salinity is an important factor in determining many aspects of the chemistry of natural waters and of biological processes within it, and is a thermodynamic state variable that, along with temperature and pressure, governs physical characteristics like the density and heat capacity of the water[14].

2.3.10 Sodium Absorption Ratio (SAR)

If the proportion of sodium is high in groundwater for irrigation purpose, it can destroy soil structure. A simple method for evaluating the values of high-sodium is the Sodium Adsorption Ratio[14,16].

Table 2: Classification of the SAR values

Type of water	**Classification**	**SAR value**
Low	Excellent	**<10**
Medium	Good	**10-18**
High	Doubtful	**18-26**
Very high	Unsuitable	**>26**

2.4 Toxic Metals

Metallic elements (mercury, arsenic, cadmium, barium, selenium, aluminum, tin and lead)which are able to induce toxicity even at lower levels of exposure are considered as systemic toxicants whereas such metals are called toxic metals. Occupying the top position on the list of hazardous substances, the following sections provide insight into the mechanisms through which these metals exert their toxicity within the body of living organisms.

2.4.1 Manganese

Manganese can be termed as a metal which is one of the most abundant on earth. Though it is not found in its natural form, it is actually a component of more than 100 minerals. Manganese can exist in 11 oxidative states. Manganese occurs naturally in many surface water and groundwater sources and in soils that may erode into these waters. However, human activities are also responsible for much of the manganese contamination in water in some areas. Ambient manganese concentrations in seawater have been reported to range from 0.4 to 10 μg/L, with an average of about 2 μg/L. Levels in fresh water typically range from 1 to 200 μg/L. Manganese has a median level of 16 μg/L in surface waters. Higher levels in aerobic water is usually associated with industrial pollution. Concentration of manganese in drinking water above 0.5 mg/L is beyond the tolerable limit of our body and results in generation of aesthetic effect [14,15,19].

2.4.2 Iron

Iron is present in significant amounts in soils and rocks, principally in insoluble forms. However, many complex reactions which occur naturally in ground formations can give rise to more soluble forms of iron which will therefore be present in water passing through such formations. Appreciable amounts of iron may therefore be present in ground waters. Severe problems can be caused in drinking water supplies by the presence of iron although there is normally no harmful effect on people consuming water with significant amount of iron. Rather, the problems are primarily aesthetic, as the soluble (reduced) ferrous (Fe^{2+}) iron is oxidized in air to the insoluble ferric (Fe^{3+}) form, resulting in color or turbidity (or, in severe cases, precipitate formation). Laundry becomes stained if washed in water with excessive iron, and vegetables likewise become discolored on cooking. Taste problems may also occur. When water rich in iron is used to make tea (in which tannins are present) there may be a reaction giving rise to off-color which may in severe cases resemble that of ink. So to avoid this problems WHO stated the maximum permissible limit to be 0.3mg/L [14,15].

2.4.3 Mercury

Mercury, considered the most toxic heavy metal, has become part of the environment owing to anthropogenic activities including agriculture, municipal wastewater discharge, mining, incineration, and discharges of industrial wastewater. Having different bioavailability and toxicities associated with them, it exists in nature as inorganic salts ,an elemental or metallic form, in andasorgano-mercurial compounds in which their toxicity varies in ascending order (ionic < metallic <organic).Water containing mercury concentration above 1 μg/L is hazardous to human being. It affects the unborn and children to a greater extent. Yet it has been proven to cause permanent brain and neurological damage and also it is known to cause developmental problems [14,20].

2.4.4 Arsenic

Arsenic, a naturally occurring metalloid, has ubiquitous distribution in the environment. Despite being the 20th most abundant element in the earth's crust, it ranks highest on the list of hazardous substances toxic to public health. Arsenic is used in the glass and semiconductor industries and as a fungicide in timber processing. Its existence as elemental, inorganic, and organic in large quantities all over the world makes it one of the most important metals, having adverse effects on the environment and human health. Very toxic to human being where some arsenical compounds are carcinogens and some are with a variety of other health effects. The WHO states that inorganic arsenic is a documented human carcinogen, and that a relatively high incidence of skin and possibly other cancers that increase with dose and age has-been observed in populations ingesting water containing high concentrations of arsenic. WHO proposed that the maximum permissible limit of arsenic for drinking and irrigation purpose 10 and 15 µg/L respectively above which is very hazardous to human health and plant growth [14,16,20].

2.4.5 Lead

Lead (Pb) is one of the most abundant natural substances on earth. Owing to its physical properties including low melting point and high malleability, it has widespread in industries. In terms of usage, it ranks fifth on the list of metals. Its use is associated with more than900 industries, including mining, smelting, refining, battery manufacturing, and so on. In addition to industry, it has applications in fertilizers and pesticide used for agriculture purposes, and in improving the octane rating of gasoline in vehicular traffic systems. Exposure to lead in drinking water can cause damage to the central and peripheral nervous system resulting to learning disabilities, shorter stature, impaired hearing, and impaired formation. For pregnant women, it is stored in bones along with calcium and during maternal calcium release it can also cross the placental barrier exposing the fetus: - reduced growth of the fetus and premature birth generally named as 'Toxic cumulative poison'. Lead is one of the most commonly determined heavy metals. Because it accumulates in body tissue it follows that strict limits on its presence in raw and finished drinking waters must be imposed. According to WHO and FAO limits lead concentration below 10 and 25 µg/L is ideal for drinking and irrigation respectively. Usage of groundwater above this limit leads to the above mentioned problems [14,19,20].

2.4.6 Cadmium

Major sources of this metal are in ores, including those of zinc. Cadmium in water is due nearly exclusively to industrial discharges (e.g. from electroplating, paint-making, manufacture of plastics etc...)and landfillleachates. It is highly toxicsoprolonged exposure to drinking of cadmium contaminated water can cause chronic anemia. Under such circumstances Cd manifest in our body result in cancer and cardiovascular diseases. Hence severe restrictions on its concentrations in water must be used [14,19,20].

2.4.7 Aluminium

Aluminum is one of the most abundant elements in the earth's crust. Aluminum sulphate is very widely used for color and colloid-removal in the treatment of waters for drinking. Previously it was not considered to be a significant health hazard in drinking waters, aluminum has more recently been shown to pose a danger to persons suffering from kidney disorders. It causes neurological problems and has been cited as a contributory factor to Alzheimer disease. Its concentration should not exceed 200 µg/L as per the WHOguidelines [20].

2.4.8 Barium

Naturally occurring mineral (e.g. in barytes). According to the WHO guidelines, food and water are the main source of barium intake by humans, where barium occurs in drinking water supplies contribute a significant proportion of total intake. Excessive amounts of barium can cause muscular, cardiovascular and renal damage. Although not markedly toxic, barium in excess quantities is clearly undesirable. As per the WHO guidelines the maximum permissible limit is 700 µg/L for drinking purpose [14].

2.4.9 Chromium

Natural occurrence is in ore, but chromium arises in waters from discharges from electroplating, tanning, textile, paint and dyeing plants. Chromium is toxic, to a degree which varies with the form in which it occurs, whether as the trivalent Cr^{III} or the hexavalentCr^{VI} form. The latter is considered the more hazardous [14,20].

2.4.10 Selenium and Tin

Weathering of rocks/soils is the main source of selenium, but major environmental sources are man-made. This metal is toxic element except it is found in a relatively small concentrations. Major tin sources are its ores, effluents from tin-plating and alloy manufacture. Little concern regarding tin itself and its inorganic compounds, but it is very toxic if it is present in its organometallic compound. High to very high toxicity, depending on the compound structure. Triorganotins are very toxic. Tri-*n*-alkyltinsare phytotoxic and therefore cannot be used in agriculture [14].

3. Statement of the problem and significance of the study

There is fresh water scarcity and greater demand for water; so it's credible that people are using ground water for different purposes like irrigation, drinking water and other domestic purposes. Irrigational practice using groundwater is common next to wastewater irrigation. This is not an option but a condition agriculturalists are facing because of water scarcity. And from previous literature review, it's known that ground water around municipal sewage areas can be physically, chemically and biologically contaminated, which can be seen as a series problem and threatening to human welfare. Due to lack of awareness of the community and negligence of some agriculturalists water from dug wells around Mai-Bela and wastewater from Mai-Bela is being used for irrigation and other domestic purposes. Nobody took responsibility to examine if the water meets any of the health standards. So understanding the vulnerability of the groundwater to contamination due to the presence of wastewater drainage in Mai-Bela area. Therefore, in this study, the attention is paid to investigate the effect of municipal wastewater seepage on the physical and chemical properties of groundwater around Mai-Bela, Asmara. This research focuses mainly on analyzing the physico-chemical properties and the toxic metals of the groundwater around Mai-Bela and find the suitability of the ground water for drinking, irrigation and other domestic purposes. There are no that much efforts made to study regarding the quality of water in this research study site. Therefore this study could be a baseline for further studies, to draw significant recommendations for the Mai-Bela area administration.

4. Objective

The general objective of this study is:

- Qualitative and Quantitative determination of ground water around Mai-Bela, Asmara.

Specific Objectives of this study are:

- Analysis of Physico-Chemical parameters of ground water around Mai-Bela.
- To assess suitability of the groundwater for drinking and other domestic purposes.
- To assess suitability of the ground water for irrigation purpose.
- To give suggestions and recommendations based on the results of the analysis to the Mai-Bela area administration.

5. Materials and Methodology

5.1 Sampling

The objective of sampling is to collect representative samples. Representative sample means a sample in which relative proportions or concentrations of all pertinent components would be the same as in the material being sampled. Even though the effluent flows for a long distance but the areas with large population residence and intensive agricultural practices were concerned in this study. So the area selected extend from Vilajo to Weki-Duba. Only five sample wells were selected from the area mentioned and near the river basin. The five wells were selected because they were well built, have been used for a long period of time and most importantly there was no rain water, no rain water flood and no other contaminant entering the wells from the ground but only the ground water. So the sample selection method was convenient sampling method. But the remaining once were only temporary open wells so they were excluded from the study. One sample site was located in a residential area so that comparison between the samples from the irrigated area and the residential area can take place.

5.1.1 Sample Location

For the purpose of this study, the water samples were collected from five wells around Mai-Bela. Four of them were located in irrigated agricultural area and the fifth one is located in a residential area compound. The sampling locations are shown in Table3.

Table 3: Sample locations

Sample Name	Mai-Bela 1	Mai-Bela 2	Mai-Bela 3	Mai-Bela 4	Mai-Bela 5
Sample Code	MB1	MB2	MB3	MB4	MB5
Location	Vilajo	Vilajo	Paradiso	Adi Segdo	Para Duba
GPS Location (Easting)	37P0491554	37P0491517	37P0491318	37P0488387	37P0488067
(Northing)	1696312	1696389	1696507	1696326	1696257
Altitude (m)	2291	2290	2297	2306	2308
Distance from the flow (m)	27	33	115	64	200
Area of location	Irrigated area	Irrigated area	Living area	Irrigated area	Irrigated area

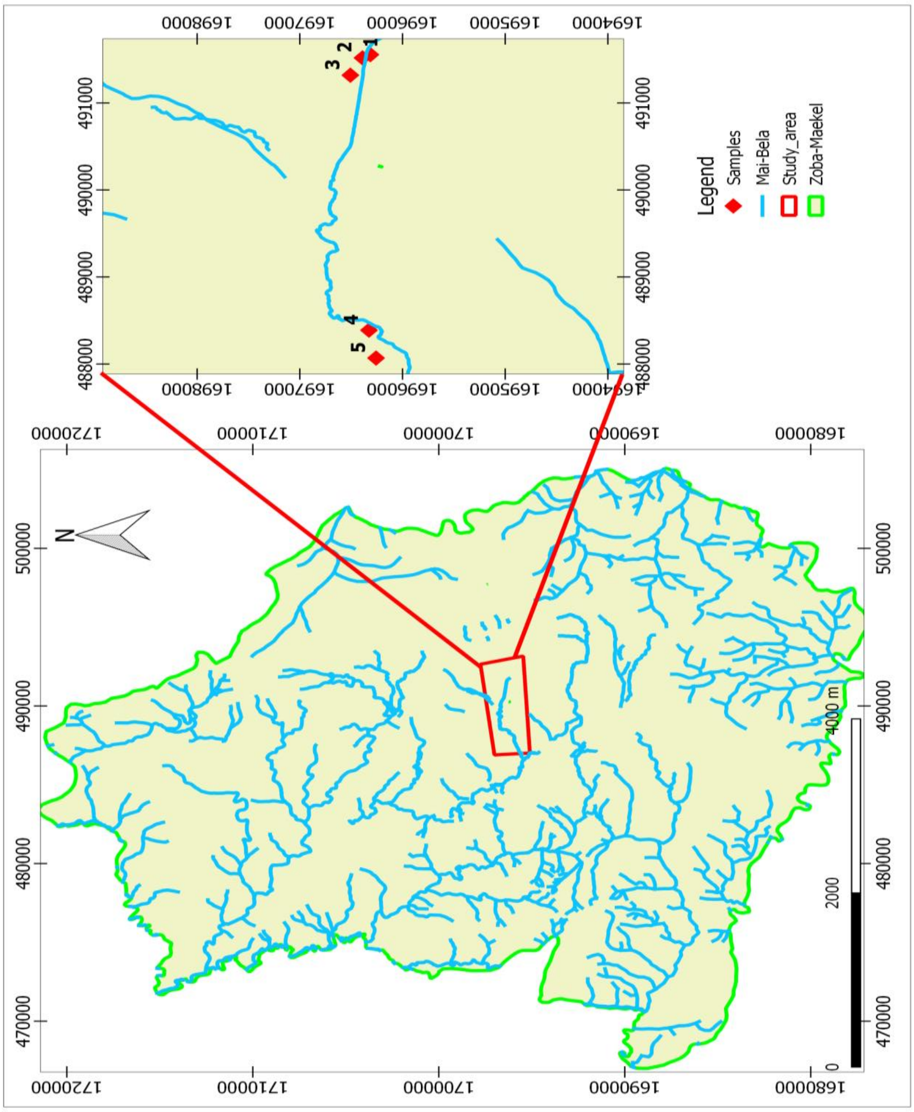

Figure 4: Geographicalmap of the sample locations

5.1.2 Sample Collection

From each site groundwater samples for both physicochemical and toxic metal determination were collected by using polyethylene bottles. The necessary care was made during sample collection and preservation. The bottles were first washed with detergent and then washed with distilled water twice and finally rinsed with nitric acid and made ready for sampling. On the field each sample bottle was first washed several times with the respective well water then filled with the water from each well. Finally, only for the toxic metal determination, each water sample was acidified by adding concentrated HNO_3(1ml of conc. HNO_3 per 100 ml water sample). The acid treated water samples were then placed in refrigerator at 4ºCwaiting for analysis.

5.2 Methods of sample analysis

Totally five samples were collected and analyzed for this study. Out of which four samples were collected from four different wells within the wastewater irrigated area. The fifth sample was taken from a well inside a residential house near the wastewater drainage. The wells are situated at a distances of 27m, 33 m, 115 m, 64 m and 200 m, respectively for wells 1, 2, 3, 4 and 5 from the stream in which the wastewater flows. All the chemicals and standards used during preparation and analysis were of the highest purity analytical grade available. De-ionized water was used throughout the analysis wherever applicable. pH was measured by pH metric method. Electrical conductivity and salinity was determined by using conductometric method. In the total hardness determination, first bromocresol green and methyl red indicator was added to the water samples as the titrate formed light greenish blue color, it was finally determined by titration against EDTA. The indicator reacts with calcium and magnesium ions to yield a wine red colored complex. Two titration methods were adopted to determine the concentration of calcium and magnesium ions in water. One method measures the concentration of calcium ions alone and the second measures the total hardness. The concentration of magnesium ions was calculated as the difference between the two test results. Total alkalinity (TA) and bicarbonate concentrations were estimated by titrimetric methods using phenolphthalein and methyl orange as indicator and sulphuric acid as a titrant. Chloride concentration was analyzed by titration against mercurial nitrate. To measure total dissolved solid (TDS), a dedicated TDS meter was used. Sodium and potassium were determined by flame photometric method. Iron, manganese, nitrate, nitrite, sulphates and ammonia, were determined by spectrophotometric method. Chemical Oxygen Demand (COD) was determined by using photometric method all the above parameters were analyzed in the Water Resource Department, Asmara-Eritrea. Inductively Coupled Plasma Optical Emission Spectroscopy (ICPOES) was used for measuring the heavy metals concentration was determined in the SGS Mineral Service Geochemistry Bisha-Eritrea Laboratory.

6. Limitations of the Study

Even though this study was done as good as possible but there were a number of limiting factors faced.

1. There was no budget funded.
2. It was done in a short period of time
3. Sample size was limited

These were the major limitations but it didn't stop us from obtaining the precise results thanks to all the bodies whom cooperated to accomplish this study.

6. Result and Discussion

6.1 Results

The respective values of all water quality parameters (physicochemical properties, cation and anion content) of the groundwater samples are presented in Tables 4. All the results were compared with standard permissible limit recommended by the WHO and FAO.Results of the heavy metal analysis are given in Table 5. Bar graphs showing the comparison of various physicochemical parameterconcentration levels with WHO standards for various water samples are given in Figure 3-8.

Table 4: Physico-chemical parameters for groundwater samples

	Parameters	WHO Standard	MB1 (sample1)	MB2 (sample2)	MB3 (sample3)	MB4 (sample4)	MB5 (sample5)	FAO Standard
1	pH	6.5-8.5	7.93	7.21	7.58	7.38	7.76	6.5-8.4
2	Temperature/°C	25	22.4	24.1	21.4	19.2	20.5	-
3	EC(μS/cm)	1000	6070	4100	1964	4440	5680	3000
4	TDS(mg/L)	500	4066.9	2747	1315.88	2974.8	3805.6	-
5	TH(mg/L)	500	1404	964	800	1092	1520	-
6	TA(mg/L)	250	812	828	308	380	296	-
7	Salinity (‰)	<0.5	3.3	2.1	0.8	2.3	3	2
8.	Ca (mg/L)	150	313.6	233.6	140.8	344	355.2	-
9	Mg (mg/L)	150	148.8	91.2	107.52	55.68	151.68	-
10	Na (mg/L)	200	737.15	500	79.12	508.76	619.16	-
11	K (mg/L)	12	22.4	17	7.9	17.3	22	-
12	Mn (mg/L)	0.5	0.2	0.9	0.2	0.6	0.6	-
13	Fe (mg/L)	0.3	0.03	0.02	0.04	0.06	0.02	5
14	HCO_3(mg/L)	300	990.64	1010.16	375.76	463.6	361.12	-
15	SO_4(mg/L)	400	675	512	330	525	650	-
16	Cl (mg/L)	600	738	480	220	684	1168	350
17	NO_3(mg/L)	50	496.0032	17.7144	86.3577	347.6451	188.2155	45
18	NO_2(mg/L)	3	0.890425	0.36471	0.147857	0.558569	0.630854	-
19	NH_3(mg/L)	1.5	1.505608	0.522106	0	0.570674	1.238484	-
20	COD(mg/L)	75	25	20	0	5	130	-

N.B.:' –'represents not available, WHO: for drinking purpose. FAO: for irrigation purpose. ‰: per 1000

6.2 Discussion

6.2.1 Physicochemical analysis

6.2.1.1 pH

The test for pH of groundwater sample was carried out to determine whether they are acidic or alkaline in nature. The values obtained where in the range of 7.21-7.93, which is within the range, 6.5-8.5, recommended by WHO for drinking water. Although the values indicate that the groundwater samples are slightly basic, it is in agreement with what was reported by other researchers in similar studies.

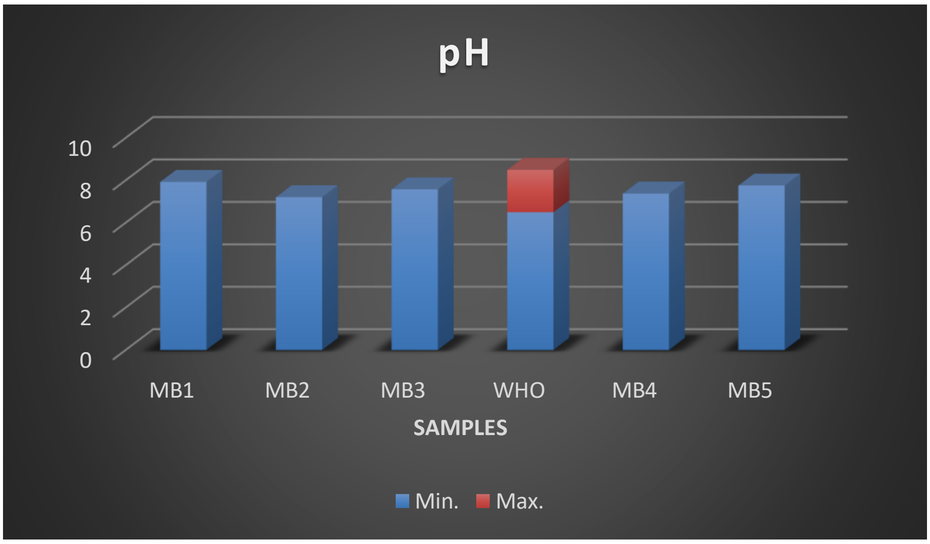

Figure 4: The pH level of the water samples

6.2.1.2 Temperature

Temperature is basically important for the chemical and biological reactions of organisms in water. The temperature of the samples lie between 19.2 to 24.1°C. The values reported in this work are within the range recommended by WHO (25ºC) but the slight difference in the range can be due to the location of the wells and time of measurement.

6.2.1.3 Electrical Conductivity

Electrical Conductivity for the ground water samples ranged from1964 – 6070µS/cm. The most desirable limit of EC in drinking water is prescribed as 1000 µS/cm by WHO. EC of the sample of MB3is lower than the other sample sites, maybe because of the safety usage of water by the people living near that study site. For the other remaining samples the EC values are far higher than the permissible limit proposed by WHO. Significantly, the EC values of samples from area codes MB1& MB5 are greater than the others. This trend has been supported by the total dissolved salts (TDS) values. The source of EC may be due to an abundance of dissolved salts due to poor irrigation management, minerals from rain water runoff and municipal discharges in Mai-Bela. The qualities of water is poor and unsuitable for drinking purpose as well as for irrigation with a limit of <3000 µS/cm.

6.2.1.4 Total Dissolved Solid (TDS)

In this study the TDS values of the water samples from the five sites vary from 1315.88 to 4066.9 mg/Land exceed the maximum permissible limits of WHO (500 mg/L) for drinking purpose. The presence of excessive solids in water may be due to intensive agricultural activities and discharged of domestic wastewater from the capital city of Asmara and geological parameters. The presence of excessive soluble solid materials or solutes in water indicate pollution which can lead to a laxative effect. Similar trend was observed that is with increased electrical conductivity, TDS also increased in all the samples.

6.2.1.5 Total Hardness(TH)

The total hardness values ranges from 800 to 1520mg/L. The recorded values for all studied sites are higher than the permissible limit of WHO (500 mg/L). Higher values are mainly due to high content of calcium salts, which might have been generated from the weathering of dominant limestone rocks in the area. The analysis data indicate that water from the study sites is unsuitable for drinking purposes. The high concentration calcium above the permissible value may lead to precipitate and hyper absorption of oxalates to the blood stream in human and cause renal kidney stone accumulation and also create heart diseases.

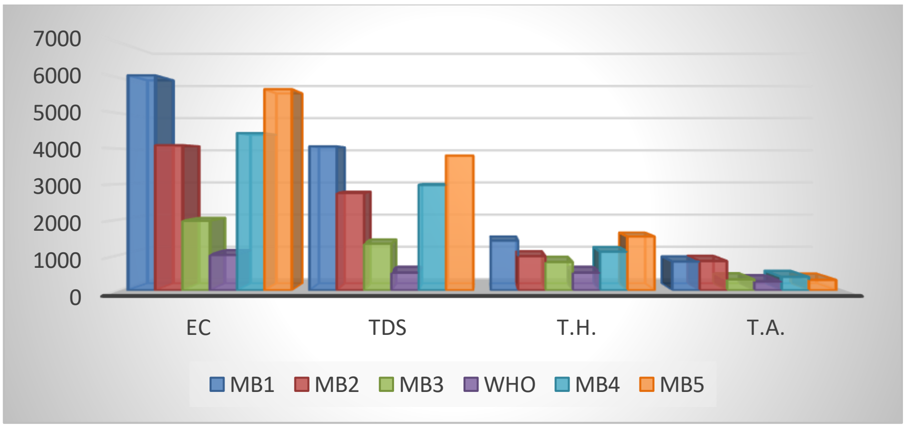

Figure 5: Comparison of EC, TDS, TH and TA concentration levels with WHO standard for various water samples

6.2.1.6 Total Alkalinity(TA)

The total alkalinity of water samples were found in the range of 296 to 828mg/L. In all the samplesthealkalinity exceeds the permissible limit ofWHO (250 mg/L).The alkalinity of samples of MB1&MB2 is higher than the other samples. The high content resulted may be due to the soil background, waste discharge in to the drainage and microbial decomposition of organic matter in the ground water. It maybe also due to the low water table and lower temperature bringing down the rate of decomposition of salts to the minimum, thereby increasing the alkalinity. High alkalinity in water bodies leads to sour taste and salinity.

6.2.1.7 Salinity

The salinity values obtained range from 0.8 to 3.3‰ which exceeds the permissible limit of WHO (0.5 ‰). The increased level of salinity may be due to pollution by sewage, industrial waste and discharge of domestic sewage containing a large amount of chlorides. The higher salinity in all the water samples is also supported by higher TDS, TA and Cl ion values as well. High salinity content in water bodies harms metallic pipes and structure as well as agricultural crops.

6.2.1.8 Calcium and magnesium

Calcium and magnesium are among the most common constituents present in natural water and their salts are important contributors to the hardness of water. In this study, calcium and magnesium contents in mg/L ranged from 140.8 to 355.2 and91.2 to 151.68 respectively. The recorded value for calcium is higher than the permissible limit of WHO and magnesium concentrations lie within the prescribed limit of WHO(150 mg/L for each). Higher values of calcium are related to sewage and weathering calcium rich rocks in the geophysical locations around Mai-Bela. If calcium rich water is used for drinking frequently, it may lead to arise heart diseases and kidney stone formation.

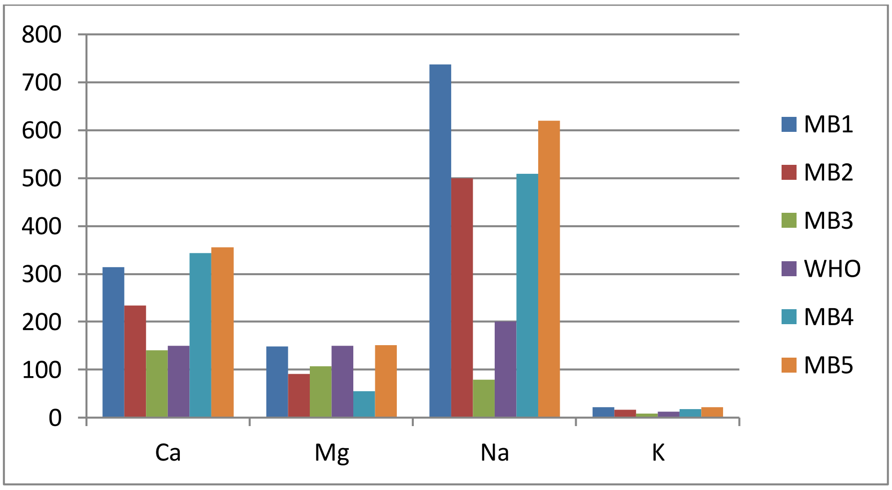

Figure 6: Comparison of Ca^{+2},Mg^{+2},Na^{+} and K^{+}concentration levels with WHO standard for various Water samples

6.2.1.9 Sodium and Potassium

Sodium and potassium concentration lie in the range of79.12 to 737.15mg/L and7.9 to 22.4 mg/L respectively. All the samples have high values of sodium and potassium and exceeded the permissiblelimit of WHO(200mg/L and 12mg/L respectively), except sampleMB3.Especially for sodium the results have a very wide range of concentration among the lowest and highest values obtained, may be due to the poor groundwater management and protection from external contaminants of the people using it. High potassium values may cause nervous and digestive disorder. Water containing more than 200 mg/L sodium should not be used for drinking by those on moderately restricted sodium diet.

6.2.1.10 Iron and Manganese

The Iron and Manganese concentration lie in the range from0.02 to 0.04 mg/L and 0.2 to 0.9 mg/L respectively. Most of the samples were within limits of Iron to be used but for Manganese except for MB1& MB3 all the others were above the limit compared with WHO standards(0.3 and 0.5 mg/L respectively).

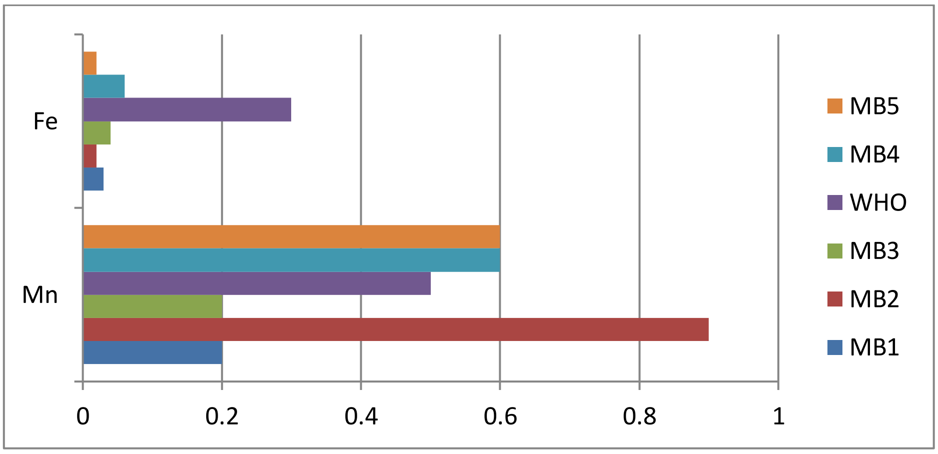

Figure 7: Comparison of Fe and Mn concentration

Levels with WHO standard for various water samples

6.2.1.11 Chloride

The chloride ion concentration found in the study area ranges from 220– 1168mg/L. The permissible limit of chloride is 600mg/L and 350 mg/L according to WHO and FAO respectively. The samples MB2and MB3 were almost within the permissible limit and sample MB5 showed significantly higher value when compared to other samples. The origin of chloride ion in groundwater is from weathering rocks, domestic and discharged industrial wastes, municipal effluence around Mai-Bela.

6.2.1.12 Sulphate

Sulphate ion concentration of the samples lie in the range of330 to 675mg/L. Samples from area codes MB1, MB2, MB4 and MB5 have moderately high values of sulphate and exceeds the permissible limit of WHO, except MB3.These higher values may be related to the discharge of sulphate containing municipal sewages from the city of Asmara and also due to intensive agricultural activities. The high concentration of sulphate, has laxative effect and causes gastro-intestinal irritation.

6.2.1.13 Bicarbonate

The bicarbonate values obtained are ranged from 361.12 to 1010.16 mg/L which exceeds the permissible limit of WHO (300 mg/L). The bicarbonate concentration of MB1 and MB2 is significantly higher than the other samples. High content of bicarbonate in water bodies leads to alkalinity and salinity.

6.2.1.14 Nitrogen- Nitrate and Nitrogen - Nitrite

In this study the nitrate-N and nitrite-N contents in mg/L were ranged from17.71 to 496 and0.15to 0.89respectively.The nitrate content for certain water samples were found to be high except sample MB2, which lies within the permissible limit of WHO (50 mg/L). The nitrite content in all the samples is found to be within the limit (3 mg/L). The biodegradable organic matter, that give these two anions ($N\text{-}NO_2^-$ and $N\text{-}NO_3$) may be derived from the aerobic decomposition of nitrogenated organic waste and industrial wastes dumped into the drainageMai-Bela. The weathering of rocks and agricultural activities are also responsible for the addition of NO_3^- to the ground water. Nitrate as such presents no particular health problems but when it is converted into nitrite in the body it can cause many health problems. Nitrate concentration above 10mg/L is dangerous to pregnant women and poses a serious health threat to infants less than six months of age because of its ability to cause methaemoglobinaemia or blue baby syndrome in which blood loses its ability to carry sufficient oxygen.

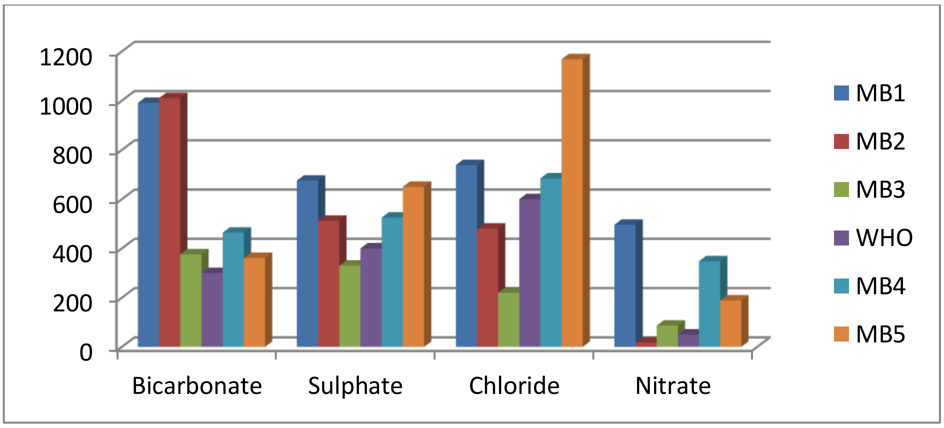

Figure 8: Comparison of HCO_3^-, SO_4^{-2}, Cl^- and NO_3^-

Concentration levels with WHO standard for various water samples

6.2.1.15 Ammonia

Concentration of ammonia ranges from 0 to 1.51 mg/L. The sample MB3 was free from ammonia. Its content in the remaining samples is within the permissible limit of WHO (1.5 mg/L). Ammonia can occur in ground water from agricultural activities, animal manure and waste water drainage. Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution.

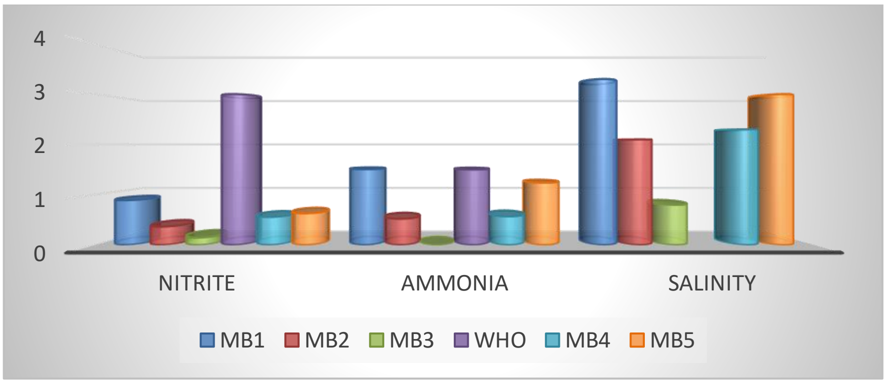

Figure 8: Comparison of NO_2^-, NH_3, and Salinity Concentration levels with WHO standard for various water samples

6.2.1.16 Chemical Oxygen Demand (COD)

COD values fell below permissible limit WHO (75 mg/L) in all the samples except sample MB5.The COD value of sample MB5 is significantly higher which may be due to the presence of chemicals that are oxygen demanding in nature coming from the different human activities. This could be an indication of organic pollution from different agricultural fertilizers brought by the runoff into the sewage around Mai-Bela. Sample MB3was free from oxygen demanding chemicals.

6.2.2 Toxic Metal Analysis

Table 5: Toxic metal analysis for ground water (in µg/L)

SN	Toxic Metals	WHO	MB-1	MB-2	MB-3	MB-4	MB-5	FAO
1	Al(µg/L)	200	123	60.4	50.2	102	106	5000
2	As (µg/L)	10	95.4	10.4	42.8	31	27.1	15
3	Ba(µg/L)	700	68.6	61.5	90.4	151	60.9	-
4	Cd (µg/L)	3	2.59	1.02	1.84	1.8	2.75	7
5	Co (µg/L)	-	1.22	2.33	0.95	0.83	1.82	50
6	Cr (µg/L)	50	22.5	2.57	20.1	22.3	20.6	100
7	Cu (µg/L)	2000	23.8	8.65	3.28	26.8	31.5	200
8	Hg (µg/L)	1	16.3	12	24.2	22	12.3	-
9	Ni (µg/L)	20	25.72	33	13.43	17.3	17.1	200
10	Pb(µg/L)	10	39.22	34.9	34.7	32	54.4	25
11	Se(µg/L)	10	82.74	54.28	141	34	55.3	20
12	Sn(µg/L)	-	24.8	11.3	20.8	10.9	8.76	-
13	V (µg/L)	-	10.7	9.11	3.1	7.45	2.2	-
14	Zn (µg/L)	3000	29.5	20.6	11.7	7.2	1.07	-

N.B.:' –'represents not available

Those metals are heavy metals but they occur in a very small amount that's why they are called trace metals but this doesn't mean they don't have any effect in human wellbeing. On the contrary, they do have adverse effect in our health. So this is the main reason for why they should be studied frequently and abolish the cause of the contamination if possible. The results of the heavy metals analysis showed that the concentrations of arsenic, mercury, nickel, lead and selenium were higher than the permissible limit proposed by WHO. The major possible sources for this metals may be due to the entry of municipal and industrial wastes in to the drainage. The presence of high concentration of heavy metals may be a cause for kidney damage, bone damage, nervous disorder and cancer. Barium of water samples collected lies in the range of 60.9 to 151(µg/L). The values lie below the WHO range (700µg/L). According to the results obtained, cadmium was found to be below the limit but alarming comparing with the WHO standard value (3µg/L). Suppose if the concentration was above this permissible limit, it might be highly toxic for human beings, cancer and chronic kidney disease may also occur. The range of cadmium concentration varied from 1.02-2.75(µg/L) in all the samples.Nickel by nature is not hazardous metal for human health but is harmful for aquatic life and plant life. It originates mainly from minerals and more significantly from industrial wastewater drainage. The nickel values obtained are ranged from 13.43 to 33µg/L, where samples of MB3, MB4 & MB5 were below the permissible value, however samples of MB1 & MB2 were found to be above the permissible value. Tin is very toxic metal not in free metal form but in organo-metalic form. It is produced due to use of principally synthetic substances used for pest control and disposal of other industrial and municipal wastewater seepage to the ground water. The results of the heavy metal analysis showed that tin concentration ranges from 8.76-24.8µg/L. In this study, adding up the above mentioned metals, about thirty six metals were detected quantitatively in all samples. Where some are very toxic and are above the WHO limit, some are toxic but below the permissible limit and some are of no health hazard. The main source for those metals are natural mineral rocks and industrial wastewater seepage to the groundwater. So the attention should be paid to those metals, which are very toxic, for their concentration not to increase through time.

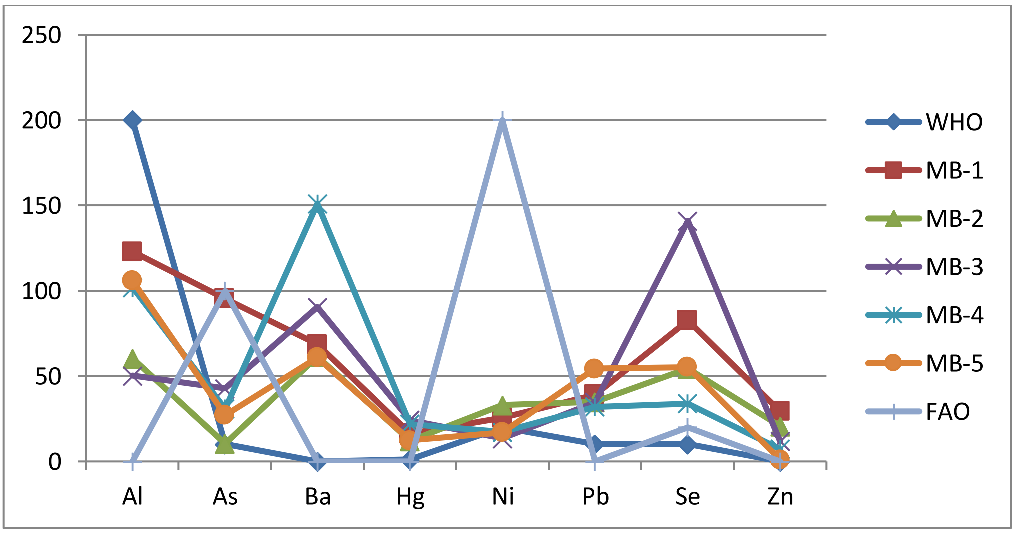

Figure 10: Concentrations of Al, As, Ba, Hg, Ni, Pb, Se and Zn Compared with WHO and FAO standards.

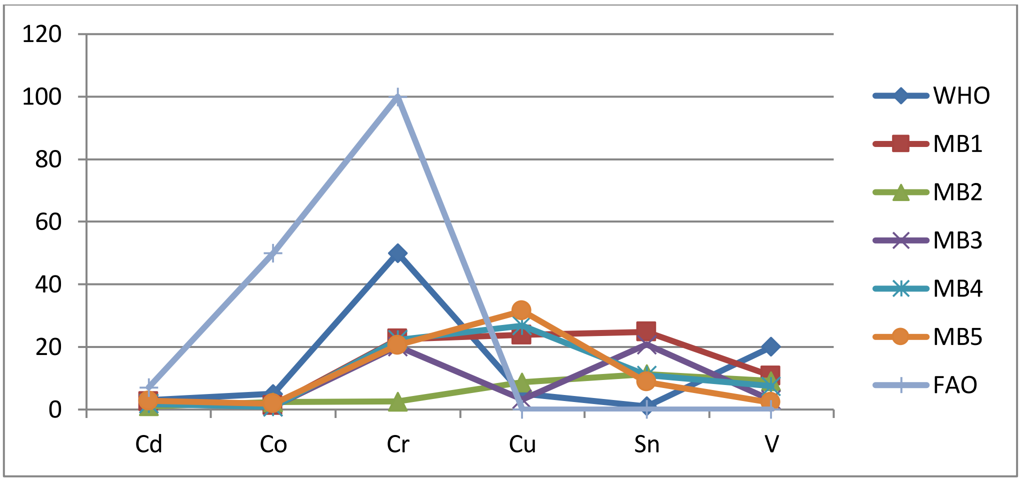

Figure 11: Concentration of Cd, Co, Cr, Cu, Sn and VCompared with WHO and FAO standards.

6.2.3 Quality of Ground water for irrigation

The suitability of groundwater for irrigation is determined on the basis of physical, chemical and bacteriological characteristics. The criteria for suitability of groundwater for irrigation are based on Total Dissolved Solids (TDS), Electrical Conductivity (EC), Sodium Salts concentration and other ions like chloride and nitrate[16].

6.2.3.1 Sodium Absorption Ratio (SAR)

$$\mathbf{SAR}=\frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \qquad (1)[16]$$

Table 6: SAR value for the groundwater samples

	MB1	MB2	MB3	MB4	MB5
SAR	48.48	39.24	7.101	35.99	38.89

Based on the results of SAR, all the water samples from the respective wells are having higher value for irrigation purpose except the sample MB3 as per the FAO permissible limit which is 13. This means that this water is sodic or sodium rich water which is unfavorable for plant growth.

6.2.3.2 pH in plant growth

Acidity and alkalinity are the major irrigation water quality criteria in which neither acidic nor alkaline water is favorable for plant growth. According to the results of the pH analysis, the values for all the water samples (7.21-7.93) lie within the FAO guidelines of water for irrigation purpose. The FAO range is 6.5-8.4.

6.2.3.3 Electrical conductivity (EC)

In an agriculturally irrigated area, electrical conductivity is a good indication for salinity of the water because saline water is not suitable for plant growth. Except sample MB3, all the others are saline exceeding the FAO standard value which is 3000μS/cm.

6.2.3.4 Chloride

The chloride content of the water used for irrigation purpose should not exceed 350mg/Las it may cause leaf burn. Except sample MB3, all the others exceeded the standard FAO limits, so it is unsuitable for plant growth.

7. Conclusion

The physico-chemical parameters and the toxic metals of ground water from five different study sites located along the waste water drainage flow around Mai-Bela, Asmara, were determined to investigate their quality. The present investigation showed that most of the physico-chemical parameters of the samples MB1,MB2,MB4 and MB5 have higher values than the WHO values in physical and chemical parameters, the intensive agricultural practices has also been the reason to amplified contamination of these four samples in comparison with MB3 even though all the samples may not be fit for drinking and irrigation purposes. However, most of the physicochemical parameters of the sample MB3 were within the permissible limit, because of the safety usage of water by the people living near the study site. In general, those water samples cannot be used unless they are subjected to some purification techniques. The individual and the community can help minimize groundwater pollution by simple housekeeping and management practices. The amount of industrial, household and agricultural waste generated can be minimized by implementing wastewater treatment.

8. Recommendations

As per this study it is recommended that the populace should have to use simple housekeeping and management practices before using it for any purpose. Most Importantly the people around the area have to keep their homeland as clean as it is possible as they are the primary victim of the pollution of their environment. As per the current status it is highly recommended that to use the simple technique of phyto-remediation as it is highly contaminated with the toxic metals. In addition the administration should bring an acute awareness among the people of Mai-Bela area about the quality of the groundwater, safety usage of water and disadvantages of intensive agricultural activities on water pollution.

Acknowledgement

We would like to thank the Professors and Faculty members of Department of Chemistry, College of Science, Eritrea Institute of Technology for thei7r constant support and encouragements to perform our project work. Also we thank the Water Resource Department, Asmara, for physicochemical analysis and SGS Mineral Service Geochemistry Bisha-Eritrea Laboratory for the toxic metal analysis. Our deepest appreciation and dedication goes to Prof. A. Manohar who gave his constant regard and support. Once again we would like to thank for our beloved parents for being by our side throughout this project and for the financial support as well.

Reference

[1]. S.S. Kolekar. “Physico-chemical analysis of ground water quality parameters – A Review.”Journal of Chemical and Pharmaceutical Sciences, 10(1),376-378,2017 (ISSN: 0974-2115)

[2]. UNESCO.GroundwatercontaminationinventoryA Methodological Guide, International Hydrological Program**(2002).**

[3]. Devendra Dohare, Shriram Deshpande and Atul Kotiya. (May, 2014). “Analysis of Ground Water Quality Parameters: A Review.”International Science Congress Association. [Online]. 3(5), 26-31. Available: www.isca.in [12/03/2018] (ISSN: 2278-9472)

[4]. Alnos Easa and Ashraf Abou-Rayan. ‘’ DOMESTIC WASTEWATER EFFECT ON THE POLLUTION OF THE GROUNDWATER IN RURAL AREAS IN EGYPT’’, Fourteenth International Water Technology Conference, IWTC 14, Cairo, Egypt, 2010, 909-923.

[5]. Leena Deshpande. “Water Quality Analysis Laboratory Methods, National Environmental Engineering Research Institute (NEERI),**(2015)**

[6]. P. Thamilarasu and R. Sharmila. (March | 2015). “PHYSICO-CHEMICAL CHARACTERISTICS OF GROUNDWATER ANALYSIS IN NAMAKKAL DISTRICT OF TAMILNADU STATE.”Rasayan J. Chem.. [Online],8(1),92-97. Available: http] (ISSN: 0976-0083)

[7]. Yousif Algamal.“Assessment and statistical study of physico-chemical properties of water quality in some local water treatment plants in Jeddah, Kingdom of Saudi Arabia.”Advances in Applied Science Research, 6(7), 49-56, 2015. Available online at: www.pelagiaresearchlibrary.com (ISSN: 0976-0083)

[8]. N. I. Onwughara, V. I. E. Ajiwe and H. O. Nnabuenyi, (2013). “Physicochemical Studies of Water from Selected Boreholes in Umuahia North Local Government Area, in Abia State, Nigeria.”International Journal of Pure & Applied Bioscience. [Online]. 1(3), 34-44. Available online at www.ijpab.com (ISSN: 2320 – 7051)

[9]. Nikunj Ashiyani, Dr. Falguni Parekh, Dr. T.M.V. Suryanarayana, (Mar, 2015), “Analysis Of Physico-Chemical Properties of Groundwater.”International Journal of Innovative Research in Science, Engineering and Technology. [Online]. 4(3),1094-1098. Available: DOI: 10.15680/IJIRSET.2015.0403061 1094-1098 (ISSN(Online) : 2319 - 8753)

[10]. EZERIBE, A. I., OSHIEKE, K. C. & JAURO, A.. (2012). “PHYSICO-CHEMICAL PROPERTIES OF WELL WATER SAMPLES FROM SOME VILLAGES IN NIGERIA WITH CASES OF STAINED AND MOTTLE TEETH.”Science World Journal. [Online].7(1), 1-3. Available: www.scienceworldjournal.org[22/05/2018] (ISSN 1597-6343)

[11]. K. Jacques Fatombi1, T. Angèle Ahoyo, Odilon Nonfodji, Taofiki Aminou. (Dec, 2012)“Physico-Chemical and Bacterial Characteristics of Groundwater and Surface Water Quality in the Lagbe Town: Treatment Essays with Moringa oleifera Seeds.”Journal of Water Resource and Protection. [Online], 4, 1001-1008. Available: http://dx.doi.org/10.4236/jwarp.2012.412116

[12]. World Health Organization. (2011a) Guidance for Drinking Water Quality. 4th ed. [online]. Available at http://whqlibdoc.who.int/publications/2011/9789241548151_eng. [accessed 22 November 2011].

[13]. SUNITA R. DANDWATE. (2012). “Study of Physicochemical Parameters of Groundwater Quality of

Kopargaon Area, Maharastra State, India during Pre-monsoon and Post-monsoon Seasons."E-Journal of Chemistry.[Online], 9(1), 15-20. Available: http://www.e-journals.net. (ISSN: 0973-4945)

[14]. Environmental Protection Agency, Parameters of Water Quality, Interpretation and Standards,**(2001).**

[15]. Srajan Shrivastava."Water Quality Analysis of Water Bodies of Kantajhar Basti." B.Sc. thesis,Department of Chemical Engineering, National Institute of Technology, Rourkela, India, (2014)

[16]. PRIYANKA TIWARI. (2017)."WATER QUALITY ASSESMENT FOR DRINKING AND IRRIGATION PURPOSE."Indian J.Sci.Res.. [Online], 13 (2), 140-142. (ISSN: 2250-0138)

[17]. Amr H. Mostafa, Raed S. Al-Wasify, Amr M. Sayed and Bakry M. Haroun. (2013). "Microbiological and Physicochemical Evaluation of Groundwater in Egypt."International Journal of Environment and Sustainability. [Online]. 2(2), 1-10. Available: www.sciencetarget.com. (ISSN 1927-9566)

[18]. Anjum Praveen, Rajesh Kumar, Pratima And Rajat Kumar. (Apr, 2013)."Physio- Chemical Properties of the Water of River Ganga at Kanpur", International Journal of Computational Engineering Research. [Online], 3(4),134-137. Available: www.ijceronline.com [02/04/2018]

[19]. Emhemmed Alhibshi, Khadija Albriky, and Abulnabi Bushita. "Concentration of Heavy Metals in underground water wells in Gharian district, Libya." International Conference on Agricultural, Ecological and Medical Sciences (AEMS-2014), Bali, Indonesia, 2014. Available: http://dx.doi.org/10.15242/IICBE.C0214005

[20]. Yang Guan, Chaofeng Shao and Meiting Ju. (2014). "Heavy Metal Contamination Assessment and Partition for Industrial and Mining Gathering Areas."International Journal of Environmental Research and Public Health. [Online]. 11, 7286-7303. Available: doi:10.3390/ijerph110707286. [12/05/2018] (ISSN 1660-4601).