ADDIS ABABA UNIVERSITY SCHOOL OF GRADUATE STUDIES
ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAIT)
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING (SCEE)

IMPACT ASSESSMENT OF KOSHE (ቆሼ) OPEN DUMP SITE LEACHATE ON GROUND WATER QUALITY, Addis Ababa

By:
TAREKEGN TADESSE WEJU

A Thesis submitted to The School of Civil and Environmental Engineering Presented in Partial Fulfillment of the Requirements for a Degree of Masters of Science in Water Supply and Environmental Engineering (Civil Environmental Engineering Stream)

Advisor: Dr. ZERIHUN GETANEH

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Addis Ababa University

Addis Ababa Institute of Technology

The School of Civil and Environmental Engineering

This is to certify that the thesis prepared by **Tarekegn Tadesse Weju,** entitled; **impact assessment of Koshe (ቆሼ) open dump site leachate on groundwater quality, Addis Ababa** and submitted in partial fulfillment of the requirement for the degree Master of Science (Civil and Environmental Engineering, Major of Water Supply and Environmental Engineering) complies with the regulations of the university and the meets accepted standards concerning originality and quality.

Signed by the examining Committee

1) Dr. AGIZEW NIGUSIE Internal Examiner	Signature	12/07/23 Date
2) Dr. MEBRUK MOHAMMED External Examiner	Signature	14/07/2023 Date
3) Dr. ZERIHUN GETANEH Advisor	Signature	12/07/23 Date
4) Dr. ABREHAM GEBRIE Chairman	Abrham Gebre (Dr.) Dean, School of Civil & Environmental Engineering Signature	Date

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DEDICATION

This thesis is dedicated to the more than 113 people who died and other people who suffered injuries on March 11, 2017, when the Koshe open dump site's disastrous slope failure

DECLARATION

I, Tarekegn Tadesse Weju, declare that this research is my work, and additional sources used have been properly and fully acknowledged using references. This dissertation has not been submitted before for any degree or examination in any other University.

I am responsible for the research and its articulation alone. In no way do any of the persons mentioned in the acknowledgment bear any direct responsibility for this work.

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Abstract

One of the primary threats to the quality of groundwater is thought to be open dump sites. The study focused on Koshe open dump site which is the official active Open dump site for Addis Ababa city. The main purpose of this study was to assess the impact of Koshe open dump site leachate on groundwater quality around the dump site. The study was conducted from November 2022 to May 2023 giving a total of thirty-eight (38) parameters of the six (6) groundwater samples and one (1) leachate sample. Judgment sampling was used for data gathering. Physico-chemical parameters were analyzed at Horticoop Ethiopia (Horticulture) PLC Soil, Water, and Plant Analysis Laboratory. Samples of leachate and groundwater were analyzed to evaluate the impact of leachates on groundwater through the comparison of their physicochemical nature. Groundwater and leachate samples were collected and analyzed for selected water quality parameters and compared to the Ethiopian Water Quality Standard, EPA, and WHO Guidelines for drinking-water quality fourth edition WHO. The physicochemical characteristics of the groundwater samples around the Koshe open dump sites indicated high concentrations of Electrical conductivity, Potassium, Iron, Chromium, Lead, Mercury, Total Alkalinity, Nitrate, Phosphate, Cadmium, Bicarbonates, Arsenic, Salinity, Cobalt, and Silicon above the Ethiopian standard, WHO, and EPA thresholds for acceptable drinking water quality. Because of the distance and located on upstream of Koshe, the well located in Ayer Tena high school was all most in all parameters, especially in parameters that indicate the impact of leachate on groundwater quality(Arsenic, cadmium, chromium, Lead, Mercury, molybdenum, nitrate, potassium & phosphate) shown significantly low concentration relative to the other wells. The leachate quality analysis revealed an extensive range of different contaminants that affect groundwater quality. Parameters such as; Electrical conductivity (EC), Total suspended solids (TSS), Turbidity, Total dissolved solids (TDS), Dissolved oxygen (DO), Potassium, Sodium, Iron, Manganese, Lead, Mercury, Total Alkalinity, Chloride, Ammonia, Phosphate, Sodium, Boron, Arsenic, Cobalt, BOD, and COD fall in the red category of Effluent & Solid Waste Disposal Regulations SI6 which is referred to as being a high environmental hazard. According to the National sanitation foundation water quality index (NSFWQI), The Weighted arithmetic index method (WAIM), and The Canadian Council of Ministers' environment water quality index (CCME WQI) analysis of the water quality status of groundwater well samples fall in poor quality and unfit to drink category. Nemerow's pollution index (NPI) analysis indicated that the contributing parameters which are responsible for polluting water quality in all groundwater well samples are Hydrogen ion (pH), Electrical conductivity (EC), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), iron, Phosphate, Molybdenum, Temperature, Bicarbonates, Nitrate, Cadmium, Ammonia, Total Alkalinity, Arsenic, and Mercury.

The result of the correlation analysis indicated a strong positive and negative association between parameters at a 0.01 and 0.050 confidence level. The presence of physicochemical parameters such as Arsenic, cadmium, chromium, Lead, Mercury, molybdenum, nitrate, potassium & phosphate in groundwater wells which are located around open dump sites can lead to the conclusion that indicated there is a significant impact of the Koshe dumpsite on the groundwater quality.

Keywords: - Municipal solid waste, open dump site, Groundwater, Leachate, WQI, Pearson Correlation, Nemerow's pollution index (NPI)

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ABBREVIATIONS AND ACRONYMS

(APHA)	American Public Health Association
(EPA)	Environmental Protection Agency
(MCLG)	Maximum Contaminant Level or Goal
(MSW)	Municipal Solid Waste
(WHO)	World Health Organization
(WQI)	Water Quality Index
(U.S. EPA)	United States Environmental Protection Agency
(ES)	Ethiopian Standard
(pH)	Hydrogen ion
(EC)	Electrical conductivity
(TDS)	Total dissolved solids
(TSS)	Total suspended solids
(BOD)	Biochemical Oxygen Demand
(COD)	Chemical Oxygen Demand
($\mathrm{Na^+}$)	Sodium
($\mathrm{Ca^{2+}}$)	Calcium
($\mathrm{Mg^{2+}}$)	Magnesium
($\mathrm{HCO_3^-}$)	Bicarbonates
($\mathrm{Cl^-}$)	Chloride
($\mathrm{SO_4^{2-}}$)	Sulfate
($\mathrm{PO_4^+}$)	Phosphate
($\mathrm{NO_3^-}$)	Nitrate
($\mathrm{K^+}$)	Potassium
($\mathrm{NH_4^+}$)	Ammonia
(Fe)	Iron
($\mathrm{Cr_3^+}$)	Chromium,
(Zn)	Zinc
(Mn)	Manganese
(Cd)	Cadmium

(Pb) ……………………………..Lead

(Ni) ……………………………..Nickel

(Cu) ……………………………..Copper

(B) ………………………………Boron

(As) ……………………………..Arsenic

(Hg) …………………………….Mercury

(P) ………………………………Phosphorus

(Si) ………………………………Silicon

(Mo) …………………………….Molybdenum

(Co) …………………………….Cobalt

(Se) ……………………………..Selenium

1. INTRODUCTION

1.1 Background of the study

The amount and quality of municipal solid waste (MSW) are determined by several factors, including population, lifestyle, food habits, the standard of living, the extent of industrial and commercial activities in the area, residents' cultural traditions, and climate(Report of Ministry of Environment, Japan, 2006).

Cities are a threat to the environment because they generate an estimated 1.7–1.9 billion metric tons of municipal solid waste (MSW). By 2025, it is expected to reach approximately 2.2 billion metric tons per year. In Sub-Saharan Africa, the annual production is around 62 million tons(UNEP, 2002).

In developing countries, waste collection rates are frequently less than 70%, despite the increased rate of production. More than half of the waste collected is dumped in uncontrolled landfills, while 15% is recycled in an unsafe and unregulated manner. In African countries, household waste makes up the majority. The volume, weight, and density of waste generated per capita per day in Addis Ababa range from 0.4 to 1.23 lit/capita/day, 0.11 to 0.25 kg/capita/day, and 205 to 370 kg/m3 respectively (AACA, 2014). Regardless of the increasing volume of waste generated, the performance of the city‘s solid waste collection and disposal system is poor (WHO, 1996).

Koshe is the only Open dump site in the city of Addis Ababa established in 1964(Haile & Abiye, 2012). It’s an open dump site serving around 5,460,591 million people in the municipality and encircled by city dwellers, business areas, and even schools (Weldeghebrael, 2021). All the wastes collected and transported from all over the city are disposed of at this site without considering any environmental and health factors. Because of being on duty for so long time, the site is full of waste and it’s almost out of control. There is no sewerage system to capture the discharge of liquid wastes; the site is not closed off on all sides to protect the illegal penetration of the nearby residents. These and many more related reasons make the place to be a threat to human health and the environment. It covers an estimated 36 hectares with piles of garbage as deep as 40 meters and takes in about 4,000 tonnes of organic waste every day, according to the UNDP’s office in Ethiopia. Because of urbanization and the increasing population in Ethiopia, the inhabitants are living even inside the junkyard with no hesitation. The existence of almost 2,000 waste collectors depends on this hazardous disposal facility. Most of them are poor and their sources of income rely on the materials they can collect and sell from the site. On 11th March 2017, the Koshe open dump site has undergone a catastrophic slope failure killing more than 113 people who are living at the toe of the slope while several others were left injured(Raviteja & Munwar Basha, 2017).

This paper aims to assess the impact of Koshe open dump sites on groundwater quality using Physicochemical data. Figure 1 shows the map of the Koshe open dump site and Figure 2 shows the location map of all wells around the Koshe dump site.

Figure 1The map of the Koshe open dump site

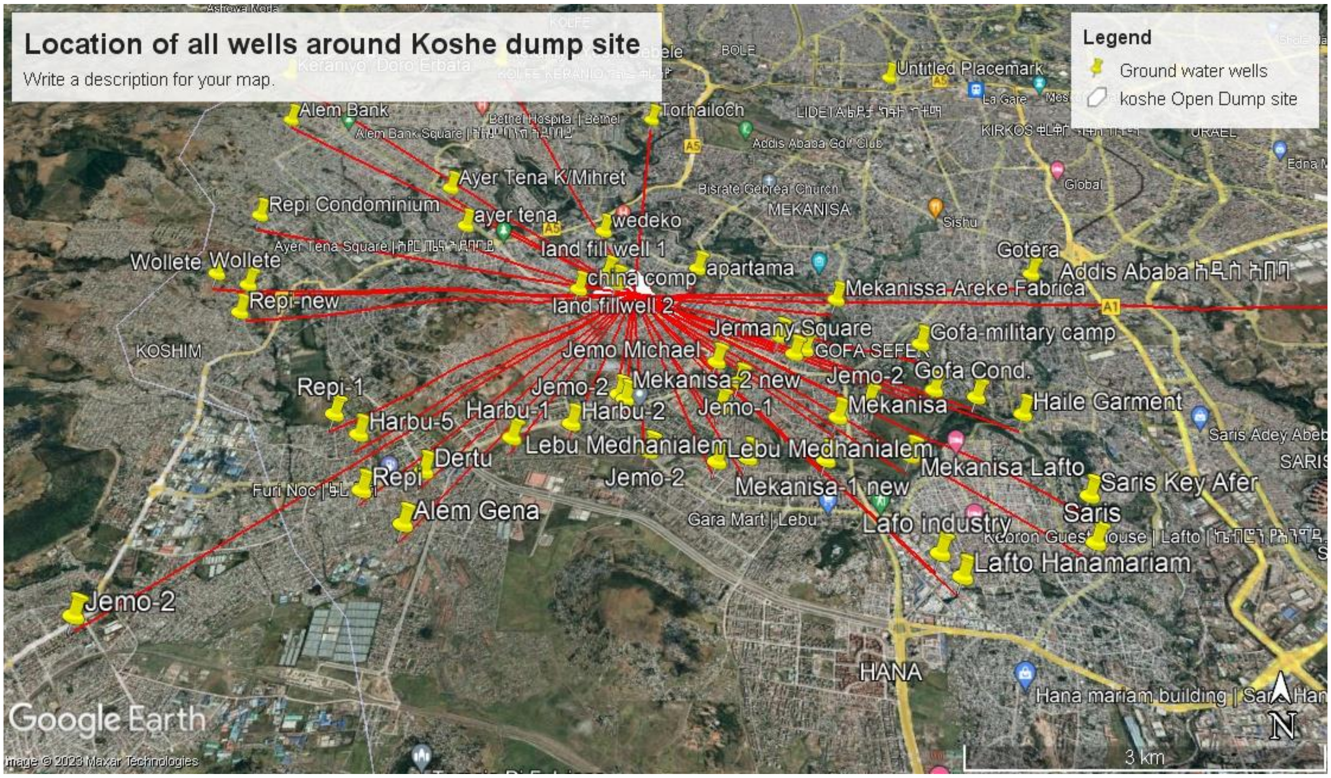


Figure 2 The location map of all wells around the Koshe dump site

1.2 Statement of problem

Originally the dump site was on the outer edge of the city (approximately 8 kilometers from the city center), but due to urban expansion, it is now in the heart of the city. There are many homes, ring roads and schools that have been built next to the dump site, and poor air quality is a significant concern in these areas. The dump site receives waste from all sources without specialized treatment: household, commercial, construction, and even hazardous and medical wastes(Abeba, 2022; FCSWM, 2013). The city does minimal compaction at the site and does not apply any cover to the open dump(Haile & Abiye, 2012). Addis Ababa City Government has set solid waste management as one of its top priorities and its immediate priority is to close the Koshe open dumpsite and replace it with a new sanitary landfill located on the territory of Sendafa (Oromiya)(FCSWM, 2013). The city has installed a landfill gas collection system in the closed section of the dump site and has started constructing a flaring station to manage methane emissions from the site(AACA, 2014).

According to (Tesema, 2010) The major problems associated with the Koshe open dump site are the site is already been full, Surrounded by housing areas and institutions, Nuisance and health hazards for people living nearby More than 200 - 300 waste pickers per day, work continuously and living nearby the site and interfering the operation of the work for the collection of salvageable materials such as wood, scrap metals, and discarded food, No daily cover with soil, No leachate containment or treatment, No rainwater drain-off, No odor or vector control, and No fence.

The dump site is not equipped with a leachate management system that prevents the toxic liquid waste from leaking into the environment(Abeba, 2022; Haile & Abiye, 2012; Kebede et al., 2006). Regarding the groundwater resource, the question of the quality of the groundwater system in and around the city and its vulnerability to pollution becomes an important issue, especially when one considers the large, long-used dump site at Koshe (Kebede et al., 2006).

Therefore the measure to protect the groundwater from the impact of the Koshe open dump is a critical issue for the city to secure sources of water and to guarantee the safety of the community. Some researchers tried (Haile & Abiye, 2012; Raviteja & Munwar Basha, 2017) to distinguish the contents of the concentration of the Koshe open dump leachate by conducting a laboratory test to identify the types of pollutants which affect the surface water, other researchers focus on the solid waste management part but all the research previously conducted did not perform correlation analysis between leachate and groundwater, did not determine Water Quality Index (WQI) using Pollution index of groundwater (PIG) method, National Sanitation Foundation Water Quality Index (NSF WQI), Nemerow' pollution index (NPI) also called Row's pollution index, The Canadian council of minister of environment water quality index (CCME WQI) & Weighted Arithmetic index method to compare with WHO standards.

Therefore, this study aimed to evaluate the impact of Koshe (ቆሼ) open dump sites on groundwater quality and give an appropriate solution for each problem.

1.3 Research objectives

1.3.1 General objectives

To assess the impact of Koshe open dump site leachate on groundwater quality around the dump site.

1.3.2 Specific objectives

- To determine the physicochemical characteristics of groundwater around the dump site.
- To determine the physicochemical characteristics of the leachate of the dump site.
- To evaluate the toxicity level of leachate
- To conduct a water quality index of samples.
- To assess the correlation between levels of pollutants in groundwater wells and the Open dumpsite leachate.

1.4 Research questions

- What are the physio-chemical characteristics of leachate?
- What are the physio-chemical characteristics of groundwater?
- How hazardous is the leachate?
- Which groundwater well is safe for domestic use which is located around the dump site?
- How are pollutants in groundwater wells correlated with the open dump leachate?

1.5 Scope of study

The study is limited to identifying the impact assessment of Koshe open dump site on groundwater quality. The lack of standard laboratories as well as the high cost of testing each sample affected the number of samples tested. Analysis of leachate and groundwater quality was done in rainy seasons. The analyses were limited to selected chemical and heavy metal parameters that are commonly found in dumpsite leachates and which affect groundwater. Geological and hydrogeological input was based on accessible data. The scope of this study did not cover the health conditions of residents around the dumpsites. The study targeted key water quality Parameters (i.e. Physical and chemical parameters). Sampling depends on the location of the well (i.e. Upstream and downstream of the open dump) and distance from the dump site.

1.6 Definition of terms

1.6.1 Operational definition

Maximum permissible level:

A required level whose non-fulfillment would disqualify the water for drinking and domestic use because of its probable health hazard. (ES, 2013)

Potable water:

Water that is safe to drink, pleasant to the taste, and useable for domestic purposes (ES, 2013)

Quality water:

Water intended for drinking and domestic use conforms to all the requirements specified in the Ethiopian standard. (ES, 2013)

Safe water:

Water intended for drinking and domestic use whose limit for toxic substance, bacteriological, and organoleptic levels conform to the requirements of this standard. (ES, 2013)

Physical Parameters

Physical parameters relate to measurements that are essentially physical in nature temperature, flow, electrical conductivity, and gravimetric measurements such as the mass of suspended solids per unit volume. (Stephenson, 2009)

Chemical Parameters

Chemical parameters are those which relate to the concentrations of chemical species in water. (Stephenson, 2009)

Aerobic: Waste decomposition in an oxygen-present environment.

Anaerobic: Waste decomposition in an oxygen-absent environment.

Biodegradable: Able to be broken down by natural biological processes.

Dumpsites: Also known as traditional landfills are excavated pieces of land or pits where waste materials are stored.

Groundwater: Water that infiltrates and is stored in the spaces between particles in the earth.

Hydraulic head: Measurement of liquid pressure used to determine the hydraulic gradient between two or more points

Infiltration: This is the process of water movement from the soil surface into the other soil layers.

Landfill: An old and easiest method of waste disposal that involves burying the waste in specially constructed sites.

Leachate: Contaminant-laden water that flows from landfills or other contaminated sites.

Physico-chemical: Combination of both physical and chemical parameters.

Percolation: The process by which water permeates the soil or porous rock into the subsurface environment.

Plume: The column of effluent moving through the water

Sanitary landfill: A designed and engineered method of disposing of solid wastes to reduce groundwater pollution.

Static Water Level (SWL): means the level at which water stands in a Water Well when no water is being removed from the Aquifer. SWL is expressed as the distance from the ground surface or measuring point near the ground surface to the water level in the well.

The dynamic water level (DWL): refers to the depth at which water is found in a well or borehole when pumped or in a naturally flowing condition. It indicates the interaction between the aquifer (the underground layer of water-bearing rock) and the pumping or natural conditions.

Drawdown (DD): is the term used to describe the decrease in water level in a well or borehole when water is pumped out. It is a key parameter that is monitored to understand and manage groundwater resources effectively.

1.7 Significance of the study

Currently, there are no programs put in place by any stakeholder to monitor the extent of the impact of Koshe open dump site leachate on groundwater quality around the dump site. This study thus provides the basis for putting in place result-oriented monitoring programs to mitigate the problem and check the quality of the water periodically. Furthermore, the study provides information on the characteristics of leachate generated at the dumpsites and the quality of groundwater around the dumpsites.

Residents around the dumpsites depend on groundwater for drinking and other domestic purposes, and their knowledge of the quality of the groundwater they consume is low. This study will provide useful information to all stakeholders on the quality of groundwater consumed by people residing near the dumpsites to enhance the quality of water. It is hoped that studies like this one will offer useful data for practices and policies aimed at reducing the environmental impact of solid waste disposal, as well as contribute to the development of a healthy society and environmentally sustainable development of groundwater in Addis Abeba, which can be replicated in other regions of the country that face comparable issues.

1.8 Organization of the paper

The research proposal contains five chapters**.** The First chapter is the Introduction which contains the background of the study, statement of the problem, basic research questions, objectives of the study, definition of terms, the significance of the study, Scope of the study, and organization of the paper. The second chapter is the Literature review which deals with the literature relevant to the study and has an introduction, theoretical review, and empirical review. The third chapter is Research Methodology under this chapter; the study were describe the study area and period, research approach, research design and type, parameters examined, description of the sampling point, on-site and off-site analysis, and data analysis. The fourth chapter is Results and Discussion/Data Presentation, analysis & Interpretation: This chapter were summarize the results/findings of the study and interprets and/or discusses the findings. The fifth chapter contains the Conclusion, and recommendation:-This chapter comprises two sections, which include a conclusion, and recommendations. The summary of findings was drawn from the results discussed in chapter four; the conclusions were drawn from the summary of findings.

2. LITERATURE REVIEW

2.1 Introduction

2.1.1 Topography

The elevation of Addis Ababa varies from 2000 m at Akaki to 3200 m at Entoto. The most significant landforms in the city are the Entoto ridge on Addis' northern side, the flat and sloping landform in the middle of the city, and the young volcanic mountains Wechacha (3350m above sea level), Furi (2850m asl), and Yerer (3099m asl) to the west, southwest, and southeast. The two main rivers that flow through the city are Kebena (Big Akakai) on the east and Small Akaki on the west. These two rivers merge outside of Addis and run southward toward Aba Samuel Lake (FCSWM, 2013).

2.1.2 Geology

2.1.2.1 Regional Geology

Addis Ababa is situated in the middle of a well-drained plateau and is surrounded by hills and mountains. It is covered by contemporary aerial photographs taken in 2002 at a scale of 1:8,000 and topographic maps from 1978 with the Ethiopian Mapping Authority's 0938D3 (NW), 0838B1 (SW), 0938-D4 (NE), and 0838B2 (SE) numbers that are scaled to 1:50,000 (FCSWM, 2013).

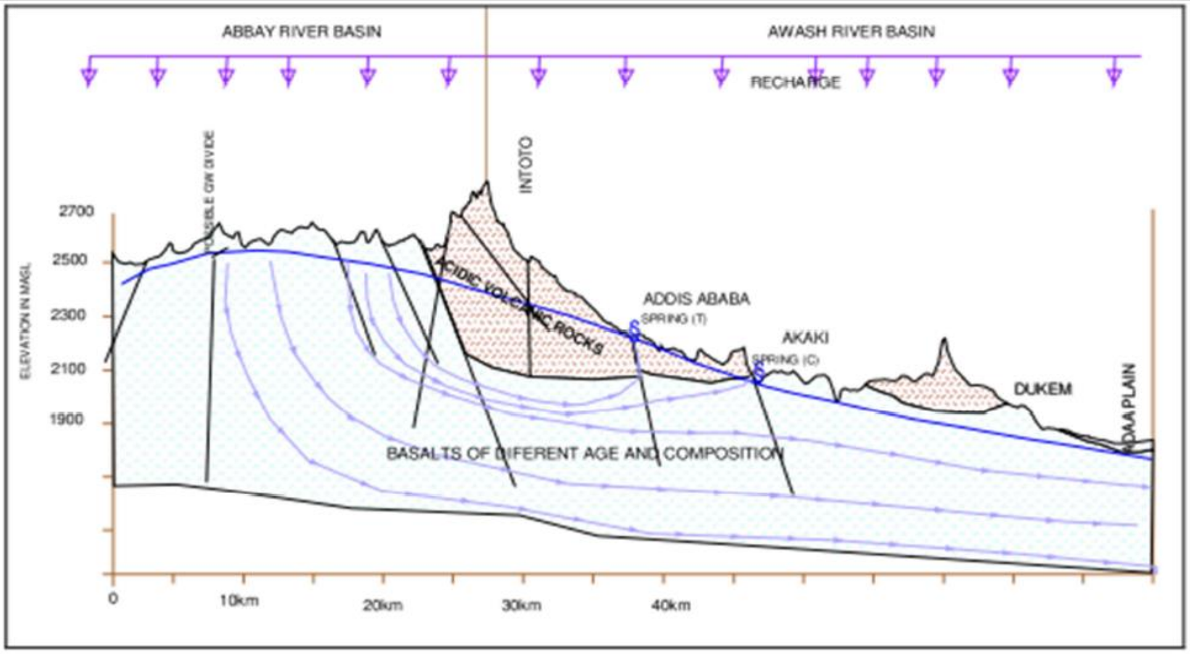


Figure 3 Geological section of Addis Ababa (Source:- solid waste management in addis ababa Agence Francaise de development / Addis Ababa city government Solid waste management project Draft strategy report October 2013)

Geological setup

The geological backdrop of the Addis Ababa region in general and the study area (Koshe) in particular is composed of Oligo-Miocene and Quaternary volcanic rocks. The northern portion of the dump site, which is covered in more recent volcanic, is dominated by rhyolites, felsic flows, and flood basalts (Fig. 4). Welded tuffs, basaltic, rhyolitic, trachytic, and trachybasaltic lava flows are the main lithologies. There are at least four volcanic centers in the area (Mt. Wochacha, Mt. Furi, Mt. Yerer, and Entoto), which are the main sources of volcanic materials for the area. From north to south, the age of the rocks exhibits a trend to decline (Haile & Abiye, 2012).

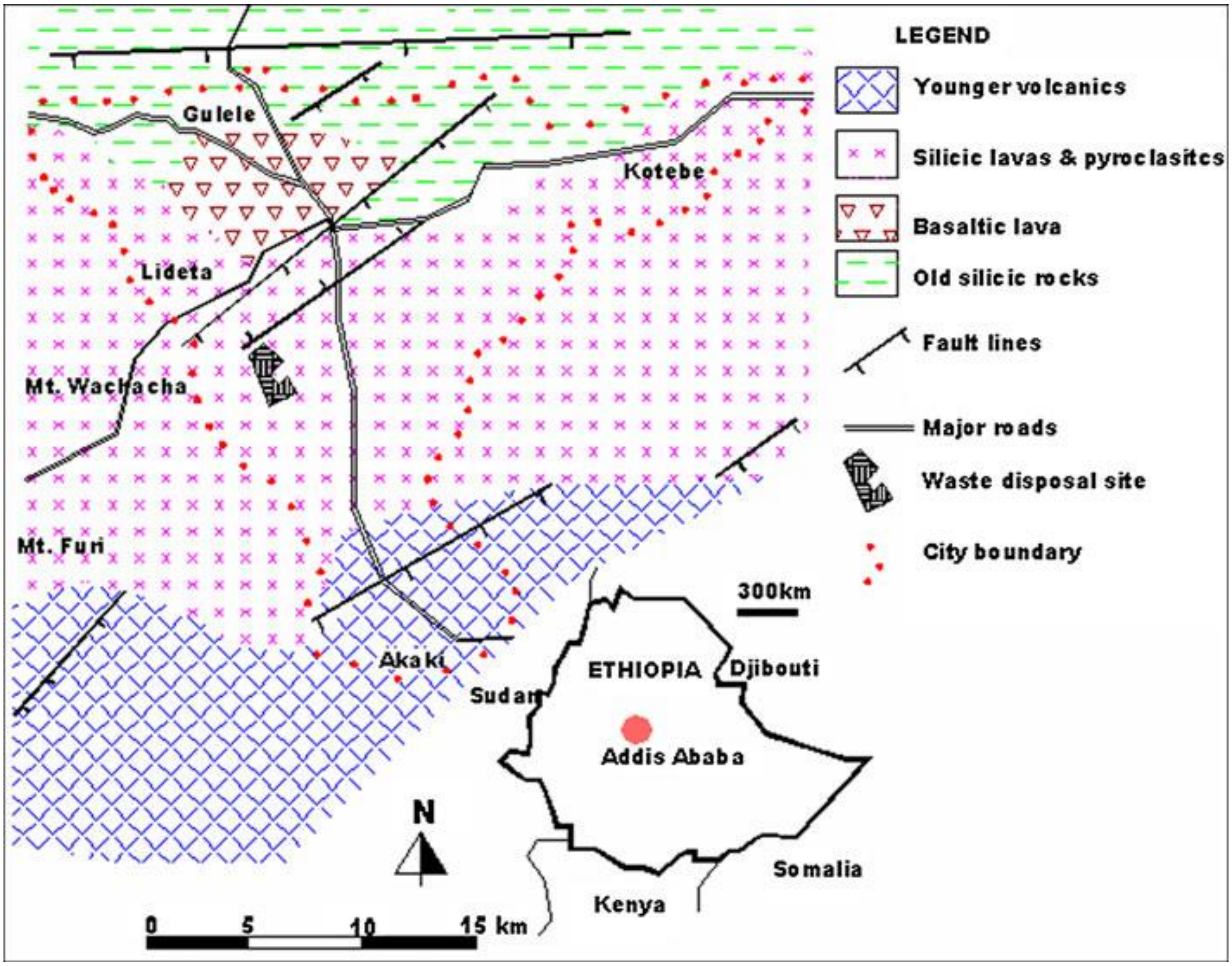


Figure 4 Location and geological map of Koshe area in Addis Ababa (\source: (Haile & Abiye, 2012)

2.1.2.2 Addis Ababa general Soils description

Alluvial

Alluvial soils can be found along the Small Akaki and Kebena (Big Akaki) rivers' banks. Clay and gravel that have been transported from higher to lower land make up these structures. The unified soil classification system classifies alluvial soils collected from a terrace near Bole as inorganic silts and very fine sands or clayey silts with slight plasticity (ML), which contain 46% silt, 34% clay, and 20% sand. This soil just slightly swells (FCSWM, 2013).

Residual

The residual soils cover the majority of Addis Ababa. These soils include lateritic soils and black cotton soils. The surviving soils are those that have developed naturally as a result of the deterioration of the underlying rocks. These soils are typical in the Kolfe Keraniyo and Gulele regions. Rhyolite and basalt formed the foundation of Kolfe's soils. 62% of the grains in the remaining soil samples were clay, 33% were silt, and 5% were sand. According to the unified soil classification system, the remaining soils in these regions are inorganic clays with low to medium plasticities, like gravely clays, sandy clays, and silty clays (CL). This type of soil does not swell much (FCSWM, 2013).

Lacustrine black cotton soils

Addis Ababa, which is flat and has a lower height than other adjacent places, is covered in black cotton soils. These soils can be found on the plains in the foothill regions of Mekanisa, Bole, Ayat Real State, Legatafo, and Yerer. According to a study of soil samples from the Bole and Mekanisa region, the soil is mostly composed of clay, 22% silt, and 2% sand. According to the unified soil classification system, this soil is categorized as MH, which stands for exceptionally high plasticity and a high degree of swelling (FCSWM, 2013).

2.1.3 Climatic conditions

2.1.3.1 General climatic conditions of Addis Ababa

Addis Ababa has a temperate tropical climate because of its altitude, which runs from 2000 to 3200 meters. The wet season, which lasts from June through the end of September, as well as the year-round low thermal amplitude, are characteristics of this climate. However, temperatures drop because of height when one travels from the south (Akaki) to the north (Gulele, Yeka) (FCSWM, 2013).

2.1.3.2 Rain

As in most of Ethiopia, the rainy season in Addis Ababa runs from late July to late September (FCSWM, 2013). Summers are pleasant and sunny with chilly evenings. The highest average temperatures are found in March, April, and May, while the lowest average temperatures are found in July and August. November and December are frigid months with little rain (FCSWM, 2013). The average annual rainfall in the region between 1976 and 1988 was 1225 mm, with a range of 1066.5 to 1294 mm at Addis Ababa Bole Climatic Station (1949 to 1988) and Addis Observatory (1900 to 1991). According to (FCSWM, 2013)the average maximum and lowest temperatures are 22.6 and 9.8 °C, respectively.

For the years 1982 through 1986, the mean annual potential evapotranspiration determined using the Penmann method resulted in a value of 1276 mm (Tefera, 2023). The same year's typical annual rainfall is 1113 mm. According to (FCSWM, 2013), the real evapotranspiration determined for the same year using the Thonrwahite and Mater (1957) method was 828 mm yearly.

The National Meteorological Services Agency (NMSA) provides monthly average rainfall data for the five stations in and near Addis Ababa. The stations include Bole, Akaki, Sebeta, Addis Ababa Observatory, and Kotebe. The duration of the record varies depending on the station. The Kotebe station only kept records from 1997 to 2003, which is a brief period. The longest record, however, was amassed at the Addis Ababa Observatory and spans 53 years, from 1951 to 2003. The data series at the Kotebe station has a lot of missing data in addition to the brief duration. November 1998 through August 2001's worth of data was absent (FCSWM, 2013).

Table 1:-Mean Monthly Rainfall (mm) (Source:- solid waste management in addis ababa Agence Francaise de Development / Addis Ababa city government Solid waste management project strategy report October 2013)

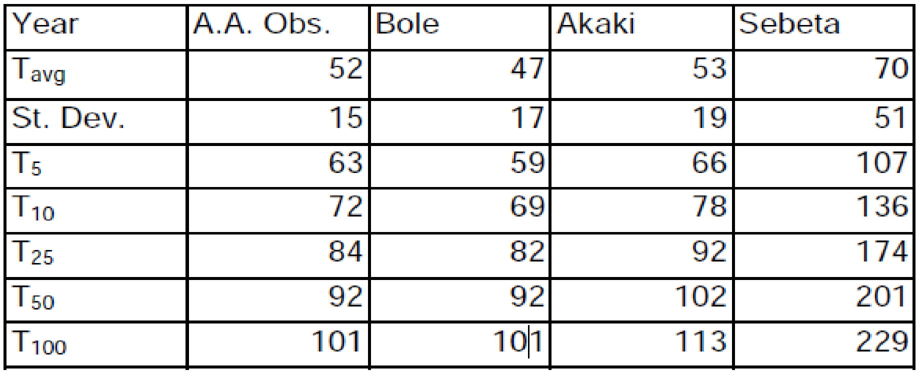
Station	Record Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
A.A. Obs.	1951-2010	16.3	35.4	64.4	88.6	77.2	126.1	258.0	273.3	172.3	37.2	8	**11.1**	**1168**
Bole	1964-2010	15.8	37.3	68.0	88.6	77.3	118.1	250.4	238.8	137.6	32.9	6.2	**5.6**	**1077**
Akaki	1983-2010	8.5	31.1	57	83.9	70.7	113	244	248	110	19.6	2.1	**4**	**992**
Sebeta	1964-2010	14.8	58.1	73.9	92.1	89.4	150.1	292.9	324.3	134.3	33.9	8.4	7.3	1279

2.1.3.3 Maximum Daily Rainfall

The daily rainfall data supplied by the National Meteorological Services Agency (NMSA) is used to extract the maximum 24-hour rainfall at the four stations (A.A. Obs., Bole, Akaki, and

Sebeta). Until 2003. A 5 to 100 years return time was used to calculate rainfall characteristics using the Gumbel frequency analysis. The drainage structures, interceptor drains, culverts, etc. will be designed based on these maximum rainfalls (FCSWM, 2013).

Table 2 24-hour maximum rainfall data and the computed outputs for various return periods (Source:- solid waste management in addis ababa strategy Report October 2013)



Year	A.A. Obs.	Bole	Akaki	Sebeta
T_{avg}	52	47	53	70
St. Dev.	15	17	19	51
T_5	63	59	66	107
T_{10}	72	69	78	136
T_{25}	84	82	92	174
T_{50}	92	92	102	201
T_{100}	101	101	113	229

2.1.3.4 Temperature

Average monthly minimum and maximum temperature data are available at the three stations, Addis Ababa Observatory, Bole, and Akaki. Though rainfall has a greater impact, the aerial temperature change is less significant. Three stations allow for a precise representation of the five landfills. According to (FCSWM, 2013), the adiabatic lapse rate is around 0.5°C per 100 m of altitude rise.

Table 3 Average monthly maximum and minimum temperatures data at the three stations (Source:- solid waste management in addis ababa strategy Report October 2013)

Month	A.A. Observatory		Bole		Akaki	
	T_{min} (ºC)	T_{max} (ºC)	T_{min} (ºC)	T_{max} (ºC)	T_{min} (ºC)	T_{max} (ºC)
Jan	9.0	24.0	7.9	24.2	11.8	26.1
Feb	10.3	25.1	8.1	25.8	12.9	27.3
Mar	11.7	25.1	10.8	25.6	14.3	27.3
Apr	12.2	24.8	11.3	25.9	15.2	27.4
May	12.3	25.4	11.4	25.9	15.5	27.9
Jun	11.4	23.5	10.9	23.8	14.5	26.4
Jul	11.4	21.0	11.2	21.5	14.3	24.3
Aug	11.6	21.1	11.3	21.1	14.2	23.9
Sep	11.4	21.9	10.5	22.2	14.3	25.2
Oct	10.3	23.1	8.7	23.2	14.0	25.2
Nov	8.8	23.4	6.2	23.4	12.9	25.8
Dec	8.3	23.5	6.5	23.5	11.8	25.5
Year	10.7	23.5	9.6	23.8	13.8	26.0

2.1.3.5 Wind

The only place where statistics on average monthly wind speeds are available is at the Addis Ababa Observatory. The 1994 to 2003 time period was covered by the ten-year data collection. The wind speed for the month is often not very high. On a monthly average, the minimum and maximum wind speeds are 0.2 and 0.9 m/sec, respectively. Seasonal variations can be seen in the wind speed data, with the wet season (June to September) having low values (FCSWM, 2013).

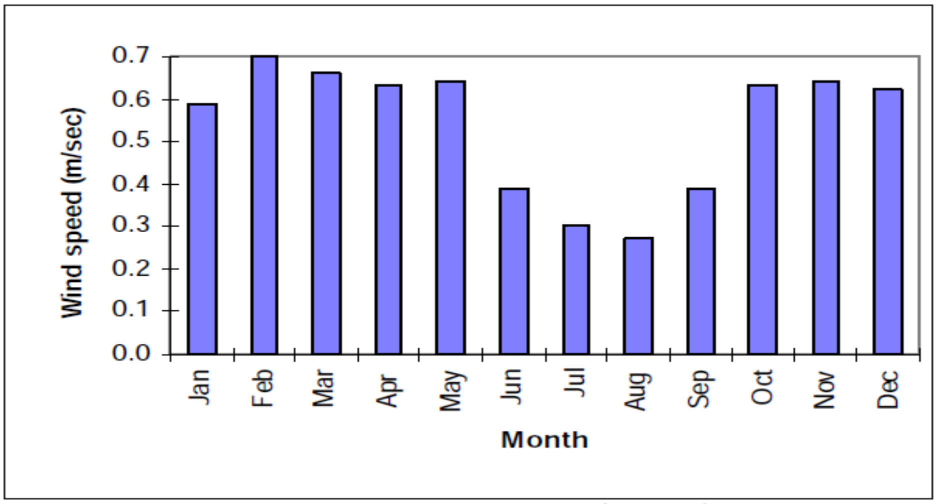


Figure 5 Mean Monthly Wind Speed (m/sec)

2.1.3.6 Water Budget

Hydrometeorology as well as geomorphology, geology, and the layers' ability to retain and convey water all have an impact on the subsurface's groundwater volume. The land in question is situated in a region with a lot of precipitation. Using the 1982 to 1986 data from the AirPort Climatic Station, the mean annual precipitation, runoff, and actual evapotranspiration are calculated. This yields an estimated annual infiltration depth of 137 mm. The hydraulic properties and storage capacity must be suitable for this depth of penetration to be practical, though (FCSWM, 2013).

2.2 Forms of subsurface water

Water in the soil mantle is called subsurface water and is considered in two zones (Fig. 6):

- Saturated zone, and
- Aeration zone.

Saturated Zone

Water can penetrate any soil pore in this region, which is referred to as the groundwater zone. A free surface is susceptible to atmospheric pressure, and the water table acts as its upper boundary (LOHMAN, 1972).

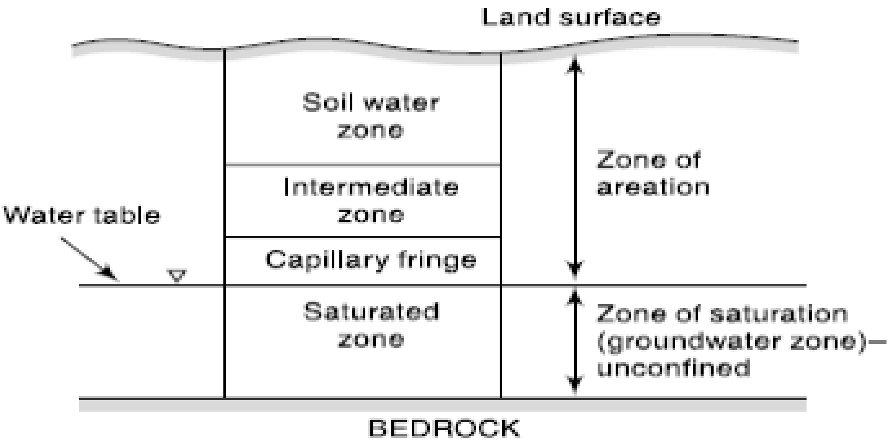


Figure 6 Classification of Subsurface Water (Source: (LOHMAN, 1972))

Zone of Aeration

In this location, the soil pores are hardly wet. The distance between the land's surface and the water table determines this zone's perimeter. The aeration zone is divided into three subzones:

Soil water zone:

This is located in the primary root band of the vegetation, near the ground surface, where evapotranspiration removes water from the atmosphere (LOHMAN, 1972).

i) Capillary fringe:

In this, capillary action holds the water in place. According to (LOHMAN, 1972), this region stretches from the water table upward to the top of the capillary rise.

ii) Intermediate zone :

This is located between the capillary fringe and the soil water zone. The soil texture and moisture content affect the subzones that make up the zone of aeration's thickness, which varies from area to region. In agricultural practice and irrigation engineering, the soil moisture in the aeration zone is crucial. Here, just the saturated zone was taken into account (LOHMAN, 1972).

Based on their location and field circumstances, aquifers are divided into confined and unconfined categories. A water table, or free water surface, is present in an unconfined aquifer, commonly referred to as a water table aquifer (Fig. 7). Through the infiltration of precipitation from the ground surface, this aquifer gets recharged. When a well is drilled into an unconfined aquifer, it will show a static water level that corresponds to the local water table level (LOHMAN, 1972).

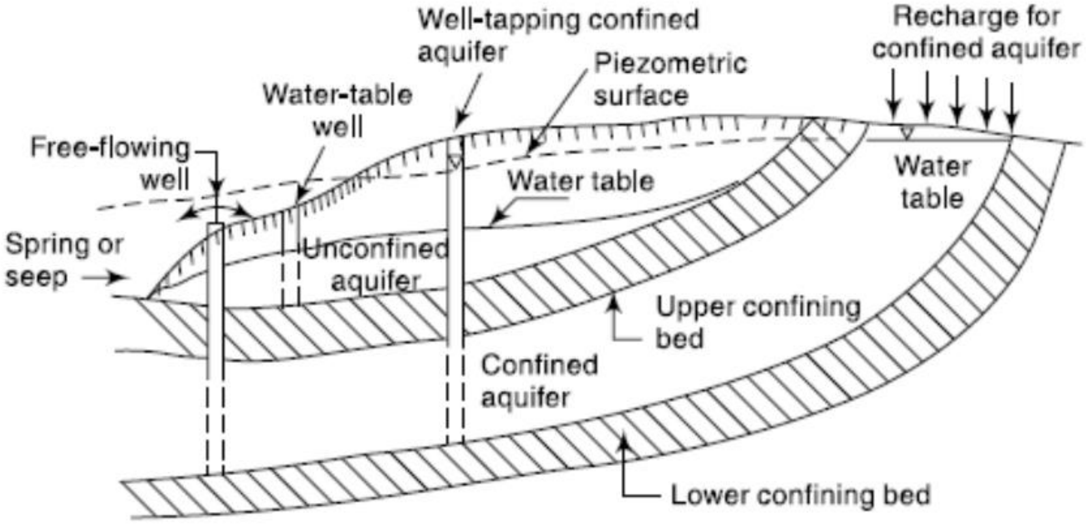


Figure 7 Confined and Unconfined Aquifers(Source: (LOHMAN, 1972)

Aquifers that are enclosed between two impermeable beds, such as aquicludes or aquifuges, are referred to as confined aquifers or artesian aquifers (Fig. 7). Only locations where the aquifer is exposed at ground level can recharge it. The water in the confined aquifer will be under pressure, hence the piezometric level will be significantly higher than the aquifer's top level. Sometimes, a well sunk into an aquifer can reach a level above the surface of the ground; at this level, water will flow naturally without the need for a pump (LOHMAN, 1972).

2.3 Solid waste

2.3.1 Sources of waste in Addis Ababa municipality

Around 76% of the rubbish generated by families originates from a variety of sources, with the next largest contributors being commercial, institutional, and industrial sources (18%), followed by streets and public areas (6%), according to (FCSWM, 2013; UN, 2022).

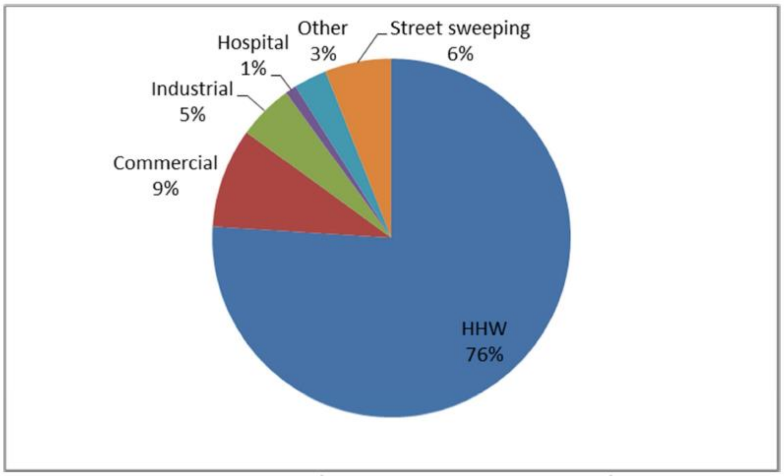


Figure 8 Distribution of waste generation by type of producers (source: (FCSWM, 2013)

2.3.1.1 Household Waste composition

In 2013, Addis Ababa City Administration generated the following types of household waste:

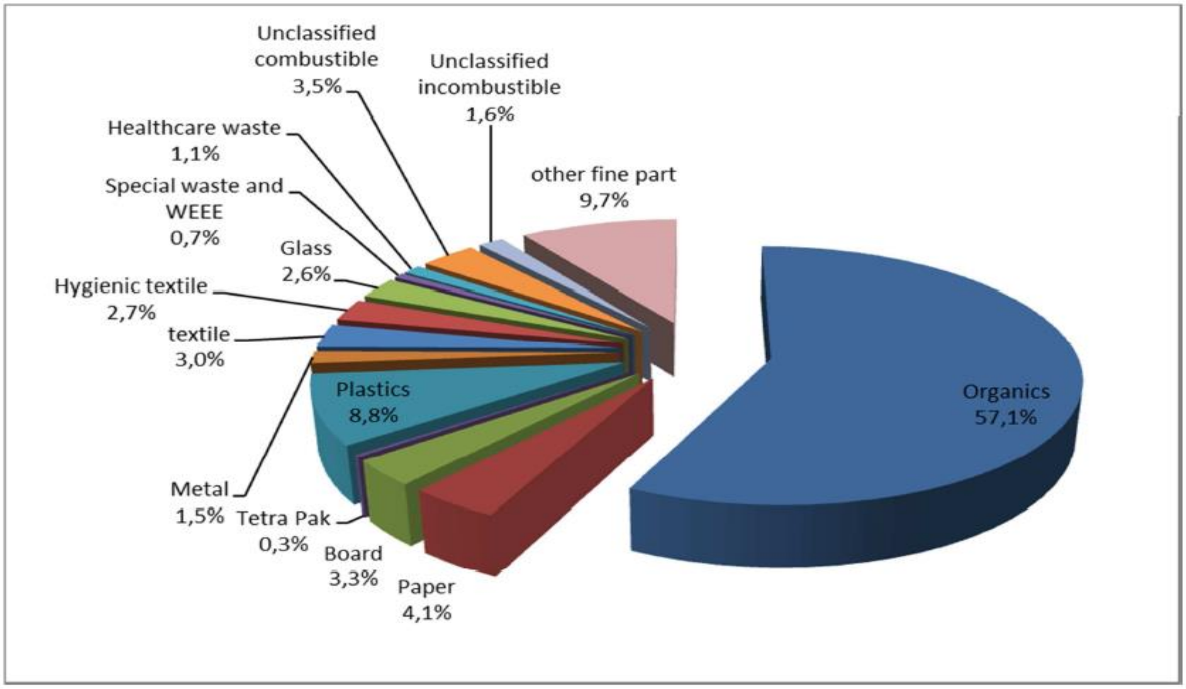


Figure 9 Composition of household waste generated (source: (FCSWM, 2013)

2.3.1.2 Street sweeping

The Addis Ababa City Administration is in charge of handling domestic garbage in addition to street sweeping, collecting, and treatment (FCSWM, 2013).

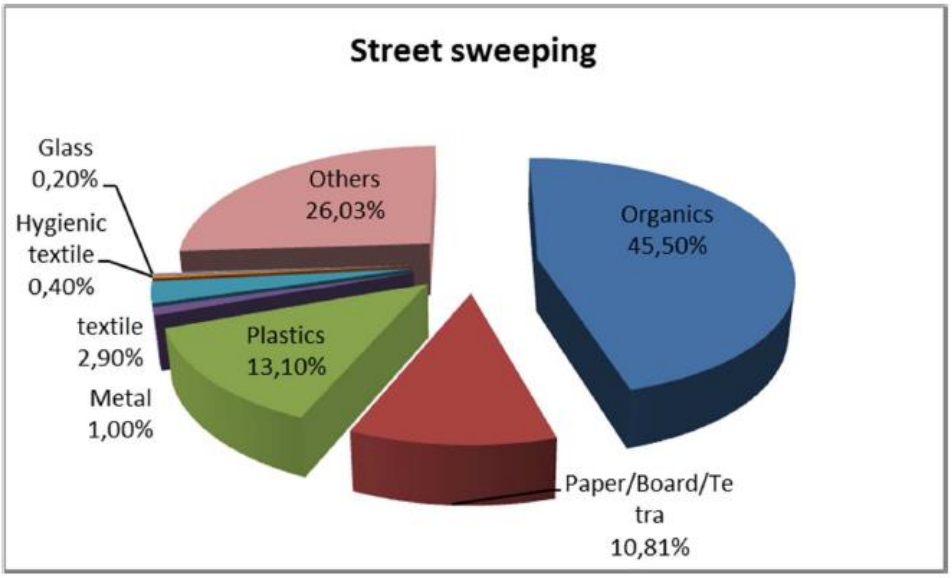


Figure 10 Composition of street sweeping waste generated (source: (FCSWM, 2013)

2.3.1.3 Commercial and institutional waste

In addition to handling household waste, the Addis Ababa City Administration is also in charge of collecting and handling waste from businesses and institutions. Twelve (12) private businesses have contracts with the Addis Ababa Cleaning Agency to pick up trash from businesses and institutions (FCSWM, 2013).

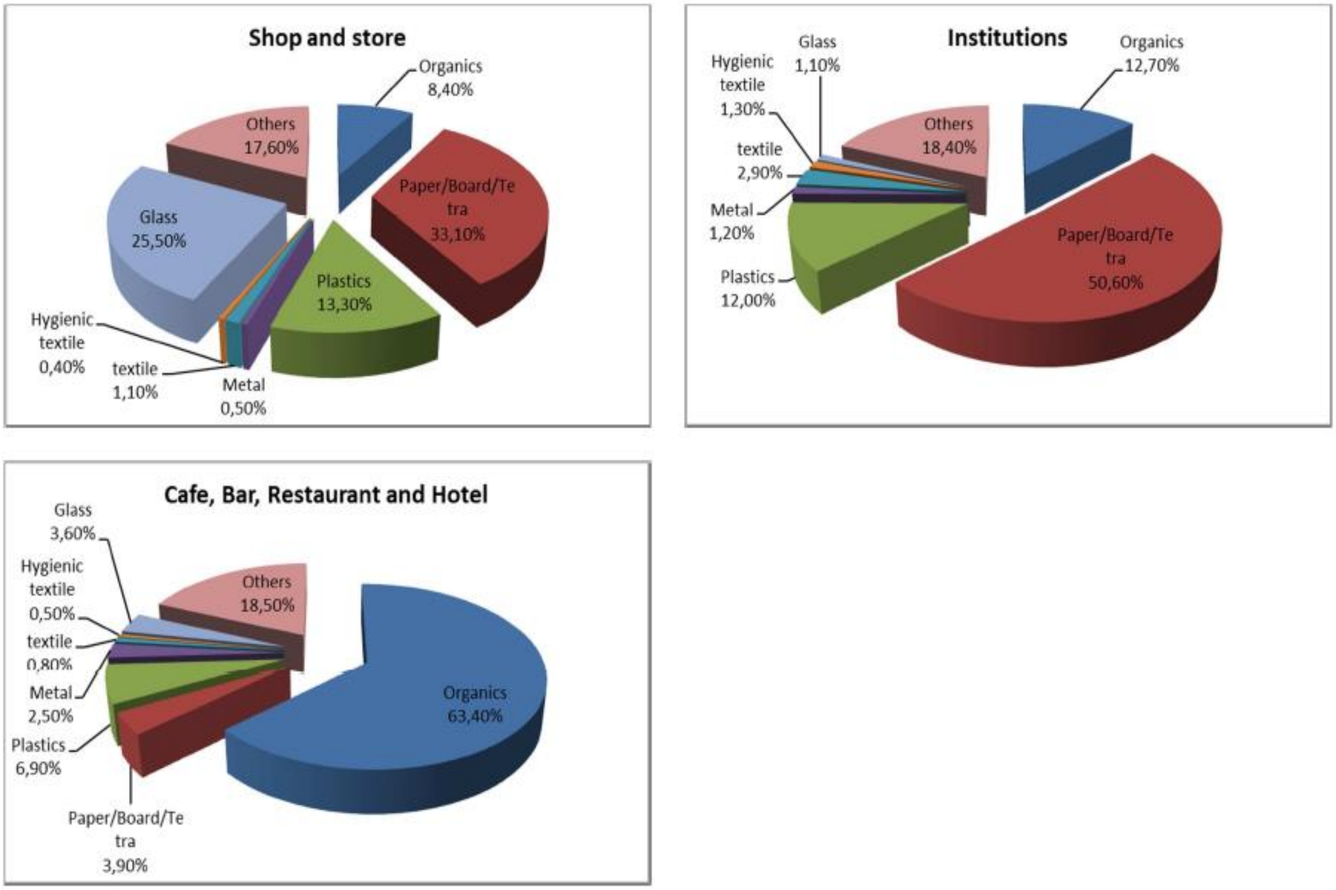


Figure 11 Composition of waste produced by Shop and stores, Institutions and Cafe, bars, restaurants, and Hotels (source: (FCSWM, 2013)

2.3.1.4 Industrial waste

An industry assessment finds that 50% of enterprises are ignorant of who manages their waste, even though industrials should manage their rubbish with private organizations. And this survey shows that, in reality, even for hazardous trash, the majority of industrials used municipal garbage services (rather than engaging private businesses or unlicensed operators) (FCSWM, 2013).

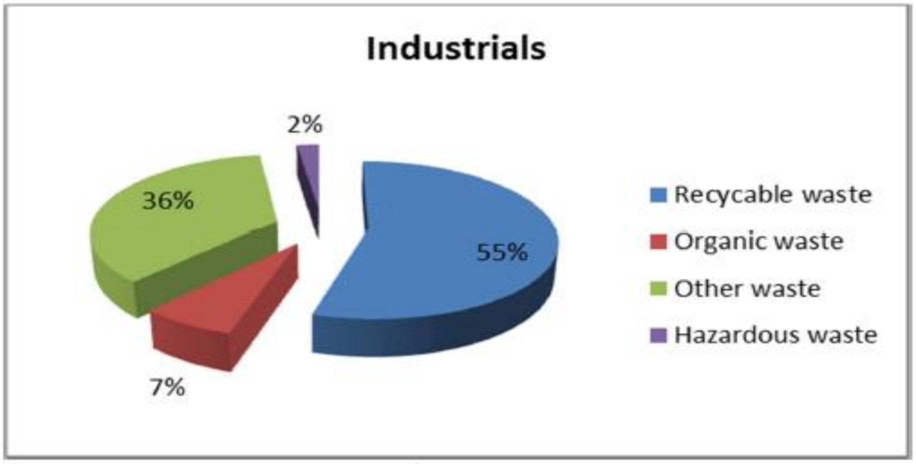


Figure 12 Composition of waste produced by Industrials (source: (FCSWM, 2013)

2.3.1.5 Hospital waste

According to the characterization survey, hospitals and clinics produce 0.29 tonnes per employee annually. Private organizations manage hospital waste, however, hospitals also use municipal services, such as hazardous waste disposal. Some of them have access to hazardous waste incinerators (FCSWM, 2013).

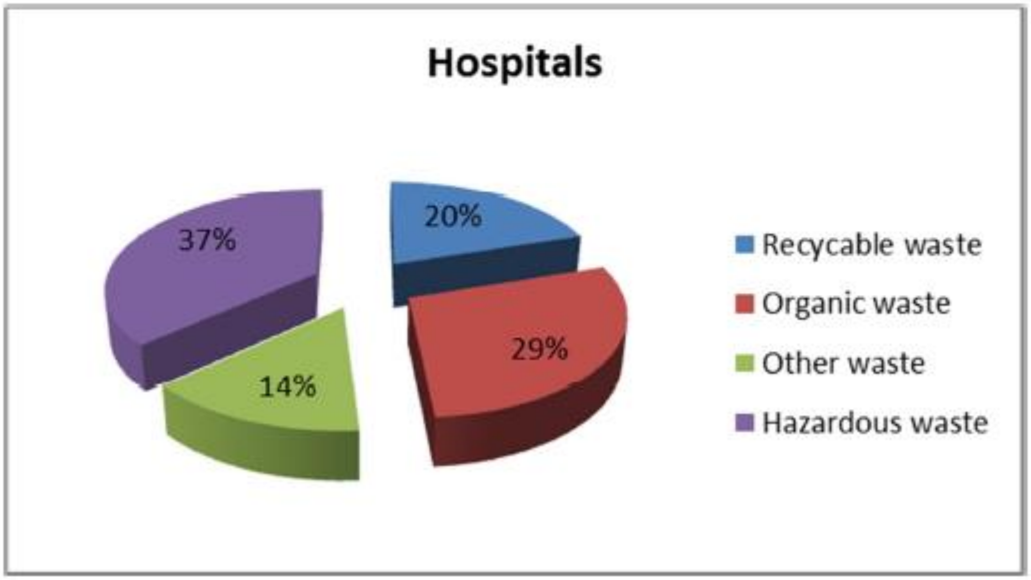


Figure 13 Composition of waste produced by hospitals (source: (FCSWM, 2013)

2.3.2 Existing services of solid waste management

The collection, transportation, disposal, and street sweeping of household, business, and institutional garbage are all handled by the Addis Ababa City Administration (AACA). Subcities are responsible for waste collection, which Werada offices are responsible for. Street sweeping, billing, knowledge, and oversight are the responsibilities of the Warada offices (FCSWM, 2013).

According to the survey carried out during this study by industrials and workshops, some of these activities use municipal rubbish collection services, even though they shouldn't be collected by AACA (FCSWM, 2013).

The formal waste management sector is under the control of the AACA. The institutional framework offers primary collection, secondary collection, and Koshe Rappi landfill management at three different service levels (FCSWM, 2013).

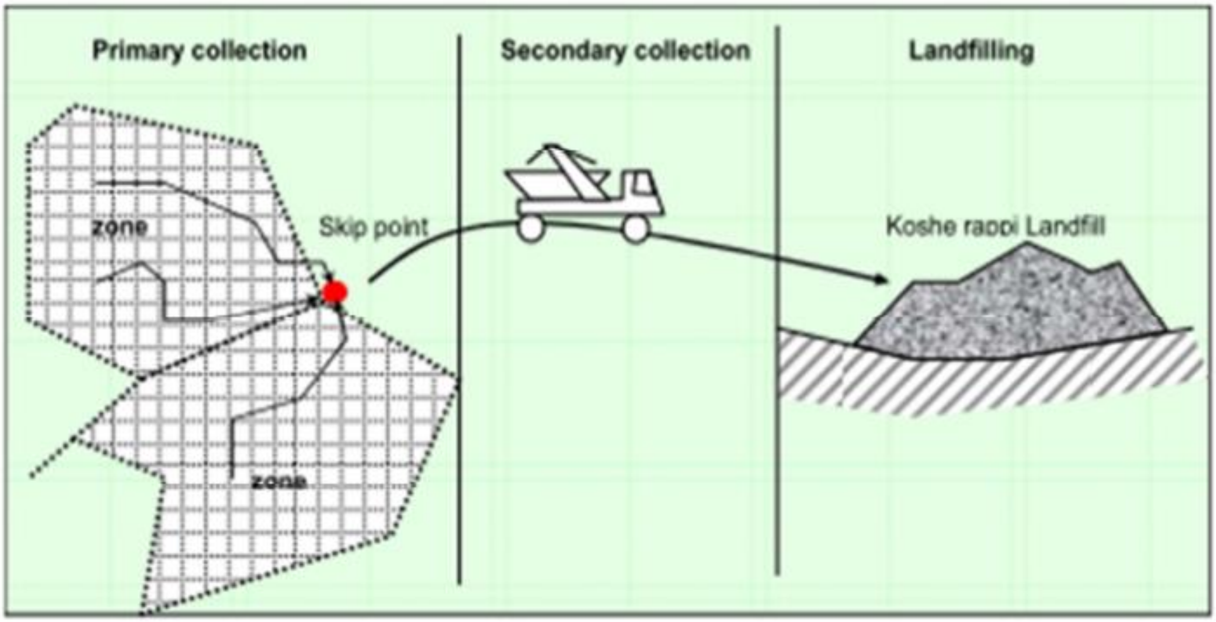


Figure 14 Current collection system in Addis Ababa (source: (FCSWM, 2013)

Solid waste landfills are a necessity in modern-day society because the collection and disposal of waste materials in centralized locations help minimize risks to public health and safety. Solid waste landfills, which are regulated differently than hazardous waste landfills, may accept a variety of solid, semi-solid, and small quantities of liquid wastes. Landfills generally remain open for decades before undergoing closure and post-closure phases, during which steps are taken to minimize the risk of environmental contamination (Encyclopedia, 2000).

Municipal solid waste (MSW) landfills accept nonhazardous wastes from a variety of sources, such as households, businesses, restaurants, medical facilities, and schools. Many MSW landfills also can accept contaminated soil from gasoline spills, conditionally exempted hazardous waste from businesses, small quantities of hazardous waste from households, and other toxic wastes. Industrial facilities may utilize their captive landfill (i.e., a solid waste landfill for their exclusive use) to dispose of non-hazardous waste from their processes, such as sludge from paper mills and wood waste from wood processing facilities (Encyclopedia, 2000).

A landfill is an engineered pit, in which layers of solid waste are filled, compacted, and covered for final disposal. It is lined at the bottom to prevent groundwater pollution. Engineered landfills consist of a lined bottom; a leachate collection and treatment system; groundwater monitoring; gas extraction (the gas is flared or used for energy production) and a cap system. The capacity is planned and the site is chosen based on an environmental risk assessment study (UNEP, 2002). There are also landfills specially designed to encourage anaerobic biodegradation of the organic fraction of the waste for biogas production by monitoring the oxygen conditions and moisture content. Landfills need expert design as well as skilled operators and proper management to guarantee their functionality(UNEP, 2002).

Physical Parameters

Physical parameters relate to measurements that are essentially physical in nature temperature, electrical conductivity, Resistivity, and Total suspended solids (TSS) (Stephenson, 2009).

Organoleptic parameters

Organoleptic parameters are measurements that may be determined by human senses, including sight (whether the water is clear or turbid), color (whether the water is colored or not), and smell. The organoleptic parameter in drinking water supplies is the highest source of consumer complaints for water utilities(Stephenson, 2009).

Chemical parameters

Chemical parameters are those that have to do with the amounts of different chemical species in water. These characteristics can contain harmful substances like arsenic, lead, mercury, and cadmium. Others have a health impact: sodium has been linked to heart disease, nitrites to bowel cancer, and nitrates to infantile methemoglobinemia. Chemical parameters are used for the assessment of treatment efficiency and to monitor compliance with legal standards (Stephenson, 2009).

2.4 Differences between Landfills and Dumpsites

A sanitary landfill is an arbitrary location that permits the gathering of rubbish, whereas a sanitary landfill is an engineered system. Most of the time, sanitary landfills are built in areas where groundwater and runoff are not an issue. Local governments and citizens must be taken into account. Modern equipment, well-trained staff, and the prevention of burning must be offered(OYIBOKA, 2020).

According to (OYIBOKA, 2020) One of the biggest issues the globe is having is waste disposal. Man creates garbage in his daily existence, which, if improperly managed, can cause health and environmental issues. The challenge for governments is to choose the best waste management and disposal practices. When the human population was not as large as it is today, a few decades ago, trash disposal was a simple process. People stored their rubbish in dumps, which are simply excavated areas of ground or pits. The majority of homes, particularly those in rural regions, have trash cans, whereas metropolitan communities have a shared trash can for inhabitants. Dumps lack processing control and are not governed by the government. They are everywhere, and they might or might not be covered in soil. They are also not monitored, which increases the likelihood that the liquid solid waste produces may contaminate the water supply.

Open dumps can draw pests like flies and rodents and release unpleasant odors that are dangerous to people. Due to this, dumps are seen as unlawful and have been replaced by landfills. Landfills that are governed by the government have replaced communal dumps (OYIBOKA, 2020).

A landfill should be contained in a small space and covered with several layers of dirt. The bottom of the pit must also have a liner to stop leachate, or the liquid from solid waste, from seeping through and contaminating the water supply(OYIBOKA, 2020).

A landfill must also have leachate treatment systems, and groundwater testing, and be covered with soil each day to prevent pest infestation and the release of offensive odors. A new landfill is built after the previous one is full. Toxins that are produced by the inability of garbage to decompose naturally can be found in old landfills. Landfills entice scavengers because they are good sources of recyclable goods, but if they are reckless, they run the risk of getting buried under the garbage. Although dumps and landfills are utilized to manage waste issues, they eventually run the risk of becoming environmental and health risks(OYIBOKA, 2020).

In conclusion, a dump is an area of land that has been excavated and used to store rubbish, whereas a landfill is an area of land that has been excavated and used to store waste, but is subject to government regulation. More compact than a landfill, it. Leachate collection and treatment systems are not present in dumps, but they are in landfills(OYIBOKA, 2020).

In contrast to a dump, a landfill contains a liner at the bottom to catch the liquid created by solid trash. To ward off pests and stop foul odors from escaping into the air, landfills are routinely covered with soil. Since air and water do not easily access the dump, it also aids in reducing the rate of rot. On the other side, dumps are virtually often covered, which accelerates the decay process and causes harmful gases to be released into the atmosphere(OYIBOKA, 2020).

Municipal solid waste, building materials, and possibly some types of agricultural and industrial garbage are all stored in sanitary landfills. Liners stop leachate from leaking from a properly constructed landfill. The primary idea of landfill design is to store trash without harming the ecosystem. In contrast, a dumpsite or open dump is just a big hole in the earth where trash is dumped. The hole could be a former quarry, open-pit mine, or clay pit that is now used as a garbage dump(OYIBOKA, 2020).

2.5 Major Sources of Groundwater Contamination

Groundwater contamination issues are one of the most important global environmental challenges, and they are made more difficult by a wide range of sources and chemistry(Ali, 2012).

Depending on how exposed the aquifer is to such activities, numerous human activities frequently cause groundwater contamination(Ali, 2012).

The following are only a few examples of the major sources of groundwater contamination:(Ali, 2012)

- Sewer leaks, sewage effluent, sewage sludge, urban runoff, landfills, latrines, and septic tanks are examples of municipal sources.
- Agricultural sources such as animal feces, leached salts, fertilizers, and pesticides;
- Industrial sources such as water treatment facilities, plant effluent, hydrocarbons, and pipeline and tank leaks; and
- Sources for mining wastes that deal with both liquid and solid mining wastes.

2.6 Factors Affecting Groundwater Quality

- ✓ **Landfill Lifespan**:

The longevity of the landfill is closely related to groundwater contamination. Due to the length of time and age of the landfills, as well as the kind of decomposed waste, pollutants produced over the years differ significantly in terms of physicochemical composition and heavy metal content. (OYIBOKA, 2020)states that leachate constituent concentration (mg/L) is divided into four phases: transition (0–5 years), acid production (5–10 years), methane fermentation (10–20 years), and final maturity (>20 years). When waste is first deposited at the landfill, groundwater may not already be affected. Between 1988 and 1993, aging caused more than 3400 Municipal Solid Waste Landfills to close or be abandoned in the United States(OYIBOKA, 2020).

These abandoned landfills need to be monitored to assess the risk of soil and groundwater pollution and to gather data on leachate migration (U.S. EPA, 2003). The amount of leachate produced by a landfill is also strongly influenced by its age. A landfill's deterioration is accompanied by an increase in leachate production. Leachate produced during the first five years of trash deposition in landfills has a ph range of 3.7 to 6.5, indicating the presence of bicarbonate ions and carboxylic acids. Leachate's ph eventually reaches a neutral or mildly alkaline range between 7.0 and 7.6. Long-term landfill use results in alkaline leachate with a ph range of 8.0 to 8.55(OYIBOKA, 2020).

- ✓ **Leachate Migration**

Water flowing through landfills in open landfills atop an aquifer like Solous frequently collects within or beneath the waste (OYIBOKA, 2020). This is because, in addition to rainwater percolating, degradation processes that are active within the waste also produce leachate, (OYIBOKA, 2020). Leachate from the landfill or dump flows outward and downward more as a result of the higher hydraulic head. Groundwater resources below the surface are at risk from downward flow. When nearby wells or boreholes have low water quality, leachate is likely to be created and migrate(OYIBOKA, 2020).

The flow direction of groundwater may differ from that of surface water. However, groundwater flows continually and slowly through the cracks in the rock and soil. A pollution plume will develop if a landfill contaminates the groundwater. The wells in that plume will be contaminated, but if other wells, including those near the dump, are not in the plume, they might not be harmed. Additionally, the fluctuation in leachate concentrations and groundwater flow directions affects how the leachate pollution plume behaves in the groundwater zone. (OYIBOKA, 2020).

However, according to(OYIBOKA, 2020), factors such as site design, waste type, hydrogeology, geochemistry, and climatic conditions might affect leachate migration from disposal sites. A comprehensive examination that takes into account all of these elements is a difficult endeavor.

2.7 Factor affecting leachate quality

The quality of leachate varies greatly. Numerous interrelated aspects, including the refuse density, time, composition, and depth of the trash, the availability of moisture and oxygen, landfill design in its operation (process waste), and waste age, can be blamed for the variance in leachate quality(Bassam et al., 2006).

- ✓ Depth of Waste
- ✓ Age of Landfill

- ✓ Waste Composition
- ✓ Moisture Availability
- ✓ Available Oxygen
- ✓ Temperature
- ✓ Landfill design in its operation, (Processed Waste)

2.8 Evaluation of Water Quality

There are numerous ways to assess the quality of water. However, the types of water pollutants cannot be expressed using these methods. (OYIBOKA, 2020)made an effort to create a program that would be affordable for monitoring the quality of groundwater through existing well samples. The mechanism for delivering a cumulatively determined numerical expression describing a certain level of water quality is provided by the Water Quality Index technique (WQI). One of the main benefits of WQI is that it mixes information from various water quality criteria into a mathematical equation that assigns a value to the condition of the water (OYIBOKA, 2020).

(OYIBOKA, 2020)in the United States created the first Water Quality Index using ten (10) of the most frequently measured water quality indicators, including dissolved oxygen, ph, coliforms, specific conductance, alkalinity, and chloride. Horton's technique for evaluating the quality of the water is now widely utilized throughout Africa, Asia, and Europe.

2.9 Concepts on the Quality of Groundwater

- **Water Quality Index (WQI) Concept**

The term "Water Quality Index" was first used in Germany more than 150 years ago, in 1848, when the presence or absence of specific organisms in water was employed as a gauge of a water source's suitability or otherwise(Uddin et al., 2021). The several water quality indices that are currently in use were created as instruments to classify the combined effects of water quality indicators and to offer details on the level of purity and quality of the water source under consideration(Uddin et al., 2021).

A. National Sanitation Foundation Water Quality Index (NSF WQI) (Wills & Irvine, 1996)

First developed by Horton in 1965. The main objective of **the NSF** water quality index method is to convert complex water analytical data into information that is easily understandable by any person or the general public. Summarized and simplify the raw analytical data of water samples in a single value. (eg. Wqi = 45.25 or 125) (Robert M. Brown, NinaI. McClelland, 1970)

How the National sanitation foundation water quality index developed

NSF WQI method was developed in 1970 by (Brown et al.) in collaboration with the National sanitation foundation (USA)(Robert M. Brown, NinaI. McClelland, 1970)

During the initial phase of the development of the NSF WQI method, Mr. Brown identified and selects one hundred forty-two (142) water quality experts who are water quality monitoring and assessment professionals. (Robert M. Brown, NinaI. McClelland, 1970)

- In the first phase, he ask them to identify Thirty-five 35 water quality parameters to be included in NSF WQI
- In the second phase, he asks them for an additional Nine (9) water quality parameters
- Then he asks them to select fifteen (15) important parameters out of forty-four (44) water quality parameters to be included in NSF WQI
- Finally Mr. Brown select nine (9) of the fifteen 15 water parameters to be incorporated in NSF WQI.

❖ STAGE 1

- Selection of water quality parameters to incorporate in the NSF WQI method

Table 4 Weight water quality parameters

Parameter	Weight
DO	0.17
Fecal coliform	0.15
Ph	0.12
BOD	0.1
Nitrate	0.1
Phosphate	0.1
Water temperature	0.1
Turbidity	0.08
Total dissolved solids	0.08

Since fecal coliform is not the target parameter in this study, the assigned weight (0.15) is just distributed evenly to all eight (8) parameters and becomes as shown in Table 5.

Table 5 New Weight water quality parameters

No	Parameters	Weight
1	Dissolved oxygen (DO)	0.189
2	Hydrogen ion (pH)	0.139
3	Biochemical Oxygen Demand (BOD)	0.119
4	Nitrate	0.119
5	Phosphate	0.119
6	Temperature	0.119
7	Turbidity	0.099
8	Total dissolved solids TDS	0.099

❖ STAGE 2

- Development of rating curve

Mr. Brown asks all hundred forty-two (142) to prepare separate rating curves using plain graph paper for all nine parameters that are incorporated in the NSF WQI method as shown in Figure 69. (Robert M. Brown, NinaI. McClelland, 1970)

❖ STAGE 3

- NSF WQI weight factor
- NSF WQI = $\sum_{i=0}^{n} Q_i W_i$
- Q_i = sub-indicate value for the i^{th} Water parameter
- W_i = weight associated with the i^{th} Water quality parameter
- $n = Number\ of$ water quality parameter

Table 6 Water quality status

Water Quality rating	**Water Quality status**
91-100	Excellent Quality
71-90	Good Quality
51-70	Moderate Quality
26-50	Poor Quality
0-25	Very Poor Quality

A. Find Q-value (Q_i) from the graph using a mean value of each parameter
B. Calculate NSF WQI using an Excel sheet

B. Nemerow's pollution index (NPI) also called Row's pollution index (Dawood, 2017)

❖ **NPI = $\frac{C_n}{S_n}$**

  - C_n= Concentration the n^{th} Parameter
  - S_n = prescribed standard limits of the n^{th} Parameter

❖ If the water parameter **NPI value > 1**

  - It indicates it is present in surplus amount or concentration

- The particular parameters have the potential of contributing pollution to in the water bodies' studies.

C. The Canadian Council of Minister of environment water quality index (CCME WQI)(Salman & Elnazer, 2015)

- ❖ CCME WQI consists of three main element
  - ➢ **F_1 (Slope)**

The proportion of variables (referred to as "failed variables") that do not achieve their objective at least once during the period under consideration is represented by F1 (scope):(Munna et al., 2013)

- ➢ **F_2 (Frequency)**

The percentage of individual tests that do not satisfy the objective (failed tests) is represented by the frequency (F2):(Munna et al., 2013)

- ➢ **F_3 (Amplitude)**

The amount by which failed test values fall short of their goals is indicated by the F3 (amplitude) parameter. Three steps are used to determine F3:(Munna et al., 2013)

.Formula & steps for calculating CCME WQI

- **Step 1**: Calculating the scope value (F_1 Value)

$$F_1 = \frac{No\ of\ failed\ variable}{Total\ No\ of\ variables}\ \text{X } 100$$

- **Step 2**: Calculating the Frequency value (F_2 Value)

$$F_2 = \frac{No\ of\ failed\ tests}{Total\ No\ of\ tests}\ \text{X } 100$$

- **Step 3**: Calculating the Amplitude value (F_3 Value)
- ✓ Three sub-steps
  - ➢ **Step 3.1**:

The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "**excursion**" and expressed as follows. When the test value must not exceed the objective:(Munna et al., 2013)

✓ $$\boldsymbol{excursion} = \left(\frac{\text{failed tests of value}}{\text{Objective}} \right) - 1$$

- **Step 3.2**:

The overall amount by which individual tests are out of compliance is computed by adding up their deviations from their goals and dividing by the entire number of tests (both those who succeeded and those that failed). The normalized sum of excursions, often known as nse, is calculated as follows:(Munna et al., 2013)

- ✓ **Normalized sum** $\boldsymbol{excrusion\ (nse)}$
- ✓ $nse = \frac{\sum_{i=1}^{n} \text{excursion}}{\text{Total No of tests}}$
- **Step 3.3**:
- ✓ $F_3 = \frac{\text{nse}}{0.01\text{nse}+0.01}$
- Overall calculation
- ✓ CCME WQI = $100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right]$

Table 7 After CCME WQI Calculation

CCME WQI	**Rating**	**Water Quality Characteristics**
95-100	Excellent	Water quality is intact; conditions are very close to natural or desired levels
80-94	Good	Water quality is intact, and only one minor threat or deterioration is observed, conditions rarely differed from the natural or desirable level.
65-79	Fair	Water quality is usually intact, but occasionally endangered or deteriorated; conditions sometimes deviate from natural or desirable levels.
45-64	Marginal	Water quality is frequently endangered or deteriorated. Conditions often deviate from natural or desirable levels.
0-44	Poor	Water quality is always endangered or deteriorated; conditions usually deviate from natural or desirable levels.

Source: (A Canadian Water Quality Guideline-Water Quality Index (CCME-WQI) based assessment study of water quality in Surma River (Salman & Elnazer, 2015))

Table 8 CCME WQI terms

CCME WQI Terms	
Variables	Parameters
Objectives	Standard limit
No of fail variable	No of the Parameters exceed the limit
Total No of the failed variable	Total No of the Parameters Studied
Total No of tests	Example 12 water parameters are studied and 2 sampling seasons then-No of test 12*2= 24

Source: (A Canadian Water Quality Guideline-Water Quality Index (CCME-WQI) based assessment study of water quality in Surma River (Salman & Elnazer, 2015))

D. Weighted Arithmetic index method(Satish Chandra et al., 2017)

- Calculation of weight Arithmetic index method
    - **Step 1**: Calculate the unit weight (W_n) factors for each parameter by using the formula

Where: $\boldsymbol{W_n} = \frac{\boldsymbol{K}}{\boldsymbol{S_n}}$, $\boldsymbol{S_n}$ = Standard desirable value of the i^{th} Parameters.

- **K** = $\frac{1}{\frac{1}{S_1}+\frac{1}{S_2}+\frac{1}{S_3}+\cdots+\frac{1}{S_n}} = \frac{1}{\sum\frac{1}{S_n}}$
- On Summation of all selected parameters unit weight factors
    - ✓ $W_n = 1(unity)$
        - **Step 2**: Calculate the sub-index (Q_n) value by using the formula

$\boldsymbol{Q_n} = \frac{[(\boldsymbol{V_n}-\boldsymbol{V_o})]}{[(\boldsymbol{S_n}-\boldsymbol{V_o})]}$ ***100,**

- ✓ $\boldsymbol{V_n}$ = mean concentration of the n^{th} Parameters.
- ✓ $\boldsymbol{S_n}$ = Standard desirable value of the n^{th} Parameters.
- ✓ $\boldsymbol{V_0}$ = Actual values of the parameters in pure water (generally $V_0 = 0$, for most parameters except for PH)
- ✓ $\boldsymbol{Q_{PH}} = \frac{[(\boldsymbol{V_{PH}}-\boldsymbol{7})]}{[(\boldsymbol{8.5}-\boldsymbol{7})]}$ ***100,**
    - **Step 3**: Combining Step 1 & **Step 2** WQI is calculated as follows
- ✓ Overall **WQI** = $\frac{\sum \boldsymbol{W_n Q_n}}{\sum \boldsymbol{W_n}}$

- ✓ WQI was developed by Brown et.al (1972)

Table 9 Water Quality Status

Water Quality Index	**Water Quality status**
0-25	Excellent Quality
26-50	Good Quality
51-75	Poor Quality
76-100	Very Poor Quality
>100	Unfit to drink

2.10 Correlation analysis

First of all the correlation matrix for all possible pairs of variables, was calculated. A correlation analysis is a bivariate method that was applied to describe the degree of relation between two chemical parameters. (Rosso, 2008).

A high correlation coefficient (near 1 or −1) means a good relationship between two variables and its value around zero meant no relationship between them at a significant level (p) of 0.7 are considered to be strongly correlated whereas r>0.5–0.7 shows moderate correlation (Singh et al., 2008).

2.11 Empirical Review

Different researchers have sought to address the effect of landfill sites on groundwater from various angles(Abd El-Salam & Abu-Zuid, 2015; Abu-Rukah & Al-Kofahi, 2001; Academic, 2012; Ali, 2012; Bassam et al., 2006; Chihanga, 2015; EMA, 2007; Haile & Abiye, 2012; JUMA, 2014; Longe & Balogun, 2010; Nkwunonwo et al., 2020; Ofomola et al., 2017; OYIBOKA, 2020; Parvin & Tareq, 2021; Przydatek & Kanownik, 2019; Salman & Elnazer, 2015; Shah et al., 2023; Singh et al., 2008; Smahi et al., 2013; Uddin et al., 2021).

According to Singh et al. (2008), the groundwater samples used in their study came from locations adjacent to the dump sites. In all, 11 groundwater samples, 5 MSW samples, and 1 leachate sample were collected. Samples of solid waste, leachate, and groundwater were compared hydro chemically to evaluate the impact of leachates on groundwater. The results suggest that some indicator traits, such as heavy metals of the three sample types mentioned above, may have an empirical association (Singh et al., 2008).

Furthermore, the K/Mg ratio indicates that leachate contamination of three groundwater samples was very severe. Additionally, numerous studies show NO_3^- and Pb levels that exceed those permitted by World Health Organization (WHO) drinking water rules. The preponderance of Fe and Zn in groundwater and solid waste samples could be attributed to the region's metal plating businesses (Singh et al., 2008).

(Abd El-Salam & Abu-Zuid, 2015) has indicated that the Sampling was conducted every two months over one year giving a total of six leachate samples and 12 groundwater samples. From each site, three leachate samples and six groundwater samples were collected. Leachate and groundwater quality close to the landfills were examined to assess the environmental effects of landfilling solid waste. Leachate's properties were highly varied, with significant contamination of organics, salts, and heavy metals, according to the results of physio-chemical tests. The leachate was biodegradable and un-stabilized, as shown by the BOD5/COD ratio (0.69) of the sample.

It was also discovered that conductivity, total dissolved solids, chlorides, sulfates, Mn, and Fe exceeded WHO and EPA guidelines, and the groundwater in the area around the dumps was not severely contaminated. The findings suggested that, in addition to ongoing monitoring of the groundwater and leachate treatment processes, factors increasing anaerobic biodegradation that result in leachate stability should be adjusted(Abd El-Salam & Abu-Zuid, 2015).

(Smahi et al., 2013) has indicated that the sampling network was composed of 19 wells, of which 3 (W1, W2, and W3) were upstream of the landfill (control wells). The other 16 remaining wells were downstream of the landfill. The majority of wells are used for drinking water supply, irrigation, animal feed, and for industry. Piezo metric level and geochemical tests of 19 wells have been completed to assess the extent of groundwater pollution caused by this waste. The quality of the groundwater down-gradient of the dump site is deteriorating, to the point where the wells are no longer functional, according to physicochemical data. The mapping of three locations downstream of the landfill was made possible by the statistical treatment of physicochemical data using principal components analysis.

The first is not very polluted, the second is slightly polluted, and the third is distinguished by water mineralization and an almost complete lack of organic debris. The radius of groundwater contamination increased from 200 meters in 1989 to around 1 km in 2001 to more than 2 km in 2013 (Smahi et al., 2013).

(Longe & Balogun, 2010) has indicated that to investigate the extent of groundwater contamination, six sampling points designated W1 to W6 were selected between 10 and 375 m down-gradient of the landfill site while the leachate sample was designated. Leachate and groundwater samples' water quality parameters (physicochemical composition and heavy metals) were analyzed. The mean concentrations of all measured parameters except NO_3^-, PO_4^+ And Cr^- Conform to the stipulated World Health Organization potable water standards and the Nigerian Standard for Drinking Water Quality(Longe & Balogun, 2010).

Except for NO_3^-, PO_4^+, and Cr^- All measured parameters' mean concentrations meet the WHO's requirements for drinkable water and the Nigerian Standard for Drinking Water Quality. Mean concentration values for TDS, DO, NH_4^+ , SO_4^+ , PO_4^+ , NO_3^- And Cl^- Are 9.17mgL^{-1} , 3.19 mgL^{-1}, 0.22 mgL^{-1}, 1.60 mgL^{-1}, 10.73 mgL^{-1}, 38.5 mgL^{-1}And 7.80 mgL^{-1}Respectively. The mean concentration values for Fe, Mn, Zn and Cr^- In groundwater samples are 0.07 mgL^{-1}, 0.08mgL^{-1} , 0.08 mgL^{-1} And 0.44 mgL^{-1} Respectively(Longe & Balogun, 2010).

The current findings indicate that the influence of landfill operations on the groundwater supply is crucial. It is assumed that the existing clay and silty clay soil strata at the landfill site had a substantial impact on the natural attenuation of leachate into the groundwater system. However, it has been noted that very soon, uncontrolled leachate accumulation at the base of the landfill poses a potential risk of pollution to groundwater resources in the absence of a properly built leachate collection system. The study suggests upgrading the Solous landfill to a level that would ensure adequate preservation of the area's surface and groundwater resources(Longe & Balogun, 2010).

3. RESEARCH DESIGN AND METHODOLOGY

3.1 Study area and period

The dump site is located in the South Western part of the city, on the territory of the Kolfe Keranio sub-city, in the previous Woreda 23/ Kebele 16, new Wereda 01 and Nifa Silk Lafto sub-city Wereda 02, about 8 kilometers away from the city center. Coordinates: 8°58’57’’N and 38°41’78’’E. The Koshe (Rappi) dump sited was established in 1964(FCSWM, 2013).

This study was conducted in Addis Ababa city, the capital city of Ethiopia, which is one of the largest urban centers in sub-Saharan Africa. The city covers an area of fifty-one thousand nine hundred forty-eight and eighty-five hundredths (51,948.85) hectares of land(AACA, 2014).

Kolfe Keraniyo and Nifas Silk Lafto are one of the eleven (11) sub city in Addis Ababa city Administration in which the dump site and wells near the dump site are the specific study area. Koshe dump site is located in Kolfe Keraniyo Area = (229,637.80)m^2 , two hundred twenty-nine thousand six hundred thirty-seven and eight tenths square meter, Perimeter = (2142.0578m) two thousand one hundred forty-two and five hundred seventy-eight ten-thousandths meter, and Nifas silk Lafto Area = (34,644.97m^2), thirty-four thousand six hundred forty-four and ninety-seven hundredths square meter, Perimeter = (836.88m) eight hundred thirty-six and eighty-eight hundredths meter.(Weldeghebrael, 2021). The study was conducted from November 2022 to May 2023.

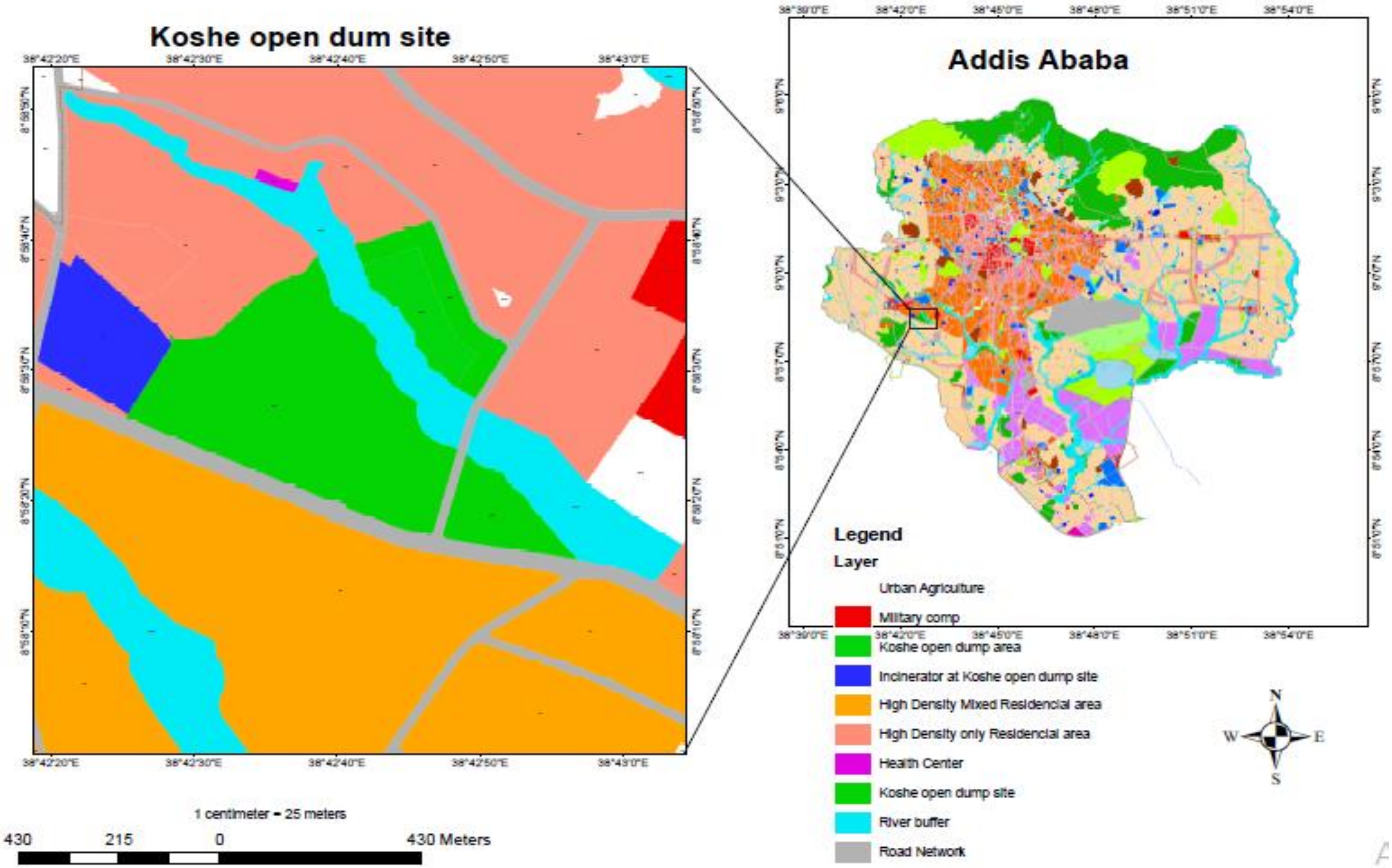


Figure 15 Land use the Land cover of the study area

Topography

As illustrated in Figure 16 the study area elevation ranges from 2019m to 3024m. And also the topographic Profile graphs of the study area as indicated in Figure 4 all samples are located downstream of the Koshe open dump site except Ayer Tena.

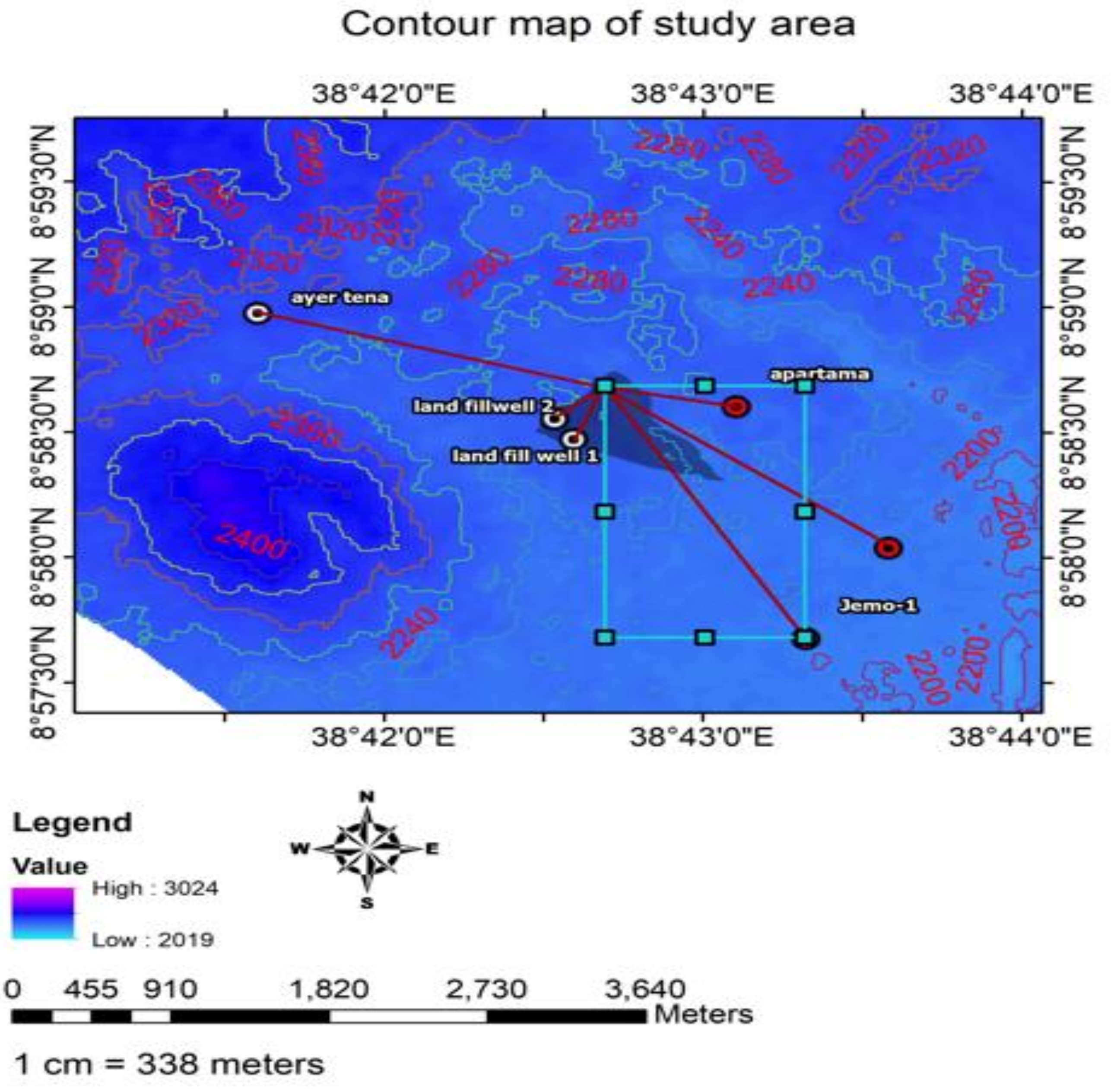


Figure 16 Contour map of the study area

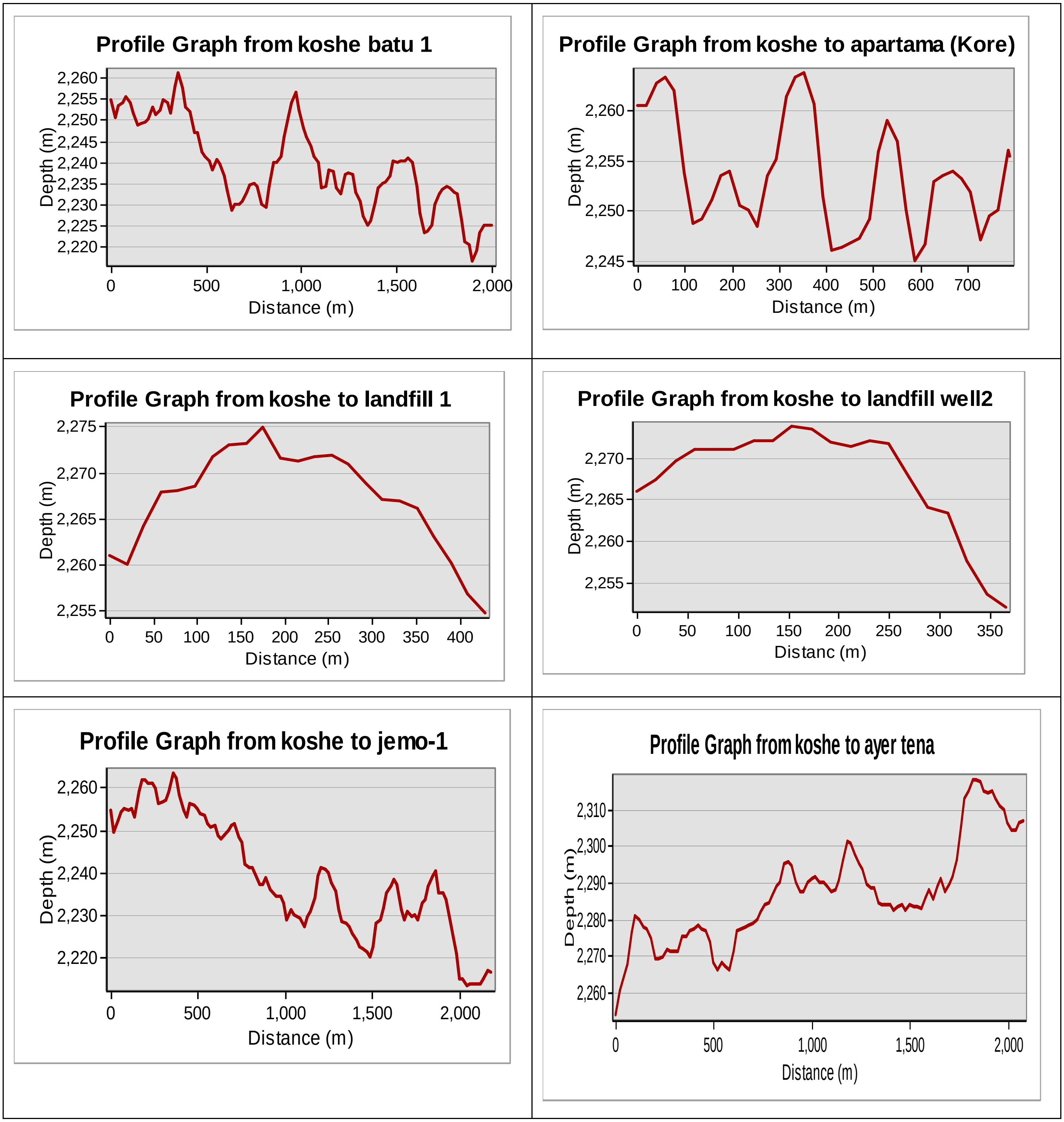


Figure 17 Profile graph of the study area

3.2 Research approach

To assess the impact of leachates on the groundwater quality, four general approaches/ methodologies were followed:

(1) The Physico-chemical nature of leachate and groundwater were compared with WHO, EPA, and Ethiopian standards(Abu-Rukah & Al-Kofahi, 2001; Flyhammar, 1995).

(2) The hazardousness leachate was analyzed using Effluent and Solid Waste Disposal Regulations SI6 2007 (EMA, 2007).

(3) The status of groundwater wells samples was analyzed using the water quality index(Academic, 2012; Dawood, 2017; Salman & Elnazer, 2015; Satish Chandra et al., 2017; Wills & Irvine, 1996).

(4) Using Bivariate Correlation analysis (Pearson correlation analysis) statistical techniques the association between leachate and groundwater sample was conducted(Güler & Thyne, 2004; Kumar & Alappat, 2005).

3.3 Research design/type

A descriptive quantitative study design was used to determine each variable to achieve the objective of the study.

3.3.1 Sampling design

3.3.1.1 Sample and Sampling Techniques

The lack of standard laboratories as well as the high cost of testing each sample affected the number of samples. The total number of wells around the land is forty-two 42 but most of the wells are significantly far away from the dump site as shown in figure 2. Depending on the location of the well (i.e. Upstream and downstream of the dump site) and distance from the dump site, thirty-eight (38) parameters, one(1) leachate, and Six (6) groundwater sample points were selected for the study as shown in (figure 18) below.

Figure 18 Location of sample groundwater wells around the dump site

Table 10 Description of the wells

Well data																
		Design well data											Current Well Data			
No	Site name	Locality	X-UTM	Y-UTM	Elevation	Depth	Casing(Ø)	SWL	DWL	DD	Pump.p (m)	Disharge,l/s	Working Hour	Working Hour	Disharge,l/s	Remark
1	Keraniyo-1/97	Keraniyo, Doro Erbata	463595	995915	2475	150	8	66			150	6	10	16	4	
2	Deginet-1	Wollete	463973	991974	2321	405	12&8	45.25	83.1	37.85	195	54.1	10	22	20	
3	Deginet-2	Wollete	463590	992116		420	12&8	80.1	144.77	64.67	195	50.6	10	20	22	
4	Repi roll	Repi Condominium	463850	993100	2400	150	8	84.71	-	-	-	11.3	10	22	18	
5	Yeshi debele	Keraniyo,Yeshi Debele	466403	996384	2387	430	12&8	59.1	237.3	178.2	240	10	10	0	0	dry
6	Alem bank	Alem Bank	463835	994912	2466	416	14&8	120.05	203.39	83.34	238	7.73	10	16	5	
7	Ayer tena-new	Ayer Tena K/Mihret	466050	993650	2360	201	10	71	82	11	-	20	10	20	9	
8	Success	Ayer Tena	466842	993128	2307	250	10	38	95	57	170	5	10	14	5	
9	Augusta	Torhailoch	468505	995156	2296	250	10	0	167.15	167.15	13.3		10	20	5	
10	Repi-33	Repi-new	463985	991540	2282	185	8	25	40	15		20	10	18	14	
11	Alemgena BH	Alem Gena	466200	988800		100	6		38		62	5	10	16	4	
12	Mekanisa-2/97 BH	Dertu	466308	989421	2230	184	8	2.6	56.12	53.52	152	15	10	22	9	
13	Site-19 BH	Jemo-2	468261	990357		196	10	7	113	106	130	17	10	18	8	
14	Site-01 BH	Jemo-2	463453	987806		184	10	1	14	13	123-135	47	10	22	26	
15	Site-16 BH	Harbu-1	467135	989840		213	10	3	97	94	130	25	10	16	12	
16	Site-18	Lebu Medhanialem	469191	989547		230	8	3	106	103	134	8	10	16	9	
17	Site-20	Mekanisa-1 new	470277	989578		230	10	13	89	76	130-140	15	10	20	16	
18	Site-21	Mekanisa-2 new	469245	990260		240	10	1.8	50	48.2	132-138	30	10	20	16	
19	Site-23	Repi	465741	989188	2274	135	10	3	36	33	100	20	10	18	15	
20	Site-24	Jemo-2	468512	989680		230	10	0	14	14	120-130	60	10	20	19	
21	Site-26	Jemo-1	469458	990594		181	8	0	25	25	159-171	15	10	16	10	
22	Site-27	Jemo-2	468196	990422		180	8	5	19	14	162-168	18	10	18	9	
23	Site-28	Harbu-2	467723	990028		161	8	2.65	8	5.35	111	20	10	22	20	
24	Site-29	Jemo-2	470790	990330		240	10	0	45	45	120-126	40	10	22	16	
25	Gofa-codominium	Gofa Cond.	471925	990400	2212	352	12&8	21.8	51.14	29.34	92.5	58.1	10	22	18	
26	Kosta-sefer	Saris Key Afer	472792	989152		500	12&8	7.5	119.94	112.44	201	50	10	22	30	
27	Lafto-Hana	Lafto Hanamariam	471400	988250	2205	84	8	9	-		75	21.3	10	22	18	
28	Site-25	Gofa (Lafto-2)	471500	990500		200	8	12	20	8	130	17	10	18	16	
29	Mekanisa-1/98(old)	Mekanisa	470453	990127	2225	140	10	22	25.36	3.36	86	50	10	22	19	
30	Mekanisa-2/96	Jermany Square	470070	991000	2214	170	8	10	66	56	154	10	10	18	12	
31	Mekanisa-1/97	Mekanisa Lafto	471125	989636	2215	-	10	11	-		103	26	10	22	28	
32	Mekanisa--1/96	Lebu Medhanialem	469500	989600	2217	150	8	4	39	35	121	3	10	14	3	
33	Repi-31	Harbu-5	465591	989872	2274	257	10	7	66	59	135	30	10	18	11	
34	Repi-32	Repi-1	465295	990132	-	200	8	10	32	22	120	20	10	22	10	
35	Jemo-michael	Jemo Michael	469231	990882	2237	552	14&8	25	100.34	75.34	183	30	10	20	20	
36	Yohanes-menafsha	Jomo	477566	991862	2262	344	12&8	28.86	122.7	94.73	202	9.3	10	10	10	
37	Gofa-military camp	Gofa-military camp	471454	991141	2250	309	10	38.58	55.1	16.52	157	31.4	10	10	25	
38	Fitawerari	Gotera	472882	992205	2298	312	10&6	90	114.93	24.93	156	16	10	10	12	
39	Lafto-Bridge	Haile Garment	472364	990174	2218	300	10	26.23	27.11	2.85	150	31	10	10	30	
40	Ginbot-20	Saris	472716	988618	2220	328	10	38.52	48.12	9.6	160	30	10	10	30	
41	Mekanisa(Areke Fabri	Mekanissa Areke Fabric	470610	991840	2221	463	12&8	8.06	54.3	46.24	180	40	10	16	30	
42	Lafto -industry sefer	Lafo industry	471236	988500	2211	340	10&6	42.2	143.2	101	194	15	10	18	10	

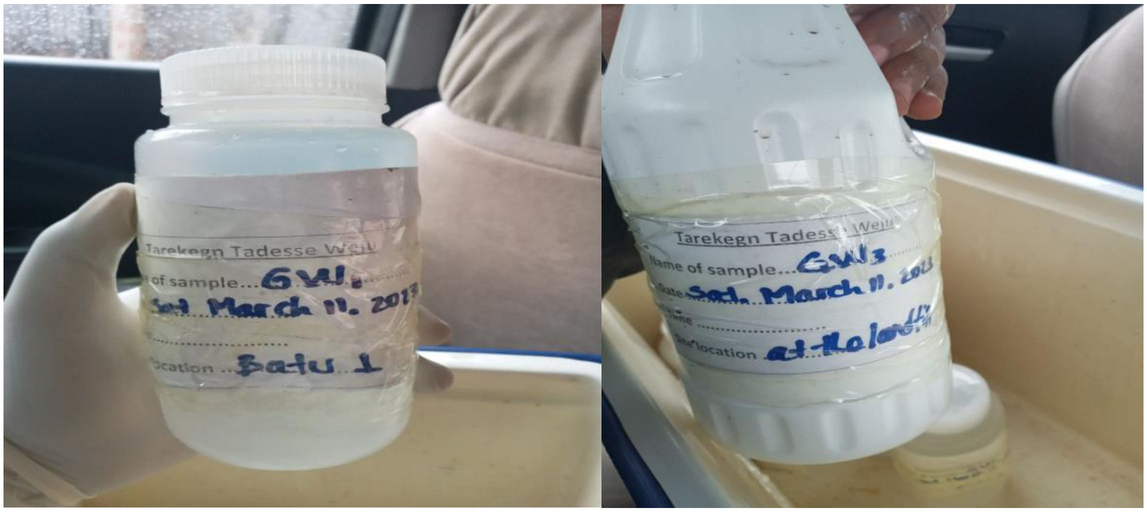
3.3.2 Quality control and Assurance

Water samples were collected in 0.50-liter plastic containers and before collection as part of quality control measures all the bottles were soaked with $HNO3$ after being washed with nonionic detergent and rinsed with double distilled water and rinsed again two to three times using well water at the point of collection and before usage.

Picture 1 Sample preparation

Picture 2 ice box, 500ml plastic container, and ice

Each bottle was labeled according to the sampling location while all the samples were preserved at $4^{o}c$ and transported to the laboratory. All the samples were collected, preserved, and analyzed according to the Standard Methods for the Examination of Water and Wastewater (APHA, 2012)("Standard Methods: For the Examination of Water and Waste Water," 1990). (Chunlong (Carl) Zhang, 2007)



Picture 3 Plastic Sample container

Picture 4 Sampling of groundwater and leachate

Picture 5 Sample Collection

The leachate was collected in pre-conditioned high-density polyethylene bottles. The bottles were conditioned by washing initially with detergent, then with nitric acid, and finally rinsing with distilled water. This was done to avoid contamination.

Picture 6 Leachate Sample Collection

Because the open dump site is not equipped with leachate collectors, the samples were collected at the leachate ponds formed around the sites. To obtain a good representation of the leachates within each SWD site, four samples were collected initially from different locations within each site and mixed to make one sample.

All the samples were collected, preserved, and analyzed according to the Standard Methods for the Examination of Water and Wastewater (APHA, 2012).

3.3.3 Sources of Data

The main sources of data for this research were Addis Ababa Environmental Protection Authority, Addis Ababa Water and Sewage Authority, and Addis Ababa Solid Waste Management Agency representatives. Groundwater and leachate samples were collected around the dump site.

Repi/Koshe (the city‘s solid waste disposal site) was visited. Moreover, informal discussions were made with residents living on riversides and near Koshe.

3.3.4 Primary source

In the study, both primary and secondary data were employed. Direct field surveys were used to gather the primary data. The data was gathered from groundwater samples near Addis Abeba City's Koshe open dump site.

3.3.5 Secondary source

Secondary data comprised information from journals, articles, textbooks, and other publications. World Health Organization(WHO, 2012), Environmental Protection Agency(U.S. EPA, 2009), Topography, Climatic conditions, Forms of subsurface water, Sources of Waste in Addis Ababa municipality, Existing services of solid waste management, the Description of wells, Geology of landfill site, waste composition, the water level of the well, and Ethiopian Standard(ES, 2013) for Drinking Water Quality standard limits were also part of the secondary data utilized.

3.4 Parameters Examined

This study examined thirty-eight (38) parameters of physical and chemical (including heavy metals) namely; Temperature (°C), Electrical conductivity EC (μs/cm), Resistivity (Ω m), Total suspended solids TSS (mg/l), Turbidity, (NTU), Hydrogen ion (ph), Total dissolved solids TDS (mg/l), Dissolved oxygen (DO) (mg/l), Potassium, mg/l as (K), Sodium, mg/l as (Na), Iron, mg/l as (Fe), Manganese, mg/l as (Mn), Total Chromium, mg/l as (Cr_3), Lead, mg/l as (Pb), Mercury, mg/l as (Hg), Zinc, mg/l as (Zn), Nickel, mg/l (Ni), Copper, mg/l as (Cu), Total Alkalinity, mg/l as (Caco_3), Chloride, mg/l as Cl, Ammonia, mg/l as (NH_4^+), Nitrate, mg/l as (NO_3^-), Phosphate, mg/l as (PO_4^+), Sulfate (SO_4^{2-}), mg/l, Cadmium (Cd), (mg/l), Calcium, (Ca^{2+}) mg/l, Magnesium (Mg^{2+}) (mg/l), Bicarbonates (HCO_3^-) (mg/l), Boron (B) (mg/l), Arsenic (As) (mg/l), Selenium (Si) (mg/l), Salinity (% or mg/l), Phosphorus (P) (mg/l), Molybdenum (Mo) (mg/l), Cobalt (mg/l) (Co), Silicon (mg/l) (Si), Biochemical Oxygen Demand (BOD_5) mg/l and Chemical Oxygen Demand (COD) (mg/l). The selection criteria for these parameters are based on the fact that they are the typical pollutant components found in groundwater close to dumpsites, to compare the result with other ground wells which are located around open dump sites in different countries, and to characterize the wells deeply to open further investigation on mitigation measures (Academic, 2012; Chihanga, 2015; Dawood, 2017; EMA, 2007; JUMA, 2014; Nkwunonwo et al., 2020; Ofomola et al., 2017; Salman & Elnazer, 2015; Satish Chandra et al., 2017; Shah et al., 2023; Wills & Irvine, 1996).

Sample preparation was performed on March 10, 2023. Sampling and analysis were conducted in three phases. First phase sampling and Laboratory analysis were conducted on March 11, 2023, for the Turbidity, Potassium, Sodium, Iron, Manganese, Total Chromium, Lead, Mercury, Zinc, Nickel, Copper, Total Alkalinity, Chloride, Ammonia, Nitrate, Sulfate Cadmium Sodium, Calcium, Magnesium, Bicarbonates, Boron, Arsenic, Selenium, Salinity, Phosphorus, Molybdenum, Cobalt, and Silicon for all five groundwater wells and leachate except for the well located in Ayer Tena high school because the pump was not working on that day.

Second-phase sampling and on-site analysis were conducted on April 18, 2023, for the Temperature, Electrical conductivity, Resistivity, Hydrogen ion, Total dissolved solids, Dissolved oxygen, and Salinity for all Six groundwater wells and leachate. The reason why it took this much time to conduct an on-site analysis is the absence of equipment and financial difficulties for the stock solution and other related expenses.

The final and third phase of sampling and Laboratory analysis was conducted on May 01, 2023, for the same parameter in phase one for a well located in ayer tena high school and also for parameters such as the Phosphate, BOD, and COD for all six groundwater wells and leachate.

3.5 Description of the sampling points

Table 11 illustrates the location of the six (6) sampled wells concerning their distance in meters to the nearest Koshe open dump site. The distance between the sampling points ranged from 0 km to 1.887 km.

Table 11 Description of the sampling points

SAMPLE ID	SAMPLE SITE	LOCATION	REMARKS
Around Batu-1 condominium	1.219Km from the East part of the dumpsite	469932.00 m E 991261.00 m N Lat 8.967806° Long 38.726333°	Groundwater sampled. This is well-located in a place called Batu-1 Condominium
Around Kore	413m from the northern part of the dumpsite	469056.00 m E 992301.00 m N Lat 8.976825° Lon 38.718495°	Groundwater sampled. This is well-located in a place called Apartama
Landfill well-1	0 m from the West part of the dumpsite	468015.00 m E 992212.00 m N Lat 8.975785° Lon 38.709772°	Groundwater sampled. This is well-located inside the open dump site
Landfill well-2	0 m from the South part of the dumpsite	468123.00 m E 992060.00 m N Lat 8.975206° Lon 38.710301°	Groundwater sampled. This is well-located inside the open dump site
Jemo 1	1.867 Km from the south-east part of the dumpsite	469458.00 m E 990594.00 m N Lat 8.967049° Long 38.737226°	Groundwater sampled. This is well-located in a place called Jemo-1 Condominium
Ayer Tena	1.887 Km from the West part of the dumpsite	466307.00 m E 992989.00 m N Lat 8.983397° Long 38.695818°	Groundwater sampled. This is well-located on the side of Ayer tena high school

L1	10m from the East part of the dumpsite	468839.00 m E 991913.00 m N Lat 8.974328° Long 38.716781°	Leachate sampled. Dark brown color
Koshe Open dump site	The Perimeter and area of the Koshe Open dump site are 2978..938 m and 264.282.77 m^2 Respectively.	468379.00 m E 992335.00 m N Lat 8.974674° Long 38.717107°	

3.6 Analytical Techniques and Laboratory Analysis

Water samples were evaluated to understand the impact of Koshe open dump site leachate on groundwater quality in surrounding wells. The data was presented in the form of tables, figures, and text for effective data and results presentation. Results of laboratory analyses were subjected to data evaluation by use of standard statistical methods (Rosso, 2008) The employed analytical procedures were following the standard recommendation of the (APHA, 2012) for the analysis of all parameters in potable and wastewater. All samples were analyzed for selected physical, chemical, and heavy metals parameters.

3.7 Onsite analysis

Temperature (°C), Electrical conductivity EC (μs/cm), Resistivity (Ω m), Hydrogen ion (pH), Total dissolved solids TDS (mg/l), Dissolved oxygen (DO) (mg/l), and Salinity (NaCl) were subjected to in-situ measurement by OAKTON 600 series waterproof portable meter kit.

Picture 7 On-site measurement

3.7.1 **Calibration** on-site measurement

pH was calibrated by (pH) 4 & 7 solutions. Electrical Conductivity (EC) was calibrated by standard KCl solution. Dissolved oxygen (DO) was calibrated by Oxygen saturated water. Temperature (°C), total dissolved solids (TDS), Salinity (NaCl), and Resistivity were calibrated by Deionized Water.

3.8 Offsite analysis

Examined parameters including Turbidity, (NTU), Potassium, mg/l as (K), Sodium, mg/l as (Na), Iron, mg/l as (Fe), Manganese, mg/l as (Mn), Total Chromium, mg/l as ($\mathrm{Cr_3}$), Lead, mg/l as (Pb), Mercury, mg/l as (Hg), Zinc, mg/l as (Zn), Nickel, mg/l (Ni), Copper, mg/l as (Cu), Total Alkalinity, mg/l as ($\mathrm{Caco_3}$), Chloride, mg/l as Cl, Ammonia, mg/l as ($\mathrm{NH_4^+}$), Nitrate, mg/l as ($\mathrm{NO_3^-}$), Phosphate, mg/l as ($\mathrm{PO_4^+}$), Sulfate (SO_4^{2-}), mg/l, Cadmium (Cd), (mg/l), Sodium, ($\mathrm{Na^+}$) mg/l, Calcium, ($\mathrm{Ca^{2+}}$) mg/l, Magnesium ($\mathrm{Mg^{2+}}$) (mg/l), Bicarbonates ($\mathrm{HCO_3^-}$) (mg/l), Boron (B) (mg/l), Arsenic (As) (mg/l), Selenium (Si) (mg/l), Salinity (% or mg/l), Phosphorus (P) (mg/l), Molybdenum (Mo) (mg/l), Cobalt (mg/l) (Co), Silicon (mg/l) (Si), Biochemical Oxygen Demand ($\mathrm{BOD_5}$) mg/l and Chemical Oxygen Demand (COD) (mg/l) were analyzed offsite analysis in the laboratory as prescribed by the Standard Methods for the Analysis of Water and Wastewater (APHA, 2012).

3.8.1 Calibration of offsite analysis

The Calibration of the heavy metals was analyzed using ICP-OES by preparing the standard stock solution. As shown in Appendix B, the calibration of each parameter indicates that Arsenic($r^2 = 0.9998$), lead($r^2 = 0.9996$), Boron($r^2 = 0.9999$), Zinc($r^2 = 0.9999$), Cadmium($r^2 = 0.9995$), Mercury ($r^2 = 0.9914$), Copper($r^2 = 1$), Nickel($r^2 = 0.9999$), Cobalt($r^2 = 0.9996$), Ammonia ($r^2 = 1$), Selenium ($r^2 = 0.9990$), Iron ($r^2 = 0.9997$), Nitrate ($r^2 = 1$), Manganese ($r^2 = 0.9999$), Chromium ($r^2 = 0.9998$), Calcium($r^2 = 0.9993$), Magnesium ($r^2 = 0.9985$), Potassium($r^2 = 1$), Sodium($r^2 = 0.9998$), Phosphorus($r^2 = 0.9989$), Molybdenum($r^2 = 0.9996$), and Silicon ($r^2 = 0.9998$).

3.9 Data analysis

3.9.1 Physico-chemical characteristics of groundwater and leachate

The data were collected, tabulated, and analyzed using Statistical Package for Social Sciences (SPSS) version 11.0 software package (BELLE, 1386). They were presented in the form of a range, arithmetic mean, standard deviation, and 95% and 99% confidence interval and compared the result with (WHO. EPA and Ethiopian standards).

3.9.2 Hazardous of leachate

The results of the descriptive statistics were summarized in (Appendix A) for the leachate samples that were taken from the Koshe open dump site. Leachate sample results were compared to the EPA standard(Agency, n.d.), the landfill standard(Chu, 2008), and the Effluent and Solid Waste Disposal Regulations SI6 2007 (EMA, 2007). SI6 adopts the pollutants pays principle to govern the disposal of waste (solid waste and effluent) and assigns licenses to the following four classes:(Chihanga, 2015)

- **BLUE – Blue** is described as being environmentally friendly in terms of the leachate's physical and chemical properties.
- **GREEN** - Concerning the physical and chemical characteristics of the leachate, Green is referred to as being a low environmental hazard.
- **YELLOW** - **Yellow** is categorized as a medium hazardous to the environment in terms of the leachate's physical and chemical properties.
- **RED** - Concerning the physical and chemical characteristics of the leachate, **Red** is referred to as being a high environmental hazard.

Table 12 Hazardousness of the leachate

Leachate of Koshe open dump site			**Effluent & Solid Waste Disposal Regulations SI6 (EMA, 2007)**				
			BLUE		**GREEN**	**YELLOW**	**RED**
No	**Parameter**	**Concentration**	**SAFE**		**LOW HAZARD**	**MEDIUM HAZARD**	**HIGH HAZARD**
1	Temperature (°C)		less than 25	b/n 25 & 35	b/n 35 & 40	b/n 40 & 45	More than 45
2	EC (µs/cm)		less than 200	b/n 200 & 1000	b/n 1000 & 2000	b/n 2000 & 3000	b/n 3000 & 3500 and ≥ 3500
3	TSS (mg/l)		less than 10	b/n 10 & 25	b/n 25 & 50	b/n 50 & 100	b/n 100 & 150
4	Turbidity (NTU)		less than 5	≤ 5			More than 5
5	pH		b/n 6 & 7.5	b/n 6 & 9	b/n 5 & 6 and b/n 9 & 10	b/n 4 & 5 and b/n 10 & 12	b/n 0 & 4 and b/n 12 & 14
6	TDS (mg/l)		Less than 100	b/n 100 & 500	b/n 500 & 1500	b/n 1500 & 2000	b/n 2000 & 3000 and ≥ 3000

7	DO (%)		More than 75	b/n 60 & 75	b/n 50 & 60	b/n 30 & 50	b/n 15 & 30 and ≤ 15
8	Potassium (mg/l)						More than 3500
9	Sodium (mg/l)		Less than 200	Less than 200	b/n 200 & 300	b/n 300 & 500	b/n 500 & 1000 and ≥ 1000
10	Iron (mg/l)		Less than 0.3	b/n 0.3 & 1	b/n 1 & 2	b/n 2 & 5	b/n 5 & 8 and ≥ 8
11	Manganese (mg/l)		Less than 0.1	Less than 0.1	b/n 0.1 & 0.3	b/n 0.3 & 0.4	b/n 0.4 & 0.5 and ≥ 0.5
12	Chromium (mg/l)		Less than 1.0	Less than 1.0	b/n 1 & 1.2	b/n 1.2 & 1.6	b/n 1.6 & 2 and ≥ 2
13	Lead (mg/l)		Less than 0.05	Less than 0.05	b/n 0.05 & 0.10	b/n 0.10 & 0.20	b/n 0.20 & 0.50 and ≥ 0.5
14	Mercury (mg/l)		Less than 0.01	Less than 0.01	b/n 0.01 & 0.02	b/n 0.02 & 0.03	b/n 0.03 & 0.05 and ≥ 0.05
15	Zinc (mg/l)		Less than 0.3	b/n 0.3 & 0.5	b/n 0.5 & 4.0	b/n 4.0 & 5.0	b/n 5.0 & 15 and ≥ 15
16	Nickel (mg/l)		Less than 0.3	Less than 0.3	b/n 0.3 & 0.6	b/n 0.6 & 0.9	b/n 0.9 & 1.5 and ≥ 1.5
17	Copper (mg/l)		Less than 1.0	Less than 1.0	b/n 0.1 & 2.0	b/n 2.0 & 3.0	b/n 3.0 & 5.0

							and ≥ 5
18	Total Alkalinity (mg/l)						More than_500
19	Chloride (mg/l)		Less than 200	b/n 200 & 250	b/n 250 & 300	b/n 300 & 400	b/n 400 & 500 More than_500
20	Ammonia (mg/l)		Less than 0.5	Less than 0.5	b/n 0.5 & 1.0	b/n 1.0 & 1.5	b/n 1.5 & 2.0 More than 2.0
21	Nitrate (mg/l)		*	*	*	*	*
22	Phosphate (mg/l)		Less than 0.5	Less than 0.5	b/n 0.5 & 1.5	b/n 1.5 & 3	b/n 3 & 5 More than 5.0
23	Sulfate (mg/l)		Less than 100	b/n 100 & 250	b/n 250 & 300	b/n 300 & 400	b/n 400 & 500 More than 500
24	Cadmium (mg/l)		Less than 0.01	Less than 0.01	b/n 0.01 & 0.05	b/n 0.05 & 0.1	b/n 0.1 & 0.3 More than 0.3
25	Sodium		Less than 200	Less than 200	b/n 200 & 300	b/n 300 & 500	b/n 500 & 1000 More than1000
26	Calcium (mg/l)		*	*	*	*	*
27	Magnesium (mg/l)		*	*	*	*	*
28	Bicarbonates(mg/l)		*	*	*	*	*

29	Boron (mg/l)		Less than 0.50	Less than 0.50	b/n 0.5 & 1.00	b/n 1.00 & 1.50	b/n 1.50 & 2.00 More than 2.00
30	Arsenic (mg/l)		Less than 0.05	Less than 0.05	b/n 0.05 & 0.1	b/n 0.1 & 0.15	b/n 0.15 & 0.30 More than 0.30
31	Selenium (mg/l)		Less than 0.05	Less than 0.05	b/n 0.05 & 0.1	b/n 0.05 & 1.50	b/n 1.5 & 3.00 More than 3.00
32	Salinity (%)						
33	Phosphorus (mg/l)						
34	Molybdenum(mg/l)						
35	Cobalt (mg/l)						Less or greater than 0.20
36	Silicon (mg/l)						
37	BOD (mg/l)		Less than 15	b/n 15 & 30	b/n 30 & 50	b/n 50 & 100	b/n 100 & 120 More than 120
38	COD (mg/l)		Less than 30	b/n 30 & 60	b/n 60 & 90	b/n 90 & 150	≤b/n 150 & 200 More than 200

3.9.3 Water quality index

A) **National Sanitation Foundation Water Quality Index (NSF WQI)** (Wills & Irvine, 1996)
B) **Nemerow's pollution index (NPI) also called Row's pollution index** (Dawood, 2017)
C) **The Canadian Council of Minister of environment water quality index (CCME WQI)**(Salman & Elnazer, 2015)
D) **Weighted Arithmetic index method**(Satish Chandra et al., 2017)

3.9.4 Correlation analysis

The correlation matrix for all possible pairs of variables was calculated. A Pearson correlation analysis is a bivariate method, which was applied to describe the degree of relation between two chemical parameters. The result of the correlation analysis was considered in the subsequent interpretation(Al-Arifi et al., 2013; BELLE, 1386; Helsel et al., 2020; Rosso, 2008).

When the correlation coefficient is high (around 1 or -1), it indicates a strong association between two variables; when it is low (about zero), it indicates a weak relationship; and when it is in the range of 0.5 to 0.7, it indicates a moderate relationship (Singh et al., 2008).

4. RESULTS AND DISCUSSION

4.1 Groundwater quality analysis

Table 13 Physico_chemical parameter

Sample	Unit	Batu-1	Kore	Lanfillwell-1	Lanfillwell-2	jemo-1	Ayer Tena High school	Leachate
PH		6.840	7.770	8.610	8.620	6.910	6.470	8.300
EC	µS/cm	460.650	509.800	600.000	599.300	376.150	279.200	27600.000
TDS	mg/l	255.200	283.750	334.900	334.600	207.100	155.100	15085.000
TSS	mg/l	0.000	0.000	33.000	29.500	1.200	0.150	2000.000
BOD	mg/l	61.560	53.750	51.520	50.200	49.850	76.500	40000.000
COD	mg/l	416.500	501.000	434.500	432.500	356.000	502.000	65000.000
Phosphate	mg/l	2.217	4.076	7.369	7.245	2.901	1.956	22.560
Dissolved_oxygen	mg/l	0.0450	0.1200	0.1100	0.1150	0.0600	0.0000	0.2100
Sodium	mg/l	19.360	19.190	50.790	50.670	23.870	16.690	1430.770
Calcium	mg/l	61.480	73.620	68.400	69.070	46.580	37.830	157.150
Magnesium	mg/l	15.150	17.790	15.100	14.950	10.690	9.140	108.920
Bicarbonates	mg/l	219.200	244.000	292.800	292.000	224.800	170.800	9108.920
Sulphate	mg/l	5.180	3.560	6.190	6.320	4.550	1.090	243.280
Chloride	mg/l	28.600	56.800	28.400	27.500	14.200	1.420	126.640
Nitrate	mg/l	18.52	47.65	47.79	48.87	11.18	17.45	2774.59
Potassium	mg/l	5.990	5.320	24.890	24.610	10.510	4.910	2739.330
Ammonia	mg/l	0.007	0.001	0.007	0.007	0.007	0.300	1054.790
Iron	mg/l	0.290	0.600	0.070	0.840	0.390	0.270	10.250
Chromium	mg/l	0.030	0.070	0.080	0.060	0.050	0.007	1.510
Zinc	mg/l	0.610	0.160	0.070	0.009	0.070	1.109	0.570
Manganese	mg/l	0.020	0.030	0.004	0.020	0.020	0.013	0.670
Cadmium	mg/l	0.010	0.010	0.010	0.010	0.010	0.002	0.020
Lead	mg/l	0.130	0.180	0.150	0.150	0.100	0.061	0.440
Nickel	mg/l	0.030	0.080	0.030	0.030	0.030	0.019	0.450
Copper	mg/l	0.060	0.070	0.080	0.001	0.080	0.036	0.650
Turbidity	NTU	0.020	0.010	1.810	1.850	0.020	1.120	111.100
Temperature	°C	31.300	27.050	23.550	23.450	26.850	21.100	24.600
Total_Alkalinity	mg/l	180.000	200.000	288.000	275.500	184.000	140.000	380.000
Salinity	%	0.200	0.300	0.350	0.300	0.200	0.100	16.400
Resistivity	mg/l	1.950	1.760	1.489	1.494	2.400	3.250	33.330
Boron	mg/l	0.080	0.220	0.080	0.020	0.070	0.020	2.030
Arsenic	mg/l	0.050	0.060	0.060	0.060	0.040	0.008	0.160
Mercury	mg/l	0.020	0.030	0.030	0.030	0.030	0.010	0.040
Phosphorus	mg/l	0.280	0.290	0.630	0.650	0.290	0.290	7.670
Silicon	mg/l	38.840	34.280	49.590	49.460	47.010	35.970	9.350
Molybdenum	mg/l	0.002	0.002	0.010	0.010	0.001	0.010	0.060
Cobalt	mg/l	0.020	0.030	0.030	0.020	0.020	0.007	0.180
Selenium	mg/l)	0.030	0.030	0.020	0.020	0.020	0.028	0.080

4.1.1 Physical Parameters

4.1.1.1 Temperature

Liquid stream temperature was measured for compliance monitoring and process control. (Stephenson, 2009)

As illustrated in Table 13, the temperature of the groundwater wells which are located at the batu_1 condominium (31.3°C), around Kore (27.05°C), at the landfill site (well 1) (23.55°C), at the landfill site (well 2) (23.55°C), around jemo_1(26.85°C) and around Ayer Tena high school (21.10°C) were higher than Ethiopian EPA Standard (20°C) But Comparing with WHO standard (30°C) only the temperature of the groundwater well's which are located at the batu_1 condominium (31.3°C) is slightly higher than WHO standard. In all samples, however, the temperatures ranged between 21.1°C and 31.3°C.

Similar results were recorded in another study in Kilifi County Kenya Open dumpsite where the temperatures ranged between 28 °C and 30 °C(JUMA, 2014).

The temperature has various impacts on the quality of water a variety of other inorganic components and chemical pollutants that may alter taste will depend on temperature, and cool water is typically more palatable than warm water. High water temperatures can increase corrosion issues as well as taste, odor, and color issues caused by microorganisms(WHO, 2012).

4.1.1.2 Electrical conductivity EC

The electrical conductivity of water or wastewater, which is indicative of the concentration of inorganic (ionized) salts and used for compliance monitoring, process control, and performance monitoring(Stephenson, 2009).

Analysis of the Electrical conductivity of sampled groundwater (table 13) shows that in Some sample locations like batu_1 condominium (460.65µs/cm), around kore (509.80 µs/cm), at the landfill site (well 1) (600.00 µs/cm) and at the landfill site (well 2) (599.3 µs/cm) were exceeded WHO acceptable level of 400.00 µs/cm but sampled groundwater located in Ayer Tena high school (279.20 µs/cm) and around jemo_1(376.15 µs/cm) satisfying WHO and EPA limits of (400 µs/cm & (500 µs/cm).) respectively for potable water.

Previous studies reported by (Chihanga, 2015) & (Ali, 2012)in Pomona Landfill, Harare, and Solid Waste Disposal in Urban Kano, Nigeria find out that Electrical conductivity ranged between 192 – 716 µs/cm and 178- 309 µs/cm respectively.

Higher Electrical conductivity values (,309 - 4200 µs/cm, and 1160–1485 µs/cm) were observed by (Abd El-Salam & Abu-Zuid, 2015) respectively.

Water's conductivity is a measurement of how well it can carry an electrical current. The geology of the location where groundwater flows have an impact on its conductivity(JUMA, 2014). In addition to leaving mineral deposits on plumbing fittings, water with high conductivity can taste and smell bad(WHO, 2012). The results indicate that most of the wells had very high electrical conductivity as compared to the guideline thus implying that the water is not suitable for drinking.

4.1.1.3 Resistivity

Reciprocal conductivity is used in compliance monitoring, process control, and performance monitoring in high-purity water applications(Stephenson, 2009). The units of conductivity are sometimes given as mhos/meter or milliohms/meter. Resistivity (ρ) is the inverse of conductivity ($\rho = 1 / \sigma$). The units of resistivity are Ohm meters (Ωm)(EPA, 1995).

It was also observed that the Resistivity of sampled groundwater (table 13) in sample locations around jemo_1 (2.4 Ωm) and Ayer Tena high school (3.25 Ωm) were within the limit of WHO acceptable level between 2 to 200 Ω·m for drinking water but sampled groundwater located in at the landfill site (well 1) (1.489Ωm), at the landfill site (well 2) (1.494 Ωm), batu_1 condominium (1.95 Ωm), and around kore (1.76 Ωm) did not satisfy WHO permissible limits(WHO, 2012).

4.1.1.4 Total suspended solids TSS

The concentration of insoluble material in water or wastewater is measured for compliance monitoring and performance monitoring(Stephenson, 2009).

As illustrated in table 13TSS of the sample from batu_1 condominium (0 mg/l), around Kore (0 mg/l), the landfill site (well 1) (33 mg/l), and at the landfill site (well 2) (29.5 mg/l), around jemo_1 (1.2 mg/l), and Ayer Tena high school (0.15 mg/l) were below WHO acceptable level of 600mg/l for drinking(WHO, 2012).

Previous studies reported by (Abd El-Salam & Abu-Zuid, 2015) in the Borg El-Arab landfill find out that Total suspended solids (TSS) ranged between 682 - 1591 mg/l.

TSS can include a wide variety of materials, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life(EPA, 1995).

4.1.2 Organoleptic parameters

4.1.2.1 Turbidity

For process management and compliance monitoring in the treatment of potable or higher-quality waters, a measurement of the number of colloidal particles (mainly fine clay) present in water or wastewater that causes haze or cloudiness is measured by light scattering. (nephelometric turbidity units), (Stephenson, 2009).

Table 13 presents that the Turbidity of all of sampled which are from batu_1 condominium (0.02 NTU), around Kore (0.01 NTU), the landfill site (well 1) (1.81 NTU), and at the landfill site (well 2) (1.85 NTU), around jemo_1 (0.02 NTU), and Ayer Tena high school (1.12 NTU) were below WHO acceptable level of (5 NTU)for drinking(WHO, 2012)(EPA, 1995)(ES, 2013).

Past studies revealed by (Chihanga, 2015) & (Ali, 2012) in Pomona landfill, Harare, and Solid Waste Disposal in Urban Kano, Nigeria stated that turbidity ranged between 0.09 – 63 NTU and 3 – 29 NTU respectively.

4.1.3 Chemical parameters

4.1.3.1 Chemical Parameters (Inorganic)

4.1.3.1.1 Hydrogen ion (pH)

A measure of the acidity or alkalinity of a solution defined as $\mathrm{Log}_{10}[H^{+}]$ Where $[H^{+}]$ Represents the molar hydrogen ion concentration. The ph value ranges from 1 (very acidic) through 7 (neutral) to 14 (very alkaline) and is used for compliance and performance monitoring and process control(Stephenson, 2009).

As shown in Table 13, the pH of the groundwater wells only which are located around Ayer Tena high school (6.47), were below permissible levels allowed by Ethiopian EPA (6.5 - 8.5), WHO (6.5 - 8.5) and also EPA (6.5 - 8.5) Standard and other samples which are located around the landfill site (well 1) (8.61) and at the landfill site (well 2) (8.62) and were exceeded permissible levels allowed by Ethiopian EPA, WHO and EPA Standard. However, the groundwater wells around jemo_1 (6.91), Kore area (7.77), and the batu_1 condominium (6.84) meet the EPA, WHO, and Ethiopian standards of 6.5 to 8.5 for potable water(WHO, 2012)(EPA, 1995) (ES, 2013).

Past studies revealed by (Ali, 2012; Chihanga, 2015; Longe & Balogun, 2010; Parvin & Tareq, 2021; Przydatek & Kanownik, 2019; Smahi et al., 2013) stated that pH of the groundwater well ranged between (6.3 - 8.2), (5.53 -7.8), (7–7.2), (6.3 - 7.5), (5.30 - 7.07), (6.7 - 7.1), (7.4 - 8.8) and (6.4 - 8.10) respectively.

Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters(WHO, 2012). The pH of water indicates if it is acidic, basic, or neutral on a scale of 0-14. A value below 7 is acidic and above 7 is basic. Drinking water with a ph below 6.5 may have a bitter or metallic taste and a pH above 8.5 may have a soda taste, deposits, and a slippery feel. pH can contribute to aesthetic problems (bad taste) and cause corrosion of plumbing components, like pipes, and dissolving metals like lead, copper, and zinc into the water(Shah et al., 2023).

4.1.3.1.2 Total dissolved solids TDS

Total dissolved solids, the concentration of all materials present in the solution used for compliance and performance monitoring in the treatment of water and wastewater. (Stephenson, 2009)

The TDS value of all samples which are from batu_1 condominium (255.2mg/l), around Kore (283.75mg/l), the landfill site (well 1) (334.90mg/l), at the landfill site (well 2) (334.60mg/l), around jemo_1 (207.1mg/l), and Ayer Tena high school (155.10mg/l) did satisfy WHO, EPA and Ethiopian standard acceptable level of 1000mg/l, 500mg/l, and 1000mg/l, respectively for drinking water as shown in table 13(WHO, 2012)(EPA, 1995) (ES, 2013).

Similar results were recorded in another study in Amin Bazar and Matuail landfill where the TDS ranged between 0 to 502 mg/l (Parvin & Tareq, 2021). And also Lower results were reported (Longe & Balogun, 2010) in another study in the Solous Igando Lagos city dumpsite where the TDS ranged between 3 to 23 mg/l.

4.1.3.1.3 Dissolved oxygen (DO)

The quantity of oxygen gas present in a liquid is used to measure the efficiency of aeration and de_aeration systems as well as to manage their operation(Stephenson, 2009).

The DO value of all samples which are from batu_1 condominium (0.045mg/l), around Kore (0.12mg/l), the landfill site (well 1) (0.11mg/l), at the landfill site (well 2) (0.115mg/l), around jemo_1 (0.06mg/l), and Ayer Tena high school (0mg/l) did not satisfy WHO permissible range of 6.5 to 8.5 for drinking water as shown in table 13(WHO, 2012).

Similar results were reported in another study in Amin Bazar and Matuail landfill where the TDS ranged between 0 to 2.45 mg/l.(Parvin & Tareq, 2021) And also higher results were revealed by (OYIBOKA, 2020), (Smahi et al., 2013), and (Longe & Balogun, 2010) in different dumpsites where the DO ranged between (0 to 3.8 mg/l), (1.3 to 6.4 mg/l) and (2.91 to 3.94 mg/l) respectively.

When looking specifically at drinking water, healthy water should consist of dissolved oxygen levels that range from 6.5-8.0 mg/L. While high DO levels will make drinking water taste better, it's important to understand that corrosion becomes more likely in this scenario, which is something that drinking water facilities must take into account. If DO levels drop below 6.5 mg/L, it's likely that the water is contaminated and may be unsafe to drink(Nkwunonwo et al., 2020).

4.1.3.1.4 Potassium

The Potassium value of some samples which are from the batu_1 condominium (5.99 mg/l), around Kore (5.32 mg/l), landfill site (well 1) (24.89mg/l), at the landfill site (well 2) (24.61 mg/l), and around jemo_1 (10.51 mg/l) and at Ayer Tena high school (4.91mg/l) exceeded ES permissible limits of 1.5 mg/l for drinking water as shown in table 13(ES, 2013).

The concentration of Potassium on different dump sites in past studies had equally revealed that, ranged between (3.28 – 126 mg/l), (1.53 – 43 mg/l), (1.5 – 34.9 mg/l) and (1.2 – 23.9 mg/l). (Ali, 2012), (Singh et al., 2008), (Smahi et al., 2013) and (Al-Arifi et al., 2013)

This substance can be used as a signal for other harmful substances in groundwater because potassium leakage from landfills for residential trash is often extremely high. A few potassium compounds may be very dangerous when consumed. High levels of potassium disrupt nerve impulses, which impairs almost all bodily processes but primarily the heart's ability to beat (Shah et al., 2023).

4.1.3.1.5 Iron

The amount of iron in water, which may be soluble or total (soluble plus suspended), is used to assess iron salt coagulation performance and compliance in drinkable waters(Stephenson, 2009).

Analysis of the Iron of sampled groundwater is shown (table 13) in that in Some samples around Kore (0.60 mg/l), at the landfill site (well 2) (0.84 mg/l) and around jemo_1(0..39 mg/l) exceeded WHO, EPA and Ethiopian standard acceptable level of 0.3 mg/l but sampled groundwater located at the landfill site (well 1) (0.07 mg/l), batu_1 condominium (0.29 mg/l), and from Ater Tena high school (0.27 mg/l), satisfied the standard(WHO, 2012)(EPA, 1995)(ES, 2013).

Similar results were recorded in another study (Abd El-Salam & Abu-Zuid, 2015; Ali, 2012; Chihanga, 2015; Longe & Balogun, 2010; Parvin & Tareq, 2021) in different Open dumpsites where the Iron ranged between (0 – 1 mg/l), (0 – 1.05 mg/l), (0.02 – 0.15 mg/l), (0.04 – 3.26 mg/l) and (0.044 – 5.90 mg/l) respectively.

Iron in water is not generally regarded to be dangerous, according to the WHO guideline (WHO, 2012). The taste may be affected by a high concentration of iron (Shah et al., 2023). But other studies (Nkwunonwo et al., 2020) suggest that The flavor, smell, and look of water can all be significantly impacted by high iron levels in the water. Additionally, iron can harm skin and plumbing fixtures while serving as the perfect breeding environment for particular bacteria.

4.1.3.1.6 Manganese

Manganese concentration, either soluble or total (soluble plus suspended), is used to monitor potable water compliance and performance(Stephenson, 2009). The analysis suggests that the Manganese value of all samples which are from batu_1 condominium (0.02 mg/l), around Kore (0.03 mg/l), the landfill site (well 1) (0.004 mg/l), at the landfill site (well 2) (0.02 mg/l), around jemo_1 (0.02 mg/l), and Ayer Tena high school (0.013 mg/l) satisfied WHO, EPA and Ethiopian standard acceptable level of 0.05 mg/l for drinking water as shown in table 13 (WHO, 2012)(EPA, 1995) (ES, 2013).

Similar results were recorded in another study (OYIBOKA, 2020), (Ali, 2012) and (Parvin & Tareq, 2021) in different dumpsites where the Manganese ranged between (0 – 0.01 mg/l), (0 – 0.87 mg/l) and (0 – 0.12 mg/l) respectively.

According to recent research, children who are exposed to high quantities of manganese in dissolved form may experience learning disabilities (Shah et al., 2023)(WHO, 2012). Hemoglobinuria, gastrointestinal problems, ataxia, pneumonia, diarrhea, stomatitis, and paralysis are all possible effects of heavy metal toxicity in the body(Nkwunonwo et al., 2020).

4.1.3.1.7 Total Chromium

The total concentration of chromium present as Cr_3 Used for compliance monitoring. (Stephenson, 2009). The Chromium value of all samples which are from batu_1 condominium

(0.03mg/l), around Kore (0.07mg/l), the landfill site (well 1) (0.08mg/l), at the landfill site (well 2) (0.06mg/l), around jemo_1 (0.05mg/l), and Ayer Tena high school (0.007mg/l) satisfy (EPA, 1995) permissible limits of 0.1mg/l for drinking water as shown in table 13. But comparing the result with the Ethiopian Standard and WHO standard (WHO, 2012)(ES, 2013) all of them except samples from Ayer Tena the exceeded acceptable level of 0.05mg/l.

Similar results were recorded in another study (Parvin & Tareq, 2021) and (Abd El-Salam & Abu-Zuid, 2015) in different dumpsites where the Chromium ranged between (0.05 – 0.09 mg/l), and (0.006 – 0.158 mg/l) respectively.

Recent research (Nkwunonwo et al., 2020) revealed that Potential Chromium toxicity in the body system can lead to hemoglobinuria, gastrointestinal disorders, ataxia, pneumonia, diarrhea, stomatitis, and paralysis.(Nkwunonwo et al., 2020) Others stated that Chromium beyond acceptable levels can cause Allergic dermatitis(Shah et al., 2023).

4.1.3.1.8 Lead

The concentration of lead in water for compliance monitoring (Stephenson, 2009).

As shown in Table 13, the Lead value of all samples from batu_1 condominium (0.13 mg/l), around Kore (0.18 mg/l), the landfill site (well 1) (0.15 mg/l), at the landfill site (well 2) (0.15 mg/l), around jemo_1 (0.10 mg/l), and Ayer Tena high school (0.061 mg/l) did not satisfy WHO, EPA and Ethiopian Standard permissible limits of (0.01 mg/l), (0.015 mg/l) and (0.01 mg/l) respectively for drinking water(WHO, 2012)(EPA, 1995)(ES, 2013).

Similar results were recorded in another study (OYIBOKA, 2020) and (Parvin & Tareq, 2021) in different dumpsites where the Lead ranged between (0 – 0.38 mg/l), and (0.007 – 0.17 mg/l) respectively.

According to (WHO, 2012)(Shah et al., 2023), and (Nkwunonwo et al., 2020) Lead can create major health problems if too much enters to body from drinking water or other sources. (Hout, 2012) It can harm the kidneys and brain and interfere with the creation of red blood cells, which are responsible for delivering oxygen to every cell in the body. Pregnant women, young children, and infants are most at risk of lead exposure. Scientists have connected children's lower IQS to lead's negative effects on the brain(Shah et al., 2023)(Nkwunonwo et al., 2020).

4.1.3.1.9 Mercury

The concentration of mercury, usually from industrial wastewater, for compliance monitoring(Nkwunonwo et al., 2020). It was also observed that (table 13), the Mercury value of all samples from batu_1 condominium (0.02 mg/l), around Kore (0.03 mg/l), the landfill site (well 1) (0.03 mg/l), at the landfill site (well 2) (0.03 mg/l), around jemo_1 (0.03 mg/l), and Ayer Tena high school (0.01 mg/l) exceeded WHO, EPA, and Ethiopian Standard permissible limits of (0.006 mg/l), (0.002 mg/l) and (0.001 mg/l) respectively for drinking water(WHO, 2012)(EPA, 1995)(ES, 2013).

Different results were recorded in another study (Przydatek & Kanownik, 2019) in different dumpsites where the Mercury ranged between (0.05 – 0.30 mg/l) in the dry season.

According to (Nkwunonwo et al., 2020) and (Shah et al., 2023) Short-term, high-level exposure might result in respiratory discomfort, diarrhea, and skin rashes. Low-level, long-term exposure might induce muscle tremors, irritation, personality changes, or rashes. Beginning symptoms of mercury-induced nerve damage include loss of sensation in the hands and feet, trouble walking, and slurred speech. It has occasionally resulted in death and paralysis.

4.1.3.1.10 Zinc

The concentration of zinc in water or wastewater is used for compliance monitoring (Stephenson, 2009). The analysis suggests that the Zinc value of all samples from batu_1 condominium (0.61 mg/l), around Kore (0.16 mg/l), the landfill site (well 1) (0.07 mg/l), at the landfill site (well 2) (0.009 mg/l), around jemo_1 (0.07 mg/l), and Ayer Tena high school (1.109 mg/l) did not exceed WHO, EPA and Ethiopian standard acceptable level of 3 mg/l, 5 mg/l, and 5 mg/l, respectively for drinking water as shown in table 13 (WHO, 2012)(EPA, 1995) (ES, 2013).

Relatively similar results were recorded in another study (OYIBOKA, 2020), (Chihanga, 2015), (JUMA, 2014), (Longe & Balogun, 2010), (Abd El-Salam & Abu-Zuid, 2015) and (Przydatek & Kanownik, 2019) in different dumpsites where the Zinc ranged between (0 – 0.20 mg/l), (0.07 –

0.10 mg/l), (0.07 – 0.10 mg/l), (0 – 0.23 mg/l), (0.001 – 0.343 mg/l) and (0.002 – 0.088 mg/l) respectively.

The studies of (Nkwunonwo et al., 2020) indicate that the threshold values for zinc in surface and groundwater typically do not exceed 0.01 and 0.05 g/l, respectively. Zinc is an essential trace metal. However, because zinc dissolves in pipes, the amounts in tap water can be much greater. It should be highlighted that customers might not be comfortable drinking water with zinc concentrations exceeding 0.003 mg/L(*Drinking Water 21*, n.d.).

4.1.3.1.11 Nickel

The concentration of nickel in water or wastewater for compliance monitoring (Stephenson, 2009). As illustrated in Table 13, the concentration of Nickel of all samples from batu_1 condominium (0.03 mg/l), the landfill site (well 1) (0.03 mg/l), at the landfill site (well 2) (0.03 mg/l), around jemo_1 (0.01 mg/l), and Ayer Tena high school (0.019mg/l) did not exceed WHO, acceptable level of 0.07 mg/l for drinking water(WHO, 2012). But samples from around Kore (0.08 mg/l) exceeded the WHO standard.

In another study (Parvin & Tareq, 2021)and (Abd El-Salam & Abu-Zuid, 2015) in different dumpsites where the mean of concentration Nickel was 0.02 between (0. – 0.20 mg/l) and ranged between (0.001 – 0.152 mg/l) respectively were also recorded.

Although nickel is essential to the nutrition of many creatures, it can also be poisonous and carcinogenic in excessive concentrations. Compared to men, women experience nickel allergies more frequently. Dermatitis can develop upon touch with exposed skin. When ingested through water, in little doses, it is harmless to humans and important in our diet. The greatest risk of developing health issues when nickel is inhaled is because it has a strong carcinogenic potential(Nkwunonwo et al., 2020).

4.1.3.1.12 Copper

The concentration of copper in water or wastewater for compliance monitoring (Stephenson, 2009). Table 13presents, the concentration of Copper of all samples from batu_1 condominium (0.06 mg/l), around Kore (0.07 mg/l), the landfill site (well 1) (0.001 mg/l), at the landfill site (well 2) (0.08 mg/l), around jemo_1 (0.08 mg/l), and Ayer Tena high school (0.036 mg/l) did not exceed WHO, EPA, and Ethiopian Standard permissible limits of (2 mg/l), (1.30 mg/l) and (2.00 mg/l) respectively for drinking water(WHO, 2012)(EPA, 1995)(ES, 2013).

Similar results were recorded in another study (Chihanga, 2015), (Ali, 2012), (Abd El-Salam & Abu-Zuid, 2015) and (Przydatek & Kanownik, 2019) in different dumpsites where the Copper ranged between (0 – 0.20 mg/l), (0 – 2.48 mg/l), (0.004 – 0.067 mg/l) and (0.002 – 0.018 mg/l) respectively.

Drinking water with excessive copper content may result in headaches, nausea, vomiting, diarrhea, stomach cramps, liver damage, and renal illness. Red blood cells may become damaged by high copper levels, and they may lose some of their capacity to carry oxygen. High copper levels may have an impact on male fertility(Division & 2023, n.d.).

4.1.3.1.13 Total Alkalinity

Alkalinity is a metric for how well bases can neutralize acids or how well water can act as a buffer. Determining a stream's capacity to neutralize acidic pollutants from rainfall or wastewater requires measuring its alkalinity. Alkalinity does not refer to pH but instead refers to the ability of water to resist changes in ph(Stephenson, 2009). There are no fixed standards for alkalinity since the variations in geology cause alkalinity to vary. In freshwater, alkalinity levels typically range from 20 to 200 mg/L. (EPA, 1995)(WHO, 2012) It was also observed that (table 13) Total Alkalinity samples from batu_1 condominium (180 mg/l), around jemo_1 (184 mg/l), and Ayer Tena high school (140 mg/l) did not exceed the permissible range of freshwater(Shah et al., 2023) between 20 to 200 for drinking water(ES, 2013). But samples from around Kore (200 mg/l), the landfill site (well 1) (288 mg/l), and the landfill site (well 2) (288 mg/l) exceeded the permissible range.

Similar results were recorded in another study (Ali, 2012) in different dumpsites where the Total Alkalinity ranged between (80 – 465 mg/l).

4.1.3.1.14 Chloride

When treating high-purity water, the concentration of chloride ions in the water is used to monitor process compliance, performance compliance, and compliance with the criteria for potable water(Stephenson, 2009). It was also observed that (table 13), the concentration of Chloride in all samples from batu_1 condominium (28.4 mg/l), around Kore (56.8 mg/l), the landfill site (well 1) (28.40 mg/l), at the landfill site (well 2) (27.5 mg/l), around jemo_1 (14.2 mg/l), and Ayer Tena high school (1.42 mg/l) did not exceed WHO and Ethiopian Standard permissible limits of 250 mg/l for drinking water(WHO, 2012) (ES, 2013).

In different studies (Chihanga, 2015), (Ali, 2012) and (Longe & Balogun, 2010) in different dumpsites where the Chloride ranged between (13 – 165 mg/l), (41.45 – 346 mg/l) and (2.84 – 13.47 mg/l) respectively stated.

Chloride in drinking water is not dangerous. The Guidelines for Canadian Drinking Water Quality recommend an aesthetic objective for chloride levels of 250 mg/L based on the possibility of unpleasant tastes at concentrations above this level and the increased risk of corrosion of pipes. There is no health-based drinking water guideline for chloride. (Nkwunonwo et al., 2020) But some recent studies revealed that (Shah et al., 2023) high chlorides in water may affect kidney function.

4.1.3.1.15 Ammonia

The concentration of dissolved ammonia gas and ammonium ions in water or wastewater for compliance and performance monitoring and process control(Stephenson, 2009).

Table 13presents, the concentration of Ammonia of all samples from batu_1 condominium (0.007 mg/l), around Kore (0.001 mg/l), the landfill site (well 1) (0.007 mg/l), at the landfill site (well 2) (0.007 mg/l), and around jemo_1 (0.007 mg/l) did not exceed WHO and Ethiopian Standard permissible limits of (0.2 mg/l), and (1.50 mg/l) respectively for drinking water(WHO, 2012)(ES, 2013). But a sample from Ayer Tena high school (0.30mg/l) exceeded the standards.

In another study (Longe & Balogun, 2010) and (Abd El-Salam & Abu-Zuid, 2015) in different dumpsites due to the impact of a septic tank where the concentration of Ammonia ranged between (0.12 – 0.30 mg/l) and (1.20 – 5.10 mg/l) respectively. This might be a result of leakage from the septic tank and sewer line (Longe & Balogun, 2010).

4.1.3.1.16 Nitrate

The concentration of nitrate ions for compliance and performance monitoring of potable waters and wastewater and process control of nitrification/denitrification(Stephenson, 2009). As illustrated in Table 13**,** The concentration of nitrate of all samples from batu_1 condominium (18.52 mg/l), around Kore (47.65 mg/l), the landfill site (well 1) (47.79 mg/l), at the landfill site (well 2) (48.87 mg/l), around jemo_1 (11.18 mg/l), and Ayer Tena high school (17.45mg/l exceeded WHO and EPA permissible limits of (11.00 mg/l) and (10.00 mg/l) respectively for drinking water(WHO, 2012)(EPA, 1995).

Similar results were recorded in another study (Chihanga, 2015), (Ali, 2012), (Singh et al., 2008) and (Longe & Balogun, 2010) in different dumpsites where the Nitrate ranged between (0.05 – 45 mg/l), (6.64 – 68 mg/l), (32 – 73.5 mg/l) and (17.4 – 60.5 mg/l) respectively.

Drinking water with nitrate levels above the maximum permissible level can cause serious illness in young children under the age of six months, which if left untreated, can result in death. Breathlessness and blue-baby syndrome are symptoms(Shah et al., 2023).

According to (Shah et al., 2023)(Nkwunonwo et al., 2020) Nitrate can cause blue baby syndrome. This can affect infants less than 6 months old. Nitrate may cause birth defects. This can affect women who are or may become pregnant. Nitrate may cause thyroid disease. This can affect everyone. Nitrate may increase the risk of certain kinds of cancer. This can affect everyone. (Hye-Knudsen, 1985) Infants who consume high levels of nitrate in drinking water for a prolonged time may die if not treated(EPA, 1995).

4.1.3.1.17 Phosphate

The concentration of phosphate ions (mostly from detergents and fertilizers) in water for compliance and performance monitoring(Stephenson, 2009).

As shown in Table 13, The concentration of Phosphate of all samples from batu_1 condominium (2.217 mg/l), around Kore (4.076 mg/l), the landfill site (well 1) (7.369 mg/l), at the landfill site (well 2) (7.245 mg/l), around jemo_1 (2.901 mg/l), and Ayer Tena high school (1.9256mg/l) exceeded WHO permissible limits of (0.10 mg/l) for drinking water(WHO, 2012).

In another study (Singh et al., 2008), (Longe & Balogun, 2010) and (Abd El-Salam & Abu-Zuid, 2015) in different dumpsites where the concentration of Phosphate ranged between (0.018 – 0.65 mg/l no agricultural activities and the presence of fertilizers), (7.07 – 15.12 mg/l due to small agricultural activities and presence of fertilizers) and (0.08 – 0.15 mg/l located away from agriculture) respectively.

Unless they are present in extremely high concentrations, phosphorus is neither hazardous to humans nor animals. Extremely high phosphate levels may cause digestive issues(Shah et al., 2023)(Nkwunonwo et al., 2020).

4.1.3.1.18 Sulfate

The concentration of Sulphate ions in water for compliance and performance monitoring (Stephenson, 2009). Table 13presents, the concentration of Sulphate of all samples from batu_1 condominium (5.18 mg/l), around Kore (3.56 mg/l), the landfill site (well 1) (6.19 mg/l), at the landfill site (well 2) (6.32 mg/l), around jemo_1 (4.55 mg/l), and Ayer Tena high school (1.09 mg/l) did not exceed WHO and Ethiopian Standard permissible limits of (250 mg/l) for drinking water(WHO, 2012) (EPA, 1995)(ES, 2013).

Similar results were recorded in another study (Smahi et al., 2013) and (Longe & Balogun, 2010) in different dumpsites where the concentration of Sulphate ranged between (5.60 – 116.20 mg/l) and (1.20 – 2.00 mg/l) respectively.

Drinking water with a high Sulphate content might cause diarrhea and dehydration in people who have not adapted to it. Sulfate sensitivity is frequently greater in infants than in adults. Sulphate can provide an unpleasant or medicinal flavor to water and have laxative effects at high concentrations. (Shah et al., 2023).

4.1.3.1.19 Cadmium

It was also observed that (table 13), the concentration of Cadmium of all samples from batu_1 condominium (0.01 mg/l), around Kore (0.01 mg/l), the landfill site (well 1) (0.01 mg/l), at the landfill site (well 2) (0.01 mg/l), and around jemo_1 (0.01 mg/l) exceeded WHO, EPA, and Ethiopian Standard permissible limits of (0.003 mg/l), (0.005 mg/l) and (0.003 mg/l) respectively for drinking water(WHO, 2012)(EPA, 1995)(ES, 2013). But the sample from Ayer Tena high school (0.002 mg/l) satisfies permissible standard limits.

Similar results were recorded in another study (Longe & Balogun, 2010), (Parvin & Tareq, 2021) and (Abd El-Salam & Abu-Zuid, 2015) in different dumpsites where the concentration of Cadmium ranged between (0.20 – 0.71 mg/l), (0.05 – 0.09 mg/l) and (0.006 – 0.158 mg/l) respectively.

Higher levels of cadmium in water can result from the use and disposal of items containing cadmium. For example, water draining from a landfill could have higher levels of cadmium. Excess levels of cadmium may damage kidneys(Shah et al., 2023).

4.1.3.1.20 Sodium

Table 13presents, the concentration of Sodium of all samples from batu_1 condominium (19.36 mg/l), around Kore (19.19 mg/l), the landfill site (well 1) (50.79 mg/l), at the landfill site (well 2) (50.67 mg/l), around jemo_1 (23.87 mg/l), and Ayer Tena high school (16.69mg/l) did not exceed WHO and Ethiopian Standard permissible limits of (200 mg/l) for drinking water (WHO, 2012).

Similar results were recorded in another study (Singh et al., 2008), (Smahi et al., 2013) and (Al-Arifi et al., 2013) in different dumpsites where the concentration of Cadmium ranged between (20.4 – 27 mg/l), (34.70 – 778.40 mg/l) and (20 – 398 mg/l) respectively.

Sodium in a water supply well does not present a substantial or unique health risk because the level obtained from water is much less than from the diet(Shah et al., 2023).

4.1.3.1.21 Calcium

Table 13presents, the concentration of Calcium of all samples from batu_1 condominium (61.48 mg/l), around Kore (73.62 mg/l), the landfill site (well 1) (68.40 mg/l), at the landfill site (well 2) (69.07 mg/l), around jemo_1 (46.58 mg/l), and Ayer Tena high school (37.83mg/l) did not exceed WHO and Ethiopian Standard permissible limits of (75 mg/l) for drinking water but all except samples from jemo_1 are close to the permissible limits(WHO, 2012)(ES, 2013).

Similar results were recorded in another study (Ali, 2012) and (Al-Arifi et al., 2013) in different dumpsites where the concentration of Calcium ranged between (13 – 368 mg/l) and (49 – 523 mg/l) respectively.

4.1.3.1.22 Magnesium

Table 13presents, the concentration of Magnesium of all samples from batu_1 condominium (15.15mg/l), around Kore (17.79 mg/l), the landfill site (well 1) (15.10 mg/l), at the landfill site (well 2) (14.95 mg/l), around jemo_1 (10.69 mg/l), and Ayer Tena high school (9.14 mg/l) did not exceed WHO and Ethiopian Standard permissible limits of (50 mg/l) for drinking water (WHO, 2012)(ES, 2013).

Similar results were recorded in another study (Ali, 2012) and (Smahi et al., 2013) in different dumpsites where the concentration of Magnesium ranged between (16 – 228 mg/l) and (5.40 – 110.80 mg/l) respectively.

4.1.3.1.23 Bicarbonates

It was also observed that (table 13), the concentration of Bicarbonate of all samples from batu_1 condominium (219.20 mg/l), around Kore (244 mg/l), the landfill site (well 1) (292.8 mg/l), at the landfill site (well 2) (292 mg/l), around jemo_1 (224.80 mg/l), and Ayer Tena high school (170.80 mg/l) exceeded WHO permissible limits of (120 mg/l) for drinking water(WHO, 2012).

Similar results were recorded in another study (Smahi et al., 2013) and (Al-Arifi et al., 2013) in different dumpsites where the concentration of Bicarbonate ranged between (114.20 – 1413.50 mg/l) and (145 – 283 mg/l) respectively.

4.1.3.1.24 Boron

Table 13presents, the concentration of Boron of all samples from batu_1 condominium (0.08 mg/l), around Kore (0.22 mg/l), the landfill site (well 1) (0.08 mg/l), at the landfill site (well 2) (0.02 mg/l), around jemo_1 (0.07 mg/l), and Ayer Tena high school (0.02mg/l) did not exceed

WHO and EPA permissible limits of (0.3 mg/l) for drinking water respectively (WHO, 2012)(EPA, 1995).

4.1.3.1.25 Arsenic

Table 13presents, the concentration of Arsenic of all samples from batu_1 condominium (0.05 mg/l), around Kore (0.06 mg/l), the landfill site (well 1) (0.06 mg/l), at the landfill site (well 2) (0.06 mg/l), and around jemo_1 (0.04 mg/l), exceeded WHO, EPA, and Ethiopian Standard permissible limits of (0.01 mg/l) for drinking water respectively. But the sample from Ayer Tena high school (0.008mg/l) satisfies Standard permissible limits.

Similar results were recorded in another study (Chihanga, 2015) in different dumpsites where the concentration of Arsenic ranged between (0 – 0.01 mg/l) respectively.

Arsenic is harmful to your health. Drinking water contaminated with arsenic can have negative health effects, including skin thickening and coloring, stomach discomfort, nausea, vomiting, diarrhea, immunological, neurological, or reproductive system abnormalities, and diabetes. Cancer of the bladder, lungs, skin, kidney, liver, and prostate can also be caused by consuming water with high amounts of arsenic. Children are more vulnerable to high concentrations of arsenic in drinking water than adults because they consume more water relative to their body weight and because they are going through critical periods of development, particularly in the brain(Smith & Steinmaus, 2011).

4.1.3.1.26 Selenium

As illustrated in table13, the concentration of Selenium of all samples from batu_1 condominium (0.03 mg/l), around Kore (0.03 mg/l), the landfill site (well 1) (0.02 mg/l), at the landfill site (well 2) (0.02 mg/l), around jemo_1 (0.02 mg/l), and Ayer Tena high school (0.028 mg/l) did not exceed WHO permissible limits of (0.04 mg/l) for drinking water but samples from batu_1 condominium (0.03 mg/l) and around Kore (0.03 mg/l) are close to the permissible limits (WHO, 2012).

Agricultural runoff that leaches natural selenium compounds from dry, undeveloped soil is one source of selenium in drinking water, along with mine discharge, natural deposits, refinery discharge, and discharge from natural sources. Long-term selenium exposure above the maximum contaminant level might result in fingernail or hair loss, numbness in the extremities, or circulation issues(EPA, 1995)(U.S. EPA, 2009).

4.1.3.1.27 Salinity

Table13presents, the concentration of Salinity of all samples from batu_1 condominium (0.2 %) (2000 mg/l), around Kore (0.3 %) (3000 mg/l), the landfill site (well 1) (0.35 %) (3500 mg/l), at the landfill site (well 2) (0.3 %) (0.30 mg/l) and around jemo_1 (0.20 %)(2000 mg/l) exceeded WHO permissible limits of (0.12 %) (1200 mg/l) for drinking water respectively but a sample from Ayer Tena high school (0.10 %)(1000 mg/l) satisfying WHO permissible limits (WHO, 2012). Salinity is the saltiness or measure of dissolved salt in water(Al-Arifi et al., 2013).

Less than 600 mg/l is regarded as good quality drinking water. 600 to 900 mg/l is regarded as fair quality. 900 to 1200 mg/L is regarded as poor quality. Greater than 1200 mg/l is regarded as unacceptable(EPA, 1995)(Al-Arifi et al., 2013).

Similar results were recorded in another study (Al-Arifi et al., 2013) in a dumpsite where the concentration of Salinity ranged between (288 – 3120 mg/l). The total amount of salt in the water can affect the taste of the water(Shah et al., 2023).

4.1.3.1.28 Phosphorus

As illustrated in table13, the concentration of Selenium of all samples from batu_1 condominium (0.28 mg/l), around Kore (0.29 mg/l), the landfill site (well 1) (0.63 mg/l), at the landfill site (well 2) (0.65 mg/l), around jemo_1 (0.29 mg/l), and Ayer Tena high school (0.29mg/l) did not exceed WHO permissible limits of (40.00 mg/l) for drinking water(WHO, 2012).

4.1.3.1.29 Molybdenum

The concentration of Molybdenum in samples from the landfill site (well 1) (0.01 mg/l), Ayer Tena high school (0.01 mg/l), and at the landfill site (well 2) (0.01 mg/l) equaled with WHO permissible limits of (0.01 mg/l) for drinking water but samples from batu_1 condominium

(0.002 mg/l), around Kore (0.002 mg/l), and around jemo_1 (0.001 mg/l) satisfied WHO (WHO, 2012) permissible limits as shown in table13.

Molybdenum is known as a trace element that is crucial for both humans and animals. For several population groups, safe and appropriate intake levels have been recommended, including 0.015-0.04 mg/day for babies, 0.025-0.15 mg/day for kids aged 1 to 10, and 0.075-0.25 mg/day for everyone over the age of 10(Quality, 1996).

4.1.3.1.30 Cobalt

Table13presents, the concentration of Cobalt of all samples from batu_1 condominium (0.02 mg/l), around Kore (0.03 mg/l), the landfill site (well 1) (0.02 mg/l), at the landfill site (well 2) (0.03 mg/l), around jemo_1 (0.02 mg/l), and Ayer Tena high school (0.007 mg/l) exceeded WHO permissible limits of (0.0009mg/l) for drinking water respectively(WHO, 2012).

4.1.3.1.31 Silicon

Table13 presents the concentration of Silicon of all samples from batu_1 condominium (38.84 mg/l), around Kore (34.28 mg/l), the landfill site (well 1) (49.59 mg/l), at the landfill site (well 2) (49.46 mg/l), around jemo_1 (47.01 mg/l), and Ayer Tena high school (35.97 mg/l) exceeded WHO permissible limits of (30 mg/l) for drinking water respectively(WHO, 2012).

The reason why the concentration of silicon in groundwater is higher than leachate is, silicon is more commonly found in rocks and minerals that make up the Earth's crust, rather than being specifically present in water sources. When these rocks erode over time, they release silicon into the environment, which can then be transported by water (Way, 2006).

4.1.3.2 Chemical Parameters (Organic)

4.1.3.2.1 BOD

Biochemical Oxygen Demand is a measure of the concentration of organic matter in wastewater that can be aerobically biologically degraded and is used for compliance and performance monitoring(Stephenson, 2009).

Table13 presents the concentration of BOD of all samples from batu_1 condominium (61.56 mg/l), around Kore (53.75 mg/l), the landfill site (well 1) (51.52 mg/l), at the landfill site (well 2) (50.20 mg/l), around jemo_1 (49.85 mg/l), and Ayer Tena high school (76.50mg/l) exceeded WHO permissible limits of (1 mg/l) for drinking water respectively(WHO, 2012).

Similar results were recorded in another study (Abd El-Salam & Abu-Zuid, 2015) in a dumpsite where the concentration of BOD ranged between (36 – 95 mg/l).

If the BOD is high, that means that microorganisms are using most of the Oxygen. This situation makes it difficult for larger aquatic animals to survive. However, if the BOD. Is low, there is an abundance of Oxygen which leads to good water quality. The BOD is an important water quality factor that is directly related to the overall health of the water body(Stephenson, 2009).

4.1.3.2.2 Chemical Oxygen Demand

Chemical Oxygen Demand is a measure of the concentration of organic matter in wastewater that can be chemically oxidized by dichromates and is used for compliance and performance monitoring(Stephenson, 2009).

When treated wastewater is discharged into the environment, it can introduce pollution in the form of organic content to receiving waters. High levels of wastewater COD indicate concentrations of organics that can deplete dissolved oxygen in the water, leading to negative environmental and regulatory consequences. To help determine the impact and ultimately limit the amount of organic pollution in water, oxygen demand is an essential measurement. (Stephenson, 2009).

Table13presents, the concentration of COD of all samples from batu_1 condominium (416.50 mg/l), around Kore (501 mg/l), the landfill site (well 1) (434.50 mg/l), at the landfill site (well 2) (432.50 mg/l), around jemo_1 (356.00 mg/l), and Ayer Tena high school (502 mg/l) exceeded WHO permissible limits of (5 mg/l) for drinking water respectively(WHO, 2012).

Similar results were recorded in another study (Chihanga, 2015) and (Smahi et al., 2013)in a dumpsite where the concentration of COD ranged between (108 – 756 mg/l) and (0 – 332.80 mg/l).

4.2 Leachate quality analysis

Table 14 Physical and chemical properties of the leachate

Leachate of Koshe open dump site			**Effluent & Solid Waste Disposal Regulations SI6 (EMA, 2007)**				
			BLUE		**GREEN**	**YELLOW**	**RED**
No	**Parameter**	**Concentration**	**SAFE**		**LOW HAZARD**	**MEDIUM HAZARD**	**HIGH HAZARD**
1	Temperature (°C)	24.50	less than 25	b/n 25 & 35	b/n 35 & 40	b/n 40 & 45	More than 45
2	EC (µs/cm)	27,600	less than 200	b/n 200 & 1000	b/n 1000 & 2000	b/n 2000 & 3000	b/n 3000 & 3500 and ≥ 3500
3	TSS (mg/l)	2,000	less than 10	b/n 10 & 25	b/n 25 & 50	b/n 50 & 100	b/n 100 & 150 more than 150
4	Turbidity (NTU)	111.10	less than 5	≤ 5			More than 5
5	pH	8.3	b/n 6 & 7.5	b/n 6 & 9	b/n 5 & 6 and b/n 9 & 10	b/n 4 & 5 and b/n 10 & 12	b/n 0 & 4 and b/n 12 & 14
6	TDS (mg/l)	15,085	Less than 100	b/n 100 & 500	b/n 500 & 1500	b/n 1500 & 2000	b/n 2000 & 3000 and ≥ 3000
7	DO (%)	4.00	More than 75	b/n 60 & 75	b/n 50 & 60	b/n 30 & 50	b/n 15 & 30 and ≤ 15

8	Potassium (mg/l)	2,739.33					More than_3500
9	Sodium (mg/l)	1,430.77	Less than 200	Less than 200	b/n 200 & 300	b/n 300 & 500	b/n 500 & 1000 and ≥ 1000
10	Iron (mg/l)	10.25	Less than 0.3	b/n 0.3 & 1	b/n 1 & 2	b/n 2 & 5	b/n 5 & 8 and ≥ 8
11	Manganese (mg/l)	0.67	Less than 0.1	Less than 0.1	b/n 0.1 & 0.3	b/n 0.3 & 0.4	b/n 0.4 & 0.5 and ≥ 0.5
12	Chromium (mg/l)	1.51	Less than 1.0	Less than 1.0	b/n 1 & 1.2	b/n 1.2 & 1.6	b/n 1.6 & 2 and ≥ 2
13	Lead (mg/l)	0.44	Less than 0.05	Less than 0.05	b/n 0.05 & 0.10	b/n 0.10 & 0.20	b/n 0.20 & 0.50 and ≥ 0.5
14	Mercury (mg/l)	0.04	Less than 0.01	Less than 0.01	b/n 0.01 & 0.02	b/n 0.02 & 0.03	b/n 0.03 & 0.05 and ≥ 0.05
15	Zinc (mg/l)	0.57	Less than 0.3	b/n 0.3 & 0.5	b/n 0.5 & 4.0	b/n 4.0 & 5.0	b/n 5.0 & 15 and ≥ 15
16	Nickel (mg/l)	0.45	Less than 0.3	Less than 0.3	b/n 0.3 & 0.6	b/n 0.6 & 0.9	b/n 0.9 & 1.5 and ≥ 1.5
17	Copper (mg/l)	0.65	Less than 1.0	Less than 1.0	b/n 1.0 & 2.0	b/n 2.0 & 3.0	b/n 3.0 & 5.0 and ≥ 5
18	Total Alkalinity (mg/l)	380					More than_500
19	Chloride (mg/l)	126.64	Less than 200	b/n 200 & 250	b/n 250 & 300	b/n 300 & 400	b/n 400 & 500 More than_500
20	Ammonia (mg/l)	1,054.79	Less than 0.5	Less than 0.5	b/n 0.5 & 1.0	b/n 1.0 & 1.5	b/n 1.5 & 2.0 More than 2.0
21	Nitrate (mg/l)	2,774.59	*	*	*	*	*
22	Phosphate (mg/l)	22.56	Less than 0.5	Less than 0.5	b/n 0.5 & 1.5	b/n 1.5 & 3	b/n 3 & 5 More than 5.0

23	Sulfate (mg/l)	243.28	Less than 100	b/n 100 & 250	b/n 250 & 300	b/n 300 & 400	b/n 400 & 500 More than 500
24	Cadmium (mg/l)	0.02	Less than 0.01	Less than 0.01	b/n 0.01 & 0.05	b/n 0.05 & 0.1	b/n 0.1 & 0.3 More than 0.3
25	Calcium (mg/l)	157.15	*	*	*	*	*
26	Magnesium (mg/l)	108.92	*	*	*	*	*
27	Bicarbonates(mg/l)	9108.92	*	*	*	*	*
28	Boron (mg/l)	2.03	Less than 0.50	Less than 0.50	b/n 0.5 & 1.00	b/n 1.00 & 1.50	b/n 1.50 & 2.00 More than 2.00
29	Arsenic (mg/l)	0.16	Less than 0.05	Less than 0.05	b/n 0.05 & 0.1	b/n 0.1 & 0.15	b/n 0.15 & 0.30 More than 0.30
30	Selenium (mg/l)	0.08	Less than 0.05	Less than 0.05	b/n 0.05 & 0.1	b/n 0.05 & 1.50	b/n 1.5 & 3.00 More than 3.00
31	Salinity (%)	16.40	*	*	*	*	*
32	Phosphorus (mg/l)	7.67	*	*	*	*	*
33	Molybdenum(mg/l)	0.06	*	*	*	*	*
34	Cobalt (mg/l)	0.18					Less or greater than 0.20
35	Silicon (mg/l)	9.35	*	*	*	*	*
36	BOD (mg/l)	40,000	Less than 15	b/n 15 & 30	b/n 30 & 50	b/n 50 & 100	b/n 100 & 120 More than 120
37	COD (mg/l)	65,000	Less than 30	b/n 30 & 60	b/n 60 & 90	b/n 90 & 150	≤b/n 150 & 200 More than 200

- NTU = Nephelometric Turbidity Units
- * - No prescribed limits currently exist for these parameters.

Temperature (24.50 °C), Zinc (0.57 mg/l), Copper (0.65 mg/l), Chloride (126.64 mg/l), and Sulfate (6.50 mg/l), values for leachate fall in the blue category which is considered safe concerning wastewater disposal as shown in table 14.

Chromium (1.51 mg/l) values for leachate fall in the yellow category which is considered to present a medium environmental hazard concerning wastewater disposal.

EC (26,995 µs/cm), TSS (2,000 mg/l), Turbidity (111.10 NTU), TDS (15,085 mg/l), DO (4.00 %), Potassium (2,739.33 mg/l), Sodium (1,430.77 mg/l), Iron (10.25 mg/l), Manganese (0.67 mg/l), Lead (0.44 mg/l), Mercury (0.04 mg/l), Total Alkalinity (380 mg/l), Ammonia (1,054.79 mg/l), Phosphate (22.56 mg/l), Sodium (1,430.77 mg/l), Boron (2.03 mg/l), Arsenic (0.16 mg/l), Cobalt (0.18 mg/l), BOD (40,000 mg/l), and COD (65,000 mg/l) values for leachate fall in the red category which is considered to present high environmental hazard concerning wastewater disposal as shown in table 14.

EC (26,995 µs/cm), Potassium (2,739.33 mg/l), Sodium (1,430.77 mg/l), Lead (0.44 mg/l), Zinc (0.57 mg/l), Nickel (0.45 mg/l), Copper (0.65 mg/l), Ammonia (1,054.79 mg/l), Sulphate (6.50 mg/l), Sodium (1,430.77 mg/l), Magnesium (108.92 mg/l), Arsenic (0.16 mg/l), BOD (40,000 mg/l), and COD (65,000 mg/l) values of Koshe open dump site leachate have a similar range of concentration in landfill manuals of EPA(Agency, n.d.) as shown in table 14.

Typical constituents of leachate from municipal solid waste (MSW) landfills (Chu, 2008) have also a similar range of concentrations with Koshe open dump site leachate in Turbidity (111.10 NTU), TDS (15,085 mg/l), Potassium (2,739.33 mg/l), Sodium (1,430.77 mg/l), Lead (0.44 mg/l), Mercury (0.04 mg/l), Copper (0.65 mg/l), Chloride (126.64 mg/l), Total Alkalinity (380 mg/l), Sulphate (6.50 mg/l), Sodium (1,430.77 mg/l), Calcium (157.15 mg/l), Magnesium (108.92 mg/l), TSS (2,000 mg/l), BOD (40,000 mg/l), and COD (65,000 mg/l) as shown in table 14.

Nitrate (2,774.59 mg/l), Calcium (157.15 mg/l), Magnesium (108.92 mg/l), Bicarbonates (414.80 mg/l), Salinity (16.40 %), Phosphorus (7.67 mg/l), Molybdenum (0.06 mg/l), and Silicon (9.35 mg/l) were also present in the leachate samples as shown in table 14.

4.3 Water quality index

The water quality index (WQI) expressed the overall water quality of any water samples under investigation into a single value.

4.3.1 National sanitation foundation water quality index method (NSFWQI)

Table 15 Physico-Chemical Characteristics of the Sample

Parameter	Batu -1	Kore	Landfill well 1	landfill well 2	Jemo-1	Ayer Tena
Dissolved oxygen DO (mg/l) or (%)	0.045	0.12	0.11	0.115	0.06	0
Hydrogen ion (pH)	6.84	7.77	8.61	8.62	6.91	6.47
Biochemical Oxygen Demand BOD (mg/l)	61.56	53.75	51.52	50.2	49.85	76.5
Nitrate (mg/l)	18.52	47.65	47.79	48.87	11.18	17.45
Phosphate (mg/l)	2.217	4.076	7.369	7.245	2.901	1.956
Temperature (°C)	31.3	27.05	23.55	23.45	26.85	21.10
Turbidity (NTU)	0.02	0.01	1.81	1.85	0.02	1.12
Total dissolved solids TDS (mg/l)	255.2	283.75	334.9	334.6	207.1	155

Table 16 Q-Value analysis of each sample

Parameter	Batu -1	Kore	landfill well 1	landfill well 2	Jemo-1	Ayer Tena
	Q-Value	Q-Value	Q-Value	Q-Value	Q-Value	Q-Value
Dissolved oxygen DO	0.70	0.95	1.40	0.95	0.65	0.00
Hydrogen ion (pH)	88.00	90.00	60.00	67.00	88.00	73.00
Biochemical Oxygen Demand BOD	2.00	2.00	2.00	2.00	2.00	2.00
Nitrate	40.00	14.00	15.00	12.00	50.00	42.00
Phosphate	25.00	18.00	8.50	7.5	21.00	27.00
Temperature	10.00	12.00	20.00	20.00	15.00	21.00
Turbidity	90.00	90.00	88.00	88.00	90.00	92.00
Total dissolved solids TDS	63.00	61.00	58.00	58.00	71.00	75.00

Table 17 Analysis of NSF Water Quality Index for sample around Batu-1

Batu -1				
Parameter	**Weight**	**Mean value**	**Q-Value**	**WQ**
Dissolved oxygen DO (mg/l)	0.189	0.045	0.70	0.132
Hydrogen ion (pH)	0.139	6.84	88.00	12.210
Biochemical Oxygen Demand BOD (mg/l)	0.119	61.56	2.00	0.238
Nitrate (mg/l)	0.119	18.52	40.00	4.750
Phosphate (mg/l)	0.119	2.217	25.00	2.969
Temperature (°C)	0.119	31.3	10.00	1.188
Turbidity (NTU)	0.099	0.02	90.00	8.888
Total dissolved solids TDS (mg/l)	0.099	255.2	63.00	6.221
			∑QW	**36.5946**

Table 18 Analysis of NSF Water Quality Index for sample around Kore

Kore				
Parameter	**Weight**	**Mean value**	**Q-Value**	**WQ**
Dissolved oxygen DO (mg/l)	0.189	0.12	0.95	0.179
Hydrogen ion (pH)	0.139	7.77	90.00	12.488
Biochemical Oxygen Demand BOD (mg/l)	0.119	53.75	2.00	0.238
Nitrate (mg/l)	0.119	47.65	14.00	1.663
Phosphate (mg/l)	0.119	4.076	18.00	2.138
Temperature (°C)	0.119	27.05	12.00	1.425
Turbidity (NTU)	0.099	0.01	90.00	8.888
Total dissolved solids TDS (mg/l)	0.099	283.75	61.00	6.024
			∑QW	**33.0406**

Table 19 Analysis of NSF Water Quality Index for sample around landfill well 1

Landfill well 1				
Parameter	**Weight**	**Mean value**	**Q-Value**	**WQ**
Dissolved oxygen DO (mg/l)	0.189	0.11	1.40	0.264
Hydrogen ion (pH)	0.139	8.61	60.00	8.325
Biochemical Oxygen Demand BOD (mg/l)	0.119	51.52	2.00	0.238
Nitrate (mg/l)	0.119	47.79	15.00	1.781
Phosphate (mg/l)	0.119	7.369	8.50	1.009
Temperature (°C)	0.119	23.55	20.00	2.375
Turbidity (NTU)	0.099	1.81	88.00	8.690
Total dissolved solids TDS (mg/l)	0.099	334.9	58.00	5.728
			∑QW	**28.4099**

Table 20 Analysis of NSF Water Quality Index for sample around landfill well 2

Landfill well2				
Parameter	**Weight**	**Mean value**	**Q-Value**	**WQ**
Dissolved oxygen DO (mg/l)	0.189	0.115	0.95	0.179
Hydrogen ion (pH)	0.139	8.62	67.00	9.296
Biochemical Oxygen Demand BOD (mg/l)	0.119	50.2	2.00	0.238
Nitrate (mg/l)	0.119	48.87	12.00	1.425
Phosphate (mg/l)	0.119	7.245	7.50	0.891
Temperature (°C)	0.119	23.45	20.00	2.375
Turbidity (NTU)	0.099	1.85	88.00	8.690
Total dissolved solids TDS (mg/l)	0.099	334.6	58.00	5.728
			∑QW	**28.8212**

Table 21 Analysis of NSF Water Quality Index for sample around Jemo-1

Jemo-1				
Parameter	**Weight**	**Mean value**	**Q-Value**	**WQ**
Dissolved oxygen DO (mg/l)	0.189	0.06	0.65	0.123
Hydrogen ion (pH)	0.139	6.91	88.00	12.210
Biochemical Oxygen Demand BOD (mg/l)	0.119	49.85	2.00	0.238
Nitrate (mg/l)	0.119	11.18	50.00	5.938
Phosphate (mg/l)	0.119	2.901	21.00	2.494
Temperature (°C)	0.119	26.85	15.00	1.781
Turbidity (NTU)	0.099	0.02	90.00	8.888
Total dissolved solids TDS (mg/l)	0.099	207.1	71.00	7.011
			∑QW	**38.6814**

Table 22 Analysis of NSF Water Quality Index for sample around Ayer Tena

Ayer Tena				
Parameter	**Weight**	**Mean value**	**Q-Value**	**WQ**
Dissolved oxygen DO (mg/l)	0.189	0	0.00	0.000
Hydrogen ion (pH)	0.139	6.47	73.00	10.129
Biochemical Oxygen Demand BOD (mg/l)	0.119	76.5	2.00	0.238
Nitrate (mg/l)	0.119	17.45	42.00	4.988
Phosphate (mg/l)	0.119	1.956	27.00	3.206
Temperature (°C)	0.119	21.10	21.00	2.494
Turbidity (NTU)	0.099	1.12	92.00	9.085
Total dissolved solids TDS (mg/l)	0.099	155	75.00	7.406
			∑QW	**37.545**

Table 23 Water Quality status of the sample

WQI calculation result		
Sample location	**Index value**	**water Quality status**
Batu -1	36.59	Poor Quality
Kore	33.04	Poor Quality
Landfill well 1	28.41	Very Poor Quality
Landfill well 2	28.82	Very Poor Quality
Jemo-1	38.68	Poor Quality
Ayer Tena	37.55	Poor Quality

According to the Analysis of the NSF Water Quality Index samples which are collected from the batu-1 condominium (36.59), around Kore (33.04), Ayer Tena High School (37.55) and Jemo-1(38.68) have poor quality water. And also the wells which are located inside of the Koshe open dump site Landfill Well 1 (28.41) and Landfill Well 2 (28.82) have a very poor quality of water as shown in Table 23.

4.3.2 The weighted arithmetic index method

Table 24 Weighted Arithmetic index (WQI) analysis of a sample from Batu-1 Condominium

	Weighted Arithmetic index method (WQI)									
BATU-1 Condominium										
Parameters	**WHO Standards (Sn)**	**1/Sn**	**∑1/Sn**	**K= 1/(∑1/Sn)**	**Wi = K/Sn**	**Ideal Value (Vo)**	**Mean Con. Value (Vn)**	**Vn/Sn**	**Qn= (Vn/Sn)*100**	**WnQn**
PH	8.5	0.1176	755.28	0.0013	0.00016	7	6.84	-0.1067	-10.67	-0.002
EC	400	0.0025	755.28	0.0013	0.00000	0	433.65	1.0841	108.41	0.000
TDS	1000	0.0010	755.28	0.0013	0.00000	0	255.2	0.2552	25.52	0.000
TSS	600	0.0017	755.28	0.0013	0.00000	0	0	0.0000	0.00	0.000
BOD	1	1.0000	755.28	0.0013	0.00132	0	61.56	61.5600	6156.00	8.151
COD	5	0.2000	755.28	0.0013	0.00026	0	416.5	83.3000	8330.00	2.206
Phosphate	0.1	10.0000	755.28	0.0013	0.01324	0	2.217	22.1700	2217.00	29.353
Sodium	200	0.0050	755.28	0.0013	0.00001	0	19.36	0.0968	9.68	0.000
Calcium	75	0.0133	755.28	0.0013	0.00002	0	61.48	0.8197	81.97	0.001
Magnesium	50	0.0200	755.28	0.0013	0.00003	0	15.15	0.3030	30.30	0.001
Bicarbonates	120	0.0083	755.28	0.0013	0.00001	0	219.2	1.8267	182.67	0.002
Sulphate	200	0.0050	755.28	0.0013	0.00001	0	5.18	0.0259	2.59	0.000
Chloride	250	0.0040	755.28	0.0013	0.00001	0	28.6	0.1144	11.44	0.000
Nitrate	5	0.2000	755.28	0.0013	0.00026	0	18.52	3.7040	370.40	0.098
Potassium	12	0.0833	755.28	0.0013	0.00011	0	5.99	0.4992	49.92	0.006
Ammonia	0.2	5.0000	755.28	0.0013	0.00662	0	0.007	0.0350	3.50	0.023
Iron	0.3	3.3333	755.28	0.0013	0.00441	0	0.29	0.9667	96.67	0.427
Chromium	0.1	10.0000	755.28	0.0013	0.01324	0	0.03	0.3000	30.00	0.397
Zinc	5	0.2000	755.28	0.0013	0.00026	0	0.61	0.1220	12.20	0.003
Manganese	0.3	3.3333	755.28	0.0013	0.00441	0	0.02	0.0667	6.67	0.029
Cadmium	0.003	333.3333	755.28	0.0013	0.44134	0	0.01	3.3333	333.33	147.112
Lead	10	0.1000	755.28	0.0013	0.00013	0	0.13	0.0130	1.30	0.000
Nickel	5	0.2000	755.28	0.0013	0.00026	0	0.03	0.0060	0.60	0.000
Copper	1.3	0.7692	755.28	0.0013	0.00102	0	0.06	0.0462	4.62	0.005
Turbidity	5	0.2000	755.28	0.0013	0.00026	0	0.02	0.0040	0.40	0.000
Temperature	30	0.0333	755.28	0.0013	0.00004	0	31.3	1.0433	104.33	0.005
Total Alkalini	100	0.0100	755.28	0.0013	0.00001	0	180	1.8000	180.00	0.002
Boron	2.4	0.4167	755.28	0.0013	0.00055	0	0.08	0.0333	3.33	0.002
Arsenic	0.01	100.0000	755.28	0.0013	0.13240	0	0.05	5.0000	500.00	66.200
Mercury	0.006	166.6667	755.28	0.0013	0.22067	0	0.02	3.3333	333.33	73.556
Phosphorus	40	0.0250	755.28	0.0013	0.00003	0	0.28	0.0070	0.70	0.000
Molybdenum	0.01	100.0000	755.28	0.0013	0.13240	0	0.002	0.2000	20.00	2.648
Selenium	0.05	20.0000	755.28	0.0013	0.02648	0	0.03	0.6000	60.00	1.589
	∑1/Sn	**755.28**		**∑(Wn)**	**1**				**∑(Wn Qn)**	**331.815**

Table 25 Weighted Arithmetic index (WQI) analysis of a sample from Kore

	Weighted Arithmetic index method (WQI)									
KORE										
Parameters	**WHO Standards (Sn)**	**1/Sn**	**∑1/Sn**	**K= 1/(∑1/Sn)**	**Wi = K/Sn**	**Ideal Value (Vo)**	**Mean Con. Value (Vn)**	**Vn/Sn**	**Qn= (Vn/Sn)*100**	**WnQn**
PH	8.5	0.1176	755.28	0.0013	0.00016	7	7.77	0.5133	51.33	0.008
EC	400	0.0025	755.28	0.0013	0.00000	0	509.8	1.2745	127.45	0.000
TDS	1000	0.0010	755.28	0.0013	0.00000	0	283.75	0.2838	28.38	0.000
TSS	600	0.0017	755.28	0.0013	0.00000	0	0	0.0000	0.00	0.000
BOD	1	1.0000	755.28	0.0013	0.00132	0	53.75	53.7500	5375.00	7.117
COD	5	0.2000	755.28	0.0013	0.00026	0	501	100.2000	10020.00	2.653
Phosphate	0.1	10.0000	755.28	0.0013	0.01324	0	4.076	40.7600	4076.00	53.967
Sodium	200	0.0050	755.28	0.0013	0.00001	0	19.19	0.0960	9.60	0.000
Calcium	75	0.0133	755.28	0.0013	0.00002	0	73.62	0.9816	98.16	0.002
Magnesium	50	0.0200	755.28	0.0013	0.00003	0	17.79	0.3558	35.58	0.001
Bicarbonates	120	0.0083	755.28	0.0013	0.00001	0	244	2.0333	203.33	0.002
Sulphate	200	0.0050	755.28	0.0013	0.00001	0	3.56	0.0178	1.78	0.000
Chloride	250	0.0040	755.28	0.0013	0.00001	0	56.8	0.2272	22.72	0.000
Nitrate	5	0.2000	755.28	0.0013	0.00026	0	47.65	9.5300	953.00	0.252
Potassium	12	0.0833	755.28	0.0013	0.00011	0	5.32	0.4433	44.33	0.005
Ammonia	0.2	5.0000	755.28	0.0013	0.00662	0	0.001	0.0050	0.50	0.003
Iron	0.3	3.3333	755.28	0.0013	0.00441	0	0.6	2.0000	200.00	0.883
Chromium	0.1	10.0000	755.28	0.0013	0.01324	0	0.07	0.7000	70.00	0.927
Zinc	5	0.2000	755.28	0.0013	0.00026	0	0.16	0.0320	3.20	0.001
Manganese	0.3	3.3333	755.28	0.0013	0.00441	0	0.03	0.1000	10.00	0.044
Cadmium	0.003	333.3333	755.28	0.0013	0.44134	0	0.01	3.3333	333.33	147.112
Lead	10	0.1000	755.28	0.0013	0.00013	0	0.18	0.0180	1.80	0.000
Nickel	5	0.2000	755.28	0.0013	0.00026	0	0.08	0.0160	1.60	0.000
Copper	1.3	0.7692	755.28	0.0013	0.00102	0	0.07	0.0538	5.38	0.005
Turbidity	5	0.2000	755.28	0.0013	0.00026	0	0.01	0.0020	0.20	0.000
Temperature	30	0.0333	755.28	0.0013	0.00004	0	27.05	0.9017	90.17	0.004
Total Alkalinity	100	0.0100	755.28	0.0013	0.00001	0	200	2.0000	200.00	0.003
Boron	2.4	0.4167	755.28	0.0013	0.00055	0	0.22	0.0917	9.17	0.005
Arsenic	0.01	100.0000	755.28	0.0013	0.13240	0	0.06	6.0000	600.00	79.440
Mercury	0.006	166.6667	755.28	0.0013	0.22067	0	0.03	5.0000	500.00	110.334
Phosphorus	40	0.0250	755.28	0.0013	0.00003	0	0.29	0.0073	0.73	0.000
Molybdenum	0.01	100.0000	755.28	0.0013	0.13240	0	0.002	0.2000	20.00	2.648
Selenium	0.05	20.0000	755.28	0.0013	0.02648	0	0.03	0.6000	60.00	1.589
	∑1/Sn	**755.28**		**∑(Wn)**	**1**				**∑(Wn Qn)**	**407.006**

Table 26 Weighted Arithmetic index (WQI) analysis of a sample from landfill well-1

	Weighted Arithmetic index method (WQI)									
LANDFILL WELL 1										
Parameters	**WHO Standards (Sn)**	**1/Sn**	**∑1/Sn**	**K= 1/(∑1/Sn)**	**Wi = K/Sn**	**Ideal Value (Vo)**	**Mean Con. Value (Vn)**	**Vn/Sn**	**Qn= (Vn/Sn)*100**	**WnQn**
PH	8.5	0.1176	755.28	0.0013	0.00016	7	8.62	1.0800	108.00	0.017
EC	400	0.0025	755.28	0.0013	0.00000	0	600	1.5000	150.00	0.000
TDS	1000	0.0010	755.28	0.0013	0.00000	0	334.75	0.3348	33.48	0.000
TSS	600	0.0017	755.28	0.0013	0.00000	0	33	0.0550	5.50	0.000
BOD	1	1.0000	755.28	0.0013	0.00132	0	51.52	51.5200	5152.00	6.821
COD	5	0.2000	755.28	0.0013	0.00026	0	434.5	86.9000	8690.00	2.301
Phosphate	0.1	10.0000	755.28	0.0013	0.01324	0	7.369	73.6900	7369.00	97.566
Sodium	200	0.0050	755.28	0.0013	0.00001	0	50.79	0.2540	25.40	0.000
Calcium	75	0.0133	755.28	0.0013	0.00002	0	68.4	0.9120	91.20	0.002
Magnesium	50	0.0200	755.28	0.0013	0.00003	0	15.1	0.3020	30.20	0.001
Bicarbonates	120	0.0083	755.28	0.0013	0.00001	0	292.8	2.4400	244.00	0.003
Sulphate	200	0.0050	755.28	0.0013	0.00001	0	6.19	0.0310	3.10	0.000
Chloride	250	0.0040	755.28	0.0013	0.00001	0	28.4	0.1136	11.36	0.000
Nitrate	5	0.2000	755.28	0.0013	0.00026	0	47.79	9.5580	955.80	0.253
Potassium	12	0.0833	755.28	0.0013	0.00011	0	24.89	2.0742	207.42	0.023
Ammonia	0.2	5.0000	755.28	0.0013	0.00662	0	0.007	0.0350	3.50	0.023
Iron	0.3	3.3333	755.28	0.0013	0.00441	0	0.07	0.2333	23.33	0.103
Chromium	0.1	10.0000	755.28	0.0013	0.01324	0	0.06	0.6000	60.00	0.794
Zinc	5	0.2000	755.28	0.0013	0.00026	0	0.009	0.0018	0.18	0.000
Manganese	0.3	3.3333	755.28	0.0013	0.00441	0	0.04	0.1333	13.33	0.059
Cadmium	0.003	333.3333	755.28	0.0013	0.44134	0	0.01	3.3333	333.33	147.112
Lead	10	0.1000	755.28	0.0013	0.00013	0	0.15	0.0150	1.50	0.000
Nickel	5	0.2000	755.28	0.0013	0.00026	0	0.03	0.0060	0.60	0.000
Copper	1.3	0.7692	755.28	0.0013	0.00102	0	0.001	0.0008	0.08	0.000
Turbidity	5	0.2000	755.28	0.0013	0.00026	0	1.81	0.3620	36.20	0.010
Temperature	30	0.0333	755.28	0.0013	0.00004	0	23.55	0.7850	78.50	0.003
Total Alkalinity	100	0.0100	755.28	0.0013	0.00001	0	288	2.8800	288.00	0.004
Boron	2.4	0.4167	755.28	0.0013	0.00055	0	0.02	0.0083	0.83	0.000
Arsenic	0.01	100.0000	755.28	0.0013	0.13240	0	0.06	6.0000	600.00	79.440
Mercury	0.006	166.6667	755.28	0.0013	0.22067	0	0.03	5.0000	500.00	110.334
Phosphorus	40	0.0250	755.28	0.0013	0.00003	0	0.63	0.0158	1.58	0.000
Molybdenum	0.01	100.0000	755.28	0.0013	0.13240	0	0.01	1.0000	100.00	13.240
Selenium	0.05	20.0000	755.28	0.0013	0.02648	0	0.02	0.4000	40.00	1.059
	∑1/Sn	**755.28**		**∑(Wn)**	**1**				**∑(Wn Qn)**	**459.170**

Table 27 Weighted Arithmetic index (WQI) analysis of a sample from landfill well-2

	Weighted Arithmetic index method (WQI)									
LANDFILL WELL 2										
Parameters	**WHO Standards (Sn)**	**1/Sn**	**∑1/Sn**	**K= 1/(∑1/Sn)**	**Wi = K/Sn**	**Ideal Value (Vo)**	**Mean Con. Value (Vn)**	**Vn/Sn**	**Qn= (Vn/Sn)*100**	**WnQn**
PH	8.5	0.1176	755.28	0.0013	0.00016	7	9.5	1.6667	166.67	0.026
EC	400	0.0025	755.28	0.0013	0.00000	0	570	1.4250	142.50	0.000
TDS	1000	0.0010	755.28	0.0013	0.00000	0	334.75	0.3348	33.48	0.000
TSS	600	0.0017	755.28	0.0013	0.00000	0	33	0.0550	5.50	0.000
BOD	1	1.0000	755.28	0.0013	0.00132	0	50.2	50.2000	5020.00	6.647
COD	5	0.2000	755.28	0.0013	0.00026	0	432.5	86.5000	8650.00	2.291
Phosphate	0.1	10.0000	755.28	0.0013	0.01324	0	7.245	72.4500	7245.00	95.924
Sodium	200	0.0050	755.28	0.0013	0.00001	0	50.67	0.2534	25.34	0.000
Calcium	75	0.0133	755.28	0.0013	0.00002	0	69.07	0.9209	92.09	0.002
Magnesium	50	0.0200	755.28	0.0013	0.00003	0	14.95	0.2990	29.90	0.001
Bicarbonates	120	0.0083	755.28	0.0013	0.00001	0	292	2.4333	243.33	0.003
Sulphate	200	0.0050	755.28	0.0013	0.00001	0	6.32	0.0316	3.16	0.000
Chloride	250	0.0040	755.28	0.0013	0.00001	0	28.4	0.1136	11.36	0.000
Nitrate	5	0.2000	755.28	0.0013	0.00026	0	48.87	9.7740	977.40	0.259
Potassium	12	0.0833	755.28	0.0013	0.00011	0	24.61	2.0508	205.08	0.023
Ammonia	0.2	5.0000	755.28	0.0013	0.00662	0	0.007	0.0350	3.50	0.023
Iron	0.3	3.3333	755.28	0.0013	0.00441	0	0.84	2.8000	280.00	1.236
Chromium	0.1	10.0000	755.28	0.0013	0.01324	0	0.08	0.8000	80.00	1.059
Zinc	5	0.2000	755.28	0.0013	0.00026	0	0.07	0.0140	1.40	0.000
Manganese	0.3	3.3333	755.28	0.0013	0.00441	0	0.04	0.1333	13.33	0.059
Cadmium	0.003	333.3333	755.28	0.0013	0.44134	0	0.01	3.3333	333.33	147.112
Lead	10	0.1000	755.28	0.0013	0.00013	0	0.15	0.0150	1.50	0.000
Nickel	5	0.2000	755.28	0.0013	0.00026	0	0.03	0.0060	0.60	0.000
Copper	1.3	0.7692	755.28	0.0013	0.00102	0	0.001	0.0008	0.08	0.000
Turbidity	5	0.2000	755.28	0.0013	0.00026	0	1.81	0.3620	36.20	0.010
Temperature	30	0.0333	755.28	0.0013	0.00004	0	23.55	0.7850	78.50	0.003
Total Alkalinity	100	0.0100	755.28	0.0013	0.00001	0	288	2.8800	288.00	0.004
Boron	2.4	0.4167	755.28	0.0013	0.00055	0	0.08	0.0333	3.33	0.002
Arsenic	0.01	100.0000	755.28	0.0013	0.13240	0	0.06	6.0000	600.00	79.440
Mercury	0.006	166.6667	755.28	0.0013	0.22067	0	0.03	5.0000	500.00	110.334
Phosphorus	40	0.0250	755.28	0.0013	0.00003	0	0.65	0.0163	1.63	0.000
Molybdenum	0.01	100.0000	755.28	0.0013	0.13240	0	0.01	1.0000	100.00	13.240
Selenium	0.05	20.0000	755.28	0.0013	0.02648	0	0.02	0.4000	40.00	1.059
	∑1/Sn	**755.28**		**∑(Wn)**	**1**				**∑(Wn Qn)**	**458.757**

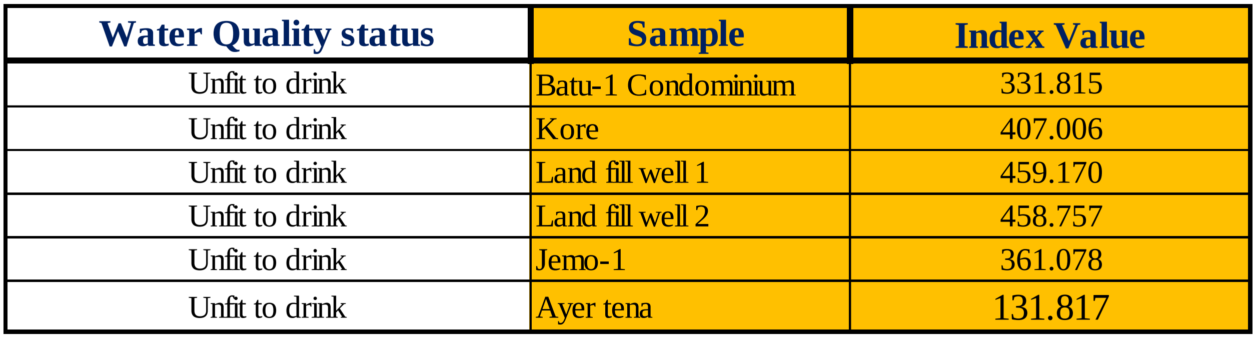
Table 28 Weighted Arithmetic index (WQI) analysis of a sample from Jemo-1

	Weighted Arithmetic index method (WQI)									
JEMO 1										
Parameters	**WHO Standards (Sn)**	**1/Sn**	**∑1/Sn**	**K= 1/(∑1/Sn)**	**Wi = K/Sn**	**Ideal Value (Vo)**	**Mean Con. Value (Vn)**	**Vn/Sn**	**Qn= (Vn/Sn)*100**	**WnQn**
PH	8.5	0.1176	755.28	0.0013	0.00016	7	8.68	1.1200	112.00	0.017
EC	400	0.0025	755.28	0.0013	0.00000	0	376.15	0.9404	94.04	0.000
TDS	1000	0.0010	755.28	0.0013	0.00000	0	207.1	0.2071	20.71	0.000
TSS	600	0.0017	755.28	0.0013	0.00000	0	1.2	0.0020	0.20	0.000
BOD	1	1.0000	755.28	0.0013	0.00132	0	49.85	49.8500	4985.00	6.600
COD	5	0.2000	755.28	0.0013	0.00026	0	356	71.2000	7120.00	1.885
Phosphate	0.1	10.0000	755.28	0.0013	0.01324	0	2.901	29.0100	2901.00	38.409
Sodium	200	0.0050	755.28	0.0013	0.00001	0	23.87	0.1194	11.94	0.000
Calcium	75	0.0133	755.28	0.0013	0.00002	0	46.58	0.6211	62.11	0.001
Magnesium	50	0.0200	755.28	0.0013	0.00003	0	10.69	0.2138	21.38	0.001
Bicarbonates	120	0.0083	755.28	0.0013	0.00001	0	170.8	1.4233	142.33	0.002
Sulphate	200	0.0050	755.28	0.0013	0.00001	0	4.55	0.0228	2.28	0.000
Chloride	250	0.0040	755.28	0.0013	0.00001	0	14.2	0.0568	5.68	0.000
Nitrate	5	0.2000	755.28	0.0013	0.00026	0	11.18	2.2360	223.60	0.059
Potassium	12	0.0833	755.28	0.0013	0.00011	0	10.51	0.8758	87.58	0.010
Ammonia	0.2	5.0000	755.28	0.0013	0.00662	0	0.007	0.0350	3.50	0.023
Iron	0.3	3.3333	755.28	0.0013	0.00441	0	0.39	1.3000	130.00	0.574
Chromium	0.1	10.0000	755.28	0.0013	0.01324	0	0.05	0.5000	50.00	0.662
Zinc	5	0.2000	755.28	0.0013	0.00026	0	0.07	0.0140	1.40	0.000
Manganese	0.3	3.3333	755.28	0.0013	0.00441	0	0.02	0.0667	6.67	0.029
Cadmium	0.003	333.3333	755.28	0.0013	0.44134	0	0.01	3.3333	333.33	147.112
Lead	10	0.1000	755.28	0.0013	0.00013	0	0.1	0.0100	1.00	0.000
Nickel	5	0.2000	755.28	0.0013	0.00026	0	0.03	0.0060	0.60	0.000
Copper	1.3	0.7692	755.28	0.0013	0.00102	0	0.08	0.0615	6.15	0.006
Turbidity	5	0.2000	755.28	0.0013	0.00026	0	0.02	0.0040	0.40	0.000
Temperature	30	0.0333	755.28	0.0013	0.00004	0	26.85	0.8950	89.50	0.004
Total Alkalinity	100	0.0100	755.28	0.0013	0.00001	0	184	1.8400	184.00	0.002
Boron	2.4	0.4167	755.28	0.0013	0.00055	0	0.07	0.0292	2.92	0.002
Arsenic	0.01	100.0000	755.28	0.0013	0.13240	0	0.04	4.0000	400.00	52.960
Mercury	0.006	166.6667	755.28	0.0013	0.22067	0	0.03	5.0000	500.00	110.334
Phosphorus	40	0.0250	755.28	0.0013	0.00003	0	0.29	0.0073	0.73	0.000
Molybdenum	0.01	100.0000	755.28	0.0013	0.13240	0	0.001	0.1000	10.00	1.324
Selenium	0.05	20.0000	755.28	0.0013	0.02648	0	0.02	0.4000	40.00	1.059
	∑1/Sn	**755.28**		**∑(Wn)**	**1**				**∑(Wn Qn)**	**361.078**

Table 29 Weighted Arithmetic index (WQI) analysis of a sample from Ayer tena

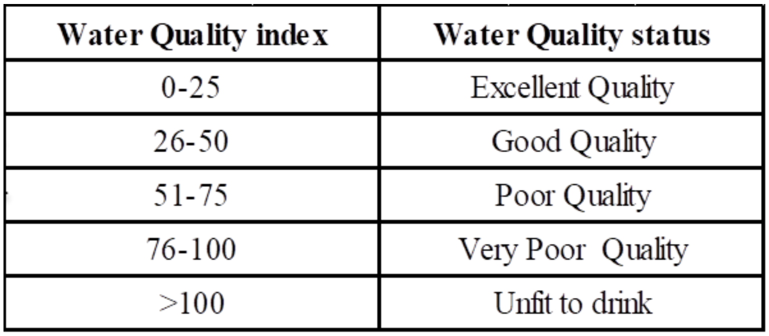
	Weighted Arithmetic index method (WQI)									
AYER TENA										
Parameters	WHO Standards (Sn)	1/Sn	∑1/Sn	K= 1/(∑1/Sn)	Wi = K/Sn	Ideal Value (Vo)	Mean Con. Value (Vn)	Vn/Sn	Qn= (Vn/Sn)*100	WnQn
PH	8.5	0.1176	755.28	0.0013	0.00016	7	6.47	-0.3533	-35.33	-0.006
EC	400	0.0025	755.28	0.0013	0.00000	0	279.2	0.6980	69.80	0.000
TDS	1000	0.0010	755.28	0.0013	0.00000	0	155.1	0.1551	15.51	0.000
TSS	600	0.0017	755.28	0.0013	0.00000	0	0.15	0.0003	0.03	0.000
BOD	1	1.0000	755.28	0.0013	0.00132	0	76.5	76.5000	7650.00	10.129
COD	5	0.2000	755.28	0.0013	0.00026	0	502	100.4000	10040.00	2.659
Phosphate	0.1	10.0000	755.28	0.0013	0.01324	0	1.956	19.5600	1956.00	25.898
Sodium	200	0.0050	755.28	0.0013	0.00001	0	16.69	0.0835	8.35	0.000
Calcium	75	0.0133	755.28	0.0013	0.00002	0	37.83	0.5044	50.44	0.001
Magnesium	50	0.0200	755.28	0.0013	0.00003	0	9.14	0.1828	18.28	0.000
Bicarbonates	120	0.0083	755.28	0.0013	0.00001	0	170.8	1.4233	142.33	0.002
Sulphate	200	0.0050	755.28	0.0013	0.00001	0	1.09	0.0055	0.55	0.000
Chloride	250	0.0040	755.28	0.0013	0.00001	0	1.42	0.0057	0.57	0.000
Nitrate	5	0.2000	755.28	0.0013	0.00026	0	17.45	3.4900	349.00	0.092
Potassium	12	0.0833	755.28	0.0013	0.00011	0	4.91	0.4092	40.92	0.005
Ammonia	0.2	5.0000	755.28	0.0013	0.00662	0	0.3	1.5000	150.00	0.993
Iron	0.3	3.3333	755.28	0.0013	0.00441	0	0.27	0.9000	90.00	0.397
Chromium	0.1	10.0000	755.28	0.0013	0.01324	0	0.007	0.0700	7.00	0.093
Zinc	5	0.2000	755.28	0.0013	0.00026	0	1.109	0.2218	22.18	0.006
Manganese	0.3	3.3333	755.28	0.0013	0.00441	0	0.013	0.0433	4.33	0.019
Cadmium	0.003	333.3333	755.28	0.0013	0.44134	0	0.002	0.6667	66.67	29.422
Lead	10	0.1000	755.28	0.0013	0.00013	0	0.061	0.0061	0.61	0.000
Nickel	5	0.2000	755.28	0.0013	0.00026	0	0.019	0.0038	0.38	0.000
Copper	1.3	0.7692	755.28	0.0013	0.00102	0	0.036	0.0277	2.77	0.003
Turbidity	5	0.2000	755.28	0.0013	0.00026	0	1.12	0.2240	22.40	0.006
Temperature	30	0.0333	755.28	0.0013	0.00004	0	21.1	0.7033	70.33	0.003
Total Alkalinity	100	0.0100	755.28	0.0013	0.00001	0	140	1.4000	140.00	0.002
Boron	2.4	0.4167	755.28	0.0013	0.00055	0	0.02	0.0083	0.83	0.000
Arsenic	0.01	100.0000	755.28	0.0013	0.13240	0	0.008	0.8000	80.00	10.592
Mercury	0.006	166.6667	755.28	0.0013	0.22067	0	0.01	1.6667	166.67	36.778
Phosphorus	40	0.0250	755.28	0.0013	0.00003	0	0.29	0.0073	0.73	0.000
Molybdenum	0.01	100.0000	755.28	0.0013	0.13240	0	0.01	1.0000	100.00	13.240
Selenium	0.05	20.0000	755.28	0.0013	0.02648	0	0.028	0.5600	56.00	1.483
	∑1/Sn	755.28		∑(Wn)	1				∑(Wn Qn)	131.817

Table 30 Water quality status of a sample



Water Quality status	Sample	Index Value
Unfit to drink	Batu-1 Condominium	331.815
Unfit to drink	Kore	407.006
Unfit to drink	Land fill well 1	459.170
Unfit to drink	Land fill well 2	458.757
Unfit to drink	Jemo-1	361.078
Unfit to drink	Ayer tena	131.817

Table 31 Water quality status



Water Quality index	Water Quality status
0-25	Excellent Quality
26-50	Good Quality
51-75	Poor Quality
76-100	Very Poor Quality
>100	Unfit to drink

According to the Analysis of the Weighted Arithmetic index (WQI) (table-30) samples which are collected from the batu-1 condominium(331.815), around Kore (407.006), Landfill Well 1(459.17), Landfill Well2(458.757), Jemo-1 (361.078), and Ayer Tena (131.817) categorized as unfit to drink.

4.3.3 The Canadian Council of ministers environment water quality index (CCME WQI)

Table 32 Failed variables of sample Kore

No	Parameters	WHO Standards	KORE
1	**PH**	8.5	7.77
2	**EC**	400	**509.8**
3	**TDS**	1000	283.75
4	**TSS**	600	0
5	**BOD**	1	53.75
6	**COD**	5	501
7	**Phosphate**	0.1	4.076
8	**Sodium**	200	19.19
9	**Calcium**	75	73.62
10	**Magnesium**	50	17.79
11	**Bicarbonates**	120	244
12	**Sulphate**	200	3.56
13	**Chloride**	250	56.8
14	**Nitrate**	5	47.65
15	**Potassium**	12	5.32
16	**Ammonia**	0.2	0.001
17	**Iron**	0.3	0.6
18	**Chromium**	0.1	0.07
19	**Zinc**	5	0.16
20	**Manganese**	0.3	0.03
21	**Cadmium**	0.003	0.01
22	**Lead**	10	0.18
23	**Nickel**	5	0.08
24	**Copper**	1.3	0.07
25	**Turbidity**	5	0.01
26	**Temperature**	30	27.05
27	**Total Alkalinity**	100	200
28	**Boron**	2.4	0.22
29	**Arsenic**	0.01	0.06
30	**Mercury**	0.006	0.03
31	**Phosphorus**	40	0.29
32	**Molybdenum**	0.01	0.002
33	**Selenium**	0.05	0.03

Scope	CODE	CCME Data
No of failed variable (Parameter)	X	11
Total No of variables (Parameter Studied)	Y	33
	F1	33.333
Frequency	**CODE**	**CCME Data**
Total No of tests	Z	33
Total No of failed tests (All Parameter Exceeding)	E	11
	F2	33.333

	Failed tests of value	Objective		C = Excursion
	A	B	A/B	C = A/B Value -1
1	509.8	400	1.27	0.27
2	53.75	1	53.75	52.75
3	501	5	100.20	99.20
4	4.076	0.1	40.76	39.76
5	244	120	2.03	1.03
6	47.65	5	9.53	8.53
7	0.6	0.3	2.00	1.00
8	0.01	0.003	3.33	2.33
9	200	100	2.00	1.00
10	0.06	0.01	6.00	5.00
11	0.03	0.006	5.00	4.00
				214.88

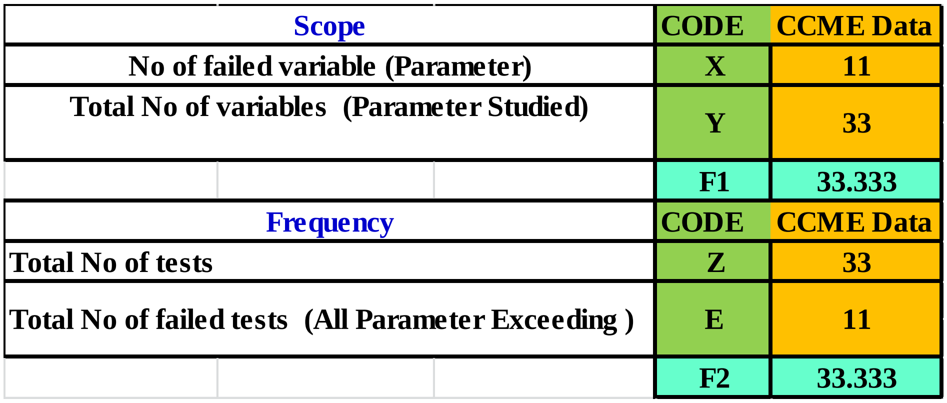
Total No of tests		33
C = Excursion		214.88
	nse	6.512

nse value	0.01*nse	0.01*nse+0.01
6.51	0.0651	0.0751
	F3	86.687

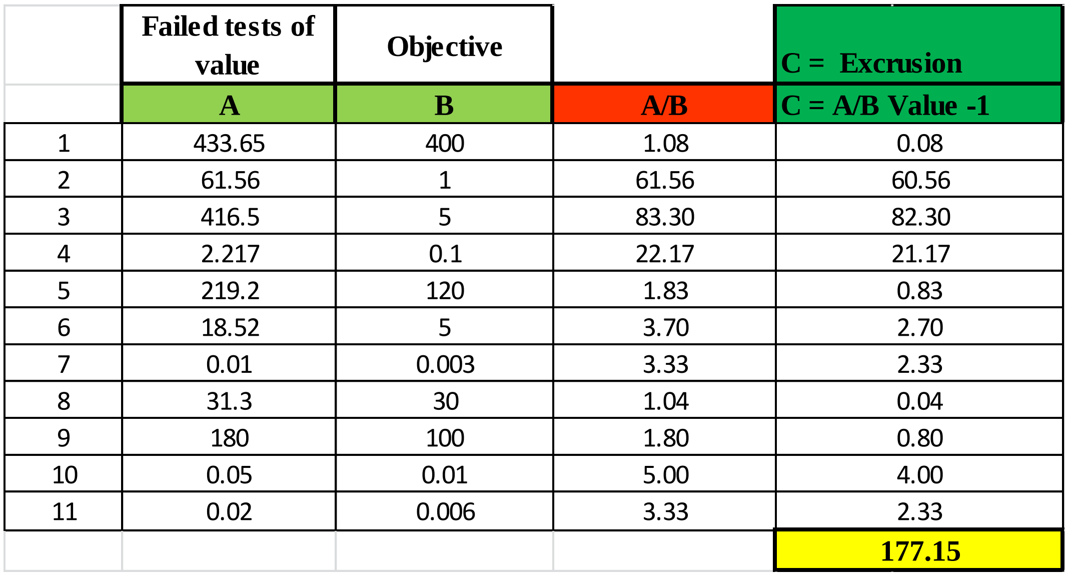
Compoent of CCME WQI	Value	Square value		
F1	33.333	1111.111		
F2	33.33	1111.11		
F3	86.6872	7514.67		
	Sum	9736.89		
	Square root value	98.676		
	Divided by 1.732	1.73		
	D	56.972		
CCME WQI for Kore				
		100	56.972	43.03
CCME WQI value for Sample from Kore			43.03	

Table 33 Failed variable Sample from batu-1

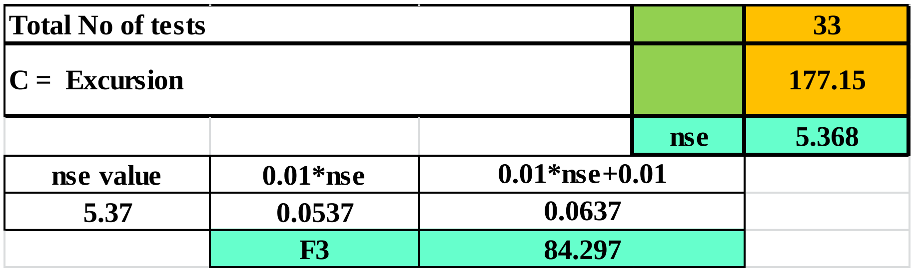
No	Parameters	WHO Standards	BATU-1
1	**PH**	8.5	6.84
2	**EC**	400	433.65
3	**TDS**	1000	255.2
4	**TSS**	600	0
5	**BOD**	1	61.56
6	**COD**	5	416.5
7	**Phosphate**	0.1	2.217
8	**Sodium**	200	19.36
9	**Calcium**	75	61.48
10	**Magnesium**	50	15.15
11	**Bicarbonates**	120	219.2
12	**Sulphate**	200	5.18
13	**Chloride**	250	28.6
14	**Nitrate**	5	18.52
15	**Potassium**	12	5.99
16	**Ammonia**	0.2	0.007
17	**Iron**	0.3	0.29
18	**Chromium**	0.1	0.03
19	**Zinc**	5	0.61
20	**Manganese**	0.3	0.02
21	**Cadmium**	0.003	0.01
22	**Lead**	10	0.13
23	**Nickel**	5	0.03
24	**Copper**	1.3	0.06
25	**Turbidity**	5	0.02
26	**Temperature**	30	31.3
27	**Total Alkalinity**	100	180
28	**Boron**	2.4	0.08
29	**Arsenic**	0.01	0.05
30	**Mercury**	0.006	0.02
31	**Phosphorus**	40	0.28
32	**Molybdenum**	0.01	0.002
33	**Selenium**	0.05	0.03



Scope	CODE	CCME Data
No of failed variable (Parameter)	X	11
Total No of variables (Parameter Studied)	Y	33
	F1	33.333
Frequency	CODE	CCME Data
Total No of tests	Z	33
Total No of failed tests (All Parameter Exceeding)	E	11
	F2	33.333

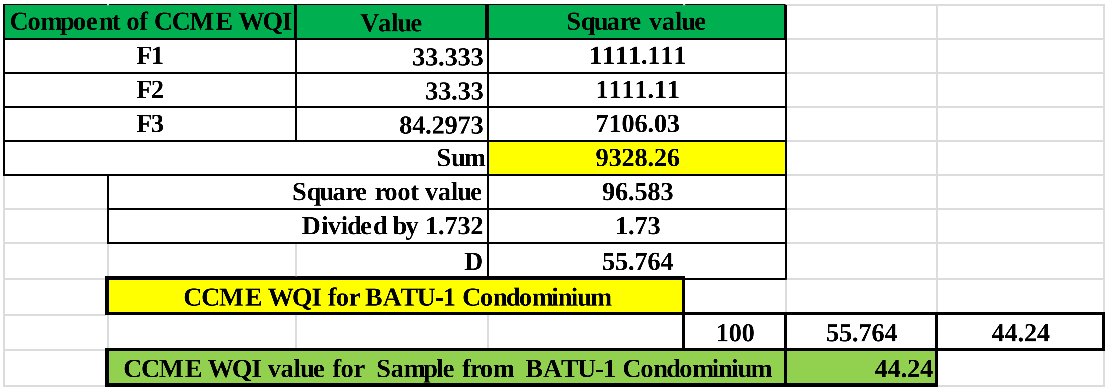


	Failed tests of value	Objective		C = Excursion
	A	B	A/B	C = A/B Value -1
1	433.65	400	1.08	0.08
2	61.56	1	61.56	60.56
3	416.5	5	83.30	82.30
4	2.217	0.1	22.17	21.17
5	219.2	120	1.83	0.83
6	18.52	5	3.70	2.70
7	0.01	0.003	3.33	2.33
8	31.3	30	1.04	0.04
9	180	100	1.80	0.80
10	0.05	0.01	5.00	4.00
11	0.02	0.006	3.33	2.33
				177.15



Total No of tests		33
C = Excursion		177.15
	nse	5.368

nse value	0.01*nse	0.01*nse+0.01
5.37	0.0537	0.0637
	F3	84.297



Compoent of CCME WQI	Value	Square value		
F1	33.333	1111.111		
F2	33.33	1111.11		
F3	84.2973	7106.03		
	Sum	9328.26		
	Square root value	96.583		
	Divided by 1.732	1.73		
	D	55.764		
CCME WQI for BATU-1 Condominium				
		100	55.764	44.24
CCME WQI value for Sample from BATU-1 Condominium			44.24	

Table 34 Failed variable of landfill well 1

No	Parameters	WHO Standards	LANDFILL WELL 1
1	**PH**	8.5	8.62
2	**EC**	400	600
3	**TDS**	1000	334.75
4	**TSS**	600	33
5	**BOD**	1	51.52
6	**COD**	5	434.5
7	**Phosphate**	0.1	7.369
8	**Sodium**	200	50.79
9	**Calcium**	75	68.4
10	**Magnesium**	50	15.1
11	**Bicarbonates**	120	292.8
12	**Sulphate**	200	6.19
13	**Chloride**	250	28.4
14	**Nitrate**	5	47.79
15	**Potassium**	12	24.89
16	**Ammonia**	0.2	0.007
17	**Iron**	0.3	0.07
18	**Chromium**	0.1	0.06
19	**Zinc**	5	0.009
20	**Manganese**	0.3	0.04
21	**Cadmium**	0.003	0.01
22	**Lead**	10	0.15
23	**Nickel**	5	0.03
24	**Copper**	1.3	0.001
25	**Turbidity**	5	1.81
26	**Temperature**	30	23.55
27	**Total Alkalinity**	100	288
28	**Boron**	2.4	0.02
29	**Arsenic**	0.01	0.06
30	**Mercury**	0.006	0.03
31	**Phosphorus**	40	0.63
32	**Molybdenum**	0.01	0.01
33	**Selenium**	0.05	0.02

Scope	CODE	CCME Data
No of failed variable (Parameter)	X	13
Total No of variables (Parameter Studied)	Y	33
	F1	39.394
Frequency	CODE	CCME Data
Total No of tests	Z	33
Total No of failed tests (All Parameter Exceeding)	E	13
	F2	39.394

	Failed tests of value	Objective		C = Excursion
	A	B	A/B	C = A/B Value -1
1	8.62	8.5	1.01	0.01
2	600	400	1.50	0.50
3	51.52	1	51.52	50.52
4	434.5	5	86.90	85.90
5	7.369	0.1	73.69	72.69
6	292.8	120	2.44	1.44
7	47.79	5	9.56	8.56
8	24.89	12	2.07	1.07
9	0.01	0.003	3.33	2.33
10	288	100	2.88	1.88
11	0.06	0.01	6.00	5.00
12	0.03	0.006	5.00	4.00
13	0.01	0.01	1.00	0.00
				233.91

Total No of tests		33
C = Excursion		233.91
	nse	7.088

nse value	0.01*nse	0.01*nse+0.01
7.09	0.0709	0.0809
	F3	87.636

Compoent of CCME WQI	Value	Square value		
F1	39.394	1551.882		
F2	39.39	1551.88		
F3	87.6363	7680.11		
Sum		10783.88		
Square root value		103.845		
Divided by 1.732		1.73		
D		59.957		
CCME WQI for LANDFILL WELL 1				
		100	59.957	40.04
CCME WQI value for Sample from LANDFILL WELL 1			40.04	

Table 35 Failed variable of landfill well 2

No	**Parameters**	**WHO Standards**	**LANDFILL WELL 2**
1	**PH**	8.5	9.5
2	**EC**	400	570
3	**TDS**	1000	334.75
4	**TSS**	600	33
5	**BOD**	1	50.2
6	**COD**	5	432.5
7	**Phosphate**	0.1	7.245
8	**Sodium**	200	50.67
9	**Calcium**	75	69.07
10	**Magnesium**	50	14.95
11	**Bicarbonates**	120	292
12	**Sulphate**	200	6.32
13	**Chloride**	250	28.4
14	**Nitrate**	5	48.87
15	**Potassium**	12	24.61
16	**Ammonia**	0.2	0.007
17	**Iron**	0.3	0.84
18	**Chromium**	0.1	0.08
19	**Zinc**	5	0.07
20	**Manganese**	0.3	0.04
21	**Cadmium**	0.003	0.01
22	**Lead**	10	0.15
23	**Nickel**	5	0.03
24	**Copper**	1.3	0.001
25	**Turbidity**	5	1.81
26	**Temperature**	30	23.55
27	**Total Alkalinity**	100	288
28	**Boron**	2.4	0.08
29	**Arsenic**	0.01	0.06
30	**Mercury**	0.006	0.03
31	**Phosphorus**	40	0.65
32	**Molybdenum**	0.01	0.01
33	**Selenium**	0.05	0.02

Scope	CODE	CCME Data
No of failed variable (Parameter)	X	14
Total No of variables (Parameter Studied)	Y	33
	F1	42.424
Frequency	CODE	CCME Data
Total No of tests	Z	33
Total No of failed tests (All Parameter Exceeding)	E	14
	F2	42.424

	Failed tests of value	Objective		C = Excrusion
	A	B	A/B	C = A/B Value -1
1	9.5	8.5	1.12	0.12
2	570	400	1.43	0.43
3	50.2	1	50.20	49.20
4	432.5	5	86.50	85.50
5	7.245	0.1	72.45	71.45
6	292	120	2.43	1.43
7	48.87	5	9.77	8.77
8	24.61	12	2.05	1.05
9	0.84	0.3	2.80	1.80
10	0.01	0.003	3.33	2.33
11	288	100	2.88	1.88
12	0.06	0.01	6.00	5.00
13	0.03	0.006	5.00	4.00
14	0.01	0.01	1.00	0.00
				232.96

Total No of tests		33
C = Excursion		232.96
	nse	7.060

nse value	0.01*nse	0.01*nse+0.01
7.06	0.0706	0.0806
	F3	87.592

Compoent of CCME WQI	Value	Square value		
F1	42.424	1799.816		
F2	42.42	1799.82		
F3	87.5923	7672.41		
	Sum	11272.05		
	Square root value	106.170		
	Divided by 1.732	1.73		
	D	61.299		
CCME WQI for LANDFILL WELL 2				
		100	61.299	38.70
CCME WQI value for Sample from LANDFILL WELL 2			38.70	

Table 36 Failed variable of Jemo-1

No	Parameters	WHO Standards	JEMO 1
1	**PH**	8.5	8.68
2	**EC**	400	376.15
3	**TDS**	1000	207.1
4	**TSS**	600	1.2
5	**BOD**	1	49.85
6	**COD**	5	356
7	**Phosphate**	0.1	2.901
8	**Sodium**	200	23.87
9	**Calcium**	75	46.58
10	**Magnesium**	50	10.69
11	**Bicarbonates**	120	170.8
12	**Sulphate**	200	4.55
13	**Chloride**	250	14.2
14	**Nitrate**	5	11.18
15	**Potassium**	12	10.51
16	**Ammonia**	0.2	0.007
17	**Iron**	0.3	0.39
18	**Chromium**	0.1	0.05
19	**Zinc**	5	0.07
20	**Manganese**	0.3	0.02
21	**Cadmium**	0.003	0.01
22	**Lead**	10	0.1
23	**Nickel**	5	0.03
24	**Copper**	1.3	0.08
25	**Turbidity**	5	0.02
26	**Temperature**	30	26.85
27	**Total Alkalinity**	100	184
28	**Boron**	2.4	0.07
29	**Arsenic**	0.01	0.04
30	**Mercury**	0.006	0.03
31	**Phosphorus**	40	0.29
32	**Molybdenum**	0.01	0.001
33	**Selenium**	0.05	0.02

Scope	CODE	CCME Data
No of failed variable (Parameter)	X	11
Total No of variables (Parameter Studied)	Y	33
	F1	33.333
Frequency	CODE	CCME Data
Total No of tests	Z	33
Total No of failed tests (All Parameter Exceeding)	E	11
	F2	33.333

	Failed tests of value	Objective		C = Excrusion
	A	B	A/B	C = A/B Value -1
1	8.68	8.5	1.02	0.02
2	49.85	1	49.85	48.85
3	356	5	71.20	70.20
4	2.901	0.1	29.01	28.01
5	170.8	120	1.42	0.42
6	11.18	5	2.24	1.24
7	0.39	0.3	1.30	0.30
8	0.01	0.003	3.33	2.33
9	184	100	1.84	0.84
10	0.04	0.01	4.00	3.00
11	0.03	0.006	5.00	4.00
				159.21

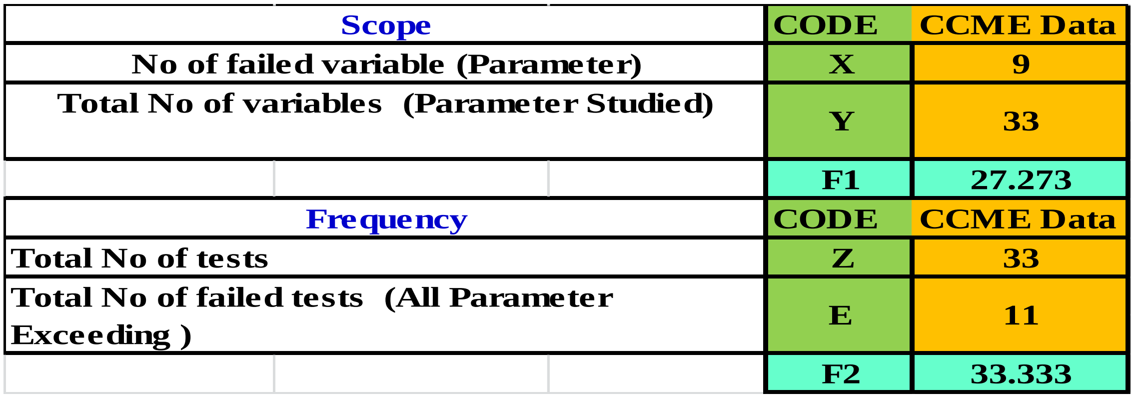
Total No of tests		33
C = Excursion		159.21
	nse	4.825

nse value	0.01*nse	0.01*nse+0.01
4.82	0.0482	0.0582
	F3	82.832

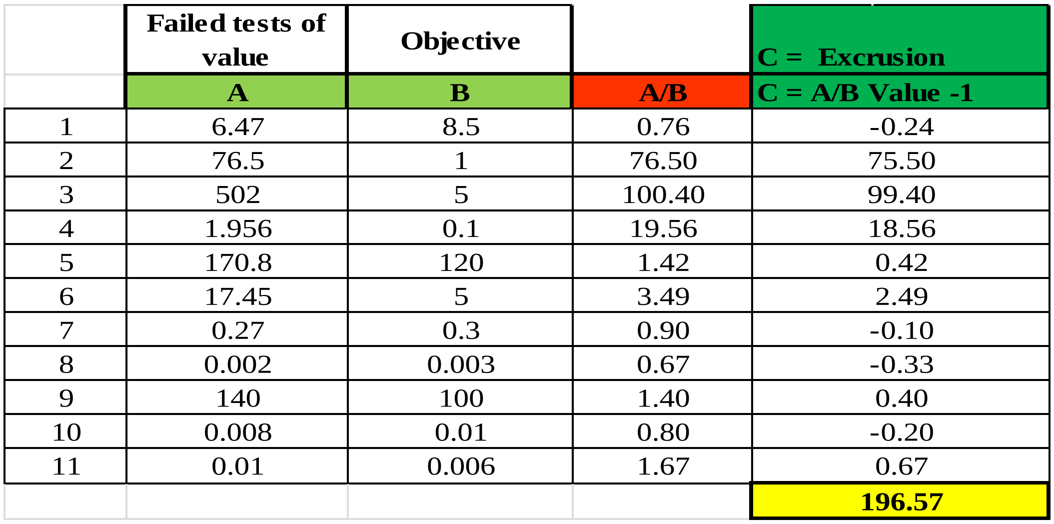
Compoent of CCME WQI	Value	Square value		
F1	33.333	1111.111		
F2	33.33	1111.11		
F3	82.8316	6861.08		
	Sum	9083.30		
	Square root value	95.306		
	Divided by 1.732	1.73		
	D	55.027		
CCME WQI for JEMO-1				
		100	55.027	44.97
CCME WQI value for Sample from JEMO-1			44.97	

Table 37 Failed variable of Ayer Tena

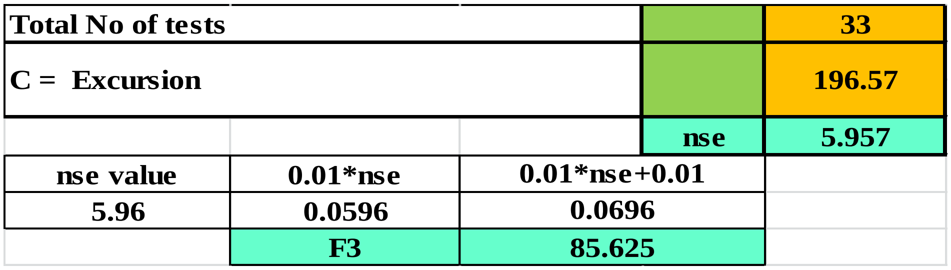
No	Parameters	WHO Standards	Ayer Tena
1	**PH**	8.5	6.47
2	**EC**	400	279.2
3	**TDS**	1000	155.1
4	**TSS**	600	0.15
5	**BOD**	1	76.5
6	**COD**	5	502
7	**Phosphate**	0.1	1.956
8	**Sodium**	200	16.69
9	**Calcium**	75	37.83
10	**Magnesium**	50	9.14
11	**Bicarbonates**	120	170.8
12	**Sulphate**	200	1.09
13	**Chloride**	250	1.42
14	**Nitrate**	5	17.45
15	**Potassium**	12	4.91
16	**Ammonia**	0.2	0.3
17	**Iron**	0.3	0.27
18	**Chromium**	0.1	0.007
19	**Zinc**	5	1.109
20	**Manganese**	0.3	0.013
21	**Cadmium**	0.003	0.002
22	**Lead**	10	0.061
23	**Nickel**	5	0.019
24	**Copper**	1.3	0.036
25	**Turbidity**	5	1.12
26	**Temperature**	30	21.1
27	**Total Alkalinity**	100	140
28	**Boron**	2.4	0.02
29	**Arsenic**	0.01	0.008
30	**Mercury**	0.006	0.01
31	**Phosphorus**	40	0.29
32	**Molybdenum**	0.01	0.01
33	**Selenium**	0.05	0.028



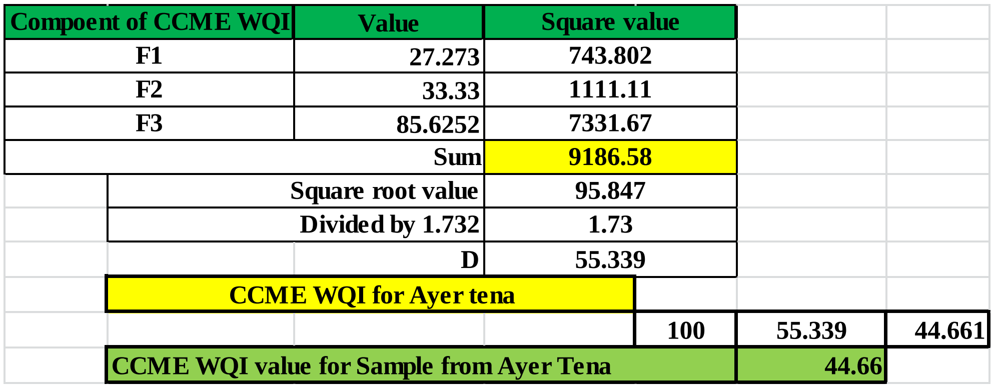
Scope	CODE	CCME Data
No of failed variable (Parameter)	X	9
Total No of variables (Parameter Studied)	Y	33
	F1	27.273
Frequency	CODE	CCME Data
Total No of tests	Z	33
Total No of failed tests (All Parameter Exceeding)	E	11
	F2	33.333



	Failed tests of value	Objective		C = Excursion
	A	B	A/B	C = A/B Value -1
1	6.47	8.5	0.76	-0.24
2	76.5	1	76.50	75.50
3	502	5	100.40	99.40
4	1.956	0.1	19.56	18.56
5	170.8	120	1.42	0.42
6	17.45	5	3.49	2.49
7	0.27	0.3	0.90	-0.10
8	0.002	0.003	0.67	-0.33
9	140	100	1.40	0.40
10	0.008	0.01	0.80	-0.20
11	0.01	0.006	1.67	0.67
				196.57



Total No of tests			33
C = Excursion			196.57
		nse	5.957
nse value	0.01*nse	0.01*nse+0.01	
5.96	0.0596	0.0696	
	F3	85.625	



Compoent of CCME WQI	Value	Square value		
F1	27.273	743.802		
F2	33.33	1111.11		
F3	85.6252	7331.67		
Sum		9186.58		
Square root value		95.847		
Divided by 1.732		1.73		
D		55.339		
CCME WQI for Ayer tena				
		100	55.339	44.661
CCME WQI value for Sample from Ayer Tena			44.66	

Table 38 Result displayed

RESULT DISPLAYED					
	F1	**F2**	**F3**	**CCME WQI**	**Rating**
KORE	33.333	33.333	86.687	43.03	**Poor water quality**
BATU-1 Condominium	33.333	33.333	84.297	44.24	**Poor water quality**
LANDFILL WELL 1	39.394	39.394	87.636	40.04	**Poor water quality**
LANDFILL WELL 2	42.424	42.424	87.592	38.70	**Poor water quality**
JEMO 1	33.333	33.333	82.832	44.97	**Poor water quality**
AYET TENA HIGH SCHOOL	27.273	33.333	85.625	44.66	**Poor water quality**

According to the Analysis of the Canadian Council of minister environment water quality index (CCME WQI) in Table 38 samples which are collected from the batu-1 condominium (44.24), around Kore (43.03), site Landfill Well 1 (40.04), Landfill Well 2 (38.70), Jemo-1 (44.97), and Ayer Tena (44.66) have a poor quality of water.

4.3.4 Nemerow's pollution index (NPI) also called Row's pollution index

Table 39 Nemerow's Pollution Index analysis of all sample

	C_n = Concentration of the n^th parameter						S_n = prescribed standard limits of the n^th parameter
Parameters	**Batu-1 Condominium**	**Kore**	**Land fill wel 1**	**Land fill wel 2**	**Jemo 1**	**Ayer Tena**	**WHO Standards (Sn)**
PH	0.805	0.91412	1.0141	1.1176	1.0212	0.7612	8.5
EC	1.084	1.2745	1.5000	1.4250	0.9404	0.6980	400
TDS	0.255	0.28375	0.3348	0.3348	0.2071	0.1551	1000
TSS	0.000	0	0.0550	0.0550	0.0020	0.0003	600
BOD	61.560	53.75	51.5200	50.2000	49.8500	76.5000	1
COD	83.300	100.2	86.9000	86.5000	71.2000	100.4000	5
Phosphate	22.170	40.76	73.6900	72.4500	29.0100	19.5600	0.1
Sodium	0.097	0.09595	0.2540	0.2534	0.1194	0.0835	200
Calcium	0.820	0.9816	0.9120	0.9209	0.6211	0.5044	75
Magnesium	0.303	0.3558	0.3020	0.2990	0.2138	0.1828	50
Bicarbonates	1.827	2.03333	2.4400	2.4333	1.4233	1.4233	120
Sulphate	0.026	0.0178	0.0310	0.0316	0.0228	0.0055	200
Chloride	0.114	0.2272	0.1136	0.1136	0.0568	0.0057	250
Nitrate	3.704	9.53	9.5580	9.7740	2.2360	3.4900	5
Potassium	0.499	0.44333	2.0742	2.0508	0.8758	0.4092	12
Ammonia	0.035	0.005	0.0350	0.0350	0.0350	1.5000	0.2
Iron	0.967	2	0.2333	2.8000	1.3000	0.9000	0.3
Chromium	0.300	0.7	0.6000	0.8000	0.5000	0.0700	0.1
Zinc	0.122	0.032	0.0018	0.0140	0.0140	0.2218	5
Manganese	0.067	0.1	0.1333	0.1333	0.0667	0.0433	0.3
Cadmium	3.333	3.33333	3.3333	3.3333	3.3333	0.6667	0.003
Lead	0.013	0.018	0.0150	0.0150	0.0100	0.0061	10
Nickel	0.006	0.016	0.0060	0.0060	0.0060	0.0038	5
Copper	0.046	0.05385	0.0008	0.0008	0.0615	0.0277	1.3
Turbidity	0.004	0.002	0.3620	0.3620	0.0040	0.2240	5
Temperature	1.043	0.90167	0.7850	0.7850	0.8950	0.7033	30
Total Alkalinity	1.800	2	2.8800	2.8800	1.8400	1.4000	100
Boron	0.033	0.09167	0.0083	0.0333	0.0292	0.0083	2.4
Arsenic	5.000	6	6.0000	6.0000	4.0000	0.8000	0.01
Mercury	3.333	5	5.0000	5.0000	5.0000	1.6667	0.006
Phosphorus	0.007	0.00725	0.0158	0.0163	0.0073	0.0073	40
Molybdenum	0.200	0.2	1.0000	1.0000	0.1000	1.0000	0.01
Selenium	0.600	0.6	0.4000	0.4000	0.4000	0.5600	0.05

According to the Analysis of Nemerow's Pollution Index, (Table 39) the contributing parameters responsible for polluting water quality in a sample from Batu – condominium [Electrical conductivity (EC), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Phosphate, Bicarbonates, Nitrate, Cadmium, Temperature, Total Alkalinity, Arsenic, and Mercury], in a sample from Kore [Electrical conductivity (EC), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Phosphate, Bicarbonates, Nitrate, Cadmium, iron, Total Alkalinity, Arsenic, and Mercury], in a sample from landfill well 1 & 2 [Hydrogen ion (ph), Electrical conductivity (EC), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), iron, Phosphate, Bicarbonates, Nitrate, Cadmium, Total Alkalinity, Arsenic, and Mercury], in a sample from Jemo-1 [Hydrogen ion (ph), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Phosphate, Bicarbonates, Nitrate, iron, Cadmium, Total Alkalinity, Arsenic, and Mercury], and finally in a sample from Ayer tena high school [Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Phosphate, Bicarbonates, Nitrate, Ammonia, Total Alkalinity, Molybdenum, and Mercury].

4.4 Correlation analysis

The correlation matrix for each pair of variables that could exist was first calculated. A bivariate technique called Pearson correlation analysis was used to describe the degree of relationship between two chemical parameters. In the interpretation that follows, the correlation analysis's findings are taken into account. A high correlation coefficient (around -1 or 1) indicates a strong association between two variables, whereas one that is low (around zero) indicates there is none at a significant threshold (p) of 0.05. According to (Singh et al., 2008), parameters with $r>0.7$ are thought to be substantially linked, whereas $r>0.5-0.7$ indicates a moderate correlation.

Table 40 Correlation matrix of chemical constituents of groundwater around Koshe open dump site

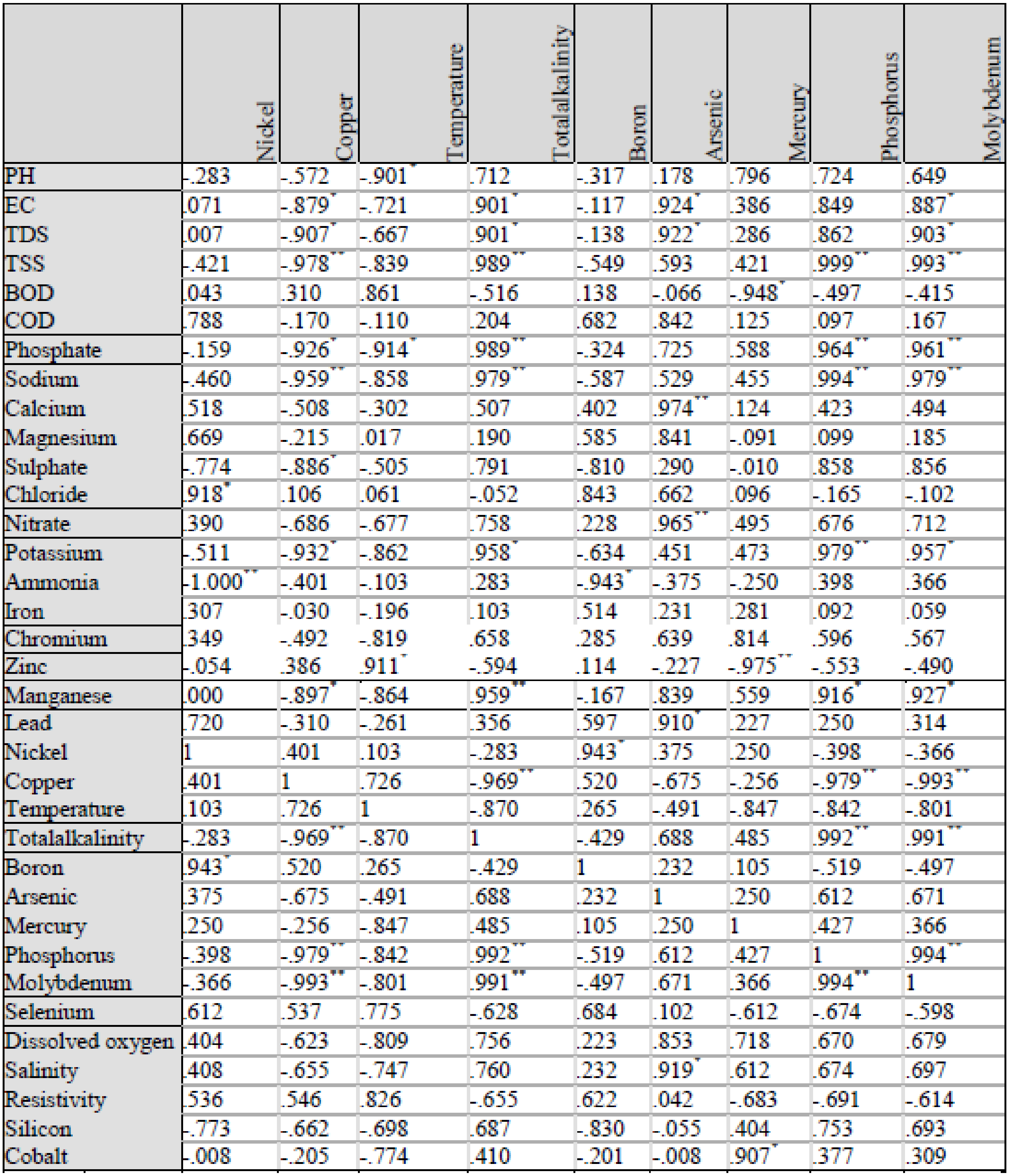
	PH	EC	TDS	TSS	BOD	COD	Phosphate	Sodium	Calcium	Magnesium
PH	1	.425	.408	.717	-.916*	-.199	.734	.758	-.013	-.328
EC	.425	1	.987**	.841	-.284	.589	.918*	.799	.815	.584
TDS	.408	.987**	1	.851	-.209	.568	.901*	.805	.819	.589
TSS	.717	.841	.851	1	-.494	.073	.960**	.996**	.401	.078
BOD	-.916*	-.284	-.209	-.494	1	.161	-.584	-.546	.099	.354
COD	-.199	.589	.568	.073	.161	1	.282	.000	.931*	.971**
Phosphate	.734	.918*	.901*	.960**	-.584	.282	1	.949*	.551	.238
Sodium	.758	.799	.805	.996**	-.546	.000	.949*	1	.327	-.004
Calcium	-.013	.815	.819	.401	.099	.931*	.551	.327	1	.940*
Magnesium	-.328	.584	.589	.078	.354	.971**	.238	-.004	.940*	1
Sulphate	.494	.564	.627	.867	-.174	-.256	.694	.869	.115	-.152
Chloride	-.325	.354	.322	-.190	.208	.961**	.043	-.255	.795	.909*
Nitrate	.390	.935*	.911*	.657	-.321	.781	.817	.609	.905*	.723
Potassium	.788	.745	.747	.984**	-.585	-.085	.926*	.996**	.240	-.095
Ammonia	.283	-.071	-.007	.421	-.043	-.788	.159	.460	-.518	-.669
Iron	.399	.079	.150	.051	-.277	.269	.138	.040	.256	.193
Chromium	.751	.657	.629	.569	-.728	.474	.741	.562	.548	.320
Zinc	-.855	-.438	-.341	-.554	.969**	-.002	-.675	-.593	-.065	.191
Manganese	.642	.967**	.950*	.907*	-.502	.457	.982**	.882*	.695	.412
Lead	-.054	.703	.681	.227	.042	.987**	.433	.157	.964**	.949*
Nickel	-.283	.071	.007	-.421	.043	.788	-.159	-.460	.518	.669

Copper	-.572	-.879*	-.907*	-.978**	.310	-.170	-.926*	-.959**	-.508	-.215
Temperature	-.901*	-.721	-.667	-.839	.861	-.110	-.914*	-.858	-.302	.017
Totalalkalinity	.712	.901*	.901*	.989**	-.516	.204	.989**	.979**	.507	.190
Boron	-.317	-.117	-.138	-.549	.138	.682	-.324	-.587	.402	.585
Arsenic	.178	.924*	.922*	.593	-.066	.842	.725	.529	.974**	.841
Mercury	.796	.386	.286	.421	-.948*	.125	.588	.455	.124	-.091
Phosphorus	.724	.849	.862	.999**	-.497	.097	.964**	.994**	.423	.099
Molybdenum	.649	.887*	.903*	.993**	-.415	.167	.961**	.979**	.494	.185
Selenium	-.881*	-.257	-.228	-.687	.810	.541	-.610	-.747	.321	.620
Dissolved oxygen	.557	.871	.817	.653	-.558	.672	.838	.625	.767	.555
Salinity	.471	.911*	.870	.656	-.441	.738	.832	.618	.846	.650
Resistivity	-.911*	-.305	-.268	-.701	.857	.469	-.651	-.760	.261	.566
Silicon	.792	.316	.318	.768	-.631	-.563	.633	.818	-.276	-.578
Cobalt	.726	.233	.112	.389	-.917*	-.177	.488	.443	-.163	-.369

	Sulphate	Chloride	Nitrate	Potassium	Ammonia	Iron	Chromium	Zinc	Manganese	Lead
PH	.494	-.325	.390	.788	.283	.399	.751	-.855	.642	-.054
EC	.564	.354	.935*	.745	-.071	.079	.657	-.438	.967**	.703
TDS	.627	.322	.911*	.747	-.007	.150	.629	-.341	.950*	.681
TSS	.867	-.190	.657	.984**	.421	.051	.569	-.554	.907*	.227
BOD	-.174	.208	-.321	-.585	-.043	-.277	-.728	.969**	-.502	.042
COD	-.256	.961**	.781	-.085	-.788	.269	.474	-.002	.457	.987**

Phosphate	.694	.043	.817	.926*	.159	.138	.741	-.675	.982**	.433
Sodium	.869	-.255	.609	.996**	.460	.040	.562	-.593	.882*	.157
Calcium	.115	.795	.905*	.240	-.518	.256	.548	-.065	.695	.964**
Magnesium	-.152	.909*	.723	-.095	-.669	.193	.320	.191	.412	.949*
Sulphate	1	-.512	.273	.871	.774	-.107	.143	-.174	.602	-.131
Chloride	-.512	1	.609	-.333	-.918*	.287	.375	.067	.225	.912*
Nitrate	.273	.609	1	.545	-.390	.300	.801	-.469	.910*	.871
Potassium	.871	-.333	.545	1	.511	.018	.536	-.620	.844	.074
Ammonia	.774	-.918*	-.390	.511	1	-.307	-.349	.054	.000	-.720
Iron	-.107	.287	.300	.018	-.307	1	.643	-.149	.195	.294
Chromium	.143	.375	.801	.536	-.349	.643	1	-.754	.780	.582
Zinc	-.174	.067	-.469	-.620	.054	-.149	-.754	1	-.615	-.123
Manganese	.602	.225	.910*	.844	.000	.195	.780	-.615	1	.593
Lead	-.131	.912*	.871	.074	-.720	.294	.582	-.123	.593	1
Nickel	-.774	.918*	.390	-.511	-1.000**	.307	.349	-.054	.000	.720
Copper	-.886*	.106	-.686	-.932*	-.401	-.030	-.492	.386	-.897*	-.310
Temperature	-.505	.061	-.677	-.862	-.103	-.196	-.819	.911*	-.864	-.261
Totalalkalinity	.791	-.052	.758	.958*	.283	.103	.658	-.594	.959**	.356
Boron	-.810	.843	.228	-.634	-.943*	.514	.285	.114	-.167	.597
Arsenic	.290	.662	.965**	.451	-.375	.231	.639	-.227	.839	.910*
Mercury	-.010	.096	.495	.473	-.250	.281	.814	-.975**	.559	.227
Phosphorus	.858	-.165	.676	.979**	.398	.092	.596	-.553	.916*	.250
Molybdenum	.856	-.102	.712	.957*	.366	.059	.567	-.490	.927*	.314
Selenium	-.624	.671	-.085	-.804	-.612	.022	-.380	.752	-.456	.402
Dissolved oxygen	.203	.528	.960**	.579	-.404	.317	.898*	-.689	.904*	.776
Salinity	.233	.580	.990**	.561	-.408	.304	.854	-.584	.913*	.836
Resistivity	-.590	.598	-.157	-.812	-.536	-.015	-.457	.811	-.507	.327
Silicon	.805	-.739	.074	.866	.773	-.100	.254	-.579	.477	-.424
Cobalt	.070	-.201	.234	.488	.008	-.095	.519	-.950*	.402	-.079

	Nickel	Copper	Temperature	Totalalkalinity	Boron	Arsenic	Mercury	Phosphorus	Molybdenum
PH	-.283	-.572	-.901*	.712	-.317	.178	.796	.724	.649
EC	.071	-.879*	-.721	.901*	-.117	.924*	.386	.849	.887*
TDS	.007	-.907*	-.667	.901*	-.138	.922*	.286	.862	.903*
TSS	-.421	-.978**	-.839	.989**	-.549	.593	.421	.999**	.993**
BOD	.043	.310	.861	-.516	.138	-.066	-.948*	-.497	-.415
COD	.788	-.170	-.110	.204	.682	.842	.125	.097	.167
Phosphate	-.159	-.926*	-.914*	.989**	-.324	.725	.588	.964**	.961**
Sodium	-.460	-.959**	-.858	.979**	-.587	.529	.455	.994**	.979**
Calcium	.518	-.508	-.302	.507	.402	.974**	.124	.423	.494
Magnesium	.669	-.215	.017	.190	.585	.841	-.091	.099	.185
Sulphate	-.774	-.886*	-.505	.791	-.810	.290	-.010	.858	.856
Chloride	.918*	.106	.061	-.052	.843	.662	.096	-.165	-.102
Nitrate	.390	-.686	-.677	.758	.228	.965**	.495	.676	.712
Potassium	-.511	-.932*	-.862	.958*	-.634	.451	.473	.979**	.957*
Ammonia	-1.000**	-.401	-.103	.283	-.943*	-.375	-.250	.398	.366
Iron	.307	-.030	-.196	.103	.514	.231	.281	.092	.059
Chromium	.349	-.492	-.819	.658	.285	.639	.814	.596	.567
Zinc	-.054	.386	.911*	-.594	.114	-.227	-.975**	-.553	-.490
Manganese	.000	-.897*	-.864	.959**	-.167	.839	.559	.916*	.927*
Lead	.720	-.310	-.261	.356	.597	.910*	.227	.250	.314
Nickel	1	.401	.103	-.283	.943*	.375	.250	-.398	-.366
Copper	.401	1	.726	-.969**	.520	-.675	-.256	-.979**	-.993**
Temperature	.103	.726	1	-.870	.265	-.491	-.847	-.842	-.801
Totalalkalinity	-.283	-.969**	-.870	1	-.429	.688	.485	.992**	.991**
Boron	.943*	.520	.265	-.429	1	.232	.105	-.519	-.497
Arsenic	.375	-.675	-.491	.688	.232	1	.250	.612	.671
Mercury	.250	-.256	-.847	.485	.105	.250	1	.427	.366
Phosphorus	-.398	-.979**	-.842	.992**	-.519	.612	.427	1	.994**
Molybdenum	-.366	-.993**	-.801	.991**	-.497	.671	.366	.994**	1
Selenium	.612	.537	.775	-.628	.684	.102	-.612	-.674	-.598
Dissolved oxygen	.404	-.623	-.809	.756	.223	.853	.718	.670	.679
Salinity	.408	-.655	-.747	.760	.232	.919*	.612	.674	.697
Resistivity	.536	.546	.826	-.655	.622	.042	-.683	-.691	-.614
Silicon	-.773	-.662	-.698	.687	-.830	-.055	.404	.753	.693
Cobalt	-.008	-.205	-.774	.410	-.201	-.008	.907*	.377	.309



	Nickel	Copper	Temperature	Totalalkalinity	Boron	Arsenic	Mercury	Phosphorus	Molybdenum
PH	-.283	-.572	-.901*	.712	-.317	.178	.796	.724	.649
EC	.071	-.879*	-.721	.901*	-.117	.924*	.386	.849	.887*
TDS	.007	-.907*	-.667	.901*	-.138	.922*	.286	.862	.903*
TSS	-.421	-.978**	-.839	.989**	-.549	.593	.421	.999**	.993**
BOD	.043	.310	.861	-.516	.138	-.066	-.948*	-.497	-.415
COD	.788	-.170	-.110	.204	.682	.842	.125	.097	.167
Phosphate	-.159	-.926*	-.914*	.989**	-.324	.725	.588	.964**	.961**
Sodium	-.460	-.959**	-.858	.979**	-.587	.529	.455	.994**	.979**
Calcium	.518	-.508	-.302	.507	.402	.974**	.124	.423	.494
Magnesium	.669	-.215	.017	.190	.585	.841	-.091	.099	.185
Sulphate	-.774	-.886*	-.505	.791	-.810	.290	-.010	.858	.856
Chloride	.918*	.106	.061	-.052	.843	.662	.096	-.165	-.102
Nitrate	.390	-.686	-.677	.758	.228	.965**	.495	.676	.712
Potassium	-.511	-.932*	-.862	.958*	-.634	.451	.473	.979**	.957*
Ammonia	-1.000**	-.401	-.103	.283	-.943*	-.375	-.250	.398	.366
Iron	.307	-.030	-.196	.103	.514	.231	.281	.092	.059
Chromium	.349	-.492	-.819	.658	.285	.639	.814	.596	.567
Zinc	-.054	.386	.911*	-.594	.114	-.227	-.975**	-.553	-.490
Manganese	.000	-.897*	-.864	.959**	-.167	.839	.559	.916*	.927*
Lead	.720	-.310	-.261	.356	.597	.910*	.227	.250	.314
Nickel	1	.401	.103	-.283	.943*	.375	.250	-.398	-.366
Copper	.401	1	.726	-.969**	.520	-.675	-.256	-.979**	-.993**
Temperature	.103	.726	1	-.870	.265	-.491	-.847	-.842	-.801
Totalalkalinity	-.283	-.969**	-.870	1	-.429	.688	.485	.992**	.991**
Boron	.943*	.520	.265	-.429	1	.232	.105	-.519	-.497
Arsenic	.375	-.675	-.491	.688	.232	1	.250	.612	.671
Mercury	.250	-.256	-.847	.485	.105	.250	1	.427	.366
Phosphorus	-.398	-.979**	-.842	.992**	-.519	.612	.427	1	.994**
Molybdenum	-.366	-.993**	-.801	.991**	-.497	.671	.366	.994**	1
Selenium	.612	.537	.775	-.628	.684	.102	-.612	-.674	-.598
Dissolved oxygen	.404	-.623	-.809	.756	.223	.853	.718	.670	.679
Salinity	.408	-.655	-.747	.760	.232	.919*	.612	.674	.697
Resistivity	.536	.546	.826	-.655	.622	.042	-.683	-.691	-.614
Silicon	-.773	-.662	-.698	.687	-.830	-.055	.404	.753	.693
Cobalt	-.008	-.205	-.774	.410	-.201	-.008	.907*	.377	.309

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

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

Arsenic is used industrially as an alloying agent, as well as in the processing of glass, pigments, textiles, paper, metal adhesives, wood preservatives, and ammunition(Howard, 2003). Common industrial uses for cadmium today are in batteries, alloys, coatings (electroplating), solar cells, plastic stabilizers, and pigments(Kiersma, 2014). In the metallurgical industry, chromium is used to produce stainless steels, alloy cast irons, nonferrous alloys, and other miscellaneous materials(Services, 2002). Lead and lead compounds have been used in a wide variety of products found in and around our homes, including paint, ceramics, pipes and plumbing materials, solders, gasoline, batteries, ammunition, and cosmetics(Hostettmann & Marston, 2009). Mercury has a wide variety of industrial uses: Electrical equipment e.g. batteries and semiconductors (Hostettmann & Marston, 2009). Within primary uses, molybdenum is employed in the manufacture of chemical and steel products -structural and stainless steel- as well as pure molybdenum elements(Hostettmann & Marston, 2009). Today, purified nitrate is commercially manufactured for many uses from fertilizer to a variety of foods such as cured meats and toothpaste(Hostettmann & Marston, 2009). It is used in a wide variety of industrial applications, including the production of potassium carbonate and other potassium chemicals, soaps and detergents, and fertilizers(Hostettmann & Marston, 2009). Phosphate can also be turned into phosphoric acid, which is used in everything from food and cosmetics to animal feed and electronics-related solid waste which is being dumped at the open dump site(EPA, 2012). Therefore, it is possible to infer that the groundwater well's pollution is caused by artificial inputs rather than being connected to natural processes.

In this study, the relationship between various elements has been studied using the Pearson correlation matrix **(**Table 40**).** The result of the correlation analysis indicated a strong negative association between pH and BOD (-0.916*), Copper and EC (-0.879*), Copper and TDS (-0.907*), Copper and Phosphate (-0.926*), Temperature and pH (-0.901*), Temperature and Phosphate (-.914*), Mercury and BOD (-0.948*), Selenium and pH (-0.881*), Resistivity and EC (-0.911*), Cobalt and BOD (-0.917*), Phosphate and Potassium (-0.917*), Chloride and Ammonia (-0.918*), Ammonia and Chloride (-0.918^{*}), Copper and Sulfate (-0.886^{*}), Copper and Potassium (-0.932*), Copper and Manganese (-0.897*), Boron and Ammonia (-0.943*), Cobalt and Zinc (-0.950*), pH and Resistivity (-0.911^{*}*), & Resistivity and Silicon (-0.938*) is significant at a 0.05 confidence level.

But also the matrix shows up that a strong positive association between EC and Phosphate (0.918*), TDS and Phosphate (0.901*), Sodium and Phosphate (0.949*), COD and Calcium (0.931*), Calcium and Magnesium (0.940*), Nitrate and EC (0.935*), Nitrate and Calcium (0.905*), Potassium and Phosphate (0.926*), Manganese and TDS (0.950*), Manganese and TSS (0.907*), Manganese and Sodium (0.882*), Lead and Magnesium (0.949*),Total alkalinity and EC (0.901*), Total alkalinity and TDS (0.901*), Arsenic and EC (0.924*), Molybdenum and EC (0.887*), Molybdenum and TDS (.903*), Salinity and EC (0.911*), TDS and Nitrate (0.911*), Magnesium and Chloride (0.909*), Chloride and Lead (0.912*), Manganese and Nitrate (0.91*), Nickel and Chloride (0.918*), Temperature and Zinc (0.911*), Total alkalinity and Potassium (0.958*), Arsenic and Lead (0.91*), Phosphorus and Manganese (0.916*), Molybdenum and Potassium, (0.957*), Molybdenum and Manganese (0.927*), Dissolved oxygen and Chromium (0.898*), Dissolved oxygen and Manganese (0.904*), Salinity and Manganese (0.913*), TDS and Arsenic (0.922*), Ammonia and Boron (0.957*), Nickel and Boron (0.943*),Salinity and Arsenic (0.919*), & Mercury and Cobalt (0.907*) is significant at same confidence level.

In (Table 40**),** the result of the correlation analysis indicated a strong negative association between Mercury and Zinc (-0.975**), Nickel and Ammonia (-1.000**), TSS and Copper (-.978**), Sodium and Copper (-0.959**), Copper and Total alkalinity (-0.969**), Copper and Molybdenum (-0.993**), Phosphorus and Copper (-0.979**), & Selenium and Silicon (-0.961**) is significant at a 0.01 confidence level.

But also the result of the matrix shows that a strong positive association between EC and TDS (0.987**), TSS and Phosphate (0.960**), TSS and Sodium (0.996**), COD and Magnesium (0.971**), Chloride and COD (0.961**),Potassium and TSS (0.984**), Potassium and Sodium (0.996**), Zinc and BOD (0.969**), Manganese and EC(0.967**), Manganese and Phosphate(0.982**), Lead and COD (0.987**), Lead and Calcium (0.964**), Total alkalinity and TSS (0.989**), Total alkalinity and Phosphate (0.989**), Total alkalinity and Sodium (0.979**), Arsenic and Calcium (0.974**), Phosphorus and TSS (0.999**), Phosphorus and Phosphate (0.964**), Phosphorus and Sodium (0.994**), Molybdenum and TSS (0.993**), Molybdenum and Phosphate (0.961**), Molybdenum and Sodium (0.979**), Total alkalinity and Manganese (0.959**), Arsenic and Nitrate (0.965**), Phosphorus and Potassium (0.979**), Dissolved oxygen and Nitrate (0.960**), Salinity and Nitrate (0.990**), Copper and Phosphorus (0.979**), Total alkalinity and Phosphorus (0.992**), Total alkalinity and Molybdenum (0.991**), Phosphorus and Molybdenum (0.994**), Selenium and Resistivity (0.995**), & Dissolved oxygen and Salinity (0.990**) is significant at same confidence level.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The Water Quality analysis indicates that the concentrations of Electrical conductivity (EC), Potassium (K), Iron (Fe), Chromium (Cr_3), Lead (Pb), Mercury (Hg), Total Alkalinity as$CaCO_3$, Nitrate (NO_3^-), Phosphate (PO_4^+), Cadmium (Cd), Bicarbonates (HCO_3^-), Arsenic (As), Salinity, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved oxygen (DO), Nickel, Molybdenum, Cobalt (Co), and Silicon (Si) in groundwater samples exceeded WHO, EPA, and Ethiopian standard guidelines indicating a significant impact of leachate on groundwater quality.

Because of the distance and located on upstream of Koshe, the well located in Ayer Tena high school was all most in all parameters, especially in parameters that indicate the impact of leachate on groundwater quality(Arsenic, cadmium, chromium, Lead, Mercury, molybdenum, nitrate, potassium & phosphate) shown significantly low concentration.

The leachate quality analysis revealed an extensive range of different contaminants that affect groundwater quality. Parameters such as; Electrical conductivity (EC), Total suspended solids (TSS), Turbidity, Total dissolved solids (TDS), Dissolved oxygen (DO), Potassium, Sodium, Iron, Manganese, Lead, Mercury, Total Alkalinity, Chloride, Ammonia, Phosphate, Sodium, Boron, Arsenic, Cobalt, BOD, and COD fall in the red category of EMA regulations which is referred to as being a high environmental hazard. Groundwater wells near the KOSHE open dump site were found to be contaminated due to the lack of a leachate collection system and unchecked accumulation of leachates at the dump site's base.

According to the National sanitation foundation water quality index (NSFWQI) analysis, the water quality status of groundwater well samples from the batu-1 condominium, Jemo-1, and Ayer Tena high school fall in the poor quality category, and also landfill well-1 and landfill well-2 fall in even very poor quality. The Weighted arithmetic index method (WAIM) analysis shows that all groundwater well samples fall in unfit to drink category. And also The Canadian Council of Ministers' environment water quality index (CCME WQI) analysis revealed that all groundwater well sample fall in poor quality. Nemerow's pollution index (NPI) analysis indicated that the contributing parameters which are responsible for polluting water quality in all groundwater well samples are Hydrogen ion (pH), Electrical conductivity (EC), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), iron, Phosphate, Molybdenum, Temperature, Bicarbonates, Nitrate, Cadmium, Ammonia, Total Alkalinity, Arsenic, and Mercury.

The result of the correlation analysis indicated a strong positive and negative association between parameters at a 0.01 and 0.050 confidence level.

The presence physico chemical parameter such as Arsenic, cadmium, chromium, Lead, Mercury, molybdenum, nitrate, potassium & phosphate in groundwater wells which are located around open dump sites can lead to the conclusion that indicated there is a significant impact of the Koshe dumpsite on the groundwater quality

5.2 Recommendations

The groundwater wells located around the Koshe Open dump site should not be used for drinking purposes unless they get proper treatment. Addis Ababa Water and Sewerage Authority should improve the quality of groundwater. It is important to have appropriate scientific monitoring programs for the area's groundwater quality. These programs should be created with a selection of critical parameters and sampling frequency that will enable the effect on the groundwater to be detected across temporal and spatial scales.

The government would need to take alternate sanitary means of waste disposal, such as recycling, into consideration to prevent the ongoing contamination of groundwater through the disposal of household and industrial waste. Instead of ignoring the impact of leachate, effective water resource management techniques must be used to lower the prevalence of waterborne diseases.

Modern waste management and treatment regulations should be implemented at the Koshe dump site, and waste disposal must be governed by pre-treatment before disposal or after disposal. Leachate should be used for recycling and other uses, and separate treatment facilities for waste and leachate should be included in the study area. Additionally, there is a need for public education regarding the particular uses of groundwater in the study area. To protect public health and safety, the proper purification methods must be used if the water is to be used domestically.

The capital of Africa, Addis Ababa, should look for national and international support in the field of modern technology for the implementation of better sustainable environmental sanitation practices. To stop the ongoing groundwater contamination, it is necessary to ban traditional landfills or dump sites and build modern, sanitary landfills in their place. To prevent contaminating the public's water supply, the government must place new landfills far from the general public. Strategic waste management, and adequate and proper planning, design, and construction are required to reduce groundwater vulnerability to pollution from landfills. Because a high rate of infiltration contributes to waste decomposition and enhances leachate migration, the surface of closed landfills must be covered with materials that prevent high rates of infiltration, especially clay or peat material. Building barriers like cut-off walls, trenches, or defense wells may be necessary because leachate has harmed or contaminated the aquifer.

To protect the investigation and use of groundwater, it is crucial to conduct a thorough analysis of the hydrogeology and groundwater flow direction in the area. More studies should be done to track contamination levels and develop mitigation plans by government organizations such as the Addis Ababa City Administration, Ethiopian Environmental Protection Authority, and Addis Ababa City Solid Waste Management Agency. More investigation is required to improve the overall knowledge of the sources of contamination in the studied area. To prioritize and identify the contaminants and their related sources which cause the greatest threat to the quality of the groundwater in this sensitive area, immediate action is needed. Future research and monitoring efforts should give priority to identifying such pollutants and their sources.

Reference

AACA, 2002. (2014). *Assessment of the contemporary municipal solid waste management in the urban environment: The case of Addis Ababa, Ethiopia*.

Abd El-Salam, M. M., & Abu-Zuid, G. I. (2015). Impact of landfill leachate on the groundwater quality: A case study in Egypt. *Journal of Advanced Research*, *6*(4), 579–586. https://doi.org/10.1016/j.jare.2014.02.003

Abeba, A. (2022). *Report on the Verification and classification of existing waste types at the dumpsite " Koshe Reppi " Current Working Status*. *May*, 1–69.

Abu-Rukah, Y., & Al-Kofahi, O. (2001). The assessment of the effect of landfill leachate on ground-water quality - A case study. El-Akader landfill site - North Jordan. *Journal of Arid Environments*, *49*(3), 615–630. https://doi.org/10.1006/jare.2001.0796

Academic, A. (2012). *Evaluation of Groundwater Quality Using Contamination Index in Parts of Alimosho , Lagos - Nigeria* . *4*(4).

Agency, E. P. (n.d.). *An Ghníomhaireacht um Chaomhnú Comhshaoil LANDFILL MANUALS LANDFILL*.

Al-Arifi, N. S., Al-Agha, M. R., & El-Nahhal, Y. Z. (2013). Environmental Impact of Landfill on Groundwater, South East of Riyadh, Saudi Arabia. In *Journal of Natural Sciences Research www.iiste.org ISSN* (Vol. 3, Issue 15). Online. www.iiste.org

Ali, a. (2012). *Groundwater Pollution Threats of Solid Waste Disposal in Urban Kano, Nigeria: Evaluation and Protection Strategies*. 1–265. http://www.manchester.ac.uk/escholar/uk-ac-man-scw:198714

APHA. (2012). *Standard Methods for the Examination of Water and Wastewater*. 1496.

Bassam, R., Tuffaha, R., Haddad, M., & Engineer, E. (2006). Impacts of Solid Waste Leachate on Soil and its Simulation to Ground Water at Nablus Area. *An-Najah National University*, 1–120.

BELLE, G. V. L. D. F. (1386). *Biostatistics A Methodology for the Health Sciences*.

Chihanga, T. F. (2015). *An Investigation of Groundwater Vulnerability within The Vicinity of A Landfill: A Case Study Of Pomona Landfill*. *September*, 102.

Chu, L. M. (2008). Landfills. *Encyclopedia of Ecology, Five-Volume Set*, *i*, 2099–2103. https://doi.org/10.1016/B978-008045405-4.00345-1

Dawood, A. S. (2017). Using of Nemerow's Pollution Index (NPI) for Water Quality

Assessment of Some Basrah Marshes, South of Iraq. *Journal of University of Babylon*, *25*(5), 1708–1720. https://www.researchgate.net/publication/319451012%0D

Division, M. D. of H. E. H., & 2023. (n.d.). *Copper in Drinking Water How to Protect Yourself and*.

Drinking Water 21. (n.d.). 21.

EMA. (2007). Environmental Management (Effluent and Solid Waste Disposal) Regulations, 2007. In *Environmental Management Agency* (pp. 1–54).

EPA. (2012). Phosphorus: Forms of Phosphorus. *EPA's Web Archive*, 1–16. https://archive.epa.gov/water/archive/web/html/vms56.html

EPA, U. (1995). Superfund Program Representative Sampling Guidance. *Program*, *4*(December), 1–58.

ES. (2013). CES 58 Compulsory Ethiopian Standard. *CES 58 Compulsory Ethiopian Standard*.

FCSWM. (2013). *a Ddis a Baba C Ity G Overnment - Ethio -French C ooperation Solid Waste Management Project – Strategic and Technical Studies and Original Works Supervision F Inal Report*. *33*(December).

Flyhammar, P. (1995). Analysis of the Cadmium Flux in Sweden with Special Emphasis on Landfill Leachate. *Journal of Environmental Quality*, *24*(4), 612–621. https://doi.org/10.2134/jeq1995.00472425002400040010x

Güler, C., & Thyne, G. D. (2004). Hydrologic and geologic factors controlling surface and groundwater chemistry in Indian Wells-Owens Valley area, southeastern California, USA. *Journal of Hydrology*, *285*(1–4), 177–198. https://doi.org/10.1016/j.jhydrol.2003.08.019

Haile, T., & Abiye, T. A. (2012). Environmental impact and vulnerability of the surface and ground water system from municipal solid waste disposal site: Koshe, Addis Ababa. *Environmental Earth Sciences*, *67*(1), 71–80. https://doi.org/10.1007/s12665-011-1480-3

Helsel, D. R., Hirsch, R. M., Ryberg, K. R., Archfield, S. A., & Gilroy, E. J. (2020). Statistical methods in water resources. *U.S. Geological Survey Techniques and Methods*, *2020*(4-A3), 1–484. https://doi.org/10.3133/tm4a3

Hostettmann, K., & Marston, A. (2009). Occurrence and distribution. *Saponins*, 18–121. https://doi.org/10.1017/cbo9780511565113.003

Hout, J. J. (2012). Lead in drinking water. *Journal of Environmental Health*, *75*(1), 56.

Howard, G. (2003). Arsenic, Drinking-water and Health Risk Substitution in Arsenic Mitigation:

a Discussion Paper (report prepared for the Arsenic Policy Support Unit, Local Government Division, Government of Bangladesh World Health Organization). *World Health*.

Hye-Knudsen, P. (1985). Nitrate in drinking water and methaemoglobinaemia. *Ugeskrift for Laeger*, *147*(1), 51–53.

JUMA, T. O. (2014). *The impacts of dumpsite and domestic waste leachate*.

Kebede, S., Travi, Y., Alemayehu, T., & Marc, V. (2006). Water balance of Lake Tana and its sensitivity to fluctuations in rainfall, Blue Nile basin, Ethiopia. *Journal of Hydrology*, *316*(1–4), 233–247. https://doi.org/10.1016/j.jhydrol.2005.05.011

Kiersma, M. E. (2014). National Institute for Occupational Safety and Health. *Encyclopedia of Toxicology: Third Edition*, 454–455. https://doi.org/10.1016/B978-0-12-386454-3.00340-7

Kumar, D., & Alappat, B. J. (2005). Evaluating leachate contamination potential of landfill sites using leachate pollution index. *Clean Technologies and Environmental Policy*, *7*(3), 190–197. https://doi.org/10.1007/s10098-004-0269-4

LOHMAN, S. W. (1972). Ground-Water Hydraulics Ground-Water Hydraulics. *GEOLOGICAL SURVEY PROFESSIONAL PAPER 708*.

Longe, E. O., & Balogun, M. R. (2010). Groundwater quality assessment near a municipal landfill, Lagos, Nigeria. *Research Journal of Applied Sciences, Engineering and Technology*, *2*(1), 39–44.

Munna, G. M., Chowdhury, M. M. I., Ahmed, A. A. M., & Chowdhury, S. (2013). A Canadian Water Quality Guideline-Water Quality Index (CCME-WQI) based assessment study of water quality in Surma River. *Journal of Civil Engineering and Construction Technology*, *4*(3), 81–89. https://doi.org/10.5897/JCECT12.074

Nkwunonwo, U. C., Odika, P. O., & Onyia, N. I. (2020). *A Review of the Health Implications of Heavy Metals in Food Chain in Nigeria*. *2020*.

Ofomola, M. O., Umayah, O. S., & Akpoyibo, O. (2017). Contamination assessment of dumpsites in Ughelli, Nigeria using the Leachate Pollution Index method. *Journal of Applied Sciences and Environmental Management*, *21*(1), 77. https://doi.org/10.4314/jasem.v21i1.8

OYIBOKA, I. J. (2020). *EFFECTS OF LANDFILL SITES ON GROUNDWATER QUALITY IN IGANDO, ALIMOSHO LOCALGOVERNMENT AREA, LAGOS STATE*. *March*, 274–282.

Parvin, F., & Tareq, S. M. (2021). Impact of landfill leachate contamination on surface and groundwater of Bangladesh: a systematic review and possible public health risks assessment. *Applied Water Science*, *11*(6). https://doi.org/10.1007/s13201-021-01431-3

Przydatek, G., & Kanownik, W. (2019). Impact of small municipal solid waste landfill on groundwater quality. *Environmental Monitoring and Assessment*, *191*(3). https://doi.org/10.1007/s10661-019-7279-5

Quality, D. (1996). Molybdenum in Drinking-water. *WHO Guidelines for Drinking-Water Quality*, *2*, 7. https://apps.who.int/iris/bitstream/handle/10665/75372/WHO_SDE_WSH_03.04_11_eng.pdf?sequence=1&isAllowed=y

Raviteja, K. V. N. S., & Munwar Basha, B. (2017). *Probabilistic Back Analysis of Koshe Landfill Slope Failure*.

Report of Ministry of Environment, Japan, 2006. (2006). *Part Two Current Environmental Issues and Government Environmental 1 . Prevention of Global Warming and Preservation of the Ozone Layer* (Vol. 2006).

Robert M. Brown, NinaI. McClelland, R. A. (1970). *A-Water-Quality-Index-Do-we-dare-BROWN-R-M-1970.pdf*.

Rosso, N. T. K. and R. (2008). *Applied Statistics for Civil and* (second). Blackwell.

Salman, S. A., & Elnazer, A. A. (2015). Evaluation of groundwater quality and its suitability for drinking and agricultural uses in SW Qena Governorate, Egypt. *Advances in Natural and Applied Sciences*, *9*(5), 16–26.

Satish Chandra, D., Asadi, S. S., & Raju, M. V. S. (2017). Estimation of water quality index by weighted arithmetic water quality index method: A model study. *International Journal of Civil Engineering and Technology*, *8*(4), 1215–1222.

Services, H. (2002). Toxicological Profile for Chromium. *ATSDR's Toxicological Profiles*, *September*. https://doi.org/10.1201/9781420061888_ch63

Shah, A., Arjunan, A., Baroutaji, A., & Zakharova, J. (2023). A review of physicochemical and biological contaminants in drinking water and their impacts on human health. *Water Science and Engineering*, *xxx*. https://doi.org/10.1016/j.wse.2023.04.003

Singh, U. K., Kumar, M., Chauhan, R., Jha, P. K., Ramanathan, A. L., & Subramanian, V. (2008). Assessment of the impact of landfill on groundwater quality: A case study of the Pirana site in western India. *Environmental Monitoring and Assessment*, *141*(1–3), 309–

321. https://doi.org/10.1007/s10661-007-9897-6

Smahi, D., Hammoumi, O. El, & Fekri, A. (2013). Assessment of the Impact of the Landfill on Groundwater Quality: A Case Study of the Mediouna Site, Casablanca, Morocco. *Journal of Water Resource and Protection*, *05*(04), 440–445. https://doi.org/10.4236/jwarp.2013.54043

Smith, A. H., & Steinmaus, C. M. (2011). Arsenic in drinking water. *Bmj*, *342*(7806). https://doi.org/10.1136/bmj.d2248

Stephenson, T. (2009). Principles of Water and Wastewater Treatment Processes. In *Water Intelligence Online* (Vol. 8). https://doi.org/10.2166/9781780401713

Tesema. (2010). *Overview of Addis Ababa City*. 39. http://www.un.org/esa/dsd/susdevtopics/sdt_pdfs/meetings2010/icm0310/2b-2_Tessema.pdf

U.S. EPA. (2009). National Primary Drinking Water Guidelines. *Epa 816-F-09-004*, *1*, United States Environmental Protection Agency. 7p. https://www.epa.gov/sites/production/files/2016-06/documents/npwdr_complete_table.pdf

Uddin, M. G., Nash, S., & Olbert, A. I. (2021). A review of water quality index models and their use for assessing surface water quality. *Ecological Indicators*, *122*, 107218. https://doi.org/10.1016/j.ecolind.2020.107218

UN, A. R. (2022). *UNITED NATIONS HUMAN SETTLEMENT PROGRAMME (UN-HABITAT) ANNUAL REPORT 2022*.

UNEP. (2002). United Nations Environment Programme. Nairobi, Kenya. *United Nations Environment Programme*, 64. http://www.unep.org/gc/gc22/Media/UNEP_Annual_Report_2002.pdf

Way, S. W. J. (2006). *Standard Operating Procedure for the Analysis of Silica in Fresh Waters*. *March*, 1–11.

Weldeghebrael, E. H. (2021). *ADDIS ABABA : CITY SCOPING*. *June*.

WHO. (1996). Guides for municipal solid waste management in Pacific Island countries. In *Healthy Cities - Healthy Islands document series* (Issue no.6., p. 183 p.).

WHO. (2012). Water quality for drinking: WHO guidelines. *Water Quality for Drinking: WHO Guidelines*, 876–883. https://doi.org/10.1007/978-1-4020-4410-6_184

Wills, M., & Irvine, K. N. (1996). Application of the National Sanitation Foundation Water

Quality Index in the cazenovia Creek, MY, Pilot Watershed Management Project. *Middle States Geographer*, 95–104.

APPENDIX

APPENDIX A: Analytical Results

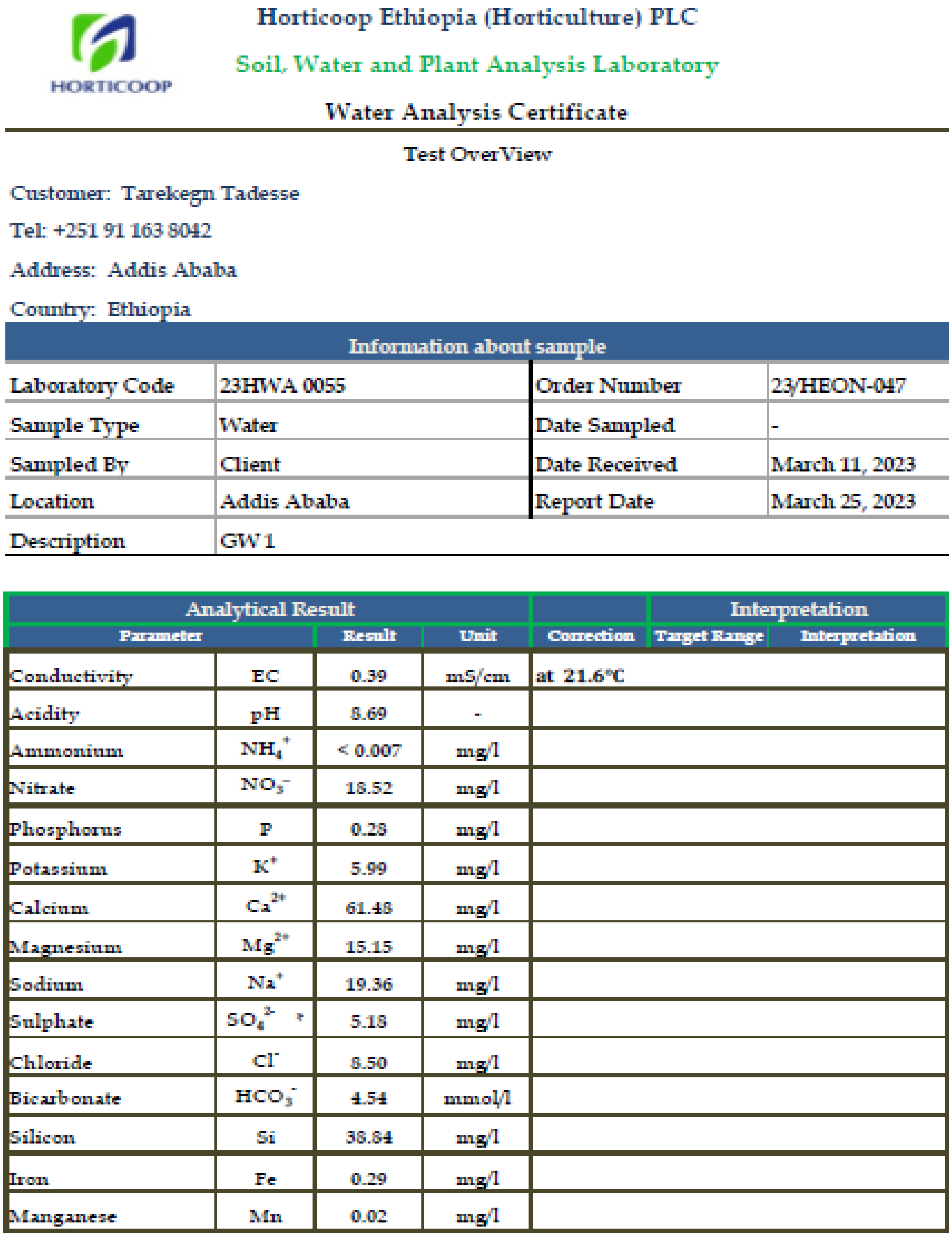
Table 41 Name of sample

1	Batu-1 Condominium	GW-1
2	Kore	GW-2
3	Landfill well -1	GW-3
4	Landfill well -2	GW-4
5	Jemo1	GW-5
6	Ayer tena high school	GW-6
7	leachate	Leachate

Table 42 on situ analysis

Sample	**Unit**	**Batu-1**	**Kore**	**Lanfillwell-1**	**Lanfillwell-2**	**jemo-1**	**Ayer Tena High school**	**Leachate**
PH		6.840	7.770	8.610	8.620	6.910	6.470	8.300
EC	(µs/cm)	460.650	509.800	600.000	599.300	376.150	279.200	27600.000
TDS	mg/l	255.200	283.750	334.900	334.600	207.100	155.100	15085.000
Dissolved_oxygen	mg/l	0.0450	0.1200	0.1100	0.1150	0.0600	0.0000	0.2100
Temperature	(°C)	31.300	27.050	23.550	23.450	26.850	21.100	24.600
Salinity	(%)	0.200	0.300	0.350	0.300	0.200	0.100	16.400
Resistivity	(Ω)	1.950	1.760	1.489	1.494	2.400	3.250	33.330

Table 43 Groundwater sample from Batu-1 Condominium



Horticoop Ethiopia (Horticulture) PLC

Soil, Water and Plant Analysis Laboratory

Water Analysis Certificate

Test OverView

Customer: Tarekegn Tadesse

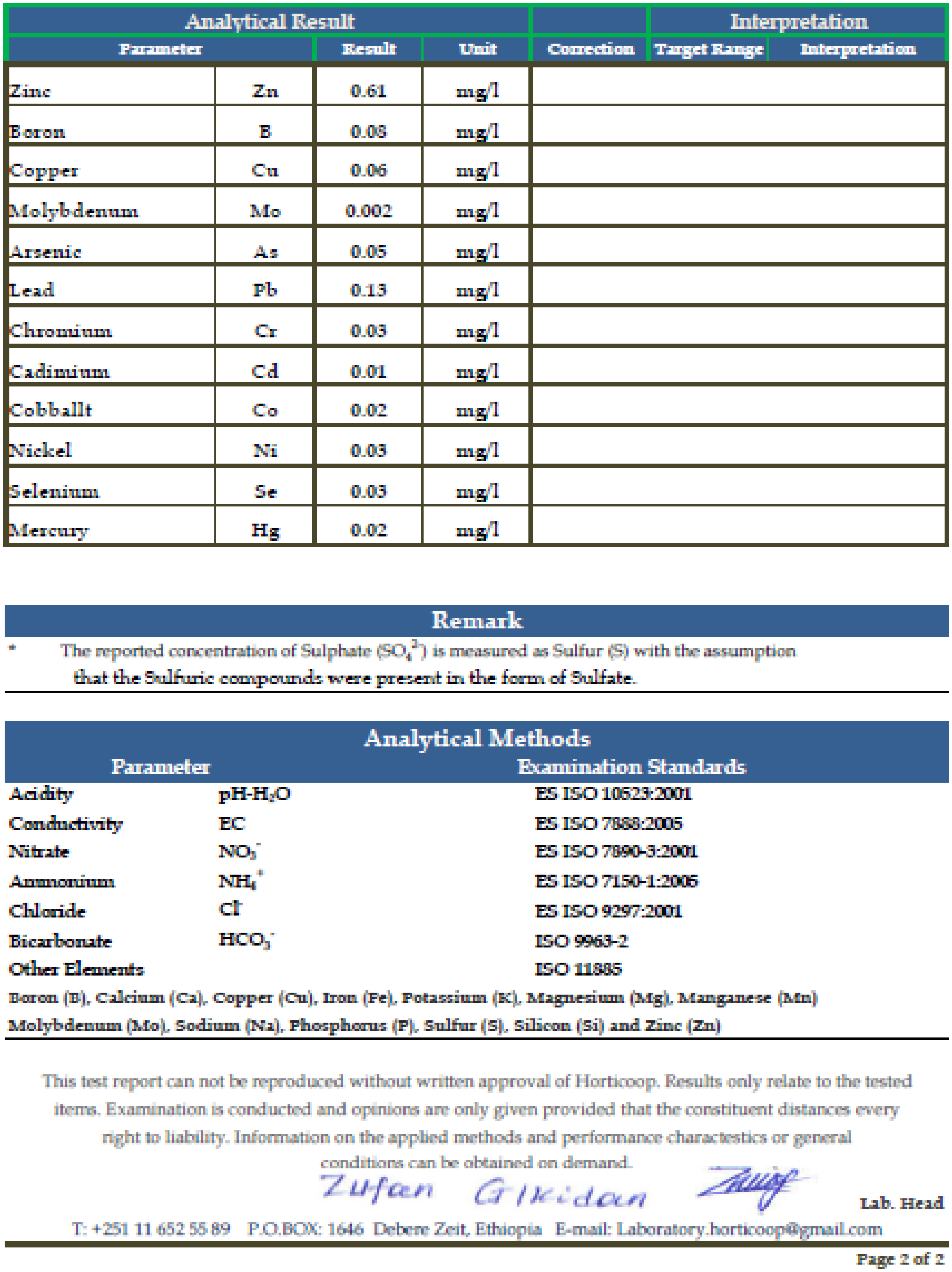
Tel: +251 91 163 8042

Address: Addis Ababa

Country: Ethiopia

Information about sample			
Laboratory Code	23HWA 0055	Order Number	23/HEON-047
Sample Type	Water	Date Sampled	-
Sampled By	Client	Date Received	March 11, 2023
Location	Addis Ababa	Report Date	March 25, 2023
Description	GW 1		

Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Conductivity	EC	0.39	mS/cm	at 21.6°C		
Acidity	pH	8.69	-			
Ammonium	NH_4^+	< 0.007	mg/l			
Nitrate	NO_3^-	18.52	mg/l			
Phosphorus	P	0.28	mg/l			
Potassium	K^+	5.99	mg/l			
Calcium	Ca^{2+}	61.48	mg/l			
Magnesium	Mg^{2+}	15.15	mg/l			
Sodium	Na^+	19.36	mg/l			
Sulphate	SO_4^{2-} *	5.18	mg/l			
Chloride	Cl^-	8.50	mg/l			
Bicarbonate	HCO_3^-	4.54	mmol/l			
Silicon	Si	38.84	mg/l			
Iron	Fe	0.29	mg/l			
Manganese	Mn	0.02	mg/l			



Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Zinc	Zn	0.61	mg/l			
Boron	B	0.08	mg/l			
Copper	Cu	0.06	mg/l			
Molybdenum	Mo	0.002	mg/l			
Arsenic	As	0.05	mg/l			
Lead	Pb	0.13	mg/l			
Chromium	Cr	0.03	mg/l			
Cadimium	Cd	0.01	mg/l			
Cobballt	Co	0.02	mg/l			
Nickel	Ni	0.03	mg/l			
Selenium	Se	0.03	mg/l			
Mercury	Hg	0.02	mg/l			

Remark

* The reported concentration of Sulphate (SO_4^{2-}) is measured as Sulfur (S) with the assumption that the Sulfuric compounds were present in the form of Sulfate.

Analytical Methods

Parameter		Examination Standards
Acidity	pH-H_2O	ES ISO 10523:2001
Conductivity	EC	ES ISO 7888:2005
Nitrate	NO_3^-	ES ISO 7890-3:2001
Ammonium	NH_4^+	ES ISO 7150-1:2005
Chloride	Cl^-	ES ISO 9297:2001
Bicarbonate	HCO_3^-	ISO 9963-2
Other Elements		ISO 11885

Boron (B), Calcium (Ca), Copper (Cu), Iron (Fe), Potassium (K), Magnesium (Mg), Manganese (Mn) Molybdenum (Mo), Sodium (Na), Phosphorus (P), Sulfur (S), Silicon (Si) and Zinc (Zn)

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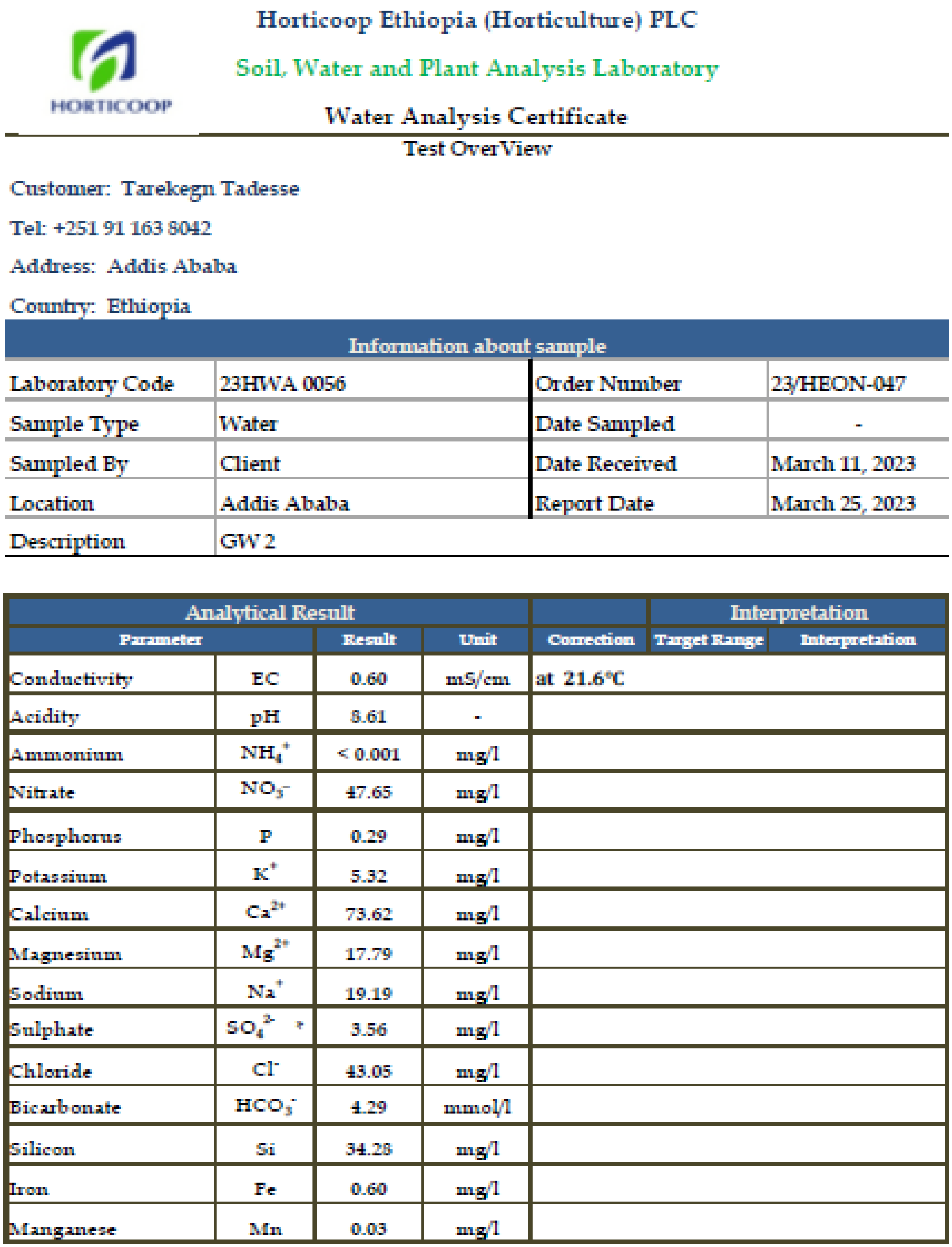
Zufan G/kidan

Lab. Head

T: +251 11 652 55 89 P.O.BOX: 1646 Debere Zeit, Ethiopia E-mail: Laboratory.horticoop@gmail.com

Page 2 of 2

Table 44 Groundwater sample from Kore



Horticoop Ethiopia (Horticulture) PLC

Soil, Water and Plant Analysis Laboratory

HORTICOOP

Water Analysis Certificate

Test OverView

Customer: Tarekegn Tadesse

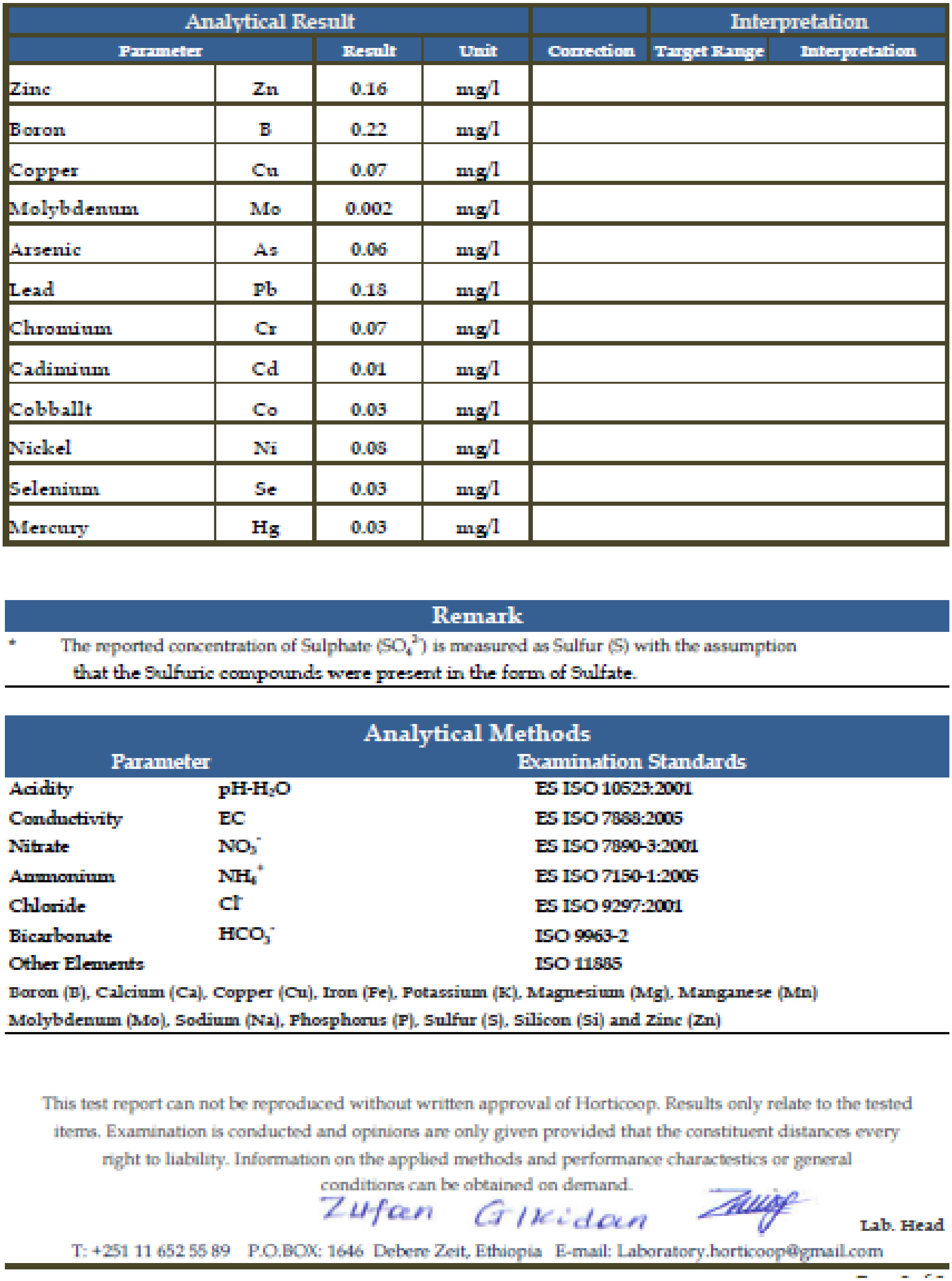
Tel: +251 91 163 8042

Address: Addis Ababa

Country: Ethiopia

Information about sample			
Laboratory Code	23HWA 0056	Order Number	23/HEON-047
Sample Type	Water	Date Sampled	-
Sampled By	Client	Date Received	March 11, 2023
Location	Addis Ababa	Report Date	March 25, 2023
Description	GW 2		

Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Conductivity	EC	0.60	mS/cm	at 21.6°C		
Acidity	pH	8.61	-			
Ammonium	NH_4^+	< 0.001	mg/l			
Nitrate	NO_3^-	47.65	mg/l			
Phosphorus	P	0.29	mg/l			
Potassium	K^+	5.32	mg/l			
Calcium	Ca^{2+}	73.62	mg/l			
Magnesium	Mg^{2+}	17.79	mg/l			
Sodium	Na^+	19.19	mg/l			
Sulphate	SO_4^{2-} *	3.56	mg/l			
Chloride	Cl^-	43.05	mg/l			
Bicarbonate	HCO_3^-	4.29	mmol/l			
Silicon	Si	34.28	mg/l			
Iron	Fe	0.60	mg/l			
Manganese	Mn	0.03	mg/l			



Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Zinc	Zn	0.16	mg/l			
Boron	B	0.22	mg/l			
Copper	Cu	0.07	mg/l			
Molybdenum	Mo	0.002	mg/l			
Arsenic	As	0.06	mg/l			
Lead	Pb	0.18	mg/l			
Chromium	Cr	0.07	mg/l			
Cadimium	Cd	0.01	mg/l			
Cobballt	Co	0.03	mg/l			
Nickel	Ni	0.08	mg/l			
Selenium	Se	0.03	mg/l			
Mercury	Hg	0.03	mg/l			

Remark

* The reported concentration of Sulphate (SO_4^{2-}) is measured as Sulfur (S) with the assumption that the Sulfuric compounds were present in the form of Sulfate.

Analytical Methods

Parameter		Examination Standards
Acidity	pH-H_2O	ES ISO 10523:2001
Conductivity	EC	ES ISO 7888:2005
Nitrate	NO_3^-	ES ISO 7890-3:2001
Ammonium	NH_4^+	ES ISO 7150-1:2006
Chloride	Cl^-	ES ISO 9297:2001
Bicarbonate	HCO_3^-	ISO 9963-2
Other Elements		ISO 11885

Boron (B), Calcium (Ca), Copper (Cu), Iron (Fe), Potassium (K), Magnesium (Mg), Manganese (Mn) Molybdenum (Mo), Sodium (Na), Phosphorus (P), Sulfur (S), Silicon (Si) and Zinc (Zn)

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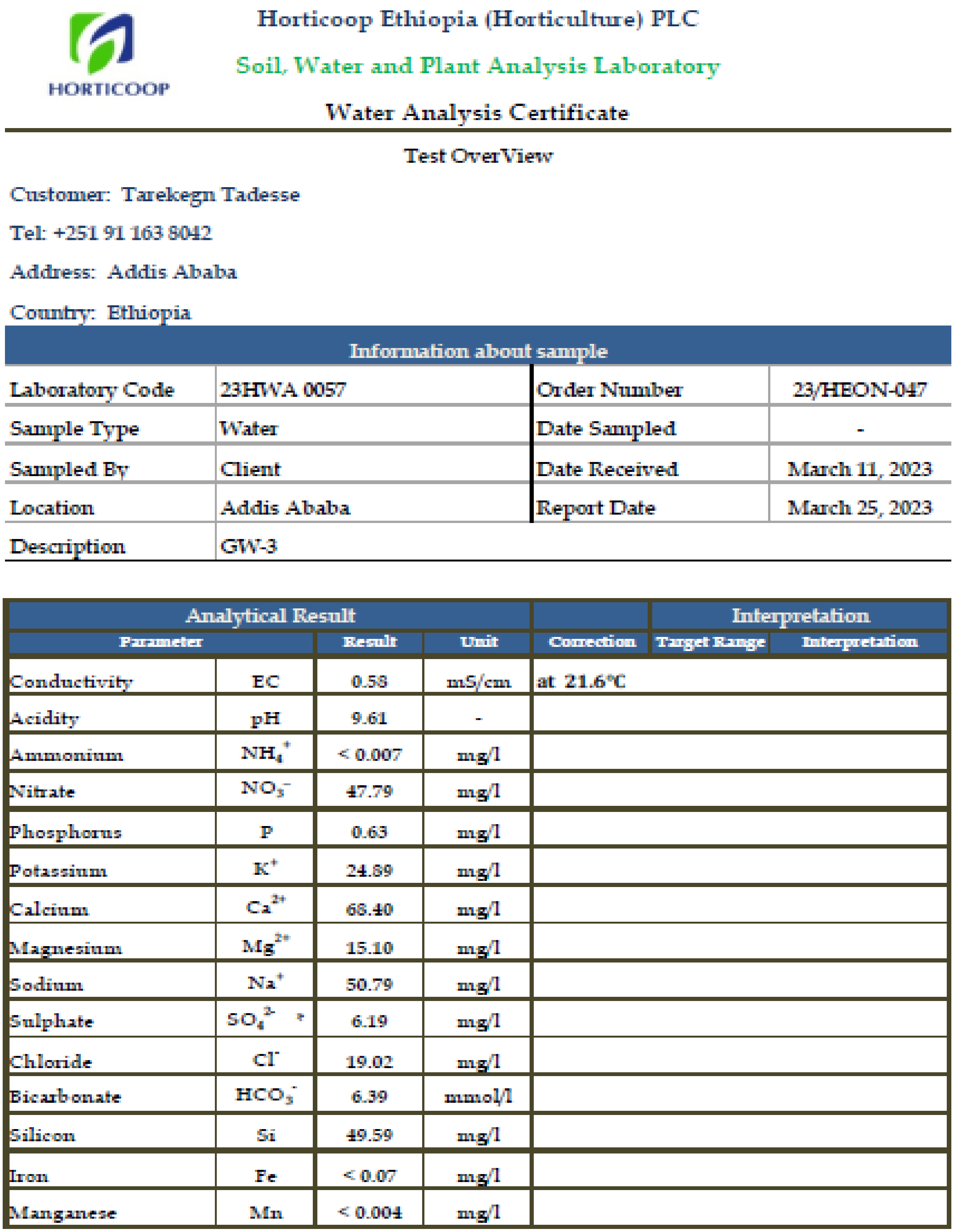
Zufan G/kidan

Lab. Head

T: +251 11 652 55 89 P.O.BOX: 1646 Debere Zeit, Ethiopia E-mail: Laboratory.horticoop@gmail.com

Table 45 Groundwater sample from Landfill well-1



HORTICOOP

Horticoop Ethiopia (Horticulture) PLC

Soil, Water and Plant Analysis Laboratory

Water Analysis Certificate

Test OverView

Customer: Tarekegn Tadesse

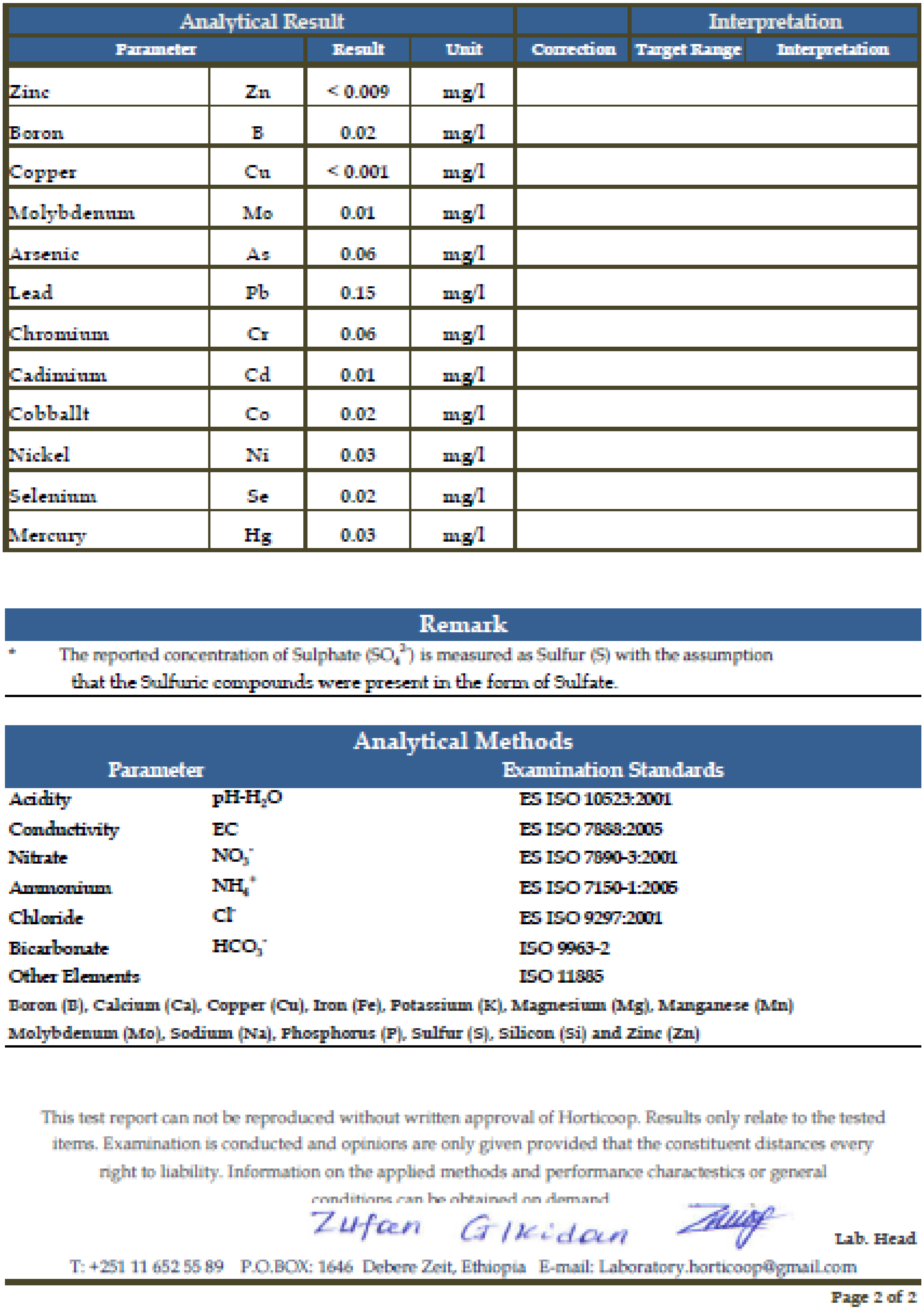
Tel: +251 91 163 8042

Address: Addis Ababa

Country: Ethiopia

Information about sample			
Laboratory Code	23HWA 0057	Order Number	23/HEON-047
Sample Type	Water	Date Sampled	-
Sampled By	Client	Date Received	March 11, 2023
Location	Addis Ababa	Report Date	March 25, 2023
Description	GW-3		

Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Conductivity	EC	0.58	mS/cm	at 21.6°C		
Acidity	pH	9.61	-			
Ammonium	NH_4^+	< 0.007	mg/l			
Nitrate	NO_3^-	47.79	mg/l			
Phosphorus	P	0.63	mg/l			
Potassium	K^+	24.89	mg/l			
Calcium	Ca^{2+}	68.40	mg/l			
Magnesium	Mg^{2+}	15.10	mg/l			
Sodium	Na^+	50.79	mg/l			
Sulphate	SO_4^{2-} *	6.19	mg/l			
Chloride	Cl^-	19.02	mg/l			
Bicarbonate	HCO_3^-	6.39	mmol/l			
Silicon	Si	49.59	mg/l			
Iron	Fe	< 0.07	mg/l			
Manganese	Mn	< 0.004	mg/l			



Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Zinc	Zn	< 0.009	mg/l			
Boron	B	0.02	mg/l			
Copper	Cu	< 0.001	mg/l			
Molybdenum	Mo	0.01	mg/l			
Arsenic	As	0.06	mg/l			
Lead	Pb	0.15	mg/l			
Chromium	Cr	0.06	mg/l			
Cadimium	Cd	0.01	mg/l			
Cobballt	Co	0.02	mg/l			
Nickel	Ni	0.03	mg/l			
Selenium	Se	0.02	mg/l			
Mercury	Hg	0.03	mg/l			

Remark

* The reported concentration of Sulphate (SO_4^{2-}) is measured as Sulfur (S) with the assumption that the Sulfuric compounds were present in the form of Sulfate.

Analytical Methods

Parameter		Examination Standards
Acidity	pH-H_2O	ES ISO 10523:2001
Conductivity	EC	ES ISO 7888:2005
Nitrate	NO_3^-	ES ISO 7890-3:2001
Ammonium	NH_4^+	ES ISO 7150-1:2005
Chloride	Cl^-	ES ISO 9297:2001
Bicarbonate	HCO_3^-	ISO 9963-2
Other Elements		ISO 11885

Boron (B), Calcium (Ca), Copper (Cu), Iron (Fe), Potassium (K), Magnesium (Mg), Manganese (Mn) Molybdenum (Mo), Sodium (Na), Phosphorus (P), Sulfur (S), Silicon (Si) and Zinc (Zn)

Zufan G/kidan

Lab. Head

T: +251 11 652 55 89 P.O.BOX: 1646 Debere Zeit, Ethiopia E-mail: Laboratory.horticoop@gmail.com

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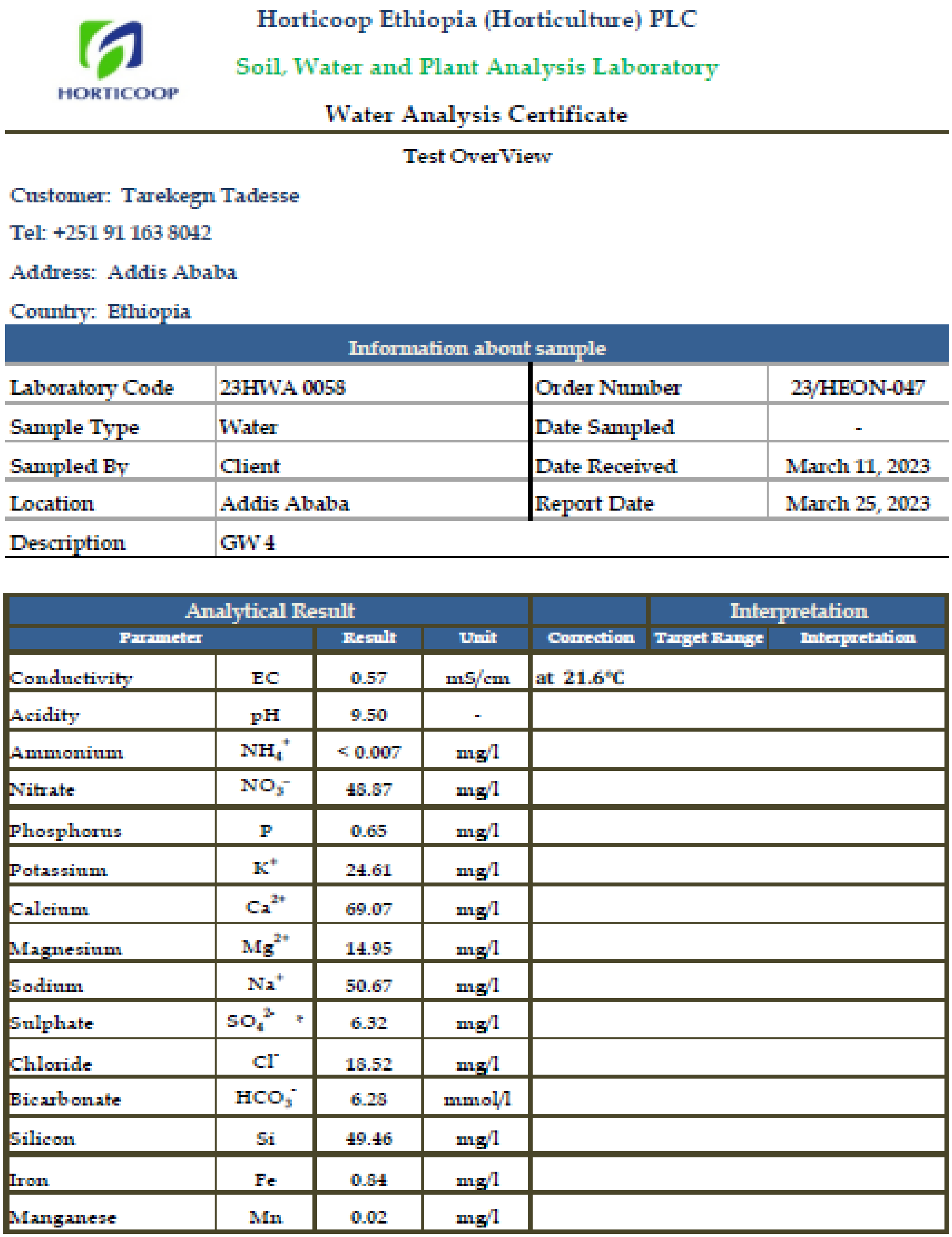
Table 46 Groundwater sample from Landfill well-2



Horticoop Ethiopia (Horticulture) PLC

Soil, Water and Plant Analysis Laboratory

Water Analysis Certificate

Test OverView

Customer: Tarekegn Tadesse

Tel: +251 91 163 8042

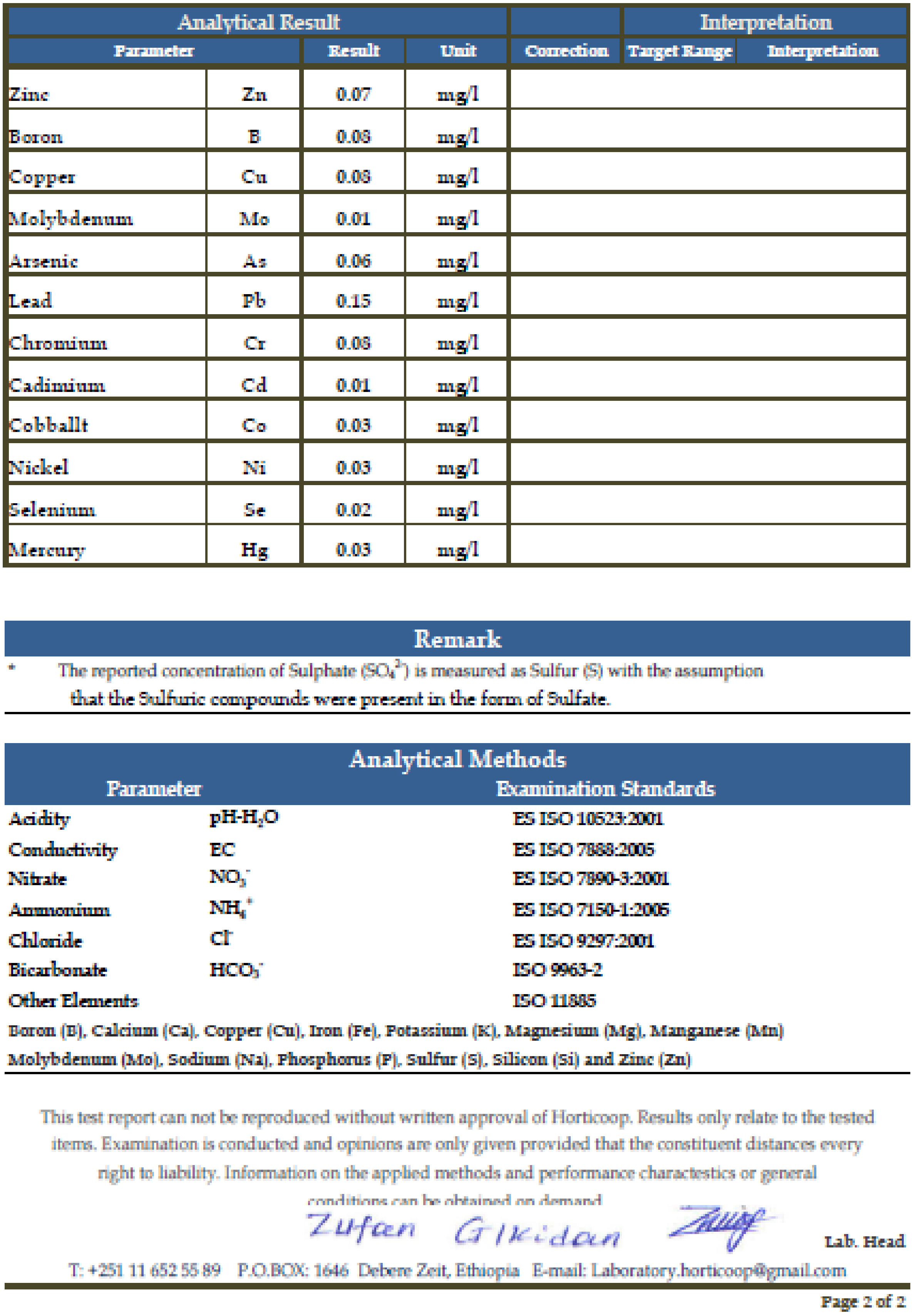
Address: Addis Ababa

Country: Ethiopia

Information about sample

Laboratory Code	23HWA 0058	Order Number	23/HEON-047
Sample Type	Water	Date Sampled	-
Sampled By	Client	Date Received	March 11, 2023
Location	Addis Ababa	Report Date	March 25, 2023
Description	GW 4		

Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Conductivity	EC	0.57	mS/cm	at 21.6°C		
Acidity	pH	9.50	-			
Ammonium	NH_4^+	< 0.007	mg/l			
Nitrate	NO_3^-	48.87	mg/l			
Phosphorus	P	0.65	mg/l			
Potassium	K^+	24.61	mg/l			
Calcium	Ca^{2+}	69.07	mg/l			
Magnesium	Mg^{2+}	14.95	mg/l			
Sodium	Na^+	50.67	mg/l			
Sulphate	SO_4^{2-} *	6.32	mg/l			
Chloride	Cl^-	18.52	mg/l			
Bicarbonate	HCO_3^-	6.28	mmol/l			
Silicon	Si	49.46	mg/l			
Iron	Fe	0.84	mg/l			
Manganese	Mn	0.02	mg/l			



Analytical Result					Interpretation	
Parameter		**Result**	**Unit**	**Correction**	**Target Range**	**Interpretation**
Zinc	Zn	0.07	mg/l			
Boron	B	0.08	mg/l			
Copper	Cu	0.08	mg/l			
Molybdenum	Mo	0.01	mg/l			
Arsenic	As	0.06	mg/l			
Lead	Pb	0.15	mg/l			
Chromium	Cr	0.08	mg/l			
Cadimium	Cd	0.01	mg/l			
Cobballt	Co	0.03	mg/l			
Nickel	Ni	0.03	mg/l			
Selenium	Se	0.02	mg/l			
Mercury	Hg	0.03	mg/l			

Remark

* The reported concentration of Sulphate (SO_4^{2-}) is measured as Sulfur (S) with the assumption that the Sulfuric compounds were present in the form of Sulfate.

Analytical Methods

Parameter		Examination Standards
Acidity	pH-H_2O	ES ISO 10523:2001
Conductivity	EC	ES ISO 7888:2005
Nitrate	NO_3^-	ES ISO 7890-3:2001
Ammonium	NH_4^+	ES ISO 7150-1:2005
Chloride	Cl^-	ES ISO 9297:2001
Bicarbonate	HCO_3^-	ISO 9963-2
Other Elements		ISO 11885

Boron (B), Calcium (Ca), Copper (Cu), Iron (Fe), Potassium (K), Magnesium (Mg), Manganese (Mn) Molybdenum (Mo), Sodium (Na), Phosphorus (P), Sulfur (S), Silicon (Si) and Zinc (Zn)

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Zufan G/kidan

Lab. Head

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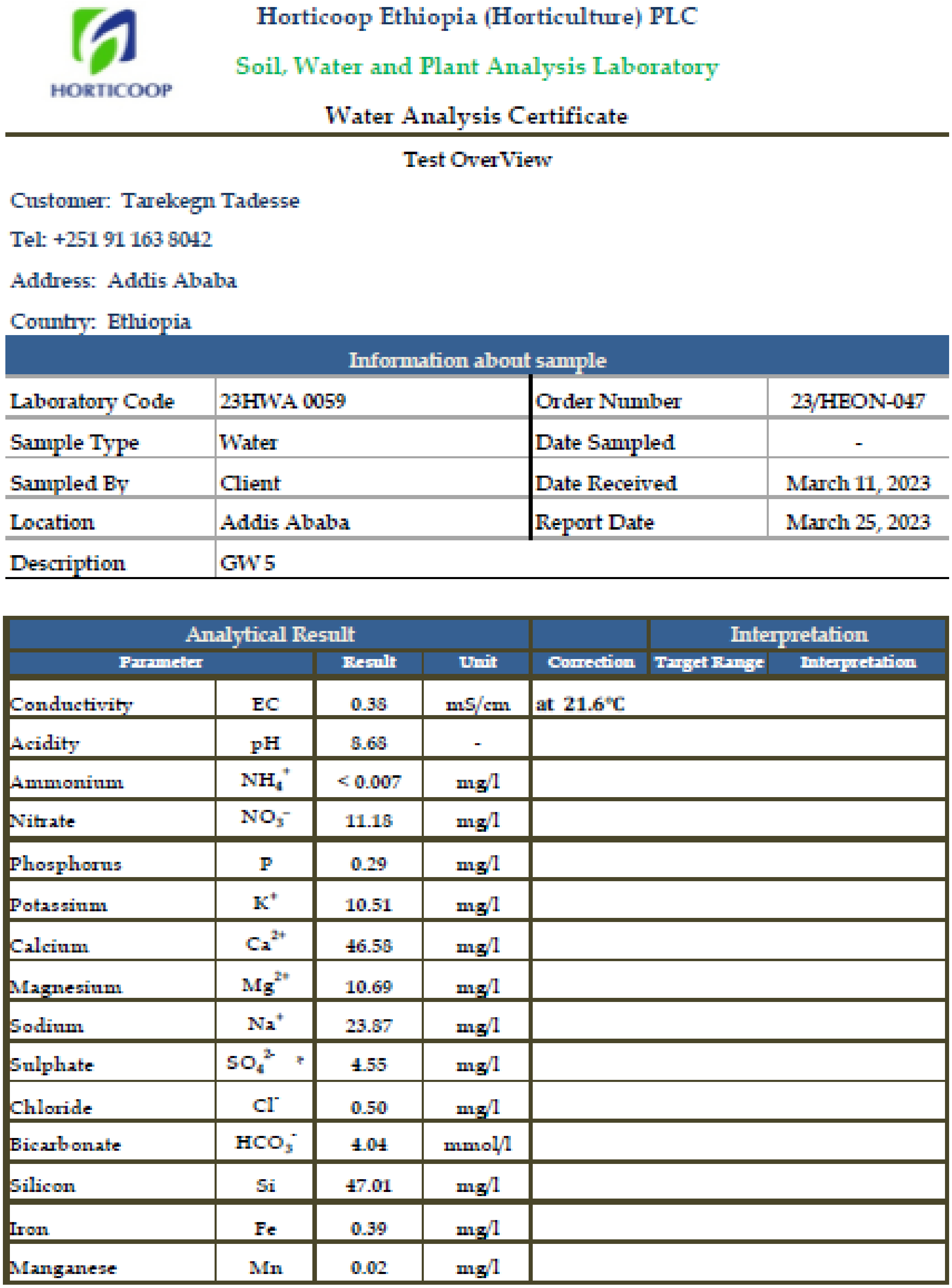
Table 47 Groundwater sample from Jemo-1



Horticoop Ethiopia (Horticulture) PLC

Soil, Water and Plant Analysis Laboratory

Water Analysis Certificate

Test OverView

Customer: Tarekegn Tadesse

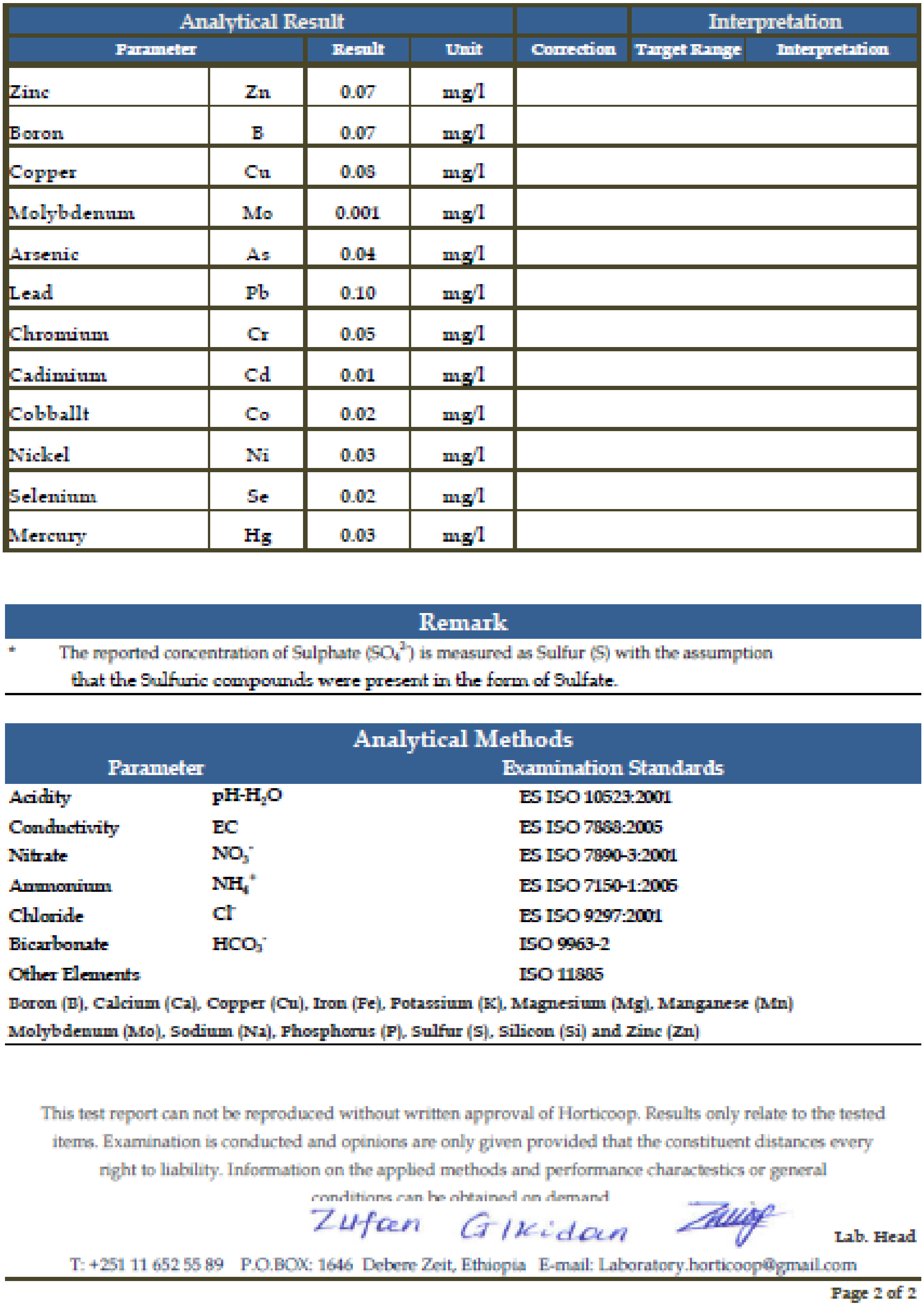
Tel: +251 91 163 8042

Address: Addis Ababa

Country: Ethiopia

Information about sample			
Laboratory Code	23HWA 0059	Order Number	23/HEON-047
Sample Type	Water	Date Sampled	-
Sampled By	Client	Date Received	March 11, 2023
Location	Addis Ababa	Report Date	March 25, 2023
Description	GW 5		

Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Conductivity	EC	0.38	mS/cm	at 21.6°C		
Acidity	pH	8.68	-			
Ammonium	NH_4^+	< 0.007	mg/l			
Nitrate	NO_3^-	11.18	mg/l			
Phosphorus	P	0.29	mg/l			
Potassium	K^+	10.51	mg/l			
Calcium	Ca^{2+}	46.58	mg/l			
Magnesium	Mg^{2+}	10.69	mg/l			
Sodium	Na^+	23.87	mg/l			
Sulphate	SO_4^{2-} *	4.55	mg/l			
Chloride	Cl^-	0.50	mg/l			
Bicarbonate	HCO_3^-	4.04	mmol/l			
Silicon	Si	47.01	mg/l			
Iron	Fe	0.39	mg/l			
Manganese	Mn	0.02	mg/l			



Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Zinc	Zn	0.07	mg/l			
Boron	B	0.07	mg/l			
Copper	Cu	0.03	mg/l			
Molybdenum	Mo	0.001	mg/l			
Arsenic	As	0.04	mg/l			
Lead	Pb	0.10	mg/l			
Chromium	Cr	0.05	mg/l			
Cadimium	Cd	0.01	mg/l			
Cobballt	Co	0.02	mg/l			
Nickel	Ni	0.03	mg/l			
Selenium	Se	0.02	mg/l			
Mercury	Hg	0.03	mg/l			

Remark

* The reported concentration of Sulphate (SO_4^{2-}) is measured as Sulfur (S) with the assumption that the Sulfuric compounds were present in the form of Sulfate.

Analytical Methods

Parameter		Examination Standards
Acidity	pH-H_2O	ES ISO 10523:2001
Conductivity	EC	ES ISO 7888:2005
Nitrate	NO_3^-	ES ISO 7890-3:2001
Ammonium	NH_4^+	ES ISO 7150-1:2005
Chloride	Cl^-	ES ISO 9297:2001
Bicarbonate	HCO_3^-	ISO 9963-2
Other Elements		ISO 11885

Boron (B), Calcium (Ca), Copper (Cu), Iron (Fe), Potassium (K), Magnesium (Mg), Manganese (Mn) Molybdenum (Mo), Sodium (Na), Phosphorus (P), Sulfur (S), Silicon (Si) and Zinc (Zn)

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Zufan G/kidan

Lab. Head

T: +251 11 652 55 89 P.O.BOX: 1646 Debere Zeit, Ethiopia E-mail: Laboratory.horticoop@gmail.com

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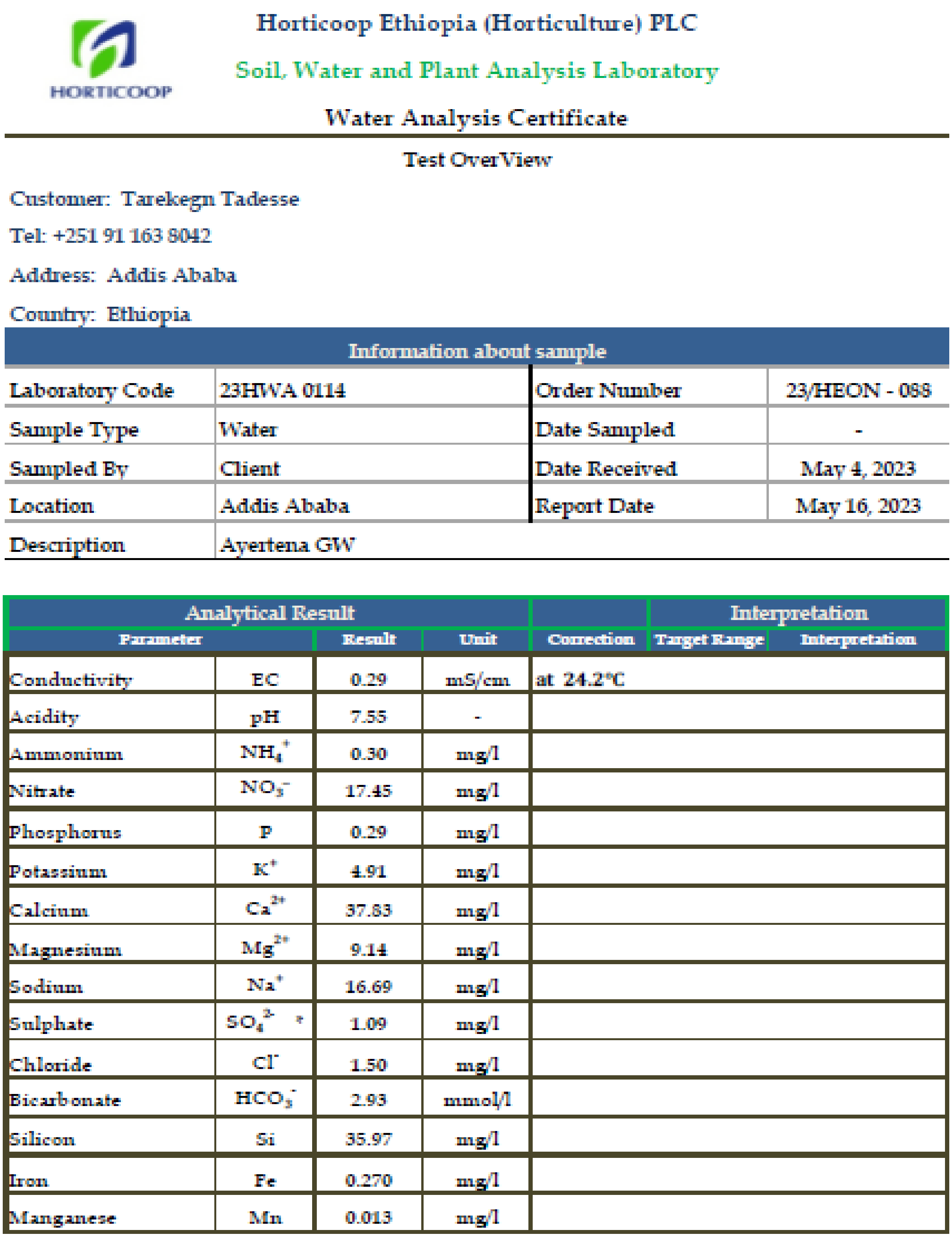
Table 48 Groundwater sample from Ayer Tena



Horticoop Ethiopia (Horticulture) PLC

Soil, Water and Plant Analysis Laboratory

Water Analysis Certificate

Test OverView

Customer: Tarekegn Tadesse

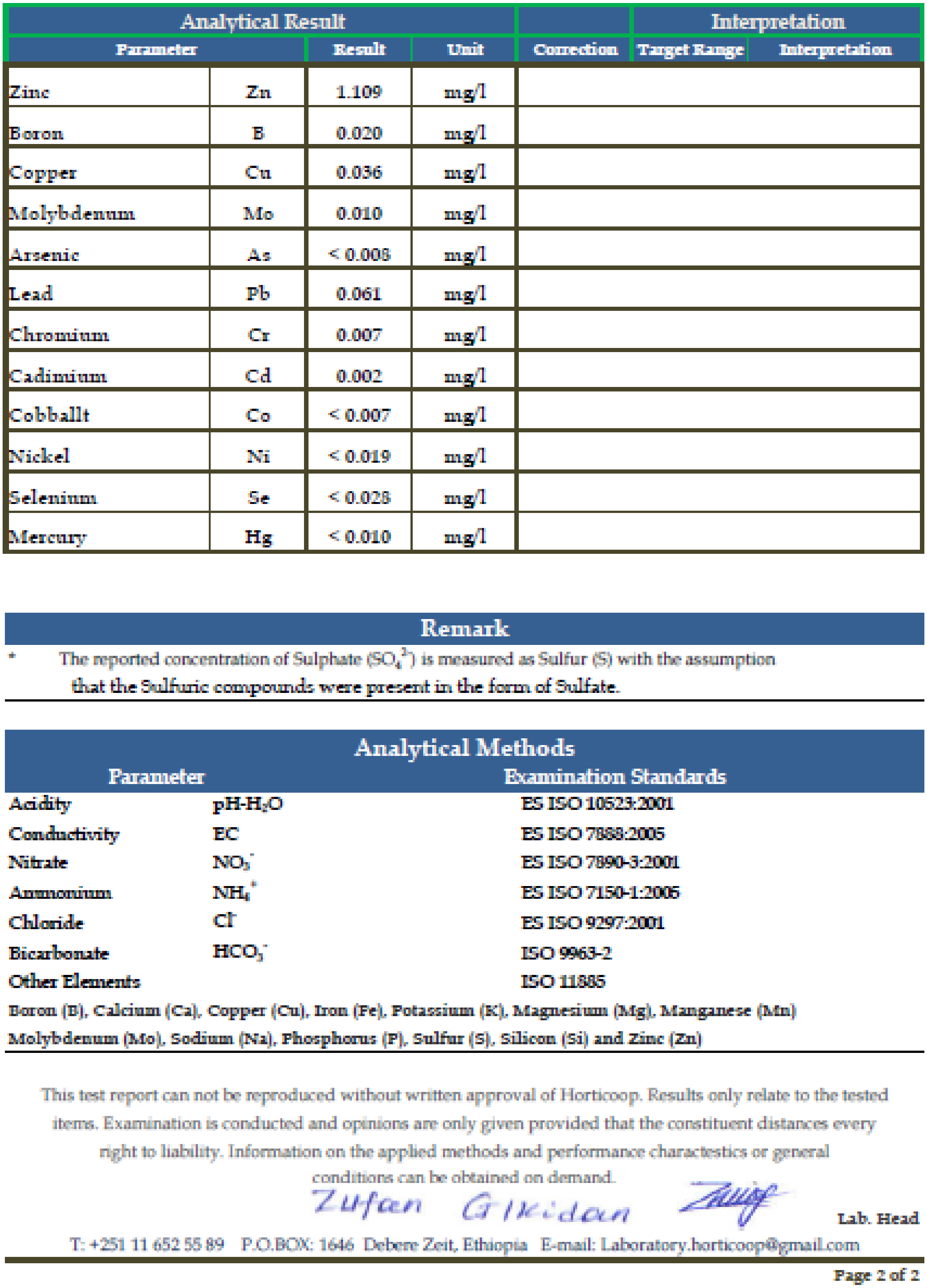
Tel: +251 91 163 8042

Address: Addis Ababa

Country: Ethiopia

Information about sample			
Laboratory Code	23HWA 0114	Order Number	23/HEON - 088
Sample Type	Water	Date Sampled	-
Sampled By	Client	Date Received	May 4, 2023
Location	Addis Ababa	Report Date	May 16, 2023
Description	Ayertena GW		

Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Conductivity	EC	0.29	mS/cm	at 24.2°C		
Acidity	pH	7.55	-			
Ammonium	NH_4^+	0.30	mg/l			
Nitrate	NO_3^-	17.45	mg/l			
Phosphorus	P	0.29	mg/l			
Potassium	K^+	4.91	mg/l			
Calcium	Ca^{2+}	37.83	mg/l			
Magnesium	Mg^{2+}	9.14	mg/l			
Sodium	Na^+	16.69	mg/l			
Sulphate	SO_4^{2-}	1.09	mg/l			
Chloride	Cl^-	1.50	mg/l			
Bicarbonate	HCO_3^-	2.93	mmol/l			
Silicon	Si	35.97	mg/l			
Iron	Fe	0.270	mg/l			
Manganese	Mn	0.013	mg/l			



Analytical Result					Interpretation	
Parameter		**Result**	**Unit**	**Correction**	**Target Range**	**Interpretation**
Zinc	Zn	1.109	mg/l			
Boron	B	0.020	mg/l			
Copper	Cu	0.036	mg/l			
Molybdenum	Mo	0.010	mg/l			
Arsenic	As	< 0.008	mg/l			
Lead	Pb	0.061	mg/l			
Chromium	Cr	0.007	mg/l			
Cadimium	Cd	0.002	mg/l			
Cobballt	Co	< 0.007	mg/l			
Nickel	Ni	< 0.019	mg/l			
Selenium	Se	< 0.028	mg/l			
Mercury	Hg	< 0.010	mg/l			

Remark

* The reported concentration of Sulphate (SO_4^{2-}) is measured as Sulfur (S) with the assumption that the Sulfuric compounds were present in the form of Sulfate.

Analytical Methods

Parameter		Examination Standards
Acidity	pH-H_2O	ES ISO 10523:2001
Conductivity	EC	ES ISO 7888:2005
Nitrate	NO_3^-	ES ISO 7890-3:2001
Ammonium	NH_4^+	ES ISO 7150-1:2006
Chloride	Cl^-	ES ISO 9297:2001
Bicarbonate	HCO_3^-	ISO 9963-2
Other Elements		ISO 11885

Boron (B), Calcium (Ca), Copper (Cu), Iron (Fe), Potassium (K), Magnesium (Mg), Manganese (Mn) Molybdenum (Mo), Sodium (Na), Phosphorus (P), Sulfur (S), Silicon (Si) and Zinc (Zn)

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Zufan G/kidan

Lab. Head

T: +251 11 652 55 89 P.O.BOX: 1646 Debere Zeit, Ethiopia E-mail: Laboratory.horticoop@gmail.com

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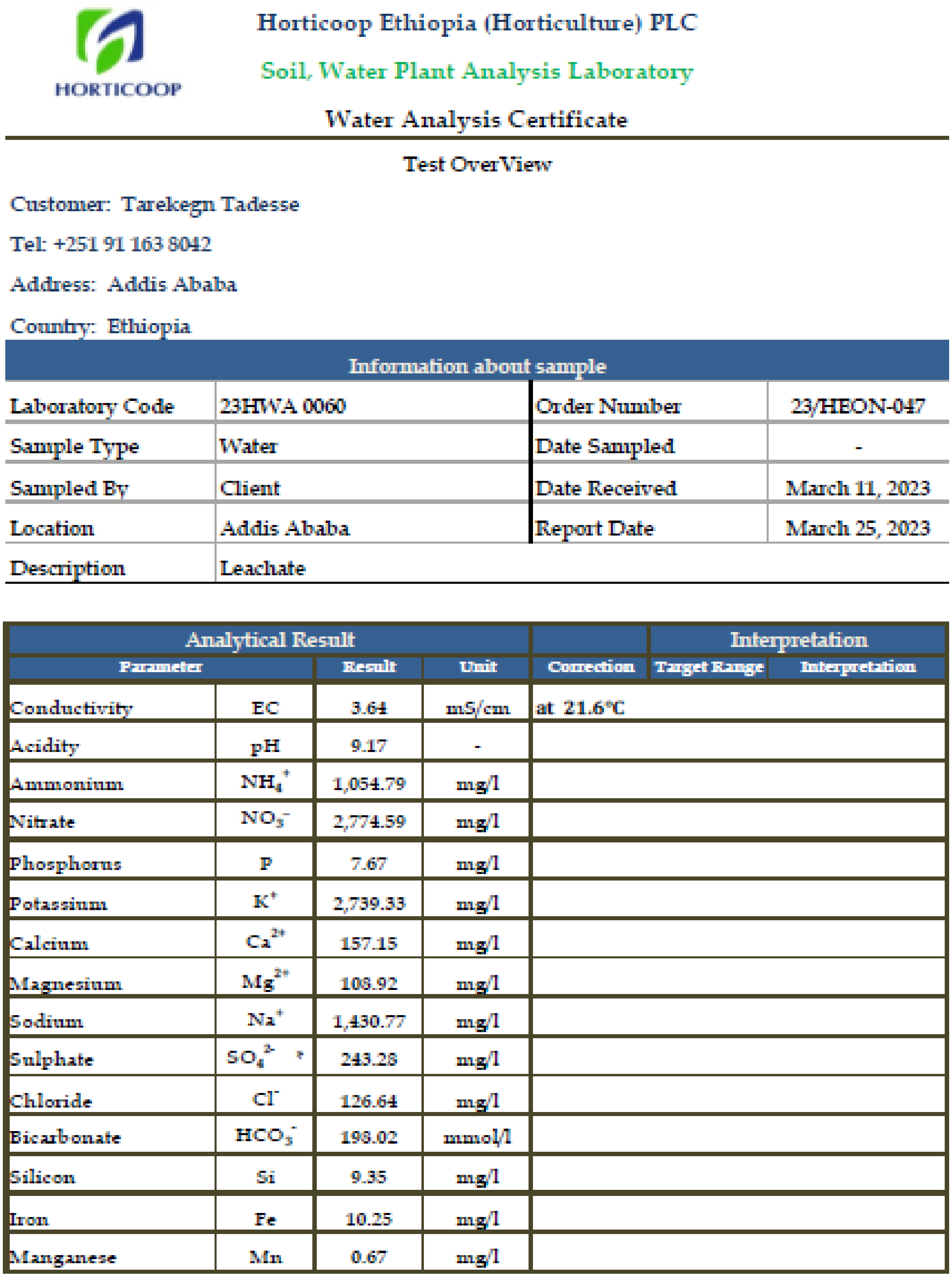
Table 49 Leachate sample from Koshe Open dump site



Horticoop Ethiopia (Horticulture) PLC

Soil, Water Plant Analysis Laboratory

Water Analysis Certificate

Test OverView

Customer: Tarekegn Tadesse

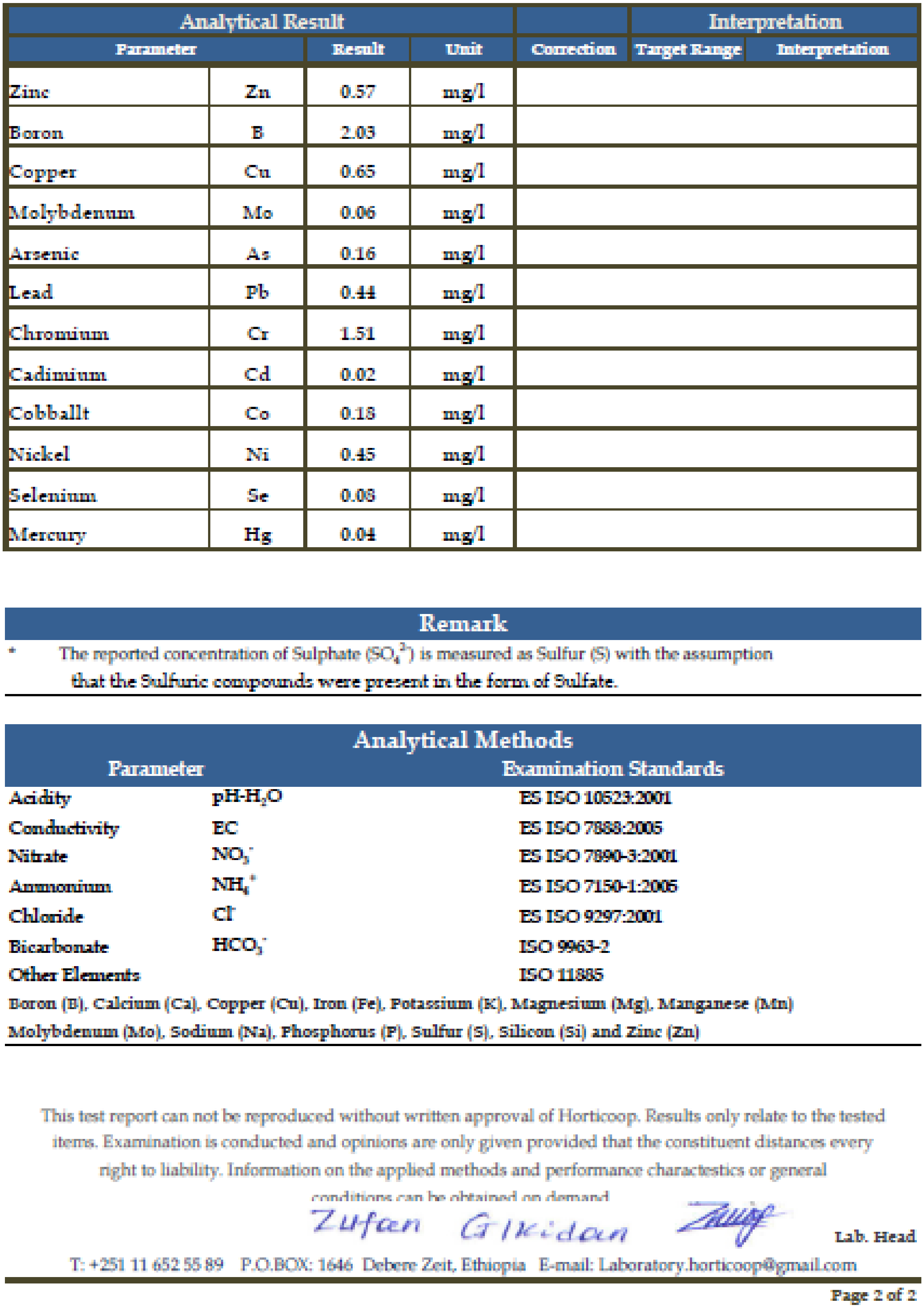
Tel: +251 91 163 8042

Address: Addis Ababa

Country: Ethiopia

Information about sample			
Laboratory Code	23HWA 0060	Order Number	23/HEON-047
Sample Type	Water	Date Sampled	-
Sampled By	Client	Date Received	March 11, 2023
Location	Addis Ababa	Report Date	March 25, 2023
Description	Leachate		

Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Conductivity	EC	3.64	mS/cm	at 21.6°C		
Acidity	pH	9.17	-			
Ammonium	NH_4^+	1,054.79	mg/l			
Nitrate	NO_3^-	2,774.59	mg/l			
Phosphorus	P	7.67	mg/l			
Potassium	K^+	2,739.33	mg/l			
Calcium	Ca^{2+}	157.15	mg/l			
Magnesium	Mg^{2+}	108.92	mg/l			
Sodium	Na^+	1,430.77	mg/l			
Sulphate	SO_4^{2-}	243.28	mg/l			
Chloride	Cl^-	126.64	mg/l			
Bicarbonate	HCO_3^-	198.02	mmol/l			
Silicon	Si	9.35	mg/l			
Iron	Fe	10.25	mg/l			
Manganese	Mn	0.67	mg/l			



Analytical Result					Interpretation	
Parameter		Result	Unit	Correction	Target Range	Interpretation
Zinc	Zn	0.57	mg/l			
Boron	B	2.03	mg/l			
Copper	Cu	0.65	mg/l			
Molybdenum	Mo	0.06	mg/l			
Arsenic	As	0.16	mg/l			
Lead	Pb	0.44	mg/l			
Chromium	Cr	1.51	mg/l			
Cadimium	Cd	0.02	mg/l			
Cobballt	Co	0.18	mg/l			
Nickel	Ni	0.45	mg/l			
Selenium	Se	0.08	mg/l			
Mercury	Hg	0.04	mg/l			

Remark

* The reported concentration of Sulphate (SO_4^{2-}) is measured as Sulfur (S) with the assumption that the Sulfuric compounds were present in the form of Sulfate.

Analytical Methods

Parameter		Examination Standards
Acidity	$pH\text{-}H_2O$	ES ISO 10523:2001
Conductivity	EC	ES ISO 7888:2005
Nitrate	NO_3^-	ES ISO 7890-3:2001
Ammonium	NH_4^+	ES ISO 7150-1:2006
Chloride	Cl^-	ES ISO 9297:2001
Bicarbonate	HCO_3^-	ISO 9963-2
Other Elements		ISO 11885

Boron (B), Calcium (Ca), Copper (Cu), Iron (Fe), Potassium (K), Magnesium (Mg), Manganese (Mn) Molybdenum (Mo), Sodium (Na), Phosphorus (P), Sulfur (S), Silicon (Si) and Zinc (Zn)

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Zufan G/Kidan **Lab. Head**

T: +251 11 652 55 89 P.O.BOX: 1646 Debere Zeit, Ethiopia E-mail: Laboratory.horticoop@gmail.com

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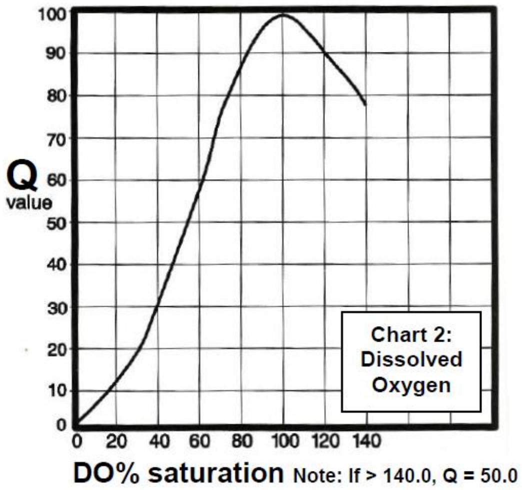


Figure 19 Rating curves for DO

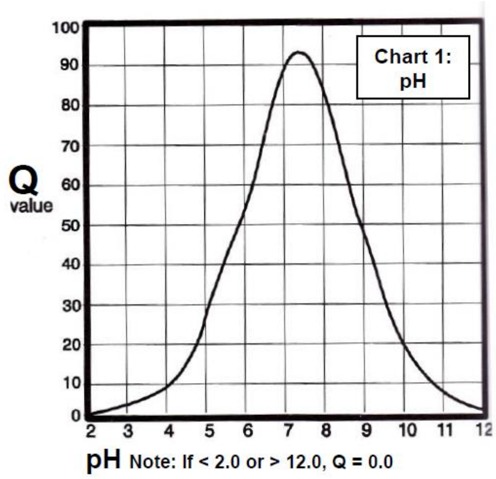


Figure 20 Rating curves for ph

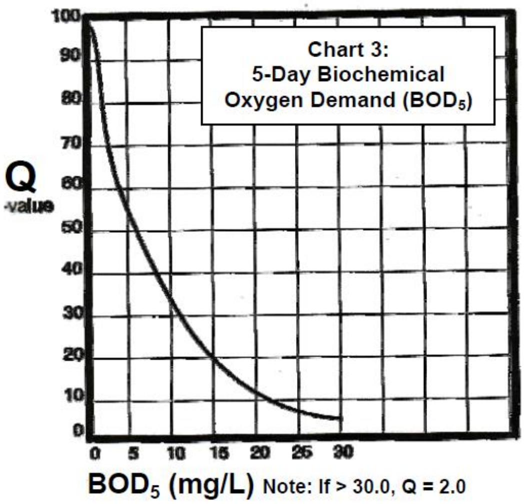


Figure 21 Rating curves for BOD

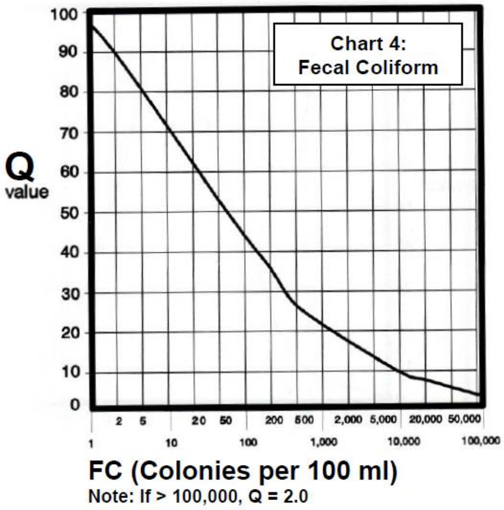


Figure 22 Rating curves for Fecal coliforms

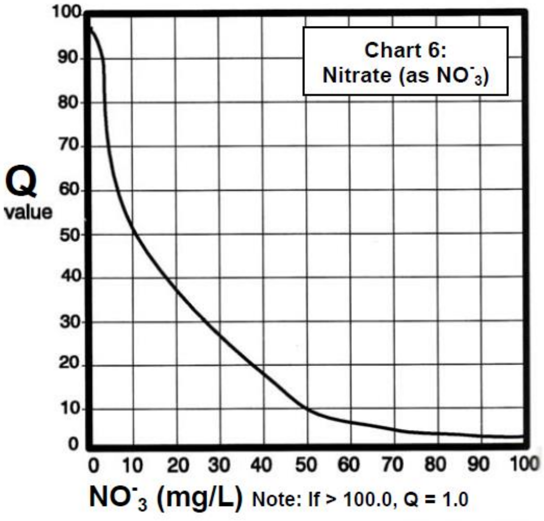


Figure 23 Rating curves for Nitrate

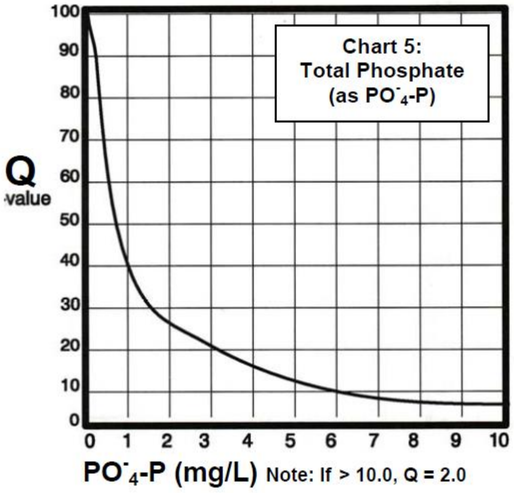


Figure 24 Rating curves for Phosphate

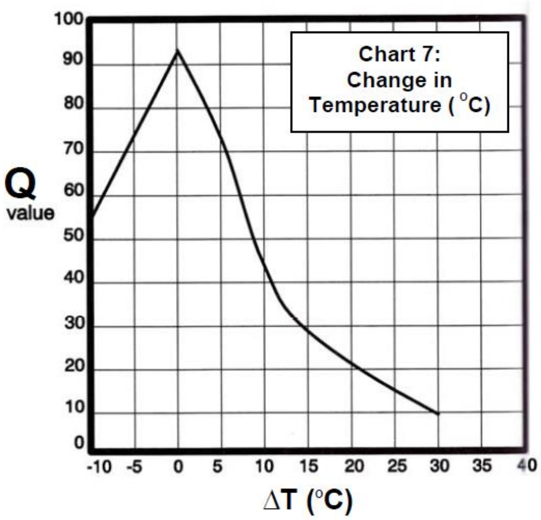
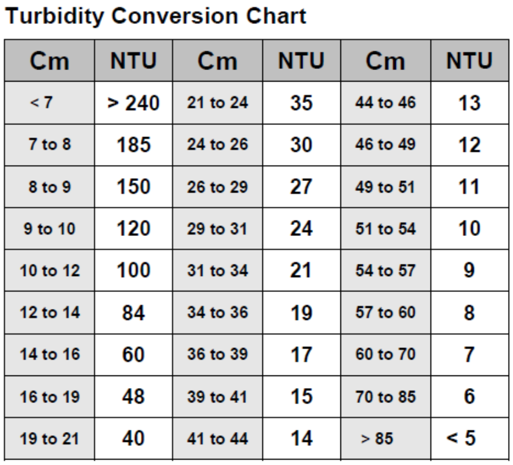


Figure 25 Rating curves for Temperature



Turbidity Conversion Chart

Cm	NTU	Cm	NTU	Cm	NTU
< 7	> 240	21 to 24	35	44 to 46	13
7 to 8	185	24 to 26	30	46 to 49	12
8 to 9	150	26 to 29	27	49 to 51	11
9 to 10	120	29 to 31	24	51 to 54	10
10 to 12	100	31 to 34	21	54 to 57	9
12 to 14	84	34 to 36	19	57 to 60	8
14 to 16	60	36 to 39	17	60 to 70	7
16 to 19	48	39 to 41	15	70 to 85	6
19 to 21	40	41 to 44	14	> 85	< 5

Figure 26 Rating curves for Turbidity

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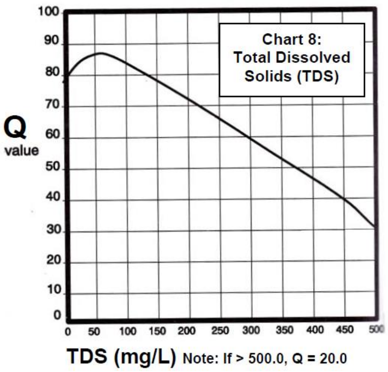

Figure 27Rating curves for Total dissolved solids TDS
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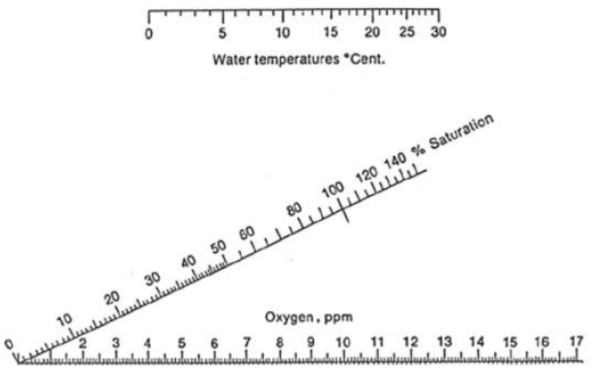

Figure 28 Rating curves for Total dissolved solids DO mg/l to %
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APPENDIX B: CALIBRATION

Table 50 Ammonium-Nitrogen Standard solution

Volume of Standard Solution ml	Mass of Ammonium-Nitrogen µg
0.00	0
2.00	2
6.00	6
10.00	10
20.00	20
30.00	30
40.00	40

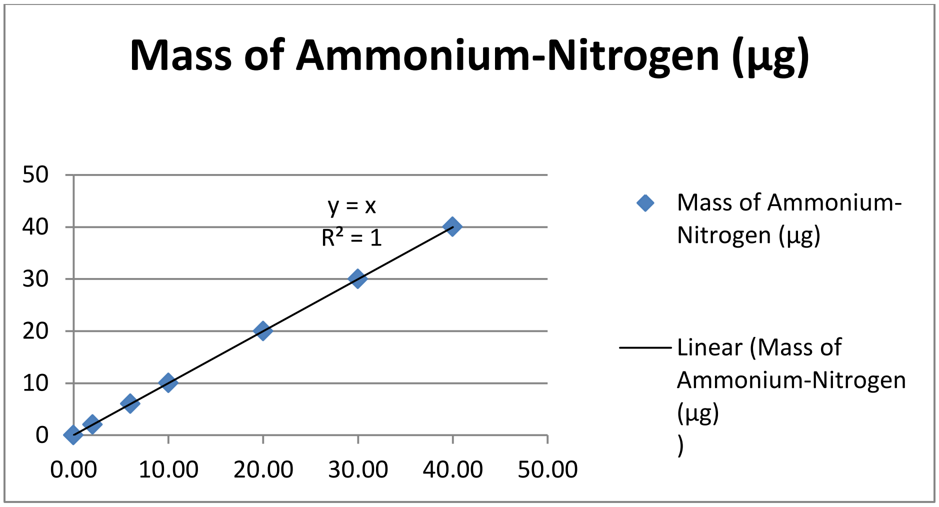


Figure 29 Calibration curve of Ammonium-Nitrogen

Table 51 Nitrate Standard solution

Volume of Standard Solution ml	Amount of Nitrate-Nitrogen mg/l
1.00	1
5.00	5
10.00	10
15.00	15
20.00	20
25.00	25

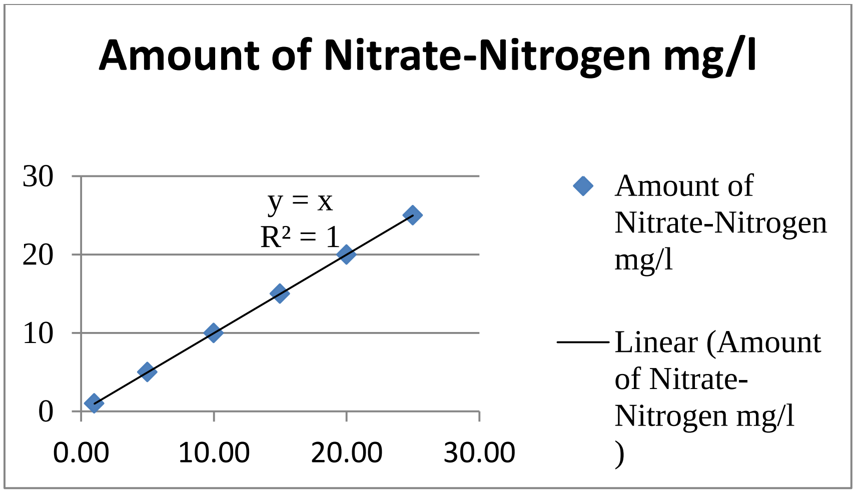
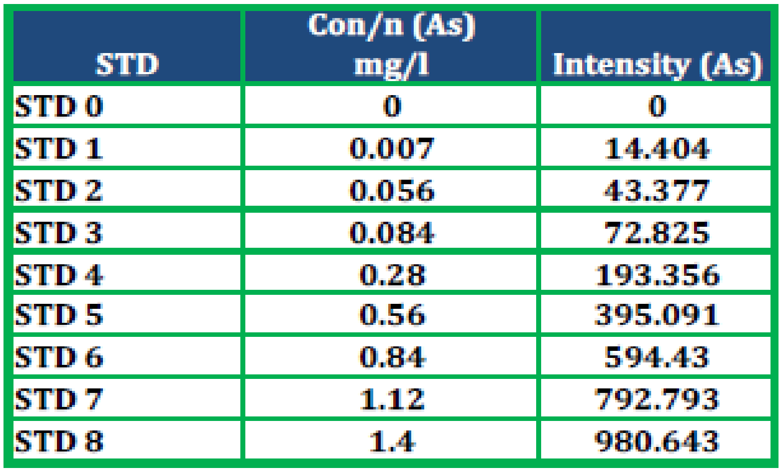


Figure 30 Calibration curve of Nitrate

Table 52 Arsenic Standard solution



STD	Con/n (As) mg/l	Intensity (As)
STD 0	0	0
STD 1	0.007	14.404
STD 2	0.056	43.377
STD 3	0.084	72.825
STD 4	0.28	193.356
STD 5	0.56	395.091
STD 6	0.84	594.43
STD 7	1.12	792.793
STD 8	1.4	980.643

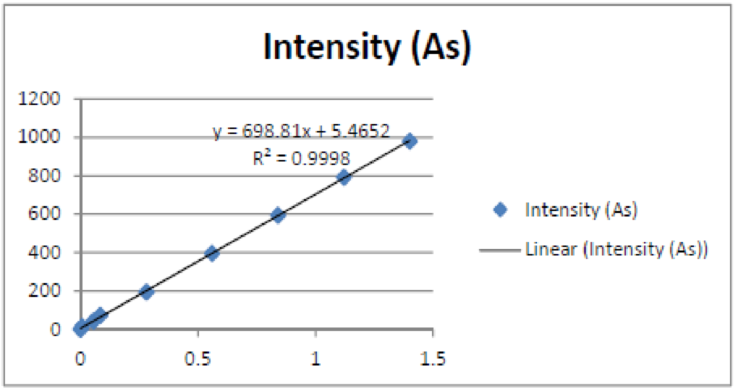


Figure 31 Calibration curve of Arsenic

Table 53 Lead Standard solution

STD	Con/n (Pb) mg/l	Intensity (Pb)
STD 0	0	0
STD 1	0.007	16.865
STD 2	0.056	41.376
STD 3	0.084	54.129
STD 4	0.28	136.682
STD 5	0.56	265.552
STD 6	0.84	401.514
STD 7	1.12	527.116
STD 8	1.4	656.943

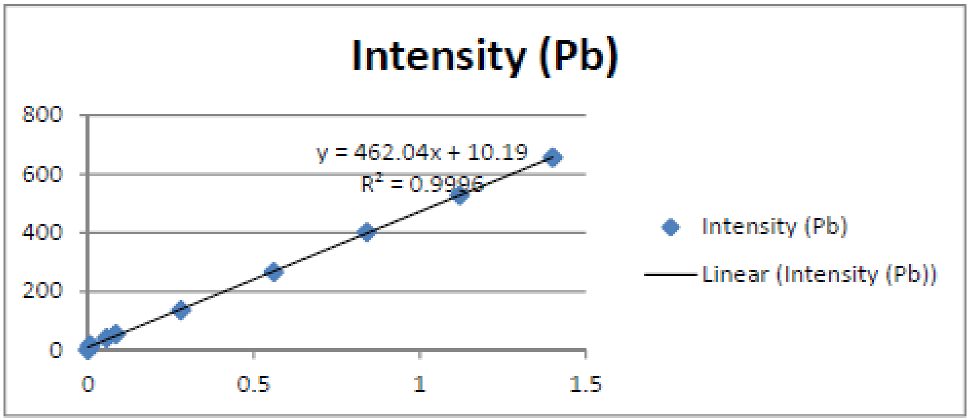


Figure 32 Calibration curve of Lead

Table 54 Boron (B) Standard solution

STD	Con/n (B) mg/l	Intensity (B)
STD 0	0.00	0
STD 1	0.18	1969.46
STD 2	0.30	3333.1
STD 3	0.36	3973.35
STD 4	0.60	6670.16
STD 5	1.20	13222.85
STD 6	1.80	20180.35
STD 7	2.40	27229.65
STD 8	3.00	33714.15

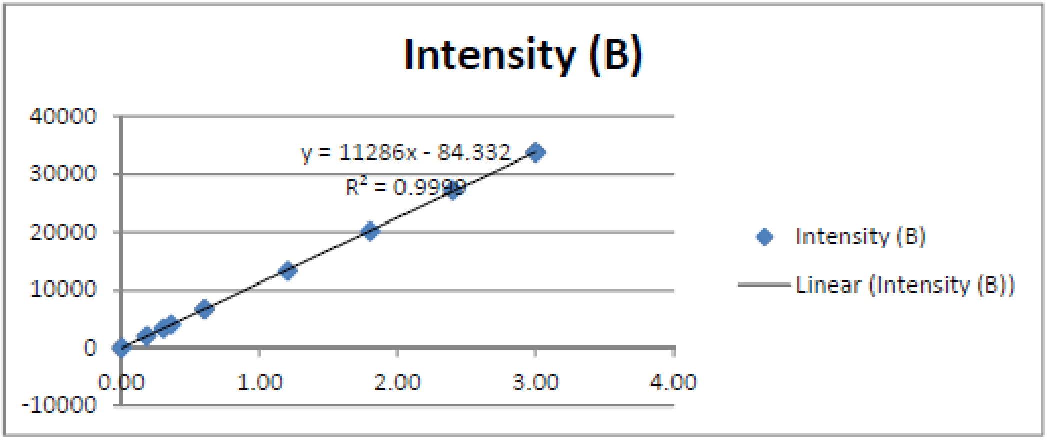


Figure 33 Calibration curve of Boron (B)

Table 55 Zinc (Zn) Standard solution

STD	Con/n (Zn) mg/l	Intensity (Zn)
STD 0	0.00	0
STD 1	0.18	4688.332
STD 2	0.30	8100.312
STD 3	0.36	9171.132
STD 4	0.60	15249.132
STD 5	1.20	31452.832
STD 6	1.80	47022.332
STD 7	2.40	63406.432
STD 8	3.00	78991.132

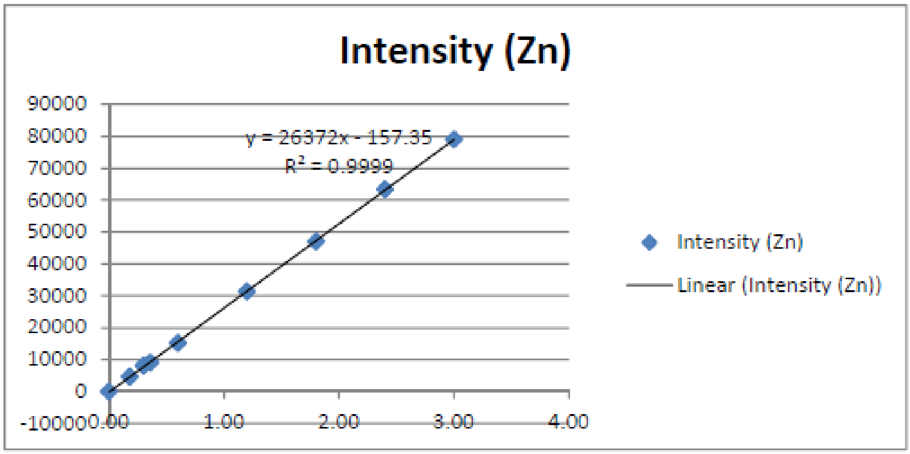


Figure 34 Calibration curve of Zinc (Zn)

Table 56 Cadmium (Cd) Standard solution

STD	Con/n (Cd)	Intensity (Cd)
STD 0	0	0
STD 1	0.007	124.719
STD 2	0.056	677.425
STD 3	0.084	1148.545
STD 4	0.28	3441.535
STD 5	0.56	6817.145
STD 6	0.84	9859.465
STD 7	1.12	13312.165
STD 8	1.4	16203.165

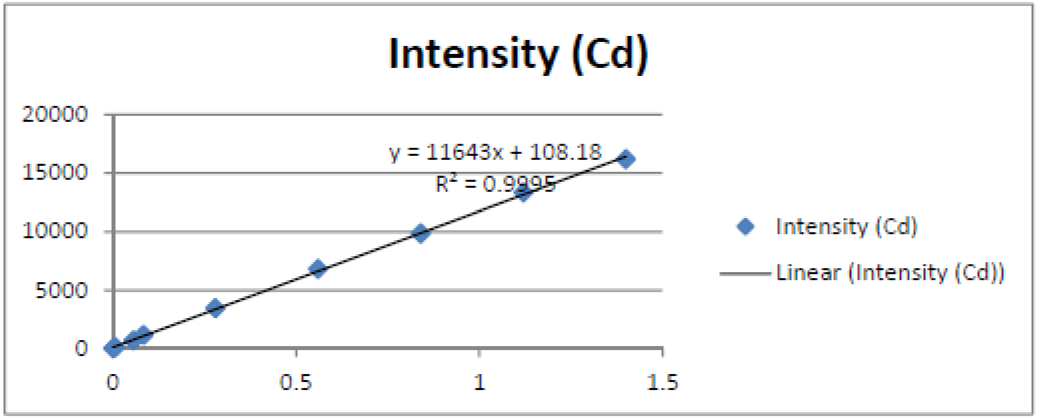


Figure 35 Calibration curve of Cadmium (Cd)

Table 57 Mercury (Hg) Standard solution

STD	Con/n (Hg)	Intensity (Hg)
STD 0	0.00	0
STD 1	0.07	20.27
STD 2	0.06	112.672
STD 3	0.08	265.748
STD 4	0.28	1129.87
STD 5	0.56	1702.93
STD 6	0.84	2432.3
STD 7	1.12	3143.55
STD 8	1.40	3997.94

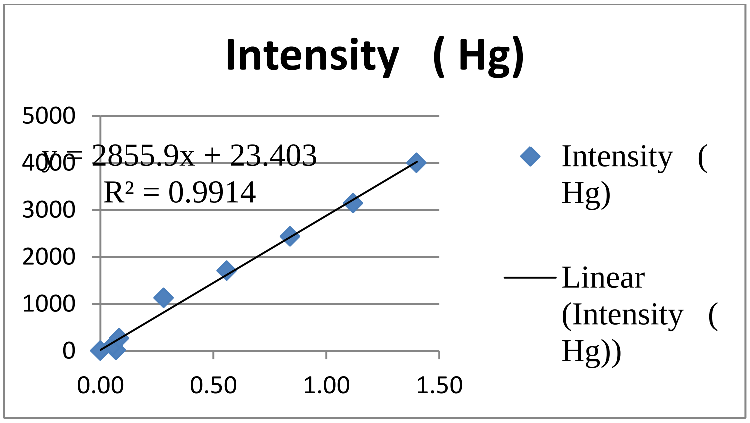


Figure 36 Calibration curve of Mercury (Hg)

Table 58 Copper (Cu) Standard solution

STD	Con/n (Cu)	Intensity (Cu)
STD 0	0.00	0
STD 1	0.18	7449
STD 2	0.30	12530.2
STD 3	0.36	14884.1
STD 4	0.60	25192.2
STD 5	1.20	51218.7
STD 6	1.80	77414.3
STD 7	2.40	102045.7
STD 8	3.00	127942.7

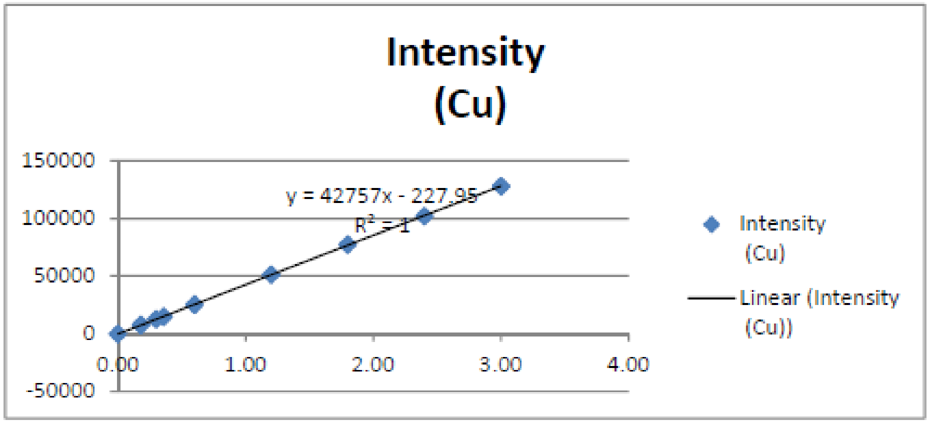
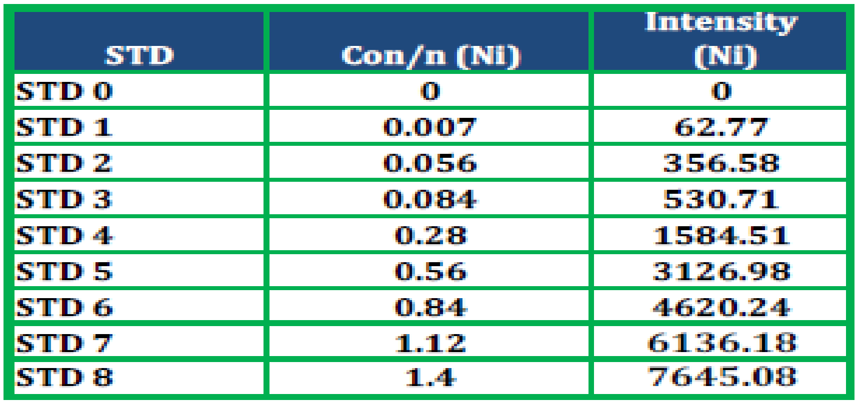


Figure 37 Calibration curve of Copper (Cu)

Table 59 Nickel (Ni) Standard solution



STD	Con/n (Ni)	Intensity (Ni)
STD 0	0	0
STD 1	0.007	62.77
STD 2	0.056	356.58
STD 3	0.084	530.71
STD 4	0.28	1584.51
STD 5	0.56	3126.98
STD 6	0.84	4620.24
STD 7	1.12	6136.18
STD 8	1.4	7645.08

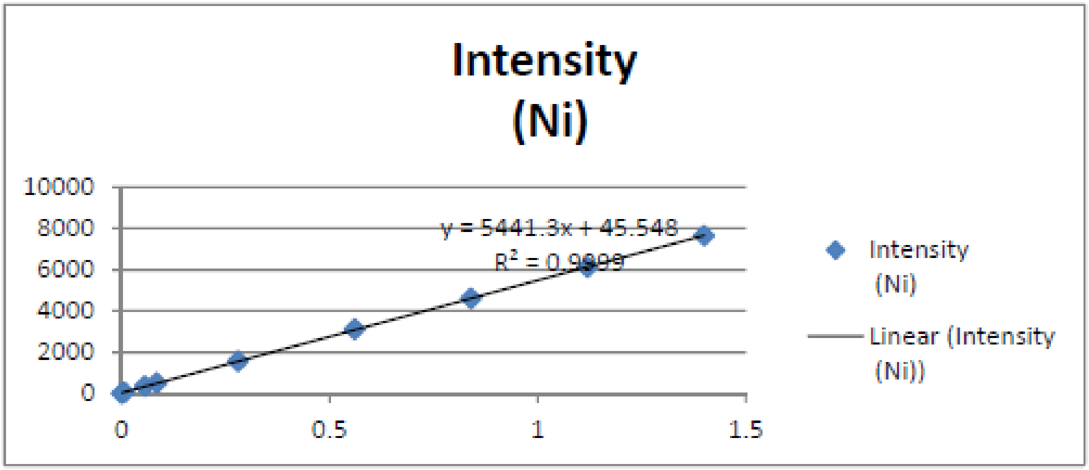
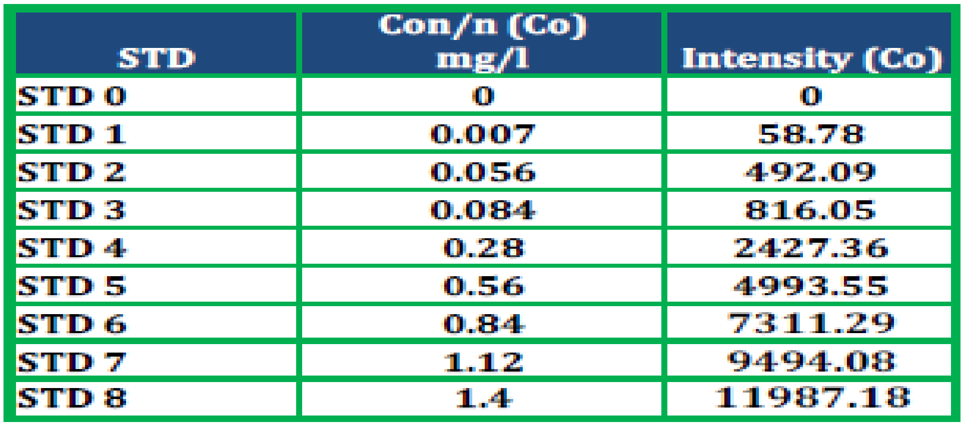


Figure 38 Calibration curve of Nickel (Ni)

Table 60 Cobalt (Co) Standard solution



STD	Con/n (Co) mg/l	Intensity (Co)
STD 0	0	0
STD 1	0.007	58.78
STD 2	0.056	492.09
STD 3	0.084	816.05
STD 4	0.28	2427.36
STD 5	0.56	4993.55
STD 6	0.84	7311.29
STD 7	1.12	9494.08
STD 8	1.4	11987.18

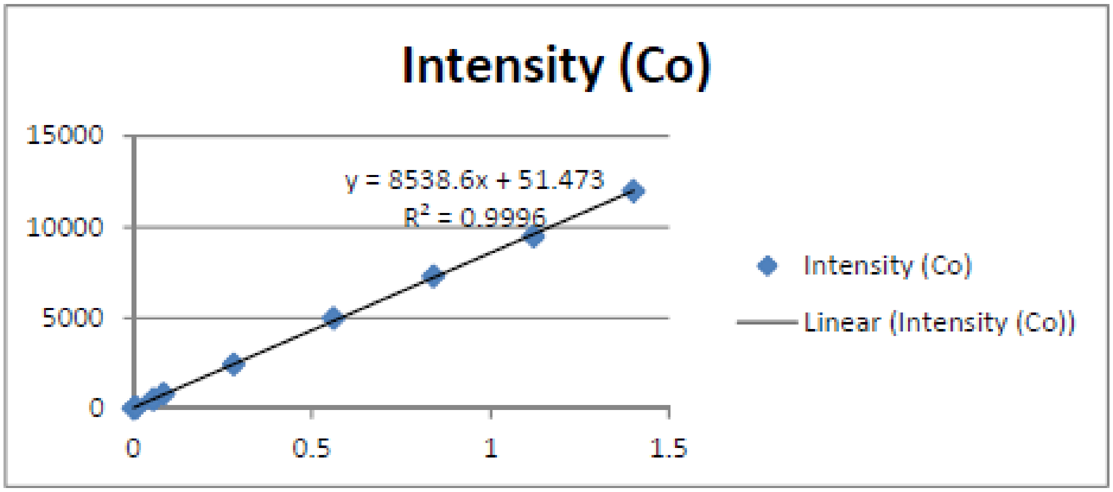


Figure 39 Calibration curve of Cobalt (Co)

Table 61 Selenium (Se) Standard solution

STD	Con/n (Se) mg/l	Intensity (Se)
STD 0	0	0
STD 1	0.007	9.587
STD 2	0.056	32.409
STD 3	0.084	39.483
STD 4	0.28	148.028
STD 5	0.56	326.819
STD 6	0.84	496.971
STD 7	1.12	687.894
STD 8	1.4	855.764

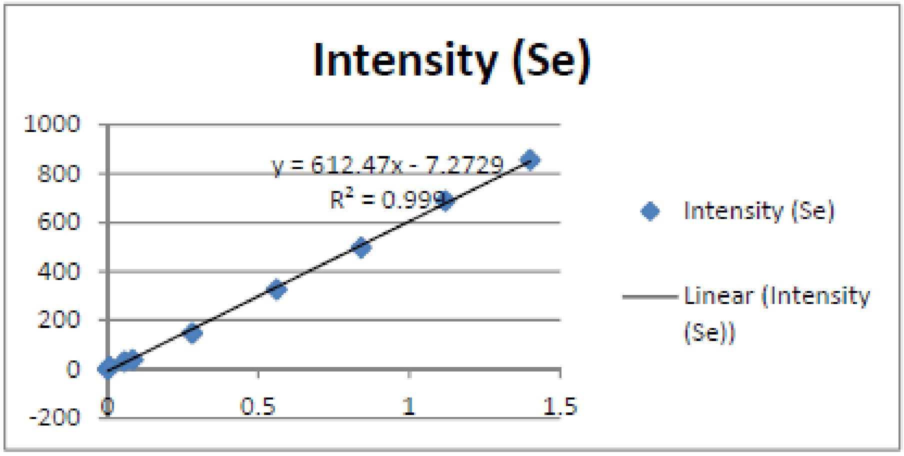


Figure 40 Calibration curve of Selenium (Se)

Table 62 Iron (Fe) Standard solution

STD	Con/n (Fe) mg/l	Intensity (Fe)
STD 0	0	0
STD 1	0.72	6663.534
STD 2	1.2	11057.654
STD 3	1.44	12952.054
STD 4	2.4	21562.354
STD 5	4.8	44387.854
STD 6	7.2	66780.854
STD 7	9.6	89698.654
STD 8	12	109253.554

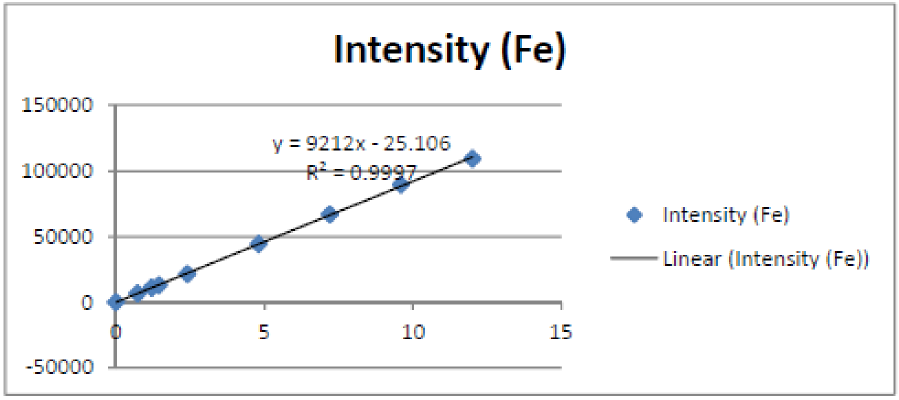


Figure 41 Calibration curve of Iron (Fe)

Table 63 Manganese (Mn) Standard solution

STD	Con/n (Mn) mg/l	Intensity (Mn)
STD 0	0.00	0
STD 1	0.18	6931.841
STD 2	0.30	11205.781
STD 3	0.36	13172.281
STD 4	0.60	22358.681
STD 5	1.20	45875.181
STD 6	1.80	69187.581
STD 7	2.40	90704.681
STD 8	3.00	114062.881

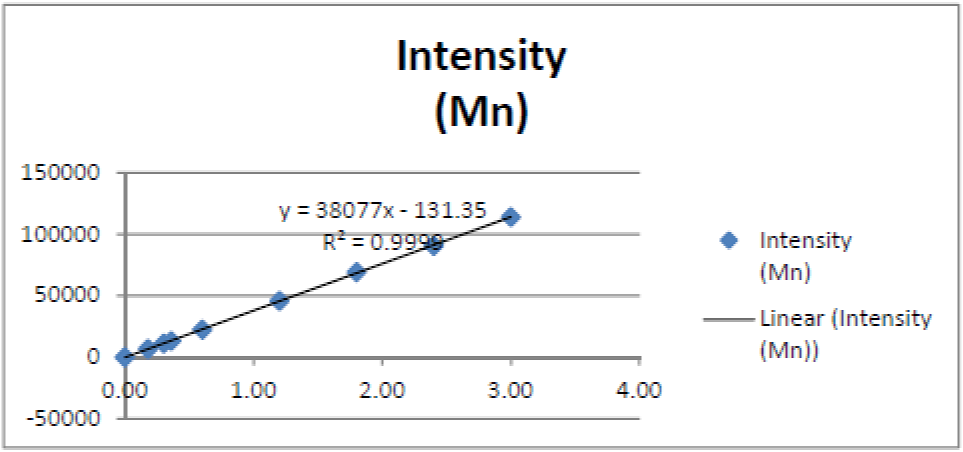


Figure 42 Calibration curve of Manganese (Mn)

Table 64 Chromium Standard solution

STD	Con/n (Cr)	Intensity (Cr)
STD 0	0	0
STD 1	0.007	158.241
STD 2	0.056	365.301
STD 3	0.084	577.811
STD 4	0.28	1672.061
STD 5	0.56	3258.071
STD 6	0.84	4804.641
STD 7	1.12	6426.181
STD 8	1.4	7919.561

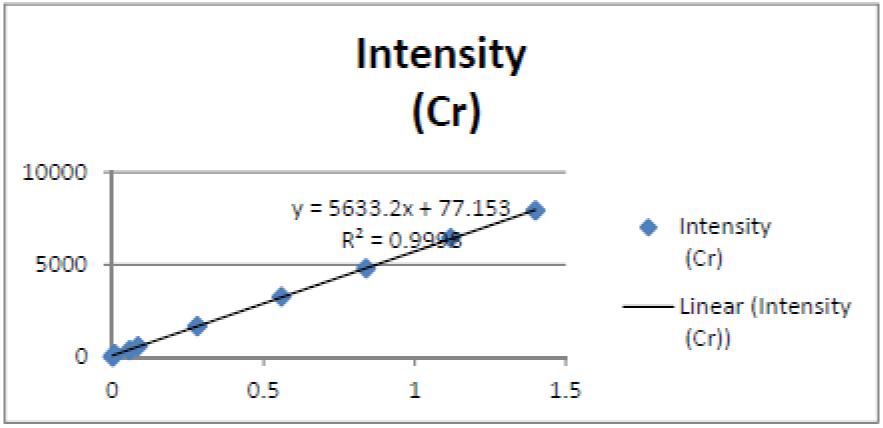


Figure 43 Calibration curve of Chromium

Table 65 Calcium Standard solution

STD	Con/n (Ca) mg/l	Intensity (Ca)
STD A0	0.00	0
STD A1	1.88	17091.32
STD A2	3.77	36212.82
STD A3	5.66	55261.32
STD A4	7.55	75838.52
STD A5	9.44	92593.72
STD A6	18.88	190512.52
STD A7	37.77	362141.52
STD A8	56.65	550378.52
STD A9	75.54	755151.52
STD A10	97.43	930608.52

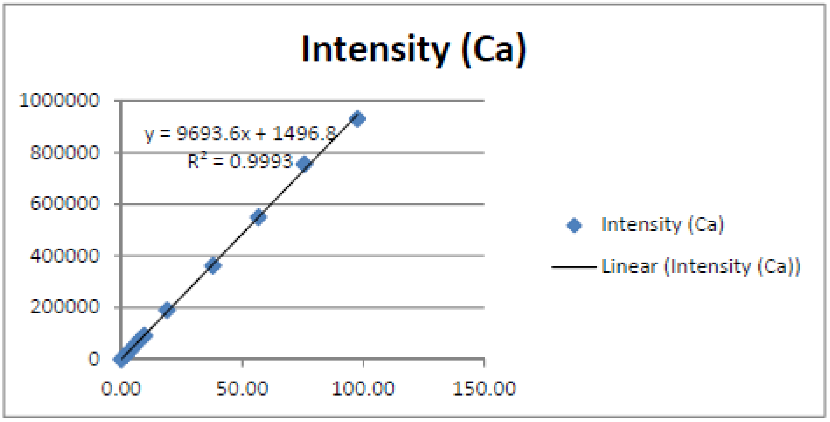


Figure 44 Calibration curve of Calcium

Table 66 Magnesium Standard solution

STD	Con/n (Mg) mg/l	Intensity (Mg)
STD A0	0.00	0
STD A1	1.88	328040.46
STD A2	3.77	679767.46
STD A3	5.66	1005588.46
STD A4	7.55	1362108.46
STD A5	9.44	1698728.46
STD A6	18.88	3431538.46
STD A7	37.77	6411238.46
STD A8	56.65	9288798.46
STD A9	75.54	12488578.46
STD A10	97.43	15292778.5

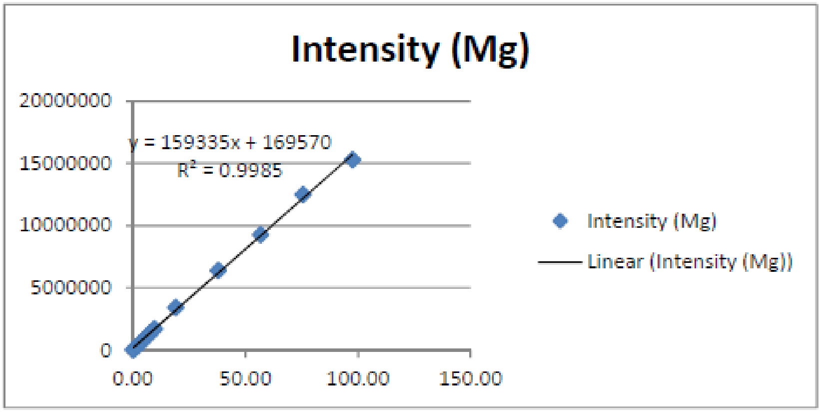


Figure 45 Calibration curve of Magnesium

Table 67 Potassium Standard solution

std	Con/n (K)mg/l	Intensity (K)
STD A0	0.00	
STD A1	4	9703.18
STD A2	8	19121.78
STD A3	12	28484.38
STD A4	16	38205.98
STD A5	20	48713.38
STD A6	40	95634.98
STD A7	80	193474.98
STD A8	120	293846.98
STD A9	160	388839.98
STD A10	200	484224.98

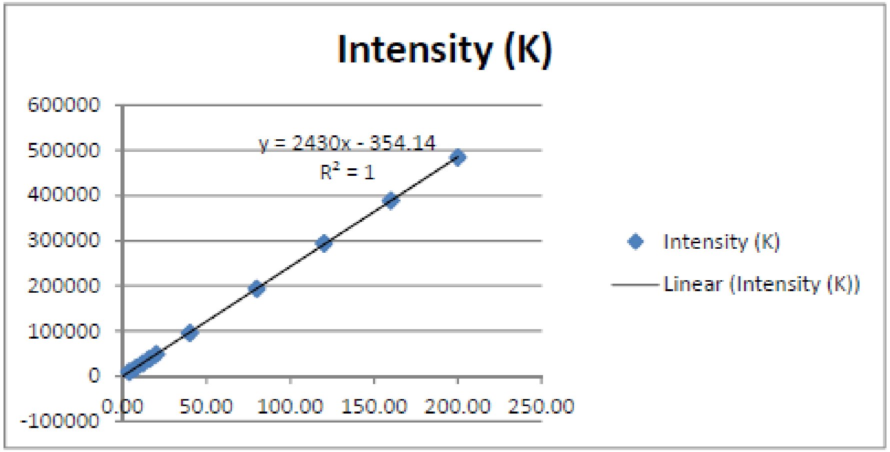


Figure 46 Calibration curve of Potassium

Table 68 Sodium Standard solution

std	Con/n (Na)mg/l	Intensity (Na)
STD A0	0.00	0
STD A1	4	101948.9
STD A2	8	208472.9
STD A3	12	318373.9
STD A4	16	429362.9
STD A5	20	538204.9
STD A6	40	1072309.9
STD A7	80	2208429.9
STD A8	120	3287139.9
STD A9	160	4485889.9
STD A10	200	5530239.9

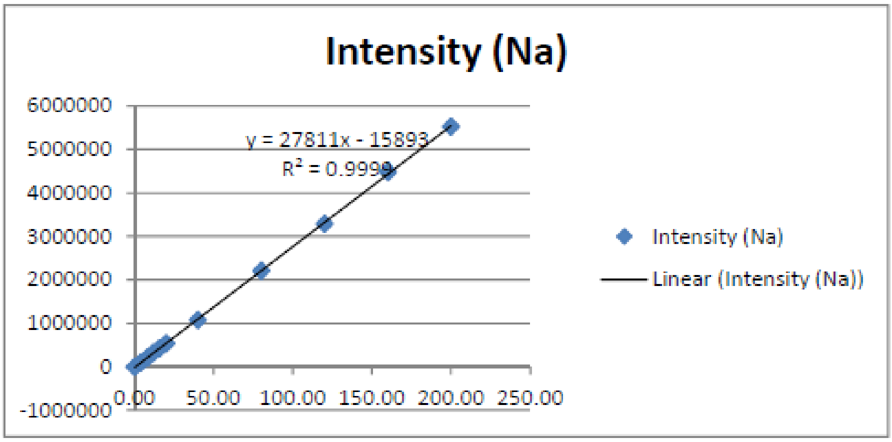


Figure 47 Calibration curve of Sodium

Table 69 Phosphorus (P) Standard solution

std	Con/n (P)mg/l	Intensity (P)
STD A0	0.00	0
STD A1	2	1026.517
STD A2	4	2128.877
STD A3	6	3266.847
STD A4	8	4431.697
STD A5	10	5535.807
STD A6	20	10871.487
STD A7	40	22282.487
STD A8	60	32954.387
STD A9	80	45154.787
STD A10	100	55938.787

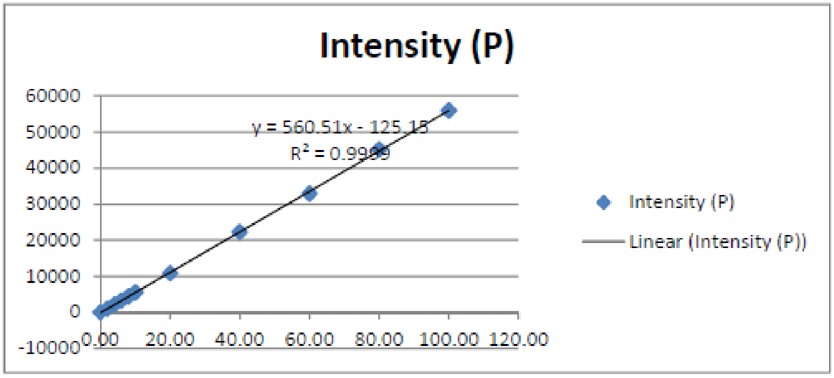


Figure 48 Calibration curve of Phosphorus

Table 70 Molybdenum (Mo) Standard solution

std	Con/n (Mo)mg/l	Intensity (Mo)
STD A0	0.00	0
STD A1	0.02	122.086
STD A2	0.04	242.457
STD A3	0.06	363.899
STD A4	0.08	474.876
STD A5	0.1	610.878
STD A6	0.2	1186.706
STD A7	0.4	2327.646
STD A8	0.6	3479.746
STD A9	0.8	4573.446
STD A10	1	5583.536

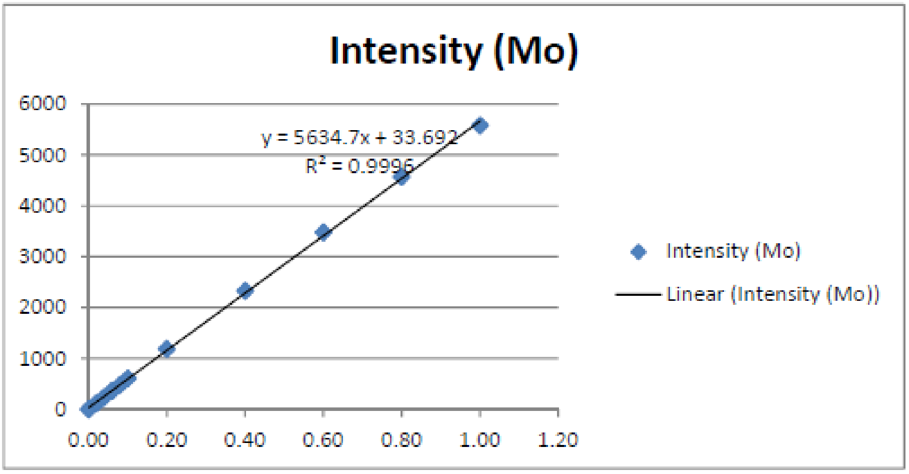


Figure 49 Calibration curve of Molybdenum

Table 71 Silicon (Si) Standard solution

std	Con/n (Si)mg/l	Intensity (Si)
STD A0	0.00	0
STD A1	1	5134.59
STD A2	2	10276.23
STD A3	3	15712.83
STD A4	4	21258.23
STD A5	5	27262.33
STD A6	10	53935.53
STD A7	20	105177.43
STD A8	30	157170.43
STD A9	40	208546.43
STD A10	50	257963.43

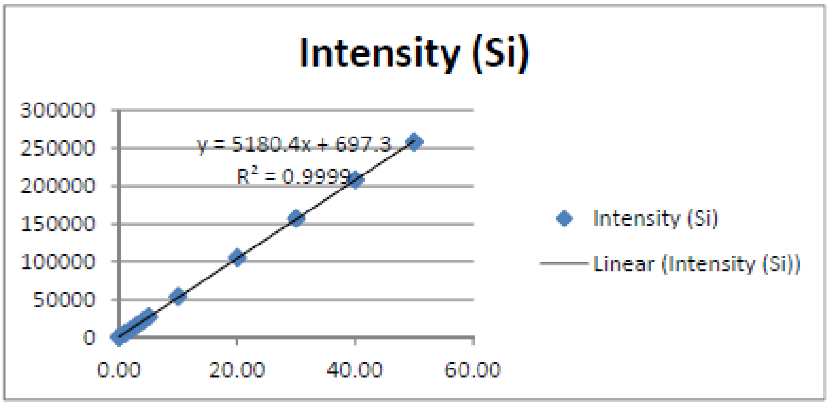


Figure 50 Calibration curve of Silicon (Si)

APPENDIX C: Sampling of groundwater and leachate

Picture 8 Sample from Batu-1 condominium

Picture 9 Sample from Around Kore

Picture 10 Sample from Landfill well-1

Picture 11 Sample from Landfill well-2

Picture 12 Sample from Jemo 1

Picture 13 Sample from Ayer tena high school

Picture 14 Leachate sample from Koshe open dump site

Picture 15 On situ measurement by OAKTON 600 series waterproof portable meter kit

Picture 16 On-site measurement

Picture 17 Sampling for On-site measurement