Ambient Air Quality Status Evaluation in Bishoftu Town, Oromia National Regional State, Ethiopia

By Endale Hailu G/Silassie

A Thesis submitted to the Department of Architecture

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Environmental Architecture

Office of Post Graduate Studies

Adama Science and Technology University

Adama

July, 2020

Ambient Air Quality Status Evaluation in Bishoftu Town, Oromia National Regional State, Ethiopia

By Endale Hailu G/Silassie

Advisor: DR. Eshetu Temesgen Gelan (PhD)

A Thesis submitted to the department of Architecture

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Environmental Architecture

Office of Post Graduate Studies

Adama Science and Technology University

Adama

July, 2020

APPROVAL OF BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the final open defense by Endale Hailu have read and evaluated his thesis entitled "Ambient Air Quality Status Evaluation in Bishoftu Town, Oromia National Regional State, Ethiopia" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of master's in Environmental Architecture.

______________________	______________________	______________________
Name of Student	Signature	Date
______________________	______________________	______________________
Supervisor /Advisor	Signature	Date
______________________	______________________	______________________
External Examiner	Signature	Date
______________________	______________________	______________________
Internal Examiner	Signature	Date
______________________	______________________	______________________
Chairperson	Signature	Date
______________________	______________________	______________________
Head of Department	Signature	Date
______________________	______________________	______________________
School Dean	Signature	Date
______________________	______________________	______________________
Postgraduate Dean	Signature	Date

DECLARATION

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name: Endale Hailu Gebresilassie

Signature:___________________

This MSc Thesis has been submitted for examination with my approval as thesis advisor.

Name: Dr. Eshetu Temesgen Gelan (Ph.D.)

Signature:________________________

Date of submission____________________

ADVISOR’S APPROVAL SHEET

To: Architecture department

Subject: Thesis Submission

This is to certify that the thesis entitled “Ambient Air Quality Status Evaluation in Bishoftu Town, Oromia National Regional State, Ethiopia” submitted in partial fulfillment of the requirements for the degree of Master‘s in Environmental Architecture, the Graduate program of the department of Architecture, and has been carried out by Endale Hailu Gebresilassie Id. No PGR/18197/11, under my supervision. Therefore, I recommend that the student has fulfilled the requirements and hence hereby he can submit the thesis to the department.

Dr. Eshetu Temesgen Gelan (Ph.D.)	____________________________	___________________
Name of Advisor	Signature	Date

ACKNOWLEDGMENT

First and foremost, I would like to thank to Almighty God for availing me the opportunity to carry out my research thesis. I would like to thanks my thesis advisor Dr. Eshetu Temesgen Gelan for his give constructive comments and suggestions throughout the thesis work and that motivate me to do the best. His support has been invaluable to the completion of the thesis.

I also thank my esteemed environmental architecture MSC classmates and all architecture departments' members for their oneness, morale and encouragement throughout two years stay in Adama science and Technology University. Finally, my sincere thanks go to my family for their continuous moral, spiritual, physical, and emotional support during the course of my study.

TABLE OF CONTENTS

CONTENTS PAGE

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AQI	Air Quality Index
CSA	Central Statistical Authority
EEFCCC	Ethiopia Environmental Forest Climate & Change Commiss
EEPA	Ethiopia Environmental Protection Authority
EPA	Environmental Protection Authority
ESID	Ecologically Sustainable Industrial Development
FDRE	Federal Democratic republic of Ethiopia
GPS	Geographical Positioning System
NAAQS	National Ambient Air Quality Standards
ND	Not detected
OUPI	Oromia Urban Planning Institute
PM	Particulate Matter
PPB	Parts per Billion
PPM	Parts per Million
SPSS	Statistical Package for Social Science
TSP	Total suspended Particle
UK	United Kingdom
VOCs	Volatile Organic Compound
WHO	World Health Organization

ABSTRACT

Nowadays due to the rapid development of urbanization and industrialization experiencing a negative impact on ambiant air quality, threatens the health of a large fraction of the world's population. The aim of this study is to evaluate the ambient air quality status in Bishoftu, Oromia National regional state, Ethiopia. Cross-sectional study was conducted from December 01, 2019 to June 18, 2020. A total of 33 sample sites were selected using simple random and stratified sampling methods to cover the cores and peripheries of the city. Ambiant air pollutant concentration data where measured with electronic instruments in all sample sites. The mean average concentration of all pollutant in Bishoftu town shows the concentration of $PM_{2.5}$ was 94.8 µg/ m^3 , which was 3.8 times more than the daily WHO air quality guidelines (25 µg/ m^3), and 1.46 times more than the Ethiopia air quality guidelines (65 µg/ m^3) .The mean concentration of PM_{10} was 220.3 µg/ m^3 , which was 4.4 times more than the daily WHO air quality guidelines (50 µg/ m^3), and 1.46 times more than Ethiopia air quality guidelines (150 µg/ m^3). The mean concentration of SO_2 was 1166.7 µg/ m^3 , which was 2.33 times more than the daily WHO air quality guidelines (500 µg/ m^3), and Ethiopia air quality guidelines (500 µg/ m^3) respectively. From land uses which are considered in this study commercial, residential, recreational and industrial site, industry site record highest mean average concentration of $PM_{2.5}$,$PM_{10,}$ SO_2 were recorded, which is 510.9µg/m^3, 1282.8µg/m^3 and 1172.5 µg/m^3 respectively which is higher than the WHO air quality guideline and Ambient Environment Standards for Ethiopia 2003. While the mean concentration of CO and NO_2 were below the WHO air quality guideline and Ambient Environment Standards for Ethiopia 2003. This implies that Industrial zone was one of the main agents that causes air pollution in bishoftu town. Furthermore, Bishoftu Environmental Protection Authority and others stakeholders should give attention for industrial emission of air pollution, and air quality management plan in bishoftu town.

KEYWORDS:- Air pollution; Ambient air Quality; Industries, Bishoftu

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Air pollution introduces chemicals, particulates or biological materials which cause discomfort, disease or death to humans and damage to both the living organisms (such as food crops) and the built environment. Today, air pollution presents the world's greatest environmental health risk with cities recording dangerously high levels of air pollution (UNEP, 2018).

Increasing number of industries in urban environments has led to an increase in the rates of air pollution. Available data shows that the air quality in most major cities of the World has deteriorated to levels that make air quality management strategies necessary(Anenberg et al., 2015). Air pollution is a major environmental health risk; poor air quality reduces human life expectancy by more than eight months on average and by more than two years in the most polluted cities and regions(EPA, 2017). Correspondingly, air pollution is a problem that accumulates with urbanization and threatens human health. The quality of the air is more important for all cities which have busiest traffic flow and highest population, The air we breathe contains emissions from many different sources: industry, motor vehicles, heating and commercial sources, household fuels as well as tobacco smoke. (Yolsal, 2016).

Air pollutants produced in environments have many detrimental impacts on human health. Chronic obstructive pulmonary disease (COPD) is a common worldwide respiratory disease (Khaefi et al., 2017). Most of the African population is dependent on biomass for cooking and heating, with most of the combustion happening in low efficiency stoves in unvented kitchens (Muindi, 2017). Recently, an increasing of research has shown that air pollution even in relatively low doses also affects educational outcomes across several distinct age groups and varying lengths of exposure (Roth, 2017).

Clean air is considered to be a basic requirement for human health and wellbeing. In spite of the introduction of cleaner technologies in industry, energy production and transport, air pollution remains a major health risk(WHO, 2000). Ambient Air Quality is a basic requirement of human health and well-being and become a common problem to almost all major cities in the world. Africa has low green house gas GHG emissions; it's susceptible to some of the worst effects of climate change. WHO found out that air pollution is becoming a policy driver in the region, its effects particularly seen on health getting worse. Even though most cities air quality, control has improved over the past decades, the visible and noticeable air pollution (smoke, dust, smog) has continued as main problem. Ethiopia has faced a challenge from air pollution too. Bishoftu is one of the towns in Ethiopia with a population of over 285,000 (Two hundred eighty five thousand) people and has the greatest concentration of different air pollutant sources. Research shows that in developing nations especially those in Africa, capabilities of air quality management are either absent or only rudimentary; (WHO, 2012). The situation in Bishoftu town, air quality management is rudimentary. As town grows both economically and spatially, air pollution from industrial, vehicle emissions, open burning of waste and other sources has become an increasing health concern in the cities. This research therefore, evaluate and identify ambient air pollutants in Bishoftu town to Enhance the local community's awareness on the effects of ambient air quality and pollution , and bring commitment among the society to address such issues.

1.2. Statement of the problem

Ambient air pollution is the leading environmental health risk factor worldwide. World Health Organization (WHO, 2016) estimations show that 90 per cent of people worldwide breathe air containing high levels of pollutants. Air pollution causes 1 in every 9 deaths globally. Of the total annual air pollution related deaths, 4.2 million result from exposure to ambient (outdoor) air pollution and 3.8 million from exposure to household air pollution in smoke from dirty cook stoves and fuels. which shows ambient air pollutants where main contributor for air pollution.

There are limited published health studies relating to ambient air pollution in Ethiopia generally. However, the few available studies show worrying morbidity and mortality impacts of ambient air pollution in the country. According to the World Health Organization, in 2012 alone Ethiopia recorded 13,257 premature deaths (7,995 male, 5,262 female) attributed to ambient air pollution, mainly from acute respiratory diseases, heart diseases and stroke. Compared to other Eastern Africa countries, Ethiopia's health burden from ambient air pollution is the biggest based on the reported number of deaths attributed to ambient air pollution in the region as shown in the Table 1 below. (WHO, 2016)

Table 1 Deaths attributed to ambient air pollution in Eastern Africa countries.

Country	**Number Of Death**
Burundi	3,001
Djibouti	212
Eritrea	1,243
Ethiopia	**13,257**
Kenya	5,102
Rwanda	2,227
South Sudan	2,632
Sudan	8,093
Tanzania	5,765
Uganda	7,989

Source: WHO AAP database, 2016

Factors have produced far-reaching changes in air quality in urban contexts. Bishoftu town is among the fast-growing cities of Ethiopia, incorporate different land uses such as residential, commercial, recreational (different lake side's resorts), industrial zone. However, there is no study conducted in Bishoftu town which evaluate the status of ambient air quality.

1.3. Objectives

1.3.1. General objective

The main objective of the study is to Evaluation Ambient Air Quality Status in Bishoftu town, Oromia National Regional State Ethiopia.

1.3.2. Specific objective

- To evaluate ambient air quality status in the study area.
- To compare current ambient air quality status compliance of national and international standard and sampling variation.
- To produce ambient air quality index based on selected air quality parameters for the study area.
- To identify potential ambient pollution sources site.

1.4. Research Questions

The research study was addressing the following scientific questions concerning air pollutants in Bishoftu town:

- What is the level of Ambient Air pollutant concentration at different sample site and land uses in Bishoftu city compared to WHO and EEPA Standards?
- What is the rate of pollution at different sample site or air quality index(AQI) ?
- What is the status of Ambient Air Pollution in Bishoftu city?

1.5. Significance of study

A number of individuals and groups are going to benefit from this research output; the most beneficiaries will be the local community/residents investors, tourists as well as all stake holders which works on air quality and pollutions in bishoftu town.

The research output will contribute to:

- Enhance the local community's awareness on the effects of ambient air quality and pollution , and bring commitment among the society to address such issues.
- Act as baseline data/secondary information for future studies in areas of similar characteristics/challenges.

1.6. Scope and limitation of the study

The study site was located in the Federal Democratic Republic of Ethiopia, Oromia National regional state, Bishoftu town. The study area incorporates different four land uses, such as industrial, commercial, recreational, and residential because of most residents where live inside or near to those land uses in bishoftu town. The study was conducted from December 01,2019 to June 30,2020 G.C. The limitation for this research was the problem of unavailable air quality monitoring stations data in Bishoftu city. Since, air quality analysis new for bishoftu town, there was unavailable experimental laboratories and air quality monitoring stations in Bishoftu town. Similarly, it was too difficult to know the trend analysis of air quality index. In case of this problem, such data was collected by observation. This may not be showing the true characteristics of the air pollution status. Therefore, this study was limited to studying only thirty three sample sites and four different land use types purposively.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Air Pollution

An estimated 41% of global waste is burned openly. In developing, low income countries that figure is even higher(. An estimated 620 million tons of waste per year are burned openly. (Cogut, 2016).Waste incineration is defined as the combustion of solid and liquid waste in controlled incineration facilities(Guendehou & Koch, 2006). the total amount of solid waste from these sources was 4.09 Mt/year, which resulted in the emissions of carbon dioxide equivalent, carbon monoxide, sulfur dioxide, nitric oxide, and particulate matter of 1247.3 kt/year, 103.0 kt/year, 1.2 kt/year, 7.4 kt/year, and 19.6 kt/year, respectively(Pansuk & Junpen, 2018). As study conducted (Kasim & Abshare, 2017)in Dire Dawa Ethiopia, an air quality index indicated that ambient air quality for SO_2 was very poor, NO_2 ranged from moderate to very poor, whereas CO rating was moderate. Significant positive correlations existed between temperature and NO_2,CO_2, and CO and between humidity and VOCs. Poor urban planning, inadequate pollution control measure, and weak capacity to monitor air quality have implications for energy usage, air quality, and local meteorological parameters, with subsequent feedback into global climate change. Ambient air pollution is the leading environmental health risk factor globally, resulting in nearly 3.5 million premature deaths in 2017 from stroke, ischemic heart disease, chronic obstructive pulmonary disease, lung cancer, lower respiratory infections, and diabetes.

2.2. Sources of Outdoor Air Pollution

Outdoor air pollution is caused mainly by the combustion of petroleum products or coal by motor vehicles, industry, and power stations. In some countries, the combustion of wood or agricultural waste is another major source. Pollution can also originate from industrial processes that involve dust formation (for example, from cement factories and metal smelters) or gas releases (for instance, from chemicals production). Indoor sources also contribute to outdoor air pollution, and in heavily populated areas, the contribution from indoor sources can create extremely high levels of outdoor air pollution. Air pollution causes health effects and environmental problems are becoming serious through the world.

Ambient air pollutants includes particulate matter (PM_{10} and $PM_{2.5}$), nitrogen oxides (including oxides of nitrogen (NOx) and nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Carbon monoxide (CO), and Ozone (O_3).

Particulate Matter (PM2.5 & PM10)

Airborne particulate matter (PM) is categorized into different size fractions. Total Suspended Particulate (TSP) includes all particle sizes and is a good measure of nuisance dust. PM10 (particles $\leq$ 10 microns) is a criteria pollutant and is a serious health risk because PM10 particles can penetrate the lungs. PM2.5 (particles $\leq$ 2.5 microns) is also a criteria pollutant which has even greater health impact due to risk of penetration deeper into the respiratory system.

Research has linked particulate pollution to lung and heart disease, strokes, cancer, and reproductive harm.

Natural sources:- Large particles (generally PM10 and above) come from natural sources stirred up by wind or human activity. PM10 occurs naturally; for example, as sea salt, dust (airborne soil), or pollen. Airborne soil particles, although natural, are also produced by human-made processes such as construction and industrial activities. Natural particulates can make up a large portion of PM10 in some areas.

As a pollutant;- Small particles (generally PM2.5 and below) are by-products of combustion, e.g. emissions from vehicles and power stations. Particles from these sources react with other gases in the atmosphere to create particles of various chemical compositions. Gas to particle conversion can also produce fine particulate.

Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) is a naturally occurring gas which acts as the primary source of carbon in life on Earth. It is also a primary greenhouse gas; carbon dioxide absorbs and emits infrared radiation causing warming of the Earth's surface and lower atmosphere. Indoors, elevated levels of CO_2 can lead to drowsiness, headaches as well as a reduction in productivity.

*Natural sources:-*In the carbon cycle, carbon is released into the atmosphere from various sources and absorbed again in natural sinks (reservoirs). Humans and plants give off carbon dioxide through respiration, making them a source of CO_2.Plants absorb CO_2 during photosynthesis, making them a sink. The ocean acts both as a source and a sink, releasing CO_2 and absorbing it through natural processes. Volcanic eruptions act as a natural source of CO_2.

*Industrial sources:-*Since the industrial revolution there has been a significant increase in atmospheric carbon dioxide due to human activity. The main sources of CO_2 gas include electricity generation, transportation, and industrial processes which all involve combustion of fossil fuels. The increase in atmospheric CO_2 has been shown to cause changes in the global environment including climate change and ocean acidification.

*Indoor sources:-*People are the main source of carbon dioxide emissions in indoor environments due to CO_2 being the main gas emitted during respiration. The higher the number of occupants in a building space, the higher the concentration of CO_2. Most heating, ventilation and air conditioning (HVAC) systems re-circulate indoor air leading to increasing CO_2 concentrations. It is therefore important to measure indoor CO_2 to ensure healthy levels are maintained.

Carbon monoxide (CO)

Carbon monoxide (CO) is a toxic, odorless gas. If inhaled it will displace oxygen from the hemoglobin molecule in our blood and lead to severe disability or even death. It is one of the 'criteria' pollutants measured in ambient air.

*Outdoor sources:-*Carbon monoxide is found naturally at low concentrations in the atmosphere from volcanic activity and forest fires. CO is produced from the partial oxidation of carbon-containing compounds in situations where there is not enough oxygen present to produce carbon dioxide. The main source of outdoor CO is combustion processes from transportation and industrial activity.

*Indoor sources:-*Malfunctioning fuel burning appliances such as furnaces, cookers, water boilers and gas room heaters can all lead to carbon monoxide leaks in areas occupied by people.

*Industrial uses:-*Carbon monoxide is very important in industry since it is a precursor to a number of important organic chemicals.CO gas has various niche applications in the chemical, food, medical, and semiconductor industries.

Nitrogen dioxide (NO_2)

Inhalation of nitrogen dioxide (NO_2) can impair lung function and increase susceptibility to infection, particularly in children. It can also aggravate asthma. NO_2 is not only a toxic gas but it is also a precursor to several harmful secondary air pollutants such as ozone and particulate matter. It also plays a role in the formation of acid rain and photochemical smog.

*Natural sources:-*Nitrogen dioxide is not usually released directly into the air. NO_2 forms when nitric oxide (NO) and other nitric oxides (NOX) react with other chemicals in the air. Some NO_2

is formed naturally in the atmosphere by lightning and some is produced by plants, soil and water.

As a pollutant:-The major source of nitrogen dioxide in urban environments is the burning of fossil fuels. In urban areas this is most commonly associated with motor vehicle exhaust. Areas with high density road networks close to large populations such as in towns and cities are most at risk of over exposure. Industrial sites will also produce high concentrations of NO_2. These include any industry that use combustion processes such as power plants, electric utilities and industrial boilers.

Sulfur dioxide (SO_2)

Sulfur dioxide (SO_2) is a toxic gas with a strong irritating smell. Inhaling sulfur dioxide has been associated with respiratory disease and difficulty breathing. It is also a precursor to acid rain and atmospheric particulates.

Natural sources:-Sulfur dioxide is present at very low concentrations in the atmosphere and is naturally emitted during volcanic
eruptions, as well as at geothermal sites.

As a pollutant:-Fossil fuel combustion at power plants is the largest emission source of SO_2 into the atmosphere. Other sources include extracting metal from ore and the burning of high sulfur containing fuels by ships, trains and machinery. Perimeter monitoring at industrial sites is common to measure the concentration of SO_2 being emitted into the
atmosphere.

Industrial uses:-Sulfur dioxide is an intermediate component in the formation of sulfuric acid. Sulfuric acid is a very important commodity chemical used in several industrial processes including the fertilizer industry and metal treatments.SO_2 gas is also used directly in many industries. It acts as a preservative for dried fruits due to its antimicrobial properties and is used in wine making (in the form sodium bisulfite) to protect the wine from spoilage.

Volatile organic compounds (VOCs)

Volatile organic compounds (VOCs) are carbon containing gases and vapors such as gasoline fumes and solvents. They evaporate easily at ordinary room temperature which is why they are termed volatile. Many VOCs such as benzene and formaldehyde are highly toxic and can cause cancer and other serious health problems. VOCs such as 1,3 butadiene are also involved in the formation of ground level ozone. The severity of the health effect depends largely on the type of organic compound present as well as the exposure time.

*Natural sources:-*The largest source of VOCs is from vegetation however some compounds notably benzene are created during volcanic eruptions and forest fires. Although natural sources of VOC emissions are larger overall, anthropogenic sources are the main contributors of VOCs in urban areas.

*As a pollutant:-*Anthropogenic sources include fuel production, distribution, and combustion. The largest emissions come from motor vehicles due to either evaporation or incomplete combustion of fuel, and from biomass burning.

*Indoor sources-*Typical indoor VOC sources include paint, cleaning supplies, furnishings, glues, permanent markers and printing equipment. Levels can be particularly high when ventilation is limited.

2.4. Ambient air pollution in Ethiopia

Ambient air pollution is a major global environmental health problem and affects low, middle, and high-income countries. According to World Health Organization (WHO,2016), ambient air pollution causes an estimated 4.2 million premature deaths annually worldwide due to exposure to small particulate matter ($PM_{2.5}$), which causes cardiovascular and respiratory disease as well as cancers. It is estimated that 91 per cent of these premature deaths occurred in low- and middle-income countries. According to EEPA reports, the air pollutants of concern in Ethiopia include particulate matter (PM_{10} and $PM_{2.5}$), nitrogen oxides (including oxides of nitrogen (NOx) and nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Carbon monoxide (CO), and Ozone (O_3).

- Particulate matter (PM_{10} and $PM_{2.5}$): The main sources of PM are motor vehicles, domestic heating and cooking, open burning of waste as well as fugitive dust emissions from construction activities and unpaved roads. PM_{10} levels have been found to be higher in urban areas during dry months as opposed to sub-urban areas.
- Nitrogen oxides (NOx): Emissions of NO_X are mainly from traffic, open burning and industrial sources, as well as domestic cooking and heating. Studies have pointed to higher concentrations of NOX at roadside locations as well as highly populated areas and industrial areas compared to rural areas.

- Sulphur dioxide (SO_2): The main contributors of SO_2 emissions are traffic as well as industrial processes such as cement production.
- Carbon monoxide (CO): CO emissions are mainly from transportation sector with peak concentrations occurring in early mornings and late afternoons as a result of traffic density.
- Ozone (O_3): Ozone is not usually emitted directly into the air, but at ground-level is created by a chemical reaction between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. The main contributors to O_3 are motor vehicles and industrial processes. A pilot study conducted in 2004 reported O_3 concentration of <45ppb28. This is below the 70 parts per billion (ppb) standard for US EPA which is one of the most stringent ambient air quality standards in the world.

2.5. Vegetation greening for air quality management

Urban green space, such as parks, playgrounds, and residential greenery, can promote mental and physical health and reduce morbidity and mortality in urban residents by providing psychological relaxation and stress alleviation, stimulating social cohesion, supporting physical activity, and reducing exposure to air pollutants, noise and excessive heat(Braubach et al., 2017). Urban green space exposure and general health, weight status, depression, and stress (via cortisol concentration)(Kondo et al., 2018).Policies that reduce greenhouse gas emissions can also reduce outdoor levels of air pollutants that harm human health by targeting the same emissions source(Division et al., 2015).

2.6.Policies and legislation on air pollution

This section looks at the international, regional and national, protocols, conventions, agreements, Policies and Legislation on Air Pollution. According to WHO 2018 report Most sources of outdoor air pollution are well beyond the control of individuals and demands concerted action by local, national and regional level policy-makers working in sectors like transport, energy, waste management, urban planning, and agriculture. There are many examples of successful policies in transport, urban planning, power generation and industry that reduce air pollution:

- **for industry:** clean technologies that reduce industrial smokestack emissions; improved management of urban and agricultural waste, including capture of methane gas emitted from waste sites as an alternative to incineration (for use as biogas);

- **for energy:** ensuring access to affordable clean household energy solutions for cooking, heating and lighting;
- **for transport:** shifting to clean modes of power generation; prioritizing rapid urban transit, walking and cycling networks in cities as well as rail interurban freight and passenger travel; shifting to cleaner heavy-duty diesel vehicles and low-emissions vehicles and fuels, including fuels with reduced sulfur content;
- **for urban planning:** improving the energy efficiency of buildings and making cities more green and compact, and thus energy efficient;
- **for power generation:** increased use of low-emissions fuels and renewable combustion-free power sources (like solar, wind or hydropower); co-generation of heat and power; and distributed energy generation (e.g. mini-grids and rooftop solar power generation);
- **for municipal and agricultural waste management:** strategies for waste reduction, waste separation, recycling and reuse or waste reprocessing; as well as improved methods of biological waste management such as anaerobic waste digestion to produce biogas, are feasible, low cost alternatives to the open incineration of solid waste. Where incineration is unavoidable, then combustion technologies with strict emission controls are critical.

2.6.1. International Policies

The United Nations framework convention on climate change is entered into force on 21st march 1994, after being ratified by 50 states. The convention's general objective is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (article 3).

The Kyoto protocol on climate change: The conference of the parties (COP) of the United Nations framework convention on climate change held a conference in Kyoto, Japan on December 1-11, 1997 and agreed on a plan to reduce greenhouse gas emissions which was resultant of this protocol. The developed countries are required to reduce these emissions by five per cent in the 2008-2012 periods relative to 1990 which is used as the base year. Increasingly, other programs such as REDD+ (which are rooted in articles 2 and 3 of the protocol), and wetland conservation and restoration are seeking to reduce GHG emissions.

2.6.2. Regional level Policies

East African community: Is treaty of 1999 established the east African community to focus on various areas of cooperation including environment and natural resources management. One of the key objectives of the treaty is the commitment to promote sustainable utilization of natural resources. Sustainable utilization of natural resources aims at minimizing industrial air pollution for safer air quality.

2.6.3. National level Policies

The constitution of Federal Democratic Republic of Ethiopia: federal constitution (adopted on the 21st of august 1995) sets out important articles related to sustainable development and environmental rights article 43 and article 44 discuss the right to sustainable development and about environmental rights as follows:-All persons have the right to live in a clean and healthy environment, Under article-92, the constitution discusses about environmental objectives as: government shall endeavor to ensure that all Ethiopians live in a clean and healthy environment.

2.7. Gap identification

From the literature review it is clear that industries pose a major challenge to air pollution both to the environment and communities around. New partnerships among all relevant stakeholders should be formed and specifically the industries to undertake joint planning and accelerate projects to mitigate challenges affecting them all. The main challenge here is coming up with means to mitigate air pollution from industries.

2.8. Theoretical framework

From the review of literature, major factors contributing to industrial air pollution include; unchecked/uncontrolled emissions by industries, insufficient technology to come up with ways to mitigate industrial air pollution, poor implementation of policies governing industrial pollution. Inadequate involvement of the local communities in the planning process has also been a major challenge. Continuous air pollution comes about as a result of various factors which are either directly or indirectly linked to the issue of study. It can lead impairment of air quality in interest areas, health complications by individuals within the local areas, and affecting soils fertility and acidity in an area. When these occur, there’s an outcry action to be taken thus calling for an appropriate management plan. To achieve sustainability in this area of study, it calls for more attention from government officials and other relevant stakeholders to restore the quality of air. For results to be achieved, the interest community must be involved fully.

2.9. Operational definitions

Some of the few key terms that was define in this area of study/research are as follows: -

- Air Pollution**:** Air pollution is any atmospheric condition in which certain substances are present in such concentrations and duration that they may produce harmful effects on man and his environment. Common air pollutants include; carbon monoxide, nitrogen oxide, Sulphur dioxide, lead and Total Suspended Particulates (TSP), the latter being the most widespread and the most serious for human health.
- Air Quality**:** this term means the state (condition or situation) of the air around us. Good air quality refers to clean, clear, unpolluted air. Clear air is essential to maintaining the delicate balance of life on the earth, not just for humans, but wildlife, vegetation, water and soil. Poor air quality occurs when pollutants reach high enough concentrations to endanger human health and/or the environment.
- Air Quality Index**:** The standard system that state and local air pollution control programs use to notify the public about levels of air pollution. The AQI tracks levels of two pollutants - ozone (smog) and particle pollution (tiny particles from ash, vehicle exhaust, soil dust, pollen, and other pollution).
- Primary pollutants**:** Air pollutants emitted directly from a source (including particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2)
- Secondary pollutants**:** Air pollutants formed by chemical reactions and are often found downwind from the source of the initial compounds. This group includes ozone (O_3), formed by the reaction of nitrous oxides and volatile organic compounds in the presence of sunlight, and some forms of particulate matter. Some pollutants, such as particulate matter, can have both primary (e.g., black carbon the most strongly light-absorbing component of PM, formed by incomplete combustion) and secondary (e.g., sulfate, nitrate) components.
- Abatement**:** The reduction or elimination of pollution.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Study areas

Bishoftu town is located in Oromia National Regional State found at a distance of 47.9 kilometers southeast of Addis Ababa or Finfine (capital city of Ethiopia). Geographically it is stretched between 8 degrees 43' North – 8 degrees 48' North latitude and 38 degrees 00' East – 38 degrees 48' East longitude (Fig. 2). The altitude of bishoftu town is situated at an average elevation of 1971m above sea level.Thus, it belongs to “weyina dega” agro-climatic zone. The average annual temperature and rainfall of the town are 19.32^0c and 860mm respectively.

Bishoftu town is one of recreational town in Ethiopia, known for five crater lakes: Lake Bishoftu, Lake Hora, Lake Bishoftu Guda, Lake Koriftu, and the seasonal Lake Cheleklaka. And it is also one of oromo cultural celebration festival “Erecha” takes place at hora harsadi lakes once a year, according to bishoftu town cultural and tourism office, around two million participants were in 2018 festival. In addition, the town is the home of vast military camps, research and educational institutions, industries and urban agriculture. These have contributed to the rapid expansion of the town.

Bishoftu town is among the largest urban center in Oromia Region in its population size, and indeed one of few towns in the country with a threshold population of over 100,000 (OUPI,2019). According to Bishoftu town administration office, the number of registered population of the town as of 2017 is 213,689 which was 100,114 as of 2007 reported by the population and housing census of 2007(CSA, 2007). The town administrative area currently encompasses 9 urban Kebeles and 6 sub-urban Kebeles.

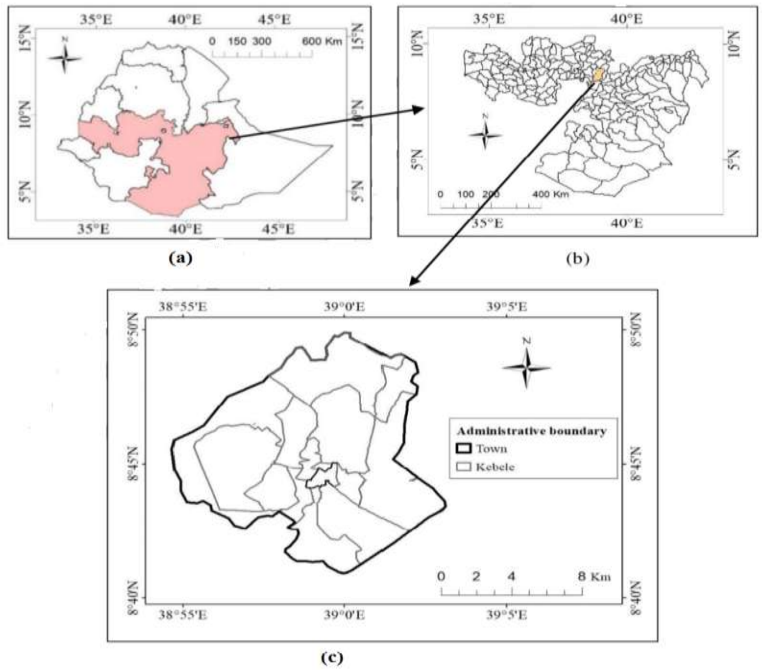

Figure 1 Location map of the study area: (a) Regions of Ethiopia, (b) Weredas of Oromia regional state, (c) Bishoftu town

3.2. Study site

Bishoftu city administration is located in , Oromia regional state, East Shewa zone of Ada'a wereda.

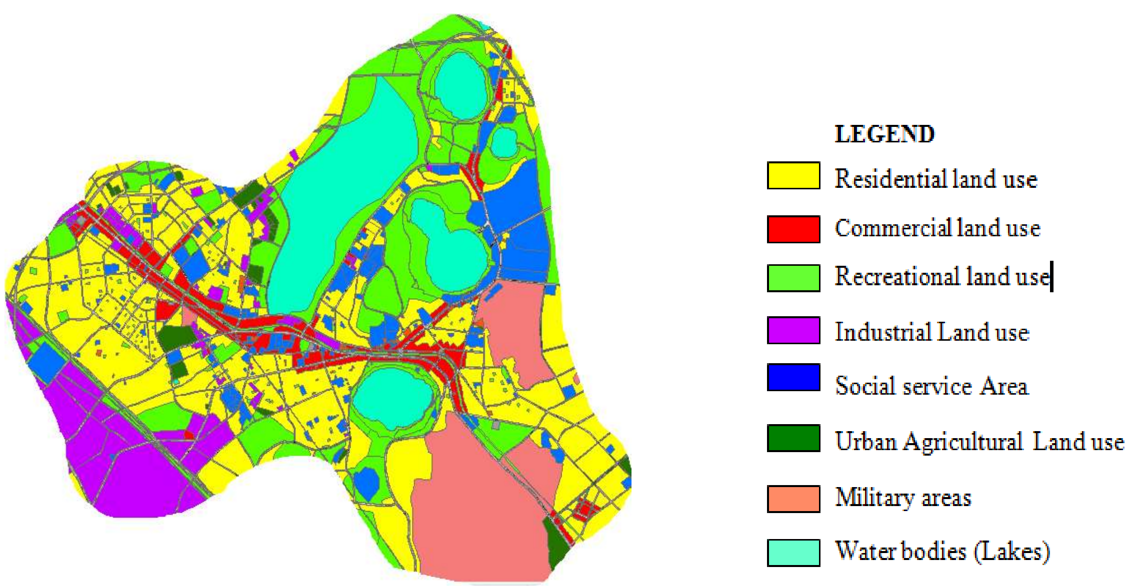

Figure 2 Study site land use categories.

3.3. Sampling site and Methods

Each sample site where selected in Bishoftu town which have most residents live in or near to the given land uses. In this study Stratified Sampling and Simple random sampling methods where used to cover the cores and peripheries of the town. Stratified Sampling where used for sampling four different land uses such as recreational, residential, commercial and industrial land use from Bishoftu town relative to the pollutants on the basis of preexisting information about the site. Simple random sampling where used for sampling different thirty three samples sites from sampled land uses. it is the simplest and most fundamental probability-based sampling method (EPA QA/G-5S,2012). Those sample sites were collected from different land uses, 8 sample sites were from commercial areas, 7 sample sites were from residential,14 sample sites were from recreational, and 4 sample sites were from industrial site.

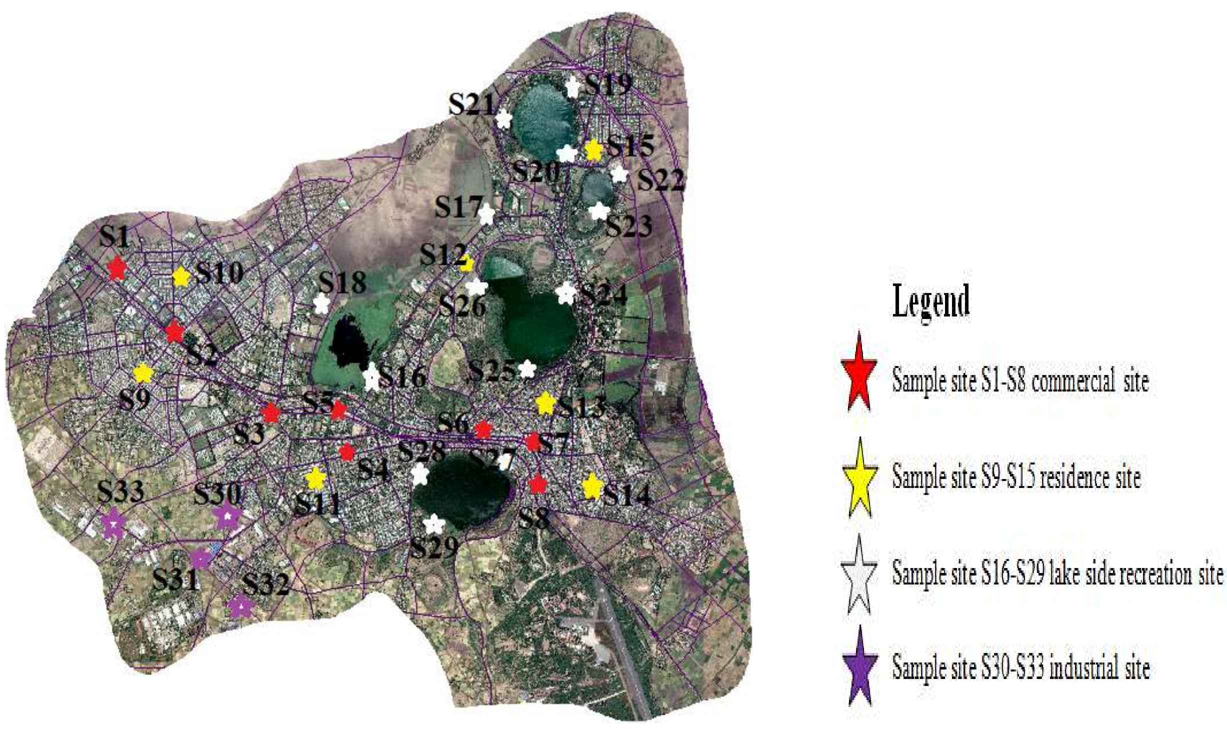

Figure 3 Specific sample sites location.

3.4. Study Design

Cross sectional study was conducted from December 01, 2019 to June 18,2020. The study aimed to assess ambient air pollutant concentration in Bishoftu town to achieve sustainable of ambient air quality management. The study adopted direct electronic instruments for measuring ambient air pollutants concentration, longitudinal and latitudes data, for each site measurements' where done from 7 a.m. on May 1 2020 up to 6 p.m. on June 5 2020 to generate required data.

3.6. Data collection

3.6.1. Data sources

In this study both primary and secondary data collection where used. These sources of data were utilized to collect the necessary data collection and to achieve objectives of the study. The primary data were collected through observation, direct instrumental measurement and captured photos.. Secondary data was collected were socio demographic data, census data, structural plan, Arial photo of Bishoftu and, different books, journals, magazines, internet web sites and related literatures.

3.6.2. Data gathering tools

In order to obtain sufficient and reliable information from primary and secondary data sources, the researcher used three basic data gathering methods, namely observation, photography and instrumental measurements.

Observation: An observation was an important tool in this data collection. The sheet was used to obtain primary data. The extent of air pollution by industries in the area e.g. by observing roof tops of buildings, different strategies in place by industries to manage the air pollution will be observed.

Photography: In this study photos were taken to depict the current air pollution situation within industrial area, for instance, fumes released in the atmosphere, corrosion on roof tops.

Instrumental measurements: -Portable air quality monitors

Data were measured using portable digital instrument or equipment from 7:00AM to 4:00PM daily. An average of 15-minute readings for each location was recorded. the measurements were done in the open space to minimize obstructions to wind and parameters. For quality assurance, the equipment and meters were all pre-calibrated before use. By delivering a consistent flow of calibration gas to the sensor head, without forcing air at the sensor, it ensures the most accurate calibration possible. It can also be used to humidify the gas which is important for best results with GSS sensors.

Aeroqual's Series 500 Gas Sensing

According to EPA 2014 Air Sensor Guidebook featuring low cost air sensors, Aeroqual's Series 500 was measured for Sulfur dioxide, nitrogen dioxide, carbon dioxide , carbon monoxide, and VOCs sensors. Aeroqual's portable air quality monitors are tools for air quality professionals and enthusiasts alike to gather real-time information on the surrounding air. They are a flexible air quality monitoring solution that can be configured with 27 different gas sensors and particle sensor for a range of uses from environmental monitoring to industrial applications. But in this study portable air monitors are designed to make ambient air quality monitoring easy. They are used by researchers, professionals, and non-experts alike to gather indicative air quality data. Small enough to fit comfortably in the hand, they can be used anywhere – indoors or outdoors, on the street, up a mountain, they've even been used in Antarctica.

Figure 4 Aeroqual's serial 500 series gas sensing

HP 5800D Lesser PM2.5 meter.

This product is a high-tech air quality monitor to measure the P2.5 and PM10 use of a laser PM2.5 sensor , single-chip microcomputer technology and high visibility LCD dot matrix LCD. This instrument is of high precision, short measuring time, stable performance, strong function, easy operation, low power consumption, with functions of time display, real time measurement, very suitable for indoor and outdoor environmental monitoring, can also be used in the detection of air purification machine to air purification effect.

Figure 5 HP 5800D leaser PM 2.5 meter

GARMIN Geographical Positioning System GPS.

GPS monitors are tools for positioning a specific site.The sampled locations' coordinates and altitudes were obtained with handheld automated Garmin GPS.

Figure 6 GARMIN Geographical Positioning System GPS

3.6.3. Data collection procedures

Based on the following steps data was measured with different tools and monitoring sensors; -

Step 1. Gather data. Use the monitor and interchangeable sensors to take spot measurements, or an log data overtime and space.

Step 2. Download data, connected to a PC and download measurements using Aeroqual's free software or 0-5V analog.

Step 3. Analyze data, analyze the data to identify trends, discover leaks or pollution hotspots, or dive deep into the numbers for research.

3.7. Data Analysis

The locations coordinates, altitudes land use and daily data measurements were recorded in Excel spreadsheet for reference and further analysis. Mean concentration values and standard deviation from the sampled locations were calculated from the spreadsheet. Consecutively two days data was collected for each site and the mean data was used for analysis. Sample sites location was collected using GPS. Descriptions of data analytical methods were used for mean, minimum, maximum and standard deviation. SPSS20 version was used for correlation analysis, and whereas Origin Pro9 version was used for graphical analysis. Status of every pollutant particulate matter (PM_{10} and $PM_{2.5}$), Carbon dioxide (CO_2), Sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), Volatile organic matter (VOC) were measured at different conditions (place, time) throughout the study. All data collected were recorded in one database, and level of all pollutants found was analyzed with appropriate measures. This result was found to compare with WHO and EEPA standards for specific pollutants.

3.8. Ethical Consideration

In order to address ethical consideration so aspects of the measurements to be effective, the researcher is expected to suffer a lot to convince the importance of this research to improve ambient air quality. According to Leedy and Ormrod (2010), most ethical issues fall into one of the following four categories; informed consent, confidentiality, security and honesty. Therefore, the researcher was tried to consider the following basic ethical issues throughout the study.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

The study presented a measurement for ambient air pollution concentrations at different sample site and land use types. The concentration of particulate matter (PM_{10} and $PM_{2.5}$), Carbon dioxide (CO_2), Sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), Volatile organic matter (VOC), measured in air and have been compared to limit values set out in WHO and Ambient Environment Standards for Ethiopia 2003 for ambient air quality . Finally Air quality index (AQI) was used to describe ambient air quality. It serves as indicator of air quality based on concentrations for air pollutants.

(a) Mendube residential sample site (S12) (b) Erecha site recreational sample site (S24)

Figure 7 Photo captured during data collection

Ethiopia has adopted national ambient air quality standards (NAAQS). The WHO guidelines are the reference point. It is reported that the Ethiopian Environmental Protection Authority and the United Nations Industrial Development Organization have prepared the guideline ambient environment standards (including air quality standards) for Ethiopia under the Ecologically Sustainable Industrial Development (ESID) Project in 2003. Under this, guideline limit has been set for six air pollutants such as SO2, NO2, CO, O3, PM10, PM2.5 and lead.

Table 2 Air quality guidelines of Ethiopia and WHO (EPA and ESID 2003)

pollutants	Ethiopia Air quality guidelines (microgram per cubic meter)	WHO Air quality guidelines (microgram per cubic meter)
Sulphur dioxide (10 minutes)	500	500
Sulphur dioxide (daily)	125	20
Sulphur dioxide (annual)	50	-
Nitrogen dioxide (1 hour)	200	200
Nitrogen dioxide (annual)	40	40
Carbon monoxide (15 minutes)	100000	-
Carbon monoxide (30 minutes)	60000	-
Carbon monoxide (8 hours)	10000	-
Ozone (8 hours)	120	100
Ozone (1 hours)	-	180
Particulate matter less than 10 microns (annual)	50	20
Particulate matter less than 10 microns (daily)	150	50
Particulate matter less than 2.5 microns (annual)	15	10
Particulate matter less than 2.5 microns (daily)	65	25
Lead (annual)	0.5	-

Source:*1. Guidelines Ambient Environment Standards for Ethiopia 2003, The Environmental Protection Agency and The United Nations Industrial Development Organization prepared under the Ecologically Sustainable Industrial Development (ESID) Project, August, Addis Ababa*(EPA & ESID, 2003)

4.1 Ambiant air pollutant concentration at different sample sites.

4.1.1 Concentration of particulate maters (PM2.5 AND PM10)

As shown in figure 8 and 9 bellow the highest concentration of $PM_{2.5}$ and PM_{10} recorded were 863.6 µg/ $m^3$and 1999 µg/ m^3 respectively, at Steely RMI in Industry site. Whereas, the lowest concentration of $PM_{2.5}$ and PM_{10} recorded were 13.6 µg/ $m^3$and 20.5 µg/ m^3respectively, at Goma Zaf in residential site. (Figure 8&9)

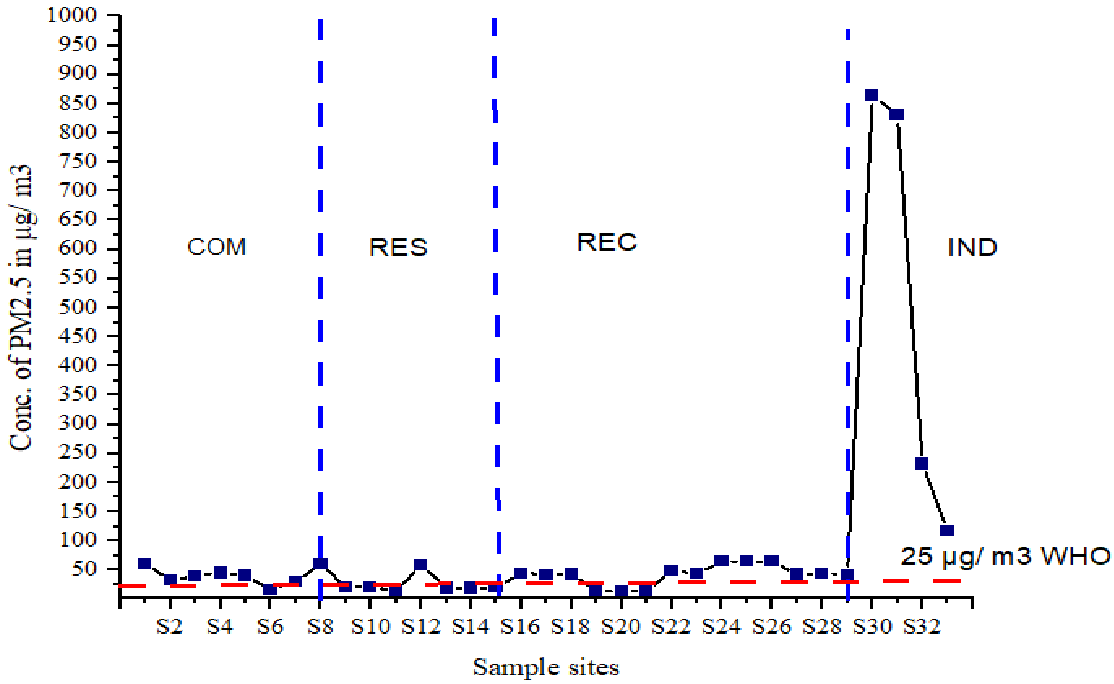

Figure 8 Concentration of $PM_{2.5}$ in different sample site and land uses types.

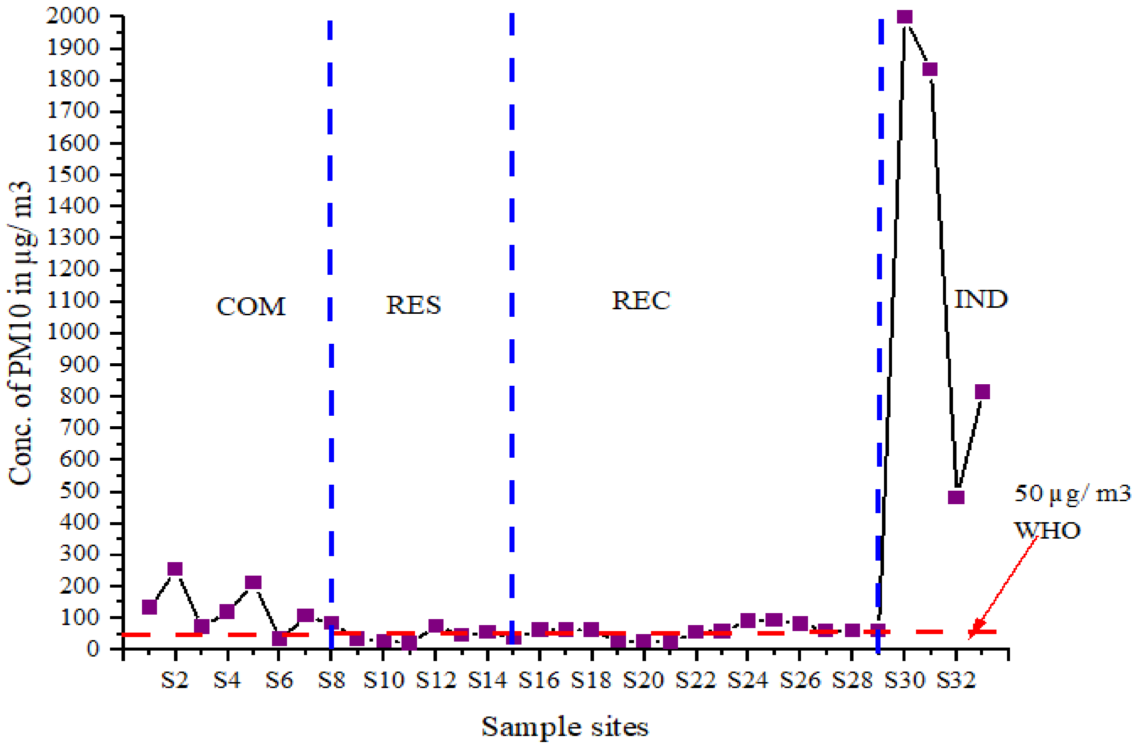

Figure 9 Concentration of PM_{10} in different sample site and land uses types

The highest concentration of $PM_{2.5}$(863.6 µg/ m^3) was 34.5 times more than the daily WHO air quality guidelines (25 µg/ m^3), and 13.3 times more than the daily ambient Environment Standards for Ethiopia 2003 (65 µg/ m^3) at Industrial site, respectively. A pilot survey conducted at Gondar in Ethiopia shows that burning of biomass fuels results in exposure to high levels of indoor air pollution, with consequent health effects. Particulate matter measurements are important in air quality, public health, epidemiological studies and decision making for short and long-term policies implementation(Andrés et al., 2018). In 2017, fine particulate matter ($PM_{2.5}$) was estimated to be associated with 2.9 million premature deaths(Anenberg et al., 2015).

The highest concentration of PM_{10}(1999 µg/ $m^{3)}$ was 39.98 times more than the daily WHO air quality guidelines (50µg/ m^3) and 13.3 times more than the daily ambient Environment Standards for Ethiopia 2003 (150 µg/ m^3)at Industrial site. PM_{10} are particles in the air with diameters of 10 µm (microns) or less. These particles can consist of direct emissions such as dust, emissions from combustion engines, from the burning of solid fuels or natural sources such as windblown salt, plant spores and pollens(EPA, 2017).

In 2017, fine particulate matter ($PM_{2.5}$) was estimated to be associated with 2.9 million premature deaths (Anenberg et al., 2015). The WHO estimations reveal an alarming death toll of 7 million people every year caused by exposure to fine particles ($PM_{2.5}$) in polluted air that penetrate deep into the lungs and cardiovascular system, causing diseases such as stroke, heart disease, lung cancer, chronic obstructive pulmonary diseases and respiratory infections, including pneumonia.

4.1.2 Concentration of carbon dioxide and volatile organic compounds (CO_2 and VOC_S)

As indicated in Figure 10 bellow, the highest concentration of CO_2 and VOCs recorded were 494,000µg/m^{3}and 3,120,000µg/m^{3}at Steely RMI in Industry site and babogaya and cheleleka lake side recreational land use areas, respectively. Whereas, the lowest concentration of $CO_2$and VOC recorded were 45,000µg/m^3 and 980,000µg/m^{3}at Kuriftu Resort recreational site and Mandube in residential site, respectively.

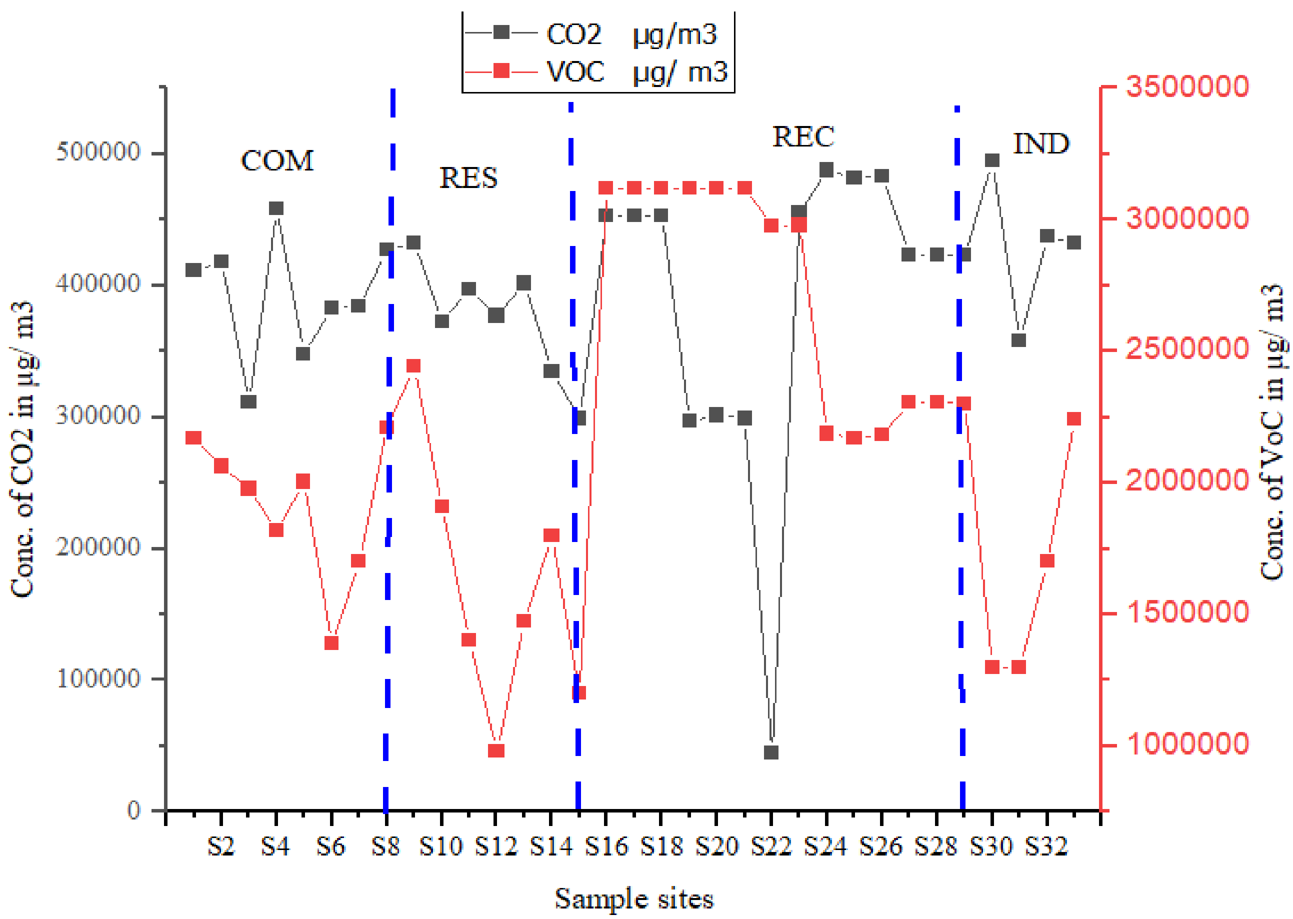

Figure 10 Concentration of CO_2 and VOC in different sample site and land uses types.

Moreover, for CO_2 and VOC_S in Ethiopia Environment Standards or limit value sis not seated. According to EPA reported, the industrial revolution has been a significant increase in atmospheric carbon dioxide due to human activity. The main sources of CO_2 gas include electricity generation, transportation, and industrial processes which all involve combustion of fossil fuels. The increase in atmospheric CO_2 has been shown to cause changes in the global environment including climate change.

4.1.3 Concentration of carbon monoxide (CO)

As shown in Figure 11 bellow, the highest concentration of CO recorded was 17,400µg/m^{3}at Abyssinia Steel in Industry site. Whereas, the lowest concentration of CO was not detected in all residential land uses except babogaya 09, where recorded 6900 µg/m^3 and not detected in all recreational land uses except around pyramid resort and Bishoftu resort, recorded 2900 µg/m^3 and 2750 µg/m^3.

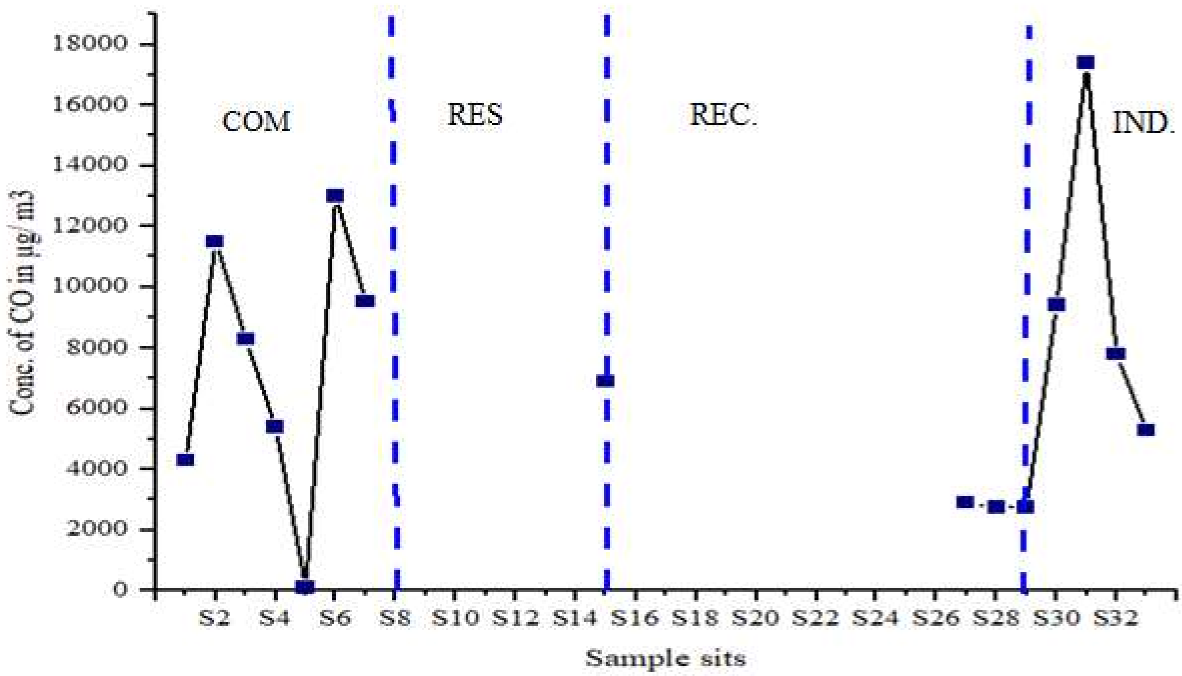

Figure 11 Concentration of CO in different sample site and land uses types.

Vehicle exhaust contributes roughly 75 percent of all carbon monoxide emissions nationwide, and up to 95 percent in cities (EPA, 2014).The highest concentration of CO was less than daily ambient Environment Standards for Ethiopia 2003 (100,000 µg/ m^3). Carbon monoxide is an indicator for traffic emissions and fuel combustion activities. Carbon monoxide levels are low and are not an area of focus in ambient air quality management.

4.1.4 Concentration of Sulphur dioxide and Nitrogen dioxide (SO_2 and NO_2)

As indicated in Figure 12 below, the highest concentration of SO_2 and NO_2 recorded were 6,000 µg/m^3 and 250 µg/m^3at Circle in commercial site and Steely RMI in industrial site respectively. the lowest concentration of SO2 and NO2 was not detected in all recreational land uses and residential land uses except babogaya 09, where recorded 650 µg/m^3 and 4 µg/m^3.

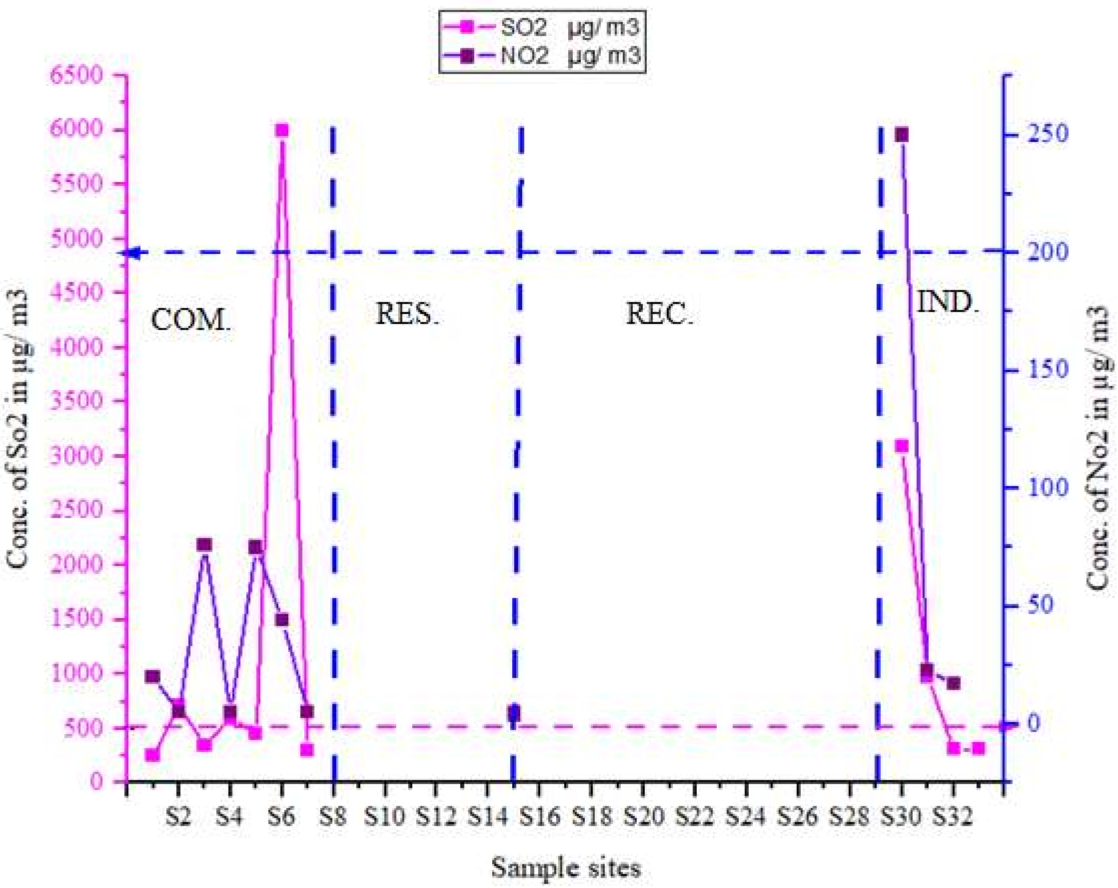

Figure 12 Concentration of SO_2 and NO_2 in different sample site and land uses types.

The highest concentration of SO_2 was 12 times more than the daily WHO air quality guidelines (500µg/ m^3) and ambient Environment Standards for Ethiopia 2003 (500 µg/ m^3)at Circle in commercial site. Also, the highest concentration of $NO_2$was 1.25 times more than the daily WHO air quality guidelines (200µg/ m^3)and ambient Environment Standards for Ethiopia 2003

(200 µg/ m^3)at Steely RMI in industrial site. Major sources SO_2 include power plants, refineries, and industrial boilers(EPA, 2014).

4.2 Ambiant air pollutant concentration at different Land uses.

Table 3 bellow shows the results from all land uses which was considered in the study, commercial, residential, recreational and industrial land uses. The highest mean average concentration of $PM_{2.5}$,$PM_{10,}$ SO_2 were recorded at industrial site, which is 510.9µg/m^3,1282.8µg/$m^3$and 1172.5 µg/m^3 respectively. This result was higher than the WHO air quality guidelines at Industrial site. This implies that the industrial site was one of the major sources of ambient air pollution.

Table 3 Summary of the mean average ambient air pollutant concentrations at all land uses

Land use type	$PM_{2.5}$ µg/ m^3	PM_{10} µg/ m^3	CO_2 µg/ m^3	CO µg/ m^3	SO_2 µg/ m^3	NO_2 µg/ m^3	VOC µg/ m^3
Commercial site	40.7	126.3	392500.0	7442.9	1237.1	32.9	1916188
Residential site	42.5	42.5	373428.6	6900.0	650	4	1601000
Recreational site	41.9	59.5	391214.3	2800.0	ND	ND	2723429
Industrial site	510.9	1282.8	430250.0	9975.0	1172.5	96.7	1635750
WHO	25	50	-	-	500	200	-
EEPAS	65	150	-	100000	500	200	-

The health burden due to particulate matter (PM) air pollution (PM10 and PM2.5) is one of the biggest environmental health concerns in the WHO European Region and around the world(WHO, 2007).The TSP concentration is expected to be high at the limestone quarry, which provides the factory with its main raw material, because it generates lots of dust as a result of rocks mining and crushing(Abu-allaban & Abu-qudais, 2011).The average PM10,NO_2, and SO2 concentrations in the urban area were 85.2, 49.3, and 37.4 lg/m3, which were 1.13, 1.25, and 1.41 times the values of the suburban area during the period of March 2009 to February 2010(Zhao et al., 2013).

4.3 Mean average concentration of pollutants in of Bishoftu town.

As result shows in Table 4 bellow, The mean average concentration of $PM_{2.5}$ was 94.8 µg/ m^3 , which was 3.8 times more than the daily WHO air quality guidelines (25 µg/ m^3), and 1.46 times more than the daily ambient Environment Standards for Ethiopia 2003 (65 µg/ m^3) . The mean concentration of PM_{10} was 220.3 µg/ m^3 , which was 4.4 times more than the daily WHO air quality guidelines (50 µg/ m^3), and 1.46 times more than the daily ambient Environment Standards for Ethiopia 2003 (150 µg/ m^3). The mean concentration of SO_2 was 1166.7 µg/ m^3 , which was 2.33 times more than the daily WHO air quality guidelines (500 µg/ m^3), and the daily ambient Environment Standards for Ethiopia 2003 (500 µg/ m^3) respectively. From the result the status of daily mean concentration of ambiant air pollutant in Bishoftu town $PM_{2.5,}$ PM_{10} and SO_2 were higher than the WHO air quality guideline and Ambient Environment Standards for Ethiopia 2003. While the mean concentration of CO and NO_2 were below the WHO air quality guideline and Ambient Environment Standards for Ethiopia 2003.

Table 4 Summary of maximum, mean, and minimum ambient air pollutant concentration.

	$PM_{2.5}$ µg/ m3	PM_{10} µg/ m3	CO_2 µg/ m3	CO µg/ m3	SO_2 µg/ m3	NO_2 µg/ m3	VOC µg/ m3
Maximum	863.6	1999	494000	17400	6000	250	3120000
Mean	94.8	220.3	392484.8	7153.3	1166.7	47.6	2157803.0
Minimum	13.6	20.5	45000	ND	ND	ND	980000
WHO	25	50	-	-	500	200	-
EEPAS	65	150	-	60000	500	200	-

$PM_{2.5}$ is considered to be one of the most important environmental factors contributing to the global human disease burden (Fantke et al., 2015). The burden of ill human health attributable to particulate air pollution is a critical problem of growing concern. As noticed by Rohde & Muller (2015) shows that the population-weighted average exposure to $PM_{2.5}$ was 52 µg/m^3 in China.PM10 (45–589 mg/m^3), PM2.5 (25–200 mg/m^3), and heavy metals were highest at VN followed by JC and IIT(Mukesh & Maloo, 2005).Particulate matter (PM) pollution is currently one of the main concerns at a global scale for its adverse effects on the human health, environment and climate(Gozzi et al, 2017).

As study conducted Haritash (2006), the average ambient air concentrations of SO_2 and NO_2 were found below the permissible limits at all the centers and NOx levels in Patras were significantly higher than the limits for human health and plants protection. Both, NOx and SO_2 levels were higher in Patras than in Volos. The Patras harbor high traffic seems to drive the diurnal pattern of SO_2 in that city(Saitanis, 2005).

4.4 Ambiant air Quality Status of Bishoftu town.

Air quality index (AQI).

Air quality index (AQI) was used to describe ambient air quality. It serves as indicator of air quality based on concentrations for air pollutants that have adverse effects on human health and the environment. The index was a tool for effective communication of air quality status to people in terms that are easy to understand. It transforms complex air quality data of various pollutants into a single number (index value), nomenclature, and color.

The AQI was a rating scale for outdoor or ambient air. The lower the AQI value, the better the air quality. Within AQI rating, as noted by the U.S. Environmental Protection Agency [EPA] (2015) and adopted by Ethiopian Environmental Protection Authority, A stands for very good (0–15), B for good(16–31), C for moderate (32–49), D for poor (50–99),and E for very poor (100 and over). AQI values were calculated for $PM_{2.5}$, PM_{10}, CO, $SO_2$and NO_2 concentration levels within the sampled locations (see table 5). The indices for the pollutants were derived using the formula

$$AQI\ Pollutant = \frac{Pollutant\ data\ reading}{Standard} * 100$$

Table 5 Air quality index (AQI) ratings for the concentration of $PM_{2.5}$, PM_{10}, CO, SO_2, and NO_2

Land Use Type	Sample site	Site Code	Ratings				
			$PM_{2.5}$	PM_{10}	CO	SO_2	NO_2
Commercial areas	Ashewa Tera	S1	E	E	A	D	A
	Get Eshet	S2	E	E	A	E	A
	Zikuala	S3	E	E	A	D	C
	Mikael	S4	E	E	A	E	A
	Menahiriya	S5	E	E	A	D	C
	Circle	S6	D	D	A	E	B
	Gebiya	S7	E	E	A	D	A
	60 Mazoriya	S8	E	E	A	A	A

Residence		105 Sefer	S9	D	D	A	A	A
		Sunshine	S10	D	D	A	A	A
		Goma zaf	S11	D	C	A	A	A
		Mandube	S12	E	E	A	A	A
		Kebele 06	S13	D	D	A	A	A
		Kata 08	S14	D	E	A	A	A
		Babogaya 09	S15	D	D	A	E	A
Recreational	Cheleleka Lake Side	Seranti Resort	S16	E	E	A	A	A
		Around Mendube	S17	E	E	A	A	A
		Holand Dairy	S18	E	E	A	A	A
	Babogaya Lake Side	Adulala Resort	S19	D	D	A	A	A
		Babogaya R.Cent.	S20	D	D	A	A	A
		Meat and Milk In	S21	D	D	A	A	A
	Kuriftu Lake Side	Kuriftu Resort	S22	E	E	A	A	A
		Gurage Amba	S23	E	E	A	A	A
	Hora Harsadii	Erecha site	S24	E	E	A	A	A
		Ras Hotel	S25	E	E	A	A	A
		Mendube	S26	E	E	A	A	A
	Bishoftu Lake Side	Pyramid Hotel	S27	E	E	A	A	A
		Bishoftu Hotel	S28	E	E	A	A	A
		Gezahegn Hotel	S29	E	E	A	A	A
Industry		Steely RMI	S30	E	E	A	A	E
		Abysinia Steel	S31	E	E	B	E	A
		C&E Brothers	S32	E	E	A	D	A
		Sentinail	S33	E	E	A	D	A

As noticed in the analysis, high concentrations of SO_2 recorded at Abysinia Steel .This outcome could be due to the interlink age between vehicular activities and industrial land use. Air quality in terms of SO_2 concentration outcome was very poor (E) across the land use in the city (Table 4). Similarly, the concentration of NO_2 recorded was poor (D) at both C&E Brothers and Sentinail in industrial site whereas, at Steely RMI NO_2 recorded was very poor (E). The quality of the air we breathe may be affected by urban developments, transport emissions on major roads, industrial and agricultural activity, or by domestic sources of pollution(EPA, 2016). The average PM10,NO_2, and SO2 concentrations in the urban area were 85.2, 49.3, and 37.4 lg/m3, which were 1.13, 1.25, and 1.41 times the values of the suburban area during the period of March 2009 to February 2010(Zhao et al., 2013).

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The aim of this study is to evaluate the ambient air quality status in Bishoftu, Oromia National regional state, Ethiopia. Cross-sectional study was conducted from December 01, 2019 to June 18, 2020. A total of 33 sample sites were collected with four different land uses types. Primary and secondary data were collected, ambiant air pollutant concentration where measured with electronic instruments in all sample sites. According to main finding of the research, The mean average concentration of all pollutant in bishoftu town shows the concentration of $PM_{2.5}$ was 94.8 µg/ m^3 , which was 3.8 times more than the daily WHO air quality guidelines (25 µg/ m^3), and 1.46 times more than the Ethiopia air quality guidelines (65 µg/ m^3) . The mean concentration of PM_{10} was 220.3 µg/ m^3 , which was 4.4 times more than the daily WHO air quality guidelines (50 µg/ m^3), and 1.46 times more than Ethiopia air quality guidelines (150 µg/ m^3). The mean concentration of SO_2 was 1166.7 µg/ m^3 , which was 2.33 times more than the daily WHO air quality guidelines (500 µg/ m^3), and Ethiopia air quality guidelines (500 µg/ m^3) respectively. from all land uses which was considered in this study commercial, residential, recreational and industrial site, the highest mean average concentration of $PM_{2.5}$,$PM_{10,}$ SO_2 were recorded at industrial site, which is 510.9µg/m^3, 1282.8µg/m^3 and 1172.5 µg/m^3 respectively. From the result the status of daily mean concentration of $PM_{2.5,}$ PM_{10} and SO_2 were higher than the WHO air quality guideline and Ambient Environment Standards for Ethiopia 2003. While the mean concentration of CO and NO_2 were below the WHO air quality guideline and Ambient Environment Standards for Ethiopia 2003. The stutus of air quality index of NO_2 recorded was poor (D) at both C&E Brothers and Sentinail in Industrial site whereas, at Steely RMI NO_2 recorded was very poor (E). This implies that Industrial zone was one of the main agents that causes air pollution in bishoftu town. Furthermore, Bishoftu Environmental Protection Authority and others stakeholders should give attention for industrial emission of air pollution, and air quality management plan in bishoftu town.

5.2. Recommendations

Depending on the results of this study, the government should work on the mitigation and implementation policy to air pollution problem in bishoftu town to ensure a sustainable Environmental sector. Beside of this the following was recommended as bellow:-

- ☞ It is essential that Bishoftu Environmental Protection Authority should give attention for emission of air pollution from industry site.
- ☞ Governmental organization with other stakeholders should be give attention on air quality management planning with requirements of air pollution.
- ☞ Urban green space, such as parks, playgrounds, buffer, green roof and Green concrete reducing exposure to air pollutants, noise and excessive heat.
- ☞ Advance studies should be conducted on the association between green roof and green concrete in line with ambient air pollution.
- ☞ A cooperative effort should be undertaken to develop and test a new approach to combining information on air quality management.

REFERENCES

Abu-allaban, M., & Abu-qudais, H. (2011). Impact Assessment of Ambient Air Quality by Cement Industry : A Case Study in Jordan, 802–810. https://doi.org/10.4209/aaqr.2011.07.0090

Andrés, M., Luna, G., Alejandro, F., Luna, G., Felipe, J., & Espinosa, M. (2018). Spatial and temporal assessment of particulate matter using AOD data from MODIS and surface measurements in the ambient air of Colombia, *12*(2), 165–177.

Anenberg, S., Miller, J., Henze, D., & Minjares, R. A. Y. (2015). *Pollution-related health impacts of transportation sector emissions in 2010 and 2015*.

Blakeman, S. (2017). A Retrospective Analysis of Open Burning Activity in Kentucky, 30.

Braubach, M., Egorov, A., Mudu, P., Wolf, T., Thompson, C. W., & Martuzzi, M. (2017). Effects of Urban Green Space on Environmental Health , Equity and Resilience, 187–205. https://doi.org/10.1007/978-3-319-56091-5

Central Statistical Authority (CSA) (2007). National Population and Housing Census, Addis Ababa, Ethiopia.

Cogut, A. (2016). *Open burning of waste: a global health disaster*.

Division, E. S., Selin, N. E., Chemistry, A., Committee, T., Reilly, J. M., & Lecturer, S. (2015). Air Quality Impacts and Benefits under U . S . Policy for Air Pollution , Climate Change , and Clean Energy.

EPA. (2014). *A Guide to Air Quality and Your Health*.

EPA. (2016). *Ambient air quality assessment*.

EPA. (2017). *Air Quality in Ireland 2017- Indicators of Air Quality*.

EPA, & ESID. (2003). *Ambient environment standards for Ethiopia*.

EPA.QA/G-5S.(2012).*Guidance to Sampling Design for Environmental Data Collection* for U.S. Environmental Protection Agency.

Evans, M. J. (2018). *Policy-relevant findings of Dynamics-Aerosol-Chemistry-Cloud Interactions in West Africa (DACCIWA) Project*. https://doi.org/10.5281/zenodo.1476843

Fantke, P., Jolliet, O., Evans, J. S., Apte, J. S., Cohen, A. J., Hänninen, O. O., … Mckone, T. E. (2015). Health effects of fine particulate matter in life cycle impact assessment : findings from the Basel Guidance Workshop, 276–288. https://doi.org/10.1007/s11367-014-0822-2

Gozzi, F., Ventura, G. Della, Marcelli, A., & Lucci, F. (2017). Current Status of Particulate

Matter Pollution in Europe and Future Perspectives : a Review, *8*(6), 1901–1909.

Guendehou, G. H. S., & Koch, M. (2006). *CHAPTER 5 INCINERATION AND OPEN BURNING*.

Haritash, A. K. (2006). Assessment of ambient air quality in urban centres of activities and health risks, 27–40. Https://doi.org/10.1007/s10661-005-9161-x

Kasim, O. F., & Abshare, M. W. (2017). Analysis of air quality in Dire Dawa , Ethiopia Analysis of air quality in Dire Dawa , Ethiopia. *Journal of the Air & Waste Management Association*, *00*(00), 1–11. https://doi.org/10.1080/10962247.2017.1413020

Khaefi, M., Geravandi, S., Hassani, G., Yari, A. R., Soltani, F., Dobaradaran, S., … Mohammadi, M. J. (2017). Association of Particulate Matter Impact on Prevalence of Chronic Obstructive Pulmonary Disease in Ahvaz , Southwest Iran during 2009 – 2013, 230–237. https://doi.org/10.4209/aaqr.2015.11.0628

Kondo, M. C., Fluehr, J. M., Mckeon, T., & Branas, C. C. (2018). Urban Green Space and Its Impact on Human Health. https://doi.org/10.3390/ijerph15030445

Muindi, K. (2017). *Air Pollution in Nairobi Slums : Sources , Levels and Lay Perceptions Air Pollution in Nairobi Slums : Sources , Levels and Lay Perceptions*.

Mukesh, S., & Maloo, S. (2005). Assessment of ambient air PM 10 and PM 2 . 5 and characterization of PM 10 in the city of Kanpur , India, *39*, 6015–6026. https://doi.org/10.1016/j.atmosenv.2005.04.041

Oromia Urban Planning Institute (OUPI) (2019). Structural Plan of Bishoftu Town,

Demographic Profile, Utilities, and Social Services Final Report, Addis Ababa, Ethiopia.

Pansuk, J., & Junpen, A. (2018). sustainability Assessment of Air Pollution from Household Solid Waste Open Burning in Thailand, (July). https://doi.org/10.3390/su10072553

Rohde, R. A., & Muller, R. A. (2015). Air Pollution in China : Mapping of Concentrations and Sources, (2), 1–14. https://doi.org/10.1371/journal.pone.0135749

Roth, S. (2017). Air pollution , educational achievements , and human capital formation Exposure to elevated levels of air pollution adversely affects, (August), 1–10. https://doi.org/10.15185/izawol.381

Saitanis, C. (2005). Comparative assessment of ambient air quality in two typical Mediterranean coastal cities in Greece, *59*, 1125–1136. https://doi.org/10.1016/j.chemosphere.2004.11.059

UNEP. (2018). *Addis Ababa City Air Quality Policy and Regulatory Situational Analysis*.

WHO. (2000). *Air quality guidelines for Europe*.

WHO. (2007). Health relevance of particulate matter from various sources Health relevance of particulate matter from various sources.

Yolsal, H. (2016). Estimation of the air quality trends in istanbul, (2). https://doi.org/10.14780/iibd.98771

Zhao, W. C., Cheng, J. P., Yu, Z. Y., Tang, Q. L., Cheng, F., Yin, Y. W., & Wang, W. H. (2013). Levels , seasonal variations , and health risks assessment of ambient air pollutants in the residential areas, 487–494. https://doi.org/10.1007/s13762-013-0178-3

APPENDIX

Table 5 Data collection of pollutants concentration in all sample sites

Site	Sample sites	PM2.5 µg/ m3	PM10 µg/ m3	CO2 µg/ m3	CO µg/ m3	SO2 µg/ m3	NO2 µg/ m3	VOC µg/ m3
S1	Ashewa Tera	61.2	133	411000	4300	250	20	2168500
S2	Get Eshet	32	252.5	418000	11500	710	5	2063000
S3	Zikuala	40	72	311000	8300	350	76	1978000
S4	Mikael	45	118.8	458000	5400	600	5	1818000
S5	Menahiriya	40.5	211	348000	100	450	75	2003000
S6	Circle	16.2	34.1	383000	13000	6000	44	1388000
S7	Gebiya	30	106	384000	9500	300	5	1700000
S8	60mazoriya	61	82.8	427000	ND	ND	ND	2211000
S9	105 Sefer	19.9	34.2	432000	ND	ND	ND	2441000
S10	Sunshine	20.65	28.9	372500	ND	ND	ND	1910000
S11	Goma Zaf	13.6	20.5	397000	ND	ND	ND	1402000
S12	Mandube	58.9	75.2	377000	ND	ND	ND	980000
S13	Kebele 06	19	45.8	401500	ND	ND	ND	1474000
S14	Kata 08	19.5	56	335000	ND	ND	ND	1800000
S15	Babogaya 09	20.2	37.1	299000	6900	650	4	1200000
S16	Seranti Resort	44.7	62.3	453000	ND	ND	ND	3120000
S17	Around Mendube	42.65	62.2	453000	ND	ND	ND	3120000
S18	Holand Dairy	43.25	62.1	453000	ND	ND	ND	3120000
S19	Adulala Resort	14.05	26.2	296500	ND	ND	ND	3120000
S20	Babogaya Rec.Cent.	13.8	26.9	301500	ND	ND	ND	3120000
S21	Meat and Milk Industry	14.15	24.9	299000	ND	ND	ND	3120000
S22	Kuriftu Resort	48.45	56.5	45000	ND	ND	ND	2977500
S23	Gurage Amba	44.15	58.25	455000	ND	ND	ND	2978500

S24	Erecha site	64.5	91.3	487500	ND	ND	ND	2185000
S25	Ras Hotel	64.5	95.1	481500	ND	ND	ND	2172000
S26	Mendube	64.5	81.5	483000	ND	ND	ND	2183000
S27	Pyramid Hotel	42.8	61.45	423000	2900	ND	ND	2304000
S28	Bishoftu Hotel	44	61.9	423000	2750	ND	ND	2307000
S29	Gezahegn Hotel	41.6	61.9	423000	2750	ND	ND	2301000
S30	Steely RMI	863.6	1999	494000	9400	3090	250	1300000
S31	Abysinia steel	831	1835	358000	17400	980	23	1300000
S32	C&E Brothers	232	482	437000	7800	310	17	1700000
S33	Sentinail	116.9	815	432000	5300	310	ND	2243000

Table 6 data collection of pollutants land use, coordinates and altitude in all sample sites.

Site	Specific Location	Land Use	GPS location		Altitudes (M)
			X	**Y**	
S1	Ashewa Tera	Commercial Site	492896	969207	1895
S2	Get Eshet		493831	968374	1907
S3	Zikuala		495349	967363	1898
S4	Mikael		496649	966821	1883
S5	Menahiriya		496663	967221	1883
S6	Circle		498244	967077	1900
S7	Gebiya		499056	967077	1880
S8	60mazoriya		499031	966433	1892
S9	105 Sefer	Residence Site	493436	967714	1922
S10	Sunshine		494009	969069	1906
S11	Goma Zaf		496446	966506	1983
S12	Mandube		497138	967659	1907
S13	Kebele 06		499187	967598	1872
S14	Kata 08		500253	966337	1869

S15	Babogaya 09		500209	971274	1877
S16	Seranti Resort	Recreational Site	496657	967608	1879
S17	Around Mendube		498017	969655	1879
S18	Holand Dairy		496099	968755	1886
S19	Adulala Resort		499462	971899	1866
S20	Babogaya Rec.Cent.		499721	971002	1834
S21	Meat and Milk Industry		498857	971127	1882
S22	Kuriftu Resort		500148	970667	1858
S23	Gurage Amba		500274	970265	1867
S24	Erecha site		499526	968966	1851
S25	Ras Hotel		499314	968024	1854
S26	Mendube		498458	968889	1852
S27	Pyramid Hotel		498474	966741	1898
S28	Bishoftu Hotel		497497	966584	1892
S29	Gezahegn Hotel		497476	966009	1864
S30	Steely RMI	Industry Site	494824	965728	1957
S31	Abysinia steel		494338	965278	1970
S32	C&E Brothers		494515	964517	1981
S33	Sentinail		493111	965776	1963