UNIVERSITY OF CAPE COAST

AMBIENT AIR QUALITY ASSESSMENT AT A PALM KERNEL OIL PRODUCTION SITE IN CAPE COAST

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BY

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Thesis submitted to the Department of Physics of the School of Physical
Sciences, College of Agriculture and Natural Sciences, University
of Cape Coast, in partial fulfilment of the requirements for the
award of Master of Philosophy degree in Physics

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DECLARATION

Candidate’s Declaration

I hereby declare that this thesis is the results of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate’s signature …………………………… DATE…………………..

Name: Victoria Adu-Abrefa

Supervisors’ Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor’s Signature: ………………….. DATE ………………

Name: Dr Francis Gorman Ofosu

Co-Supervisor’s Signature: ………………………… DATE…………………

Name: Dr George Aggrey

ABSTRACT

Ambient air inhalable particulate matter, Black Carbon (BC) and heavy metal concentration levels in the ambient air derived from combustion at a local palm kernel production site was assessed in this study. The goal of this work was to identify the effect of biomass burning from palm kernel oil production activities on ambient air quality at Akotokyir and its environs and the possible health effects. An IVL sampler and a Sierra Anderson (GAST) pump were used to sample PM_{10} air particulate matter from 20th December, 2014 to 23rd March, 2015. Elemental and black carbon concentrations were determined using Atomic Absorption Spectroscopy and Smoke Stain Reflectometer respectively. The average mass concentration of the PM_{10} particulates was found to be 121.19 $\mu g/m^3$ with maximum and minimum values of 658.68 $\mu g/m^3$ and 21.01 $\mu g/m^3$ respectively. The maximum and minimum BC mass concentration in PM_{10} particulates were 30.04 $\mu g/m^3$ and 11.42 $\mu g/m^3$ respectively and the mean percentage of BC was 8.5%. Fe, Mn, Cu, Zn, Pb, Ni, Cd, Cr, Co, Ca, Mg, Na and K in the air particulates were analysed using Atomic Absorption Spectroscopy. Na, Fe, Ca, and Mg were present as major elements whiles the rest were present in trace quantities. Principal Component Analysis (PCA) revealed 5 major sources; biomass burning (36.69%), two stroke engines (17.46%), soil dust (16.76%), and Sea salt (7.81%). The fifth source could not be identified. Comparative Air Quality Index (AQI) analysis revealed that only 48.88% of the sampling days had air quality which could be classified as good, 32.55% as moderate, 6.98% as unhealthy, 6.98% as unhealthy for sensitive group and 4.61 % as hazardous.

KEY WORDS

Ambient air

Biomass

Burning

Exposure

Palm kernel oil

Pollution

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Last but not least, I would like to thank my family and friends for supporting me. Particularly, Dennis for all his help and my course mates, I am grateful to you all.

DEDICATION

To the memory of my late mother, Susana Adu- Owusuaa, and my father, Peter Adu Nyamekye.

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AAS	Atomic Absorption Spectroscopy
ACP-AES	Inductively coupled plasma- Atomic Emission spectrometer
AQI	Air quality index
ATSDR	Agency for Toxic Substances and Disease Registry
BC	Black Carbon
EPA	Environmental Protection Agency
EPHA	European Public Health Alliance.
FAAS	Flame Atomic Absorption Spectrometer
GSS	Ghana statistical service
HDR	Human development report
HSDB	Hazardous Substances Data Bank
IAEA	International Atomic Energy Agency
INAA	Instrumental Neutron activation analysis
LCD	Liquid Crystal Display
LPG	liquefied petroleum gas
PAH	Polycyclic Aromatic Hydrocarbons
PCA	Principal Component Analysis
PIXE	Particle Induced X-Ray Emissions
PM	Particulate Matter
SME	Small and medium scale enterprises
SSR	Smoke Stain Reflectometer
TSP	Total Suspended Particulates
WHO	World Health Organization
XRF	X-Ray fluorescence spectroscopy

CHAPTER ONE

INTRODUCTION

The quality of the air in the atmosphere is affected by pollutants that are emitted in the atmosphere either through human activities or by natural occurrences like volcanic eruptions and wild bush fires. The severity of the problem depends on the capacity of the environment to assimilate the pollutants that are emitted into the environment. Increasing human activities due to population growth and technology has resulted in a rate of emission of pollutants higher than the environment can assimilate. Pollution arouses interest as an environmental issue because it impacts directly on man through effects on food supply, health, buildings and other items of cultural heritage as well as overt effects on forests, rivers, coastlines and familiar ecosystems. A number of studies of have underlined the connection between the presence of pollutants in the air and the occurrence of health problems. Policy makers need information on the quality of the air in any particular environment to enable them develop policies that will help to maintain or improve quality of the air in that environment. This thesis tries to provide information on the effect of palm kernel oil production activities to the ambient air by sampling the air at a site noted for palm kernel oil production. The sampled air will be analyzed for the presence of harmful pollutants. The concentration levels of the pollutants will be used to assess the quality of the air in that environment.

Background to the Study

Pollution has been a global problem since the dawn of civilization and has become one of most serious environmental problems. Pollution can be defined as the introduction of contaminants such as chemical substances or energy indirectly or directly into the environment which results in harmful effects on living organisms, hazards to human health, and cause adverse change in the environment (Harrison, 2001). The Royal Commission on Environmental Pollution also defines pollution as the introduction by man into the environment of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structure or amenity; or interference with the legitimate uses of the environment (Bruce, Perez –Padilla & Albalak, 2000).

Human exposure to pollution is believed to be more intense now than any other time in existence (Schell, Gallo, Denham & Ravenscroft, 2006). Excessive levels of exposure to pollution are causing a lot of damage to human & animal health, plants including tropical rainforests, as well as the wider environment (Prüss-Üstün & Corvalán, 2006). The effects of pollution can be insidious with most of the harmful effects becoming apparent after a long time after exposure or instant depending on the dose and type of pollutant. Global warming, change in climatic condition and loss of biodiversity through to the extinction of many species of both plant and animal can be attributed to environmental pollution. It is extremely essential therefore that attempts are made to control, if not completely prevent pollution.

Pollution has become a global issue due to the combined effects of population growth and technology. The larger the population the greater the pressure on the environment for food production, living space, waste disposal, industrialization, communications and so on(Ehrlich & Holdren, 1971, Seinfeld & Pandis, 1998). To be able to control pollution, there is therefore the need to look at all contributory factors critically to assess their individual contributions and then plan short-term, medium-term and long-term strategies to combat the problem. Without control measures, the waste products from human activities like; heating, agriculture, mining, manufacturing, transportation and other activities, whether they accumulate or disperse, will degrade the environment.

Despite the many efforts that have been made over recent years to clean up the environment, pollution remains a major problem and poses continuing risks to health. According to WHO, an estimated 12.6 million people died as a result of living or working in an unhealthy environment in 2012 alone which represents nearly 1 in 4 of total global deaths. The air we breathe, the food we eat, the water we drink, and the ecosystems which sustain us are estimated to be responsible for 23 per cent of all deaths worldwide (Prüss-Üstün & Corvalan, 2006). During the December 1930 Meuse fog, estimated 60 people died in two days following the fog. A couple of months after the great London smog of December, 1952 saw about 12,000 unexplained deaths during the episode and in the two months after the peak fog gradually decreased. These tragic public events in the Meuse valley and London half a century ago spurred the realization that polluted air could not only cause immediate deaths and illness but could also result in longer-term and subtler effects (Nemery, Hoet & Nemmar, 2001; Firket 1936; Davis 2003).

Pollution is a severe problem in the developing world. Mostly because, sources of pollution such as industrial emissions, poor sanitation, inadequate waste management, contaminated water supplies and exposures to indoor air pollution from biomass fuels affect large numbers of people (Briggs, 2003).

WHO has estimated that environmental exposures contribute to 19% of cancer incidence worldwide. Also, a WHO Global Health Risks report looked at six environmental exposures, (unsafe water, sanitation and hygiene, urban outdoor air pollution, indoor smoke from solid fuels, lead exposure and climate change), and estimated they account for nearly 10% of deaths and disease burden globally and around one quarter of deaths and disease burden in children under the age of five. The connection between pollution, notably toxic substance pollution, and human health has long been made in the developed world (Bruce et al, 2000; Harrison & Yin, 2000*)*. Environmental risk factors, due to air, water and soil pollution, chemical exposures, climate change, and ultraviolet radiation, contribute to more than 100 diseases and injuries. Incidents such as the Love Canal, a hazardous waste site in New York that caused illness in the 1970s, brought industrial pollutants and their effect on human health to a high point in public health studies. Connections between toxic pollution and human health have however, not been clearly ascertained in the developing world (Vrijheid, 2000).

The African is exposed to high pollution levels due to explosive population growth. This population pressure puts a high demand on the environment resulting in the release of harmful chemicals into the environment (Panyacosit, 2000). Increase in industrial activities and improper management of waste has burdened the continent with numerous water, soil and land pollution issues. Most underground water within the mining districts of Africa are heavily contaminated and acidified as a result of oxidation of pyrite (FeS_2) contained within mine tailings dumps, and also has elevated concentrations of heavy metals. Increase in refineries and other industrial activities, for example, thermal and cement plants, power plants, roads and building construction, contribute strongly to pollutants. Adding to this is pollution levels from traffic, burning of household wastes, charcoal and wood as domestic energy sources. Apart from the above is the seasonal incidence of bush burning and harmattan dust that sweeps across most parts of the continent. This puts most African cities and towns at risk of facing very acute public health disease and infections (Pope III, Burnett, Thun, Calle, Krewski, &Thuston, 2002).

With the advent of industrialization, wastes are being generated virtually by every manufacturing or industrial company. These wastes can be gaseous, liquid or solid. Studies of environmental pollution in Africa indicate that toxic metal pollution has reached unprecedented levels over the past decade (Taylor, 1999*)*. Human exposure to toxic metals has become a major health risk on the continent and is the subject of increasing attention from national and international environmentalists.

In Ghana, about 68% of the people live in rural areas. It is not only feasible, but economical to meet the growing demand for portable water by tapping into underground water. However, these ground waters are continually being polluted as a result of poorly designed waste disposal systems, leakage from underground storage tanks, mine tailing and spills among others (Xu & Usher, 2006). One very common source of pollution is the mining sector. Mining and ore processing; artisanal and commercial, is an essential industry in Ghana that supplies minerals, metals and gems needed to produce a wide variety of products and materials for export and local consumption. The process of mining requires great amount of chemicals most of which are usually not treated well before being discharged and eventually find their way into the air, rivers, lagoons and lakes. Lead, chromium, asbestos, arsenic, cadmium and mercury are among the main pollutants from mining activities. Plate 1 is a typical picture showing artisanal mining activities in Ghana.

Plate 1**:** Artisanal mining site in Ghana.

Another source of pollution in Ghana is industrial or municipal dumpsites and landfills. The waste at these dumpsites include waste from batteries, scrap metal, agricultural activities, hospitals, households, chemical waste from industrial processes etc. Such wastes are either solids or liquids with no formal treatment or pollution controls. Landfills may be operated by the government but are often poorly constructed and employ only limited measures for protection against pollution. Contaminated liquids leach from these sites into underground water and other water bodies. Such contaminants contain heavy metals, Volatile Organic Compounds or hazardous organic compounds. These wastes are usually burnt openly with little or no pollution control measure releasing hazardous organic and inorganic substances into the air. Dust from dumpsites contain toxic metals and human pathogens that come into contact with the population by means of air, water and soil.

Plate 2**:** E-waste disposal site.

Plate 3**:** Disposal of liquid waste.

Plate 4**:** Open burning at landfill site in Ghana.

The top sources contributing to lead pollution, by population, are lead smelting, mining and ore processing, industrial estates and lead-acid battery recycling and manufacturing. Lead pollution is also found in polluted sites around product manufacturing sites, e-waste recycling and chemical manufacturing site. Plate 2 is a picture showing an E-waste disposal site in Ghana.

In Ghana, significant amount of aerosols are produced by industrial activities like production of cement by Ghana Cement Company Limited (GHACEM), petroleum refinery by the Tema oil refinery, aluminum production from bauxite, burning of unused fossil fuel during refinery operations and in the production of other manufactured goods whose production processes involve combustion, such as the brick and tile industries. Plates 3 and 4 are pictures showing pollution due to dumping of liquid waste and burning of solid waste under a landfill site.

Cape Coast is bounded to the south by the Gulf of Guinea with a settlement population of about 169,894 people (GSS, 2012 census). Cape Coast is a humid area with mean monthly relative humidity varying between 85% and 99%. Some of the main pollution problem facing this land is the pollution of water bodies. The Fosu lagoon, for instance, has been found to contain Fe, Mn, Zn and Pb (Akoto, Eshun, Darko &Adei, 2014). Due to its position along the gulf, a majority of the population are fisher folks. Fish mongers use biomass generally to smoke their fish which contribute greatly to ambient air pollution. Most households in Cape Coast use biofuel such as charcoal and wood for household cooking and also the increasing vehicular fleet contributes significantly to air pollution in the area.

Types of Pollution

Pollution can either be natural or man-made and is classified according to the part of the environment it affects. There are three main types of pollution; air pollution, land pollution and water pollution.

Land pollution comprises of pollution of the soil animals and plants (fauna and flora) that inhabit it. The soil is the environment that is usually the first to be polluted by the various types of pollutants.

Water pollution involves all water bodies like the sea, rivers, lakes and wells, which may be polluted with raw sewage, factory wastes, laundry detergents and insecticide residues from agricultural activities which are introduced through various activities of man. Human activities, especially agricultural practices, have led to an increase in the levels of nitrogen and phosphorus in the environment. Other polluting substances include minerals, decaying bodies of animals or plants and disease-causing organisms. In rural areas where sanitary safeguards are lacking, pollution is mostly domestic and is mainly from garbage and excreta whilst in urban areas, in addition to the domestic source, there are the industrial sources of pollution to contend with.

Air Pollution

The air we breathe is an essential ingredient for our wellbeing and a healthy life. Unfortunately, polluted air has been common since the 1960s throughout the world (EPHA, 2009) especially in developed countries. Polluted air contains one or more hazardous substance, pollutants, or contaminants that poses a hazard to general health (Beckerman, 1992). The main pollutants found in the air we breathe include; particulate matter, Polycyclic Aromatic Hydrocarbons (PAHs), lead and other heavy metals, ground-level ozone, Sulphur dioxide, benzene, carbon monoxide and nitrogen dioxide (EPHA, 2009).

Particulate matter concentrations that have been observed in many developing countries have been much higher than those seen in developed countries (Smith, 2002). Notable among these causes are rapid urbanization, re-suspended soil dust mainly from unpaved roads, biomass burning, fast growth of vehicle numbers plus the particular pollution-intensive character of most vehicles in developing countries. In many developing countries, motor vehicles are not as fuel efficient as those in industrialized countries because many of these vehicles are relatively old and poorly maintained (Faiz, 1990).

More than three quarters of the region's population, including a large fraction of the urban population, use biomass fuels for cooking (Smith, Mehta & Maeusezahl-Feuz, (2004). Farm lands in many African countries are prepared using the slash-and-burn method which contributes greatly to the amount of particulates released into the atmosphere.

The deteriorating air quality in Ghana is as a result of rapid population growth, increased industrial activities and an unprecedented surge in motor vehicle traffic. The indiscriminate burning of household waste and farm-lands also contributes significantly to air pollution in Ghana (Dotse, Asane, Ofosu & Aboh, 2012). Additionally, the harmattan wind which blows in North-Eastern part of Ghana from December to March carries in its way a lot of dust particles which is a natural source of pollution (Ofosu, Hopke, Aboh &Bamford, 2013).

Air Pollution in Cape Coast

There is little literature on air pollution in Cape Coast as most monitoring stations in Ghana are located in Accra. As a developing urban center, motor traffic is on the rise contributing significantly to pollution in the town. Cape Coast is home to many manufacturing industries that falls within the category of Small and Medium scale Enterprises (SME). The activities carried out at some of these SMEs do not conform completely with environmental quality standards set by the Ghana EPA (EPA. 2010). Pollutants, for instance, are emitted into the atmosphere from quarry sites around the town. Such activities contribute greatly to the total concentration of air particulates in the atmosphere. Combustion sources of air pollutants are the ovens and kilns used by fish mongers, small and medium scale palm kernel oil producers, the open burning of waste and the use of biofuels for household cooking and in educational institutions. There are a number of palm kernel oil production sites dispersed within the Cape Coast metropolis. The Akotokyir site is one of the medium-sized sites with over 30 tripod stands and over 50 women whose livelihood depend solely on this industry.

Statement of the Problem

The atmosphere presently, is quite different from the natural atmosphere that existed before the industrial revolution in terms of chemical composition. Increasing human activities have increased the release of gaseous pollutants including air particulate matter into the atmosphere. This has resulted in concentrations higher than the recommended normal ambient concentrations (Atiemo, Ofosu, Aboh & Oppon, 2012). Inhalable particulate pollution in the atmosphere originates from sources of both natural and anthropogenic processes. Soil dust, biomass burning, industrial emissions and vehicular exhaust emissions are the major sources of the PM_{10} particulate (particulate matter of aerodynamic diameter less than 10 µm). Incomplete combustion processes from motor vehicle, fossil fuel and biomass burning are some of the anthropogenic sources of PM_{10} (Al Mahmud, Salam & Alam, 2008*)*. This eventually has a measurable effect on humans, animals and plants. Particulate Matter (PM) which can be inhaled into the human respiratory system is related to most serious health effects including cancer, pulmonary and cardiovascular illness (Harrison, Smith & Luhana, 1996; Wallenborne, Schladweiler & Richards, 2009).

PM_{10} particulate pollution is one of the major problems in the major cities of developed world, and has also become a serious and worsening situation in rapidly growing cities in the developing world, especially in Africa due to urbanization and industrialization (Dotse et al., 2012). It is estimated that air pollution in urban centers, due to high concentrations of particulate matter (PM), causes about 3% of deaths attributable to cardiopulmonary disease in adults, about 5% of deaths attributable to cancers of the trachea, bronchus and lung, and about 1% of death attributable to acute respiratory infections in children. This amounts to about 80 million premature deaths globally and 6.4 million years of life lost occurring predominantly in developing countries (Cohen et al., 2005). About 1.5 million deaths around the world is attributed to exposure to smoke from biomass fuels, with more than two thirds of these deaths occurring in South East Asia and Sub-Sahara Africa (Atiemo et al.,2013).

The Cape Coast metropolis, a semi-urban area in Ghana is a rapidly growing urban center with people from different socio-economic status. The main source of fuel for household cooking is biomass burning. Akotokyir is a less populated suburb of Cape which is characterized by a lot of open burning; household wood burning, charcoal and palm kernel husk burning (used mainly for the production of palm kernel oil) and construction activities which results, occasionally, in blackening of the surrounding air. Cases of choking smells and irritating eyes have also been observed and reported by inhabitants as a result of such activities.

Numerous epidemiological studies show that air particulate matter in the respirable fraction and traffic-related air pollutants are correlated with severe health effects including enhanced mortality, cardiovascular, respiratory, and allergic diseases (Oberdorster, Oberdorster & Oberdorster, 2005; Schins et al,. 2004*)*. The composition of aerosols is complex and differs depending on the source and location.

Concerns of links between ambient air concentrations of particulate matter with aero dynamic diameter less than 10 µm but most especially 2.5 µm and health risk has grown considerably in the recent decade. Both short and long term exposures influence the populations health and hence the need for consented and more effective action to improve air quality (WHO, 2004). Efficient control of air quality and related health effects requires a comprehensive understanding of the identity, sources, atmospheric interactions, and effects of hazardous pollutants. Without this understanding, the introduction of new laws, regulations, and technical devices for environmental protection runs the risk of being ineffective or even causing more harm than good through unwanted side effects. The levels of air pollution in an area and the contribution of biomass, transport and other sources vary with the neighborhood's socio-demographic characteristics, such as income and population density, the location and meteorological conditions. Data on air pollution levels exist in Ghana mainly for Accra and the northern region where studies are mostly focused on harmattan contribution to PM (Ofosu et al., 2013). Although linkage has been drawn between the use of biofuels and the emissions of some hazardous particulates, there are few studies in this area in Ghana, especially Cape Coast. The absence of data occurs despite the fact that environmental exposures and sanitary exposures could even be worse in these areas (Panyacosit, 2000). Some aerosol studies in Ghana have looked at emissions from industry and domestic biomass burning and their impact on the ambient air quality (Ofosu et al., 2013). This study will provide information for further environmental monitoring, research and policy formulation.

Purpose of the Study

The main purpose of this work is to identify the effects of biomass burning from palm kernel oil production activities on ambient air quality at Akotokyir and the neighboring environment.

Specific Objectives

The specific objectives of this work are:

1. Ascertain the levels of particulate matter in ambient air.
2. Establish daily variations in particulate mass concentrations.
3. Analyze and characterize aerosol particles.
4. Establish source signatures and contributions of the various processes.
5. Establish the total contribution of biomass burning to air pollution in the selected area of assessment.
6. Ascertain the possible health impact of the particulate levels.

Significance of the Study

Atmospheric aerosol and their precursors have increased dramatically over the past century and have been implicated in many areas ranging from human health to climate change. The significance of atmospheric aerosols on local, regional and global environments as a result of vehicular emissions, wood burning fires, palm kernel combustion, urbanization and industrial processes cannot be over emphasized. The findings of this study will therefore contribute significantly to academia by providing information on the composition of the suspended particle and the concentration of each particulate released during the combustion of palm kernel for palm kernel oil production. The findings will also provide a database on aerosol particles released during the indigenous production of palm kernel oil. This will be of help to regulators in monitoring temporal and spatial patterns of concentrations and promote policy initiatives to address air quality in Ghana. Again the findings of the study will help stakeholders in the health sector to characterize exposure-response relationships on key health issues, especially asthma cardiovascular diseases, lung cancer risk from air particulate inhalation and promote policy initiatives to address air quality.

Delimitations

Atmospheric aerosols are particles released through vehicular emissions, wood burning fires, urbanization and industrial processes. Also epidemiological studies have shown that fine air particulate matter and traffic-related air pollution correlate to severe health effects, including enhanced mortality, cardiovascular, respiratory, and allergic diseases. This study however, will focus on biomass burning contribution to ambient air particulate and the health effects associated with air pollution in relation to particulate levels and heavy metal contents.

Limitations

Elemental analysis by Atomic Absorption Spectroscopy alone could not identify all elements that were present in the sample. Hence Ion chromatography was used to determine the presence of Calcium, Sodium and Potassium ions which are important in this study.

Organization of the Study.

Chapter one outlines the introduction to pollution. This includes the different types of pollution and their effects on climate, vegetation and health. The impact of pollution globally, in Africa, Ghana and Cape Coast were also discussed. In Chapter two, atmospheric aerosols, their sources and compositions of some of the aerosols was discussed. Some prominent particulates and their effect was also discussed. The chapter also outlined some instrumental methods of analyzing the particulates. Chapter three deals with the materials and methods that were adopted in the study. The results and discussion with the conclusions drawn and recommendations were presented in cheaters four and five.

Chapter summary

Among the many factors that can contribute to a polluted air as mentioned in this chapter, the activities of palm kernel oil production was chosen to be used to assess air quality at a site in Cape Coast. The effects of the different types of pollution, including the burden of pollution globally, in Africa, Ghana and Cape Coast were elaborated in this chapter. Finally, the significance of the study, delimitations and limitations were also discussed.

CHAPTER TWO

LITERATURE REVIEW

Introduction

The extent of pollution of the air in any environment is peculiar to the type and quantity of pollutants that are introduced into that environment. For accurate information on the quality of the air in any environment, air monitoring must be done within that local area. Various industrial activities introduce different and varying concentrations of pollutants into the atmosphere. Previous air monitoring in Ghana has focused on emissions from vehicular traffic, harmattan winds and bush burning and emissions from different residential areas. This thesis measures emission from palm kernel oil production and how it affects the quality of the air at a site in Cape Coast. This chapter presents different sources of pollutions and the pollutants peculiar to this sources. It also outline various techniques employed in analyzing pollutants and the theories employed. Relevant literature in support of the study was also explored.

Atmospheric Aerosols

Atmospheric aerosols are a colloidal suspension of fine solid particles and liquid droplets directly emitted into the atmosphere and particles that are formed during gas to particle photochemical processes. They can also be described as condensed phase materials suspended as discrete particles in a gas (Pope et al, 2002). Aerosols comprise a wide range of particles having different compositions, sizes, shapes and optical and chemical properties. They have the potential to significantly influence our entire planet through their role in heterogeneous chemistry in the troposphere and stratosphere (Finlayson-Pitts & Pitts, 2000)

Once airborne, some aerosols undergo various physical and chemical interactions and transformations that can change their size, structure and composition resulting in the formation of new particles as shown in Figure 1. This happens by condensation of vaporized species, evaporation, coagulation with other particles, chemical reaction, or by activation in the presence of water vapor. They can be classified as primary or secondary aerosols. Primary aerosols are injected directly into the atmosphere whilst secondary aerosols are formed within the troposphere by local chemistry from some primary aerosols. Some pollutants may also be both primary and secondary, that is they are both emitted directly and also formed from other primary pollutants (Atiemo, et al., 2012).

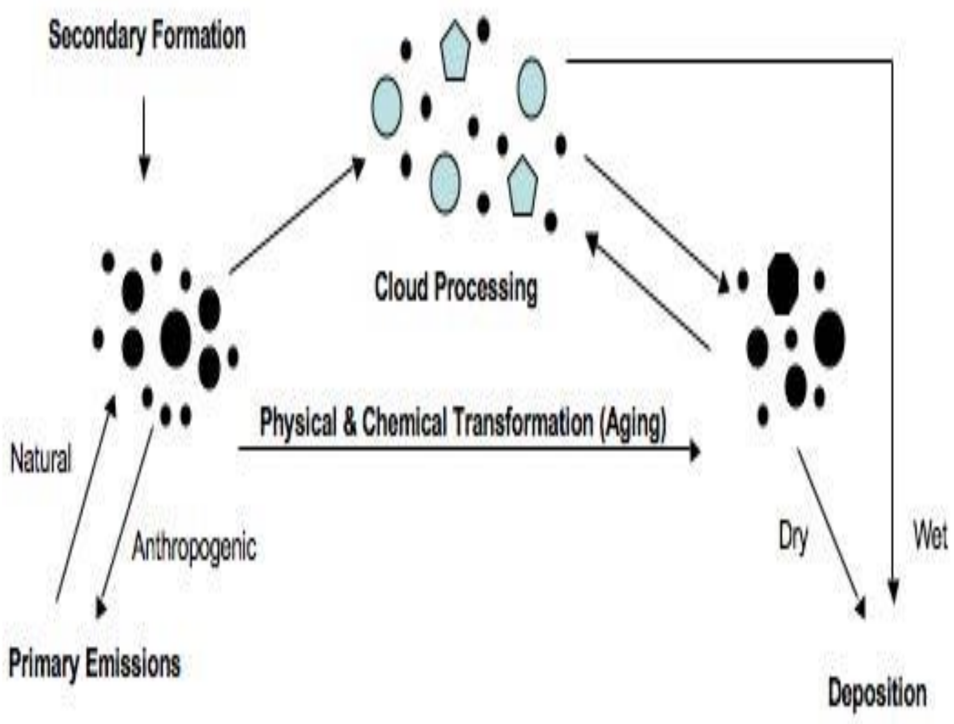

Figure 1**:** Aerosol cycling in the atmosphere.

Some primary pollutants known to cause harm when in high concentrations are Carbon compounds (CO, CO_2, CH_4 and VOCs), Nitrogen compounds (NO, N_2O and NH_3) and Sulphur compounds (H_2S and SO_2). Some secondary pollutants known to cause harm when in high concentrations are:

- NO_2 and HNO_3 formed from Nitrous Oxide
- Ozone (O_3) formed from photochemical reactions of nitrogen oxides and VOCs.
- Sulphuric acid droplets formed from SO_2 and nitric acid droplets formed from NO_2
- Sulphates and nitrates aerosols e.g., $(NH_4)_2SO_4$ and NH_4NO_3 formed from reactions of sulphuric acids droplets and nitric acid droplets with NH_3 respectively
- Organic aerosols from VOCs in gas -to- particle reactions (Seinfeld & Pandis, 1998; Dotse et al, 2012).

  While some of these particles have shorter residence time; that is from a few hours to a day, some can stay in the atmosphere for days and even weeks travelling to other regions away from the source depending on its properties and meteorological conditions.

Sources of Aerosols

Aerosols in the atmosphere arise from natural sources as well as anthropogenic activities (Seinfeld & Pandis, 1998). Natural sources of aerosols include sea spray, windblown mineral dust, emissions from volcanic activities, biological decay and smoke from burning of land biota. Emissions of particles attributable to the activities of humans i.e. anthropogenic sources of aerosols, arise primarily from four source categories: fuel combustion, industrial processes, nonindustrial fugitive sources (e.g. construction work), and transportation sources (e.g. automobiles). Soot, smoke, road dust, etc. are examples of primary anthropogenic particle emissions whilst Sulphate and nitrates formed from the oxidation of SO_2 and NO_3 respectively are as a result of the conversion of anthropogenic gases from combustion of fossil fuels.

Natural sources of aerosols can be classified as geogenic and biogenic emissions (Dotse et al., 2012). Geogenic emissions are emissions caused by the non-living world, such as volcanic emissions, sea-salt emissions and natural fires. Biogenic emissions come from the living world such as Volatile Organic Compound (VOC), emissions from forest and methane gas emission from swamps. Human activities can influence both geogenic and biogenic emissions. For example, the application of nitrogen fertilizers in agriculture can result in increased biogenic emissions of nitrogen compounds from the soil while the cutting down of trees, increase VOC emissions.

Anthropogenic sources of atmospheric air pollutants can either be classified as mobile or stationary sources. Emissions from vehicles exhaust is an example of mobile sources of anthropogenic aerosols and accounts for about 40 percent to 45 percent of all pollutants in the world. They release large levels of polycyclic aromatic hydrocarbons, benzene, metal elements, carbon monoxide, Sulphur dioxide, and formaldehyde into the atmosphere. Common stationary or immobile source emissions are from power plants, industrial factories and furnaces (Smith, 2002). Figure 2 shows some sources of atmospheric aerosols and sinks. Table 1 gives a description of common sources of aerosols.

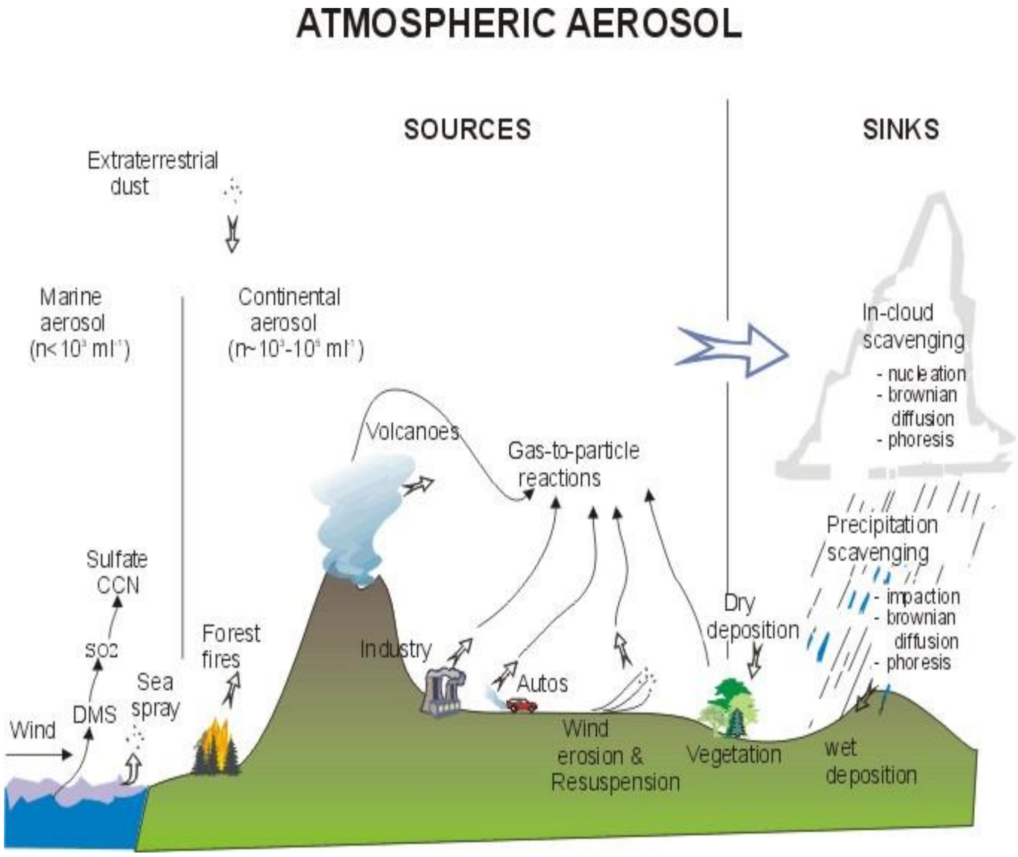

Figure 2: Some sources of aerosols and sinks.

Source: Seinfeld & Pandis, (2016).

Table 1**:** Description of some sources of aerosols

Airborne material	**Size range (µm)**	**Description**
Dust (Airborne)	0.1 -30.0	Generated by crushing of solids. Typical examples are rocks, metal, wood, and coal dust. Particle size may be up to 300 -400 µm, but the larger particles do not remain airborne.
Mists	0.01 -10.0	Suspended liquid particles formed by condensation from gaseous state or by dispersion of liquids. Mist occur above open surface electroplating tanks.
Smokes	0.01 -1.0	Aerosols mixture from incomplete combustion of organic mixture. It does not however include fly ash which is bigger.
Fumes	0.001 -1.0	Small solid particles created by condensation from vapor state. Especially volatized metals as in welding or melted plastic material. Fumes tend to coalesce into larger particles as the small fume particles collide.
Vapors	0.005	Gaseous from of materials that are liquid or solid at room temperature.
Gases	0.0005	Materials that do not usually exist as solids or liquids at room temperature, such as Carbon monoxide and ammonia. Under sufficient pressure, and or low temperature, they can be changed into liquids or solids.

Source: Hildemann, Markowski & Cass, (1991).

Combustion

This is a chemical process between fuel and an oxidizer, usually atmospheric oxygen, which oxidizes to produce smoke under high temperature. It is usually a complicated sequence of reactions. Pollution sources may vary greatly but the atmosphere is the predominant route for combustion derived contaminants, including organic molecules such as polycyclic aromatic hydrocarbons (PAHs) and heavy metals such as Lead (Pb) (Leorri, Mitra, Irabiaen, Zimmerman, Blake & Cearreta, 2014). Sources of combustion could be area or point source, stationary or mobile source, and outdoor or indoor source. Sources such as combustion of fuel in motor vehicles, aircraft and boats as well as small sources such as lawn mowers are classified as outdoor and mobile whilst sources like industrial plants, power plants, refineries, etc. are outdoor and stationary. Indoor combustion sources are related mainly to cooking, heating and tobacco smoking (Smith, 2002). Sources of combustion in the rural areas of developing countries differ quite significantly from those observed in most urban centers. This makes air pollution tends to be worse in rural indoor environments than urban outdoor environments (Smith, 2002; Panyacosit, 2000). Combustion generates a large number of particulate and gaseous products that create significant health and environmental risks. Other combustion sources apart from household include industrial related combustions, vehicular and biomass and fossil fuel combustion.

Sources of Combustion

Vehicular emissions: There is a continual increase in emission from vehicles. Particulates emitted from vehicles differ primarily due to the different fuels used in vehicles. Burning of different types of fuels results in emissions of different trace elements which are present in the fuel material. Emissions from vehicles include concentrations of black carbon, PAHs and heavy metals such as: B, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Ba, Pb. Fe, Ca, and Zn originating from the additives in lubricating oil (Morawska & Zhang, 2002).

Biomass and Bush Burnings

Biomass burning includes controlled or uncontrolled bush burning as well as burning for the purpose of heating and cooking. Bush fires affects many parts of Ghana and occurs on regular basis in many parts of South Asia, Africa, South America and Australia (Atiemo et al., 2012). Particulate emissions from biomass vary with both the combustion conditions and the fuel type. The particles are mostly Elemental Carbon (EC) and Organic Carbon (OC), but also contain levels of K, Cl, S Al, Si, P, Zn, Pb, and Fe (Lighty et al., 2000). Majority of the particles emitted from biomass burning are within the respirable size range.

Industrial Burning

Most industrial facilities e,g steam/electric generating plants, industrial boilers, steel mills, etc. burn fossil fuels or biomass in their operations. Coal, fuel oil, and natural gas are the major fossil fuels used by these sources. Other industrial emissions generated by incinerators, chemical plants, metal smelters, petroleum refining plants, charcoal making kilns, and paper mills. Industrial combustion sources are responsible for the emission of trace amounts of heavy metals and PAH. The burning of solid wastes as a method of disposal also contribute to this metals and PAHs.

Household Burnings

Due to availability and affordability, unprocessed biofuels such as wood, charcoal, kerosene are used in most developing countries. These fuels are high emitters of particulate matter and a multitude of other pollutants such as sulfur oxides, nitrogen oxides, hydrocarbons, carbon monoxide and known carcinogens such as 1, 3 butadiene, benzene and benzo[A]pyrene (Panyacosit, 2000). A great number of households in Ghana cook and/or heat daily using unrefined biomass fuels (e.g., animal dung, crop residue, wood, charcoal). These fuels are high emitters of, PAHs, CO, and other air pollutants. Burning coal and its derivatives usually produce more air pollutants, in greater amounts, than burning liquid fuels or gas (Smith, 2002; Zhang &Smith, 2000). The impact of exposure due to household open burning is particularly high, as particulates are emitted directly into the spaces at times of human occupancy. Those who are most affected, are those who belong to susceptible groups (infants, sick, elderly), and these at the same time are those who spend a significant amount of time indoors. Studies reveal that 50-80% of particulate emissions from cooking stoves are in a respirable fraction of < 2 μm size and a large amount of the PAHs are also found in this fraction (Li et al., 2005).

- Wood burning

  The emissions from wood and charcoal burnings have been found to be acidic and rich in elemental carbon as well as measurable quantity of Na, K, Fe, Br, Cl, Al, Sr, Ba, and some nitrate and sulfate (Morawska & Zhang, 2002).

- Palm kernel shell

Palm kernel shells are the fractions left when the nut has been removed after crushing in the Palm oil mill. Most palm oil mills in the metropolis burn the palm kernel shells and mesocarp fibers for fuel.

Palm kernel shells which contain residues of Palm oil are mixed with small dust-like fractions and used as fuel. Associated with the burning of these solid fuels are the emissions of dark smoke and the carry-over of partially carbonized fibrous particulates due to incomplete combustion (Zafar, 2015; Xingang, Jieyu, Xiaomeng, Tiantian & Pingkuo, 2012). Plates 5 and 6 shows pictures of emissions from palm kernel husk burning and emissions during the production of palm kernel oil. Plate 7 shows a picture of emission from bush fire.

Plate 5: Emission from burning of palm kernel husk.

Plate 6: Emission of pollutants from palm kernel oil production.

Plate 7: Pollutants emissions from bush burning.

Chemical Composition of Emissions from Combustions

The major chemical compositions of combustions are trace metal elements such as K, Cl, S Al, Si, P, Zn, Pb, and Fe, PAHs and black Carbon which constitutes particulate matter and other gasses like CO, CO_2, NOx, SO_2, HC, and water vapor (Morawska &Zhang, 2002). Inhalation of trace metals in dust or mists cause irritations to the eyes, nose, and lungs with sneezing, coughing and sore throat. Higher exposures may cause death.

Nitrogen Oxides (NO_x) can cause lung irritation and weaken the body's defense against respiratory infections such as pneumonia and influenza. In addition, they assist in the formation of ozone and other particulate matter. In many cities, NO_x pollution accounts for one third of the fine particulate pollution in the air.

Carbon monoxide (CO) is an odorless gas formed by the combustion of fossil fuels such as gasoline. Cars and trucks are the source of nearly two-thirds of this pollutant. It blocks the transport of oxygen to the brain, heart and other vital organs in the human body when inhaled. New born children and people with chronic illness are especially susceptible to the effects of carbon monoxide (Safo Adu et al, 2014).

Sulphur dioxide (SO_2) is also another harmful pollutants from the burning of Sulphur containing fuels. It react in the atmosphere to form fine particles and pose a health risk to young children and asthmatics (Valavanidis, Fiotakis, & Vlachogianni, 2008).

Impact of Pollutants

Air pollutants have a wide range of impacts, with health problems being the most enduring concern. In a typical polluted atmospheres filled with smoke, a wide range of bronchial disease are enhanced. While respiratory diseases are still the principal problem, the issues are somewhat subtler in atmospheres where the air pollutants are not so obvious. In photochemical smog, eye irritation from secondary pollutants is one of the most characteristic direct effects of smog. A high concentration of carbon monoxide in cities where automobiles operates at high density means that the human heart has to work harder to make up for the oxygen displaced from the bloods hemoglobin by carbon monoxide. This extra stress appears to reveal itself through increased incidence of complaints among people with heart problems. Lead emissions, is thought by many to be a factor in lowering the Intelligent Quotients (IQ) of children. Exposure to indoor particulate, from combustion of biofuels such as wood, charcoal, agricultural residues, and dung, has been associated with respiratory disease in less-developed countries, Studies of both short-and long-term exposures to combustion emissions and ambient fine particulate air pollution have been associated with concerns of genetic damage. Long-term epidemiologic studies have reported an increased risk of all causes of mortality, such as cardiopulmonary mortality, and lung cancer mortality due to increasing exposures to air pollution. Adverse reproductive effects (e.g., risk for low birth weight) have also been reported in Eastern Europe and North America (Lewtas, 2007). The International Energy Agency (IEA) reported in 2015 that about three million of the 6.5 million deaths that occur yearly worldwide are attributed to outdoor air pollution with 3.5 million being caused by household air pollution (WHO, 2006).

Particulate Matter (PM)

Particulate matter is a complex mixture of organic and inorganic solid particles and liquid droplets found in the air. It includes dust, ash, dirt, soot, pollen, smoke, spores, PAHs, pesticides and many others suspended in the air. They can be released into the atmosphere from both natural and anthropogenic sources. Some particles are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope.

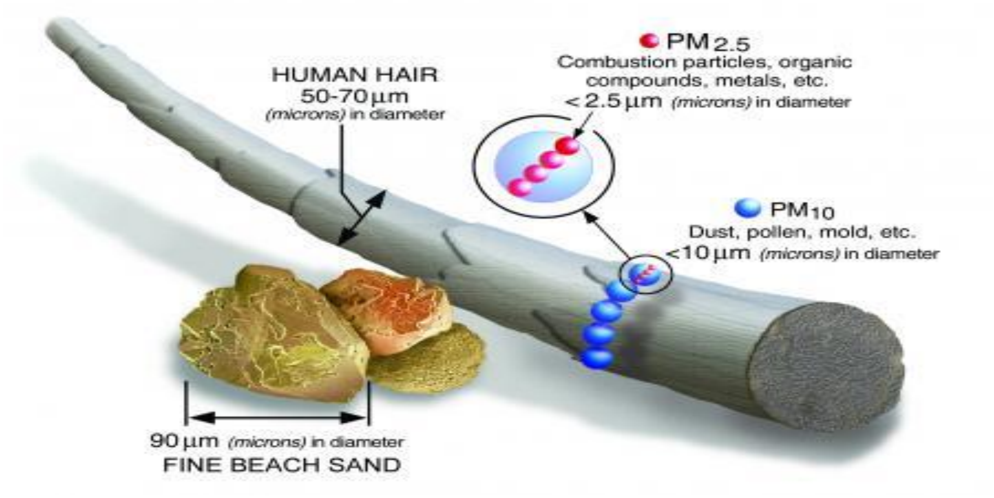

Figure 3**:** Size Comparison for PM.

Source: EPA, (2016).

Particulates vary in sizes from 0.01 µm -100 µm in diameter (Awan et al., 2011). Ultra-fine or Aitken mode particles have diameters less than 100 nm (0.1 µm). PM with diameter less than 2.5 µm are collectively called fine aerosols ($PM_{2.5}$) whilst those with diameter between 2.5 µm and 10 µm are known as coarse particles (PM_{10}). The fine or accumulation mode (also termed the respirable particulate matter) is attributed to growth of particles from the gas phase and subsequent agglomeration, while the coarse mode is made of mechanically abraded or ground particles. Fine particulates are also known as respirable particulates. The residence time of particles in the atmosphere depends on their aerodynamic diameters. Particles of natural origin e.g. dust and sea salt are mainly in the coarse particles range and therefore settle faster than anthropogenic generated aerosols which are usually in the fine range. Also the concentration, composition, and size distribution of atmospheric aerosol particles vary temporally and spatially. Table 2 shows a comparison of fine and coarse particle.

Table 2**:** Comparison of fine and coarse mode particles

ITEM	FINE PARTICLES	COURSE PRTICLES
COMPOSITION	Sulfate,SO_4^{2-}; Nitrate, NO_3^-; Ammonium, NH_4^+; Hydrogen ion, H^+; Elemental carbon, C; PAH; Metals, Pb, Cd, V, Ni, Cu, Zn; Particle-bound water; Biogenic organics.	Re-suspended dusts, soil dust, street dust; Coal and oil fly ash; Metal oxides of Si, Al, Mg, Ti, Fe. $CaCO_3$, NaCl, sea salt; Pollen, mold spores, plant parts
SOURCES	Combustion of coal, oil, gasoline; Transformation products of NOx, SO_2, and organics including biogenic organics, e.g., terpenes; High temperature processes; Smelters, steel mills, etc.	Resuspension of soil tracked onto roads and streets; Suspension from disturbed soils, e.g., farming, mining; Resuspension of industrial dusts; Construction, coal and oil Combustion, ocean spray.
LIFE TIME	Days to weeks	Minutes to hours
TRAVEL DISTANCE	100 to 1000s of kilometers.	1 to 10s of kilometers.

Source: Wilson & Suh, (1997).

Particulates are eventually removed from the atmosphere by two main mechanisms. They can settle by gravity unto the soil, on leaves of plant or on water bodies in a process known as dry deposition or they can be incorporated into cloud droplets during the formation of rain in a process known as wet deposition. This can occur within days to weeks of formation and after travelling within meters to thousands of kilometers (Pope et al, 2002). Small particles grow into larger ones via collision and aggregation and gradually settle out. The settling velocity in wind-free air is determined by the balance of two forces; frictional force and gravitational forces. Fine particles pose the most serious threat to human health by penetrating deep into the lungs. Examples of fine particulates are asbestos fibers, cigarette smoke, vehicular exhaust emissions and biomass smoke. (Wilson & Suh, 1997).

Aitken particulates

These are particles with radii less than 0.1 µm. They are the worse causes of lung damage because of their ability to penetrate the innermost passages of the lungs. They contribute to in-door air pollution. Fine and Aitken particulates are of great concern because they are able to pass more easily through the membranes of the throat and nose and enter into the lungs which can cause serious damage to the pulmonary and respiratory system (Safo-Adu et al., 2014). The deposition of particles in the respiratory system is shown in Figure 4. Basically, the smaller the particle, the more likely it will penetrate deeper in the lungs and eventually end up in the blood stream. Table 3 gives a relation between respiratory penetrations of particulates and the particle size.

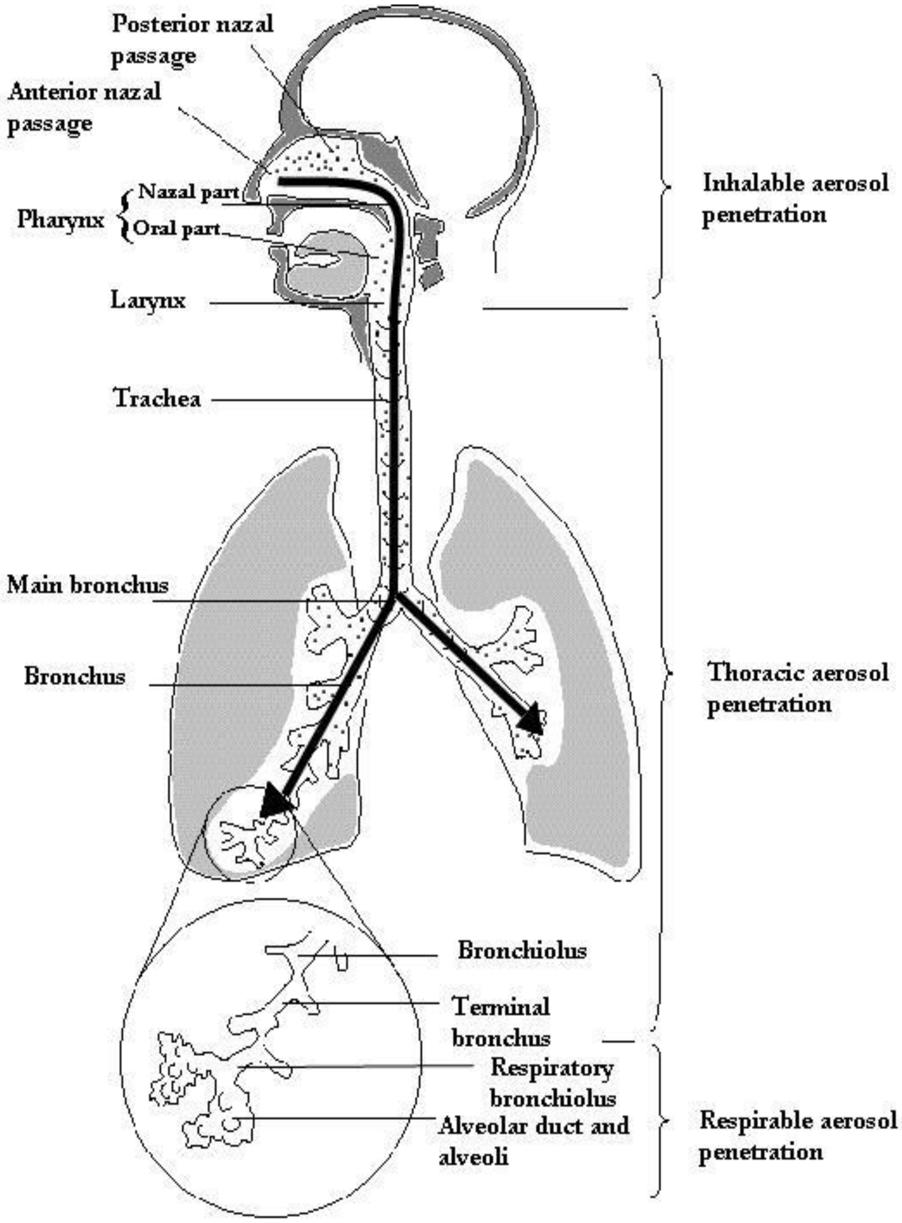

Figure 4: Deposition of air particulates in the respiratory system.

Source: Dockery & Pope, (1994).

Table 3: Respiratory penetration verse particle size

Particle size range	Penetration of particle
11µm and above	Do not penetrate
7-11 µm	Penetrate nasal passage
4.7-7 µm	Penetrate pharynx
3.3-4.7 µm	Penetrate trachea and primary bronchi
2.1-3.3 µm	Penetrate secondary bronchi
1.1-2.1 µm	Penetrate terminal bronchi
0.65-1.1 µm	Penetrate bronchioles
0.43-0.65 µm	Penetrate alveoli

Source: Panyacosit, (2002).

A number of studies that have been undertaken to examine the link between particulate emission and health have demonstrated strong links even though there are many uncertainties as to some of the precise mechanisms involved in connecting human health impacts and pollutants (Ramanathan et al., 2001). The Environmental Protection Agency of Ghana (EPA Ghana) collaborated with the United States Environmental Protection Agency (USEPA) and the United Nations Environment Programme (UNEP) to set up the first comprehensive air quality monitoring between March 2005 and December 2008. The pollutants measured for roadside locations included CO, PM_{10}, SO_2, NO_2, lead (Pb) and manganese (Mn). Out of a total of 745 roadside samples collected, 75% and 87% exceeded the Ghana EPA and WHO 24 hour PM_{10} air quality guideline of 70 $\mu g/m^3$ and 50 $\mu g/m^3$ respectively. Particulate manganese concentration ranged from 0.0001- 0.64$\mu g/m^3$, all other results were below the

24 hour EPA- Ghana guideline 1.0 µg/m^3. It was concluded by the end of the monitoring programme that the roadside locations that were monitored had high levels of PM_{10} compared with residential, industrial and commercial areas. The PM_{10} levels measured during the dry season were far higher than that measured during the wet season (Ofosu et al., 2012). The World Health Organization (WHO) estimates that 70% of global urban populations especially in third world countries breathe unhealthy particulate matter confirming epidemiological studies which show that particulate matter has adverse health effect, affecting both the respiratory and cardiovascular systems (Dockery et al., 1993, Pope et al, 2002,).

The levels of PM_{10}, $PM_{2.5}$ and Black Carbon particulates were measured at a site 1.1 km from the central business center of Ashaiman, an area with the highest population growth rate of about 4.6% (GSS, 2002). This was carried out for 90 days between February and May, 2008. The mean concentrations of PM_{10}, $PM_{2.5}$ and BC particulates obtained in the study are shown in Table 4. (Dotse et al., 2012).

Table 4: Mass concentration of PM_{10}, $PM_{2.5}$ and BC in the ambient air at Ashaiman measured between February and May 2008

Particulate	Maximum/ (µg/m^3)	Minimum (µg/m^3)	Mean/ (µg/m^3)
$PM_{2.5}$	46.43	3.85	23.26
PM_{10}	293.06	37.10	96.56
BC ($PM_{2.5}$)	4.89	1.67	2.83
BC (PM_{10})	12.44	1.99	3.98
% BC ($PM_{2.5}$)	63.14	6.12	18.40
% BC (PM_{10})	12.62	1.07	4.86

Source: Dotse et al., (2012).

The levels of PM_{10} ranged from 37.10 µg/m^3 to 293.06 µg/m^3 whilst that of $PM_{2.5}$ ranged from 3.85 µg/m^3 to 46.43 µg/m^3. The average concentration of PM_{10} was found to be 96.56 µg/m^3 and was higher than the EPA standard of 70 µg/m^3. While that of $PM_{2.5}$ at the sampling site was 23.26 µg/m^3. Clearly, the levels of PM_{10} were higher than $PM_{2.5}$ particulates which could be attributed to the varied origins of the particulates. These high levels of ambient particulate loadings could be attributed to the fact that the study area is characterized by a lot of open burning, household wood and charcoal burning, and vehicular traffic.

Black Carbon (BC)

It is called Black Carbon (BC) because of its colour. Black carbon has a graphite-like structure with the presence of some functional groups containing oxygen, Sulphur, hydrogen and nitrogen which are able to enhance catalytic processes. It is an important part of the combustion product commonly referred to as soot and represents the dark component of carbonaceous aerosol and a complex mixture of both elemental carbon and highly polymerized organic substances (Safo-Adu et al, 2014). It is a climate forcing agent formed through the incomplete combustion of fossil fuels, biofuel, and biomass and is emitted in both anthropogenic and naturally occurring soot. In indoor environments, BC concentrations is largely due to cooking with biofuels such as wood, dung and crop residue. In outdoors, it is due to fossil fuel combustion (diesel and coal), open biomass burning (associated with deforestation, waste burning and crop residue burning), and cooking with biofuels. Soot aerosols absorb and scatter solar radiation. Sources whose emissions are rich in BC can be grouped into a number of categories. These includes diesel engines, industry and residential solid fuel and open burning. The largest global sources are the open burning of forests and savannas. Household solid fuels (i.e. coal and biomass) contribute about 60 to 80% of Asian and African emissions, while on-road and off-road diesel engines contribute about 70% of emissions in Europe, North America and Latin America (Begum, et al, 2011).

Anthropogenic sources of black carbon, although distributed globally, are mostly concentrated in the tropics where solar irradiance is highest. Black carbon is often transported over long distances, mixing with other aerosols along the way (Safo-Adu et al, 2014)

In urban areas, diesel emissions are one of the major sources for elemental carbon, which is often used as a maker for urban pollution. The carbon emissions per tonne in Ghana was reported to be 0.4 per tonne in 2011 by the United Nations development program (WHO, 2006). The large concern on black carbon concentrations in air particulate matter samples is due to the adverse health effects and its contribution towards global warming.

Health effects of Black Carbon

Air pollution causes nearly two million premature deaths per year (WHO, 1998). By reducing black carbon, a primary component of fine particulate matter, the health risks from air pollution will decline. Inhalation of Black Carbon causes pulmonary and respiratory infections. Toxicology studies show that BC may operate as a universal carrier of a wide range of chemicals of varying toxicity to humans (WHO, 2012)

Black Carbon contribution to global warming

Black carbon aerosols absorb all wavelengths of solar radiation from short ultraviolet waves to longer infrared waves. Furthermore, it converts ultraviolet to infrared which it reradiates to the atmosphere around the particle. This warms the atmosphere at higher altitudes and creates a dimming effect on the surface which can result in lower temperature in the lower atmosphere. Black carbon also interacts with other compounds in the atmosphere which can potentially enhance its impact on climate (Carmichael, 2002). Black carbon particles grow with time, due to coalescence and possibly impact its ability to absorb solar radiation. Moreover, black carbon affects precipitation patterns through its effect on atmospheric temperature profiles. Rainfall levels and patterns can be affected in areas where it is emitted in large quantities. Some associates the change in rainfall patterns in sub-Saharan Africa with the increasing burning of biomass for cooking and land clearing by total population (Cohen, 2005).

Black Carbon Measurement

One of the several methods of estimating the black carbon concentration in ambient air particulate matter sampled on filters is by the use Smoke Stain Reflectometer (SSR) EEL Model 43d reflectometer. This instrument consists of an LCD display unit, measuring head which comprises of a source of light (tungsten lamp) and a photosensitive element (selenium disc). The head fits into a detachable mask which consists of a locating ring with a metal plate. The mask covers all the working area of the element except for an aperture 1.2 cm in diameter, through which the stain is measured. The Smoke Stain Reflectometer provides an estimate of the black carbon concentration on collected air filter samples by a reflectance technique. This is carried out by measuring the darkness of the stain obtained from sampling that is reflected back from the smoke stain to a photosensitive element. An electrical response is generated and then amplified to produce a meter reading. The darker the stain, the less light is reflected, so a low meter reading corresponds to a dark surface, and a high reading to a light surface. The reflectometer reads on a scale of 0 for black to 100 for white. The mass concentration of black carbon in air particulate on filters could therefore be calculated using the British or Gagel method. The Gagel method was used in this study to determine the mass concentration of Black Carbon (BC) in air particulate on filters.

Heavy metals

Heavy metals refer to metallic chemical elements that have relatively high density and toxic even at low concentrations. They mainly include transition metals, some metalloids, lanthanides and actinides. Mercury (Hg), Arsenic (As), Lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni) and Thallium (Tl) are examples of heavy metal elements emitted from diesel car exhaust and present the greatest environmental hazard due to their toxicity and wide spread distribution. Unlike almost all organic pollutants, such as organochlorines, heavy metals occur naturally in the earth's crust. They are therefore found in soils and rocks with subsequent range of natural background concentrations in sediments and waters. Anthropogenic emissions can give rise to higher concentrations of the metal relative to the normal background values (Kabata-Pendias, 2010).

Most of the heavy metals are toxic to organisms even at low concentrations; although, some such as iron, copper, manganese, and zinc are also essential elements. Concentrations of these essential elements in organisms are normally homeostatically controlled, with uptake from the environment being regulated according to nutritional demand. Effects on the organisms are manifested when this regulation mechanism breaks down as a result of either insufficient (deficiency) or excess (toxic) concentration amounts. Toxic metal elements are normally transported from place to place via the air as gas or as species adsorbed or absorbed on suspended particulate matter. They accumulate in organisms as a result of direct intake from the surroundings across the body wall, through respiration and by ingestion. Dietary uptake could include heavy metals adsorbed on particulates present on the surface of leaves which have not been absorbed by the plant (Ofosu et al., 2012). Industrialization of our world has dramatically increased the overall environmental load of heavy metal toxins, making it difficult for everyone to avoid exposure to toxic heavy metals. However, one can take steps to understand and minimize this threat through acts of prevention and treatment that will help to lessen the negative impact on health.

Toxicity of heavy metals

Most heavy metals are dangerous in the form of positively charged ions as compared to their condensed free elemental state. For instance Cadmium (Cd), Mercury (Hg), Lead (Pb) and Arsenic (As) are very toxic in their ionic states and when bonded to short chains of carbon atoms. The mechanism of their toxic action arises from the strong affinity of the positively charged ions for Sulphur. Sulfhydryl groups -SH, which occur commonly in enzymes that control the speed of critical metabolic reactions in the human body readily attach themselves to digested heavy metal cations or molecules that contain the metals. As the resultant metal - Sulphur bonding affects the entire enzymes, it cannot act normally and human health is adversely affected, sometimes fatally. The toxicity of a heavy metal depends very much on the chemical form of the element and the amount of element suspended in the atmosphere (Kabata-Pendias, 2010).

Table 5 presents the elemental concentrations and standard deviations in the ambient air of Vashi, Navi Mumbai, India (Kothai et al., 2009). Although the sampling site was located at a residential area, the city itself is situated near a heavy industrial area while a busy highway passes just 2 km from the site. This presents an idea of the heavy metals dispersed in the city’s air.

Table 5**:** Concentration of metals in the ambient air of Vashi, Navi Mumbai, India

Parameter	PM_{10}		$PM_{2.5}$	
	Mean/ (µg/m^3)	SD	Mean/ (µg/m^3)	SD/ (µg/m^3)
Na	1.239	0.497	0.462	0.386
Mg	1.122	0.291	0.264	0.140
Si	6.770	1.797	1.095	0.604
P	0.044	0.025	0.028	0.020
S	2.682	0.832	2.134	0.868
Cl	0.565	0.831	0.100	0.027
K	0.909	0.453	0.561	0.815
Ca	3.783	1.068	0.457	0.283
Se	0.024	0.023	0.014	0.009
Ti	0.347	0.096	0.046	0.026
V	0.018	0.008	0.008	0.004
Cr	0.046	0.019	0.013	0.008
Mn	0.104	0.035	0.018	0.011
Co	0.039	1.031	0.009	0.007
Ni	0.017	0.009	0.008	0.005
Cu	0.050	0.026	0.018	0.012
Zn	0.380	0.193	0.148	0.069
As	0.023	0.012	0.033	0.024
Se	0.023	0.014	0.012	0.007
Pb	0.158	0.097	0.131	0.125
Al	3.208	0.858	0.696	0.604
Br	0.043	0.018	0.031	0.017
I	0.089	0.050	0.035	0.020
Hg	0.059	0.035	0.024	0.017
Fe	3.657	1.031	0.489	0.290

Source: Kothai et al., (2009)

Health effects of some airborne heavy metals

Copper is widely used as structural metal particularly where high electrical and thermal conductivity are needed. Copper compounds are found in fungicide and other agricultural products. For example copper (ll) Sulphate is a common copper salt used as fungicide and for tanning of leather whilst Copper (ll) Oxide is used in fuel additives, cement and wood preservatives (Fonger, 1995). Excessive copper absorption occurs through the skin, by inhalation or ingestion. Airborne copper sources include fumes from smelting operations, vehicles and dust from any of the many processes involving copper and its compounds. Occupational exposure to copper dust causes nausea and upper respiratory tract inhalation (Cohen, 1974). Inhalation exposure to copper fumes usually from burning fuel, welding or smelting operations, may result in “metal fume fever”. This condition results in headache, dryness of the mouth and throat, chills, fever, and muscle aches usually beginning 4-8 hours after exposure to copper oxides. Symptoms and signs spontaneously subsides within 24-36 hours of exposure to the pollutants (Ofosu et al., 2012).

Pure manganese is a silver colored metal; which, it does not occur in the environment as a pure metal but rather, it occurs combined with other substances such as Oxygen, Sulphur, and Chlorine. Manganese is a normal constituent of air, soil, water, and food. It can be found in air, soil, and water in abundance after release from the manufacturer, use and disposal from manganese-base products. As with other elements, it cannot break down in the environment but can change its form or become attached to or separated from particles. In water, most of the manganese tends to attach to particles or settle in the sediment. The manganese-containing gasoline additive may degrade in the environment quickly when exposed to sunlight, releasing manganese. Manganese enters the body by ingesting food containing manganese and inhaling particulate manganese. Vegetarians, who consume foods rich in Manganese such as grains, beans and nuts, as well as heavy tea drinkers, may have a higher intake of manganese than the average person. Certain occupations like welding or working in a factory where steel is made may increase your chances of being exposed to high levels of manganese. As Manganese is a natural component of the environment, one is always exposed to low levels of it in water, air, soil, and food. When one breaths air containing Manganese, a small amount of the manganese enters the body through the lungs where it becomes trapped in the lungs, specifically in mucus, which may be coughed out or swallowed into the stomach (Dixit & Tiwari, 2007). Manganese is required in small amounts in the human body to manufacture enzymes necessary for the metabolism of proteins and fats. Examples of manganese-dependent enzymes include oxidoreductase, transferase, hydrolase, isomerize and ligase. Manganese is also needed for normal immune system functions, regulation of blood sugars, reproduction, digestion, bone growth, functioning of numerous organ systems and the production of cellular energy. A deficiency in manganese intake can retard growth, cause seizure activity, lead to poor bone formation and cause birth defects. At the other end of the spectrum, excess exposure to Manganese is associated with an irreversible brain disease with prominent psychological and neurological disturbances known as Manganism. Manganese neurotoxicity has been attributed to symptoms in workers that have been chronically exposed to aerosols that contain high levels of Manganese. Prolonged exposure to airborne manganese leads to prolong muscle contraction, decreased muscle movement, rigidity and muscle tremors (Su, Chen, Zou, Shen, Xia, Liang, & Yang, 2016). The United State Environmental Protection Agency (USEPA) has concluded that existing scientific information cannot determine whether or not excess manganese can cause cancer.

Lead is one of the metals found naturally in the environment, and can also be found in manufactured products. Industrial processes like lead smelters and waste incinerators as well as vehicular emissions are the major sources of airborne Lead. Lead is emitted into the air in the form of particles small enough to stay suspended in the air. It can be inhaled directly or ingested after it settles onto surfaces or soils. Once in the body it is rapidly absorbed into the bloodstream and accumulates in the bones. Lead exposure is associated with several health effects that have an adverse impact on the cardiovascular system, central nervous system, kidneys and immune system (Atiemo et. al., 2012) High concentration of lead (above 80 µg per Deci litre of blood) causes convulsion, coma and death. Lead in the environment accumulates in a food chain according to the reaction in Equation 1:

$$Pb\,(CH_3CH_2)_{4\ \text{(tetraethyl lead)}} \longrightarrow Pb + 4CH_3CH_2 \tag{1}$$

Children are more susceptible to the damaging effects of airborne lead than adults because they breathe in more air per minutes, spend more time outdoors and exhibit greater hand to mouth activities than adults. Moreover, children are more vulnerable to the health effects of Lead due to the rapid development of their minds and bodies. Adverse health effects of lead in children include delays in mental and physical development, lower IQ levels and increased behavioral problems (Yang et al., 2009).

Cadmium is present in the atmosphere mainly in particulate form. It is removed either by wet or dry deposition and enters the food chain. The atmospheric residence time depends on the particle size, the height by which the particulate is emitted and climate. Cadmium gets to the human body either by inhalation or ingestion. Its inhalation into the human body destroys normal metabolism by displacing Zinc in Zinc containing metal-enzymes leading to pulmonary and gastrointestinal effects (nausea, vomiting, diarrhoea, cardio-pulmonary depression) and liver damage (Wilson & Spengler, 1996).

Instrumental Methods for Metal Analysis

Airborne particulate matter collected on sampling filters, whether TSP, PM_{10}, $PM_{2.5}$ or dichotomous size fractions can be examined using a variety of instrumental methods for their chemical composition. The analytical tools seek to determine the qualitative and quantitative characteristics of the various elements in the samples. The common techniques used for metal analysis include: Flame Atomic Absorption Spectroscopy (FAAS), X-ray Fluorescence Spectroscopy (XRF), Particle Induced X-Ray Emissions (PIXE), Instrumental Neutron Activation Analysis (INAA), Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES), ion Chromatography for soluble metals and many others. These methods generally provide data on the elemental composition of particulate matter. The choice of a particular technique depends on factors such as the availability and sensitivity of the instrument, requirement for sample preparation and most importantly the cost of analysis. The USEPA compendium on inorganic analysis has standard procedures for some of these analytical techniques (Pope et. al., 2002). Atomic Absorption Spectroscopy (AAS) is the elemental analysis technique used in this study.

Spectrometry (ICP-MS)

This is an analytical technique used for the detection of trace metals in environmental samples. The goal of ICP is to get the elements that emit characteristic wavelength of specific light which then can be measured. Samples are decomposed to neutral elements in high temperature Argon plasma and analyzed based on their charge-mass ratios. Aqueous samples are introduced by a way of a nebulizer which aspirates the sample with high velocity argon, forming a fine mist. The aerosol then passes into a spray chamber where larger droplets are removed via a drain. Solid samples are introduced into the ICP using a laser ablation system (Safo –Adu et al. 2014; Boss & Fredeen, 1999).

Instrumental Neutron Activation Analysis (INAA)

INAA is an analytical tool based on the measurement of characteristic gamma radiations emitted from radionuclides formed directly or indirectly by neutron irradiation/bombardment of the material of interest (Atiemo et. al., 2012). It can perform simultaneous multi-elemental analysis with no or minimal chemical treatment of samples. It is a non-destructive method with adjustable parameters that can be exploited for maximum sensitivity for the desired element. In spite of these strengths however, a major setback of the INAA is its inability to detect lead (Pb), a key toxic element known to be prevalent in most anthropogenic sources. In addition, it is time consuming due to the different irradiation, decay and counting times for the elements depending on their half-lives (Pope et. al., 2002)

X-Ray Fluorescence Spectroscopy (XRF)

XRF is a non-destructive, multi-elemental analytical technique used to identify and determine the concentrations of elements present in powdered, liquid and solid samples. It provides a wide range and a fairly uniform detection limit across the periodic table from low atomic number elements like; Beryllium (Be) to high atomic number elements like; Uranium (U) and is applicable to a wide range of concentrations from a 100% to a few part- per million (ppm).

The measurement is fast with time spent being within a few seconds per element, to hours depending on the composition complexity, requested accuracy and levels of concentration. Results are accurate, and error can be as low as 0.1% if adequate calibration standards are available. X-ray Fluorescence spectrometry is one of the common tools for the determination of elemental concentration of particulates on air filter. It is a multi-elemental tool for soil/dust analysis and can be used to determine the presence a very wide range of elements. It is extensively used in the fields of metals, cement, forensics, mining and mineralogy, oil, polymers, geology for the detection of elements. This technique which is suitable for this research work could not be used because those available in the laboratories in Ghana had all broken down, I therefore had to result to the use of AAS analytical tool.

Atomic Absorption Spectrometry (AAS)

This technique can be used to analyze over sixty-two (62) different metals in a solution. Atomic Absorption Spectroscopy as an elemental analytical technique has the significant advantage of being independent of the chemical form of the element in the sample. It has greater sensitivity and detection limit, low spectral interference and requires a very small sample size. It also enables the detection of a given element in the presence of other elements without any interference. Notwithstanding these, no information is obtained on the chemical form of the analyte, and often one element can be or is determined at a time which makes it time consuming. The sample preparation techniques could be time consuming for large sample sizes while the availability of appropriate gas combinations for the determination of some elements could also be a problem.

Basic Principle of Atomic Absorption Spectrometry (AAS)

It is an analytical procedure that employs the absorption of optical radiation (light) by ground state, free atoms in the gaseous state (free atoms are formed from the samples by an “atomizer” at high temperatures) in a flame or furnace for both qualitative and quantitative determination of chemical elements.

The technique makes use of absorption spectrometry to assess the concentration of an analyte in a sample (Alloway & Ayres, 1998).

The identification of elements by this method is possible due to the characteristic radiation wavelength absorbed by the electrons of the atoms under appropriate conditions. The electrons upon absorbing a characteristic wavelength become excited for a short period of time thereby moving from the ground state to an excited state as shown in Figure 5 a.

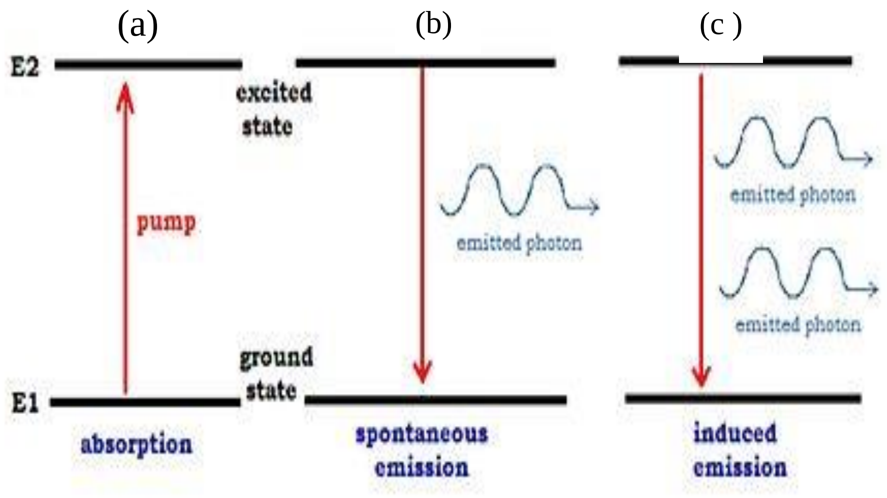

Figure 5**:** The ground and excited states of the elements during interaction with radiation.

The atom at the excited state is unstable and within this short period of time releases radiation energy and falls back to the ground state as depicted in Figure 5 (b). During which time the intensity of the radiation passing through the sample is measured. The intensity **I_0** (radiation of a given characteristic wavelength) of the light that causes the excitation is defined and is specific to a particular electron transition in a particular element and is called the incident radiation. Generally, each element corresponds to a specific wavelength and as the number of atoms in the light path increases, the amount of light absorbed increases. The intensity of the light after passing through the material (solution of the analyte), is measured as **I.** If **I** is less than $\mathbf{I_0}$, it is obvious the sample/material absorbed some of the light at a particular rate called absorbance (**A**). This is defined as the ratio of the incident intensity of radiation to the intensity of the transmitted radiation. Measuring these intensities allows us to determine the elemental concentrations of the individual elements by applying Beer - Lambert's law, which is a combination of the Lambert's law and Beer's law.

Beer's Law states that the "light absorbed is proportional to the number of absorbing species in the sample".

Lambert's Law states that "the portion of light absorbed by a transparent medium is independent of the intensity of the incident light, and each successive unit thickness of the medium absorbs an equal fraction of the light passing through it".

The Beer- Lambert Law is expressed in Equation (2) as;

$$I = I_0 \exp(-\mu l), \tag{2}$$

where;

I is the transmitted intensity of the light

I_0 is the incident intensity of the light

μ is the attenuation coefficient

l is the path length of the light

The relationship between the Beer-Lambert law and the absorbance, A is expressed in Equation (3) as;

$$A = log_{10}\left({}^{I_0}/_{I}\right) \tag{3}$$

A ranges from 0 – 1, an absorbance of zero (0) at a wavelength means that no light of that particular wavelength has been absorbed, and it implies that the intensities of the transmitted and incident are both the same, so the ratio

I_0/I is 1 and $log_{10}1 = 0$.

An absorbance of 1 happens when 90% of the light at that wavelength has been absorbed, which means that the intensity is 10% of the initial intensity, I_0. In that case; I_0/I is 100/10 = 10 and $log_{10}10 = 1$.

The relationship between the concentration of the element, the path length of the analyte and measured intensities is express in Equation (4) as;

$$log_{10}\left({}^{I_0}/_{I}\right) = \varepsilon lc, \tag{4}$$

where;

ε is the molar absorptivity or molar absorption coefficient

l is the path length of the light

c is the concentration of the measured analyte

From Equation (3) and (4), it implies that

$$C = {}^{A}/_{\varepsilon l} \tag{5}$$

Instrumentation of the Atomic Absorption Spectrometer

The atomic absorption spectrometer consist of a light source of line spectrum of an element (hollow cathode lamp), a means of isolating an absorption line (Monochromator and an adjustable slit), a device for vaporizing the element (usually flame) and a photoelectric detector (with its associated amplifying and electronic measuring equipment).

Hollow Cathode Lamp: It consist of a tungsten anode and a cylindrical cathode sealed in a glass tube that is filled with Argon or Neon at a pressure of 1 or 5 torr. The cathode is constructed using the metal whose spectrum is to be measured. When a high enough voltage is applied between the anode and the cathode, the filter gas becomes ionized and positive ions are accelerated towards the cathode. They strike the anode with enough energy to sputter metal atoms from the cathode into gas phase (Ofosu et. al., 2012). Each hollow cathode lamp is specific for a particular element and individual lamps are available for the estimation of over seventy elements. These may be single-element (mono-cathode lamp) or multi-element cathode lamps.

Monochromator and Detector: A sensitive narrow band passes monochromator is essential so that the monochromator wavelength can be adjusted to pass the element resonance line only. A detector of high sensitivity is required and a photomultiplier with a suitable amplifier which produces a cloud of atoms of elements to be determined. The cloud of atoms produced absorbs the radiation of the resonance line from the hollow cathode lamp to give a characteristic resonance radiation proportional to the energy absorbed. The radiation from the resonator is picked up by the photomultiplier and amplifier system.

Burner**:** There are two types of burners; the laminar-flow or premix burner and the turbulent-flow or total consumption burners. In the turbulent-flow burner, the sample is drawn up the capillary and nebulized by the venturic action. A typical sample flow rate is 1 – 3 ml/min. The merit of this burner is the introduction of relatively large and representative sample in the flame. Its demerits include short path length through the flame and a problem of clogging of the tip. The premix burner nebulize the sample by the flow of oxidant gas past a capillary tip. It provides relatively quiet flame and a long path length. These properties enhance sensitivity and reproducibility. The mixing chamber of premix burners contains a potentially explosive mixture which can be ignited by flashback if the flow rates are not sufficient (Alloway & Ayres, 1998).

Source Apportionment Models

Source apportionment involves the sampling of ambient particulate matter (PM), measurement and analysis to separate and identify the chemical constituents of the atmospheric aerosol. The chemical speciation of the particulate samples allows for the identification of additional particle emissions sources that may have been included in the original emission inventory (such as re-suspended road dust and distant power plants) as well as the quantification of the contribution of known emissions sources to the sampled PM. These additional data helps to validate and improve the existing emissions inventory. Identification of sources and their relative contribution to the total air pollution load can be used to further assist policy makers and modelers in developing integrated control strategies that achieve co-benefits of reducing both particulate matter and greenhouse gases simultaneously. Enrichment Factor analysis, Principal Component Analysis (PCA), Chemical Mass Balance (CMB) receptor model are some of the source apportionment models used for fingerprinting elemental particulates. In this work principal component analysis method was used to apportion natural and anthropogenic sources of metal elementals in PM_{10} and their contribution ratios.

Health Risk Assessment of PM_{10} Levels

Air particulates are known to cause or aggravate cardiac and respiratory diseases like asthma, bronchitis and emphysema. Individuals with cardiovascular diseases or chronic lung diseases, children and elderly are more vulnerable (Pope et. al., 2002). Additionally, the association of toxic elements with PM_{10} and smaller particles can even be more harmful as these can penetrate deep into the respiratory tract. In view of these health concerns, Human Health Risk assessment of PM_{10} particulates is very vital. Human Risk Assessment (HRA) is the method of determining the probability of harm occurring to people as a result of exposure to contaminants at a site. Both the toxic properties of the hazardous substance and ways that people may be exposed to these substances are evaluated. The HRA begins with problem formulation and include: (1) hazard identification, (2) hazard characterization (3) exposure assessment, and (4) risk characterization (WHO, 2004). Human risk associated particulate matter exposure basically through inhalation could be assessed using so many methods. One of such methods is by using the USEPA Air Quality Index (AQI). This is an indicator used to characterize the quality of air at a given location and can be defined as a single number for reporting the air quality with respect to its effects on human health. It combines many pollutants concentrations in a mathematical expression to arrive at a single number for the air quality (Bishoi, Prakash & Jain, 2009). It tells how clear or polluted the air is, and the associated health effects that might be of concern. The higher the AQI value, the greater the level of pollution and the greater the health risk concerned. Hence as the AQI increases, an increasingly large percentage of the population (industrial environment, roadside dwellers) are likely to experience increasingly severe adverse health effects.

The USEPA Air Quality Index ranges from 0-500. The categorization of ambient air quality with respect to AQI and their respective levels of health concern is presented in Table 6.

Table 6: Categorization of ambient air quality with respect to AQI and level of health

Air Quality Index	Levels of Health Concerns	Colour
0 – 50	Good	Green
51 – 100	Moderate	Yellow
101 – 150	Unhealthy for sensitive group	Orange
151 – 200	Unhealthy	Red
201 – 300	Very unhealthy	Purple
301 – 500	Hazardous	Maroon

Source: Pope et. al., (2002)

Chapter Summary

This chapter discussed atmospheric aerosols and their contributions to air pollution. Some sources of aerosols and the effects of some important particulates on human health were also discussed. Theories and experimental procedures underling this study were also presented.

CHAPTER THREE

MATERIALS AND METHODS

Introduction

The study attempts to provide data on emission of particulates due to palm kernel oil production and how it affects the air quality of the surroundings. This Chapter throws more light on the methodology employed in this study, the materials used and the experimental procedures employed during the analysis. Methods used to calculate the concentrations of the particulates will also be discussed in this Chapter.

Site Selection

There are a number of palm kernel oil production sites in the Cape Coast metropolis. The study tries to ascertain the effect of the activities of the palm kernel oil production industry alone and hence the influence of sources other than the use of biomass and the burning of the oil Akotokyir needed to be eliminated. This led to the selection of Akotokyir for the study.

Study Area

A study was carried out at the palm kernel oil production site at Akotokyir, a suburb of Cape Coast in the Central Region of Ghana. Akotokyir is located between Abura (one of the busiest towns in Cape Coast) and University of Cape Coast and about 5 km from the main Campus of University of Cape Coast. Due to its closeness to the University, some students of the University who could not be accommodated on campus seek residence in this locality. Most of the women engaged in this venture are a little advanced in age and report to work with their little children and grandchildren who play around the field oblivious of the health implications. Children and the aged are the most vulnerable to the negative health effects of pollution.

The mean monthly temperature for the study areas ranges from 70 °C to 93 °C whilst the predominant wind direction is south westerly.

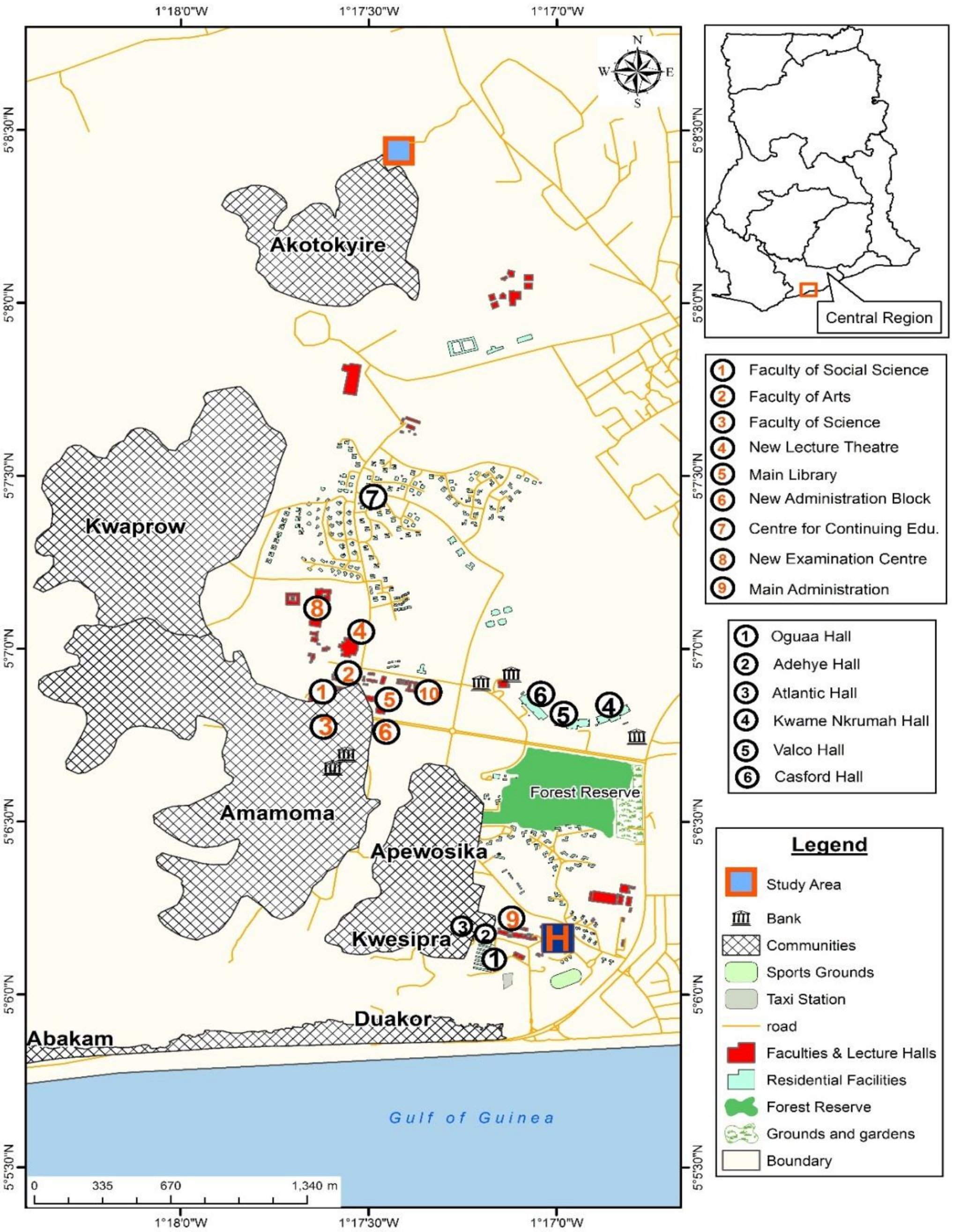

Figure 6: A map of the sampling region.

Sampling Procedure

Air sampler designed to sample particulates with diameter of about 10 µm was selected. The height of the mounted sampler, distance from palm kernel oil production activities where considered to ensure little or no obstruction in the path of particulates.

Filter Preparation

Teflon filters 37 mm in diameter and 1.0 µm pore size, obtained from Gelman, was used to sample PM_{10} particulates. Teflon filters have low chemical background, low affinity for water vapor and are not affected by most acidic and alkaline media making them preferred over other filters for sample collection (Safo-Adu, 2012). Both field and blank filters were equilibrated to a constant temperature and relative humidity between 30% and 40% in a desiccator for 24 hours. The filters were weighed using Fisher brand PS-60gram sensitive balance with a weighing accuracy of ± 0.15 mg. The weighing was also done in a temperature and relative humidity controlled environment.

The filters were handled carefully using non-serrated forceps. The forceps were cleaned with alcohol, wiped and air-dried before use. Before sampling, the filters were checked for defects such as pinholes, separation of rings, discoloration and filter non-uniformity. These were done to avoid leakage and contamination of filters which could introduce measurement errors.

Air Particulate Sampling

The ambient air particulate sampling was carried out using IVL sampler and Sierra Anderson (GAST) pump. The sampler was fixed at a height of about 1.9 m on a wooden beam and mounted at the palm kernel production site at the sampling site. The sampler location was selected to ensure that representative samples were collected and also without obstructions in the path of the particulates. This was at a distance not more than 50 m from the main working area where the burning activities were being carried out.

The air pump was controlled by a timer. The sampler was operated at an average flow rate of 17 L/min. Sampling was carried out for 12 hours every other day from 7.30 am to 7.30 pm whenever there was activity at the site. The entire sampling period covered three months from 20th December, 2014 to 23rd March, 2015. Plates 8, 9 and 10 are pictures showing the mounted sampler, the air pump and an empty and loaded Teflon filters.

Plate 8: IVL Sampler.

Plate 9: Sierra Andersen GAST Pump.

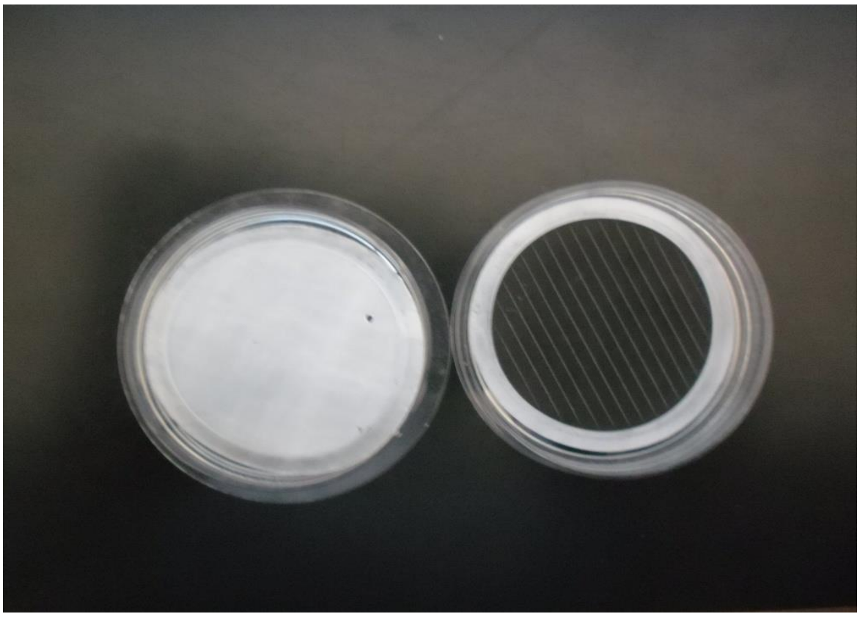

Plate 10: Empty and loaded Teflon filters.

The loaded filters were also equilibrated to the same temperature and relative humidity using a desiccator for about 24 hours before weighing for the gravimetric analysis. Each loaded filter was weighed at least four times and the average weight taken.

Sample Analysis

Loaded Teflon filters were preserved and conditioned for analysis. Different analytic procedures were employed to ensure that most important particulates were identified and counted for.

Gravimetric Analysis

Gravimetric analysis was carried out to determine the mass concentration of the aerosol samples collected in the ambient air. This was calculated as the total mass of collected particles divided by the volume of air sampled in actual conditions. The total volume of air sampled was determined by multiplying the total volumetric flow rate (l/min) and sampling time in minutes.

The mass concentrations are expressed in micrograms per actual cubic meter ($\mu g/m^3$). The Equation governing the gravimetric analysis is given in Equation (6) as:

$$C_{PM} = (M_2 - M_1)/ V_a \, , \tag{6}$$

where:

C_{PM} = mass concentration of particulate matter ($\mu g/m^3$)

M_1 = mass of empty Teflon filter in µg.

M_2= Mass of loaded filter in µg.

V_a = Total air sample volume determined from the total volumetric flow rate (L/min) and sampling time (min). (Ofosu et al., 2013; Safo-Adu, et al. 2012)

Black Carbon Analysis

After the gravimetrical analysis, the filters were examined for black carbon by measuring the reflectance using an EEL 43D Smoke Stain Reflectometer (Diffusion Systems Ltd., London, UK). The operating principle of the reflectometer is the 'Black Smoke Method'.

The reflectance readings were obtained for the loaded filters, totally black filter and totally white filter. The reflectance reading for totally black was found to be 0.4. That of a totally white was found to be 0.8. The reflectance from the loaded filters falls between reading of 0.4 and 8.0. The EEL M43D consists of a meter unit fixed in a case and a measuring head, which is connected to the meter unit. It also has a main switch and sensitivity control. The reflectometer was placed on a flat level surface with its meter unit facing upwards. The measuring head was placed in a circular mask and connected to the equipment as shown in Plate 11.

Plate 11: EEL M43D Smokestain Reflectometer.

The reflectometer was switched on and allowed to warm up for about 20 minutes. Linearity checks were performed by placing the circular mask on the standard white tile and the measuring head placed fully in the circular mask. The reading on the DS 29 universal digital readout output meter unit was noted and the coarse and fine sensitive controls used to adjust the reading to a value of ‘8.0. The circular mask was then placed on the standard grey tile and the measuring head placed fully in the circular mask and the reading for the grey displayed by the meter noted and the sensitivity controls in front of the meter adjusted to a value of ‘0.4’for grey tile. The process was repeated several times until a reading of 8.0 and 0.4 were obtained each time for the white and grey tiles respectively.

An empty filter (blank filter) taken from the same batch of filters used for the particulate sampling was placed on the white standard tile and the circular mask containing the measuring head was centrally placed on the white empty filter and the reading again set to ‘8.0. A loaded filter was carefully placed on the white standard tile ensuring that the stain was uppermost and centered on the white tile. The reflectance reading displaced by the digital display meter unit was recorded.

In this measurement, light from the high performance LED shines on the aerosol filter and is then reflected unto a photodiode located in a black housing. The intensity of the reflected light is measured by the photodiode. The reflector reading is obtained directly from the DS 29 universal digital readout and corresponds to the darkness of the filter paper which is displayed as output voltages reading. A reading of 8.0 corresponds to a totally white filter and 0.4 for totally black representing the maximum and minimum reflectance for the filter papers. The reading is converted to output voltage by multiplying it by 0.0777 (U=0.0777 x reading) as a measure of the blackness, or the ‘black smoke number’.

The relationship between the concentration of black particles collected on the filter, the output voltages for the totally white, totally black and the loaded filters, can be related to the concentration of black aerosol using the Lamber-Beers law (Safo- Adu et al, 2012).

The reflectance on the stained filters was measured five times and the average value used in calculating the black carbon concentration in each sample. Provided that thin layers of aerosol particles are collected on the filter (a single dust layer), the Equation relating the output voltages to the ‘black smoke number’ is expressed in Equation (7) as:

$$RZ = RZ_{max}(U_{RZ0} - U_{RZ})/(U_{RZ0} - U_{RZmax}), \tag{7}$$

where,

U_{RZ0}, U_{RZ}, and U_{RZmax} are the output voltages of the total white filter spot, the actual filter spot, and the total black filter spot respectively. RZ0, RZ, and RZmax are ‘black smoke numbers’ for these three types of filters, respectively (Safo-Adu et. al., 2014). The Equation used for converting ‘black smoke number’ to concentration of black particles (C) is giving in Equation (8) as:

$$C = -(RM/V)\ \ln(1- (RZ- RZ_0)/kRZ_{max}), \tag{8}$$

where

V is the sampled air volume, k and RM are calibration constants. Here, k = 0.95, RM = 11.2 µg, $U_{RZmax} = 0.5$, $URZ_0 = 8$, $RZ_{max} = 9$ were used. Finally, C is adjusted by a multiplication constant (the ratio of the filter area to the black spot area) to get the total BC concentration (Safo-Adu et. al., 2014).

Elemental analysis of air particulates on filters

To effectively analyze elements present in the sampled air by atomic absorption spectroscopy, the samples were first microwave digested using Ethos 900 Milestone Microwave Digester

Sample Digestion

The rings on all the Teflon filters were first carefully detached from the loaded area by cutting with a plastic knife. The rings were weighed and the mass subtracted from that of the initially loaded filter to obtain the mass of the particulates together with the filter alone. Both loaded and blank filters were detached from their rings and each digested using the milestone microwave acid digestion method described in Cookbook acid digestion instruction manual (1996). Each of the loaded filters and one blank filter was placed in separate Teflon bombs. 4 ml HNO_3 (65%) and 1ml H_2SO_4 were added to the content of each Teflon bomb and the samples digested for 30 minutes using Ethos 900 Milestone Microwave Digester according to the acid digestion microwave programme shown in Table 7.

Table 7**:** Acid Digestion Microwave Programme

Steps	Time (minutes)	Power (W)	Pressure (Kpa)	Temperature1 (^{0}C)	Temperature2 (^{0}C)
1	6	250	100	400	500
2	6	400	100	400	500
3	6	650	100	400	500
4	6	650	100	400	500
5	6	250	100	400	500

Source: Atiemo et al, (2012).

After digestion, the rotor containing the casket in which the Teflon bomb were kept was allowed to cool. The digested samples were transferred to small 15 ml bottles and diluted with deionized water to form 10 ml solution. They were covered tightly with appropriate lids and Aluminium foil and stored in a freezer for elemental analysis using Atomic Absorption spectrometry technique. Plate 12 shows a picture of the atomic absorption spectrometer in use.

Elemental Analysis

Plate 12: Atomic Absorption Spectrometer in use.

The digestate was then assayed for the presence of heavy metals (Lead (Pb), Nickel (Ni), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Iron (Fe), Manganese (Mn), Copper (Cu) and Zinc (Zn)) using VARIAN AA 240FS Atomic Absorption Spectrometer in an Acetylene - air flame.

Reference standards used for the elements of interest, blanks and duplicates of samples were digested at the same conditions as the samples. These served as internal positive controls. Reference standards used are from Fluka Analytical, Sigma-Aldrich Chemie GmbH, Switzerland

Quality Control/Quality Assurance

The following Quality Control and Quality Assurance techniques were used during the analysis:

Blanks: They were used to check contamination during sample preparation.

Duplicates: To check the reproducibility of the method used.

Standards: To check the efficiency of the equipment being used for the validation of the analytical results.

For the purpose of Quality Control and Quality Assurance, blanks were produced alongside with the samples to check for contamination during the sample preparation process. Duplicate samples were prepared to ascertain reproducibility of the results. Standards were applied to verify the efficiency of the equipment and for validation to ensure accuracy of the analytical results.

Air Quality Index of PM_{10} Calculation

Health effects due to exposure to ambient PM_{10} particulate pollution were assessed using the US EPA Air Quality Index **(AQI)** model. Air Quality Index is an indicator used to characterize the quality of air at any given location. It describes how clean or polluted the air at that location is, and predicts the associated health risk as well as the group of people that will be at a greater risk. The higher the AQI value, the greater the level of pollution and the greater the health concern. The AQI values were obtained for the PM_{10} particulate levels using the Equation (9) as;

$$I_p = \frac{I_{HI} - I_{LO}}{BP_{HI} - BP_{LO}}\left(C_p - BP_{LO}\right) + I_{LO} \tag{9}$$

Where

I_P refers to the Air Quality Index for PM_{10} particulates,

C_P is the concentration of PM_{10} particulate, BP_{HI} is the breakpoint that is greater than or equal to C_P, BP_{LO} is the breakpoint that is less than or equal to C_P, I_{HI} is the AQI value corresponding to BP_{HI} while I_{LO} is the AQI value corresponding to BP_{LO}.

The air quality category and the level of health concern are shown in Table 6 as proposed by United State Environmental Protection Agency (USEPA, 2012).

Chapter Summary

Air samples were collected on Teflon filters 37 mm in diameter and 1.0 µm pore size using an IVL sampler and Sierra Anderson (GAST) pump for 12 hours every other day from 20th December, 2014 to 23rd March, 2015. The mass concentration of the aerosol samples, the Black Carbon and concentration of elemental pollutants were determined. Due to the limitations of Atomic Absorption Spectroscopy, Ion Chromatography was employed to determine the presences and concentration of Calcium, Potassium, and Sodium ions. Using the US EPA Air Quality Index calculator, health effects due to exposure to ambient PM_{10} particulate pollution were assessed.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

The main purpose of the study is to identify the effects of biomass burning from palm kernel oil production activities on ambient air quality at a palm kernel oil production site in Cape Coast. The emissions at the activity site were sampled using air sampling technique. The sampled air was analyzed for the presence of Black Carbon and elements such as Fe, Mn, Cu, Cd, Pb, Cr, Mg, Co, Zn, Ni, and Ca using the Black Smoke method and Atomic Absorption Spectroscopy respectively. This chapter will present and discuss results obtained from all analytical methods employed.

PM_{10} Mass Concentration Levels

The average mass concentration of PM_{10} particulates in the sample was found to be 121.19 µg/$m^{3.}$ The maximum and the minimum concentration levels were also observed to be 658.62 µg/m^3 and 6.14 µg/m^3 respectively. The average levels of particulate varied from day to day throughout the sampling period. The daily variations may be due to the different anthropogenic emission levels from households close to the sampling site, number of tripods used for fire in a particular day, motor vehicles that ply the road and meteorological conditions (humidity, wind speed and wind direction).

The highest value of 658.62 µg/m^3 was recorded on 13th day of January, 2015 and the lowest value of 6.14 µg/m^3 recorded on 3th March, 2015. The value recorded on 13th January could largely be attributed to the harmattan winds since the peak of harmattan occurs in January in Ghana.

Comparing the ambient particulate levels obtained with the recommended WHO and Ghana EPA 24 hour PM_{10} air quality guidelines of 50 µg/m^3 and 70 µg/m^3 respectively, it was observed that values recorded for seven of the days were lower than those recommended by WHO and Ghana EPA. 21 out of 43 days recorded values above Ghana EPA guideline of 70 µg/m^3. This means that 48.8% of the sampling days recorded values above Ghana EPA 24 hour guideline for PM_{10}. The average concentration of 121.19 µg/m^3 was higher than both the WHO and Ghana EPA guidelines as shown in Table 8. The relatively high level of the average concentration can partly be attributed to the period of sampling (December – March), which falls within the dry season when the harmatann winds blow across West Africa. Particles which are suspended by vehicular movement on paved and unpaved roads and from construction works close to the site may also be major contributors to the high concentration.

A daily mean PM_{10} concentration of 59.3 µg/m^3 was reported in a study at a site located in Nima, Accra, Ghana from June to July in 2006 (Arku et al.,2008). This was much lower than the average PM_{10} level recorded in this study. This may be due to the variation between the number of sampling days and fugitive dust during the Harmatten season. Other anthropogenic sources close to the sampling site such as refuse and biomass burning could have influenced the recorded value. Dotse et al., (2012) recorded a daily mean PM_{10} concentration of 96.56 µg/m^3 at a site in Ashaiman from February to May, 2008. This value is also lower than that obtained in this study. A study on household biomass use and air pollution conducted by Zheng Zhou et al., (2011) in some parts of Accra showed James town, a community that predominantly uses biomass fuel for cooking, to have an average PM concentration of 118 µg/m^3 as compared with East Legon which uses mostly natural gas for cooking and recorded 28 µg/m^3.· Inspite of the difference in measurement periods and site, it can be deduced that biomass burning can contibute significantly to the ambient PM concentration in any location.

Table 8: Concentrations of PM_{10} and BC in ambient air compared with WHO and EPA guidelines

Particulates	Mean	max	Min	WHO	EPA (Ghana)
PM_{10}	121.19	658.62	6.14	50.00	70.00
BC	5.01	11.43	3.04	-	-
% BC	8.10	20.60	0.79	-	-

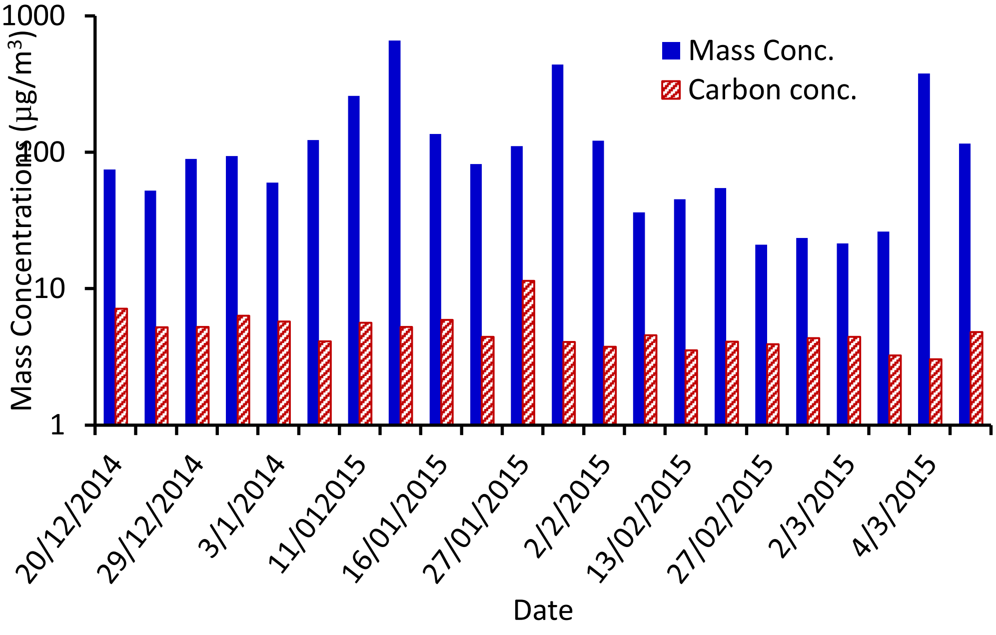

Figure 7: Daily average mass and carbon concentrations.

Levels of Black Carbon

Black carbon in ambient air generally originates from the combustion processes. Figure 8 shows the percentage of black carbon present in the air during the sampling period. The average black carbon concentration recorded during the samping period was 5.008 µg/m^3 with the maximum and minimum values being 11.428 µg/m^3 and 3.041 µg/m^3 respectively as shown in the shown in Table 9. The highest concentration was recorded on 27th January, 2015. The percentage black carbon in particulate mass was computed to ascertain the black carbon contents in the sampled air particulates. It was observed that the average percentage of black carbon in PM_{10} in the sampled air was 8.1% with the highest percentage value being recorded as 20.6% on the 2nd March, 2015. Although, the PM_{10} level recorded on 13th January, 2015 was the highest, its corresponding percentage of BC was low. This indicates that emissions from other anthropogenic non burning sources and other possible sources contributed significantly to the PM_{10} particulate at the sampling site.

Table 9: Average Elemental Concentrations in Particulates (µg/m^3)

Elements	AVERAGE	MAX	MIN
Fe	0.538538	1.605539	0.204137
Mn	0.022943	0.116018	0.004436
Cu	0.010347	0.02495	0.006653
Zn	0.006734	0.040775	0.002218
Pb	0.04551	0.157186	0.002218
Ni	0.003449	0.008317	0.002218
Cd	0.006898	0.016633	0.004436
Cr	0.018006	0.070621	0.002218
Co	0.018006	0.070621	0.002218
Ca2+	0.478063	1.365953	0.046574
Mg	0.189908	0.540265	0.017742
Na+	6.961472	100.7246	1.177202
K+	0.034491	0.083167	0.022178
C	5.008371	11.42814	3.041561
Mass concentration	126.1875	658.6762	3.597284

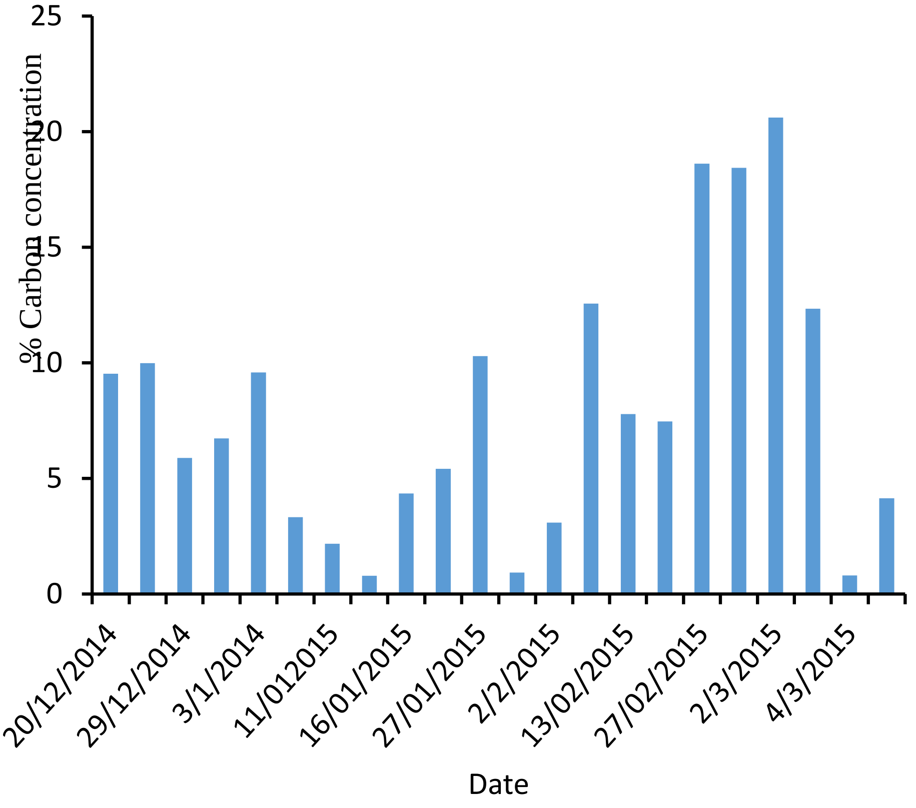

Figure 8: Percentage Black Carbon concentration in particulates.

Elemental concentrations

The elements; Fe, Mn, Cu, Zn, Pb, Ni, Cd, Cr, Mg, and Co, were analysed using Atomic Absorption Spectroscopy and ions; $Ca^{2+,}$ Na^{2+} and K^{+} were also analysed using using ion chromatography. The average, maximum and minimum concentrations of each of the elements is recorded in Table 9. The concentration level of the metals in decreasing order is Na > C > Fe > Ca > Mg > Pb > K > Mn > Co > Cr > Cu > Cd > Zn > Ni. Na, C, Fe, Ca, and Mg, are present as major elements in the sample whiles Mn, Co, Cr, Cu, Cd, Zn Cd, and Pb are present in trace quantities.

Fe in the ambient air is known to primarily be of crustal origin and Na is known to have a high marine origin. Calcium (Ca) on the other hand has both marine and crustal origin but predominantly crustal (Safo Adu et al.,2014). Nickel, Zinc, Cadmium and Cupper showed the least concentration levels with averages of 0.0035 $\mu g/m^3$, 0.0067 $\mu g/m^3$, 0.0069 $\mu g/m^3$ and 0.0103 $\mu g/m^3$ respectively. Nickel, Zinc, and Cupper are known to be trace elements in boilogical materials, soil dust and sea spray. They are also present in trace quantities in anthropogenic sources like fossil fuel combustion.

The levels of Cd and Ni at the sampling site could be attributed largly to emissions from combustion processes (Okuda. T. Nakao, S., Katsuna, M. &Tanaka,S., 2007). The mean annual concentration threshold standard set by the European Union for Cd and Ni are 5 ng/m^3 and 20 ng/m^3 respectively which are higher than that obtained for this study. The mean Pb concentration in this study was found to be 0.046 $\mu g/m^3$ and is lower than the Ghana EPA guideline of 2.5 µg/m^3. Also, the level of Mn obtained in this study was 0.0044 and is lower than the World Health Organization air quality guideline standard of 0.15 µg/m^3 . Table 10 shows the ambient air quslity standards for PM_{10} and other notable elements.

The black carbon in the particulate could be greatly attributed to the burning of wood and palm kernel shells which are used as fuel at the sampling site. Automobile and other cumbustion sources could also contribute significantly to BC concentration. It can be deduced from Figure 7, that the highest particulate mass concentration was recorded on 13th January, 2015 whilst the highest black carbon concentration was recorded on the 27th January, 2015. This shows that although the concentration of carbon increases with increase PM concentration, other factors such as burning sources could contribute significantly to the total PM concentration. The unpaved roads connecting the site to neighboring towns could contribute a large amount of dust to the PM concentration.

Table 10: Ambient Air Quality Standards

Parameter	Level (µg/m^3)			Sampling Time
	EPA (GH)	EU	WHO	
TSP	230	-	-	24 hour
	75	-	-	1 year
PM_{10}	70	50		24 hour
	-	40	-	1 year
$PM_{2.5}$	-	25	-	1 year
Pb	2.5	0.5	0.5	1year
Cd	10-20 ng/m^3	5 ng/m^3	5 ng/m^3	1 year
AS	30 ng/m^3	-	-	24 hours
	-	6 ng/m^3	-	1 year
Ni	-	20 ng/m^3	-	1 year
Mn	1	-	0.15	-

Correlation between Elements

Table 11 shows the results of the correlation between the elements. Fe showed a good correlation with Manganese (0.78) and moderate correlation with Ca (6.4) and Mg (6.5). Fe is found naturally from soil dust and since Mn correlates only with Fe, it shows that Mn is predominantly from soil dust. The moderate correlations of Fe with Ca and Mg indicate that they have other origins in addition to soil. Calcium showed a strong correlation with Magnesium (1.00) and moderate correlation with Zn. The moderate correlation between Zn, Ca and Mg, as shown in Table 11, give a clear indication of other possible sources. Zn is a major species used to identify emissions from two–stroke engine emissions (Chueinta, Hopke, & Paatero, 2000; Begum, Kim, Biswas, Hopke, 2004). Zn and Ca are additives in motor oil used in two–stroke engines emitted from old and less efficient (weak) automobile engines that burn oil. The milling machine for the palm kennel located at the site is a two stroke engine and therefore could be the major source of these elements. However, the BC correlation with Zn (0.41) and Mg (0.43) were weak suggesting the two stroke engine is not the major source of combustion.

Strong correlations were established among (Cu, Ni, Cd, BC and K) Cu-Ni (1.00), Ni-Cd (1.00), K- Ni (1.00), K-BC (0.99) and K-Cu (1.00). The strong correlation among these elements can also be seen graphically in Figure 9. BC is generally emitted from combustion processes. Its strong correlation with the metals (Cu, Ni, Cd, BC and K) therefore shows they largely originate from combustion processes. The presence of Potassium which is known to be a fingerprint of biomass burning (Ofosu et al., 2013) gives a clear indication that the elements (Cu, Ni, Cd, BC and K) originates mostly from burning of fossil and biomass fuel. Figure 9 shows how the concentration so BC, K, Cu, Ni, Cd correlated. Figure 10 also show how the concentrations of Ca, Mg, and Zn. Figure 11 describes the relationship between Mn and Fe.

Source Apportionment

Table 12 shows the output source profiles obtained for the five–factor Principal Component Analysis (PCA) solution of contributions from sources. The Principal Component Analysis was applied using varimax rotation and accounted for 93.45% of the total variance for the five factors with eigenvalues greater than unity. The source names associated with each of the factors were obtained by the inspection of the elements with the highest loadings (bold type). Four out of the five factors in Table 12 were identified as biomass emissions, two stroke engines, soil dust, and sea salt.

The first component has the elements Cu, Ni, Cd, K and BC. The high loading of BC (0.96) in the first component indicates that it is of a combustion source. K is a fingerprint of biomass burning and has its highest loading (0.98) in the first component. The first component can be said to originate from biomass burning. The second component is identified to be from two - stroke engine since it has the highest contributions of Zn, Ca and Mg which can be seen from their factor loadings. The high contribution to Fe can be seen in the third component which identifies it to be of crustal origin. The fourth component was the major source of Cr and Co but this source could not be well identified. Na was predominantly found in the fifth component. Na is mostly from Sea spray and crustal origin. Since Na did not correlate with any crustal element, the Sea could be the only source. The observations made in PCA compares well with that of the Pearson Correlation Analysis.

Table 11: Pearson Correlation Analysis of Elements

Elements	Fe	Mn	Cu	Zn	Pb	Ni	Cd	Cr	Co	Ca	Mg	Na	K	C
Fe	1.00	0.78	0.36	0.26	0.45	0.36	0.36	-0.16	-0.16	0.64	0.65	-0.15	0.36	0.39
Mn		1.00	0.22	-0.08	0.45	0.22	0.22	0.08	0.08	0.34	0.34	-0.13	0.22	0.27
Cu			1.00	0.41	-0.13	1.00	1.00	-0.27	-0.27	0.38	0.36	0.10	1.00	0.99
Zn				1.00	-0.04	0.41	0.41	-0.19	-0.19	0.60	0.59	-0.05	0.41	0.41
Pb					1.00	-0.13	-0.13	0.11	0.11	0.24	0.25	-0.15	-0.13	-0.08
Ni						1.00	1.00	-0.27	-0.27	0.38	0.36	0.10	1.00	0.99
Cd							1.00	-0.27	-0.27	0.38	0.36	0.10	1.00	0.99
Cr								1.00	1.00	-0.23	-0.23	-0.10	-0.27	-0.24
Co									1.00	-0.23	-0.23	-0.10	-0.27	-0.24
Ca										1.00	1.00	0.19	0.38	-0.44
Mg											1.00	0.19	0.36	0.43
Na												1.00	0.10	0.09
K													1.00	0.99
C														1.00

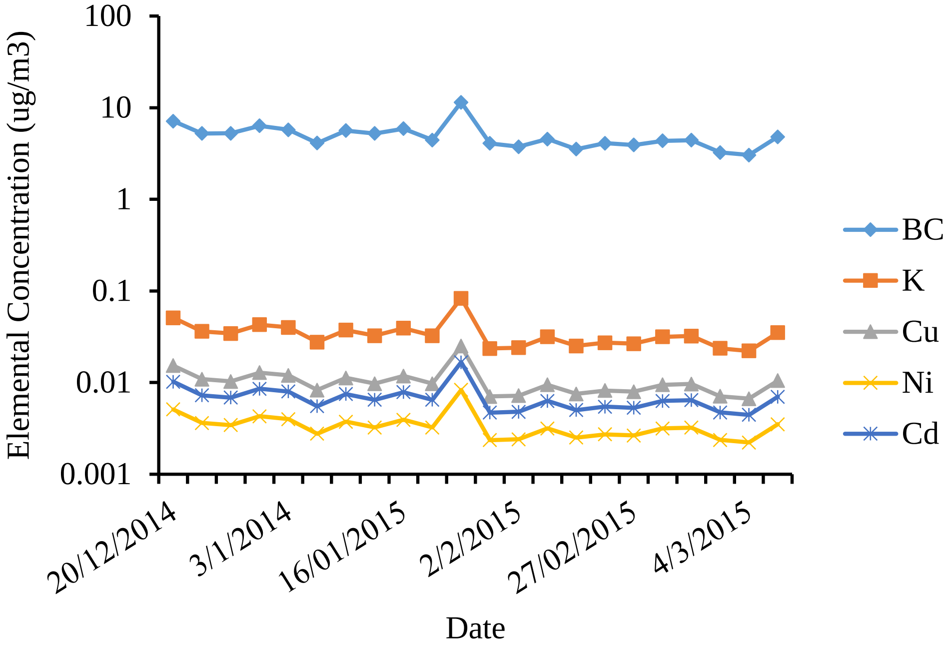

Figure 9: Time Series Graph of BC, K, Cu, Ni, and Cd.

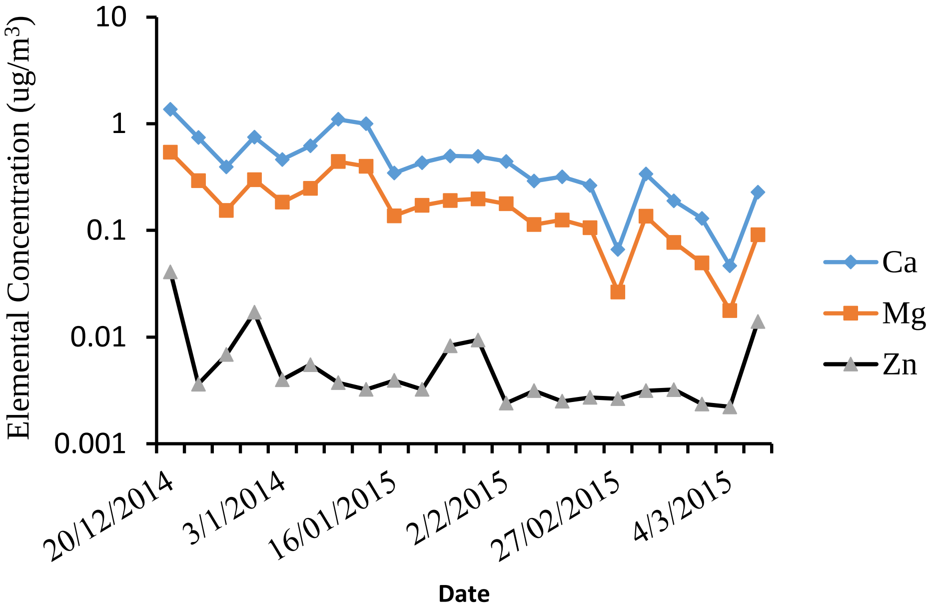

Figure 10: Times Series Graph of Ca, Mg, and Zn.

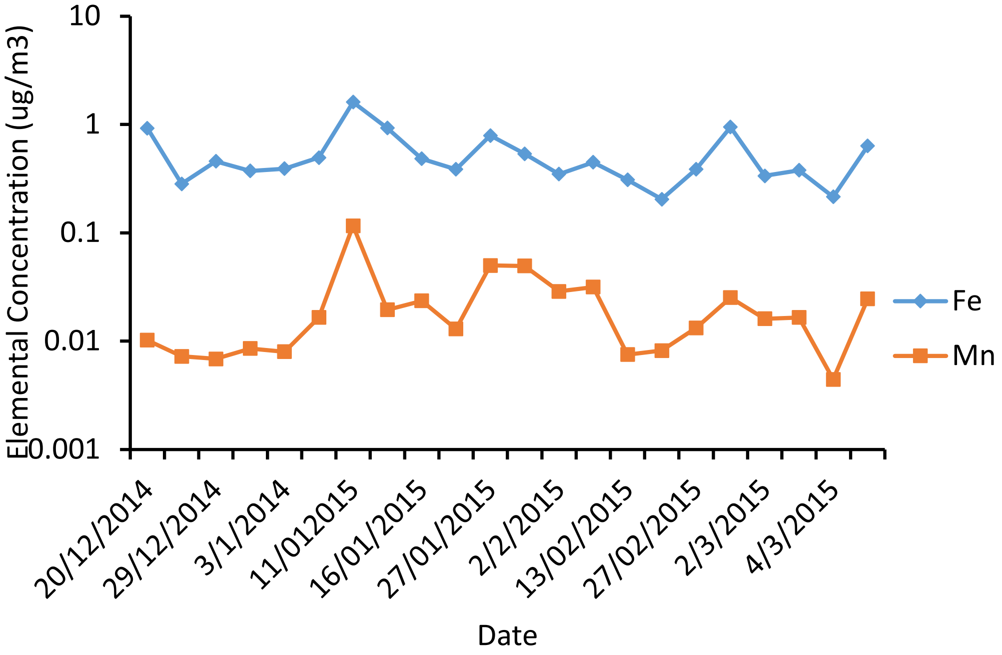

Figure 11: Time Series Graph of Fe and Mn.

Table 12: Principal Component Analysis of Elements

Elements	Factors				
	1	2	3	4	5
Fe	0.26	0.36	**0.81**	-0.13	-0.10
Mn	0.22	-0.03	**0.90**	0.09	-0.01
Cu	**0.98**	0.16	0.05	-0.11	0.02
Zn	0.29	**0.84**	-0.19	-0.06	-0.23
Pb	-0.20	0.11	**0.73**	0.08	-0.09
Ni	**0.98**	0.16	0.05	-0.11	0.02
Cd	**0.98**	0.16	0.05	-0.11	0.02
Cr	-0.15	-0.10	0.04	**0.98**	-0.03
Co	-0.15	-0.10	0.04	**0.98**	-0.03
Ca	0.21	**0.85**	0.37	-0.13	0.21
Mg	0.20	**0.85**	0.38	-0.12	0.21
Na	0.06	0.07	-0.15	-0.05	**0.97**
K	**0.98**	0.16	0.05	-0.11	0.02
BC	**0.96**	0.39	0.10	-0.07	0.04
% Variance	36.69	17.46	16.76	14.64	7.81
Source	Biomass	Two stroke engine	Crustal		Marine

Health Risk Assessment of Particulates Matter

The probability that exposure to a particulate will cause ill-health problems was assessed using the Air Quality index (AQI) defined and used by the United States Environmental Protection Agency (USEPA). The Air Quality Index (AQI) values were obtained using the USEPA AQI formula;

$$I_p = \frac{I_{HI} - I_{LO}}{BP_{HI} - BP_{LO}}\left(C_p - BP_{LO}\right) + I_{LO}\,.$$

An increase in the AQI value suggests that a considerably large percentage of the population is likely to experience severe health effects. The results of the Air Quality Index (AQI) calculated using the PM_{10} levels and the levels of health concern are shown in Figure 12. The PM_{10} Air Quality Index values, health effects and cautionary statements proposed by USEPA which serves as a guide for determining the groups of people who are at risk upon exposure to PM_{10} particulates is shown in Appendix C.

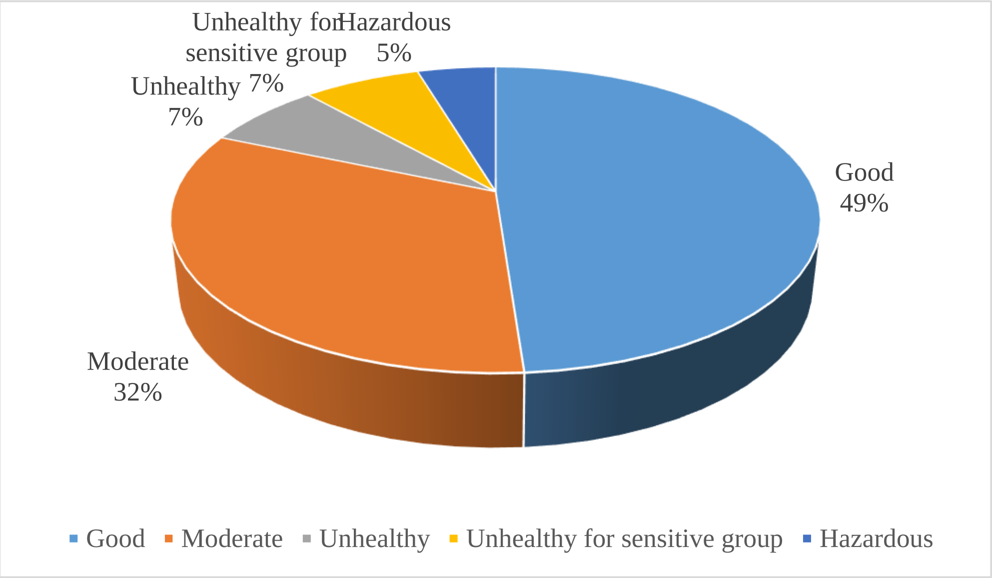

Figure 12: A Pie Chart Illustrating the Percentage Occurrence of Air Quality Categories of PM_{10} Concentrations Obtained.

AQI values obtained for this study ranged from 3 to 469. Averagely, for 21 out of the 43 sampling days, the level of PM_{10} in the atmosphere had no effects on the ambient air quality and it's considered as "good" and hence has no potential health effects on the workers and the population within the vicinity. Also 32.55% of the PM_{10} levels were considered to be "moderate", which suggests only people with cardiopulmonary diseases, infants and the aged will be affected according to United State Environmental Protection Agency guideline (Appendix C). The remaining eight (8) days had AQI values above 154. The value for three (3) of the days fell between 101-150 which according to USEPA guideline is unhealthy for sensitive people and people with cardiopulmonary diseases, infants and the aged. Another 7.1% showed values between 151-200, which is unhealthy and very unhealthy for the general population. Two (2) values above 200 were obtained and this indicates hazardous situation to the general population and can cause severe health conditions.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

In this study, the ambient air PM_{10} levels were determined at the palm kernel oil production site and the chemical composition (elemental and BC) of the particulates ascertained. The observed results were for the daily sampling of ambient air for a total of 43 days from December 2014 to March 2015. This chapter will present the summary and conclusions that were drawn from the study and also present recommendations for future works.

Summary

The daily concentrations of PM_{10} obtained from this study varied from 3.60 µg/m^3 to 658.62 µg/m^3 with an average value of 121.19 µg/m^3. The high average value agreed with similar studies on biomass burning at other two locations in Accra (Nima and Ashaiman). The average PM_{10} concentration was found to be higher than the WHO and Ghana EPA 24- hour air quality guidelines of 50 µg/m^3 and 70 µg/m^3 respectively. In such situations where the particulate mass concentrations exceed the regulatory limits, it is prudent to carry out additional analysis to identify the possible sources of the pollutants and their respective contributions to the atmospheric pollution. The BC concentration levels were necessary to assess the contributions from different combustion processes.

Atomic absorption Analysis technique and the Smokestain reflectometer were used to identify the metal elements and black Carbon levels in the air particulates on the loaded filters. The elemental analysis results revealed the emissions of Fe, Mn, Cu, Zn, Pb, Ni, Cd, Cr, Co, Mg and the ions ;Ca^{2+}', Na^{2+}

and K^+ into the ambient air. These values also compared well with values obtained from other studies on biomass burning in Accra.

Correlation studies showed a strong, moderate and weak positive correlated associations among the identified elements. This is expected since the particulates come from different emission sources. Principal component analysis revealed 5 major sources. Biomass burning, two stroke engines, soil dust, and Sea salt were the four conveniently identified main source. Cu, Ni, Cd, K and BC in the ambient air originated mostly from biomass burning. Zn, Ca and Mg were identified to have originated from two Stoke Engines. The milling machine at the sight could be responsible for that. Fe was identified to be of crustal origin. The major factor that gave the most particulate contribution at the site was biomass burning (36.69%) followed by two stroke engine (17.46%), then to crustal source(16.76%), with the least being Sea salt(7.81%). The fourth source which contributed (14.64%) could not be well identified.

Conclusions

The analysis of the sampled air revealed the presence of harmful substances whose presence affect the quality of the air. Air quality index risk evaluation revealed that 48.89% of the sampling days had air quality index falling in the good air range. This shows that generally, the ambient air quality at the site does not ensure healthy conditions. Sources of particulates other than those directly from the palm kernel oil production activities is in line with the fact that particulates can be carried over from one local region to the other.

Recommendations

In view of results and conclusions obtained from this study, the following recommendations are proposed.

1. At least three years of daily monitoring of particulate and gas at the sampling location and some other location engaged in the same activity should be done to adequately ascertain the seasonal variations.
2. Monitoring should be done to establish black smoke concentration levels due to biomass burnings in domestic and commercial kitchens.
3. Analysis of all the various organic and inorganic substances in smoke from biomass burning should be encouraged to determine their levels and possible health effect.
4. Monitoring for two size fractions in PM_{10} (Course and fine) should be done for better particulate size assessment.
5. Epidemiological studies should be conducted to establish the link between smoke levels and respiratory tract and cardiovascular diseases for both infants and adults at places where such industries are located as they most certainly contribute to morbidity.
6. Research can be conducted on the urine and blood samples of some women and children in this neighborhood to fully ascertain the bio-accumulation impact of these particulates on their health.
7. Concerted efforts should be made nationwide to stop open burnings as it contributes significantly to ambient air particles.
8. Education on environmental pollution and its effects should be encouraged.

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APPENDICES

APPENDIX A

ELEMENTAL CONCENTRATIONS (μg/m^3)

DATE	Fe	Mn	Cu	Zn	Pb	Ni	Cd	Cr	Co	Ca2+	Mg2+	Na+	k+	C	Mass Conc
20/12/2014	0.923	0.010	0.015	0.041	0.031	0.005	0.010	0.005	0.005	1.366	0.540	4.587	0.051	7.121	74.754
23/12/2014	0.283	0.007	0.011	0.004	0.014	0.004	0.007	0.011	0.011	0.743	0.293	100.725	0.036	5.223	52.335
29/12/2014	0.456	0.007	0.010	0.007	0.058	0.003	0.007	0.003	0.003	0.394	0.154	2.058	0.034	5.245	89.179
31/12/2014	0.372	0.009	0.013	0.017	0.004	0.004	0.009	0.004	0.004	0.749	0.299	3.422	0.043	6.337	94.098
3/1/2014	0.391	0.008	0.012	0.004	0.004	0.004	0.008	0.004	0.004	0.463	0.184	1.597	0.040	5.738	59.880
7/01/20115	0.494	0.017	0.008	0.006	0.003	0.003	0.006	0.003	0.003	0.621	0.248	1.380	0.028	4.102	123.303
11/012015	1.606	0.116	0.011	0.004	0.157	0.004	0.007	0.004	0.004	1.100	0.442	2.246	0.037	5.633	259.481
13/01/2015	0.926	0.019	0.010	0.003	0.117	0.003	0.006	0.003	0.003	0.998	0.398	1.620	0.032	5.231	658.676
16/01/2015	0.483	0.024	0.012	0.004	0.047	0.004	0.008	0.043	0.043	0.345	0.137	1.177	0.039	5.906	136.032
25/01/2015	0.385	0.013	0.010	0.003	0.039	0.003	0.006	0.045	0.045	0.431	0.172	1.944	0.032	4.443	82.065
27/01/2015	0.790	0.050	0.025	0.008	0.008	0.008	0.017	0.008	0.008	0.499	0.191	8.317	0.083	11.428	11.089
30/01/2015	0.537	0.049	0.007	0.009	0.066	0.002	0.005	0.071	0.071	0.494	0.198	1.883	0.024	4.075	440.557
2/2/2015	0.348	0.029	0.007	0.002	0.036	0.002	0.005	0.031	0.031	0.444	0.178	1.921	0.024	3.753	121.678
9/2/2015	0.448	0.032	0.009	0.003	0.006	0.003	0.006	0.022	0.022	0.290	0.113	2.521	0.032	4.548	36.197
13/02/2015	0.308	0.008	0.008	0.003	0.060	0.003	0.005	0.020	0.020	0.318	0.125	1.504	0.025	3.529	45.364
22/02/2015	0.204	0.008	0.008	0.003	0.147	0.003	0.005	0.041	0.041	0.264	0.106	2.177	0.027	4.089	54.775
27/02/2015	0.387	0.013	0.008	0.003	0.003	0.003	0.005	0.019	0.019	0.066	0.027	1.325	0.027	3.912	21.011
28/02/2015	0.945	0.025	0.009	0.003	0.025	0.003	0.006	0.038	0.038	0.337	0.136	2.836	0.032	4.352	3.597
2/3/2015	0.335	0.016	0.010	0.003	0.035	0.003	0.006	0.003	0.003	0.190	0.077	3.221	0.032	4.426	21.471
3/3/2015	0.378	0.017	0.007	0.002	0.012	0.002	0.005	0.012	0.012	0.130	0.050	1.416	0.024	3.244	6.295

4/3/2015	0.215	0.004	0.007	0.002	0.002	0.002	0.004	0.002	0.002	0.047	0.018	1.774	0.022	3.042	378.151
5/3/2015	0.634	0.025	0.011	0.014	0.126	0.004	0.007	0.004	0.004	0.228	0.091	3.501	0.035	4.811	6.138
AVERAGE	0.539	0.023	0.010	0.007	0.046	0.003	0.007	0.018	0.018	0.478	0.190	6.961	0.034	5.008	126.188
MAX	1.606	0.116	0.025	0.041	0.157	0.008	0.017	0.071	0.071	1.366	0.540	100.725	0.083	11.428	658.676
MIN	0.204	0.004	0.007	0.002	0.002	0.002	0.004	0.002	0.002	0.047	0.018	1.177	0.022	3.042	3.597

APPENDIX B

CARBON CONCENTRATIONS AND MASS CONCENTRATIONS

DATE	BC Conc	Mass Conc	%BC/Mass Conc
20/12/2014	7.12	74.75	9.53
23/12/2014	5.22	52.33	9.98
29/12/2014	5.24	89.18	5.88
31/12/2014	6.34	94.10	6.73
3/1/2014	5.74	59.88	9.58
7/01/20115	4.10	123.30	3.33
11/012015	5.63	259.48	2.17
13/01/2015	5.23	658.68	0.79
16/01/2015	5.91	136.03	4.34
25/01/2015	4.44	82.06	5.41
27/01/2015	11.43	111.09	10.29
30/01/2015	4.08	440.56	0.92
2/2/2015	3.75	121.68	3.08
9/2/2015	4.55	36.20	12.56
13/02/2015	3.53	45.36	7.78
22/02/2015	4.09	54.78	7.46
27/02/2015	3.91	21.01	18.62
28/02/2015	4.35	23.60	18.44
2/3/2015	4.43	21.47	20.61
3/3/2015	3.24	26.30	12.34
4/3/2015	3.04	378.15	0.80
5/3/2015	4.81	116.14	4.14
Ave.	5.01	137.55	8.50
Max	11.43	658.68	20.61
Min	3.04	21.01	0.79

APPENDIX C

PM_{10} AIR QUALITY INDEX VALUES, HEALTH EFFECTS AND CAUTIONARY STATEMENTS PROPOSED BY USEPA

Levels Of Health Concern	Air Quality Index	Levels Of Health Concern	Ambient air Concentration Range (ug/m^3)	Colours	Meaning
Good	0 -50	Good	0 -54	Green	Air quality is considered satisfactory, and air pollution poses little or no risk
Moderate	51 -100	Moderate	55 -154	Yellow	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for sensitive groups	101 -150	Unhealthy for sensitive groups	155- 254	Orange	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151 -200	Unhealthy	255- 354	Red	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.

Continuation of APPENDIX C

Very unhealthy	201 - 300	Very unhealthy	355 -425	Purple	Health warning of emergency conditions. The entire population is more likely to be affected.
Hazardous	301 - 500	Hazardous	425– upwards	maroon	Health alert: everyone may experience more serious health effects

APPENDIX D

PERCENTAGE OCCURRENCE OF AIR QUALITY CATEGORIES.

AQC	No of days occurring	Percentage occurrence
Good	21	48.88
Moderate	14	32.55
Unhealthy	3	6.98
Unhealthy for sensitive group	3	6.98
Hazardous	2	4.61