STUDY OF CONCENTRATIONS OF $PM_{2.5}$ IN THE AIR AT SELECTED SITES IN NAIROBI AND THEIR RELATIONSHIP TO RESPIRATORY DISEASES REPORTED IN LOCAL HOSPITALS

DENNIS MUIRURI MWANGI

(C50/78205/2015)

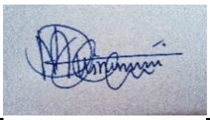
A PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ARTS IN ENVIRONMENTAL PLANNING AND MANAGEMENT, DEPARTMENT OF GEOGRAPHY, POPULATION AND ENVIRONMENTAL STUDIES,

UNIVERSITY OF NAIROBI

2023

DECLARATION

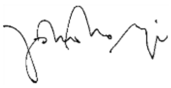
This project is my original work and it has never been submitted for examination at any other university or institution.

Signed  Date 07 June 2023

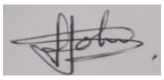
Mwangi Dennis Muiruri

(**C50/78205/2015**)

This project report has been submitted for examination with our approval as university supervisors

 /Date 07 June 2023

DR. JOHN K. MUSINGI
Department of Geography, Population and Environmental Studies
University of Nairobi

 /Date 07 June 2023

DR. ISAAC J. NDOLO
Department of Geography, Population and Environmental Studies
Universityof Nairobi

DEDICATION

This work is dedicated to my dear wife, children, parents, family and close friends for timely support. May the Almighty God bless you abundantly and prolong your lives. Thanks to everyone who supported me in one way or another. May Almighty God shower you with His blessings.

ACKNOWLEDGEMENT

First and foremost, my sincere gratitude goes to the Almighty God for the far he has brought me and many answered prayers.

Special thanks to Department of Geography, Population and Environmental Studies at the University of Nairobi including the lecturers and non - teaching staff for the skills and knowledge gained, and the support that provided to me at all times.

Secondly, a special appreciation goes to my supervisors Dr. J. K. Musingi, Dr. I J. Ndolo and Dr Nyandega for their invaluable insights, intellectual support and encouragement which made it possible to conceptualize and complete this work. They offered guidance and urged me to complete this report.

Thirdly, my deepest gratitude goes to my family for their invaluable support, encouragement and tirelessly cheering me to finalise this project. You continue to play special roles in my life everyday. May the God Almighty bless you all.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

COPD	-	Chronic obstructive pulmonary disease
EEA	-	European Environmental Agency
PSR	-	Physicians for Social Responsibility
UNEP	-	United Nations Environmental Programme
OECD	-	Organization for Economic Co-Operation andDevelopment
EPA	-	Environmental Protection Agency
KMD	-	Kenya Meteorological Department
IDSR	-	Integrated Disease Surveillance and Response Unit
CEPA	-	Canadian Environmental Protection Act
TSP	-	Total suspended particulate matter
EPA	-	Environmental Protection Agency
PM	-	Particulate Matter
WHO	-	World Health Organisation
EMCA	-	Environmental Management and Coordination Act
SEP	-	Social Economic Position

ABSTRACT

Fine particulate matter ($PM_{2.5}$) refers to dust or aerosols (droplets floating in the air) with a diameter of at most two and a half microns and once inhaled by a person, settle in the lungs, specifically the alveoli. Many empirical studies have shown an association amongst PM and the occurrence of respiratory illnesses among all age categories of humans. This research examined association amongst concentrations of $PM_{2.5}$ in the air and reported incidence of respiratory ailments at selected sites within Nairobi County in the period January 2017 - December 2020. Data on reported incidences of respiratory diseases (pneumonia, upper respiratory tract infections) were obtained from Mutuini, Mbagathi and Mama Lucy hospitals between January 2017 to December 2020 and used for the study while three hourly data on $PM_{2.5}$ concentrations in the air from August 2019 to January 2020 were obtained from six air sampling points located in Embakasi, Kawangware, Kibra, Baba Dogo, Dandora, and Langata using an E sampler.

Correlation, regression and exploratory analysis conducted on the data established that the $PM_{2.5}$ concentrations were, several times in the 24 - Hour period, higher than WHO recommended limits by as much as 4.7 times in some sampling sites but generally lower than NEMA ambient air quality guidelines during most of the time in the 24 - Hour period. The highest concentration levels of $PM_{2.5}$ were observed at the times of peak vehicular traffic (that occurs between 4pm and 8pm) in the Nairobi area and therefore it is highly likely that vehicular traffic significantly contributed to fine PM pollution in Nairobi. Hospital data showed that children under five years of age constituted at least 52.8% of all the patients that visited the three hospitals and were diagnosed with respiratory related illnesses. Additionally, there was a positive relationship amongst $PM_{2.5}$ concentrations in Kibra and reported incidents of respiratory illnesses in Mutuini, Langata and Mbagathi Hospitals. There is however a negative correlation between $PM_{2.5}$ concentration in Kawangware and reported cases of respiratory illnesses in Mama Lucy Hospital.

Based on the findings, vehicular traffic significantly contributes to $PM_{2.5}$ pollution in Nairobi. There is need for implementation of existing regulations to reduce $PM_{2.5}$ pollution as well as introduction of policies to control and reduce vehicular emission which are significantly responsible for increased $PM_{2.5}$ concentration during the day. Additionally, there is need for government intervention in installation of air pollution measurement sensors aimed at acquiring long term data to trigger further research in this field.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Air pollution is linked to health complications and a reduction in the quality of life. Gases (O_3, NO_2, SO_2, CO, for instance) and particulate matter (PM), which have a variety of grain sizes and chemical characteristics, are the two types of air pollutants that most adversely affect air quality. This report focuses on particulate matter which cause adverse health effects, especially respiratory health problems, even at low levels. The injurious effects of PM on human wellbeing depend on both the PM concentration in the air we breathe and the distribution of the particle size. The particle size distribution, and concentration of fine dust in the atmosphere depends specifically on its natural or anthropogenic sources (processing, mining, construction, vehicular emissions, etc.) and emission intensity (Nascimento et al, 2017). The instant impacts of $PM_{2.5}$ are caused by unswerving feat on the airways, and the long-standing consequences are caused by the fact that once breathed in, it can reach the alveoli, enter the circulation, and affect organs other than just the lungs. Consequently, even when $PM_{2.5}$ concentration in the atmosphere are relatively low, i.e., when they are not above the extreme tolerance levels defined by the World Health Organization (WHO) and other major environmental agencies regulations across the globe, fine particulate matter still presents a potential health risk. At their natural state, most of these compounds are found in low quantities and are mostly safe; they only become pollutants when their concentrations reach greater than the normal level and begin to have detrimental consequences. They are influenced by the pollution sources and their spreading, the state of the weather, and the geographical features in the surrounding area (Mulaku et al., 2001).

PM is derived from different sources both man-made and natural. Natural sources consist of particles, germs, animal and plant detritus, and suspended particulates. Industry pollutants and burning by-products from incineration plants, automobiles, and hydroelectric dams are examples of man - made sources. Indoor sources comprise smoking cigarettes, cookery, the burning of wood and other substances in ovens and furnaces, and the entry of outside particulate into the interior spaces (McCormack et al., 2008). Automobile emanations are the principal cause of fine PM $_{2.5}$ (with an aerodynamic diameter less than 2.5 µm) in towns, in which majority people live universally while PM_{10} (less than 10µm in aerodynamic diameter) is a multifaceted combination of components that includes a carboniferous core and other materials like organic chemicals, acids and tiny metal particles (Pagan et al., 2003).

According to Caralyn Zehnder et al. (2021), the average configuration of clean air in the lower atmosphere is as tabulated below:

GAS	SYMBOL	CONTENT
Nitrogen	N_2	78.0 8%
Oxygen	O_2	20.9 5%
Argon	Ar	0.9 3%
Carbon	CO_2	0.0 3% (this and the above three add to 99.9 98%)
Neon	Ne	18.20 parts per million
Helium	He	5.2 0 p pm
Krypton	Kr	1.1 0 p pm
Sulphur Dioxide	SO_2	1.0 0 p pm
Methane	CH_4	2.0 0 p pm
Hydrogen	H_2	0. 50 p pm
Nitrous Oxi de	N_2O	0. 50 p pm
Xenon	Xe	0.0 9 p pm
Ozone	O_3	0. 07 p pm
Nitrogen Dioxide	NO_2	0. 02 p pm
Io dine	I_2	0.0 1 p pm
Carbon Monoxide	CO	Trace
Ammonia	NH_3	Trace

Table 1 Composition of clean air
Source: Zendher et al., 2003

According to United Nations Centre for Human Settlements (UNCHS), in urban areas some air pollutants might be emmitted through incidences like volcanic explosions, winds land degradation, wild fires, sand storms, vegetation pollen dispersal, and so on; however, $PM_{2.5}$ are mainly emmitted through man-made activities, particularly industrial production and vehicle operations. These activities are majorly concentrated in towns and other urban areas and currently holding at least half of the globes' population (Galcano C et al., 2001).

The nature of air pollution in developing nations has shifted over time, from typical type 1 pollution (sulphur dioxide and big dust particles) to latest type 2 pollution comprising of nitrogen oxides, carbon-based mixtures, ozone, and ultra fine elements (Schaferput & Ring, 1997). The air pollutants of most concern include ozone (O_3), oxides of nitrogen and PM. Photochemical smog is made up of a lot of ozone, which is made at pulverized equal when NO_2, hydrocarbons, and ultraviolet light react with each other in the air (Kelly, 2012). The main source of NO_2 and PM is incineration of remnant fuel, largely from motor vehicles, as well as energy generation and industry; but, in many regions of the developing countries, exposure to domestic combustion of biomass as well as cooking is the primary source of NO_2 and particulate matter (Po et al., 2011).

Different researchers have demonstrated an relationship between air pollution and incidences of respiratory, circulatory and neural diseases as well as various types of cancer. The relationship amongst asthma and air pollution is established and the populations most at risk are children, senior citizens and those who have pre-existing respiratory problems. For Instance, Mudway et al. (2004) found that the particles in the $PM_{2.5}$ size range are capable of travelling deep into the breathing organs and lead to breathing difficulties. The effects of introduction to these particles include instant health effects such as lung, proboscis, gullet, and eye infuriation, shortness of breath, and coughing. Inhaling such hazardous particles and gases weakens the natural defences of the lungs by increasing epithelial permeability and reducing mucociliary clearance. According to Xing et al. (2016), $PM_{2.5}$ particles can irritate and harm the alveolar wall thereby impairing lung function. Besides, $PM_{2.5}$ particles have been found to have adverse effects on children as well. In the study by Liu et al. (2017), the joint comparative risk in children characterized noteworthy upsurges in coughing, panting, and lower respiratory illness. Xu et al. (2018) also found a link amongst $PM_{2.5}$ and poor lung function among school going children. However, the relationship between atmospheric PM concentrations and incidence of disease is inconsistent, and concentrations alone cannot be the only cause of hostile wellbeing effects (Hamanaka et al., 2018).

Particularly, the primary sources of interior and exterior pollutants of air have been pollution during energy production by companies, transportation, and residential sectors. For example, according to world bank group (2018), Moroccan industry consumed fossil fuels adding up to 1 million tons annually and subsequently producing 2 million tons of Carbon IV oxide (CO_2). As a result of coal usage, South Africa produced 6.3 million metric tons of CO_2, accounting for ninety decimal six percent of Africa's energy based carbon emissions and three decimal four percent of globes energy based CO_2 emission (Samuel, 2006). Mining and production of cement in by Moroccans, Zimbabweans, Zambians and South Africans contribute substantially to the pollution of air in the region, primarily through coal burning dust and CO_2**.** Similarly, several African countries' NO_2 and SO_2 emissions have grown dramatically in recent years, owing to the region's rising industrial activity (Opio et al., 2021). Although the manufacturing sector contributes to air pollution, significant cities in African countries are increasingly recognizing transportation as a leading polluter. A lot of toxic gases in the atmosphere (mostly NOx and SO_2, as well as unstable organic composites) as well as other harmful particle species are emitted by transportation systems. These pollutants are produced by the burning of diesel and gasoline, which are the most commonly utilized fuels, (UNEP, 2006).

According to Petkova et al. (2013), The interaction of meteorological and geographic conditions with human activities such as home biomass burning and industrial activity determines PM pollution in Africa. PM levels throughout the dry season in Africa has been found to be meaningfully higher than in other seasons. Nigeria and Niger are the African nations most burdened by $PM_{2.5}$ pollution, according to the Status of World wide Mid air 2020 study. According to the report, this kind of pollution is the foremost root of most neonatal deaths in Sub Saharan Africa. In another report published in the Africa Times (2016), every child in Africa under the age of five is breathing air that is tainted by higher $PM_{2.5}$ levels of pollution, since its concentration is higher than threshold for the quality of air provided by the global wellness establishment. These are indications that the $PM_{2.5}$ pollutant has the most significant impacts on the health of Africans in general. However, only a few cities in Africa have systems for monitoring air in place, and majority do not have any technology for monitoring quality of air in place. The data that does exist isn't always open to the community as well as strategically shared, that restricts awareness of public and formulation of policies. As a result, the problem is complex. In addition, for the great most of persons living in Sub-Saharan Africa (SSA), there is lack of good source of data on ambient air pollution (AAP). Independent study teams have gathered the little exposure data available, during brief studies spanning small geographic locations (Katoto et al, 2019).

Vehicle traffic is a substantial source of particulate pollution in developed towns, where the population of vehicles is increasing rapidly, and there is a lack of a suitable public transportation policy and land management, likely to result in dangerous levels of pollutants in the air near main roads. According to Gatari et al (2013), man made sources such as discharges linked to automobiles (both exhaust & non exhaust) has a substantial influence to $PM_{2.5}$ in Nairobi. Furthermore, current weather and climatic conditions have been proven to have a major impact on the quantity and composition of airborne PM. Other factors that exacerbate urban air pollution are uncontrolled or lack of integrated zoning plans for cities, exponential rise in the number of private cars, entry of vehicles, which would otherwise need not to, into cities and lack of a reliable alternative rail transportation system. With the surge in vehicle traffic on the streets of Nairobi and the economic development of the city, the urban environment is being increasingly under pressure from air pollution, (ZW et al., 2016). According to research by Approach to Pollution of Air in East Africa, Nairobi has inadequate network for monitoring quality of air and lacks long-term data needed to determine regional and temporal fluctuations in air quality. According to the available data, the city's air pollution levels frequently exceed the WHO's suggested limits of 25 μg/m^3 for $PM_{2.5}$ 24 - hour mean. As per the USEPA index for quality of air, Nairobi's quality of air is at levels that are deemed harmful for vulnerable populations. Furthermore, a review of discernibility data shows that quality of air has been worsening because the 1970s, with normal quality of air currently being 2.5 times worse than it was in the 1970s. This has increased the chances of respiratory illnesses among the people residing in Nairobi, (Desouza et al., 2020). However, the Nairobi County in partnership with UNEP and other stakeholders have advanced Nairobi's first Action for quality of Air 2019 – 2023 Plan aimed at building scientific evidence base for policy formulation.

1.2 Statement of the Problem

Each year, in excess of 3.5 million people are expected to die as consequence of outdoor pollution of air throughout the world. Between 2005 and 2010, the death rate rose by 4%, (UNEP, 2014). Furthermore, asthma affects more than 20 million individuals in the US, as well as six million kids. Asthma is a long lasting lung illness that is currently incurable, and lung tissue damage from asthma episodes may result in irreversible damage. Episodes of asthma could be provoked by a various things that consist of dusts, smokes, pollens, and Explosive Carbon-based Composites (VOCs). According to the EPA (2021), particulate matter, ozones, carbon monoxides, sulphur dioxides, and nitrogen oxide are mutual exterior triggers of pollution. In 2010, the societal cost of air pollution was projected to be $1.4 trillion in Chinese and $0.5 trillion in Indian and European (Mahmud et al., 2020). Air pollution from road travel costs roughly US$137 billion per year, while the damages caused by air pollution (including lost lives, bad health, and crop damage) from the 10,000 biggest polluting facilities cost between US$140 - 230 billion in 2009 (WHO, 2015). As per the establishment for Economic Cooperation and Development (OECD) report from 2016, the burden of ambient pollution of air in Africa was projected to be 215,212 million USD based on mortality alone, while domestic air pollution cost around USD 213,798 million in 2013.

Children are predominantly subtle to effluence in the air. They breathe mostly via their mouths, bypassing the nasal passages' filtering action and enabling contaminants to enter deeper into the lungs (Stein & Yael, 2018). In comparison to adults, they have a big lung surface area in relation to their weight and inhale more air. They also spend more time outside, especially in the afternoons and during the months of summer, when ozone levels and other pollutants are at their peak, (Jonson, 1996). Children may also overlook the early signs of air pollution's impacts, such as asthma exacerbation advancing to more severe episodes. When these variables are combined with the negative effects of certain pollutants on lung development, as well as the immaturity of the child's enzymes and immune system, which detoxify the toxins, children are more susceptible to air pollution, EPA (2021). Increasing epidemiological evidence indicate that inhaling airborne particulate matter led to an increase in breathing and heart transience and disease, and produces a series of negative breathing organs including asthma, pulmonary dysfunction, and Long - lasting Uncooperative Pulmonic Sickness (Ayres et al., 2008, Ristovski et al., 2011). In particular, temporary exposure of asthmatic persons to elevated $PM_{2.5}$ levels during moderate exercise can cause breathing difficulties with symptom like wheezing, tightness of chest, and shortness of breath (Kim et al., 2013). Exposure to small particles smaller than 5 microns in radius, such as $PM_{2.5}$ and PM_{10}, can cause serious health problems as these particles infiltrate inside the lungs and bloodstream (Villeneuve et al, 2007).

Long standing monitoring for quality of air is uncommon in Sub Saharan Africa. As a result, there are just a few PM data sets available for East African cities; in which data is available, projected $PM_{2.5}$ values are around $100\mu gM^{-3}$, in contrast to $20\mu gM^{-3}$ in majority of countries in Europe and cities in Northern America demonstrating that pollution of air in towns of Eastern Africa is a serious health hazard (Kinney et al, 2011). In developing nations, emissions of automobile (both exhaust and non exhaust) make up the bulk of pollution of air in urban areas (Kinney et al., 2011; vanVliet and Kinney, 2007). Relatedly, Kinney et al. (2011) found that $PM_{2.5}$ concentrations at street levels, near to a city roads, routinely surpassed the World Health Organization (WHO) 24 - hour recommendation of $25\mu gm^{-3}$ in Nairobi.

Egondi et al. conducted research in Nairobi in 2018 that found a strong link between outdoor PM2.5 concentrations and respiratory symptoms in the Nairobi neighbourhoods of Korogocho and Viwandani. Children who lived in highly polluted regions were found to have had a considerably greater incidences of cough and morbidity in general than children who lived in low - polluted areas. Therefore, this study was expected to contribute to the few studies on the relationship between fine particulate matter and reported hospital visits within Nairobi County.

1.2.1 Research Questions

1. What are concentration levels of $PM_{2.5}$ in air around selected sites in Nairobi City?
2. To what extent do observed $PM_{2.5}$ concentrations exceed set air quality standards?
3. What is the reported incidence of respiratory diseases within the selected sites in Nairobi city?
4. To what extent can the $PM_{2.5}$ and incidence of respiratory ailments be related?

1.3 Objectives of the Study

1. To examine $PM_{2.5}$ concentrations in air around selected sites in Nairobi City
2. To establish the extent to which $PM_{2.5}$ concentration levels at selected sites exceed set air quality standards.
3. To analyse incidence of common respiratory diseases reported in Nairobi County.
4. To suggest a association amongst $PM_{2.5}$ concentration levels and reported incidence of respiratory diseases at the selected sites

1.4 Research Hypothesis

H_0: $PM_{2.5}$ levels of concentration dont have a significant relationship to the reported cases of respiratory diseases in Nairobi City.

1.5 Scope and Limitations of the Study

The study engaged collection and recording of daily $PM_{2.5}$ concentrations in Kawangware, Karen, Kibra, Embakasi, Baba Dogo and Dandora for six months between August 2019 and January 2020. Separately, data on monthly cases of respiratory diseases was recorded from January 2017 to December 2020. In summary, $PM_{2.5}$ data concentrations used for this research was for a duration of six months while respiratory related diseases data was four years. This is mainly contributed by the cost implications of collecting long term data on air pollutants. The choice of the previously named sampling points was based on population density (Kibra, Kawangware, Dandora), proximity to industries (Embakasi, Baba Dogo) while Langata was selected for comparison due to its proximity to generally highly controlled and vegetated areas of Karen.

The choice of the hospitals was mainly based on their county status as referral hospitals, availability of data on respiratory related diseases as well as their disposition within Nairobi. For instance, Mama Lucy hospital is located to the east, Mutuini to the west and Mbagathi towards the southern part of Nairobi as shown in Figure 2. This study focused on $PM_{2.5}$

concentration but did not delve into the chemical composition of the fine particulate matter. Additionally, meteorological effects of fine particulate matter were not assessed in this study. This study was limited to a few sampling points and referral hospitals within Nairobi while the causes of respiratory illnesses and subsequent hospital visits were not determined in the study. Additionally, there were cases of missing hospital data in some months while the respiratory data was limited to four months due to financial constraints.

1.6 Significance of the Study

Air pollution in modern cities is a severe public health threat. As per State of Global Air report 2020, $PM_{2.5}$ concentrations have been the most persistent and robust predictor of fatalities from respiratory, cardiovascular, and other types of illnesses in metropolitan areas over the years. Nairobi is one of the unique counties in Kenya acting both as the capital city of the country as well as the county administrative centre. It is the most populated county with the highest number of manufacturing companies and vehicular sources of air pollutants in Kenya (Vision 2030 – Rethinking Road Traffic Report: 2010, EIU 2014). Additionally, few researches have been undertaken to investigate fine concentration of particulate matter and respiratory diseases in Nairobi.

The constantly increasing pollution levels initiated anthropogenic activities such as vehicles, construction, industries among others calls for studies to establish the actual concentrations of $PM_{2.5}$ and its relationship to the reported cases of respiratory diseases. Furthermore, because harmful effects on the respiratory system have been seen at concentrations much below ambient air quality guidelines, it appears that further study is needed to provide the required data to influence legislation and pollution management efforts. This study is therefore envisioned to inform and also trigger detailed research in air quality standards and management within Nairobi County as well as investment in long-term measurement of air pollutants.

1.7 Operational Definitions

COPD (Chronic Obstructive Pulmonary Disease): Illness involving progressive harm of lung tissue, particularly thinning and annihilation of the alveoli or air sacs.

Epidemiology: Investigation and examination of the dispersion (whom, when, and where) and factors of healthcare and illness situations in affected individuals.

In vitro: Implementing a specific treatment independent of a living creature in a controlled setting.

Macrophage: a cell responsible for identifying, inundating and crushing pathogens and apoptotic cells.

Particulate air pollution: Air pollution caused by small solid or liquid particles floating in the air.

Respiratory diseases: Sicknesses of the airlines and additional edifices of the lung in the human body.

Volatile Organic Compounds (VOCs): Organic chemicals which have a higher vapors pressures at typical room temperatures as result of a low point of boiling, causing a large number of particles to vaporize or mellow from the solid or liquid form of the molecule and discharge into the atmospheric atmosphere.

Criteria air pollutants: Set of air pollutants which are responsible for smogs, acid rains, and other health risks that are often emitted from a variety of sources, including industries, mines, transportations, energy generations, and agriculture.

Fine particulate matter ($PM_{2.5}$): Minute particle or droplet in the air which are two and a half micronsor less wide.

Particulate matter ($PM_{10)}$: Inhalable atoms, with diameter which is normally 10 micrometers as well as spallers.

Ambient air pollution: Air pollution in outdoor environments.

Total Suspended Particulate Matter: Entirety of small hard material unrestricted, recognized and/or otherwise experimental in the sky.

Air quality regulations: In the opinion of an Authority, quality requirements are necessary for protecting the public health while also providing an acceptable margin of safety.

CHAPTER TWO

2.0 LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 Introduction

The works and contributions of previous scholars on related studies were reviewed in this chapter and a conceptual framework developed.

2.2 Particulate Matter and Concerns for Air Quality

PM refers to a mixture of various chemical species not necessarily a lot of pollutants. It is comprised of a combination of solids as well as vaporisers composed of small liquid droplet, solids cores, and dry compact wreckages. PM particles differ in shape, size, and chemical composition. In addition, they may contain metallic compounds, inorganic ions, and organic compounds. Thus, for regulatory purposes, these particles are defined by their width. Particles with a thickness of 10 micrometers or fewer (PM_{10}) could be gasped into the respiratory tract and cause healthiness glitches. Fine Particulate matter is distinct as elements with a thickness of 2.5 micrometres or fewer ($PM_{2.5}$), (Xu et al., 2020). Humans come into contact with PM mainly through gasp and absorption, whereas skin contacts is a negligible exposure routes. Particulate matter is a major contributor to air pollution and, in some cases, makes breathing the main intake path for pollutants (Thron, 1996). Particles having a thickness of 10 microns or smaller ($\leq PM_{10}$) could infiltrate inside the respiratory organs and settle there, while more harmful particles with a thickness of 2.5 microns or fewer ($\leq PM_{2.5}$) $PM_{2.5}$ has the ability to get through the pulmonary barrier and enter the bloodstream. Chronic particle inhalation raises the risks of emerging circulatory disease, breathing disease, and lungs cancers, among other diseases (WHO, 2021).

In Africa, there are four major kinds of PM sources such as road transport, biomass combustion, industries and energy, and Sahara Dusts (World Health Organisation, 2006). The involvement of every PM sources is determined by various factors, such as location geographically, weather conditions, and human activity in the surrounding area. Road traffic fumes are widely recognized as a noteworthy sources of PM in urban and metropolitan areas throughout Africa (Naidja et al, 2017). Emission from automobles comes from exhausts and non-exhausts emissions. Non - exhaust emissions mainly lead to the coarses modes of > 2µM, while the fine fractions with a diameter of less than 0.1 µM consist of toxic metals. Exhaust emissions mainly contribute to fine particulate matter. Non-exhaust PM come from sources of abrasion and spring back such as road dust from vehicles and road wears, corrosions of automobile mechanisms, brake and tyre wear, etc. Exhaust emissions, on the other hand, are emitted from incomplete fuel incineration (Amato et al, 2010; Belis et al, 2013; Hulskotte et al, 2010).

Heavily inhabited urban areas with related substantial local circulation in Nairobi contribute significantly to the development of urban pollution of air. Kinney et al. found out a considerable range of 58μg/m^3 - 98μg/m^3 over eleven hours of individual exposures along busy roads and intersections in 2011. Due to the spread of pollutants during the night, the range is estimated between 45 - 85μg/m^3 with a 24 - hour sampling. Relatedly, sampling conducted Nairobi using portable air samplers by technical staff on days of the week at various areas in Nairobi for two weeks established that average daily $PM_{2.5}$ concentrations lie between 10.7 μg/m^3 at a local backgrounds sites and 98.1μg/m^3 on sidewalks in CBD suggesting that people of Nairobi are exposed to high quantities of pollution of air resulting from fine particle, which has the potential to have substantial long - term health consequences for inhabitants (Kinney et al, 2011).

2.3 Current Global, Regional, National and Local Trends

Several Multilateral Environmental Agreement (MEAs) relate to the environment and climate change. For example, the 1979 Convention on Long-term Transboundary pollution of Air in 1979; the Vienna Convention in 1985 for the fortification of the Ozones layers, the 1992 UN Outline Agreement on Weather Modification and Kyoto Protocol in 1997.

2.4 WHO Air Quality Guidelines

The WHO Air Eminence Procedures bids guidance internationally on verges and restrictions for major pollutant of air that poses risks to public health. The procedures, which are applicable around the world, are founded on experts appraisal of modern scientific breakthroughs on PM. Based on these guidelines, by plummeting PM_{10} pollutions from 70μg/m^3 to 20μg/m^3, we could minimise deaths linked to the pollution of air by 15%. The values for PM_{10} and $PM_{2.5}$ is as illustrated in the table below:

Concentration	**$PM_{2.5}$(μg/m^3)**	**PM_{10}(μg/m^3)**
24 Hr Mean	25	50
Annual Mean	10	20

Table 2: WHO Air quality Guidelines for Particulate Matter Concentrations
Source: WHO website

Total suspended particulate matter (TSP)

The Particulate Matter (TSP) air quality targets were created in the 1970s and amended in the 1980s in Canada (CEPA, 1999). Ranges of air quality targets were formulated defined as "Desirable," "acceptable," or "tolerable" based on previous scientific research before the late 1960s when many air pollution episodes in cities such as London, England resulted in significant health effects, amounting to thousands of premature deaths over a few days. The CEPA (1999) report explained how governments of the time took steps to reduce pollution levels, which were primarily composed of combustion-related particulate matter (PM) usually combined with sulphur dioxide. Various studies were afterwards conducted demonstrating adversative effect on cardio-respiratory health as well as augmented hospital admissions and augmented untimely death. These results led to a re-evaluation of the goals, not only in Canada, but also in the USA, Great Britain, the European Community and the WHO (CEPA, 1999; WHO, 2005). Instead of discarding the TSP targets, which had already been recognized as obsolete both chronologically and scientifically, new quality of air targets for particulate-matter with a thickness of 10 microns (<PM_{10}) and its Fine $PM_{2.5}$ were proposed for development. Because current information reveals that particle size is relevant, the assessment now concentrates on smaller particles (PM_{10}) compared to total suspended particles with a size of 0.005μm - 100μm. The size has an impact on where the disposition happens in the human respiratory system and the amounts of toxicity that might be experienced as a result (Nielson et al; 2017).

WHO's Global Action Plan for the Prevention and Control of Non - communicable Diseases 2013 – 2020

According to the plan, Air pollution, especially particulate matter, is a key factor of risks for adult non - communicable illnesses such ischemic heart diseases, strokes, long-lasting uncooperative pulmonary diseases, asthmas, and cancers, and stances a substantial risk factor for current and upcoming cohorts. Half of all deaths from severe lower breathing tract contagions, including pneumonia, in kids under 5 year is credited to domestic pollution of air, thus making it a major cause of child death. Therefore, pollution of air is a cause of inequality on global health, especially for women, children, the elderly, and poor individuals who are commonly susceptible to preeminent pollution extent of air, or living in households in which there is no other option than being exposed to pollution of air.

The East African treaty of 1999

Under this treaty, the partner states unilaterally agreed that development and industrialization could lead to environmental degradation and exhaustion of natural resources potentially leading to pollution. They approved to adopt procedures to control transboundary air, soil and water pollution as a result of development activities (EAC Treaty, 1999).

The Eastern Africa Regional Agreement on Air Pollution (The Nairobi Agreement, 2008)

The East African Agreements on Air Pollution was signed in 2008 in Nairobi by countries in the eastern African region (i.e sudan, Uganda, Tanzania, DRC, Somali, Rwanda, Ethiopia, Djibouti, Eritrea and Kenya) with the aim of reducing air pollutants and agreed to develop air pollution control guidelines in anthropogenic activities. They committed to coordination of values and guidelines for management of emissions and harmonization of waste water discharge standards. In addition, they agreed to strengthen capacities of member states to enforce environmental protection laws and to install environmental monitoring systems.

The Environmental Management and Coordination Act, 1999 & 2015 (EMCA)

This is the legal frameworks on managing and conserving the environments. NEMA was founded in this act to come up with regulations, recommend procedures and protocols and, give guiding principles for managing and conserving the natural resources and the environment. The amended EMCA 2015 provides the definition of standards and measures for measuring air quality as well as the definition of standards of quality of air; work related quality of air standards, standards of emissions for different sources; principles and procedures for quality of air for both moveable and motionless sources; and all other air quality standards. In the first schedule, EMCA defines ambient air quality tolerance limits for $PM_{2.5}$ and PM_{10} as shown in the table below:

Pollutant		**24hours (µg/m^3)**	**Annual average (µg/m^3)**
$PM_{2.5}$		75	35
PM_{10}	Industrial area	150	70
	Residential rural& other area	100	50
	Controlled areas	75	50

Table 3: EMCA Air Quality Guidelines for Particulate Matter
Source: EMCA regulations, 2015

2.5 Previous Studies

2.5.1 Respiratory Diseases, PM and Weather

Fine particles show a seasonal pattern. For example, $PM_{2.5}$ concentrations are normally higher in the third quarter of the year (July - September) in the eastern half of the United States**.** Liu et al. (2018) did a research on the characteristic of $PM_{2.5}$ in various urban cities in China and noted that the weather seasons determine PM concentration; peaks were noted during the winter andminima during thesummer. In other words, frequent heavy episodes of pollution occurred during the winter. Relatedly, in a study conducted by Bhaskar & Mehta (2010) in Ahmedabad on atmospheric particulate pollutants (suspended particulate matter (SPM) and PM_{10}) and their relationship with meteorology, it was observed that there was a negative correlation between both SPM and PM_{10} with rainfall. Therefore, it was established that increasing the amount of air pollutants causes a decline in the amount of rainfall expected in an area. Although the study did not focus on their impact on respiratory diseases, it showed that air pollutants have adverse effects on meteorology. Rainham et al. (2005) did a study on the association amongst air pollutants and human mortality during cold and warm weather in Toronto, Canada. The major findings documented in this study were that subtle fluctuations in composition of meteorology play a role in influencing the pollutant strength linkages with health consequences, particularly in the season of summer. Highest mortality rates were also linked to $PM_{2.5}$. In a more related study, De Sario, Katsouyanni & Michelozzi (2013) sought to investigate the link between change in climate, extreme events of weather, pollution of air, and respiratory health in Europe. It was noted that respirational sicknesses like asthma and rhinitis were on the rise worldwide, particularly as a consequence of ecological exposures such as outside pollution of air. $PM_{2.5}$ was noted as an air pollutant of concern because it has a longer lifetime and might be conveyed long distances from their regions of source. Overall, the evidence presented in this study suggested that wildfires led to higher $PM_{2.5}$ levels, which in turn had a negative effect on respiratory health.

2.5.2 Atmospheric Pollutants, Respiratory Diseases and Age groups

Air pollution is presently projected to decrease the regular expectancy of life of Europeans by 9 – 24 months (CEC, 2006). Children who breathe more air than adults in terms of weight and body surface area are at particular risk of air pollution. As a result, they absorb vast amounts of potentially hazardous chemicals which they are exposed to. Furthermore, their bodies are not fully grown yet and are motionless developing throughout infantile. This means that kids are additional susceptible to contaminants than grown ups. Their materials absorbs these constituents immediately and, because of their irresponsibility, are unable to heal the damage that has occurred. When toxic chemicals harm the brain, immunological system, or endocrine system, the consequences might be permanent and irreversible (Landrigan et al., 1998). In a different study, De Sario et al. (2013) found that the effect of $PM_{2.5-10}$ on all circulatory and cardiac illnesses was larger on dusty days compared to non - dusty days. Perez et al. (2012) also reported that in Barcelona Spain, there was a constructive collaboration of $PM_{2.5}$ throughout dusty days for circulatory and respirational death. Thalib & Al - Taiar (2012) also noted greater risk for asthma admission among people aged below 15 during dust days in Kuwait. These longitudinal studies suggest that air pollutants affect the respiratory health of different age groups in various countries.

2.5.3 Atmospheric Pollutants and Respiratory Diseases

As per the WHO (2006, 2009), the impacts of indoor and exterior pollution of air cause more than two million premature deaths every year, the majority of which occur in the home. Interior pollution of air, in particular, is accountable for the deaths of 1.6 million individuals annually, whereas outdoor pollution of air is answerable for the deaths of 800,000 people globally annually owing to lung cancer, cardiovascular disease, and respiratory disease (WHO, 2005). PM is found to cause breathing complications among children and aggravate existing conditions such as asthma, lung related complications as well as increase hospitalization for respiratory related illnesses.specifically, PM exposure, even at relatively low levels, was found to have strong association with respiratory related infant mortality in the USA (EPA, 2009).

2.5.4 Atmospheric Pollutants, Respiratory Diseases and Socio - economic position

Many epidemiological researches have revealed a relationship between socio - economic status (SEP) and health, and have observed gradients in outcomes such as death, communicable and chronic illness, and mental illness (Haan et al. 1987; Krieger et al. 1997; Marmot 2001). Air pollution is linked to reduced life expectancy, higher daily death, hospitalisation, and asthmatic, and there is evidence that it is a much more serious health issue than was previously believed (McConnell et al. 2002). Nonetheless, the association between SEP and ill health is not exclusive to the poor. Despite the fact that the poor have the highest risk of premature death and illness, research has demonstrated that there is a link between low SEP (leisurely by income or education level) and bad healthiness. At all levels of the socio - economic hierarchy, people tend to be healthier than those immediately below. This incline spreads to an income range that could be described as the middle class (O’Neill, 2003).

2.5.5 Other related Studies done in Sub Saharan Africa

Most air pollution health surveys assess exposure near a person's conscious zone or designed to assess communal exposure especially when done using environmental monitors. The use of environmental monitors as a mirror of actual individual exposure during epidemiologic research is determined by air pollutant type, study design and measurement technique (Janssen et al. 1998; Sarnat et al. 2000). Researches done across Africa have established that there are limited studies to quantify levels of outdoor exposure and assessed health outcomes. In recent research undertaken by Katoto et al in 2019, it was established that there was no systematic ambient air pollution (AAP) monitoring taking place in Sub - Saharan Africans (SSA) except in South Africa and Dakar, Senegal. The limited exposure data available was collected by an independent research team during a short-term campaign in a small geographic area, so reliable primary data on AAP was not available to the majority of SSA residents with the information available indicating pollution exposure exceeded WHO standards. However, based on the insufficient data available, African cities don't appear to have reached pollution extremes such as those of some chines and indian cities. Because epidemiological research on this issue have barely been done in SSA save for South Africa, this study found that there were significant gaps in our understanding of the existing AAP in SSA and its influence on the health of the African people.

Research conducted by Egondi et al on $PM_{2.5}$ exposure and related child indisposition and impermanence in informally disadvantaged neighbourhoods of Kenya's City established significant association between exterior fine matter in the air on breathing signs and all caused transience among the research population. Coughing and morbidity were found to be considerably greater amongst children living in highly polluted regions than in children living in low-contamination areas. In addition, there was found to be an augmented risk of respiratory linked mortality related to concentration levels of pollutant, but the association was insignificant statistically. The statistical insignificance could have been contributed to the low data available. However, the air pollution in the Korogocho and Viwandani slums during this study exceeded the WHO recommended limits by as high as five times.

Transport industry has been found to be a significant source of $PM_{2.5}$ through vehicle emissions and brake dust in Nairobi. The increase in vehicular ownership implies that pollution from both exhaust and non exhaust sources have increased over time. Estimations indicate that atleast 30,000 vehicles are introduced annually on Kenyan roads and by 2017, UNEP estimated that there were approximately 3 - 3.5M vehicles and the number is estimated to grow to five million by 2030. The substantial rise in vehicle ownership implies that vehicular pollution from both exhaust and non - exhaust sources have increased significantly over time. According to Maina et al in their study demonstrating $PM_{2.5}$ and roadside dust pollution along Thika road in Kenya using proximity model established that $PM_{2.5}$ concentrations are generally higher as you move towards Nairobi Central Business district. The average concentration was about 69µg/m^3 which is relatively higher than observations made during several European and American experiments. The study concluded that there was high $PM_{2.5}$ pollution along Thika Superhighway which poses a health risk to people exposed for long periods either working or living in close proximity to the road.

2.5.6 Models For Exposure Analysis

Various methods are used to analyse pollutants exposure and the health impact. The following is a description of various methods used:

Proximity method offers a simple way for analysing long - standing exposure classifications, but with significant limitations. Firstly, the study uses a limited number of covariate which can distort the association amongst pollution of air and health. Most researches of this kind ignore a persons contact with pollution outside of their domicile areas which oftenly may lead to biased exposure estimation. Secondly, environmental factors such as wind patterns and terrain affect isotropic dispersion assumption (Kanaroglou et al., 2000). This not withstanding, proximity methods contribute to ecological epidemiology and are very useful for health impact assessments at early stages where it is difficult to justify a large investment in complex exposure assessments (Jerrett et al., 2004).

Exclamation method involves measurement of pollutants at several stations across the study area and the data is used to approximate pollutation concentrations outside the location of measurement stations. Estimates are usually made at the grid centre in the research area so that a incessant surface of concentrations of pollutants could be fashioned (Jerrett et al., 2001a). The major benefit of the exclamation method over juxtaposition model is the use of actual pollutant capacities when calculating exposure approximations. They are reliable for analysis by enumerating differences in exposure and calculating dose response mechanisms (Jerrett et al., 2004). According to Mulugeta, the interpolation algorithm is mechanical (that is, it does not consider other factors such as terrains or local patterns). Fluctuations can be exaggerated with slopes that are too high and too many depressions while the algorithm failed at the edges because of inadequate data. As a consequence, knowledgeable subjective modification may be needed in order to provide statistics elements that are more genuine. In order to minimize the distance weighting and edge effects that are usually caused by normal interpolation methods, you can insert data in between the observed data points. In many cases, due to the expensive cost of collecting primary data, researchers are forced to collect short term data, which might or might not effectively embody the long-standing distribution of contaminants in the environment. Aside from that, researchers might find themselves obliged to make do with a handful of straight forward proxy pollutants that can be monitored easily but which exclude critical features of air pollution such as particulate matter from the equation.

Land use regression model which involves use of least - squares regression model to forecast the contamination surface founded on contamination monitoring data and prevailing extrinsic independent variables. The primary advantage of this model is that it can be tailored to the specific needs of the local community without the need for further monitoring or data collecting. You can also install additional stations to help identify areas that require more intensive monitoring. Extrapolation within a similar geographic environment is possible, but from specific land use and transportation features in metropolitan regions, a large based on the available of samples is typically needed. This requires collecting primary data with accompanying difficulties that occur during interpolation (Kanaroglou et al, 2005).

Dispersion model that uses emissions data, climatological circumstances, and landscape when approximating spatial exposure to concentrations of air pollution, based on assumptions about deterministic processes. Recently, dispersion models have been utilized in conjunction with GIS. This implies that evidence from experimental monitoring systems and data on the population demographics of the research region can be analyzed in conjunction with one another. The data addition on the terrain of the research area, models for road networks, and observations of traffic results in a more accurate portrayal of the problem than was previously possible (Jerrett et al., 2004). These models have the potential advantage of being able to take into account longitudinal and chronological variations in air pollution within the research area without the need for a solid measurement network (Bartonova et al., 1999). There are several disadvantages to these models, including the necessity for extensive cross validation with monitoring data, the use of comparatively expensive data inputs, unrealistic assumptions about distribution patterns, and temporal differences in the data that might contribute to estimation mistakes (Bellander et al., 2001).

An integrated meteorological radiation (IME) model is a model meteorological conditions are integrated in the study of pollutants to simulate movement of contaminants in the atmosphere. (Tilmes et al, 2002). They are useful in areas where extensive observations are not available to define the features of the major climatological fields needed for air quality uses. The specifics of the data attained from this model are dependent on the physics of the model, the inputs data, the grid precision, and the complexity of the surface scheme. Because of the significant implementation costs and data requirements, the IME model is rarely employed in epedimiological researches linking air quality and health. They do, however, have a wide range of applications in populated places where low levels of air pollution can result in high rates of disease and mortality (Jerrett et al., 2004).

The hybrid model is a model that combines individual or community monitoring with other methods of exposure to air pollution. This model has the advantage of measurement verification. However, this method is more problematic to execute if ambient data is not available. The pollutants investigated can also affect the cost and possibility of this technique (Mukala et al., 2000).

From literature review, it has been established that there are limited researches on the effect of PM2.5 on respiratory diseases in Kenya and SSA at large. This is largely contributed by inadequate long-standing epidemiological data and assessment of cumulative exposure. (Maina, 2018; Kinney, 2011; Katoto, 2019; Egondi, 2018; Gaita, 2014). Closer home, there are few studies done on the association amongst PM2.5 and reported cases of respiratory diseases in densely populated areas within Nairobi County. Therefore, this study is envisioned to contribute to this existing research gap and contribute towards policy formulation and implementation.

2.6 Theoretical Framework

Studies to better understand dose response mechanisms in the study of PM2.5 and linked respiratory impacts classically take one of three kinds: experimental, toxicological, or epidemiological (Peng et al., 2008). From a toxicological perspective, researchers have established that responsive oxygen classes either in PM (metals and some oxygenised organics e.g., benzoquinones) or produced stimulated cells causes pulmonary and cardiovascular effects thereby increasing hospital visits (Mills et al., 2009). Other conjectured rejoinders include up-regulating antioxidant enzymes, cell deaths, allergic immune responses, damaging lung defenses, and DNA damages, (Li et al., 2006). On the other hand, epidemiological studies have been used as the primary approach to link fine particulate matter and health effects due to complications and reservations in recognizing the accountable biological mechanisms though with inevitable inconsistencies in some studies leading to difficulties in interpretation (Brunekreef et al, 2005).

From the various study models analysed in the literature review, interpolation model was the most suitable model used to study dose response mechanisms. Using in situ observations, this technique produces concentration surfaces, which makes it a good option for analysis of air quality and health when data availability and cost implications are taken into account (Jerett et al, 2004). Additionally, it is most suitable when mobile monitoring devices are used to collect data on specific pollutants over a short period of time. Comparing mobile pollution monitoring devices to typical fixed monitoring stations, mobile pollution monitoring devices measure pollution closer to the people who are impacted by it or closer to the cars that cause it. They provide excellent spatial and temporal precision on specific paths and time (Xie et al., 2017). However, factors such as terrain, land use, wind speed among others that siginificantly affect air contaminants dispersion were not considered during the study.

2.7 Conceptual framework

The figure below represents a conceptual framework applicable to this study derived from interpolation model of exposure response relationship as described above. Based on the fundamental notion that the contact point between a human being at risk and the stressor environment is the optimum site for both considerate and managing the stressors' effect on human health. The feedback loop 1 illustrates that an outcome knowledgeable by an individual or population could perhaps be distribute to others. The feedback loop 2 shows the impact of health outcomes on people's activities and behaviours leading to even more exposure. Anthropogenic and natural factors contribute to fine particulate matter generation. The contact point between stressors and receptors in human beings remains the central point and also help in defining exposure - response associations in epidemiological studies. The model is as shown below:

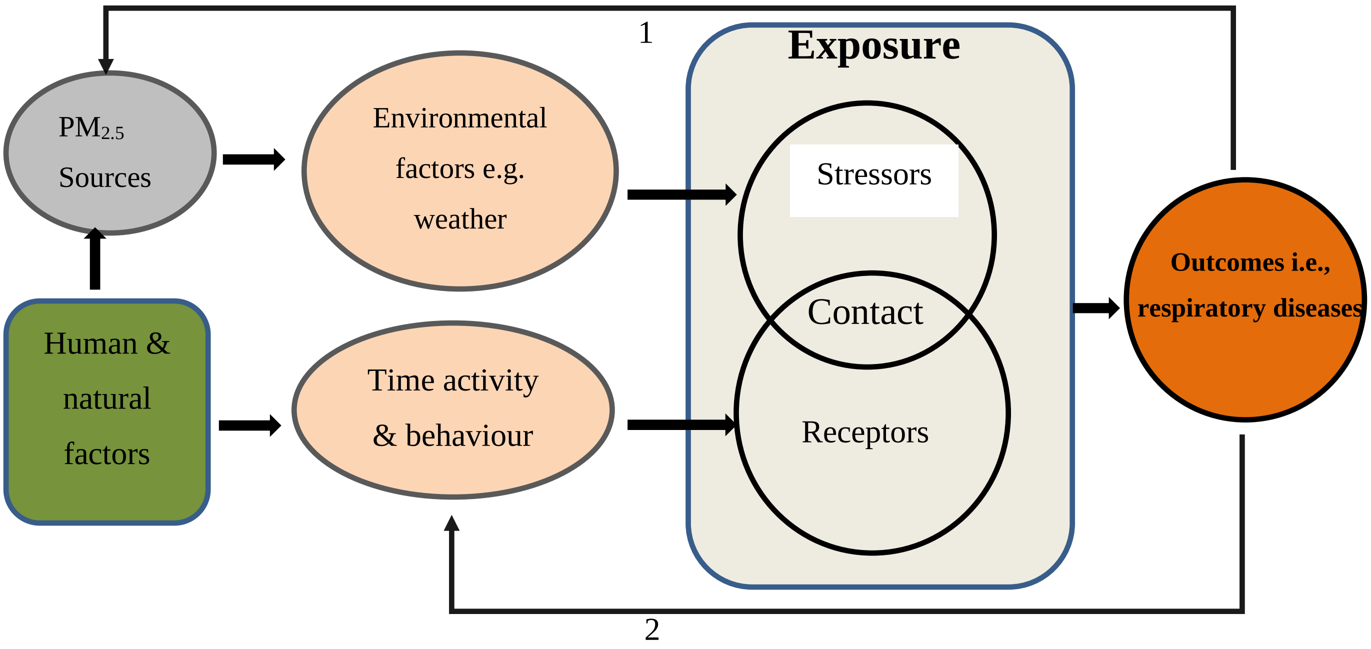


Figure 1: Conceptual framework modified from Lioy
Source: Modified from P. J & Smith, K. R. (2013)

CHAPTER THREE

3.0 STUDY AREA

3.1 Introduction

This chapter describes the area in which this study was conducted by topography, soil, weather population and social economic activities.

3.2 Study Area

Nairobi is Kenya's biggest city and one of the quickest expanding in East and central Africa and this makes it an important gateway for trade, housing, tourism among other social activities in Sub Saharan Africa. The city's population, infrastructure, and socioeconomic activity are distributed in a complicated temporal and spatial pattern. It is a transportation and communications hub and a key aviation centre in the region bordering Kiambu and Machakos counties with a surface area of 696.1km^2 at an altitude of 1,798m ASL. The county's population is estimated to be 5,958,338 by 2022. The current administrative boundary has increased from 3.84 km^2 in 1910, (Kanaroglou et al., 2005). In 1921, 1926, and 1964, the city underwent most significant physical growth. Nairobi may be Kenya's smallest administrative area, but it is the most significant in terms of the activities and functions it performs. Nairobi, like many other emerging cities, has experienced a very fast growth of population over the last three to four decades thereby piling pressure on existing infrastructure and exacerbating pollution problems. According to Nairobi County Health Plan 2019, Respiratory infections, diarrheal disorders, and skin diseases were the three most prevalent causes of illness among children under the age of five in Nairobi in 2012. In the county's three public referral hospitals, Mbagathi, Mutuini, and Mama Lucy Hospitals, respiratory disorders such as pneumonia accounted for more than 60% of total hospital visits. These hospitals receive mainly Nairobi residents especially those from densely populated and adjacent areas of Kibra, Dandora, Babadogo, Kawangware and Karen which were used as $PM_{2.5}$ sampling points. Kawangware, Kibra, Baba Dogo, Dandora were preferred sampling points because they are located within high density areas. Industrial area was preferred because of the major industrial/transport network which could greatly contribute $PM_{2.5}$ pollution while Karen sampling point was used for the study as it relatively low - density area with assumed minimal air pollution compared to other areas used in the study. The study area is illustrated by the map in figure 3 below:

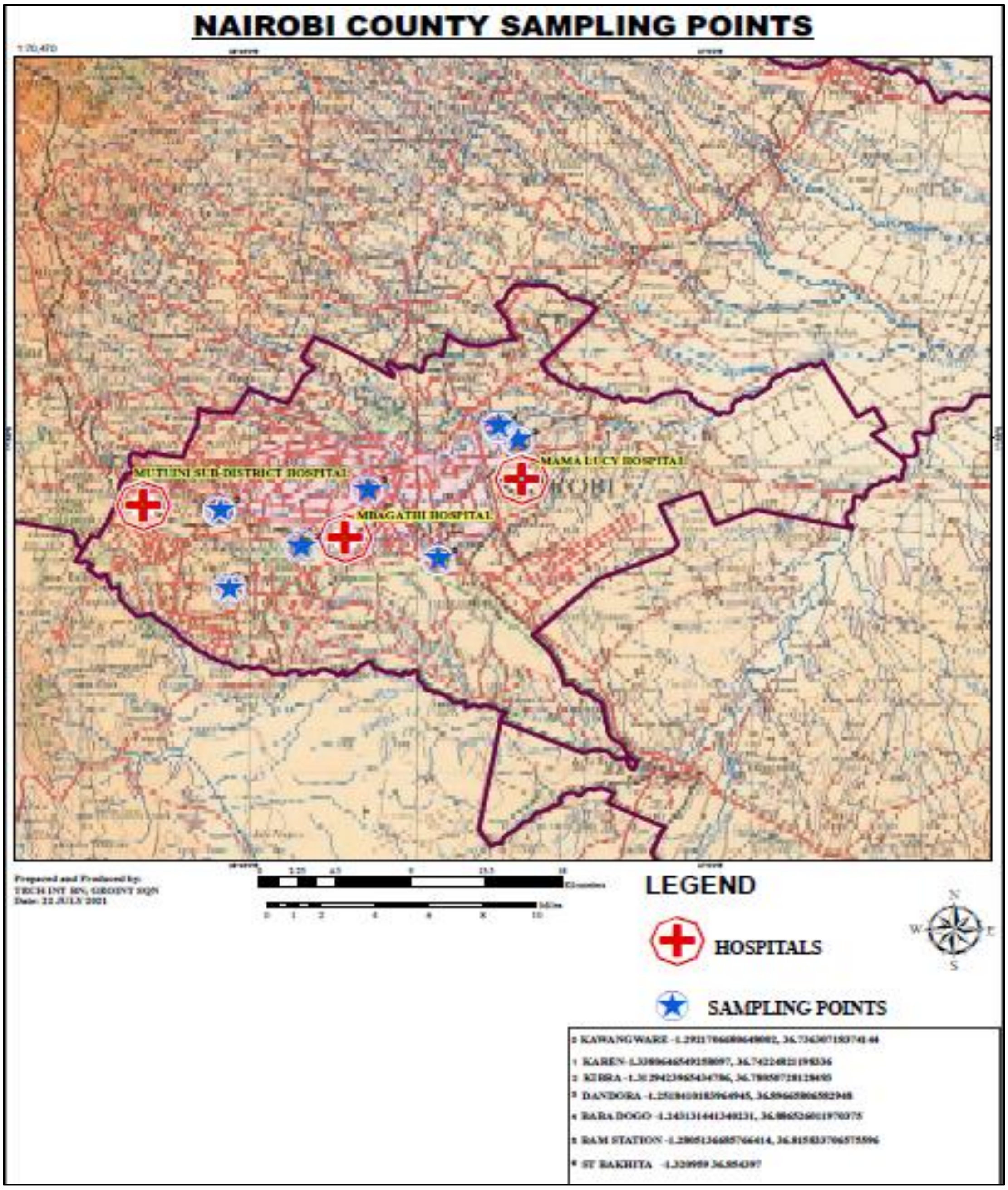


Figure 2: Location of Hospitals and sampling points in Nairobi County

3.3 Topography of Nairobi County

The city is situated on the SE tip of Kenya's agricultural centre, at latitude 1.816'S and longitude 36.848 E, 1,600 - 1,850M above sea level thereby giving the city a relatively warm climate despite its proximity to the equator. The western part of the city is high, cool and well drained while the eastern half is low, hot and generally swampy. The city is exposed to light earthquakes and tremors due to its proximity to the Great Rift Valley, with the Mathare and Ngong rivers flowing through it. The indigenous Karura Forest is to the north of the city, and the gate to Nairobi National Park (the world's only wildlife park near the capital) is 7 km south of the city centre, (Mitullah, 2003). Nairobi is fed by three drainage systems originating from neighbouring counties and running through north and souther limits characterised by rolling hilly terrain with an altitude range of between 1461 - 2301M above Sea level. According to the ISRIC categorization of soil drainage, Nairobi has a wide span of soil drainage and depths.

3.3 Physical Planning of Nairobi City

Kenya gained independence in 1963, inheriting existing resources and infrastructure as well as certain problems, such as rapid population growth. As a result, various study consortiums were formed to identify ways and means of clearing Nairobi's congestion as well as planning, housing, transportation, business and integration of the new residents into one developing city while reducing the growing effects of pollution, (Kanaroglou et al., 2005). The average population density of Nairobi is 4,515 people/ KM^2 which is the highest in the country, followed by Mombasa (4,292 people/ KM^2). The Kenyan government is currently implementing an ambitious Nairobi Metro 2030 vision to geographically reorganize Nairobi and create a world - class city region meant to operate sustainably as well as reduce the present and future problems of Nairobi.

3.5 Weather, Climate of Nairobi County and Air Pollution

Nairobi, according Urban Africa Risk Knowledge, has a subtropical highland climate located near the eastern end of the Rift Valley in East Africa and about 1,800 meters above sea level which has a major impact on its climate. Nairobi receives an average rainfall of just over 610 mm per year, primarily during the two rainy seasons. Long rains in March to May generally record about 310 mm, and short rains from November to December record about 200 mm. The temperature fluctuates throughout a wide range of time frames. The most noticeable is the diurnal cycle, in which temperature oscillates by over twelve degrees Centigrade. Nairobi's temperature varies throughout the year, although due of its location just south of the equator, the seasonal cycle is quite minor, with daily maximum temperatures fluctuating by approximately 6 degrees Celsius and daily lowest temperatures varying by approximately 5 degrees Celsius. Nairobi's urbanization trend, which includes the development of concrete surfaces and glass facades, particularly in the central business district and the suburbs, has increased solar radiation reflection in the atmosphere, raising air temperatures in the city in addition to temperature inversions (Julius et al., 2020). Temperature inversions suppress vertical mixing of air leading to trapping of air pollutants near the surface and thus causing more exposure (Thi et al., 2019). Separately, Recent Findings by Ongoma et al (2016) indicate that humidity levels in Nairobi are lower in the more urban setting than in the less urban setting as a result of urbanization. Study by Rasa et al. (2018) in South America established that there was a positive correlation between relative humidity and $PM_{2.5}$ whereby the higher the RH, the higher the fine particulate matter concentration. High RH reduced oxygen intake in internal combustion engines resulting to incomplete combustion.

3.6 Activities of Nairobi population

Nairobi's population has grown rapidly since it was founded in 1899. In particular, it increased from 11,000 in 1906 to 30,000 in 1928, 267,000 in 1962, 828,000 in 1979, 1.3 million in 1989 and 3.1 million in 2009 (Kotze et al., 2012). Mathare, Embakasi North, Ruaraka, and Kamukunji are the four most densely inhabited sub counties, each having a population density of above 20,000 people/Km^2. Westlands, Langata, Kasarani, and Embakasi East are the least inhabited areas. Furthermore, around 58 percent of Nairobi's population is projected to live in slums or slum - like environments. The city is the economic centre of Kenya, accounting for nearly 50% of GDP and 43% of urban employment, (Fay, 2005). Nairobi's environment is under threat of water, soil and air pollution. The main causes are explosive population growth, inadequate sanitation, numerous automotive and commercial and industrial enterprises, and poor coordination between city and national environmental management agencies. The city's waste collection and disposal inefficiencies are also reflected in Dandora's only landfill inadequate management, low recycling rates, lack of waste treatment facilities, and widespread mixing of waste at the time of production, (Otiso, 2019). The absence of a well dispersed infrastructure for tracking economic activity and air quality in Nairobi is mostly to blame for the population's exposure to pollution. The majority of the city's residents work in Juakali, a large open area near to the city's main highways. Odhiambo et al,'s study of automobile pollution along Nairobi's main roads found that particulate matter concentrations were higher than the WHO's recommended levels. According to the Nairobi County health sector strategic and investment plan, prevalence rate of communicable diseases including tuberculosis, HIV/AIDS among others has more than doubled with respiratory illnesses being among the top five ranking diseases besides malaria, pneumonia diarrheal and skin diseases that are attributed to the growing population.

CHAPTER FOUR

4.0 METHODOLOGY

4.1 Introduction

This chapter presents research techniques that were adopted to tackle the research problem including research design, sampling procedure, and ethical considerations.

4.2 Study design

This study employed the exploratory research method to determine the relationship between two variables i.e., $PM_{2.5}$ concentration (independent variable) and respiratory diseases (Dependent variable).

4.3 Data Types and Sources

This study focused on the collection and analysis of experimental fine particulate matter data from six sampling points distributed across Nairobi and primary data on respiratory related diseases from three Nairobi referral hospitals. Kenya Meteorological department (KMD) in collaboration with non - state actors are regularly involved in collection of air pollution data. Specific for this research KMD provided the $PM_{2.5}$ data at a price while Nairobi County provided the respiratory disease from their central database updated regularly after dispatch from affiliated hospitals / health centres. This data was also accessed at a fee.

4.4 Data collection

4.4.1 Pilot Survey

A pilot study was conducted on June 2019 to assess the viability of data collection and the study. This involved visiting Kenya meteorological department and linking up with a team involved in $PM_{2.5}$ sampling using and E sampler within Nairobi environs. A visit to Mbagathi Hospital was then done to confirm availability of respiratory diseases data.

4.4.2 Target population

The study's target population was mainly comprised of Nairobi residents dwelling in low and middle income areas which are generally densely populated and are adjacent to the hospitals used for the study. It is assumed that majority of the patients with respiratory related conditions from these areas visit the nearby referral hospitals.

4.4.3 Sampling Procedure

Monthly data on reported cases of pneumonia, upper respiratory tract infections as well as other diseases of the respiratory system was collected for a period of four years (January 2017 – December 2020) from three public hospitals namely Mama Lucy, Mbagathi and Mutuini hospitals. A total of 621 samples were used for the study. Additionally, a total of 12,556 hourly samples of $PM_{2.5}$ concentration across the six sampling stations (BabaDogo, Kibra, Kawangware, Dandora, Embakasi and Karen) during the period between August 2019 to January 2020 were used for the study.

4.4.4 Data Collection Instruments

$PM_{2.5}$ concentration data was collected using an E sampler. The instrument provides real time particulate measurement through near forward light scattering and has a dynamic range of 0 to 65 µg/m^3 with a flow rate of 2 litres / minute. A pump brings air into the sensing chamber, in which it is exposed to visible laser light before exiting the chamber. Aerosols in the air scatter light in a proportional manner to the amount of particulate matter present in the air. Precise glass optics collects scattered light focuses on a diode and the scattering intensity measured which is proportional to the fime $PM_{2.5}$ in the air. Data on respiratory diseases was collected by hospital medical personnel who record the number of patients daily. The image of the sampler is as shown in the figure below:

Figure 3: An image of the E sampler

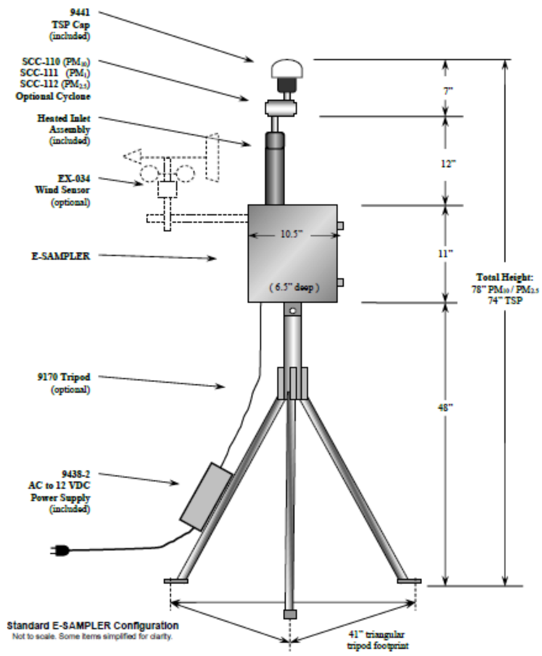


Figure 6: Labelled parts of the E sampler

4.4.5 Data collection procedure

Data on respiratory diseases was collected from individual county referral hospitals. The county hospitals are required to record the number of patients coming to their facility every day and periodically dispatch to county headquarters for research and planning purposes. On the other hand, Kenya Meteorological department jointly works with other stakeholders to collect data on air pollution among other parameters. The referral hospitals were selected based on their status and is where majority of low - and middle - income Nairobi residents are likely to be referred to. The sampling points were selected based on of their proximity to high density areas, assumed source of fine particulate matter and availability of data.

4.5 Ethical considerations

The researcher sought permission from the University of Nairobi, NACOSTI and Nairobi County before conducting the study. Besides, all the secondary data presented was referenced to avoid plagiarism and adhere to copyright regulations. No institution was coerced into providing the data.

4.6 Data Processing and Analysis

4.6.1 Data Processing

Raw data from the field was checked to remove incomplete and incorrect data coding of the data was conducted to represent various parameters and then categorised according to the homogenous groups required in the study. The data was then tabulated and safely stored for analysis as well as future use.

4.6.2 Data Analysis

The collected data was analysed statistically to establish any siginificant relationship between $PM_{2.5}$ and respiratory diseases. Data was arranged in hourly and daily spreadsheets and time series analysis was conducted in order to determine fine particulate matter concentration levels versus set air quality standards at the selected sites. Relatedly, data on respiratory illnesses was sort and classified monthly as well as per hospital and graphs plotted to analyse incidence of common respiratory diseases and trends across the hospitals. Regression and correlation analyses were done using SPSS software to establish the relationship between $PM_{2.5}$ concentration levels and reported incidences of respiratory diseases at the selected sites.

CHAPTER FIVE

5.0 RESULTS AND DISCUSSION

5.1 Introduction

This chapter presents results and discussion on average concentrations for $PM_{2.5}$ in the selected regions, the mean number of respiratory related diseases in the selected hospitals, and the relationship between the $PM_{2.5}$ concentrations and respiratory related illnesses as follows:

5.2 Presentation of Findings

5.2.1 $PM_{2.5}$ concentrations in Air in selected sites in Nairobi City

Analysis of hourly PM concentration was carried out. The graph below depicts the mean hourly $PM_{2.5}$ concentration across the selected sites:

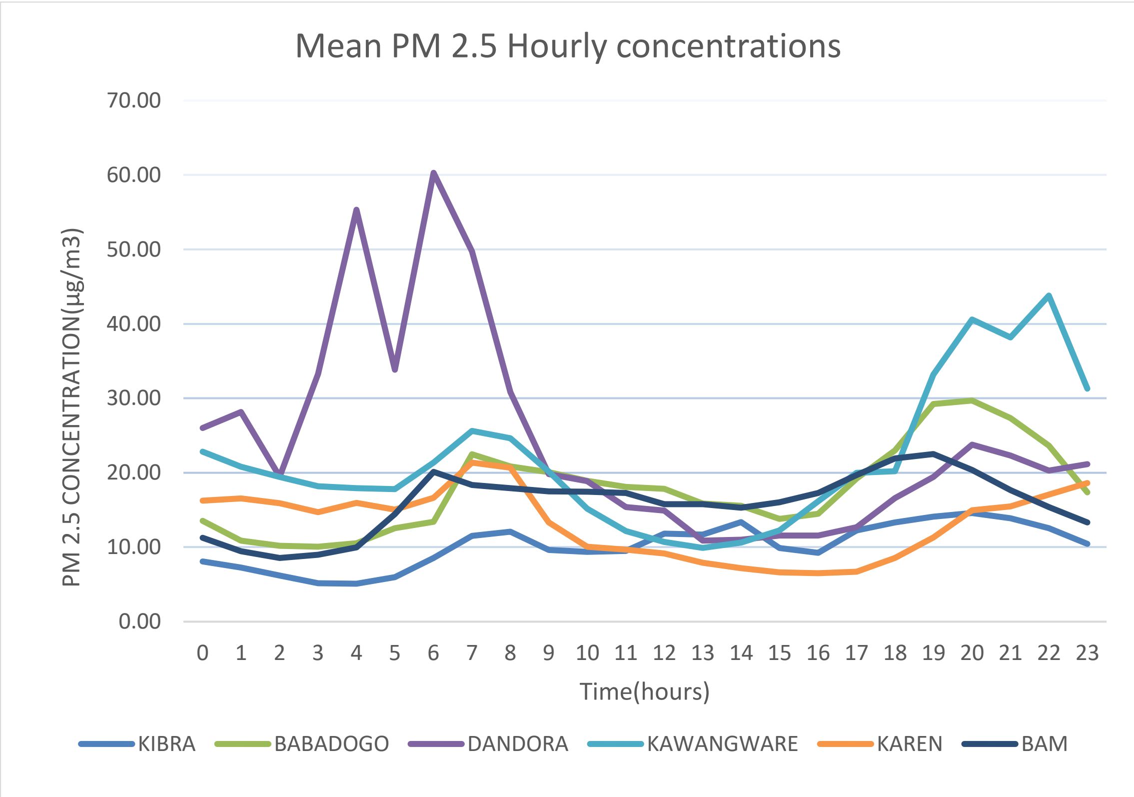


Figure 4: Mean $PM_{2.5}$ concentrations across the sampling points per hour

From Figure 5, it is observed that:

a. Dandora sampling point recorded the highest $PM_{2.5}$ concentration levels while the lowest was recorded in Kibra.
b. There was a general increase in PM2.5 concentration in the morning hours (between 0600Hrs - 0900Hrs) and in the evening (between 1800Hrs - 2200Hrs).

c. Dandora and Kawangware recorded the highest $PM_{2.5}$ concentration during morning and evening hours respectively compared to other sampling points. Relatedly, Kibra and Karen sampling points had the lowest levels in the morning and evening respectively.

From graphical analysis of daily average $PM_{2.5}$ concentration within the sampling points versus the set air quality regulations (EMCA ambient air quality tolerance limits and WHO guidelines) shown below, it was observed that:

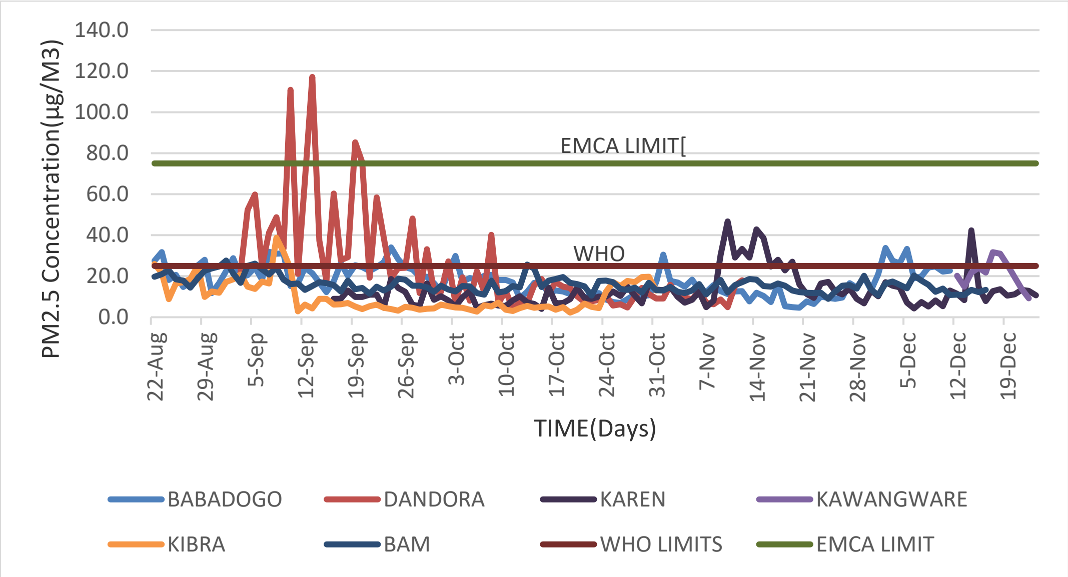


Figure 6: 24 - hour Average $PM_{2.5}$ concentration across the sampling points

a. Dandora sampling point had the highest levels of 24Hr average $PM_{2.5}$ concentration while Kibra and Karen had the lowest concentration levels during the period of measurement.

b. There were several instances during the period of measurement when the 24Hr average $PM_{2.5}$ concentration exceeded the WHO recommended limits by as much as 4.7 times in Dandora.

c. The PM concentrations of the six sampling points were within the acceptable WHO limits most of the times during the period of study. Additionally, they were within EMCA tolerance limits. However, there were instances during the period of study when the average daily $PM_{2.5}$ concentrations exceeded the ambient air quality tolerance limits between 12 Sept and 19 Sept 2021.

Mean monthly $PM_{2.5}$ concentration across the sampling points was calculated by summing up daily concentration and dividing by days of the month. The graph of the observation is shown below:

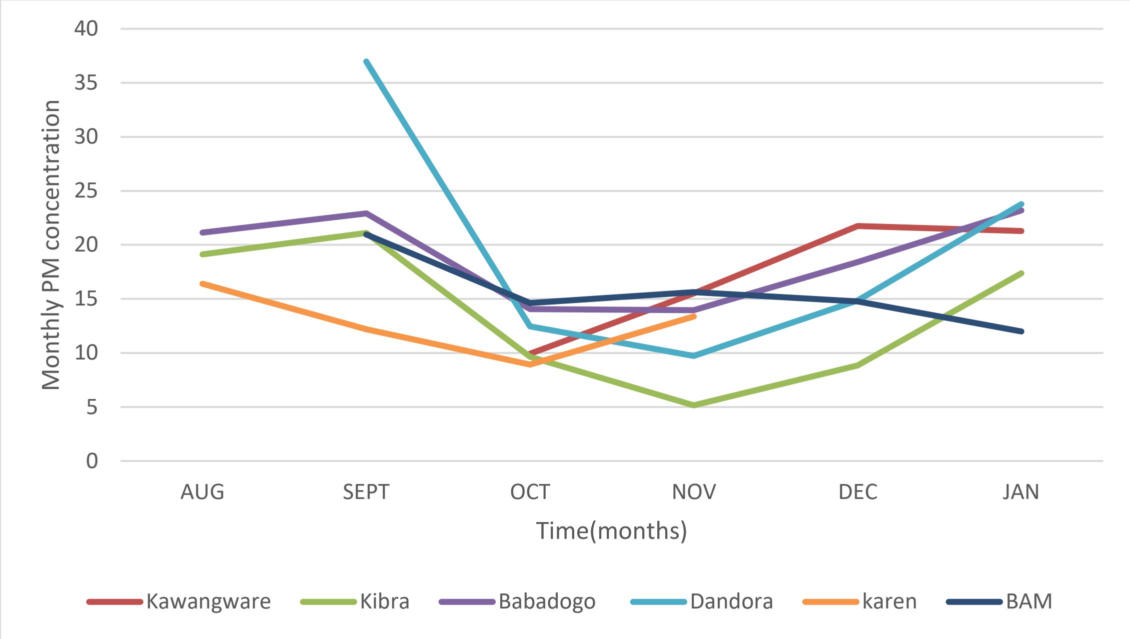


Figure 7: Mean monthly PM2.5 concentrations for the sampling points

It was observed that:

a. Kibra had the lowest monthly concentration levels compared to the other sampling points and the lowest levels were recorded during the month of November. Relatedly, Dandora had the highest concentration levels during the four months of measurement.
b. There was a general decline in concentration levels during the months of OCT and NOV and a rise towards DEC and JAN.

Discussion

The daily fine particulate matter concentrations exceeded the WHO recommended limits on several sampling points but within limits of EMCA air quality regulations during most of the period of study (August 2019 - January 2020). For instance, Dandora sampling point exceeded WHO recommended limits by as much as 4.7 times in some occasions. The highest daily fine particulate matter levels across the six sampling points were recorded during the month of September while the lowest were recorded during the month of October, November and starting to rise in December and January (see figure 5). Additionally, Mondays had peak fine particulate matter concentration in the six sampling stations compared to all other days of the week. It is important to note that in the year 2019, the month of September was a dry month while there were heavy rains in October. Therefore, the decline in $PM_{2.5}$ concentration during the month of October is likely to be associated with the onset of long rains. Previous studies have established strong relationship between decline fine particulate matter concentration and rainfall whereby the rainfall washes down and dissolves the fine particulate matter. Separately, the high fine particulate matter concentrations in Dandora are likely linked to the presence of Dandora Dumping site which is a great source of emissions.

Separately, it was established that the fine particulate matter concentrations were highest during two periods in the day across the six sampling points i.e., 1800Hrs - 2200Hrs and 0600Hrs - 0900Hrs with the period 1800Hrs - 2200Hrs having higher concentrations compared to the period 0600Hrs - 0900Hrs. On the other hand, the concentrations were lowest during the period 0100Hrs - 0500Hrs and 1000Hrs - 1700Hrs.

The period with the highest $PM_{2.5}$ concentrations across the six sampling points are also the same periods with the highest traffic flow across Nairobi County and vice versa. From previous studies, traffic flow significantly contributes fine particulate matter concentration mainly through exhaust emissions and brake dust. Therefore, a possibility that the increase as well as the decrease in fine particulate matter concentration is linked to traffic flow cannot be ruled out.

5.2.2 Patterns of respiratory infections within Nairobi County

Graphical representation for pneumonia, URTI and ORTI was conducted to establish the patterns across the various hospitals in Nairobi during the period between Jan 2017 and December 2020. In the case of pneumonia, a graph of total monthly cases recorded in the three hospitals was plotted in a graph as shown below:

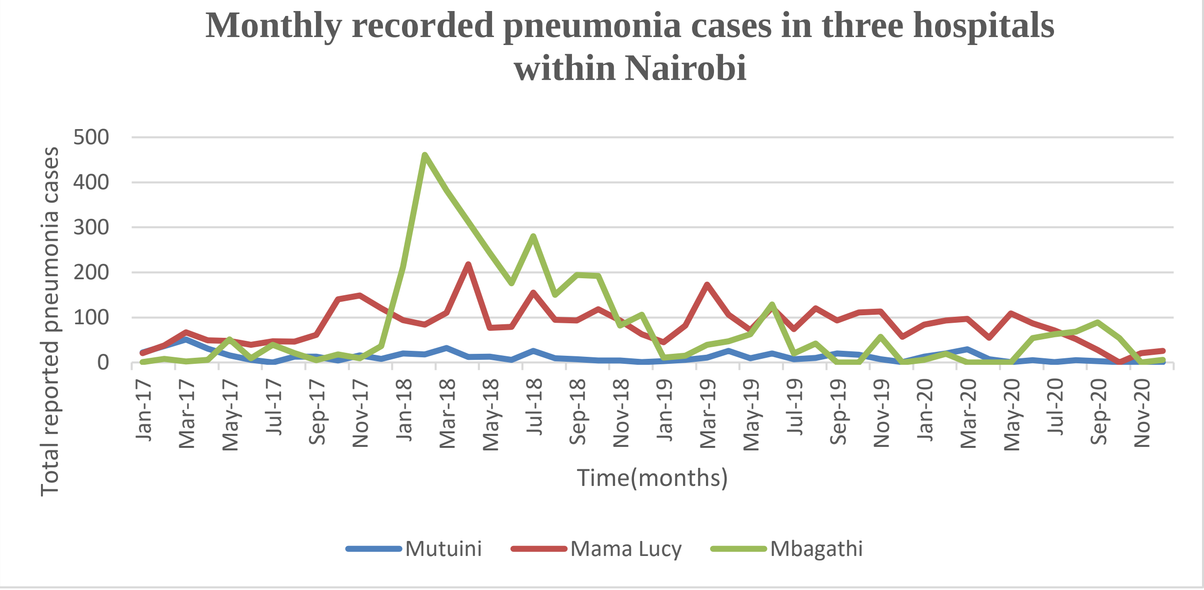


Figure 8: Monthly trends for pneumonia in Mutuini, Mama Lucy and Mbagathi Hospitals from Jan 2017 to Dec 2020

From the graph above, it was observed that:

a. Mama lucy hospital had the highest total number of reported pneumonia cases during the period of study while Mutuini had the lowest. The highest number of cases ever recorded during the period of study was between Jan 2018 to Jan 2019.
b. There was a general rise in pneumonia cases on Jan 2018 to June 2018, Jul 2018 to Nov 2018, Jan 2019 to June 2019, Jul 2019 to Nov 2019, Jan 2020 to June 2020 and July 2020 to Nov 2020.

In the case of URTI, a graphical representation of the cases was conducted during the period as shown below:

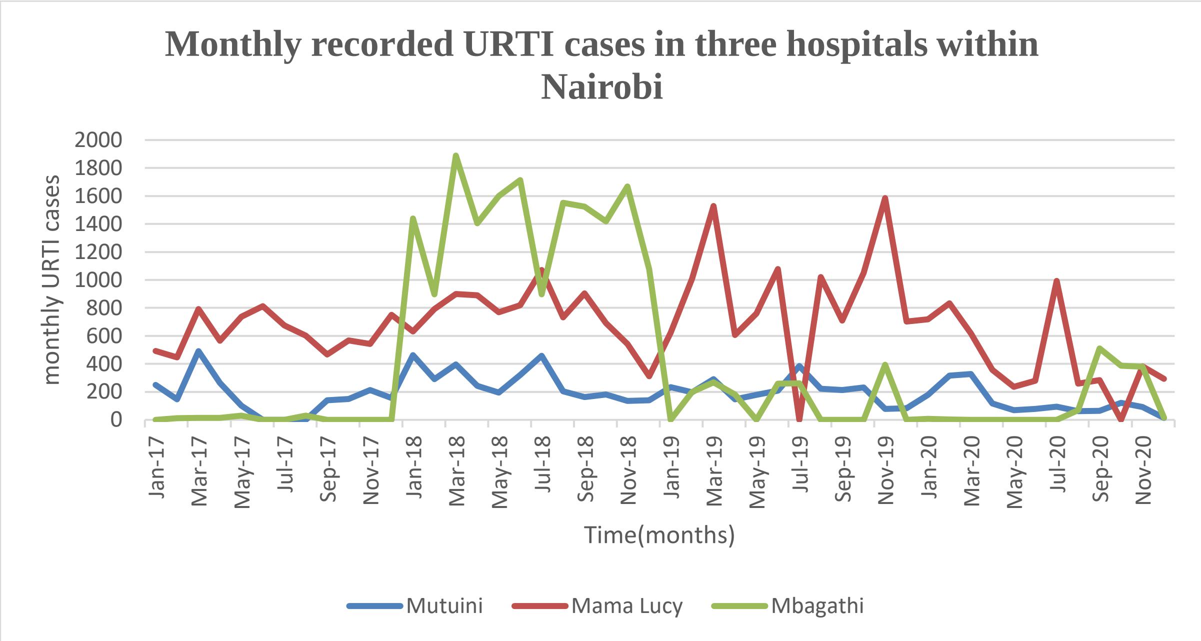


Figure 9: Monthly Totals of recorded URI cases in Mutuini, Mama Lucy and Mbagathi hospitals from Jan 2017 to Dec 2020.

From the graph above, it is observed that:

a. There was a general cyclic rise in the total number of cases during the months of Feb 2017- May 2017, Sep 2017 to Apr 2018, Jul 2018 to Nov 2018, Jan 2019 to May 2019, Aug 2019 to Dec 2019, Jan 2020 to April 2020 and Aug 2020 to Dec 2020 as shown in the figure above. There is observed to be an increase in reported cases after every three to four months.
b. The highest cases of URTI during the period of study were recorded between Jan 2018 and Jan 2019.

Graphical representation of ORTI was conducted across the three hospitals and the findings are as shown below:

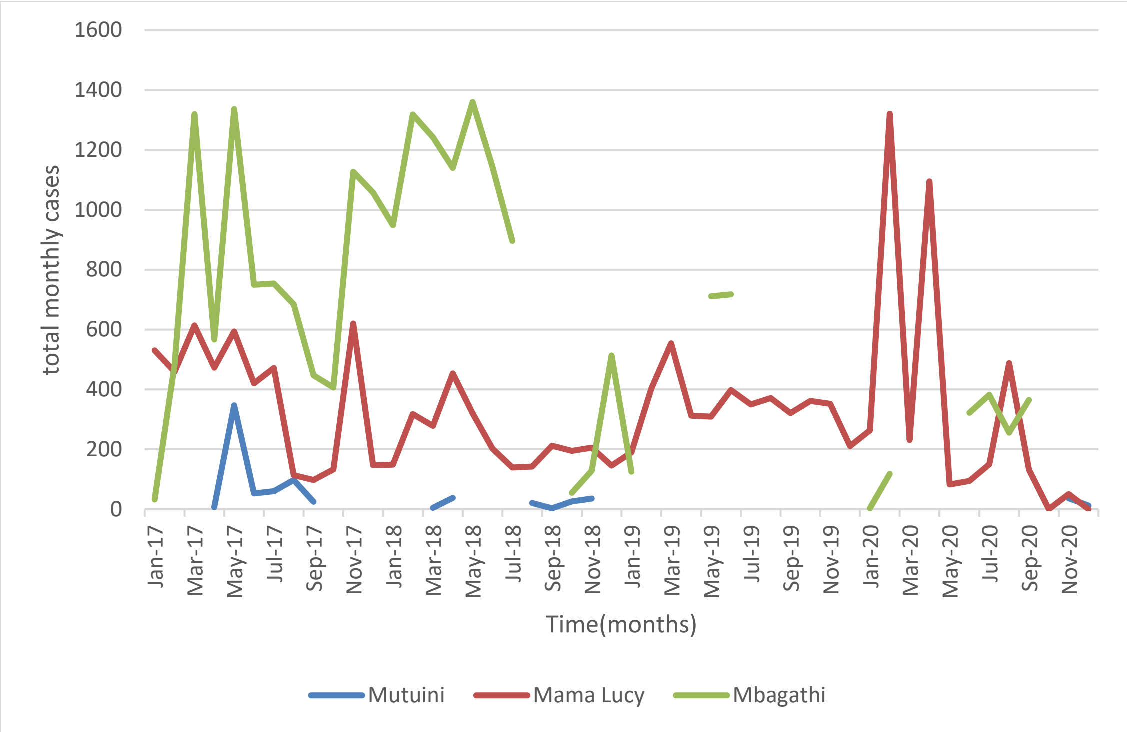


Figure 10 : Monthly Totals of ORTI for Mutuini, Mama Lucy and Mbagathi Hospitals from Jan 2017 to Dec 2020.

From the graph above it is observed that:

a. The highest cases of hospital visits were recorded between Jan and July during the three years of study with Mbagathi hospital receiving the highest number of visits.

b. There were high cases of missing data both in Mutuini and Mbagathi hospitals.

Separately, a graph was plotted to establish monthly disease trends per hospital as below:

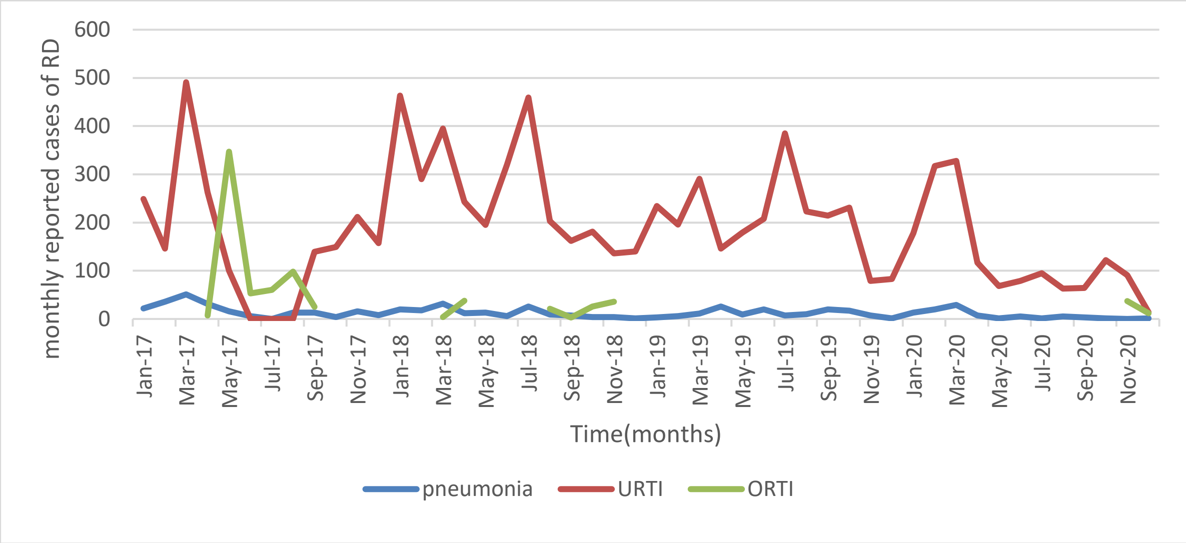


Figure 11: Reported cases of respiratory diseases from Jan 2017 to Dec 2020 in Mutuini Hospital

From the graph above, it was observed that:

a. There were higher cases of URTI compared to pneumonia cases during the period of study.
b. There was a high case of missing data in Mutuini especially on ORTI.
c. The reported cases of pneumonia and ORTI were highest during the months of January to May and lowest in the months of October to December during the period of study.

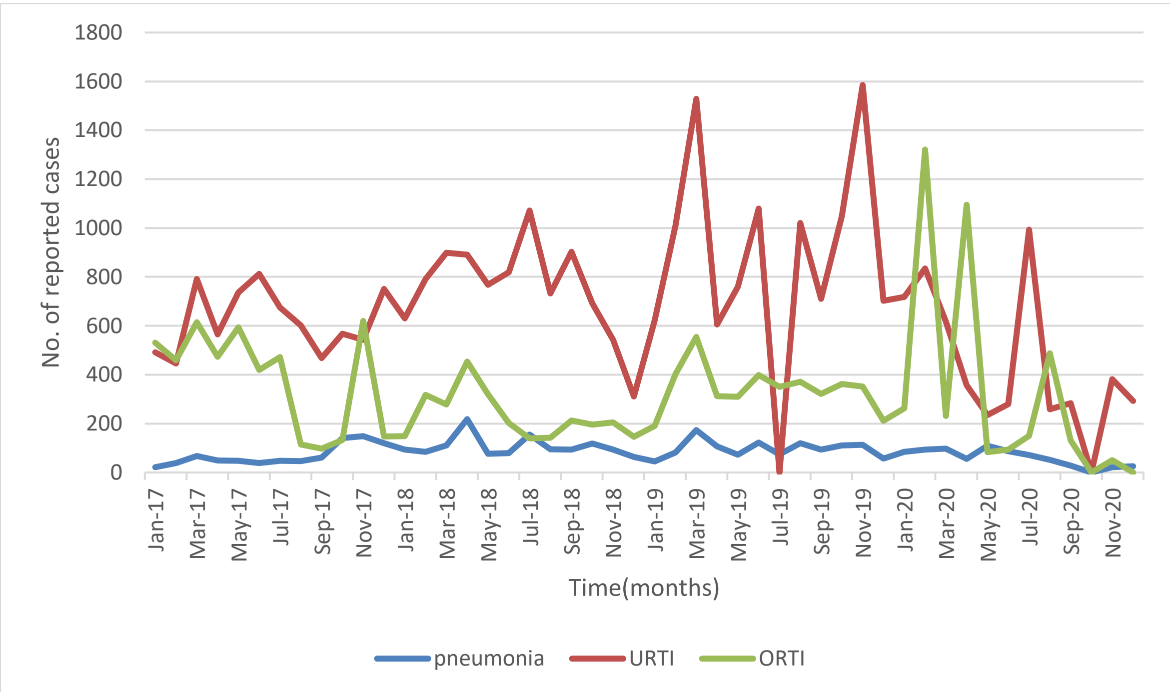


Figure 12: Reported case of respiratory diseases from Jan 2017 to Dec 2020 in Mama Lucy Hospital

From the graph above, it was observed that the highest number of reported cases are recorded in the months of January to August (first half of the year) while the lowest cases are recorded between September and December (second half of the year during the period of study.

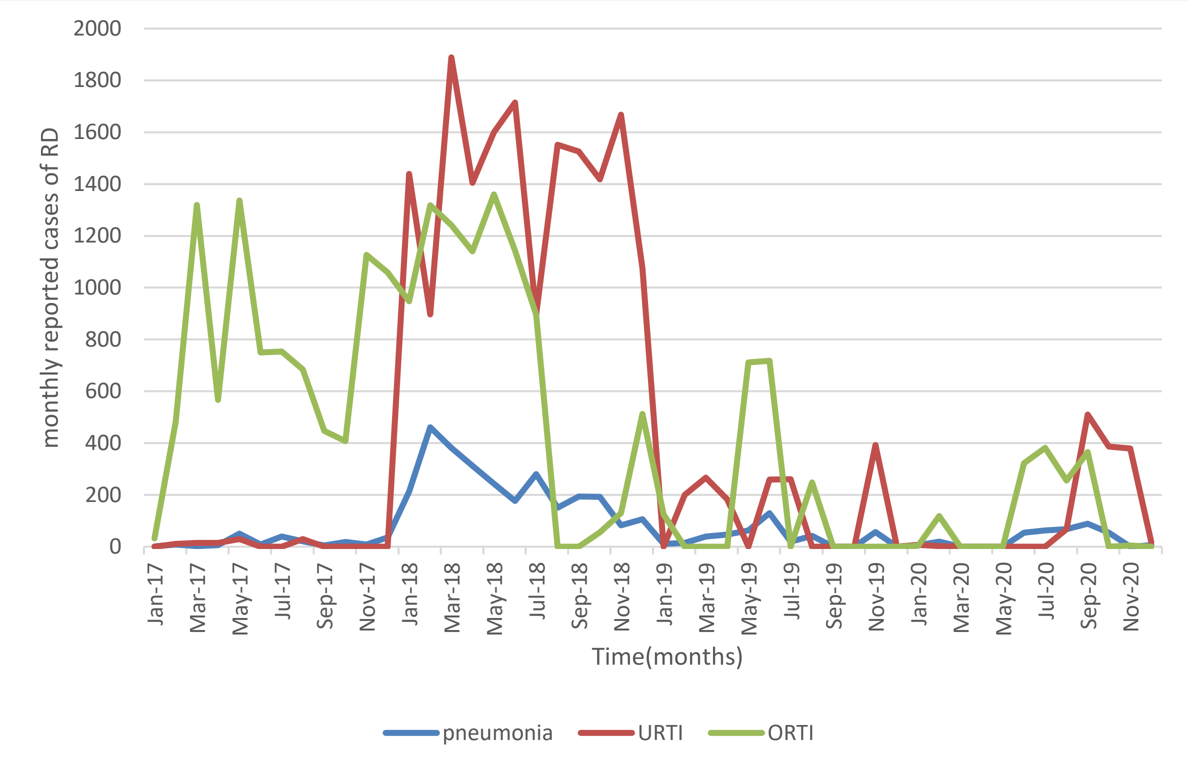


Figure 14: Reported cases of Respiratory diseases in Mbagathi during the period between Jan 2017 and Dec 2020

From the graph above, it was observed that:

a. 2018 had the highest respiratory reported cases compared to the other years during the period of study
b. The highest number of respiratory related cases were recorded in the months January to June in all the three years of study. Additionally, they were generally lowest between September to December during the same period.
c. All the line graphs are observed to follow a similar pattern during the period of study.

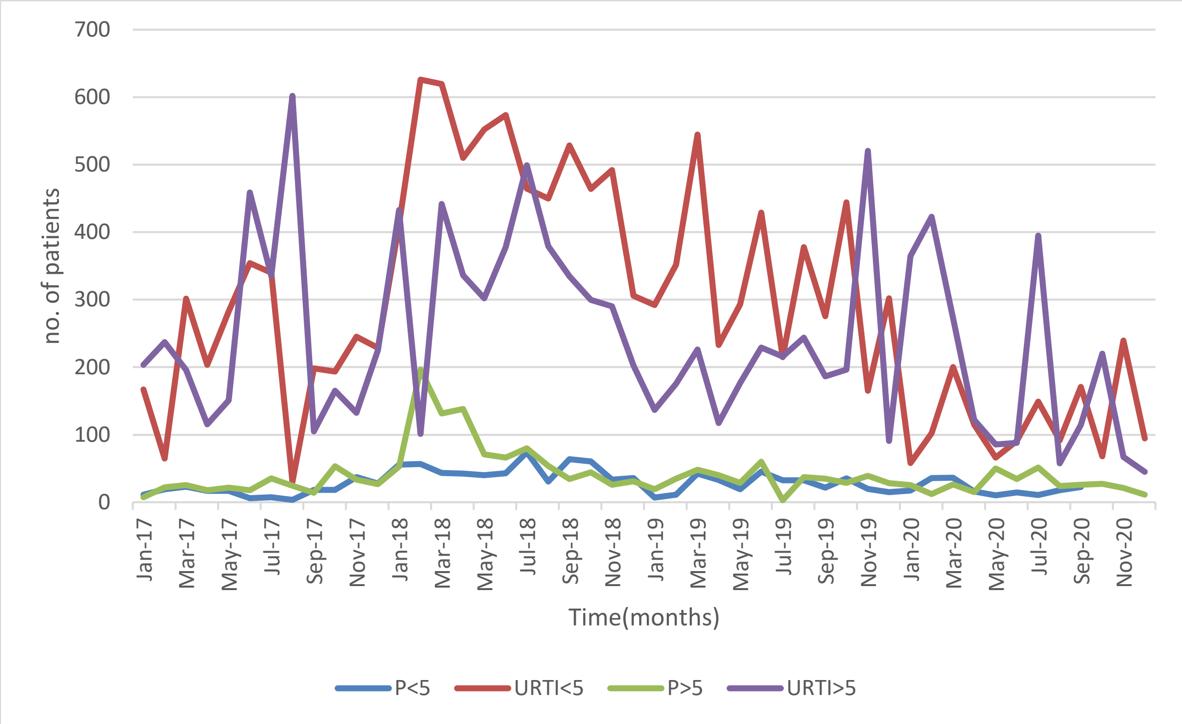


Figure 13: Average number of Pneumonia and URTI cases for both under and over 5 years recorded in the study hospitals

From the graph above, it is observed that:

a. All the parameters exhibit similar pattern during the period of study.
b. URTI (both for under & over five) had the highest number of patients reported during the period of study while Pneumonia (both for under & over five) had the lowest.
c. There are more reported cases for URTI (both under 5 and over 5 years of age) than pneumonia cases in the study hospitals during the period of study.
d. URTI for children under 5 years is the most reported ailment in the three hospitals studied while pneumonia for under five (5) years is the least common.
e. During the period of study, the highest cases of infections were experienced between January and August.

Discussion

<u>Pneumonia</u>

Mama Lucy hospital had the highest average of the number of pneumonia cases reported during the study period while Mutuini had the lowest. Additionally, the highest total number of pneumonia cases were reported during the period Jan 2018 to Jan 2019.

<u>Upper Respiratory Tract Infections (URTI)</u>

The highest average number of URTI cases was reported in Mama Lucy while the lowest was recorded in Mutuini Hospital. Mbagathi had the highest number ever recorded, in the study period, in the period between Jan 2018 to Jan 2019.

Other Respiratory Tract Infection (ORTI)

It was noted that only Mama Lucy Hospital had consistent data while Mbagathi and Mutuini had several cases of missing data on ORTI during the study period. This is as shown in Fig. 8.

URTI cases recorded in the three hospitals during the study period were higher compared to pneumonia cases while there were cases of missing data for ORTI as depicted in the figure 9. Mama Lucy Hospital has acted as county referral hospital since its inception with high end equipment and personnel compared to the other two hospitals used in the study. This is likely to contribute to the high amount of traffic in the said hospital as well as consistent recording of data. Separately, URTI is a broad classification involving infections affecting nose, sinuses throat and airways such as common cold among others. This is likely to explain the high number of reported cases of URTI across the three hospitals in general.

Cases for pneumonia and URTI for both over five and five years of age depicted a similar trend during the study period with the highest number of cases being recorded between January 2018 and January 2020. Notably, reported cases of pneumonia and URTI in the three study hospitals for under five years of age were much higher than for persons aged over five years of age. This period also coincided with the onset of COVID 19 and therefore a possibility that the numbers were affected by COVID 19 numbers cannot be ruled out. The findings confirm that there are more hospital visits for children under five years age compared to persons aged over five years.

5.2.3 $PM_{2.5}$ and Respiratory Diseases in Nairobi County

Correlation analysis was performed to establish the relationship between $PM_{2.5}$ concentrations and respiratory diseases in the three hospitals for the period between August 2019 to January 2020 on the area of study.

Table 4 below is the output of the correlation analysis:

	CORRELATION COEFFICIENT		
	MUTUINI	**MAMA LUCY**	**MBAGATHI**
Embakasi	-0.08	-0.08	-0.25
Kawangware	-0.43	-0.69	-0.11
Kibra	0.60	-0.19	-0.36
Baba dogo	0.32	-0.48	-0.37
Dandora	0.43	-0.33	-0.48
Langata	-0.46	-0.29	0.60

Table 4: Correlation Coefficients between treated cases of respiratory diseases in the neighbouring hospitals and $PM_{2.5}$ concentrations in sample points.

From the table above, the total number of respiratory diseases (RD) (i.e., Pneumonia and Upper respiratory tract infections) has a positive correlation with fine particulate matter measurements done in Kibra of 0.6 or 60%. Additionally, RD in Mutuini have generally weak negative correlation with measurements conducted in all other stations. Similarly, RD reported in Mama Lucy Hospital have a strong negative coefficient with fine particulate matter measurements conducted in Kawangware of -0.69 (69%) and weak negative correlation coefficient with other stations. Lastly, RD in Mbagathi have a strong positive coefficient with measurements with measurements conducted in Langata of 0.60 (60%) and weak negative coefficient with the other stations.

Regression analysis was then done to test hypothesis and statistical significance of the findings. The following table represents the outputs:

Location of $PM_{2.5}$ concentration (independent Variable)	**Respiratory diseases reported per hospital (dependent variable)**	**P value**	**Equation**
Kibra	Mutuini	0.892	Y = 20.593 + 0.338X
Kawangware	Mama Lucy	0.327	Y = 362.35 – 11.20X
Langata	Mbagathi	0.378	Y = -61.0 + 7.17X

Table 5: Regression equations generated from the data

From the table above, the relationship between respiratory related illnesses at Mutuini hospital is shown by the equation: Y = 20.593 + 0.338X. The p value (0.892) was larger than 0.05 (level of significance). Therefore, the relationship between the two variables is not statistically significant.

A negative relationship between respiratory related illnesses at Mama Lucy hospital and fine particulate matter concentration in Kawangware station represented by the equation:

Y = 362.35 – 11.20X was observed. The p value (0.327) was larger than 0.05. Therefore, the relationship between the two variables is not statistically significant.

The relationship between respiratory related illnesses at Mbagathi hospital and was positive and represented by the equation: Y = -61.0 + 7.17X. The p value is 0.378 is larger than 0.05. Therefore, the relationship between the two variables was statistically significant.

Discussion

From the analysis between fine particulate matter and respiratory diseases between August 2019 – January 2020, it was established that:

a. The reported cases in Mutuini Hospital (both Pneumonia and URTI) had a positive correlation coefficient of 0.6 (60%) to the fine particulate matter concentration in Kibra sampling station and a negative correlation with Kawangware (-0.43 or 43%) and Langata (-0.46 or 46%).
b. The reported cases in Mama Lucy Hospital had a negative correlation to $PM_{2.5}$ measurements in the six sampling points with the strongest negative correlation coefficient being Kawangware (-0.69 or 69%).

c. The reported cases in Mbagathi Hospital (both Pneumonia and URTI) had a strong correlation coefficient of (0.60 or 60%) to PM2.5 matter measurement within Langata and a negative correlation coefficient with all the other five stations.

5.2.4 **Test of the Research Hypothesis**

Regression analysis for areas with strongest correlation coefficients as shown in Table 5 above established that the relationship between the variables was not statistically significant. Based on the above outcome, there is a positive correlation between PM2.5 and the number of of respiratory illnesses. Based on the above, null hypothesis was rejected and alternative hypothesis adopted. Separately, statistical insignificance may be contributed by limitations of long - term air pollution data significant to compute a model.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECCOMENDATIONS

6.1 Introduction

This chapter is comprised of summary of study findings, conclusions drawn from the study and recommendations.

6.2 Summary of findings

Fine particulate matter concentration in some areas within Nairobi County such as Dandora exceed WHO recommended limits by as much as 4.7 times but within EMCA air quality regulations during most times of the study period. The concentrations are highest in the periods between 0600Hrs - 0900Hrs and 1800Hrs - 2200Hrs coinciding with the periods with the highest traffic in Nairobi. Therefore, it is highly likely that vehicular traffic significantly contributes to PM concentration within Nairobi through exhaust emissions and brake dust. The high PM concentrations in Dandora are likely contributed by the presence of dumpsite in the area. Separately, September had the highest $PM_{2.5}$ concentration and declines in the months of October, November and starts to rise again in December and January which coincides with short rains season. Therefore, rains significantly contribute in washing down the fine particulate matter in the air.

Mama Lucy Hospital had the highest number of hospital admission children under five years for respiratory related illnessed compared to the other hospitals. Majority of the patients were admitted on pneumonia related complications. Notably, the period of study coincided with the onset of COVID 19 which may have an effect on the hospital visits. The number of hospital admissions has a positive correlation with the fine particulate matter concentration measured in the nearby area which was not statistically significant during the study.

6.3 Conclusion

Based on the study, the daily fine particulate matter concentration in most areas within Nairobi was much higher than WHO recommended limits in most days of the month but generally lower than the EMCA ambient air quality guidelines set by the Kenyan government. The concentration was generally high on Mondays and significantly declines during the week. It was highest in the morning hours (between 0600Hrs - 0900Hrs) and in the evening (between 1800Hrs - 2200Hrs) coincicding with the period with the highest vehicular traffic across Nairobi. Therefore, a possibility that vehicular traffic significantly contributed the fine particulate matter concentration in Nairobi cannot be ruled out.

There was a strong positive correlation between PM2.5 concentation in Kibra and hospital visits on respiratory related illnesses in Mutuini Hospital. Relatedly, there was a strong positive correlation between fine particulate matter concentration in Langata and respiratory related hospital visits in Mbagathi Hospital. Children below five years of age were more likely to visit hospitals compared to persons over five years of age confirming the vulnerability of children to respiratory related illnesses. The effect of COVID - 19 pandemic, which began during the period of study and likely affected the number of respiratory related illnesses, on the research topic could not be assessed during the study.

Though there was a strong positive coefficient between fine particulate matter and the number of hospital visits in the study hospitals during the same period, the relationship was not statistically significant. A possibility that there exists a delay during which fine particulate matter pollution becomes significant to cause a hospital visit cannot be ruled out. Such a scenario may be caused by weather (which affects transport of the particulate matter) as well as body immunity (whereby the body continues to fight microbes until its defeated resulting to hospital visit). There is need for further research to establish whether there exists such a delay. These results suggest the need for more study on health behaviours and mortality in relation to air pollution and weather in order to develop appropriate environmental health preventative measures.

6.4 Recommendations

This study recommends that there is need to implement measures to monitor and improve air quality in Nairobi by:

a. Lowering the EMCA ambient air quality guidelines on fine particulate matter to a number much lower in line with the WHO as well as EAC guidelines
b. Formulation and adoption of a policy on vehicular exhaust emission measurements across Nairobi and Kenya at large aimed at reducing fine particulate matter pollution from vehicles.

Implementation of the already existing regulations aimed at improving the air quality within Nairobi and Kenya at large. Additionally, there is need for more investment in air quality data acquisition and monitoring network within Nairobi and Kenya at large. This is envisioned to trigger further studies on the research topics including:

a. A longitudinal study exploring the relationship between $PM_{2.5}$, respiratory diseases and weather effects in other regions in Kenya.
b. Research to investigate the delay between emission of fine particulate matter and a hospital visit as a result of the effect of the pollutant.

REFERENCES

Alena Bartonova, Jae,(1999). Air pollution exposure monitoring and estimation Part V. Traffic exposure in adults. Norway: Norwegian Institute for Air Research.

Amato, F., Nava, S, Lucarelli, F., Querol, X., Alastuey, A., Baldasano, J. & Pandolfi, M (2010) A comprehensive assessment of PM emissions from paved roads: real-world emission factors and intense street cleaning trials. Sci Total Environ 408(20): 4309 – 4318.

B. Vijay Bhaskar, V. M. (2010). Atmospheric Particulate Pollutants and their Relationship with Meteorology in Ahmedabad. Aerosol and Air Quality Research, 307 - 313.

Belis C, Karagulian F, Larsen B, Hopke P (2013) Critical review and meta analysis of ambient particulate matter source apportionment using receptor models in Europe. Atmos Environ 69:94–108. https://doi.org/10.1016/j.atmosenv.2012.11.009

Bellander, T., Berglind, N., Gustavsson, P., Jonson, T., Nyberg, F., Pershagen, G., & Järup, L. (2001). Using geographic information systems to assess individual historical exposure to air pollution from traffic and house heating in Stockholm. Environmental Health Perspectives, 109(6), 633 – 639. https://doi.org/10.1289/ehp.01109633

Brunekreef, B.; Forsberg, B. Epidemiological evidence of effects of coarse airborne particles on health Eur. Respir. J. 2005, 26 (2) 309 – 318

COUNTY annual development PLAN (CADP) 2019/2020. (n.d.). Retrieved September 26, 2021, from https://nairobiassembly.go.ke/ncca/wpcontent/uploads/paperlaid/2018/ADP-for-the-FY-2019-20.pdf.

De Sario, M., Katsouyanni, K., &Michelozzi, P. (2013). Climate change, extreme weather events, air pollution and respiratory health in Europe. European Respiratory Journal, 42(3), 826-843.

Desouza, Priyanka. (2020). Air pollution in Kenya: a review. Air Quality Atmosphere & Health. 13. 10.1007/s11869-020-00902-x.

Egondi, T., Ettarh, R., Kyobutungi, C., Ng, N., & Rocklöv, J. (2018). Exposure to OUTDOOR PARTICLES (PM2.5) and Associated Child morbidity and mortality in socially deprived neighborhoods of Nairobi, Kenya. Atmosphere, 9(9), 351. https://doi.org/10.3390/atmos9090351

Ernest, G. M., & Heather, P. (2018). Demonstrating PM2.5 and roadside dust pollution by heavy metals along Thika superhighway in Kenya, sub-Saharan Africa. Environmental Monitoring and Assessment , 17-23.

Hamanaka, R. B., & Mutlu, G. M. (2018). Particulate Matter Air Pollution: Effects on the Cardiovascular System. Front Endocrinol (Lausanne).

Hulskotte J, Roskam G, Van Der Gon HD (2014) Elemental composition of current automotive braking materials and derived air emission factors. Atmos Environ 99:436 – 445. https://doi.org/10.1016/j.atmosenv.2014.10.007

Ian, M., Nikolai, S., Sean, D., & Heather. (2004). An in vitro and in vivo investigation of the effects of diesel exhaust on human airway lining fluid antioxidants. Archives of Biochemistry and Biophysics, 29 - 32.

International Soil Reference and Information Centre (ISRIC). (2017). Encyclopedia of Soil Science, Third Edition, 1232 – 1236. https://doi.org/10.1081/e-ess3-120041260

Janssen, N. A., Hoek, G., Brunekreef, B., Harssema, H., Menswik, I., & Zuidhof, A. (1998). Personal sampling of particles in adults: relation among personal, indoor, and outdoor air concentrations. American journal of epidemiology, 147(6), 537 - 547.

Jerrett, M., Arain, A., Kanaroglou, P., Beckerman, B., Potoglou, D., Sahsuvaroglu, T., Morrison, J., & Giovis, C. (2004). A review and evaluation of Intraurban Air Pollution Exposure Models. Journal of Exposure Science & Environmental Epidemiology, 15(2), 185 – 204.

Jol, A., Kielland, G., Berge, E., Beck, J., Larssen, S., Moussiopoulos, N., &Pulles, T. (1997). Air pollution in Europe 1997.

Jon G Ayres, P. B. (Jan 2008). Evaluating the toxicity of airborne particulate matter and nanoparticles by measuring oxidative stress potential - a workshop report and consensus statement.

Jones, K. (2019). Air Quality Briefing Note. Retrieved November 15, 2021, from https://assets.publishing.service.gov.uk/media/5eb16f4b86650c4353446282/ASAP_-_East_Africa_-_Air_Quality_Briefing_Note_-_Nairobi.pdf.

Jonson, Jan & Tarrason, Leonor & Sundet, Jostein. (1999). Calculation of Ozone and Other Pollutants for the Summer 1996. Environmental Management and Health. 10. 245 - 257. 10.1108/09566169910276193.

Kanaroglou P.S., Buliung R.N., and Taylor B.W.(2005). Mobile source emissions in urban areas: The relative contribution of trucks. Presented at the Fifth International Conference on Protection and Restoration of the Environment, Thassos Island, Greece, 2000

Katoto, P. D., Byamungu, L., Brand, A. S., Mokaya, J., Strijdom, H., Goswami, N., et al. (2019). Ambient air pollution and health in Sub-Saharan Africa: Current evidence, perspectives and a call to action. Natoinal center for Biotechnology Information.

Kelly, F. J., & Fussell, J. C. (2012). Size, source and chemical composition as determinants of toxicity attributable to ambient particulate matter. Atmospheric environment, 60, 504 - 526.

Kim, K.-H., Jahan, S. A., & Kabir, E. (2013). A review on human health perspective of air pollution with respect to allergies and asthma. Environment International, 59, 41 – 52. https://doi.org/10.1016/j.envint.2013.05.007

Kinney, Patrick & Gichuru, Michael & Volavka Close, Nicole & Ngo, Nicole & Ndiba, P.K. & Law, Anna & Gachanja, Anthony & Gaita, Samuel & Chillrud, Steven & Sclar, Elliott. (2011). Traffic Impacts on PM (2.5) Air Quality in Nairobi, Kenya. Environmental science & policy. 14. 369-378. 10.1016/j.envsci.2011.02.005.

Kotze, L. J., & Morse, S. (2012). Afro-eurasia: Assessing sustainability. Berkshire Publishing Group.

Kristiina, M., Sari, A., Pekka, T., & Juha, P. (1999). Nitrogen Dioxide Exposure Assessment and Cough among Preschool Children. Archives of Environmental Health, 431 - 433.

Landrigan, P. J. (2017). Air pollution and health. The Lancet Public Health, 2(1), e4 - e5.

Lioy, P. J., & Smith, K. R. (2013). A Discussion of Exposure Science in the 21st Century: A Vision and a Strategy. New Jersey: The National Research Council (NRC) of the National Academy of Sciences.

Lokman Hakan Tecer, Omar Alagha, Ferhat Karaca, Gürdal Tuncel & Nilufer Eldes (2008) Particulate Matter (PM2.5, PM10 - 2.5, and PM10) and Children's Hospital Admissions for Asthma and Respiratory Diseases: A Bidirectional Case - Crossover Study, Journal of Toxicology and Environmental Health, Part A, 71:8, 512-520, DOI: 10.1080/15287390801907459

Mahmud, Hasan & Rahman, Md. (2020). Spatial analysis of the concentrations of selected gaseous pollutants in ambient air of rajshahi city. 61. 133 - 148.

Making the future in the shadow of Vision 2030. (2019). Nairobi in the Making, 159–176. https://doi.org/10.2307/j.ctvfrxrms.11

Meredith, C. M., Patrick, N. B., Nadia, N. H., Elizabeth, C. M., Emily, S. T., Jean, C.-B., et al. (2008). Common household activities are associated with elevated particulate matter concentrations in bedrooms of inner-city Baltimore pre-school children. Environmental research, 42 - 44.

Michael J. Gatari Gichuru, J. K. (2013). Traffic and mineral dust impact on air quality in Nairobi, Kenya. Nairobi: Environmental Health Perspectives.

Mills, N. L.; Donaldson, K.; Hadoke, P. W.; Boon, N. A.; MacNee, W.; Cassee, F. R.; Sandstrom, T.; Blomberg, A.; Newby, D. E. Adverse cardiovascular effects of air pollution Nat. Clin. Pract. Cardiovasc. Med. 2009, 6 (1) 36 – 44

Mitullah, Winnie. (2003). Urban slums reports: The case of Nairobi. Retrieved Oct 11, 2021, from http://www.begaIkwabega.com/ documenti/Nairobi-HabitatReport2003.pdf

Monitoring, reporting & verification (MRV). (2020). ECE Energy Series, 10–26. https://doi.org/10.18356/4aec3298-en

MULAKU, G. C., & KARIUKI, L. W. (2001). MAPPING AND ANALYSIS OF AIR POLLUTION IN NAIROBI,. Nairobi: International Conference on Spatial Information for Sustainable Development.

Mulugeta, G. (1996). Manual and automated interpolation of climatic and Geomorphic Statistical Surfaces: An evaluation. Annals of the Association of American Geographers, 86(2), 324–342. https://doi.org./10.111I1/j..1467-8306.1996.tb01756.

Naidja, Lamri & Ali-Khodja, Hocine & Khardi, Salah. (2017). Particulate matter from road traffic in Africa. 7. 289-304.

Nascimento, A. P., Santos, J. M., Mill, J. G., Souza, J. B., Reis Júnior, N. C., & Reisen, V. A. (2017). Association between the concentration of fine particles in the atmosphere and acute respiratory diseases in children. Revista De Saúde Pública, 51. https://doi.org/10.1590/s1518-8787.2017051006523

Ning Li, A. E. (2006). Role of the Nrf2-mediated signaling pathway as a negative regulator of inflammation: implications for the impact of particulate pollutants on asthma. Antioxidants & redox signaling, 20-22.

O'Neil, A., Russell, J. D., Thompson, K., Martinson, M. L., & Peters, S. A. E. (2020). The impact of socioeconomic position (SEP) on Women's health over the lifetime. Maturitas, 140, 1–7. https://doi.org/10.1016/j.maturitas.2020.06.001

Odhiambo, E., & Njuguna, R. (2021). Strategic management practices and performance of health non-governmental organizations in Nairobi City County, Kenya. Journal of Strategic Management, 6(1), 1 – 16. https://doi.org/10.47672/jsm.669

Ongoma, V., K., M. P., & Zablon, S. (2016). Potential effects of urbanization on Urban thermal comfort, a case study of Nairobi City, Kenya: a review. Geographica Pannonica, 23-26.

Opiyo, Ronald & Mugume, Isaac & Nakatumba Nabende, Joyce. (2021). Understanding the trend of NO2, SO2 and CO over East Africa from 2005 to 2020. Atmosphere. 12. 1283. 10.3390/atmos12101283.

Pagan, I., Costa, D. L., McGee, J. K., Richards, J. H., Dye, J. A., & Dykstra, M. J. (2003). Metals mimic airway epithelial injury induced by in vitro exposure to Utah Valley ambient particulate matter extracts. Journal of Toxicology and Environmental Health, Part A, 66(12), 1087-1112.

Peng, R. D.; Chang, H. H.; Bell, M. L.; McDermott, A.; Zeger, S. L.; Samet, J. M.; Dominici, F. Coarse particulate matter air pollution and hospital admissions for cardiovascular and respiratory diseases among Medicare patients JAMA 2008, 299 (18) 2172– 2179

Perez, L., Tobias, A., Querol, X., Künzli, N., Pey, J., Alastuey, A., ...&Sunyer, J. (2012). Coarse particles from Saharan dust and daily mortality. Epidemiology, 800-807.

Petkova, E. P., Jack, D. W., Volavka-Close, N. H., & Kinney, P. L. (2013). Particulate matter pollution in African cities. Air Quality, Atmosphere & Health, 6(3), 603-614.

Po, J. Y., FitzGerald, J. M., &Carlsten, C. (2011). Respiratory disease associated with solid biomass fuel exposure in rural women and children: systematic review and meta-analysis. Thorax, 66(3), 232-239.

Qian Liu, C. X. (2017). Effect of exposure to ambient PM2.5 pollution on the risk of respiratory tract diseases: a meta-analysis of cohort studies. journal of Biomedical Research, 15-31.

Rainham, D. G., Smoyer-Tomic, K. E., Sheridan, S. C., & Burnett, R. T. (2005). Synoptic weather patterns and modification of the association between air pollution and human mortality. International journal of environmental health research,, 351-355.

Ristovski, Z. D., Miljevic, B., Surawski, N. C., Morawska, L., Fong, K. M., Goh, F., et al. (2012). Respiratory health effects of diesel particulate matter. Respirology, 206-210.

Samuel, R. (2006, February 28). CSD-14 Report on Atmosphere and Air Pollution. https://sustainabledevelopment.un.org. Retrieved November 15, 2021, from https://sustainabledevelopment.un.org/content/documents/ecaRIM_bp2.pdf.

Sarnat, J. A., Koutrakis, P., &Suh, H. H. (2000). Assessing the relationship between personal particulate and gaseous exposures of senior citizens living in Baltimore, MD. Journal of the Air & Waste Management Association, 50(7), 1184-1198.

Shilenje, Z. W., Ongoma, Sagero, V. a., Nguru, P. O., & Kennedy. (2016). Roadside Air Pollutants along Elected Roads in Nairobi City, Kenya. *Journal of Geology & Geophysics*, 6-8.

Stein, Yael. (2018). The possible role of environmental contaminants from air pollution that can enter the brain via the olfactory nerve route. 10.13140/RG.2.2.18714.67525.

Thalib, L., & Al-Taiar, A. (2012). Dust storms and the risk of asthma admissions to hospitals in Kuwait. Science of The Total Environment, 348-349.

Thron, R. W. (1996). Direct and indirect exposure to air pollution. Otolaryngology--Head and Neck Surgery, 114(2), 281-285.

Tilmes, S., Brandt, J., Flatøy, F., Bergström, R., Flemming, J., Langner, J., Christensen, J. H., Frohn, L. M., Hov, Ø., Jacobsen, I., Eberthard, R., Stern, R., & Zimmermann, J. (2002). Comparison of five Eulerian Air Pollution Forecasting Systems for the summer of 1999 using the German Ozone Monitoring Data. Tropospheric Chemistry, 91–121. https://doi.org/10.1007/978-94-010-0399-5_5

U.S. Environmental Protection Agency. (2009). Integrated Science Assessment for Particulate Matter (Final Report). Washington, DC: U.S. EPA. EPA/600/R-08/139F. Retrieved from: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=216546

U.S. Environmental Protection Agency. (2010). National Ambient Air Quality Standards (NAAQS). U.S. EPA, Office of Air and Radiation. Retrieved from: http://www.epa.gov/air/criteria.html

US Department of Health and Human Services. (2006). The health consequences of involuntary exposure to tobacco smoke: a report of the Surgeon General. Retrieved fromhttp://www2.columbusco.org/hdpolicies/Maternity%20Policies%20Procedures/Maternity%20Tools/Smoking%20Cessation%20%20Information/3-%20Second%20Hand%20Smoke.pdf

Villeneuve, P. J., Chen, L., Rowe, B. H., & Coates, F. (2007). Outdoor air pollution and emergency department visits for asthma among children and adults: A case-crossover study in northern Alberta, Canada. Environ Health, 42.

Vliet, E. D., & Kinney, P. L. (2007). Impacts of roadway emissions on urban particulate matter concentrations in sub-Saharan Africa: new evidence from Nairobi, Kenya. Environmental Research Lettres, 2-3.

World Health Organization (WHO), (2006). Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005.Summary of risk assessment. World Health Organization, Geneva.

World Health Organization, (WHO), (2005). Indoor air pollution and health. Fact sheet N°292, 10.03.2011, 12.11.07. Retrieved from: http://www.who.int/mediacentre/factsheets/fs29

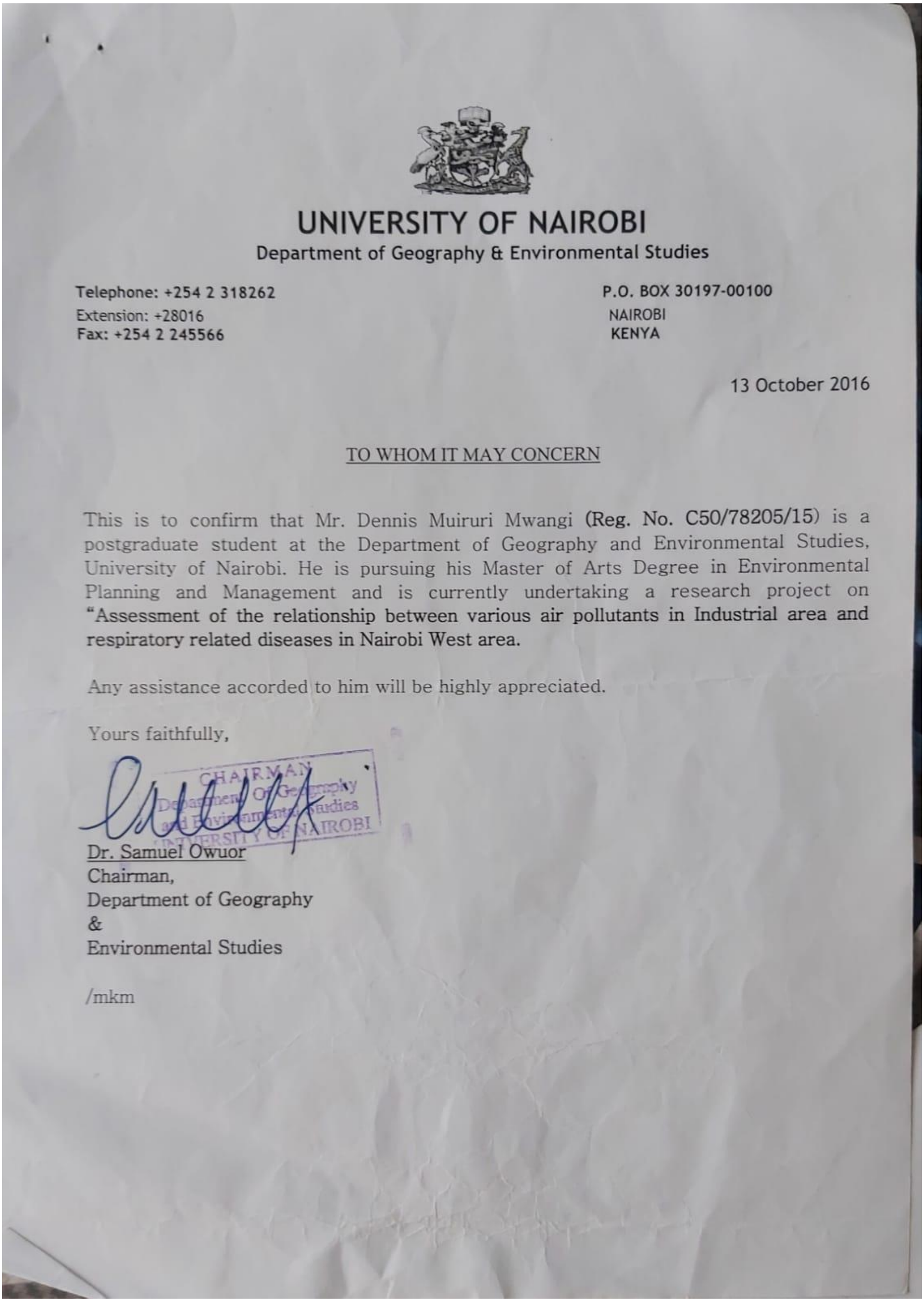
Xie, X., Semanjski, I., Gautama, S., Tsiligianni, E., Deligiannis, N., Rajan, R., Pasveer, F., & Philips, W. (2017). A review of Urban Air Pollution Monitoring and exposure assessment methods. ISPRS International Journal of Geo-Information, 6(12), 389. https://doi.org/10.3390/ijgi6120389

Xing, Y.-F., Xu, Y.-H., Shi, M.-H., & Lian, Y.-X. (2016). The impact of PM2.5 on the human respiratory system. Journal of Thoracic Disease, 2079-2085.

Yang, M., S, Y. G., Bloom Shyamali, Dharmagee, L. M., Bin Jalaludin and Iana Markevychd, L. D., & Marjut, M. K. (2020). Is PM1 similar to PM2.5? A new insight into the association of PM1 and PM2.5 with children’s lung function. *Environment International*, pp. 67-78.

APPENDICES

Research Authorization



UNIVERSITY OF NAIROBI

Department of Geography & Environmental Studies

Telephone: +254 2 318262
Extension: +28016
Fax: +254 2 245566

P.O. BOX 30197-00100
NAIROBI
KENYA

13 October 2016

TO WHOM IT MAY CONCERN

This is to confirm that Mr. Dennis Muiruri Mwangi (Reg. No. C50/78205/15) is a postgraduate student at the Department of Geography and Environmental Studies, University of Nairobi. He is pursuing his Master of Arts Degree in Environmental Planning and Management and is currently undertaking a research project on "Assessment of the relationship between various air pollutants in Industrial area and respiratory related diseases in Nairobi West area.

Any assistance accorded to him will be highly appreciated.

Yours faithfully,

Dr. Samuel Owuor
Chairman,
Department of Geography
&
Environmental Studies

/mkm

NAIROBI CITY COUNTY

Telephone: 2224281
Web: www.nairobi.go.ke

City Hall
P .o. box 30075-00100
Nairobi
Kenya

DEPARTMENT OF HUMAN RESOURCES DEVELOPMENT

Ref: HRD/ 3 / 4 / 1059/2016

DATE: 26th October 2016

Mr. Dennis Muiruri Mwangi
University of Nairobi
Nairobi

<u>0713366020</u>

<u>RE: RESEARCH AUTHORIZATION</u>

Reference is hereby made to your application letter dated **<u>13th October 2016</u>** on the above subject;

The Nairobi City County has approved your request subject to the following;

1. The period of research will be effective from **<u>27th October 2016 -27th November 2016</u>**
2. You will be attached to HEALTH **~~Environment~~ Sector**
3. You are expected to adhere to the rules and regulations pertaining to your research.
4. That during your research there will be no cost devolving on the county.
5. That you undertake to indemnify the county any claim that may arise from your research study.
6. You are required to submit a copy of the final research document to the Human Resource Development Department one week after completion.
7. Research will be on **<u>27th October to 27th November 2016</u>**
8. You are required to pay Research Fee **<u>Ksh 5000/=</u>**

Please report to the **Chief Administrative Officer** HEALTH **~~Environment~~ Sector** Mbagathi hospital

H. A. OMIDO
<u>FOR: DIRECTOR HUMAN RESOURCE DEVELOPMENT</u>

1-8243

KCB | Mtaani Agent

CASH DEPOSIT

CUSTOMER COPY

...search Permit Application Procedure (Kenyans/East Africans)

...go.ke

...ON

...unt

...ssport photo (in JPEG format) and ID/Passport Copy (pdf)

... the inbox or spam folder your email for the login credentials (ORIS account ...assword). Click on "activate account" link on the email received. If email is in ... move it to inbox first before activation.

... to the ORIS account using the provided username and password. On the ... the "apply permit" tab.

...n form to the final stage where you will be required to upload and submit:-

...m Institution/University (pdf)
...e Proposal (pdf)

...e proposal submitted should have a scanned copy of a *signed declaration page*, signed you and your supervisors (if application is academic).
Include a scanned copy of the *Bank Deposit Slip* to the same proposal, preferably the last page of the proposal.

- Ensure the NAME of the researcher/applicant is captured on the Bank-slip

BANK DETAILS FOR PERMIT FEE PAYMENT:

Currency: Kenya Shillings

Bank: Kenya Commercial Bank

Branch: Kipande House

Account Name: National Commission for Science, Technology and Innovation

Account Number: 1104162547

Swift Code: KCBLKENX

Transaction Description: *Research Permit Fee*

Undergraduate	- Kshs. 100
Masters	- Kshs. 1000
PhD	- Kshs. 2000
Individual	- Kshs. 5000
Institutions Private/Public	- Kshs. 10000
Private Companies	- Kshs. 20000

TEL: +254 713 788 787
+254 735 404 245

E-Mail: registry@nacosti.go.ke

Data from Hospitals

	MUTUINI										MAMA LUCY										MBAGATHI						
	y1	y2	y3	y4	y5	y6	y7	pneumonia	URTI	Others	y1	y2	y3	y4	y5	y6	y7	pneumon	URTI	Others	y1	y2	y3	y4	y5	y6	y7
Jan-17				19	3	190	59	22	249		20	511		3	18	144	348	21	492	531		26	6		1		
Feb-17				30	6	118	28	36	146			459			38		446	38	446	459		456	27	8		11	
Mar-17				44	7	400	91	51	491		171	443		23	44	490	301	67	791	614		543	776	2		15	
Apr-17		7		22	9	171	92	31	263	7	109	364		22	27	426	139	49	565	473		567		6		14	
May-17	300	47		10	6		100	16	100	347	120	474		12	36	535	202	48	737	594		678	659	28	23	30	
Jun-17	39	14		4	2			6	0	53	58	362		5	34	354	459	39	813	420			750	9			
Jul-17	39	21						0	0	60	63	409		8	39	340	335	47	675	472			754	7	32		
Aug-17	64	34		4	9			13	0	98		114			46		602	46	602	114		30	654	3	18	30	
Sep-17		25		7	6	88	51	13	139	25	35	63		30	31	309	159	61	468	98			447		5		
Oct-17				3	1	68	81	4	149		39	94		34	106	319	249	140	568	133			407	18			
Nov-17				8	8	111	101	16	212		202	418		66	83	379	164	149	543	620			1,127		9		
Dec-17				3	5	75	82	8	157		64	83		56	64	382	369	120	751	147		435	623	24	12		
Jan-18	1	1		18	2	337	126	20	463	2	86	63		20	74	445	186	94	631	149		543	405	129	83	452	987
Feb-18				10	8	189	101	18	290		318			84		792		84	792	318		785	533	76	385	897	
Mar-18	4			15	17	227	168	32	395	4	168	110		47	63	644	255	110	899	278		658	584	68	314	987	902
Apr-18	2	36		6	6	155	88	12	243	38	182	271		36	182	518	373	218	891	453		598	542	85	227	857	548
May-18				9	4	115	80	13	195		197	123		24	53	556	212	77	768	320		708	652	87	156	986	614
Jun-18		2		6		150	170	6	320	2	117	85		25	54	583	236	79	819	202		685	458	98	78	987	728
Jul-18				16	10	205	254	26	459		82	57		66	89	724	348	155	1072	139		896		140	140		896
Aug-18		21		1	8	118	85	9	203	21	47	95		16	79	456	277	95	733	142				75	75	776	776
Sep-18		3		6	1	51	111	7	162	3	133	79		45	48	639	264	93	903	212				140	54	896	629
Oct-18	3	23		1	3	118	63	4	181	26	76	119		42	76	485	207	118	692	195		55		138	54	789	629
Nov-18		36		3	1	81	55	4	136	36	103	102		20	73	409	134	93	543	205		129		78	4	986	682
Dec-18				1		68	72	1	140		43	103		21	42	192	119	63	311	146		457	56	86	20	658	417
Jan-19				1	2	129	105	3	234		110	80		9	36	455	168	45	623	190		125		11			
Feb-19				4	2	115	81	6	196		229	173		14	68	740	270	82	1010	402				15		200	
Mar-19				7	4	174	117	11	291		416	138		81	92	1,193	336	173	1529	554				39		267	
Apr-19		45		23	3	97	49	26	146	45	156	156		29	77	420	186	106	606	312				47		182	
May-19				6	3	95	84	9	179		145	164		23	49	491	269	72	760	309		184	527	29	34		
Jun-19		46		18	2	130	78	20	208	46	255	143		73	49	728	351	122	1079	398			718		129		259
Jul-19				4	3	169	216	7	385		350			74				74	0	350				20		261	
Aug-19				5	5	91	132	10	223		186	185		51	69	665	356	120	1021	371		248		42			
Sep-19				15	5	87	127	20	214		184	137		28	65	464	246	93	710	321							
Oct-19				11	6	113	118	17	231		229	133		60	51	775	275	111	1050	362							
Nov-19				5	2	39	40	7	79		241	111		45	68	387	1,198	113	1585	352				9	48	70	323
Dec-19		2		1		44	39	1	83	2	127	84		29	28	560	143	57	703	211							
Jan-20				10	3	98	80	13	178		150	113		36	48	69	649	84	718	263		3		6		7	
Feb-20				18	2	193	124	20	317		215	1,106		71	22	112	722	93	834	1321		118		19		2	
Mar-20	1			23	6	164	164	29	328	1	131	100		50	47	236	381	97	617	231							
Apr-20				5	2	36	81	7	117		44	1,051		27	28	194	163	55	357	1095							
May-20					1	23	45	1	68		27	56		10	99	109	126	109	235	83							
Jun-20				4	1	38	41	5	79		28	66		36	51	144	135	87	279	94		33	289	3	51		
Jul-20				1		56	39	1	95		57	93		28	43	242	751	71	993	150		33	349	3	60		
Aug-20				4	1	34	29	5	63		416	72		15	37	173	86	52	259	488		256		34	34	68	
Sep-20				3		41	23	3	64		103	29		10	18	218	65	28	283	132		365		55	34	254	256
Oct-20					1	68	54	1	122									0	0	0					54		386
Nov-20		34	3			58	33	0	91	37		24	26		21	281	101	21	382	50	5					379	
Dec-20		11	1		1	3	11	1	14	12					26	186	107	26	293	0					6		17

y1	Other Dis. Of Respiratory System <5 yrs
y2	Other Dis. Of Respiratory System >5 yrs
y3	MOH 705A Rev 2020_ Lower Respiratory Tract Infections <5 yrs
y4	Pneumonia <5 yrs
y5	Pneumonia >5 yrs
y6	Upper Respiratory Tract Infections <5 yrs
y7	Upper Respiratory Tract Infections >5 yrs