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BY
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Pulmonary Function Impairment in Female Workers Exposed to Environments with Varied Ambient Air Pollution In the central business area of Lusaka-Zambia

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER SCIENCE IN HUMAN PHYSIOLOGY

2015

DECLARATION

I Lumba Siachingili, declare that this Dissertation represents my own work and that all the sources I have quoted have been indicated and acknowledged. I further declare that this Dissertation has not previously been submitted for Degree, or other qualifications at this or other Universities. It has been prepared in accordance to the guidelines for master of Human Physiology Dissertation of the University of Zambia.

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CERTIFICATE OF COMPLETION OF DISSERTATION

I, **Lumba Siachingili**, do hereby certify that the dissertation is the product of my own work and, in submitting it for the Masters of Human Physiology; I declare that this work has not been submitted in part or in whole to another University.

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I, **Dr F. M. Goma,** having read and submitted this dissertation, I am satisfied that this is the original work of the author under whose name it is being presented. I confirm that the work has been completed satisfactorily and is hereby for presentation to the examiners.

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CERTIFICATE OF APPROVAL

The University of Zambia approves this Dissertation of **Lumba Siachingili** in partial fulfilment of the requirement for the award of the Master of Human Physiology Degree by the University of Zambia.

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DEDICATION

I affectionately dedicate this study to my husband –Raymond Lumbuka and children Mwaba and Mumbi.

To my parents- Musa Siachingili and Navie Chilimba Siachingili

To my siblings - Chibaza, Choolwe, Ng'andu, Kantu and Muungu

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LIST OF ACRONYMS

PM	-	Particulate Matter
$PM_{2.5}$	-	Particulate Matter of aerodynamic diameter less than 2.5 micrograms
FEV_1	-	Forced Expiratory Volume in 1 second
FVC	-	Forced Vital Capacity
FEV_1%	-	Forced Expiratory Volume in 1-second percentage
FVC%	-	Forced Vital Capacity percentage
PPE	-	Personal Protective Equipment
WHO	-	World Health Organization
USA-EPA	-	United States of America Environmental Protection Agency
ATS	-	American Thoracic Society
ZEMA	-	Zambia Environmental Management Agency
LCC	-	Lusaka City Council

DEFINITION OF TERMS

Ambient Air – Refers to the outdoor air in the surrounding environment.

Particulate Pollution –Tiny solid and liquid droplets suspended in the air that when inhaled can cause damage to the lungs.

Fine Particulate matter – Is a complex mixture of extremely small particles and liquid droplets. Fine particulate matter is 2.5 micrometres in diameter.

Spirometry – The measurement of how quickly air can be expelled from the Lungs.

Forced Expiratory Volume in 1 second – The volume of air that can be forcibly exhaled from the lungs in the first second of forced expiration.

Forced Vital Capacity – The total volume of air that can be forcibly exhaled after taking the deepest breath possible.

Lung Function status – Refers to how well air flows in and out of the lungs or an FEV_1/FVC ratio of greater than 70%, FEV_1% predicted greater than 80% in women, or FVC% predicted greater than 80%.

Impaired Lung Function Status – When an individual has an FEV_1/FVC ratio of less than 70% or the loss or distortion or weakening of lung tissue leading to difficulty in air flowing out of the lungs.

Personal Protective Equipment – This is the protective clothing, facemasks, respirators, goggles, or other garment designed to protect the wearer's body from injury by blunt impacts, electrical hazards, heat, chemicals, and infection, for job-related occupational safety and health purposes.

Exposure – The act of subjecting or an instance of being subjected to an action or an influence (fine particulate air Pollution).

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ABSTRACT

Previous studies have highlighted the role of ambient fine particulate matter as an important cause of both mortality and morbidity for many respiratory illnesses. When inhaled, $PM_{2.5}$ causes to the airways and lungs obstructive, restrictive or both types of functional impairment through generation of highly reactive oxygen species. Physiological consequence is functional impairment manifested by reduced forced expiratory volume in one second (FEV1), functional vital capacity (FVC) and their ratio (i.e. FEV_1/FVC).

In Zambia, cleaners play an important role in maintaining health and hygiene. The nature of their job exposes them to varying degrees of $PM_{2.5.}$ The levels of $PM_{2.5}$ in ambient Lusaka air are not known, and health-based limits for dust control in the work places are lacking.

The study was undertaken in order to examine the associations between lung function status of female adult cleaners and fine particulate matter ($PM_{2.5}$) concentrations in ambient Lusaka air.

Materials and Methods

The study included women between 18-50 years of age who had been working as street or office cleaners for 6 months or more. The cleaners were interviewed to get information on socio-demographic characteristics and other information using a structured interview schedule. The participants' lung volumes, forced expiratory volume in one second (FEV_1), forced vital capacity (FVC) and their ratio (FEV_1/FVC) were measured using a MRI spirobank G spirometer. On the day of the interview, $PM_{2.5}$ in their work environment was sampled using a personal aerosol monitor (SIDEPAK AM510).

The biomedical ethics committee of the University of Zambia, school of medicine, approved the research. Data were analysed using SPSS (version 20) for windows.

Results

Out of the 90 participants, 45 were street sweepers and 45 were office cleaners. More street sweepers had impaired lung function (FEV1/FVC) 15(75%) than office cleaners 5(25%). FEV_1 was also significantly different among street sweepers 12(70.6%) and office cleaners 5(29.4%). $PM_{2.5}$ measurements revealed significantly high levels of exposure among street sweepers. Participants with impaired lung function and those with reduced FEV_1percent predicted were exposed to significantly high concentrations of $PM_{2.5.}$

Conclusion/Recommendation: Exposure to high $PM_{2.5}$ concentration is associated with pulmonary function impairment and reduced FEV_1 % predicted among cleaners. It is therefore, recommended that cleaners, be subjected to periodic health checks, in order to check for the development of cardiopulmonary symptoms and necessitate early intervention.

CHAPTER ONE

INTRODUCTION

Air pollution is considered a hazard to human health (WHO, 2005). In the past decades, many studies highlighted the role of ambient air pollution as an important cause of both mortality and morbidity for many different cardiopulmonary diseases (Valavanidis et al. 2008). Ambient pollutants include suspended or respirable particulate matter (PM), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), and sulphur dioxide (SO_2) (ZEMA, 2011).

Of all pollutants, respirable particulate matter (PM) has the greatest effect on human health (Ghio and Devlin, 2001). Airborne PM consists of a mixture of liquid and solid air-suspended particles, which are released straight into the atmosphere or after the transformation of gas into particles from natural or human-induced processes (Diagle et al. 2001). Some of the important sources of fine particulate matter include burning fuels emitted from vehicles, open air burning of house hold wastes and the cooking fuel used (WHO, 2002).

The most important parameter for defining the toxicity of PM is particle diameter and composition (Nodari et al. 2006). The United States Environmental Protection Agency (US EPA) and other agencies in the air pollution regulation of PM have three main categories: $PM_{0.1}$ (ultrafine particulate matter), $PM_{2.5}$ (fine particulate matter) and PM_{10} (coarse particulate matter), which refer to particles with aerodynamic diameter smaller than 0.1, 2.5 and 10 micrometres (μm), respectively (US EPA, 1996). Studies show that it is the fine ($PM_{2.5}$) and ultrafine ($PM_{0.1}$) fraction that are capable of penetrating deep into lung tissue and inducing oxidative stress which are more harmful than the coarse particles (PM_{10}) (Aust et al. 2002). Furthermore, studies in analytical electron microscopy show that 96% of effectively retained particles in the lung parenchyma are $PM_{2.5}$ and only about 5% of ultrafine particles (0.1μm) are retained (Valavanadis et al. 2008). Therefore, particle size and the ability to penetrate into the lung tissue and subsequent retention of the fine particles play an important role in causing lung function impairment (Valvanidis et al. 2008). The current World Health Organisation (WHO) Air quality guidelines (AQG) provide exposure-response relationships describing the relationship between ambient PM and various health endpoints. It has set a 24-hour average guideline value of 25μg/m^3 for $PM_{2.5}$, although no level of $PM_{2.5}$ exposure is considered safe (WHO, 2005). The US Environmental protection agency revised the breakpoints for $PM_{2.5}$ indicating that $PM_{2.5}$ levels between 0.0-12μg/m^3 are good, while 12.1-35.4μg/m^3 as moderate and 35.5-55.4μg/m^3 as unhealthy to sensitive groups. The upper breakpoints range from unhealthy to hazardous (55.5-350.4μg/m^3) (US EPA, 2012).

Pathophysiology

When inhaled, air pollutants cause obstructive, restrictive or both types of functional impairment of the respiratory system manifested by reduced functional vital capacity (FVC), forced expiratory volume in one second (FEV_1) and the ratio thereof FVC/FEV_1 (Gotschi et al. 2008). The effects of these pollutants have a direct relationship with the levels of concentration of pollutant and duration of exposure to the pollutant (Nku et al. 2005). Most of these pollutants are oxidant in nature and cause harm through the generation of highly reactive oxygen species once in contact with lung epithelial cells (Logario et al. 2006). Reactive Oxygen Species, generated include superoxide, hydrogen peroxide, and hydroxyl radical. Reactive oxygen species play an important role in originating pulmonary inflammation and chemical oxidative stress (Riedl and Diaz-Sanchez, 2005). They are reactive with proteins, lipids, and deoxyribonucleic acid (DNA), leading to cellular damage. Chemical Oxidative stress exists when there is an excess of free radicals over antioxidant defences (Pope, 2007). Oxidative stress caused by PM $_{2.5}$ constituents leads to the activation of transcription factors, such as Nuclear Factor Kappa B (NFKB) and protein-1 activator, which are linked to the production of proinflammatory cytokines and chemokines (Lagorio et al. 2006; Nodari et al. 2006) these in turn increase airway resistance and reduces alveolar ventilation (Khurshid et al. 2013). $PM_{2.5}$ induces cell injury and death of respiratory epithelial cells, it possibly decreases immunity defences through the destruction of macrophages and increases airway reactivity inducing allergic symptoms (Nodari et al. 2006). Presence of allergies has been associated with impaired lung function status among susceptible occupational groups such as cleaners and street sweepers, steel plant workers and so on (Sabde and Zodpey 2008; Singh et al. 2013)

Spirometry is the most important as well as simple, non-invasive technique performed to assess the functioning ability of the lungs in most routine clinical examinations (Verma, 2006; Khurshid et al. 2013; Gree et al. 2013). Spirometric measures of lung function, namely maximum forced vital capacity (FVC) and maximum forced expiratory volume in 1 s (FEV_1) have been described as early indicators of chronic respiratory and systemic inflammation (Gotschi et.al 2008). The lowering of both the FEV_1 (FEV1< 75% predicted for age and height) and FVC (FVC<80% predicted for age and height) indicates a restrictive lung impairment while the ratio there of maybe greater than 70% (Barreiro and Perillo 2013). In obstructive impairment, the FVC may be normal but FEV_1 is reduced (Levy et al. 2007). Pope (2007) associated these outcomes with ambient air pollution, thus; lung function is an important link in investigating the effects of ambient air pollution (Gotschi et al. 2006).

Occupational exposure to fine particulate matter ($PM_{2.5}$) pollution

Occupation is an important factor in the exposure of individuals to hazardous toxins (WHO, 2002). Among the susceptible groups, street sweepers and office cleaners are at risk of developing lung function impairment due to exposure to outdoor and indoor sources of $PM_{2.5}$ (Zock 2005; Nku et al. 2005). Despite belonging to an organised workforce, cleaners are not sufficiently taken care of in terms of periodical health check-ups and provision of personal protective equipment such as gloves, facemasks and respirators. Sometimes, due to poor sensitization on the need to use this equipment others feel there is no need to use it, whilst the protective equipment maybe worn out and/or not replaced in good time (Muula et al. 2010).

The goal of this study was to examine the associations between lung function status of adult cleaners and fine particulate matter ($PM_{2.5}$) concentrations in ambient air.

Statement of the Problem

The World Health Organization estimates that both urban outdoor and indoor air pollution are estimated to cause 1.3 million deaths worldwide per year, with the primary health concerns coming from particulate matter less than 2.5 μm ($PM_{2.5}$) and ozone (O3) (WHO 2005). Short-term exposure to $PM_{2.5}$ increases cardiopulmonary morbidity and mortality while long-term exposure to $PM_{2.5}$ has been linked to adverse respiratory outcomes such as lung cancer (Pope 2007). Studies show that $PM_{2.5}$ exposure whether long term or short term, is associated with declines in lung function parameters FEV_1, FVC and their ratio (Downs et. al. 2007; Thaller et. al.2008).

The air quality in Western countries has continued to improve over the past decades mainly due to intense air monitoring and implementation of air pollution limits. However, rapid economic growth in developing countries has left air quality in many cities very poor (Huang 2014).

A review of African studies on $PM_{2.5}$ by Petkova et al (2013) showed that $PM_{2.5}$ is a problem in Africa and that monitoring and control measures remain poor in most countries. This could be the case for Zambia too except that $PM_{2.5}$ levels are unknown and that no studies have been done to provide information on the health outcomes of $PM_{2.5}$ exposures among susceptible occupational groups. Just like other African cities the levels of $PM_{2.5}$ in ambient Lusaka air are not known, and health-based limits for dust control in the various work places are lacking.

This study was therefore aimed at determining the level of air pollution in the work environments and the possible effects of these pollutants on the lung function status of individuals that are exposed to these pollutants such as female cleaners; street sweepers and office cleaners.

Justification of the Study

Although studies on lung impairment have been carried out on specific occupational groups such as miners and stone crashers (Laima 2012, Siziya et al. 2005), no study has been carried out on other occupational groups such as cleaners. The goal of this study was to determine the concentration of ambient particulate matter of aerodynamic diameter less than 2.5 micrometers ($PM_{2.5}$) in environmental air and to determine the lung function status, of the cleaners who work in those environments. The data obtained would be useful as an advocate tool for provision of protective equipment for the cleaners. It will also provide insights on the possible effects of $PM_{2.5}$ on lung function to policy makers, health care providers and researchers and provide a baseline for further study. It is envisaged that this study will help improve enforcement and implementation of air quality regulations around the city.

CHAPTER TWO

LITERATURE REVIEW

Literature shows that there is an association between long term and short-term exposure to $PM_{2.5}$ and its constituents. In a cross- sectional study among adults in Switzerland to assess the association between short-term variations in air pollutant levels and lung function status. It was revealed that, 10-micrograms per cubic meter ($\mu g/m^3$) increments in the daily level of nitrogen dioxide, total suspended particulates, and ozone were associated with respective decrements in FEV_1 of 0.67%, 0.46%, and 0.51%. Increments in nitrogen dioxide and total suspended particulates of 10 $\mu g/m^3$ were associated with respective decrements in FVC of 0.73% and 0.36%. Thus, the authors concluded that daily concentrations of nitrogen dioxide, total suspended particulates, and ozone have a significant effect on lung function (Schindler et al. 1991).

Furthermore, an evaluation of the effects of ambient ozone, fine particulate matter and strong aerosol acidity on the pulmonary function of exercising adults in New Hampshire revealed that prolonged exposures even to low levels of ozone, $PM_{2.5}$ and strong aerosol acidity, were associated with significant effects on pulmonary function among adults. They observed consistent declines in FEV_1 and FVC (Korrick et al. 1998). However, Giradot et al. (2006) replicated this study in a cross sectional survey, and found no significant associations of acute changes in pulmonary function with either $PM_{2.5}$ or ozone. A cross sectional survey of the English population to measure the extent of chronic exposure to outdoor pollutants and its influences on lung function in adults, revealed that greater exposure to particulate matter, nitrogen dioxide and sulfur dioxide was associated with lower adult FEV_1. It was found that nitrogen dioxide and sulfur dioxide had percentage size effect of 0.7% on the population mean FEV_1 while particulate matter accounted for 3% size effects (Forbes et al. 2009). In contrast a study by Gostchi et al. (2006) that assessed $FEV_{1,}$ FVC and their ratio, found no significant associations between city-specific annual mean $PM_{2.5}$ and average lung function levels. These findings did not support those of previous studies, which showed that $PM_{2.5}$ exposure had an effect on change in lung function status among adults.

Whilst increases in pollutants result in reduced lung function, the opposite is also true. A study conducted in Switzerland revealed that decreasing exposure to air borne particulates or pollutants appears to attenuate or reduce the decline in lung function. For example the net effect of a decline in PM of 10μg/m^3 or less to levels less than 10μg/m^3 over an 11 year period, resulted in annual rate of decline in FEV_1 of 9 per cent ((Downs et al. 2007). This indicated that, reducing levels of pollutants leads to a reduction in the rate of decline in lung function status.

Thaller et al. (2008) reported that forced vital capacity (FVC) and forced expired volume in 1 second (FEV_1) decreased significantly with decreased fine particulates and increased significantly with increasing fine particulates ($PM_{2.5}$). The study revealed that deleterious effects of $PM_{2.5}$ were transient and occurred at pollutant levels far below the regulatory thresholds at which $PM_{2.5}$ is said to be less harmful. Showing that even at low levels of exposure, $PM_{2.5}$ was associated with reduced lung volumes.

Other studies have reported an improvement in lung function as well as respiratory symptoms once an individual moves from a highly polluted area to a cleaner area (Kelly, 2011).

Exposure to $PM_{2.5}$ and Pre-existing Respiratory Conditions

A study conducted in Seattle revealed that exposure to pollutants tends to worsen already existing respiratory conditions. They observed decrements in FEV_1 among both adult subjects with chronic obstructive pulmonary disease (COPD) and children with asthma (Trenga et al. 2009). Koenig et al. (2005) and Dales et al. (2009) reported similar findings. The reports suggested that, in children with asthma, relatively low concentrations of urban air pollution worsen lung function over a short period, even within a day. Dales et al. (2009) further suggested that of the pollutants measured, $PM_{2.5}$ appeared to be the most important in worsening already existing lung impairment.

Furthermore, Lagorio et al. (2006) conducted a panel study on the effects of air pollution among susceptible adults. The study revealed that decrements in the FVC and/or FEV_1 observed among the participants with COPD were associated with increasing concentrations of $PM_{2.5}$ among other pollutants. This study limited the short-term effects of exposure to air pollutants particularly fine particulates ($PM_{2.5}$) on lung volumes and flow to individuals who already had impaired lung function status.

In addition to worsening pre-existing respiratory conditions, exposure to $PM_{2.5}$ has also been associated with onset of respiratory and allergy symptoms as well as conditions such as asthma. The inhalation of chemically generated particulates, dust and mould was the attributed cause for these conditions. Furthermore, studies on occupational asthma by Jaakkola et al. (2003) reported that female cleaners were at higher risk than men in developing occupational related asthma, and the associated allergic symptoms characterised by airway hyper-responsiveness and reduced FEV_1 (Makela et al. 2011; Zock et al. 2002).

Occupational Exposure

A cross sectional comparative study conducted on both male and female subjects employed in two separate chemical plants in Zagreb Croatia, aimed at estimating the effect of ambient air pollutants on the respiratory function. The study revealed that ventilator data among the chemical workers demonstrated that most of the measured tests were significantly decreased particularly the FVC and FEV_1 compared to predicted values ((Mustajbegovic et al. 2000). While other studies show that, loss in respiratory function and FVC is due to length of exposure to pollutants and the age of the subject (Ekpenyong et al. 2012; Mannino and Davies, 2005).

Occupation plays an important role on the level of personal exposure to pollutants as revealed in a study carried out in Calabar, Nigeria. The study showed that female street sweepers exposed to high concentrations of dust had lower lung function values compared to females of the same category working in an office (Nku et al. 2005). The study further revealed that use of Personal protective equipment (PPE) was essential in reducing occupational related exposures to $PM_{2.5.}$

Khurshid et al. (2013) showed that street sweepers by virtue of their exposure to dust were likely to have a FEV_1/FVC ratio less than 60%. They further showed that particle size had a bearing on the nature of lung function impairment singling out the $PM_{2.5}$

fraction's ability to penetrate the alveoli, causing restrictive lung impairment as well, while, Medina-Ramon et al. (2005) revealed that indoor generated Particulates among other pollutants were responsible for the reduced FEV_1 among indoor cleaners.

Over the years studies conducted in many developing countries have reported an increase in $PM_{2.5}$ burden and its constituents. Petkova et al. (2013) observed that in Africa, the growing ownership of motor vehicles, unpaved roads as well as continued use of biomass (firewood and charcoal) as a major domestic energy source has led to an increase in the burden of $PM_{2.5}$. Combustion of biomass fuels is usually incomplete and releases several pollutants among them Particulate matter. A study carried out on Women with long term occupational exposure to burning firewood from a rural fishing community in Nigeria revealed that 19.9% of the subjects had lower values for the lung function as well as the percentage predicted values for FEV_1 and FVC (Umoh and Peters, 2014). Therefore, cooking fuel may be considered an important source of particulate air pollution just as vehicular emissions (Kenyon and Liu, 2011).

Other studies have cited areas of residence as a contributing factor in lung impairment. For example, a study conducted in Nigeria on the effects of ambient particulate matter and lung impairment, showed that subjects who live around highly polluted areas had a reduced FEV_1% than those who live around areas of low pollutant levels (Gree et al. 2013).

CHAPTER THREE

RESEARCH QUESTION

What is the lung function status among the cleaners exposed to varied concentrations of particulate matter of aerodynamic diameter less than 2.5 micrometer ($PM_{2.5}$) in the central business area (Town Centre) of Lusaka, Zambia?

General Objective

To determine the lung function status among street sweepers and office cleaners exposed to particulate matter of aerodynamic diameter less than 2.5 micrometer ($PM_{2.5}$) in Lusaka, Zambia.

Specific Objectives

1. To measure the levels of particulate matter of diameter less than 2.5 micrometers in outdoor and indoor areas of the central business area.
2. To measure lung function indices (FEV_1, FVC and the FEV_1/FVC%) of street sweepers and office cleaners.
3. To demonstrate the association between the concentration of $PM_{2.5}$ pollution and other participant characteristics with lung function indices ($FEV_{1,}$ FVC and FEV_1/FVC ratio) in the cleaners.

CHAPTER FOUR

METHODOLOGY

STUDY DESIGN

This was a cross sectional study with two groups exposed to environments with varying concentrations of $PM_{2.5}$.

STUDY SITE

This study was conducted in Lusaka which is the capital city of Zambia and is said to be a fast growing city. Around 3 million people live in Lusaka according to the report on the state of the environment (LCC and ZEMA 2011). There are four main roads within the central business area, Cairo road (considered to be the main avenue in town), Chachacha, Freedom way and Lumumba roads. These are split into sections by six centre roads (Chiparamba, Katunjila, Katondo, Nkwazi, Malasha and Kalundwe). The central business area is enclosed by two boundary roads Benbella on the south and Kalambo on the north. These roads are lined with shops, banks and modern looking business areas, restaurants, hotels and markets. A map of the city of Lusaka has been provided in appendix VIII. The area shown as town center on the map is the central business area.

Study Population

The target population included all female cleaners who work within the central business area of Lusaka- Zambia and these were divided into two groups according to their job category, office cleaners and street sweepers. The study population was obtained from these groups within the selection criteria after obtaining consent to take part in the study.

Inclusion Criteria

Females aged between 18 and 50 years of age who had been working as street or office cleaners for 6 months or more were invited to participate in the study.

Exclusion Criteria

Individuals in both groups who used to smoke or were currently smokers.

Males were excluded from the study as they constitute a very small proportion of the people in this sector.

Sample Size Determination

Sample size calculation was based on the strength of the association between the outcome variable FEV_1/FVC % and the independent variable $PM_{2.5}$concentration. Using Pearson correlation coefficient sample size correlation SSizCorr_Tab.php at http://www.statstodo.com/SSizCorr_Pgm.php

For $\alpha = 0.05$

Power = 0.80

Anticipated r = 0.45 (According to Gree et al.2013)

Sample Size (n) = 30

Readjusting due to the design effect (DEFF)

Where DEFF =1+ δ (n-1)

δ =1 intraclass correlation coefficient if only one $PM_{2.5}$ applies to all cleaners at a particular location.

n= number of cleaners per location = 3, assuming that 3 cleaners/sweepers per location.

Therefore a cluster design effect of (DEFF) =1+ δ (n-1) =3 was obtained

Therefore, in order to identify a correlation with r $\geq$0.45;

Thirty - (30) × 3 = 90 participants were recruited.

NOTE- Use of the design effect was because each location will have one average $PM_{2.5}$ value but more than one (1) cleaner. According to the Lusaka City Council, work schedules each street or location had an average of three cleaners.

Identification and Selection of Participants

The participants in both groups were identified using a list of employees provided by the supervisors at the randomly selected location. Since two groups had to be selected and were stratified into outdoor and indoor equal number of participants were selected;45 indoor and 45 outdoor cleaners. The lists were used by the principal investigator as a sampling frame for which random sampling technique was employed in the selection of participants. The participants were selected from twelve 12 data points (Benbella, Cairo west and east, Kalambo, Chiparamba, Katunjila, Katondo, Malasha, Nkwazi, Freedom, Chachacha, Lumumba and Kalundwe). However, selection of participants depended upon them meeting the selection criteria and consenting, before the tests and interviews were done.

Dependent and Independent Variables

Independent variables

Age

Height

Weight

Use of Protective Equipment

Occupational history

Previous respiratory or heart conditions

Smoking history

Cooking fuel

$PM_{2.5}$ Concentration

Dependent variables and Reference Values.

Forced Expiratory Volume exhaled in the first second (FEV_1), Forced Vital Capacity (FVC) and FEV_1/FVC (FEV_1%) were the dependent variables. Table 3.4.3 shows the reference values for FEV_1, FVC and their ratio were used to determine lung function status according to Barreiro and Perillo (2013) and Levy et al (2009).

Table 1

Variable (Dependent)	Indicator	Predictor
FEV_1 /FVC	Normal	70%
	Restrictive lung impairment	>70%
	Obstructive lung impairment	< 70%
FEV_1 (Interpretation of predicted)	>80%	Normal
	60-75%	Mild obstruction
	50-59%	Moderate obstruction
	<49%	Severe obstruction
FVC (Interpretation of predicted)	80-120%	Normal
	70-79%	Mild reduction
	50%-69%	Moderate reduction
	<50%	Severe reduction

DATA COLLECTION

Data collection was carried out between the months of June and August 2014. A structured interview schedule (questions adapted from the American Thoracic Society - ATS respiratory questionnaire) was used to collect demographic information and to record Spirometry data from participants. Prior to its use the interview schedule was tested on fifteen (15) randomly selected female cleaners at the University of Zambia Main Library (Great East Road campus) to ascertain the levels of understanding. The questions were administered in Nyanja the most commonly spoken language. The language used was simple and the cleaners had no difficulty understanding the questions. Information pertaining to the cleaning site, cooking fuel used, smoking history, occupation history, allergies and history of respiratory diseases were captured using the interview schedule.

Measurement of Lung Function

The lung function tests and interviews on street sweepers were done at the Lusaka City Council –Waste Management Unit offices where the sweepers report for duty before going to the various assigned areas, where as for the office cleaners it was done at the actual site of work. The tests were carried out with the help of a trained spirometry technician, using a portable MRI spirobank G spirometer (Medical Research International, Spirobank G, Rome, Italy). The spirometer had been used in a previous study by Siziya (2005) and the reference values had been calibrated into the device. The tests were taken with participants in the standing position; a nose clip was applied to the participant's nose. The participants were urged to: seal their lips tightly around the mouthpiece, breathe in fully (maximal inspiration) at the start of the test, immediately blast air out as fast and as far as possible (until residual volume is reached) and not to lean forward during the test.

Three maneuvers were done and the best of the three readings was recorded. The predicted $FEV_{1,}$ FVC was determined using height and age of the participant. The FEV_1/FVC ratio was determined using the recorded FEV_1 and FVC values for each participant. Lung function status of each participant was determined using the FEV_1/FVC ratio.

Measurement of Fine Particulate Matter ($PM_{2.5}$)

A TSI SidePak AM510 Personal Aerosol Monitor (TSI incorporation St. Paul, MN United States of America) was used to sample and record the levels of fine particulate matter ($PM_{2.5}$) in the air. The SidePak uses a built-in sampling pump to draw air through the device and the particulate matter in the air scatters the light from a laser to assess the real-time concentration of particles smaller than 2.5μm in micrograms per cubic meter, or $PM_{2.5}$. The SidePak was calibrated previously against a light scattering instrument, and used in similar studies. In addition, the SidePak was zero-calibrated prior to each use by attaching a zero filter according to the instructions provided in the user guide. Measurements of $PM_{2.5}$ for both indoor and outdoor areas were taken in the morning, midday, and in the afternoon during cleaning and non-cleaning hours for an average of 30 minutes (range 30-60 minutes). In addition personal aerosol monitoring of the cleaners was done by attaching the SidePak to the participant and the sampling tube near the participants' breathing zone. The built in impactors of the aerosol monitor were set on the 2.5 cut off so as to sample only $PM_{2.5}$ concentrations in mg/m^3 then converted to $\mu g/m^3$. For each location, the data points were summarized to provide an average $PM_{2.5}$ concentration within each location. Sampling in both indoor and outdoor locations was discreet. $PM_{2.5}$ readings were stored in the sampling device and manually transferred to a data sheet for analysis.

DATA ANALYSIS

The interview responses on the interview schedule were checked for completeness during the process of data collection and coded, $PM_{2.5}$ and FEV_1/ FVC data were recorded in a Microsoft Excel data sheet then exported to SPSS software version 20 for analysis. Information pertaining to Street sweepers and that of office cleaners was categorized in relation to the cleaning area that is $PM_{2.5}$ concentration for street sweepers corresponded to the outdoor PM measured for the named site. The street or cleaning location names were entered in the Excel worksheet to match the PM characteristics with the individual responses and lung function test results for the participants but these were not included in the information transferred to SPSS for analysis.

Continuous variables such as age and the level of education were split into two groups; 18-35 years as"1" and 36-50 years as "2" while never/primary education as "1" and secondary education as "2" respectively, for analytical purpose. The categories of lung function were also split into two 'normal' [FEV_1/FVC greater than (>) 70% or if FVC % of predicted is > 80% and FEV_1 % of predicted > 80%] and 'impaired' [FEV_1/FVC < 70% or if predicted < 80% and FEV_1 % predicted < 80%].

$PM_{2.5}$ data was not normally distributed, therefore medians and interquartile ranges were used to describe $PM_{2.5}$ data by area. The Independent Samples Mann-Whitney U test for non-parametric data was used to compare medians of $PM_{2.5}$ across the indoor and outdoor cleaning sites. Explorative statistics using the Independent Samples Median Test were used to determine the association of $PM_{2.5}$ with lung function characteristics (predicted FEV_1% and FVC% and the ratio FEV_1/FVC).

Occupational history was categorized into four (4) categories, which are associated with exposure to respirable dust and toxins; metal fabrication/mining, stone crushing/milling, dusts/fumes and not applicable for those whose previous employment did not fall in the mentioned categories or those who had never worked before. Information on history of respiratory disease and heart conditions was combined as history of cardiopulmonary conditions for analytical purposes.

Chi-square was used to determine the association between the dependent variable (lung function status) and the independent variables (age, cooking fuel, history of cardiopulmonary disease, cleaning site i.e. indoor or outdoor, occupational history and presence of allergies) Statistics were done at the 5% level of significance. The analysed data has been presented in tables and graphs and numerical descriptions have been given so as to show the relationships of the variables if any.

Validity

To ensure validity, all variables as well as the confounding factors were considered in the study by capturing them in the interview schedule during data collection.

Reliability

The same data collection tool and method of collecting and processing the information were used on all the participants.

ETHICAL ISSUES

Informed Consent

An informed consent form prepared according to the Research Ethics Committee guidelines was given to the participants in order to guarantee voluntary participation. The contents of the information sheet were translated into Nyanja the commonly spoken language. Simple language was used in providing the participants with sufficient knowledge to ensure the decision to take part is a well-informed one. Contents such as the purpose of the study, its nature and methods to be used in the study were explained. The information sheet was kept by the participants while the consent forms were kept by the principal investigator. Participants gave consent either through written or using the thumb prints for those who could not write. The participants were allowed to ask questions pertaining to the study and were free to withdraw from the study at any time if they felt uncomfortable without any penalty or loss.

Permission

Approval to carry out the study was granted in writing by The University of Zambia Biomedical Research Ethics Committee (Assurance No. FWA 00000338, IRB 00001131 of IORG 0000774, Ref: 013-03-14). Permission to conduct the study was obtained from the various employers of the groups of cleaners and the Lusaka City Council (See appendix for letters of approval).

CHAPTER FIVE

RESULTS

Description of the Participants

Of the 90 participants recruited to the study 45 were street sweepers and 45 were office cleaners all female, none were tobacco smokers or had previously smoked tobacco.

Lung Function Characteristics of Participants

Table 2 describes the lung function characteristics of the participants. The table describes the lung function characteristics of the participants. 15 (75% within lung function) street sweepers had impaired lung function compared to 5 (25%) office cleaners. This difference was statistically significant at p<0.05.

Table 2: Lung Function Characteristics of Participants

Lung function variable	**Street sweepers**	**Office cleaners**	**p-value**
	No (%)	**No (%)**	
Lung function status (FEV_1/FVC)			
Normal (FEV_1/FVC > 70%)	30(42.9)	40(57.1)	
Impaired (FEV_1/FVC < 70%)	15(75.0)	5(25.0)	0.01*
FEV_1 percent predicted			
Normal (FEV_1 %predicted > 80%)	33(45.2)	40(54.8)	
Reduced (FEV_1% predicted < 80%)	12(70.6)	5(29.4)	0.059
FVC percent Predicted			
Normal (FVC% predicted > 80%)	36(46.2)	42(53.8)	
Reduced (FVC %predicted < 80%)	9(75.0)	3(25.0)	0.06

[p]Pearson's Chi-Squared Test (2-sided), *Indicates significant *p*-value at $p < 0.05$.

Contributing factors to $PM_{2.5}$ exposure and Lung Function Status

Table 3 below shows the factors that could possibly contribute to participants' exposure to $PM_{2.5}$ such as use of PPE, cooking fuel, previous occupation and allergy symptoms and their association with lung function status.

Table 3: Lung Function status by Key characteristics of participants

	Lung function Status		
	Normal (n =70, $FEV_1/FVC>70\%$)	Impaired (n = 20, $FEV_1/FVC < 70\%$)	
	No (%)	No (%)	P-Value*
Age of participant			
Less than 25years	4 (5.7)	2 (10.0)	
25-34 years	29 (41.4)	5 (25.0)	
35-44 years	31(44.3)	8 (40.0)	
45-54 years	6 (8.6)	5 (25.0)	0.169
Use of PPE			
Always	24 (34.3)	8 (40.0)	
Sometimes /never	46 (65.7)	12 (60.0)	0.792
Cooking Fuel			
Charcoal	41 (58.6)	14 (70.0)	
Electricity	29 (41.4)	6 (30.0)	0.355
History of cardiopulmonary diseases			
Yes	14 (20.0)	6 (30.0)	
No	56 (80.0)	14 (70.0)	0.343
Occupational History[p]			
Metal fabrication/ mining	2 (2.9)	0 (0.0)	
stone crushing/ milling plant	11 (15.7)	2 (10.0)	
Dusts/fumes	5 (7.1)	6 (30.0)	
Other (no previous occupation)	52 (74.3)	12 (60.0)	**0.046***
Cleaning site[p]			
Indoor -office cleaners	41 (58.6)	4 (20.0)	
Outdoor -street sweepers	29 (41.4)	16 (80.0)	**0.002***
Allergies[p]			
No	37 (52.9)	5 (25.0)	
Yes	33 (47.1)	15 (75.0)	**0.028***

[p]Pearson’s Chi-Squared Test (2-sided), *Indicates significant *p*-value at $p < 0.05$.

Age and Lung Function Status

Table 4 shows that among the participants aged between 18-35years, 37(52.9%) had normal lung function while 8(40%) had impaired lung function. Among those aged 36-50 years, 33(47.1%) had normal lung function and 12(60%) had impaired lung function. The frequency of lung impairment among those between 36-50 years was high. However the difference in lung function status between the two age groups was not statistically significant ($p>0.05$).

Use of Personal Protective Equipment (PPE) and Lung Function Status

Among the 90 participants 46 (65.7%) reported using PPE sometimes or not at all. Among those with impaired lung function 12 (60%) reported not using PPE consistently while 8(40%) reported always using PPE. However, there was no significant difference in lung function between those always using PPE and those that used PPE occasionally or never ($p>0.05$)

Cooking Fuel and Lung Function Status

Regarding cooking fuel and lung function status, table 3 shows that among those that reported using charcoal as a cooking fuel 41 had normal lung function status and 14 had impaired lung function status. Among those that reported using electricity as cooking fuel, 29 had normal lung function status while 6 had impaired lung function status. Most (70%) of the participants with impaired lung function status used charcoal as cooking fuel. There was no significant difference in lung function status between participants who used charcoal as cooking fuel and those who used electricity ($p>0.05$).

Pre-existing Cardiopulmonary Conditions and Lung Function Status

Among the participants who reported having previously or were currently suffering from a respiratory or heart condition, 14(20%) had normal lung function status and 6 (20%) had impaired lung function status. Among those that reported not having a respiratory or heart condition previously or at present, 56 (80%) had normal lung function status, while 14(70%) had impaired lung function status. Most (14) of the participants with lung function impairment had no pre-existing cardiopulmonary condition ($p>0.05$).

Occupational History and Lung Function Status

Among the participants with normal lung function status, 2.9% had previously worked in Metal fabrication or mining related industries, 15.7% had worked as stone crushers or at stone crushing sites, 7.1% previously worked in industries associated with dust and fume generation and 74.3% had not worked previously. Of those with impaired lung function status, 40.0% had previously worked in the above-mentioned industries, while 60.0% had not worked previously.

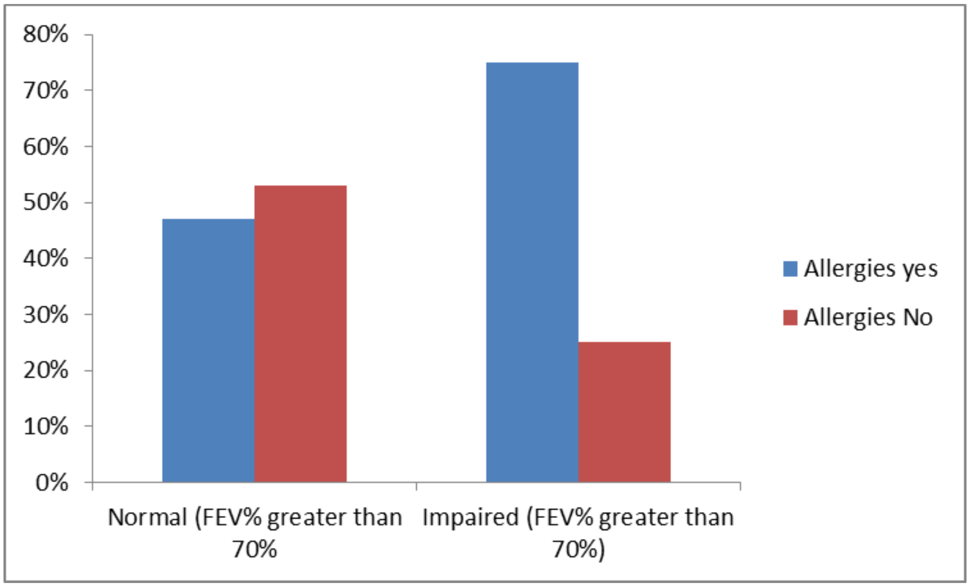
There was significant association between Previous occupation and lung function status of participants ($p = 0.046$).

Allergies and Lung Function Status

About half (53%) of the participants reported that they suffered from allergic symptoms while at work. Figure 1 below shows lung function status and allergy symptoms among these participants. Among the participants with normal lung function status, 33 had allergies while 37 had no allergies. Among those with impaired lung function status, 15 had allergies and 5 had no allergies. Most of those with impaired lung function status (75%) reported having allergy symptoms.

From the chi-squared association analysis (table 3), presence of allergy symptoms was statistically associated with lung function status as indicated by the significant p-value.

Figure1: Lung Function Status and Allergy symptoms

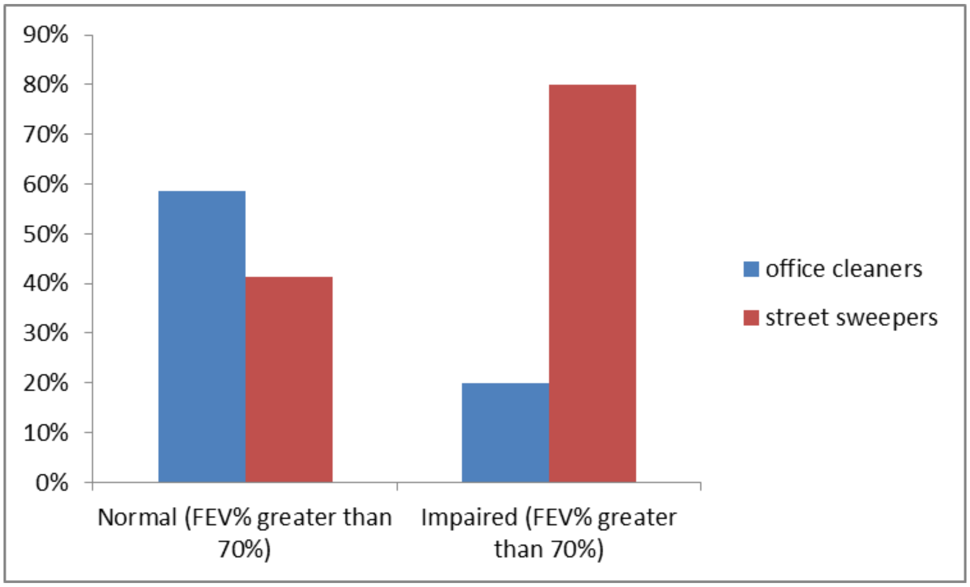


Cleaning Group and Lung Function Status

The two groups of cleaners recruited to the study were desegregated into office cleaners and street sweepers. Of the participants with normal lung function status, 29 (41.4%) were street sweepers, and 41(58.6%) were office cleaners. 80% of the participants with impaired lung function status were street sweepers while only 20% were office cleaners. Cleaning group was statistically associated with lung function status p=0.002.

Figure 2 shows a high frequency of lung impairment among street sweepers compared to office cleaners.

Figure 2 Cleaning group and Lung Function status



$PM_{2.5}$ Concentrations ($\mu g/m^3$) in Indoor and Outdoor Areas

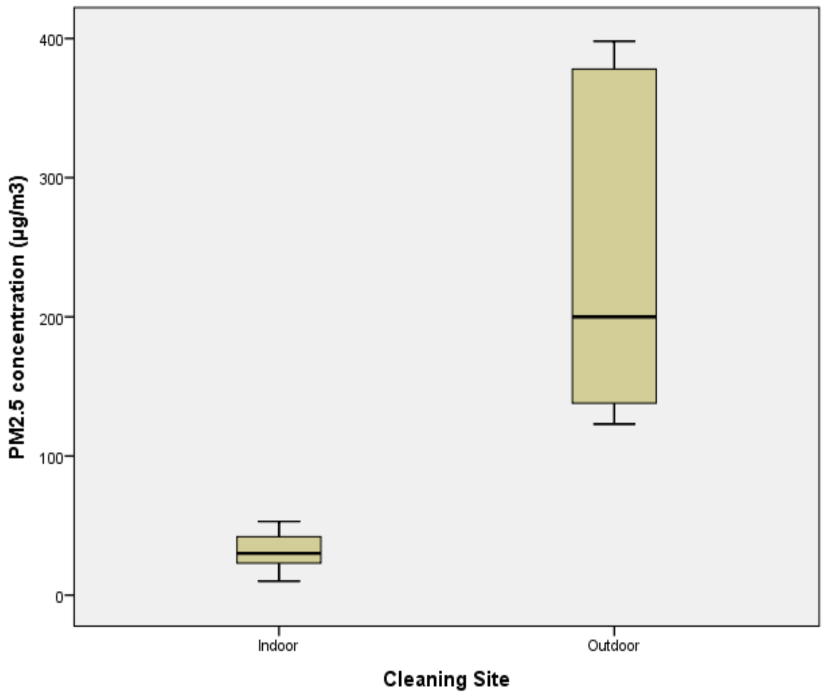
Table 4 shows the $PM_{2.5}$ concentrations in the study areas. The highest observed value for $PM_{2.5}$ outdoors, was 398$\mu g/m^3$ whilst indoors it was 53$\mu g/m^3$. The lowest observed value outdoors was 123$\mu g/m^3$ while indoors it was 10$\mu g/m^3$. The non-parametric Manny-Whitney U test revealed that $PM_{2.5}$ concentration between the indoor and outdoor study sites was significantly different ($p<0.001$).

Table 4 $PM_{2.5}$ Concentrations across Indoor and Outdoor Locations

Cleaning Site	Minimum ($\mu g/m^3$)	25thPercentile	Median	75th Percentile	Maximum ($\mu g/m^3$)
Indoors	10	23.00	30	42.50	53
Outdoors	123	138.00	200	378.00	398

The boxplots in figure 3 below illustrate the $PM_{2.5}$ variations indoors and outdoors. The $PM_{2.5}$ concentrations were higher outdoors and varied more compared to indoors. The concentration of $PM_{2.5}$ indoors was lower (30 µg/m^3) while the $PM_{2.5}$ concentration outdoors was much higher (200µg/m^3).

Figure 3 Distribution of $PM_{2.5}$ across cleaning sites.



$PM_{2.5}$ Concentrations and Lung Function Characteristics

Table 5 shows $PM_{2.5}$ exposures among the participants and the lung function characteristics.

Table 5 $PM_{2.5}$ Concentration (μg/m^3) across Lung Function Categories

Lung function variable	Minimum (μg/m^3)	Median	Maximum (μg/m^3)	Asymp.Sig. (2sided (p-value)
Lung function status (FEV_1/FVC)				
Normal	10	44.00	398	0.005*
Impaired	30	171.00	398	
FEV_1 percent predicted				
Normal	10	45.00	398	0.031*
Reduced	30	200.00	398	
FVC percent Predicted				
Normal	10	49.00	398	0.121
Reduced	38	260.00	398	

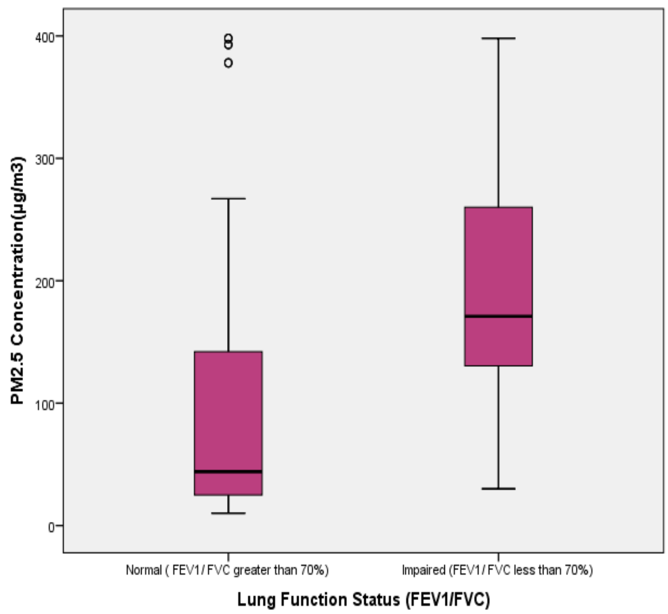
*Significant at p-value less than 0.05.

$PM_{2.5}$ and Lung Function status (FEV_1/FVC)

The participants in the two lung function categories were exposed to significantly different concentrations of $PM_{2.5.}$ (p=0.001).The median of $PM_{2.5}$ concentration among those with normal lung function status was 44.00μg/m^3 while among the participants with impaired lung function the median of $PM_{2.5}$ concentration was 171.00 μg/m^3. $PM_{2.5}$ exposure ranged from 10-398 μg/m^3 in the group with normal lung function and 30-398 μg/m^3 among those with impaired lung function.

Figure 4 shows the variations in $PM_{2.5}$ exposures in the categories of lung function status. Large variations in $PM_{2.5}$ exposure were observed among participants with impaired lung function status (30-398 µg/m^3) compared to those with normal lung function (10-398 µg/m^3).

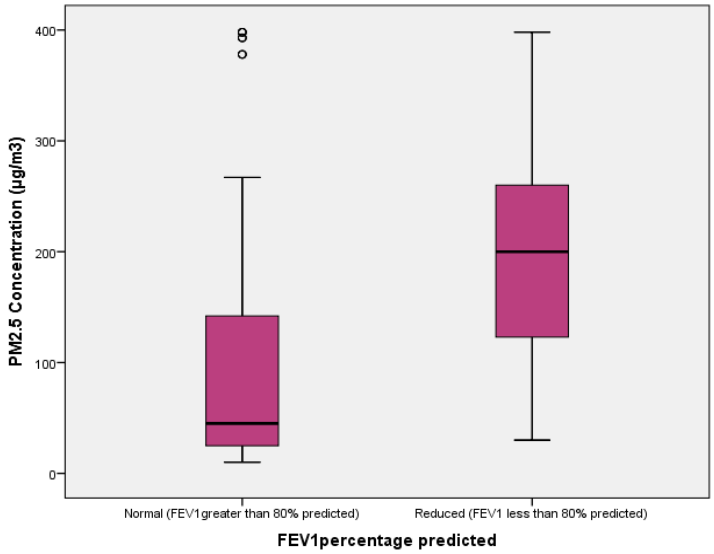
Figure 4: $PM_{2.5}$ Concentrations across Categories of Lung Function Status



$PM_{2.5}$ and FEV_1percentage predicted

Participants with reduced FEV_1 percent predicted were exposed to significantly high concentrations of $PM_{2.5}$ in comparison to those with normal FEV_1percentage predicted for age and height p=0.031 (table 5). Figure 5 below shows large variations in $PM_{2.5}$ exposures for both categories of FEV_1percent predicted. The median of $PM_{2.5}$ exposures was 45 µg/m^3 among those with normal FEV_1 percent predicted and 200 µg/m^3 among those with reduced FEV_1 percent predicted.

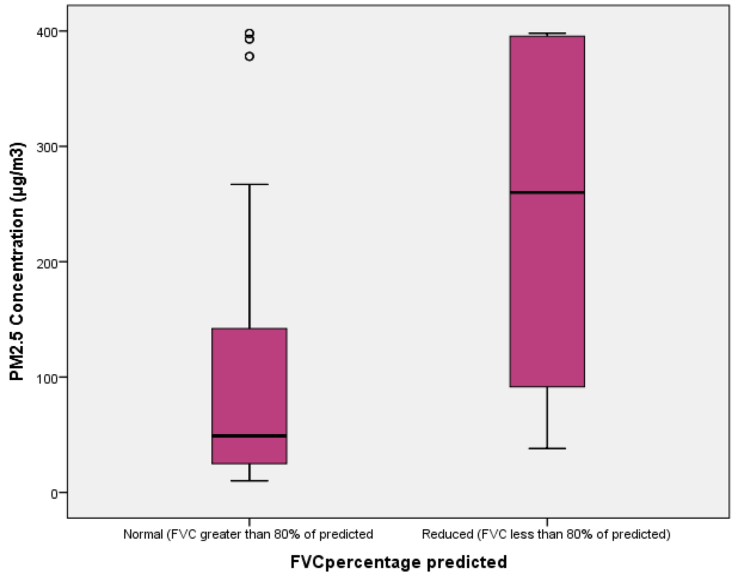
Figure 5: $PM_{2.5}$ Concentrations across Categories of FEV_1% Predicted



$PM_{2.5}$ and FVC percent predicted

$PM_{2.5}$ concentrations across categories of FVC percent predicted are shown in Figure 6. Participants with normal FVC percent predicted were exposed to low $PM_{2.5}$ concentrations (49 µg/m^3) compared to (260 µg/m^3) those with reduced FVC percent predicted for age and height. There was no significant difference in FVC percent predicted between those exposed to high $PM_{2.5}$ concentrations and those exposed to low $PM_{2.5}$ concentrations p=0.121 (table 5).

Figure 6 PM$_{2.5}$ Concentrations Across Categories of FVC% Predicted



Predictors of Lung Function status

Two separate logistic regression analyses were conducted to predict PM$_{2.5}$ exposure and cleaning group as predictors of lung function. A test of each model against a constant only model was statistically significant (chi square = 5.018 and 6.429 respectively, $p < .05$ with df = 1). Prediction success for both PM$_{2.5}$ and cleaning group was 77.8%. The Wald criterion demonstrated that both PM$_{2.5}$ and cleaning group made a significant contribution to prediction (p =0 .025 and p=0.015 respectively). An increase in PM$_{2.5}$ by one unit increases the odds ratio of having impaired lung function by 1.

Table 6: Predictors of lung Function status

	Study Sample	Odds Ratio	P-value
Characteristics		N(%)(95% CI)	
Particulate matter			
$PM_{2.5}$	90 (100)	0.99 (0.992-0.999)	0.025*
Cleaning Group			
Office cleaners	45 (50.00)	1.0	
Street sweeper	45 (50.00)	0.25 (0.08-0.76)	0.015*

*Indicates a p-value at significance level <0.05."

CHAPTER SIX

DISCUSSION

This was a study to determine the effects of fine particulate matter ($PM_{2.5}$) pollution on the lung function status of cleaners (street sweepers and office cleaners) in the central business area of Lusaka, Zambia. The study also explored the factors that contribute to $PM_{2.5}$ exposure and their association with the lung function status of the participants. Such factors as age, previous occupation, use of personal protective equipment (PPE), presence of pre-existing cardiopulmonary illnesses, allergy symptoms and present occupation were considered to determine how they affect the lung function of the cleaners.

$PM_{2.5}$ Concentration (μg/m³) in Indoor and Outdoor Areas

The results in the present study show that real-time $PM_{2.5}$ concentrations were significantly elevated in both indoor and outdoor areas. The measured $PM_{2.5}$ concentrations outdoors were higher ranging from 123μg/m^3 - 398μg/m^3 compared to 10μg/m^3 -53μg/m^3 indoors. These findings are consistent with other studies carried out in other African cities as reported by Petkova et al. (2013) who revealed that air pollution levels particularly $PM_{2.5}$ concentrations were quiet high and that they exceeded international guidelines provided by WHO and US-EPA. In most indoor areas air circulation is controlled by the presence of air conditioners, hence the small variations in the $PM_{2.5.}$ However, this does not prevent increases in $PM_{2.5}$ because as reported by Zock (2006) indoor sources of particulate matter and dust do exist, such as mould and wood coating as well as chemicals used for cleaning. Outdoor $PM_{2.5}$ was mainly because of vehicular emissions. Studies by Kenyon and Liu (2011) and Frosig and Sherson (1997) reported that most of the roadside particulate pollution was due to vehicular emissions and that these could influence indoor PM concentration levels.

Lung Function Characteristics of Participants

The study confirmed the presence of impaired lung function status among cleaners exposed to fine particulate air pollution ($PM_{2.5}$) in ambient Lusaka air. The study being the first of its nature to be carried out in Zambia, showed that 22.2% of the cleaners had impaired lung function status while 77.8% had normal lung function status. 13.3% had reduced FVC percent predicted and 18.9% had reduced FEV_1 percent predicted for age and height. Lung function status differed significantly between the street sweepers and office cleaners.

The FEV_1 percent predicted was the most important in determining lung function status as more participants with impaired lung function status had a reduced FEV_1 percent predicted than FVC. These findings are similar to those of Downs et al (2007) and Thaller et al. (2006).

$PM_{2.5}$ and Lung Function Status (FEV_1/FVC)

A significant association was observed between $PM_{2.5}$ concentration and lung function status. This finding collaborated with that of Dales et al. (2009) who reported that inter quartile increases in $PM_{2.5}$ exposure results in increased respiratory impairment.

The results of this study have also shown that the concentration of $PM_{2.5}$ across the lung function status categories were different. High concentrations of $PM_{2.5}$ (median 171.00) were associated with impaired lung function status whereas low concentrations of $PM_{2.5}$ (median 44.00) were associated with normal lung function status. Since measured $PM_{2.5}$ concentrations were low indoors compared to the outdoors, it shows that lung function impairment can occur even at low levels of exposure as some indoor cleaners also had impaired lung function. These findings were consistent with the findings by Koenig et al. (2003) which associated higher concentration of $PM_{2.5}$ to impaired lung function status in contrast to those that have reported no association between $PM_{2.5}$ concentrations and average lung function levels among exposed individuals (Göstch et al. 2006; Giradot et al. 2006).

$PM_{2.5}$ and FEV_1 and FVC percent predicted

The current study further revealed that $PM_{2.5}$ concentration had an effect on the lung function, FEV_1 percent predicted and not on the FVC percent predicted. Similar findings by Dales et al. (2009) revealed that, increases in $PM_{2.5}$ were associated with reduction in FEV_1 percent predicted while no association was observed with FVC percent predicted. FEV_1 reduces because of inhalation of fine particulate matter. The inhaled particulates cause irritation in the airways resulting in over production of mucus and proinflammatory mediators that block the airways (Jaakkola et al.2003). The ability for fine particulate matter ($PM_{2.5}$) to penetrate the alveoli and cause endothelial damage by release of inflammatory mediators such as chemokines and cytokines reduces lung function (Nodari et al. 2006). The level of lung function impairment is related to the dosage of PM an individual is exposed to (Ekpenyong et al. 2012). The result is either obstruction of the airways or destruction of lung parenchyma causing obstructive or restrictive lung impairment (Valavanadis et al. 2006) observed by reduction in the lung function indices (Trenga et al. 2006). This results in increased hospital admissions due to respiratory or cardiovascular morbidity and even mortality (Korrick et al. 1998).

Age and Lung Function Status

The frequency of lung function impairment was high among participants aged between 36-50 years compared to those aged between 18-35 years. Scientists have reported an association between age and lung function status. Studies by Mannino and Davis (2006) reported progressive reduction in lung function status due to advancing age. There was no significant association between age and lung function status in the current study this result collaborated with the findings of Ekpenyong et al. (2012) who also found a no significant association between age and respiratory impairment.

Cooking Fuel and Lung Function Status

Most (61.1%) of the participants in this study used charcoal as a cooking fuel. This finding is in line with the findings of a study done in Malawi, which showed that, most (81.5%) in the study population used charcoal as a cooking fuel. Biomass fuel use is likely to be a major driver of respiratory and cardiovascular disease (Piddock et al. 2014). Cooking fuel used was not associated with lung function status in the current study. These findings differ from a previous study by Umoh and Peters (2014) who reported the association between biomass (Charcoal and firewood) cooking fuels and impaired lung function. They reported that, exposed subjects had lower values for lung function as well as the percentage predicted values ($P < 0.05$) for FEV_1 and FVC. However, in the present study, 90% of the participants with impaired lung function status reported using charcoal as cooking fuel compared to those who reported using electricity. The WHO report on risks associated with use of biomass cooking sources cited use of such as important sources of $PM_{2.5}$ pollution in comparison to cleaner energy sources such as electricity (WHO, 2005).

Pre-existing Cardiopulmonary Conditions and Lung Function Status

Although some participants reported having previously or were currently suffering from a respiratory or heart condition, only 30.0% had impaired lung function status and found that, there was no significant association in lung function and pre-existing respiratory and heart conditions. To the contrary, a study conducted in Seattle by Lagorio et al. (2006) showed that the presence of pre-existing lung function impairment worsens in individuals exposed to high levels of $PM_{2.5,}$ a finding supported by Dales et al. (2009) and an earlier study by Lewis et al. (2005). While Pope (2007) reported, that $PM_{2.5}$ exposure worsened cardiovascular related morbidity. As observed by Pope and Dockery (2002), assessment of the relationship between fine particulate exposure and cardiopulmonary causes and effects are more conclusive when done in the long term than at a single point.

Use of Personal Protective Equipment (PPE) and Lung Function Status

The cleaners recruited to the study had low frequency of PPE use. This could be a possible explanation for the observed lung function impairment in the two groups. More street sweepers had lung function impairment than office cleaners did. In a study conducted in Nigeria, Nku et al. (2013) reported that street sweeping without precautionary measures such as proper use of personal protective equipment in the form of facemasks and respirators may predispose to respiratory conditions. Medina-Ramon et al. (2005) also made similar recommendations for office cleaners. Most street sweepers in the current study reported that the employer did not provide suitable and appropriate PPE while others reported having never used PPE. Most office cleaners on the other hand, reported that PPE was provided but was not appropriate. The present study found no association between use of PPE and lung function status. In a study conducted in Nigeria by (Nagoda et al. 2012) they observed that the use of precautionary measures such as PPE are important in reducing the occurrence of respiratory symptoms and reduced lung function status but did not state in clear terms if there is an association with lung function. The respiratory system is directly exposed to the environment due to its role in gaseous exchange, and serves as an entry point for inhalable particles. Lack of PPE especially face masks and respirators imply that the exposed individuals inhale more harmful particulates resulting in lung function impairment compared to when such PPE is provided.

Occupational History and Lung Function Status

Occupational history was significantly associated with lung function in the current study. A finding supported by previous studies that have long associated workers in foundry, cement plants, mining and stone crushing or quarries with lung function impairment (Laima 2013; Singh et al. 2013; Siziya, 2005; Johncy et al. 2013). Such occupations act as pre-exposures to causes of lung function impairment. However, the relationship is not causal but that previous occupation could be an important factor in determining respiratory health outcomes among individuals due to the risks involved such as dust, chemical particulates, metals, asbestos and so on (Gomes et al. 2001).

Cleaning Group and Lung Function Status

Cleaning group is statistically associated with lung function status. Street sweepers were exposed to high $PM_{2.5}$ concentrations ranging from 123µg/m^3 to 398µg/m^3 compared to office cleaners who were exposed to lower $PM_{2.5}$ concentrations ranging from 10-53µg/m^3. Because of these elevated concentrations, 80% of those with lung function impairment were street sweepers and only 20% were office cleaners. These findings are in collaboration with studies that have associated street sweeping and exposures to large amounts of dust resulting in respiratory conditions. A study conducted in India revealed that street sweepers were prone to be affected by health hazards during their occupational activities because of the dust levels they were exposed to (Johncy et al. 2013) in our study there was significant difference in the lung function status of street sweepers and office cleaners. This is similar to the findings by Khurshid et al. (2013) that showed declines in lung function indices in groups of cleaners exposed to high levels of dust.

Allergies and Lung Function Status

The current study showed an association between presence of allergies and lung function status. Those who developed allergy symptoms were more likely to have impaired lung function status than those who did not. This finding was consistent with those of Trenga et al. (2006); Makela et al. (2011) and Dales et al. (2009). These studies showed that allergy symptoms such as those present in asthmatic individuals are worsened in cases of exposure to pollutants and these further indicate a decrease in lung function measurements especially FEV_1. This was in agreement with the current study where 25% of those with impaired lung function status had no allergy symptoms while 75% of those who reported having allergy symptoms had impaired lung function status. Both street sweepers and office cleaners are predisposed to develop allergy symptoms regardless of lung function status (Zock et al. 2002; Medina-Ramon et al. 2006 and Johncy et al. 2013). The presence of allergy symptoms may be an indicator of increased susceptibility to the effects of $PM_{2.5}$ exposure (Lewis et al. 2005) and such individuals may develop lung function impairment even at low levels of exposure compared to those who do not manifest these symptoms (Trenga et al. 2006; USA-EPA 2012).

CHAPTER SEVEN

CONCLUSION

The study shows that real-time $PM_{2.5}$ concentrations were very high outdoors compared to indoors. A statistically significant association was observed between exposure to fine particulate pollution $PM_{2.5}$ and lung function status. Higher levels of exposure to $PM_{2.5}$ were associated with lung function impairment and reduction in the lung function indices (FEV_1% predicted and FEV_1/FVC), whereas low levels of exposure were associated with normal lung function status. Most of those with impaired lung function status were street sweepers and were exposed to higher levels of $PM_{2.5}$ compared to the office cleaners.

Both groups of cleaners are at risk of exposure to $PM_{2.5}$ hence should be provided with adequate personal protective equipment and employers should ensure these are worn for personal protection while at work. It is therefore concluded that $PM_{2.5}$ exposure is associated with a series of physiological consequences that affect normal function of the lung leading to reduction in FEV_1 and the FEV_1/FVC ratio.

Recommendations

The Lusaka City Council management should introduce measures for reduced dust exposure in the workplace. Introduce watering in the streets to promote wet sweeping which reduces dust generation.

Employers in the form of cleaning companies need to provide appropriate PPE to their employees and educate them on the benefit of proper use of PPE.

Employers should provide annual medical check-ups for their employees and ensure that to these they include spirometry testing and respiratory symptom evaluation for early diagnosis of respiratory conditions.

There is need to create environmental buffers by planting trees along the streets of the central business area. It was observed that, even with high traffic flow the streets that are lined with many trees, such as Cairo road, had far much lower outdoor levels of $PM_{2.5}$ compared to those without such tree like Lumumba and Freedom way.

Relevant regulatory bodies such as ZEMA should put limits to occupational exposures of $PM_{2.5}$ and advocate for air quality monitoring.

Limitations

This study being cross sectional and thus could not determine causality. Another limitation was lack of literature on previous studies on associations between $PM_{2.5}$ and lung function status among cleaners. Most of the literature reviewed was on the effects of respirable dust whose aerodynamic diameter in some studies was not specified but had similar composition to $PM_{2.5}$.

Studies have suggested the need to compare personal $PM_{2.5}$ to those obtained in centrally located stations (Gree et al 2013). In the current study, only real-time measurements of the levels of $PM_{2.5}$ were done. It was not safe to leave the aerosol monitor unattended to. This meant that no time weighted average $PM_{2.5}$ concentrations were taken, to make comparisons with the WHO guidelines for $PM_{2.5}$. There was a lack of information on the average $PM_{2.5}$ concentrations in the central business area of Lusaka. According to the ZEMA data base central air monitoring equipment was mounted in 2010 and it only worked for a few months. Thus comparison of the obtained $PM_{2.5}$ readings to centrally located air quality monitor readings was not possible.

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APPENDICES

APPENDIX I

PARTICIPANT INFORMATION SHEET

1. Self-Introduction

Introduction of researcher / research assistant to the participant with regard to the name, what they do and their involvement in the research.

2. Title of Research

"Effects of Fine Particulate Air Pollution on Lung Function Status among Street Sweepers and Office Cleaners in the Central Business Area of Lusaka-Zambia."

3. Purpose of the Research

To determine the lung function status among the cleaners exposed to particulate matter of aerodynamic diameter less than 2.5 micrometer in Lusaka, Zambia.

4. Procedure

You will be required to do a maximal inspiration (breath in) against a clipped nose (nose closed) after which they will be requested to make a forceful maximum expiration (breath out) into a mouth piece and the volume of the air will be measured.

You will also be asked some questions.

5. Voluntariness

Your participation in this research is entirely voluntary and you do not have to participate if you do not wish to do so. Be assured that your refusal to take part will not in any way result in penalty or loss of services to which you are otherwise entitled. If you decide to take part, you are still free to withdraw at any time without giving a reason for your withdrawal. You also have the right to end the interview at any time, and to choose not to answer particular questions that are asked in the study.

6. Guarantee of Confidentiality

Be assured that the information collected from you in this research will be kept strictly confidential and all the data collection tools used will be destroyed thereafter.

7. Risk/Benefits/Discomforts

The procedure of measuring lung volume does not involve cutting or putting something in the body and it is a painless procedure. However, you may experience some discomfort when breathing with your nose closed this is normal and will be over once the test which takes only a few minutes is done. The benefits are that, after the investigations are done, your lung function status will be determined and this will help you to ensure you use protective equipment to protection and seek medical care in case you have some impairment.

8. Compensation/Reimbursement

The participation in this research has no provision for compensation/reimbursement.

9. Consequences of Injury

In the event that the participant is injured during the procedure, the researcher will take full responsibility of the consequences to correct the situation.

If you have any questions about the study please contact the principal investigator or the chairperson for the UNZA Biomedical Research Ethics Committee at the following addresses and contact numbers;

10. Contact Details of Principal Investigator

Lumba Siachingili
The University of Zambia
School of Medicine
Department of Physiological Sciences
P.O. Box 50110
Ridgeway Campus
Cell No: +260977545589
Email: lumbablue@gmail.com
LUSAKA
ZAMBIA

11. Contact Details of Ethics Committee

The Chairperson
The University of Zambia
School of Medicine
Biomedical Research Ethics Committee
P. O. Box 50110
Ridgway Campus
Telephone: 260-1-256067

Telegrams: UNZA, LUSAKA
Telex: UNZALU ZA 44370
Fax: + 260-1-250753
E-mail: unzarec@zamtel.zm
LUSAKA
ZAMBIA

If you choose to participate in this research study, please sign the informed consent form below.

The above section will be detached and given to the participants

APPENDIX II

PARTICIPANT CONSENT FORM

INFORMED VOLUNTARY CONSENT FORM

DECLARATION

I have read (or have had explained to) the information about this study as contained in the participant information sheet. I have had the opportunity to ask questions about the research and any questions I have asked have been answered to my satisfaction.

I now consent voluntarily to participate in this study and understand that I have the right to end the interview at any time if I so wish, and to choose not to answer particular questions that are asked in the study.

My signature below signifies that I am willing to participate in this study:
Name of participant (Print): …………………………………..……..…........................
Signature of participant: ……………………..….. Consent Date: ……….…………….....
Participant's right thumb print if unable to write: ……………….……..……..………….
Name of researcher conducting voluntary consent (Print):……………….……..…….
Signature of researcher: …………….…………….……. Date: ……………......………
Name of witness (Print): ……………………………..…………………………….
Signature of witness: …………………………..…… Date: ………...……..………..

N.B The consent form should be kept separate from data collecting tools.

APPENDIX III

INTERVIEW SCHEDULE

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MEDICINE

DEPARTMENT OF PHYSIOLOGICAL SCIENCES

STRUCTURED INTERVIEW SCHEDULE

TOPIC: EFFECTS OF FINE PARTICULATE AIR POLLUTION ON LUNG FUNCTION STATUS AMONG STREET SWEEPERS AND OFFICE CLEANERS IN THE CENTRAL BUSINESS AREA OF LUSAKA - ZAMBIA

DATE OF INTERVIEW……………………………………………………….

NAME OF INTERVIEWER………………………………………………..

SERIAL NUMBER

INSTRUCTIONS TO INTERVIEWER

- Introduce yourself to the respondent
- Explain the purpose of the interview
- Get verbal consent from the respondent
- Reassure the respondent that all responses will be held in strict confidence
- Individual addresses and names should not appear on the interview schedule
- Ensure that all questions are answered and indicate response by ticking in the appropriate box or filling in the spaces provided
- Thank the respondent at the end of the interview.

Demographic data

- Age
- 18-24 Yrs [ ]
- 25-34 Yrs [ ]
- 35-44 Yrs [ ]
- 45-50 Yrs [ ]

2. Educational level

- Never been to school [ ]
- Primary school [ ]
- Secondary school [ ]
- College [ ]
- University [ ]

3. How long have you been a cleaner/ sweeper?

- Less than six months [ ]
- More than six months [ ]

4. Do you smoke?

- Yes [ ]
- No [ ]

If 'No' to Q4 go to Q5 (if the response to Q4 and Q5 is yes do not proceed to Q6 thank the respondent and End the interview)

5. Have you ever smoked? (Cigarettes, cigars, pipe. Record 'No' if subject has never smoked as much as 1 cigarrete a day or 1oz of tobacco a month, for as long as one year).

- yes
- no

6 if answer to questions 3, 4, 5 is b 'enrol' for the study.

- Age________________________________
- standing height_________________________

Knowledge and Practice

Cooking fuel

- Charcoal [ ]
- Biogas [ ]
- Firewood [ ]
- Electricity [ ]

PPE (personal protective equipment)

- Does the company provide personal protective equipment?

  1 Yes [ ]

  - No [ ]

2 If PPE is provided, how often do you wear protective clothing?

- Always [ ]
- sometimes [ ]

3 Never [ ]

R**espiratory and Allergy history**

- Do you have a condition of the chest for which you are under a doctor's care?

  1) Yes

  2) No

- Have you ever had a heart condition?

1) Yes

2) No

- If 'Yes' when did it begin?

  1) Before age 30

  2) After age 30

4 If 'Yes' before 30 (applies to those above 30 years old) was it before starting work as a cleaner?

1) Yes

2) No

5 Have you ever had fever or other allergies (other than above)?

- Yes
- No

Occupational history

Have you ever worked in?

- Foundry,

1) Yes

2) No

- Stone, mineral mining, quarry or processing company,

1) Yes

2) No

- Asbestos milling or processing,

1) Yes

2) No

- Other dusts fumes or smoke,

1) Yes

2) No

- If yes to any of the above was it for a period of over six months.

1) Yes

2) No

Cleaning site/ location___________________

Spirometry readings:

- FVC__________________________
- FEV_1__________________________
- FEV%__________________________

Thank you very much

Appendix V

Budget

ITEM	**QUANTITY**	**UNIT COST (ZMK)**	**TOTAL COST(ZMK)**
1.STATIONARY			
Reams of paper	3	25.00	75.00
Pens	4	1.00	5.00
Rubber	1	.50	.50
Pencils	2	.50	2.00
Staples	1 box	35.00	35.00
Staplers	2		65.00
Calculator	1	65.00	95.00
Tipex	1 bottle		55.00
Note Books	3	95.00	15.00
Flip charts	1	55.00	30.00
Markers	1	7.50	20.00
Spirals	4	30.00	25.00
Front and back covers	5	5.00	300.00
Flash disks	2	5.00	15.00
File folders	3	150.00	
		5.00	
SUBTOTAL ITEM			**755.00**
2.Proposal			
Ethics committee	1		500.00
Research proposal typing and printing	1	500.00	120.00

		120.00	
Research Tools • Hire of side Pak • Hand sanitizer • Face Masks • Mouth pieces (disposable) • Spirometer and batteries • Nose clips • Examination Gloves • Cotton wool • Methylated spirit	10 days 2 4 1 50 1 10 2 boxes 2 boxes 2 containers	100.00 85.00 80.00 230 5,420.00 2.50 25.00 12.50 25.00	1000.00 170.00 320.00 230.00 5,420.00 25.00 50.00 25.00 50.00
Subtotal			**7,290.00**
Training of two (2) research assistants • Lunch allowance • Out of pocket allowance • Facilitation allowance	2 2 2	250.00 240.00 500.00	500.00 580.00 1000.00
Subtotal			1,180.00
Field expenses • Lunch allowance • Transport allowance • Statistician	20 days 20 days	50.00 20.00	2000.00 400.00 1200.00
Subtotal			3,600 .00
Result dissemination meeting • Ream of paper • Refreshments/Snacks	1 50	25.00	25.00 500.00

• Venue • Presentation equipment (laptop, LCD, screen)	1 1	10.00 600.00 1,800.00	600.00 1,800.00
Subtotal			3,025.00
Sub grand total			13,765.00
Contingency (10%)			1,376.50
Grand Total			15,141.50

LUSAKA CITY COUNCIL
MEMORANDUM

TO	:	The Director of Public Health
FROM	:	The Acting Director of Human Resource & Administration
Cc	:	The Manager – Waste Management Unit
REF	:	LM/lm TCD/7/58/10
DATE	:	17th September, 2013

RESEARCH – LUMBA SIACHINGILI

The above mentioned is a student at the University of Zambia and is conducting a research entitled **"Air Pollution and Lung Function Impairment among Street Sweepers in Lusaka, Zambia".**

The research is being conducted in partial fulfillment for the award of a Masters Degree of Science Physiology. She has since paid the research fee of K60.50 on receipt number AL134204.

Kindly therefore, provide her with the necessary information to enable her carry out the research.

Banda

RABECCA C. BANDA

THE UNIVERSITY OF ZAMBIA

BIOMEDICAL RESEARCH ETHICS COMMITTEE

Telephone: 260-1-256067
Telegrams: UNZA, LUSAKA
Telex: UNZALU ZA 44370
Fax: + 260-1-250753
E-mail: unzarec@unza.zm

Ridgeway Campus
P.O. Box 50110
Lusaka, Zambia

Assurance No. FWA00000338
IRB00001131 of IORG0000774

19th June, 2014.

Our Ref: 013-03-14.

Ms. Lumba Siachingili,
University of Zambia,
School of Medicine,
Department of Physiological Sciences,
P. O Box 50110,
Lusaka.

Dear Ms. Siachingili,

RE: RESUBMITTED RESEARCH PROPOSAL: **"EFFECTS OF FINE PARTICULATE AIR POLLUTION ON LUNG FUNCTION STATUS AMONG STREET SWEEPERS AND OFFICE CLEANERS IN THE CENTRAL BUSINESS AREA OF LUSAKA-ZAMBIA" (REF. No. 013-03-14)**

The above-mentioned research proposal was presented to the Biomedical Research Ethics Committee on 17th June, 2014. The proposal is approved.

CONDITIONS:

- This approval is based strictly on your submitted proposal. Should there be need for you to modify or change the study design or methodology, you will need to seek clearance from the Research Ethics Committee.
- If you have need for further clarification please consult this office. Please note that it is mandatory that you submit a detailed progress report of your study to this Committee every six months and a final copy of your report at the end of the study.
- Any serious adverse events must be reported at once to this Committee.
- Please note that when your approval expires you may need to request for renewal. The request should be accompanied by a Progress Report (Progress Report Forms can be obtained from the Secretariat).
- **Ensure that a final copy of the results is submitted to this Committee.**

Yours sincerely,

Dr. J.C. Munthali
CHAIRPERSON

Date of approval: 19th June, 2014. **Date of expiry:** 18th June, 2015.

LUSAKA CITY COUNCIL
PUBLIC HEALTH DEPARTMENT

Director of Public Health
Civic Centre
P.O. Box 30789, Lusaka

Telephone: 260 1 252941
Telefax: 260 1 252941

PHD/6/1/2/CC/bcm

6th March, 2014

The Head – Department of Physiological Sciences
University of Zambia
P. O Box 50110
LUSAKA

Dear Sir/ Madam

RE: REQUEST TO CONDUCT RESEARCH – MS. LUMBA SIACHINGILI

We refer you as above stated.

I wish to inform you that your request for the above mentioned Student to conduct research on "**effects of Fine Particle Air Pollution on Lung Function Status among Street Sweepers and Office Cleaners in Lusaka Zambia**" has been accepted.

The Department has no objection to your request and Ms. Lumba Siachingili is welcome to conduct her research.

Yours faithfully

Greenford Sikazwe
ACTING DIRECTOR OF PUBLIC HEALTH
For/ **TOWN CLERK**

RUMPHI ENTERPRISES LIMITED.

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E-mail:rumphiclean@zamtel.zm
www.rumphienterprises.com

13th May, 2014

The Head, Department of physiological Sciences

School of Medicine

The University of Zambia

P.O. Box 50110

Lusaka.

Dear Sir/Madam

RE: REQUEST TO CONDUCT RESEARCH – MS. LUMBA SIACHINGILI

Ref to the above captioned matter,

We wish to inform you that your request for the above mentioned student to conduct research on **"effects of fine particles air pollution on lung function status among Street Sweepers and Office Cleaners in Lusaka Zambia"** has been accepted.

Our company has no objection to your request and Ms. Lumba Siachingili is welcome to conduct her research.

However, our company reserves the rights of any of our employees who will not consent to participate in the study.

Yours Faithfully
Rumphi Enterprises Ltd

for - Charity Gondwe
Managing Director.

UTUBA CLEANING SERVICES

Supplies of Industrial Machines i.e. Vacuum Wet & Dry Cleaners, Polisher Machines, Chemicals i.e. Disinfectants & Detergents, Deo-Blocks, Fumigation Domestic and Industrial, Food Staffs and Stationary.

P. O .Box 37723
Tazara House 3rd Floor

Tel/Fax: 0211 33603
Cell: 0955 700355

7th May 2014

The Head, Department of Physiological Sciences
School of Medicine
The University of Zambia
P. O. Box 50110
LUSAKA

RE: PERMISSION TO CONDUCT RESEARCH

With reference to the above mention subject.

We are pleased to inform you that your Masters student in Human Physiology department Lumba Siachingili of computer No. 512809047 has been granted permission to conduct a research on **The Effects of Fine Particulate Matters on the Lung function Status among Street Sweepers and Office Cleaners**.

Glad to do so.

Yours faithfully

O. C. CHILEMBO
UTUBA CLEANING SERVICES

MAXLIN ENTERPRISES LTD

3rd Floor, suite 2, Kulima Tower Building, P.O Box 32050, Lusaka Zambia.
Telefax: +260 211228272. Mobile: 0979927525/0966923808/0977822224
Email: maxlinenterprise@yahoo.com

13th May, 2014

The Head – Department of Physiological Sciences
University of Lusaka,
P.O Box 50110
Lusaka

Dear Sir/ Madam,

RE: RESQUEST TO CONDUCT RESEARCH – MS LUMBA SIACHINGILI

Kindly refer to the above stated matter.

I wish to inform you that your request for the above Student to conduct research on "**the Effects of Fine Particle Air Pollution on Lung Function Status Among Street Sweeper and Office Cleaners in Lusaka Zambia"** has been accepted.

Our Company has no objection on your request and Ms Lumba Siachingili is welcome to conduct her research on our workers. However, the company still reserves the rights of any of our workers who may refuse to participate in the research.

Yours Faithfully,

Linda Yombi
Managing Director

The University of Zambia
School of Medicine
P.O. Box 50110
LUSAKA
ZAMBIA

4th March, 2014

The Town Clerk
Lusaka city Council
LUSAKA

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MEDICINE
HEAD OF DEPARTMENT
04 MAR 2014
DEPARTMENT OF
PHYSIOLOGICAL SCIENCES

UFS: **Head, Department of Physiological Sciences**

Dear Sir,

RE: <u>REQUEST TO CONDUCT RESEARCH</u>

The above subject refers.

I am a master of Human Physiology student at the University of Zambia, School of Medicine and I am requesting to conduct a research on the **Effects of Fine Particulate Air Pollution On The Lung Function Status Among Street Sweepers And Office Cleaners In Lusaka Zambia.**

Your positive consideration of this request will be highly appreciated.

Yours faithfully,

Lumba Siachingili-Lumbuka (Mrs.)

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MEDICINE

Telephone: 252641
Telegram: UNZA, Lusaka
Telex: UNZALU ZA 44370
Email: shnzala@unza.zm

P.O. Box 50110
Lusaka, Zambia

==

4th March, 2014

Lumba Siachingili Lumbuka
Department of Physiological Sciences
School of Medicine
LUSAKA

Dear Ms Lumbuka,

RE: GRADUATES PROPOSAL PRESENTATION FORUM (GPPF)

Having assessed your dissertation entitled **"Effects of Fine Particulate Air Pollution on Lung Function Status among Street Sweepers and Office Cleaners in Lusaka, Zambia"**, we are satisfied that all the corrections to your research proposal have been done. The proposal meets the standards as laid down by the Board of Graduate Studies.

You can proceed and present to the Research Ethics.

Yours faithfully,

UNIVERSITY OF ZAMBIA
SCHOOL OF MEDICINE
4 MAR 2014
ASSISTANT DEAN (PG)
P.O. BOX 50110, LUSAKA

Dr. S. H. Nzala
ASSISTANT DEAN, POSTGRADUATE

CC: HOD – Physiological Sciences