The respiratory health effects associated with particulate matter ($PM_{2.5}$) exposure in children residing near a landfill site: a case of eThekwini Municipality

by

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PREFACE

The research contained in this thesis was completed by the candidate while based in the Discipline of Agrometeorology, School of Agricultural, Earth and Environmental Sciences of the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Pietermaritzburg, South Africa. The research was financially supported by the University of KwaZulu-Natal, College of Agriculture, Engineering and Science and Mangosuthu University of Technology.

The contents of this work have not been submitted in any form to another university and, except where the work of others is acknowledged in the text, the results reported are due to investigations by the candidate.

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Signed: Professor MJ Savage

Date: 29 March 2016

DECLARATION 1: PLAGIARISM

I, Phiwayinkosi R. Gumede, declare that:

(i) the research reported in this dissertation, except where otherwise indicated or acknowledged, is my original work;

(ii) this dissertation has not been submitted in full or in part for any degree or examination to any other university;

(iii) this dissertation does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons;

(iv) this dissertation does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:

a) their words have been re-written but the general information attributed to them has been referenced;

b) where their exact words have been used, their writing has been placed inside quotation marks, and referenced;

(v) where I have used material for which publications followed, I have indicated in detail my role in the work;

(vi) this dissertation is primarily a collection of material, prepared by myself, published as journal articles or presented as a poster and oral presentations at conferences. In some cases, additional material has been included;

(vii) this dissertation does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the dissertation and in the References sections.

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Signed: Phiwayinkosi R. Gumede

Date: 29 March 2016

ABSTRACT

Currently, land-filling is the main waste disposal method utilized in South Africa. However little is known about the health risk factors among children living near the landfill sites. This is a first study that sought to interrogate and determine respiratory health symptoms and outcomes in children aged between 6 and 12 years who reside within a two-kilometre radius of the Bisasar Road landfill site, Durban, South Africa, the largest landfill site in Africa. Durban is situated in the eThekwini Municipality, along the east coast of South Africa in KwaZulu-Natal province. In South Africa, there are no regulations or guidelines in place to stipulate the buffer zone between a community and a landfill site. The study also aimed to determine if there is a correlation between those respiratory health outcomes and the close proximity to the landfill site. Community experiences regarding the landfill site and its health impacts were also interrogated. Various studies undertaken on the impact of waste disposal facilities have focused mainly on the landfill site gas emissions such as methane due to its climate impact and its potential for energy production. Particulate matter ($PM_{2.5}$) exposure in children residing in the vicinity of the landfill site and the opinions of the adult residents, on the other hand, have neither been extensively investigated nor documented in developing countries, South Africa included. As the study investigated the respiratory health outcomes in children residing within a 2-km radius of Africa's largest landfill site, it was vital to adopt materials, procedures and data collection methods that would not only provide an overall health reality of the area but enable the researcher to focus on children who are the future of South Africa; that are being groomed and nurtured in this environment. A mixture of the positivist and interpretivist paradigm had to be adopted in this case as were 'scientific methods' - where all is ordered, regular and can be objectively investigated, hypotheses tested and utilised. But the social context of information needs interrogating, and also how it is developed and construed by people and the way in which it is influenced by and influences that social setting. The study adopted both qualitative and quantitative methods to explore the impact the landfill site has on children and to ascertain residents' perceptions of the landfill site. Questionnaires included predefined questions in a predetermined order were administered to participants purposively and randomly selected at the Clare Estate area near the Bisasar Road landfill site. Thus it became almost a case study as it not only tested hypotheses as in an experiment on health outcomes subsequent to the pollution reality of the area. It also gains insight into and generates knowledge from studying this particular instance and that knowledge may be relevant to other situations that will surely develop in this modern industrialised perennially waste-emitting world. Interviews that focussed more on depth than breadth were another data generation method utilised that occurred in three forms - structured, semi-structured and unstructured interviews, all aiming for an in-depth investigation explored at different levels. Furthermore, spirometry was conducted to establish the lung function patterns of randomly selected children, and $PM_{2.5}$ concentration was measured at homes of those children. Based on data or evidence collected, charts and graphs were used to show patterns. Findings are presented and discussed. In order to foreground the respiratory health of children, this study presents significant findings in understanding the characteristics of the homes and the possible sources of the indoor air pollution. The investigation highlighted, inter alia, the fact that household pests, cockroaches in this case, and settling dust are the main causes of the poor indoor air quality. In homes where $PM_{2.5}$ concentration was found to be high, most children reported respiratory health symptoms. The study also unearthed a high degree of residents' discontent due to their close proximity to the landfill site. It was evidenced that the close proximity to the landfill site was affecting health negatively. It befitted the exploration to conclude that children, the future adults of this country, that reside in the proximity of air pollution emitting sources such as landfill sites have an increased risk of respiratory health conditions. These conditions include wheezing and asthma and many other related ones that may determine their lifespan due to exposure to unchecked outdoor air pollution sources. Not only should the issue be attended to as a matter of urgency but as one that affects the future of a generation and whose impact will be more significant on the nation than all pandemic ones whose effects are swift. Overall, this study significantly advances the understanding of the possible impact of landfill activities on children residing near them. Furthermore, the study concluded that the community of Clare Estate was not only dissatisfied with the location of this landfill site, as would be the case for many similar landfill sites, but also had no other residential option and only the relocation of the landfill site could be a proactive way forward. The findings of this study will not only inform future best practices in the location of such sites but also heighten awareness of the long-term negative effects that can shorten lifespan of a generation when health considerations are not juxtaposed to progress and industrialization.

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

Section 24 of the Constitution of the Republic of South Africa (Act 106 of 1996) stipulates that "everyone has the right to an environment that is not harmful to health or well-being; and to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution". Air quality and health of the community are intertwined and very important environmental and public health matters that need protection as affirmed in the Bill of Rights in the Constitution of the Republic of South Africa. Air quality is a term generally used to define the state of ambient air, which is either good or poor. The state of air quality depends on the quantities of natural and human-induced emissions to the atmosphere, as well as on the potential for dispersing and removing pollutants from the atmosphere (Department of Environmental Affairs 2009).

The World Health Organization (2014) reported that globally, 7 million deaths were attributed to the joint effects of household and ambient air pollution in 2012. Of those deaths, 3.7 million deaths were attributable to the ambient air pollution (AAP), whilst 4.3 million deaths were attributed to indoor air pollution (IAP). In Africa alone, 757,300 deaths were attributed to both AAP (176,000 deaths) and IAP (581,300). This presents a massive concern for Africa with its existing burden of disease. Particulate matter (PM) is a pollutant of major concern in this case. $PM_{2.5}$ (particulate matter with an aerodynamic diameter of less than 2.5 µm) is respirable, can penetrate deep into the lungs and pass into the blood stream and is thus of particular concern. The reporting on the World Health Organization (WHO) Ambient Air Pollution Database by countries is still a challenge, particularly for Africa. Out of 194 countries participating in the WHO Ambient Pollution database, only 47 countries are from Sub-Saharan Africa (WHO 2014).

According to the Department of Environment and Tourism (2010), effort has been exerted in South Africa to address air pollution in recent years. However a lot more still needs to be undertaken in order to identify and reduce air pollution sources. Currently, there are few monitoring stations capable of measuring the ambient $PM_{2.5}$ and little exposure and toxicity (dose-response and health outcomes due to $PM_{2.5}$ exposure) data are available (Department of Environment and Tourism 2010).

Patil (2001) reported that communities living near air pollution generating sources such as municipal landfill sites are exposed to various pollutants at and in their homes since airborne emissions are carried to the surrounding communities by wind currents. Furthermore, many pollutants remain in the environment for extended periods of time and are carried by winds across hundreds of kilometres from the source (Mahajan 2011). This study focuses mainly on the impact of $PM_{2.5}$ on children living in close proximity to the Bisasar Road landfill site, Durban, South Africa (Figure 1.1 and 1.2).

Landfilling is still the main waste disposal method utilized in South Africa, especially in the urban areas such as the eThekwini Municipality. There are currently no South African regulations that stipulate a buffer zone between the community and a landfill site. The Bisasar Road landfill site is reputedly Africa's largest formal municipal dump which processes up to 5,000 tonnes of solid waste delivered by approximately 1,000 vehicles every working day (Hallowes et al. 2008). Operations commenced in 1980 in the largely Indian suburb of Clare Estate and it is permitted to receive general waste only (GAIA 2011). It is managed by Durban Solid Waste (DSW). The landfill site is located in the west wing of the city of Durban and it receives waste from the greater Durban region (Refer to Figure 1.2 and 1.3).

Bordering Bisasar is the Kennedy Road shack settlement which accommodates some 6,000 people in tightly packed shacks made of wood, corrugated iron, tarpaulins and plastic sheeting (Hallowes et al. 2008). These settlements mushroomed after the relaxing of the apartheid laws in the late 1980s. Many of these African residents had been displaced from their ancestral homes due to land taken away from them in 1986 without compensation to make way for the Inanda Dam to supply the Durban area with water (GAIA 2011). Ten public schools are also located within one square kilometre from the landfill site (GAIA 2011). The informal settlement is shown in Figure 1.3.

The main reasons for focusing on $PM_{2.5}$ in children living near the Bisasar Road landfill site are three-fold:

(1) the landfill site is a potential source of $PM_{2.5}$;

(2) high levels of $PM_{2.5}$ have negative effects on respiratory health; and

(3) children are a susceptible group when exposed to PM.

For purposes of this study, children's exposure to $PM_{2.5}$ was measured in an indoor environment. However, due to the lack of indoor air quality standards in South Africa, the World Health Organization (WHO) Air Quality Guidelines (2006) were used to determine whether children from households living adjacent to the landfill sites were exposed to acceptable or unacceptable levels of $PM_{2.5}$.

It is abundantly evident from related literature that the majority of outdoor air pollution studies largely rely on ambient air monitoring data from central sites situated away from human participants (Department of Environment and Tourism 2010). Considering the higher exposure time in different indoor environments, the health effects of indoor air pollution of both indoor and outdoor origin are of significant importance as far as children are concerned. Therefore, understanding the composition and sources of indoor particulate matter and its relation to outdoor-generated particulate matter is vital for personal exposure assessment. In an occupied residential house, particulate matter is emitted from several primary sources (such as cooking, sweeping, and other human activities), but could also be formed through the reactions of gas-phase precursors emitted both indoors and outdoors (Hasheminassab et al. 2014).

The study evaluated the exposure of children (aged 6-12 years) to $PM_{2.5}$ and the associated respiratory health effects. $PM_{2.5}$ was measured in households (with children aged 6-12 years) living within a 2-km radius from the landfill site to determine $PM_{2.5}$ exposures of children living in Clare Estate, and to evaluate its impact on respiratory health outcomes. Assessment of the risk to the community resulting from exposure to airborne pollutants should ideally include measurements of concentration levels of the pollutants in all microenvironments where people spend their time (Morawska et al. 2001). However, in this study, it was not possible as there were various challenges in the multi-component analysis of indoor PM in addition to the high expense in conducting measurements in all microenvironments (Mihucz et al. 2015).

This study further explored social factors related to living in the close proximity to the landfill site. Studies of subjective assessment of environmental risk demonstrate that people focus on particular risks because of their attachment to place, beliefs, values, social institutions, and moral behaviour, not necessarily on the amount of danger actual or perceived (Douglas and Wildavsky 1982). Therefore, a social context is crucial in understanding how risk is socially constructed within the Clare Estate community.

In first world countries, landfills are often a cause of concern for the population living nearby. Hence, public acceptance to waste disposal sites is very low owing to concern for adverse effects on environment and human health (Paoli et al. 2012). However, in South Africa, where people have access to few residential and survival alternatives, living close to a landfill site is sometimes turned into a racial bone of contention. This is evident in the community of Clare Estate in Durban where the Bisasar Road landfill site, eThekwini, is a source of racial discord between a mostly Indian community living in formal housing and a mostly African community living in the informal settlement.

The late Indian activist and a formal settlement representative, Sajida Khan who passed away on the 15th of July 2007 due to cancer was convinced that her cancer had been caused by exposure to the pollution sources from Bisasar Road landfill site (Leonard 2011). Khan was at the frontline in calling for the closure of the Bisasar Road landfill site (Leonard 2012). On the other hand, the shack dwellers argued against the closure of the landfill site, claiming that they did not care much about the landfill as they were mostly concerned with securing their basic social needs (housing and service delivery). The African community on the one hand, argued that they could make a living (waste picking) off the landfill whilst the other camp argued on its negative impact on their health (Leonard 2012). It all culminated in a march mobilised by informal residents protesting against formal residents who were advocating for the closure of the landfill.

The African community agreed in principle that the landfill site was not safe. Hence they engaged in environmental justice issues with NGOs but as a secondary issue (Leonard 2012). This suggests that although the African community living in the informal settlement was aware of the risks from the landfill, the basic survival needs overrode health concerns (Leonard 2012). The environmental impact assessment to set up a waste transfer station (WTS) at Bisasar received mixed reactions from Indian and African residents. The Indian community objected to the proposal of establishing a WTS because of health (noise and air pollution) related impacts whilst Africans supported it since there would be job opportunities (Leonard 2012). It is with all these facts in mind that the study explored the residents' perceptions and responses regarding operations at the Bisasar Road landfill site.

Due to the lack of clear guidelines in South Africa to ensure that communities are kept away from existing landfill sites, there is a policy vacuum. This vacuum presents some obvious questions: to what extent do landfill site emissions affect the nearby community; at what distance; and, how significant is its impact in relation to distance from the facility? To add to the predicament, there is no reliable information on the actual day-to-day and long-term effects of landfilling operations on the lives of residents living near such facilities. Furthermore, there is no evidence of the effectiveness of possible mitigating strategies in addressing community concerns. Related research conducted in other countries shows a correlation between concern and distance from the facility with the strongest concerns coming from residents who lived within 800 m; and as the distance from the landfill site increased, concerns decreased as well (Okeke and Armour 2000).

According to the Department of Environmental Affairs and Tourism (2010), extensive work has been undertaken to address air pollution in recent years in South Africa. However, few monitoring stations measure ambient $PM_{2.5}$ and little exposure and toxicity (dose-response and health outcomes due to $PM_{2.5}$ exposure) data are available. More attention has been given to landfill gas emissions such as methane due to their climatic impact and their potential for energy production (Hinds 1999). However, particulate matter ($PM_{2.5}$) exposure in children residing in and around the landfill sites has not been well investigated in developing countries including southern Africa. This study, therefore, fills a gap in the research by investigating the influence of landfill activities on indoor $PM_{2.5}$ levels and its resultant effects on children.

The study was conducted in Durban in the KwaZulu-Natal (KZN) province. The study site is shown in Figure 1.1. Research was conducted in the Clare Estate community in EThekwini Municipality, a Category A (metropolitan council) municipality situated along the east coast of South Africa in KZN. EThekwini Municipality is one of the eleven municipal districts of KwaZulu-Natal province. It spans over an area of approximately 2,297 km^2 (eThekwini Municipality 2015). It comprises 99 municipal wards, and a population size of 3,442,358 (COGTA 2011).

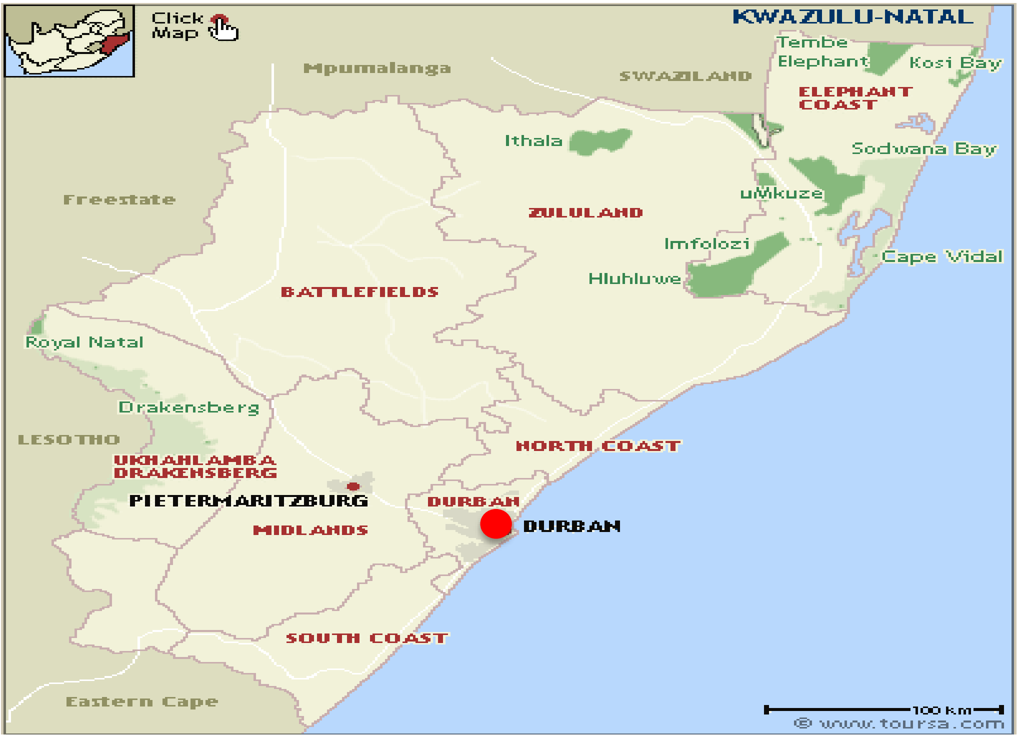

Figure 1.1 A map showing the location of the Durban study site in KZN, South Africa (acknowledgement: KZN Parks)

Study participants were recruited from Clare Estate community, residing within 2 km from the Bisasar Road landfill site. The Bisasar Road landfill site is situated in Municipal Ward 25 of the eThekwini Municipality. The municipal voting districts falling within 2 km of the landfill site were utilised to further define the study area. This provided the ability to determine the possible sample frame through its 2011 voting districts (Demarcation Board 2010). Ward 25 comprised eight voting districts with 14,697 registered voters (Demarcation Board 2010). Out of these eight voting districts, six were within the defined distance (2 km) of the landfill site. The exclusion of the two voting districts which were outside the 2-km radius reduced the number of registered voters to 11,304. The Bisasar Road landfill site location with the 2-km radius demarcation mark is shown in Figure 1.2 whilst the map showing Ward 25 is shown in Figure 1.3.

Figure 1.2 A map showing the Bisasar Road landfill site and the study area (acknowledgement: Google Maps

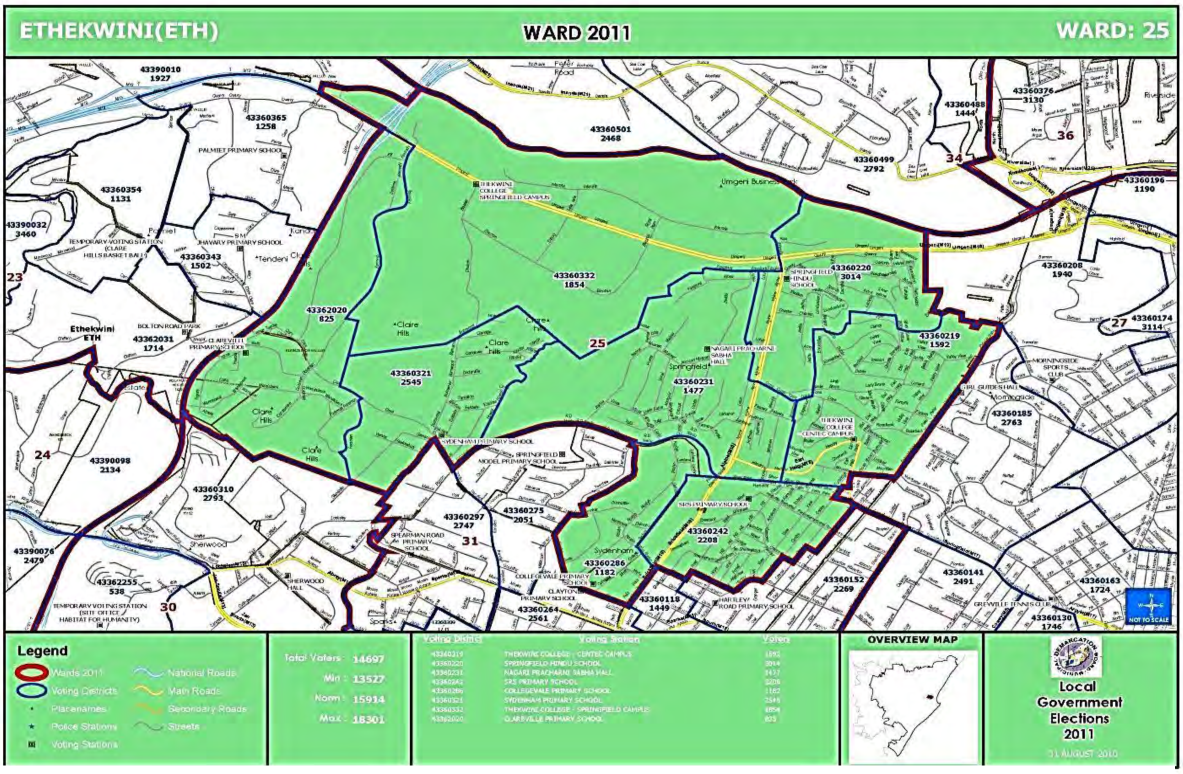

Figure 1.3 Ward 25 of eThekwini Municipality (acknowledgement: Demarcations Board)

1.2 Rationale for the research

The study was conducted on the community residing in Clare Estate which is overwhelmed by serious health problems (GAIA 2011). The Bisasar Road landfill site is surrounded by both formal and informal settlements. Informal and formal settlements are situated adjacent to each other along Kennedy Road and Foreman Road, while the formal settlements are situated along Clare, Elf Place, Howell, Burnwood and Dhulum Roads. Lohmann (2006) indicated that Clare Estate residents reported many health problems, with six out of ten of the houses in one downwind block reporting cancer cases. An article by Sharife and Bond (2009), in the Women in Action revealed that the Cancer Society of South Africa deemed Clare Estate a "cancer hotspot" because of the heavy metals and other dangerous substances that penetrate the water, air and shifting soils. They further reported that at the nearby clinic, health workers confirmed that Kennedy Road residents suffer severely from asthma, sinusitis, pneumonia and even tuberculosis.

Community concerns about the landfill site have existed for many years and grew as residents became increasingly worried about the potential health effects of landfill site emissions. There are reported concerns over possible transport of air pollutants to residential areas from landfills (Paraskaki and Lazaridis 2005). Acute lower respiratory infections (ALRI) have been reported to be the single most important cause of global mortality in children less than five years of age (Smith et al. 2014). However, there is little evidence regarding the potential health effects for children over five years of age. The increasing community concern has inspired this study to investigate the respiratory health effects associated with particulate matter ($PM_{2.5}$) in children.

To date, there is no prescribed age and distance from source recommended to provide a precise association of the respiratory impact due to the source of pollution. Different studies applied different distances from the perceived source. Hence this study investigated the health impact of $PM_{2.5}$ in 6- to 12- year old children living within a 2-km radius of the Bisasar Road landfill site. Particulate matter, in particular the fine particles ($PM_{2.5}$), are of particular concern as they can penetrate deep into the lungs and adversely affect the respiratory, central nervous and cardiovascular systems (Mazaheri et al. 2014). $PM_{2.5}$ is also significantly correlated with deaths from cardiopulmonary disease and lung cancer (Berico et al. 1997). Children are generally more susceptible to air pollution than adults since their lungs are still undergoing growth through to early adulthood (Lai et al. 2009). Children are exposed to ultrafine particles in different microenvironments, for example, at school, at home and during commuting (Mazaheri et al. 2014).

A review of 24 cross section observation studies by Smith et al. (2014) revealed that chronic obstructive pulmonary disease (COPD) is of growing concern. These studies projected COPD to be the third leading cause of global mortality and morbidity by 2020, and indoor air pollution may be the most important cause in non-smoking populations. The limited financial and human resources in the present study, have hindered the external civil societies and academic researchers to conduct health studies in Clare Estate to determine the effects of the landfill on health; and to assist local communities in addressing landfill risks (Leonard 2012).

This study used clinical diagnosis, spirometry, and chronic symptom recall to define the health outcomes. It also concentrates on two of these health outcomes, i.e. the chronic symptoms recall and spirometry to understand the effect of $PM_{2.5}$ on children. Most studies of the impact of PM from point sources in communities are conducted in developed countries. Furthermore, there are limited studies investigating perception of communities living near the landfill sites. The same holds true for studies that investigate the association between $PM_{2.5}$ from landfill sites and children. This study then provides important evidence to the region and the international community on the impact of landfill sites on the well-being of the surrounding communities, particularly on children. It will also be made accessible to eThekwini Municipality with the hope that informed decisions are made regarding the maintenance and placement of landfill sites in the future.

1.3 Justification

Much attention has been given to landfill site gas emissions such as methane due to their climate impact and their potential for energy production (Hinds 1999). However, particulate matter ($PM_{2.5}$) exposure in children residing adjacent to the landfill site has not been well investigated in developing countries, including South Africa. Therefore, this study fills a gap in the research by investigating the possible influence of landfill site activities, for the largest landfill site in Africa, on indoor $PM_{2.5}$ levels which could pose respiratory health effects on children who are the vulnerable group in post-apartheid South Africa.

Community concerns about the Bisasar Road landfill site have existed for many years and grew as residents became increasingly concerned about the potential health effects of its emissions. These climaxed locally and internationally during the time of the death of a self-taught ecologist, Sajida Khan who had a profound empathy for people in the same proximity. After several attempts by the Clare Estate community to force eThekwini Municipality to close the landfill site, in 2002, Sajida Khan led a lawsuit against eThekwini Municipality for failure to close the landfill site (GAIA 2011). However such attempts did not succeed. According to Durban Solid Waste (DSW) (Appendix B), Bisasar Road landfill site was expected to reach its capacity by 2014 but it continues to operate to date. The reason that the Bisasar Road landfill site was not closed in the early 2000s, notwithstanding a very substantial pressure campaign by 6,000 residents led by Sajida Khan, was a commitment by the World Bank to invest a potential $14.4 million grant to convert landfill methane emissions into electricity (GAIA 2011, Leonard 2012). Although Sajida Khan died and the landfill site continued to operate, she died knowing that she had been partially successful in avoiding a major World Bank investment and raising local/global consciousness.

The increasing community concerns and the lack of environmental and health impact studies led to the commissioning of this study whereby the respiratory health effects associated with particulate matter ($PM_{2.5}$) in children and the perceptions of community living adjacent (2-km radius) to Bisasar Road landfill site were investigated to gain more insight into issues emanating from the close association of the community and the landfill site.

1.4 Aims

The main aim of the research was to determine respiratory health symptoms and outcomes in children aged between 6 and 12 years who live within a 2-km radius from Bisasar Road landfill site and to establish if there is a relationship between those respiratory health outcomes and the close proximity to the landfill site. It also intended to determine community experiences regarding the landfill site and its health impacts.

1.5 Objectives

The objectives of the research were the:

- identification of the potential environmental and personal risk factors associated with the respiratory symptoms in children aged between 6 and 12 years;

- determination of the respiratory health symptoms and outcomes from children living near the Bisasar Road landfill site;
- evaluation of the statistical relationship between indoor particulate matter ($PM_{2.5}$) and respiratory health outcomes in children living near the landfill site; and
- determination of community perceptions about air quality (dust in particular) in relation to the landfill site.

1.6 Outline of thesis structure

Each chapter is mostly self-contained, comprising of a literature review, materials and methods, results and discussion, and conclusions. The result of each chapter is devoted to one or more aspects of that particular chapter.

Chapter 1 introduces the study including the study background and the study setting, presents the rationale and justification for the study, aims and objectives for the study and thesis structure.

Chapter 2 focuses on a review of the relevant literature on air pollution management in South Africa; the description of particulate matter and its health effects; the definition of indoor air quality; the respiratory health assessment; and the legislative framework to address particulate matter ($PM_{2.5}$).

Chapter 3 is devoted to the indoor characterization of the households of children residing near the landfill site.

Chapter 4 focuses on the presentation of the respiratory health symptoms and conditions among children living near the Bisasar Road landfill site.

Chapter 5 focuses on a statistical association between particulate matter ($PM_{2.5}$) and the respiratory health outcomes in children living near the Bisasar Road landfill site.

Chapter 6 is devoted to the presentation of community perceptions about air quality in households surrounding the landfill site.

The final chapter, Chapter 7, integrates the investigation, provides conclusions and documentation of the contributions of this research. Study challenges and future possibilities are included.

CHAPTER 2: RESPIRATOTY HEALTH EFFECTS IN CHILDREN – A REVIEW (PAPER 1)

2.1 Introduction

This chapter presents a review of the relevant literature on air pollution management in South Africa; the description of particulate matter and its health effects; the definition of indoor air quality; the respiratory health assessment; and the legislative framework to address particulate matter ($PM_{2.5}$).

While the focus of COP21 (2015) was on global climate change, air quality is also a very important environmental and public health concern in the world, and the efforts to prevent poor air quality are a responsibility for all. The health protection issues that dictate air quality management continue to advance as more and more studies demonstrate the need for stricter regulations. Air pollution exposures at levels that are considered unsafe to humans are frequently reported on. Air pollution in the atmosphere occurs as a result of natural processes and human activities (anthropogenic) (Godish 2004 pg 23). Human-driven activities, which are in most instances aimed at providing necessary goods and services to society, are responsible for the man-made share of indoor and outdoor air pollution, e.g., waste disposal. Ambient air pollution emissions occur at many levels, from raw material extraction, energy acquisition, production and manufacturing, use, reuse, recycling, through to ultimate disposal.

Anthropogenic atmospheric pollution is a serious environmental and health concern for both the developed and developing countries. The focus of this study, which excludes noise pollution, will be on air pollution. It manifests itself in elevated pollutant levels that are produced in environments where harm to human health and welfare is prominent (Godish 2004 pp23). It is thus a matter of urgency that all countries understand the relationship between air pollution and health. In order to understand this relationship, it is important to first understand what air pollution entails, and it is then that its health impact can be contextualised and subsequently, be mitigated. Kampa and Castanas (2008) define ambient air pollution as any substance which is able or may be able to harm humans, animals, vegetation or materials. The whole world has agreed to categorize air pollutants into criteria and non-criteria air pollutants. Criteria air pollutants are those air contaminants for which concentration limits are set as the dividing line between acceptable air quality and poor or unhealthy air quality, whilst non-criteria pollutants are those contaminants designated as toxic or hazardous by legislation (Griffin 2007 pp5-6). However, both are equally dangerous and deadly.

Air pollution is a trans-boundary matter. Hence many pollutants remain in the environment and/or atmosphere for extended periods of time and are transported by winds hundreds of kilometres from the point of origin or source (Mahajan 2011). Dispersion of these pollutants is affected by size of the particle, topography and meteorological conditions such as (air) temperature and (atmospheric) pressure (Godoy et al. 2009). According to Rahman et al. (2006), an increase in wind speed decreases the ambient pollutant concentration levels. However, high velocity of wind increases particulate concentrations if it is directed towards a particular location from polluting sources (Rahman et al. 2006). Also a combination of rain and a decrease in wind speed allows for an increase in ambient air pollutants, particularly, particulate matter (PM) (Hester and Harrison 2002).

Previously, the greatest concern was with the hazardous air pollution (HAP), which are hazardous substances linked to industrial atmosphere, thus disregarding the importance and impact of the community air pollution. With the evolution of the rigorous epidemiological investigations, the world has reached consensus about six criteria air pollutants, of which one is particulate matter (PM). This review focuses on PM with special reference to particulate matter with an aerodynamic diameter of ≤ 2.5 μm ($PM_{2.5}$).

Particulate matter can be categorised into four levels: total suspended particles (TSP), coarse particles (PM10), fine particles ($PM_{2.5}$), and ultra-fine particles (PM0.1). PM10 has been given priority regarding particle prevention and in measuring the impact caused by particles in human beings, hence PM10 (particulate matter with aerodynamic diameter of ≤ 10 μm) has been used to develop air quality standards. However, in the recent past $PM_{2.5}$ has received the attention of the world in measuring particle pollution due to its potential for causing respiratory health effects in human beings, especially in the most vulnerable groups such as children and elderly persons (Singh et al. 2011). The vulnerability of children to environmental pollution manifests in their growth and physiological development (Singh et al. 2011).

Children and elderly persons are mostly affected by indoors as they are not active occupationally and they travel less during the day than working adults. Therefore, air pollution sources are an important consideration since the state of air quality depends on the potential for dispersing and removing ambient air pollutants from the atmosphere into the indoor environment (Department of Environmental Affairs 2009). Waste disposal sites have been highlighted in the literature as one of the sources that generates air pollution, particularly, $PM_{2.5}$.

The focus of this review is mainly on the impact of $PM_{2.5}$ in children living in close proximity to Bisasar Road landfill site in the eThekwini Municipality. Pollution is thus a topical issue since landfilling is still the main waste disposal method used in South Africa, especially in urban areas such as the eThekwini Municipality. In this chapter, the literature on the broad scale of air pollution and its health impact is reviewed. The main focus is to review findings of prior research in the same field, particularly, the impact of $PM_{2.5}$ on children and the community perceptions.

This review focusses on:

- describing air pollution management in South Africa and the eThekwini Municipality;
- defining the concept of waste disposal site;
- describing particulate matter and its impact on health;
- defining the concept of the indoor air pollution;
- describing respiratory health assessment; and
- Highlighting the legislative initiatives for the management of particulate matter ($PM_{2.5}$) in South Africa and internationally.

2.2 Air pollution management in South Africa

The economic policies of apartheid led to increased industrialization, rapid urbanization, poor land use and poverty. Apartheid's spatial divide still continues to dominate the landscape even today. The residential areas found adjacent industrial developments mainly comprise the previously disadvantaged population groups to low socio-economic status (Matooane et al. 2004). These communities continue to live adjacent to waste disposal sites to this day and their vulnerability to air pollution is exacerbated by a compromised health status due to existing health issues and poor nutrition, poverty, unemployment, and poor access to adequate social services such as housing, electricity, health care, and education (Department of Housing 1997).

Between 1965 and 2004, the Atmospheric Pollution Prevention Act of 1965 was the central Act regulating air pollution in South Africa (Glazewski 2005 pg 592). In 1998, South Africa promulgated a new Act called the National Environmental Management Act (NEMA) which introduced a platform for which specific environmental control policies could be developed. Among those, the National Environmental Management: Air Quality Act No. 39 of 2004 (NEMAQA) was promulgated. Its purpose was to manage air pollution and thereby protect the health of the South African population (Republic of South Africa 2004). The objectives of this Act are:

(a) to protect the environment by providing reasonable measures for

(i) the protection and enhancement of the quality of air in the Republic;

(ii) the prevention of air pollution and ecological degradation; and

(iii) securing ecologically sustainable development while promoting justifiable economic and social development; and

(b) generally to give effect to Section 24(b) of the Constitution in order to enhance the quality of ambient air for the sake of securing an environment that is not harmful to the health and well-being of people.

This legislation introduced a shift in the manner in which air quality was managed in South Africa. As a result, municipalities are now required to develop and implement air quality management plans (AQMPs) with an objective of maintaining ambient air quality levels below specified standards for criteria pollutants and thus minimize adverse human health impacts. This Act paved the way for the following guidelines, frameworks and regulations whose aims were to prevent air pollution:

- National Framework for Air Quality Management was published and implemented in 2007. Its aim was to achieve the objectives of the Air Quality Act (AQA) which are to protect and enhance the quality of air in the country, prevent air pollution and ecological degradation and secure ecologically sustainable development while promoting justifiable economic and social development;
- Air Quality Standard gazetted on the 24th December 2009. Its aim was to regulate all criterial air pollutants;
- the National Ambient Air Quality Standard for $PM_{2.5}$ which was gazetted on the 29th June 2012. It was meant to regulate the maximum concentration for particulate matter with diameter less than 2.5 µm;

- the National Control Dust Regulations which was gazetted on 1st of November 2013. Its objective was to prescribe the general measures for the control of dust in all areas.

South Africa is a dry country with high naturally-occurring dust levels, compounded by industrial and vehicular pollution emissions. The need to formally address air pollution and appropriate mitigation measures for improved air quality and human health was first recognised in the 1960s. The first attempt to alleviate air pollution was the promulgation of the Atmospheric Pollution Prevention Act (45 of 1965). This was the first regulation that aimed at regulating fuel-burning apparatus that industries, hotels, dairies and dry cleaners were allowed to use, then followed. Certain residential areas were declared smoke-free zones.

The eThekwini Municipality is the only metropolitan council in KwaZulu-Natal Province. It is mandated by the Constitution of the Republic of South Africa (Act 106 of 1996) to manage air pollution within its jurisdiction like all other municipalities in South Africa (Republic of South Africa 1996). Section 156 (2) of the Constitution of the Republic of South Africa stipulates that a municipality may make and administer by-laws for the effective administration of matters that it has the right to administer. Accordingly, air pollution is listed as a matter which local government has authority on. National and/or provincial government may not compromise or impede a municipality's right to exercise its power to perform its function.

To achieve the above mentioned mandate, eThekwini commissioned the continuous air quality monitoring network in 2003, as one of the major elements of its Air Quality Management System. The primary objectives of the network are to quantify the quality of air in eThekwini in general, measure compliance with air quality standards and provide a means of verification for dispersion models. The network instruments continuously measure the priority pollutants, namely, sulphur dioxide (SO_2), oxides of nitrogen (NO_x), particulate matter with an aerodynamic diameter less than 10 µm (PM10), $PM_{2.5}$, ozone (O_3) and carbon monoxide (CO).

The 2009 monitoring results indicated that air monitoring stations that are situated near high volume traffic area coupled with the regional aspects of particulate matter contribute significantly towards PM10 and $PM_{2.5}$ emissions (eThekwini Municipality 2009). To date the network consists of twelve monitoring stations, of which seven are meteorological stations and one is a mobile monitoring vehicle. The operation of the network and the management of data are aligned to internationally prescribed quality control standards and guidelines and air quality compliance is assessed by comparing the results of the monitoring with the limit values contained in National Ambient Air Quality Standards (NAAQS) (eThekwini Municipality 2014a). During the first quarter of 2014, air monitoring data revealed that the maximum recorded 24-hour average for $PM_{2.5}$ was 36.3 µg m^{-3}, which means that $PM_{2.5}$ levels were in compliance with the 65 µg m^{-3} of the National Ambient Air Quality Standard (NAAQS) for $PM_{2.5}$ (refer to Table 2.1).

It is noteworthy that most air monitoring stations are in the south Durban basin (SDB) and the central business district (CBD). The CBD is of particular interest because of the number of vehicles in the city, whilst the SDB is due to the presence of major industries. However eThekwini is planning to increase the spatial coverage of the air quality monitoring network to cover the entire eThekwini Municipal area by 2018 through the rollout of a five-year programme (eThekwini Municipality 2014b).

eThekwini Municipality stipulates that the SDB is environmentally degraded, and experiences high levels of air pollution and waste disposal problems, and that the problems are further compounded by the loss of important natural resources (KMT Enterprises 2004). SDB has been in the limelight due to the poor air quality resulting from the manifestation of the polluting industries. Air quality in SDB is characterized by meteorological conditions that may either assist or retard air pollution dispersion (Jaggernath 2010).

The Vaal Triangle and South Durban are two examples of identified air pollution 'hotspots' (Naiker et al. 2012). According to Scott and Barnett (2009), there have been opposition strategies of 'advocacy and lobbying' that are aimed at the impact of air pollution on health; current plans to expand the South Durban industrial zone and the relocation of residents. Gaustella and Knudsen (2007), indicate that the Multi-Point Plan (MPP) was introduced as a landmark AQM intervention in the country, where all spheres of government came together to address severe industrial air quality problems in the South Durban area. An air quality management plan (AQMP) has been developed for eThekwini with the main focus on the interventions within the industrial sector. It is aimed at reducing the impact of air pollution from other sources of air pollution including waste disposal sites. EThekwini has made notable strides in terms of curbing the impact of air pollution in South Durban. However, much still remains to be undertaken in the whole Durban area.

2.3 Solid waste disposal facilities

A solid waste disposal facility/site is often called a landfill site. It is defined in different ways but essentially it is a facility at which garbage is disposed. The US Environmental Protection Agency (USEPA) (2006), describes a waste disposal site as consisting of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances and batteries and the like. Perez et al. (2006) describes a disposal site as a collection of discarded liquid and solid materials that serves as a breeding ground for bacteria and fungi.

Studies show that waste generation in the world is increasing. Municipal solid waste (MSW) is generated from residential and commercial sources and it is generally made up of paper, vegetable matter, plastics, metals, textiles, rubber, garbage, bottles, papers, metals and glass (Garg 2009, Pek and Jamal 2011). In 2001, Americans generated approximately 229.2 million tons of MSW (Perez et al. 2006). The average economy of African countries is growing at a significantly higher rate compared to developed countries. Africa as a continent currently has a total estimated population of about one billion people who generate an estimated 230 million tonnes of waste a year (Liebenberg 2012). The large quantities of waste produced cannot be disregarded since uncontrolled waste has the potential to cause significant environmental harm and even human illnesses and fatalities (Liebenberg 2012).

According to Liebenberg (2012), the standard of waste management varies greatly between countries in Africa and he described the following major trends and emerging issues on waste management:

- poor waste management practices, in particular the extensive dumping of waste in water bodies and uncontrolled dump sites, which exacerbates the problems of generally low sanitation levels across the African continent;
- urbanisation is on the rise in Africa and this trend is expected to continue in the future. A particular concern is the inability of infrastructure and land use planning methods (including those for waste management) to cope with urban growth, which is currently the highest in the world at 3.5% annually.

These are concerns particularly relevant to slum areas, which constitute a large part of many of the cities and towns in Africa (Liebenberg 2012). The effects of air pollution are assumed to be greater in the developing world than the developed world due to the differences in levels of exposure and co-exposure to a mixture of pollutants, the population structure, nutritional status, lifestyle and socioeconomic status (Matooane et al. 2004).

Municipal solid waste has been named as a key challenge associated with rapid urbanization in much of the developing world (including South Africa). It has been at the root of numerous conflicts between municipal authorities and communities located near landfills (Owusu et al. 2012). In their study, over 80% of respondents perceived industrial pollution as posing a considerable risk to them despite the fact that the economy of the area largely depended on the industry (Owusu et al. 2012). Respondents also argued that they had not been actively involved in identifying solutions to the environmental challenges. The study revealed a significant association between industrial pollution as a risk and perception of risk from other familiar health hazards. The most important factors influencing the respondents' pollution risk perception were environmental awareness and family health status (Omanga et al. 2014).

Although there are few studies that have investigated the perceptions of a community who live near a landfill site and its impacts, the existence of dust from landfill sites has been reported (Okeke and Armour 2000). Community opposition to landfill sites and other locally unwanted land uses (LULUs) often leads to the abandonment of such landfill sites (Okeke and Armour 2000). This is not always the case as the Clare Estate community have opposed the existence of Bisasar Road landfill site but the facility is still functional to date. Some studies have reported negative perception of the landfill sites. Tuan and Maclaren (2005) reported that communities are concerned about the poor maintenance of landfill sites and the dominant dust exposure that the landfill sites have on the community.

A study conducted in South Wales in the United Kingdom revealed that a community near the Trecatti Landfill Site expressed concerns about odours and health effects which they attributed to landfill site emissions (Fielder et al. 2001). According to Engelbrecht and Van der Walt (2007), the responses to the negative effect of air pollution have often been delayed due to social, political and economic factors. However, people's awareness, their interpretation of the impact of air pollution and their willingness to endure a certain degree of air pollution has gradually changed over time (Jaggernath 2010.

2.4 Particulate matter

Particulate matter (PM) is sometimes referred to as particulate pollutant or particulate air pollutants and its concentrations are expressed in terms of either a mass per unit volume ratio (µg m^{-3}) or in terms of a pure volumetric ratio, which are volumes of contaminant per million volumes of air (ppm) (Griffin 2007 pg 7). It ranges from 0.001 to 100 µm (Balasubramanian et al. 2010 in Gurjar et al. 2010 pg 278). Particulate matter comprises material in solid or liquid phase suspended in the atmosphere (Gurjar et al. 2010 pg 2), and those suspended particles can either be primary or secondary air pollutants. Griffin (2007 pg 10) defines particulate matter that are suspended in the atmosphere in either solid state or liquid droplet as aerosols. McGranahan in McGranahan and Murray (2003), define PM as “the presence in air of small solid and liquid particles of various physical dimensions and chemical properties”.

Particulate matter is categorized by size and continues to be the fraction of air pollution that is associated with human disease (Kampa and Castanas 2008). Mahajan (2011 pg 5) defines PM as finely divided particles that are more than 0.01 µm in size which can be droplets of liquids as in fogs and mists or solid particles like soot or those suspended in smoke. PM is further described by its “aerodynamic equivalent diameter” (AED) and the particles of the same AED tend to have the same settling velocity (Anderson et al. 2012).

Researchers, have over the years, subdivided particles into AED fractions based on how the particles are generated and where they deposit in human airways. The particles include PM10, $PM_{2.5}$; and PM0.1 particles (Anderson et al. 2012, Balasubramanian et al. 2010 in Gurjar et al. 2010 pg 278). Pope and Dockery (2006) define PM as air-suspended mixture of solid and liquid particles that vary in number, size, shape, surface area, chemical composition, solubility, and origin. The size distribution of total suspended particles (TSPs) in the ambient air is trimodal, including coarse particles, fine particles, and ultrafine particles.

According to Nastos et al. (2010), PM are microscopic solid or liquid droplets originating from anthropogenic sources such as industries, motor vehicles and natural sources such as dust storms which may also increase the concentration of PM. Singh et al. 2011 pg 3-4), define PM as either solid or liquid, which is usually categorised into the following groups based on the aerodynamic diameter of the particles:

- particle less than 100 µm, which are also called “inhalable” since they can easily enter the nose and mouth;

- particles less than 10 µm. These particles are also called "thoracic" since they can penetrate deep in the respiratory system;
- particles less than 4 µm. These particles are often called "respirable" because they are small enough to pass completely through the respiratory system and enter the bloodstream;
- particles less than 2.5 µm; and
- particles less than 0.1 µm.

Yassin et al. (2012) describe PM as a wide range of suspended particles composed of a mixture of particles and droplets and represents a complex mixture of organic and inorganic substances that are small enough to be inhaled by people. The primary health standard for PM is PM10, which refers to particles of aerodynamic less than 10 µm in diameter (Wicking-Baird et al. 1997). This standard was chosen to represent the particle size that has the potential to penetrate the upper airways of the respiratory system. However in the recent past, studies show a strong relation between $PM_{2.5}$ and health effects which led to the introduction of standards based on particle size less than 2.5 µm (Brunekreef and Forsberg 2005).

2.4.1 Sources of particulate matter

Particulate matter originates from climatic influences (rain, wind and humidity); industrial output (fossil fuels and production activities); transportation (vehicles, ships, airplanes and trains); housing (cooking, heating and cleaning); geographical location (soil erosion) and tobacco smoking (Polichetti et al. 2009). As mentioned, sources of particulate pollutants may include, among others, the natural source (droughts and strong winds); anthropogenic sources (waste disposal sites), household sources (burning of coal), agricultural sources (burning of unwanted undergrowth and leaves before harvesting); and industrial sources (metals) (Mahajan 2011 pg 5-6).

Likewise, landfill sites play a huge role in the emission of dust particles due to the many operations that occur during waste disposal processes (Wurth 2006). Particulate matter may originate from very important municipal service delivery activities like solid waste disposal, which include collection, transportation and disposal of municipal waste. Communities are exposed to such particulate matter from outdoor sources which penetrates to the indoor environment and may cause harm (Meng et al. 2009, Zhu et al. 2010). Air constantly moves in and out of the indoor environment to create the opportunity for poor ambient air conditions which affects the indoor air quality and cause adverse health effects to occupants (Hagan 1998).

According to Monn et al. (1997), the levels of indoor particulate matter are influenced by both outdoor levels and by particles generated indoors. Housing structures in informal settlements have a significant impact on poor indoor air quality because they are characterized by poor ventilation due to structural defects. Particles dispersed from their point of origin, which in this case is the landfill site, can travel for long distances without being deposited depending on the varying factors including atmospheric conditions such as wind speed, direction, rainfall and atmospheric stability which could result in the human exposure far from the point of origin (Hagan 1998). The risk of exposure is aggravated by the fact that people from informal settlements and rural areas lack information and knowledge of indoor air quality (Barnes and Mathee 2002). Hence the effect of air pollution are assumed to be greater in developing countries than in developed countries due to the differences in levels of exposure and co-exposure to a mixture of pollutants, the population structure, nutritional status (of occupants), lifestyle and socioeconomic status (Matooane et al. 2004). Given the demographic characteristics of the community residing in Clare Estate, it is expected that the effect of air pollution is countless.

Literature indicates that in developing countries, the majority of people residing near industrial areas are the working class of any capitalist society (GAIA 2011, Hallowes et al. 2008, Republic of South Africa 1998). The reality in developed countries is no different. A study by Elliott et al. (2001) estimated that 80% of the UK population reside within 2.4 km of a working or closed landfill site. Large amounts of solid waste from surrounding communities are disposed of in a landfill site and the potential of PM emissions into the atmosphere is noteworthy (Chalvatzaki et al. 2010). Operating solid waste landfills emits a variety of air pollutants that include landfill gas and particulate matter (Koshy et al. 2009).

Atmospheric dispersion can travel from a landfill site depending on the wind direction and weather patterns at that specific time (Okeke and Armour 2000). Higher wind speed results in higher particle re-suspension from the surface, whereas increased ambient temperature values lead to drier soil conditions that favour particle resuspension (Lazaridis et al. 1998). Therefore, landfill sites are sources of dust and gaseous emissions which are distributed by wind action (Republic of South Africa 1998).

According to Macklin et al. (2011), landfilling processes (mechanical and chemical) have the potential to produce both fine and coarse particulates, the make-up of which depends on the activities undertaken on-site and the types of waste being handled at that landfill site. Landfilling activities that have the potential to generate particulates include:

- movement of waste on- and off-site;
- handling storage and processing of waste;
- plant traffic both on- and off-site;
- equipments used to burn landfill gas, including gas flares or engines; and
- dust generated from the surface of the landfill.

Departmental Affairs and Tourism (2009), state that an air quality impact assessment study conducted for hazardous and general landfill sites in South Africa has indicated that given good landfill site management, significant health risks are limited to within 0.5 km of the landfill site boundary. Odour impact distances can vary from 0.2 to 5 km depending on management at the site. The dust nuisance impact is reported to be restricted to within the immediate boundary of the landfill site (Department of Environmental and Tourism 2010).

The study conducted in two communities of Staten Island (New York, USA) residing near the landfill site reported that 46% and 60% of respondents were diagnosed with asthma. Chronic bronchitis emphysema, congestive heart failure and coronary disease were also reported from both communities (Berger et al. 2000). Another study conducted in Delhi (India) which examined the general health impairments of workers employed in a municipal solid waste disposal site reported the possible symptoms of exposure to pollution from landfill sites. These include irritation of the nose, eye, and skin, headaches, fatigue, psychological disorders, allergies, diarrhoea, fungal infections, and ulceration of the skin (Ray et al. 2005).

Dust sources such as waste disposal sites outside homes, have been implicated as possible health threats to their communities as they have been suspected to be adversely affected by microbial aerosol exposure (Perez et al. 2006). The effects of exposure to bio-aerosols generated through the storage and handling of waste on health are not limited to the occupational environment since longer duration storage of residential organic waste indoors has been observed to be significantly associated with skin irritation (Perez et al. 2006).

Dust content from landfill sites may affect the health of a human's physiological responses to chemical and physical agents such as skin irritation and inflammation (Wurth 2006). Landfill site dust is generated by chemical and mechanical processes as explained by Chalvatzaki et al. (2010). According to Shala et al. (2011), dust emissions from landfill sites can contain toxic elements that can be dispersed in air. Macleod et al. (2006) emphasizes that dust does not appear to be such a major concern in landfill sites and the dispersion in landfills, although finding methods and introducing controls would assist in decreasing the dust content.

Landfill sites and their operations necessitate interrogating the influence of particulate matter, more specifically the dust that is exposed and dispersed through the ambient air (Chalvatzaki et al. 2010). According to Chalvatzaki et al. (2010), more measures need to be taken to reduce airborne dust that is most commonly caused by the movement of trucks within the landfill premises. These activities include the movement and transport of waste from one designated area to another. The handling and processing of waste, such as turning and shredding are also considered dust generators within a landfill. Vehicles that generate a significant amount of dust and fumes from exhaust pipes are also large contributors to prominent dust content that emanates from a landfill site (Environmental Agency 2003). Landfill sites are sources of air pollution, since dust emanating from landfill sites and other related pollutants in the air reach millions of people. A strategic plan needs to be implemented in order for landfill sites and their dust content to be eliminated (Shala et al. 2011).

2.4.2 Respiratory health effects associated with particulate matter exposure

Osornio-Vagas et al. (2003) state that exposure to airborne particulate matter is associated with adverse health effects. Hence the interest of studying particulate matter emerged when epidemiological studies reported adverse cardiac and respiratory health effects (Karen et al. 2002). The Department of Environmental Affairs (2009) states that the potential of particles to be inhaled and deposited in the lungs is a function of the aerodynamic characteristics of these particles in the air, and it is related to their size, shape, and density. Their impact on human health largely depends on (i) particle characteristics, especially particle size and chemical composition, and (ii) the duration, frequency, and magnitude of people's exposure to them.

Long-term studies have documented the increased cardiovascular and respiratory mortality associated with exposure to particulate matter- particularly the $PM_{2.5}$ where its association is strongly linked with lung cancer mortality (Singh et al. 2011 pg 39). Among all the air pollutants in ambient air, particulate matter affects more people than any other pollutant (Gurjar et al. 2010 pg 2). Particulate matter is one of the most important indoor air pollutants associated with a number of adverse health effects, such as premature deaths, respiratory and cardiovascular complications as well as increased mortality in infants and other parts of the sensitive population (Kubincova and Stevulova 2010, Win Lee 2010).

According to Nastos et al. (2010), PM10 particles can be inhaled and enter bronchioles and trigger asthma and cause damage in the bronchial epithelium and cilia if a human is exposed for a long period of time. Furthermore, PM10 from diesel engines combines with pollen and other allergens that contribute to sensitisation of airways to successive allergens exposure. Air pollution associated with PM has diverse effects ranging from human health, visibility and climate change (Colbeck and Lazaridis 2010). Health effects of aerosols are determined by the size distribution and chemical properties of aerosols (Harrison and Yin 2000). Their major pathway to enter the human body is via the respiratory system (Vincent 1990).

Epidemiological studies have reported that PM affects all age groups. However, the population that is mostly vulnerable to the effect of air pollution include children, elderly, and people with heart diseases, or impaired immune systems or who are either working indoors or outdoors, since their immune system is not strong enough to protect them (Raizanne 2001, Karen et al. 2005). Air pollution effects are most severe in children because they breathe more rapidly and have a greater lung surface area relative to their body size compared to adults. As a result children inhale a greater volume of air per unit time (USEPA 1998).

A strong relation between the respiratory conditions such as wheezing, shortness of breath, a blocked or runny nose, sinusitis, rhinitis, hay fever, productive cough, bronchiolitis, pneumonia and air pollution is well documented in epidemiological literature (Ehrlich et al. 2005). Brunekreef and Holgate (2002) further state that exposure to PM causes more than 2 million deaths of children per year globally. Since most of the human time is spent in an indoor environment, it is vital to take proper measures to protect inhabitants from indoor pollution exposure (Monn et al. 1997). Association between PM and hospital admissions for respiratory diseases has been reported, where high mean daily PM10 concentration doubled the risk of asthma complications even in younger asthmatic children (Nastos et al. 2010).

Matooane et al. (2004) reported that the effects of air pollution are greater in developing countries as a result of population exposure to a mixture of pollutants; the juxtaposition of industries and landfill sites within heavily populated residential areas; and a generally lower socio-economic status group than in developing countries. These groups are sensitive to air pollution risks due to biological factors such as the presence of diseases or infections and their genetic make-up, such as asthma in the African population (Keiding et al. 1995). The problem of particulate matter is receiving attention because of its impact on human health. There is increasing evidence that suggests exposure to particulate matter via inhalation, ingestion or dermal contact has adverse human health effects. The USEPA (2010) reports that the main health effect of concern is the exacerbation of existing respiratory diseases, cardiovascular diseases and lung cancer.

It is well documented that $PM_{2.5}$ poses a significant hazard to human health because it may pass through the filtration mechanisms in the upper respiratory tract and penetrate beyond the larynx to the lower airways. $PM_{2.5}$ has the potential to penetrate the blood stream through the capillaries lining the bronchioles and alveoli of the lungs. Such penetration of airways increases the health threat because it allows easy absorption of toxins into the blood stream (Budds et al. 2001). Acute lower respiratory infections (ALRI) such as pneumonia have been linked to exposure to indoor air pollution (IAP), and account for the deaths of millions of children in developing countries each year (Barnes and Mathee 2002).

In most countries, PM10 is monitored due to its ability to penetrate into the lower portion of the respiratory tract and lungs, where it contributes to respiratory disorders, reduced lung function and even lung cancer. PM10 is vital in determining the severity of the human health impact (Mahajan 2011 pg 20). However, as important as it may be, PM10 overshadows the other very important categories of particles, like $PM_{2.5}$ which also cause more health problems than PM10. Airborne $PM_{2.5}$ particles are usually called fine particles and they account for the majority of the mass of suspended particles, and slowly leading to a long atmospheric lifetime of 5 to 10 days (Gurjar et al. 2010 pg 171).

In determining the risk of exposure, the impact of distance from the source of air pollution cannot be underestimated. A study by Gauderman et al. (2004) found that in children who lived within 0.5 km away from a freeway, 8-year growth was significantly reduced compared with those who lived at least 1.5 km away from a freeway. Large deficits in 8-year growth of forced expiratory volume in 1 s (FEV1,-81 mL, p = 0·01 [95% confidence interval -143 to 18 mL]) and maximum mid-expiratory flow rate (MMEF, -127 mL s^{-1}, p = 0·03 [-243 to -11 mL]), were also estimated for the two highest-exposure quartiles of model-based pollution from a freeway, although neither deficit was statistically significant.

Ito et al. (2007) state that $PM_{2.5}$ dispersion has a negative impact on the $PM_{2.5}$ during the warmer seasons as opposed to colder seasons. Therefore, the role played by seasonal variation cannot be underestimated when assessing the respiratory health effects associated with $PM_{2.5}$. Napoleon et al. (2007) hold that $PM_{2.5}$ can be suspended for long periods of time and can also be transported over long distances by wind. Prevailing winds play a critical role in $PM_{2.5}$ dispersion since a decreased wind speed allows for the accumulation of $PM_{2.5}$ in the air which results in a negative health impact. Prevailing winds may be a factor that leads to high concentrations of $PM_{2.5}$. Therefore lower wind speeds favour increased $PM_{2.5}$ concentrations but the concentrations may vary due to prevailing wind direction (Charron and Harrison 2005).

Yassin et al. (2012) argues that although a landfill site may be in close proximity to an indoor environment, the levels of $PM_{2.5}$ indoors can be mostly associated with cooking, heating, smoking and incense burning. They further argue that ash or fly ash produced as a result of incineration is usually disposed of into landfill sites. This is deemed important as it is a concern for the indoor environments within close proximity of the landfill, which do not have appropriate methods and techniques to prevent the fly ash from being dispersed (Yassin et al. 2012).

$PM_{2.5}$ penetrate deeper into the lungs and has greater adverse health effects. Particle size determines whether particles will be filtered and removed from the upper respiratory tracts or be inhaled into the middle and lower regions of the lungs (California Environmental Protection Agency 2014). Epidemiological studies provide evidence of the association between $PM_{2.5}$ and health effects since $PM_{2.5}$ form a significant portion of PM exposure (Ostro et al. 2010). $PM_{2.5}$ pose a significant risk to human health because it is smaller in size and has a greater potential to reach the lungs after exposure and inhalation (Osornio-Vagas et al. 2003). The health effects linked to $PM_{2.5}$ exposure include premature death, which may result from heart and lung disease, cardiovascular symptoms, respiratory symptoms, asthma attacks and bronchitis (Napoleon et al. 2007, Gurjar et al. 2010 pg 2). There is however no evidence from epidemiological studies that associate the long-term exposure to direct measurements of $PM_{2.5}$

with mortality from chronic cardiovascular and respiratory diseases where annual average exposures exceed 100 µg m^{-3} (Brauer et al. 2012).

Polichetti et al. (2009) reported an increase in atherosclerosis, which is usually associated with an increase in the concentration of $PM_{2.5}$. Eczema, wheeze, including coughing have also been established as an effect of $PM_{2.5}$ (Latzin et al. 2011). Napoleon et al. (2007) assert that researchers believe that particles like $PM_{2.5}$ can penetrate into the deepest portions of the lungs without being removed in the upper airways; therefore $PM_{2.5}$ is more likely to interfere with or influence human health. Other reported symptoms of $PM_{2.5}$ inhalation include throat and nose irritation that are followed by a broncho-constriction and dyspoea (Lee et al. 2006). $PM_{2.5}$ account for hospital admissions for respiratory health effects (Neuberger et al. 2004).

The associated range of $PM_{2.5}$ specific adverse acute and chronic health effects includes respiratory hospital admissions, bronchodilator use, cough and lower respiratory symptoms, changes in peak expiratory flow, cardiovascular stress and mortality (USEPA 2010). $PM_{2.5}$ remain in the air for longer periods of time than coarse particles (days to weeks versus minutes to hours) and may travel much further thereby increasing exposure (WHO 2000). $PM_{2.5}$ has also been associated with eye irritation and dizziness (Kongtip et al. 2006). Several studies reported associations between $PM_{2.5}$ and adverse effects such as coronary heart disease, thrombosis, aneurism, vasculitis, lung cancer and premature mortality (Curtis et al. 2006, Dagher et al. 2006, Polichetti et al. 2009). Exposure to $PM_{2.5}$ has been associated with respiratory symptoms, cardiopulmonary and cardiac daily mortality, a decrease in respiratory function, and the use of asthma medication (Katsouyanni 2003).

Whilst an average adult breathes over 21.6 m^3 of air per day, children breathe even more air per kg of body mass and are more susceptible to air pollution; and if air is polluted, it reduces the amount of oxygen intake considerably thus adversely affecting health (Mahajan 2011 pg 19). The Children's Health Study conducted in Sokolov, Czech Republic that investigated short-term consequences of air pollution exposure in children's respiratory health provided significant findings about children's health in relation to air pollution, including PM. Some evidence indicated that exposure to air pollution might have enhanced the respiratory symptoms while children were experiencing respiratory infections. The study revealed that air pollution exposure was associated with decreased peak expiratory flow rates, increased respiratory symptoms, increased prevalence of school absence and fever, and it increased the use of medication (Peters et al. 1997).

Children are most susceptible in terms of being vulnerable and succumbing to many illnesses and diseases, due to their weak and developing immune system. As a result they suffer from respiratory symptoms which include asthma, wheeze and cough (Linehan et al. 2005). Asthma is a chronic inflammatory disease of the airways that is characterized by reversible airflow obstruction and accompanied by periodic attacks of wheezing, shortness of breath and a feeling of tightness in the chest and it is considered the most common chronic disease in children (Öberg et al. 2010).

The literature confirms that acute respiratory infections have been considered the primary killer in children who are under the age of five (Naeher et al. 2007). Epidemiological studies found a decline in lung function in school-aged children exposed to $PM_{2.5}$. They also found that children of ages 10 to 18 years reported negative impacts of $PM_{2.5}$ on their lung function during the period of rapid lung development (Gauderman et al. 2004). $PM_{2.5}$ has been linked to adverse health effects in children, such as bronchitis and a reduction in lung function and the WHO suggests that there is no safe limit below which adverse effects are unlikely (WHO 2000). Curtis et al. (2006) reported an association between ambient air levels of $PM_{2.5}$ and visits of children to emergency facilities for respiratory illnesses.

2.5 Indoor air quality

Indoor air quality (IAQ) is the description of chemical, physical and biological characteristics of air in an indoor (residential or occupational) environment. It is sometimes caused by the combustion of non-commercial sources of fuel such as bio-fuels in homes that are poorly ventilated and it leads to deaths of thousands of young children and women annually since children, women, and disabled are housebound for a considerable period of time (85 – 90%) (Mahajan 2011).

Molhave (2000) mentioned three types of health effects which are related to indoor environment. Those types are priority effects, secondary effects, and hypothetical or potential effects. Exposure to indoor pollutants is mainly through inhalation rather than dermal contact or ingestion. Indoor environmental factors are thought to play a part on three different levels when an individual is exposed to the pollutants. The pollutant can enter (1) the immune system to react unfavourably to some factor in the environment (sensitization) or (2) the pollutant can trigger symptoms in those already sensitized and/or (3) then maintain the inflammation in the mucosa of the respiratory passages (Sundell 2000).

Bhat et al. (2012) reported that the young, elderly and physically ill, especially those suffering from respiratory or cardiovascular diseases, are more susceptible to the effects of indoor air pollution such as acute lower respiratory infections since they fall within the group of people who may be exposed to indoor air pollutants for longer periods of the time. Processes such as mechanical recycling and composting within the landfill site give rise to high levels of particulate matter. Chalvatzaki et al. (2010) states that large amounts of solid waste are disposed of in landfill sites and the potential of particulate matter emissions into the atmosphere is significant.

2.6 Respiratory health assessment

Personal evaluation of respiratory health is very important in assessing, confirming and diagnosing the impact of foreign agents like dust. The instruments used to assess such impact includes the use of a standardised respiratory questionnaire and spirometer. The procedure used when assessing respiratory health conditions using a spirometer is called spirometry.

2.6.1 Assessment of respiratory health symptoms

A Child Health Screening Questionnaire, which was a modification of standardised validated questions from the American Thoracic Society and the British Medical Research Council (eThekwini Municipality. 2007, Reddy et al. 2012), was used to collect children's respiratory health data. The British Medical Research Council Questionnaire (MRCQ) was developed by a group of renowned Medical Research Council (MRC) researchers in the UK, as a tool to study respiratory epidemiology in communities and occupational groups (Cotes et al. 2007). Before the establishment of the MRCQ, different survey questionnaires were administered in different communities to establish the prevalence of common respiratory symptoms associated with chronic bronchitis and those symptoms varied greatly. Hence the standardisation of the questions became important so that the same participants are likely to be classified in the same way by independent observers to minimise bias (Cotes et al. 2007).

The MRCQ is recommended for use in epidemiological and occupational respiratory surveys and as part of a consultation for respiratory symptoms of assessment of lung function (Cotes et al. 2007). In its original form, it comprised 17 questions on respiratory symptoms (cough, phlegm, breathlessness, wheeze and chest illnesses) (Cotes et al. 2007). The MRCQ paved the way for the establishment of other standardised questionnaires including the questionnaire from the American Thoracic Society (Tore'n et al. 1993).

2.6.2 Lung function testing

Since the above standardised questionnaire is solely based on caregiver recall of events, spirometry is also used to confirm the detected symptoms. Spirometry is the procedure that is performed to measure the lung function. It is also alternatively referred to as the lung function test. The equipment used to measure lung function is called spirometer which comes in several different forms from various manufactures. Most spirometers display graphs, called spirograms. It specifically measures the amount (volume) and/or speed (flow) of air that can be inhaled and exhaled by an individual at a given time. Spirometry is an important tool in assessing conditions such as asthma, pulmonary fibrosis, cystic fibrosis, and Chronic Obstruction Pulmonary Disease (COPD) (Reynolds 2011).

The basic forced vital capacity (FVC) test varies slightly depending on the equipment used. Generally, the patient is asked to take the deepest breath they can, and then exhale into the sensor as hard as possible, for as long as possible (preferably at least 6 s). It is sometimes directly followed by a rapid inhalation, in particular when assessing possible upper airway obstruction. Sometimes the test will be preceded by a period of quiet breathing in and out from the sensor (tidal volume), or the rapid breath in (forced inspiratory part) will come before the forced exhalation. During the test, soft nose clips may be used to prevent air escaping through the nose and filter mouthpieces may be used to prevent the spread of microorganisms. These filters are changed after each person has performed spirometry. Normal values are based upon age, height, ethnicity, and sex and normal results are expressed as a percentage (Reynolds 2011).

Levy et al. (2004) mentioned that children in urban public housing are at high risk for asthma, given pre-eminent environmental and social exposures. For that reason, epidemiological studies have used spirometry to measure the lung function in children to measure association between lung function and environmental and social exposures (Enright et al. 2000, Levy et al. 2004).

A study of 78 children (aged between 4 and 17 years) from three public housing developments in Boston conducted by Levy et al. (2004) to better understand risk factors for asthma morbidity found that only 36% of children with persistent asthma reported being prescribed any daily controller medication, and most did not have an asthma action plan or a peak flow meter. One-time lung function measures were poorly correlated with respiratory symptoms or quality of life. In this study, for the subset of 49 children aged six or older who were able to perform spirometry, the mean FEV1% was 88% (median of 88%, standard deviation of 15%). Twenty-nine percent of children had FEV1 less than 80% of predicted. However no values were less than 60% of predicted. The mean PEF% was 97% (median of 96%, standard deviation of 17%). Twelve percent of children had a PEF less than 80% of predicted and none had a PEF less than 60% of predicted (Levy et al. 2004).

A cross-sectional study comprising 549 (76.7%) children and 167 (23.3%) adults was carried out in Malaysia where a pulmonary function test was conducted using SCHILLER SP-260 spirometer (SCHILLER AG, Baar, Switzerland). The study found that asthma in all participants who had symptoms of asthma based on self-reported asthma or who were currently on medication was confirmed by lung function test (spirometry) as bronchial asthma. There was an overall prevalence of 1.4% (10 of 716) (Ngui et al. 2011). Asthma is a critical chronic disease and a significant public health problem and its prevalence is on the rise in all regions of the world, affecting all ages but more commonly children (Ngui et al. 2011).

Of note, though is that all confirmed cases were from children between the ages of 7 and 12 years. These results highlight the importance of spirometry in confirming the true prevalence of asthma since there is a potential for the misdiagnosis of asthma if questionnaire and self-reporting are the only tools used for diagnosing asthma. Enright et al. (2000) emphasise the importance of a quality assurance (QA) program when performing spirometry testing. They emphasize that, in epidemiological studies where spirometry results are a primary outcome measurement, the results depend not only on the true lung function of participants, but also on the quality of their test performance. It is due to that reason that the 1994 American Thoracic Society (ATS) criteria for satisfactory spirometry performance is based almost exclusively on studies of adults (American Thoracic Society 1995).

To ascertain whether these criteria are suitable for younger populations, Enright et al. (2000) reviewed the spirometry data from three successive years of testing in the Children's Health

Study and found that most of the children met adult-based ATS criteria for spirometry test performance. However, age group-specific criteria are needed to ensure adequately fast peak expiratory flow (PEF) and reproducible PEF values.

2.7 Legislative and regulatory framework to address $PM_{2.5}$

South Africa is among those countries which adopted the $PM_{2.5}$ standard based on international dose-response evidence. In 2004, the National Environmental Management: Air Quality Act No 39 of 2004 (Republic of South Africa 2004) came into effect. This legislation transferred the focus on air quality management from the source to the receiving environment. However, no ambient air standards for $PM_{2.5}$ were included. Since 2004, there has been growing international evidence (i.e. epidemiological studies linking adverse health effects to $PM_{2.5}$ exposure) to suggest that there was a need in South Africa for $PM_{2.5}$ guidelines and/or standard. As a result, a new national ambient air quality standard for $PM_{2.5}$ was promulgated in 2012. Whilst it is commended that South Africa is taking $PM_{2.5}$ seriously, it is important to note that South Africa still lags behind when compared to other international standards. In fact South Africa has the highest daily concentration limit (65 µg m^{-3}). This unfortunately suggests that South Africa will still endure extensive impact of $PM_{2.5}$ for many years to come. In recent years PM has received attention from countries and agencies due to the health effects $PM_{2.5}$ has in human beings. Some initiatives include the development of standards and guidelines specific to $PM_{2.5}$. Those standards and guidelines are given in Table 2.1.

Table 2.1 National and international $PM_{2.5}$ standards

Standard	Average time	Concentration (µg m^{-3})
US Environmental Protection Agency	24 h	35
	Annual	15
World Health Organization	24 h	25
	Annual	10
South African National Ambient Air Quality Standard for Particulate Matter (NAAQS)	24 h	65
	Annual	25
Canadian Ambient Air Quality Standards	24 h	28
	Annual	10
Indian Ambient Air Quality Standard	24 h	60
	Annual	40

The main aim of this study was to determine respiratory health symptoms and outcomes in children aged between 6 and 12 years who live within a 2-km radius from the Bisasar Road landfill site and to establish if there is a relationship between those respiratory health outcomes and the close proximity to the landfill site. It also intended to determine community experiences regarding the landfill site and its health impacts. Against this background, this chapter provides a review of the air pollution management in South Africa; it defines $PM_{2.5}$ and its association with respiratory effects in humans; reviews the impact of landfill sites in the adjacent communities; defines indoor air quality; describes the respiratory health assessment procedures used in this study; and lastly, the international legislative and regulatory framework to address $PM_{2.5}$ is reviewed.

CHAPTER 3: ENVIRONMENTAL AND PERSONAL RISK FACTORS ASSOCIATED WITH THE RESPIRATORY SYMPTOMS IN CHILDREN RESIDING NEAR A LANDFILL SITE (PAPER 2)

3.1 Abstract

The importance of understanding the indoor environment in an environmental health study cannot be over emphasised. It is therefore important to understand how the housing structure and social behaviour of the residents contribute to the levels of the indoor pollution exposure. This study was conducted in an informal and formal household in the community of Clare Estate in Durban, South Africa. The main objective of the study was the characterization of the household within a 2-km radius from a landfill site with a view to identify potential environmental and personal risk factors associated with the prevalence of respiratory symptoms. A purposive sampling strategy was used to sample 157 households. The selected households were those with children aged between 6 and 12 years. A walk-through checklist (WTC) was used to gather data on home characteristics. Whilst the walkthrough investigation was conducted through questioning of an adult respondent about home characteristics associated with indoor sources of particulate matter, observations were conducted to collect data about the type of the house, conditions i.e. water damaged surfaces, moist and damp floors, moisture problems, ventilation, heating and fungal growth in different areas of the house. The study established that most households utilized electricity as a source of energy and as a result very few households had smoke from cooking or heating in the house. Whilst household pests and settling dust were found to be the possible source of poor indoor air quality, little visible mould and moisture of dampness damage was observed. The study therefore concludes that household pests and settling dust could be the possible environmental risk factors that could contribute to the indoor air pollution.

Keywords: *Air pollution, dwellings, indoor air quality, $PM_{2.5}$, respiratory health*

3.2 Introduction

The health impact of air pollution in human beings has been reported in both developed and developing countries. However, the impact of indoor pollution as a result of the outdoor pollutants has not been well investigated in South Africa. The need to investigate health effects of indoor air pollution is therefore increasing. The literature has shown that people spend most of their time in confined environments, especially at home, and the concentration of some air pollutants may be greater indoors than outdoors (Morawska et al. 2001, Palmiotto et al. 2014, Saksena and Smith 2003). Globally, about 40% of the population still rely on solid fuel. Hence indoor air pollution presents major risk factors for chronic obstructive pulmonary diseases (Pope et al. 2015). Smith (2007) reveals that poor indoor air quality poses a risk to the health of over half of the world's population, especially affecting poor people.

One major source of indoor air pollution is tobacco smoke. Tobacco contains more than 4,500 compounds and out of them, more than 250 chemicals are known to be toxic and more than 50 can cause cancer (Baena-Cagnani 2009). In indoor environments where people smoke, tobacco smoke is the major source of particulate matter. Formaldehyde is another hazardous pollutant found indoors. It is mainly produced by off-gassing from wood-based products and can also be generated by cigarette smoking, painting, or the use of varnishes and floor finishes (Salo et al. 2009). VOCs are also chemicals found in an indoor environment and are chemical compounds including aromatic hydrocarbons, aldehydes, aliphatic halogenated hydrocarbons and terpenes (Salo et al. 2009).

Poor indoor air quality is associated with respiratory diseases (Hulin et al. 2012). Indoor human behaviour has been associated with respiratory health conditions such as asthma (Hulin et al. 2012). Those activities include among others, chemical pollutants, materials or activities, such as recent painting or new wall covering, volatile organic compounds (VOCs), gas appliances, or exposure to particles through environmental tobacco smoke (ETS) or heating appliances using wood/coal. The household structure itself can be polluted by bio-contaminants, such as allergens, moulds and endotoxins, and chemical air pollutants, such as nitrogen dioxide, particulate matter, formaldehyde and VOCs. Jafta (2007) indicates that many studies associated morbidity with household conditions or characteristics. Household conditions such as dampness, humidity and visible fungal growth is considered to be a risk factor in the development of respiratory illnesses or respiratory symptoms like, wheezing, persistent cough and breathlessness (Spengler et al. 2004, Simoni et al. 2005).

The presence of water, nutrients or elevated ambient temperature within the households facilitates the multiplying of moulds, cockroaches and mites, thus increasing the concentration of allergens (Hulin et al. 2012). Major sources of mould growth indoors are floods, leaks in building fabric, condensation, unattended plumbing leaks and household mould. Mould is the most studied respiratory effect of biological pollutants in the indoor environment since it is the most common allergen. Mentese et al. (2015) have reported the association between exposure to indoor allergens and respiratory health. In a developed country such as the United States of America, allergic sensitisation has been associated with more than half of all asthma cases (Salo et al. 2008).

Indoor dampness or mould are consistently associated with increased asthma development and exacerbation, current diagnosis of asthma, dyspnoea, wheeze, cough, respiratory infections, bronchitis, allergic rhinitis, eczema, and upper respiratory tract symptoms in both allergic and non-allergic individuals (Mendell et al. 2011). The WHO (2009) has affirmed that there is sufficient evidence to conclude that a relationship exists between exposure to indoor dampness and eight outcomes including asthma exacerbation/development and wheezing. Presence of some of these conditions has been linked to proliferation of biological pollutants such as house dust mite, cockroach and fungal allergens (Howden-Chapman et al. 2005).

About 3 billion people rely on solid fuels (wood, animal dung, agricultural wastes, charcoal, and coal) for cooking/heating, with little or no access to modern forms of energy (Smith 2004, Bonjour et al. 2013). The World Health Organization (WHO) reports that, globally, about 1.5 billion people have no access to electricity, and more than 80% of them live in sub-Saharan Africa and South Asia (WHO 2009). Hence, solid fuel becomes an obvious option, especially in poverty stricken communities. Exposure to biomass fuels is a major health concern in the developing world since it is associated with asthma, especially for children and females, who generally spend most of their time in the kitchen cooking (Budds et al. 2001).

Whilst the outdoor influence on indoor environment is important, indoor factors that can exacerbate negative influences on respiratory health are equally important. Indoor air pollution is the eighth most important risk factor, responsible for 2.7% of the global burden of disease (between 1.5 and 2 million deaths yearly) (Viegi et al. 2004). The indoor environment is sometimes an epicentre of the health effects. In this study a walk-through survey checklist was used to assess the indoor environment in households near Bisasar Road landfill site, Durban, South Africa. This was performed in order to understand indoor air pollution sources which could have an impact on respiratory health other than the landfill site as an external source.

Environmental health studies that have investigated indoor environments utilise questionnaires or walkthrough checklists as investigative instruments to describe indoor environment and to identify conditions or possible sources of pollutants (Escamilla-Nuñez et al. 2008, eThekwini Municipality 2007, Jafta 2007). Using a checklist or questionnaire needs constancy and therefore, data collectors need to be skilled in order to be able to conduct data collection using such an instrument. Data from different studies show that questionnaires and walkthrough checklists can be used for assessing households for exposure indicators such as dampness, visible fungal growth, ventilation, flooring type and presence of other characteristics that are associated with the proliferation of biological pollutant sources (Jafta 2007).

Although different studies have led to different conclusions regarding the use of home characteristics as indicators of risk factors of exposure within homesteads, the use of this instrument does provide baseline information which is important in the identification of possible confounders. The main aim of this paper was the characterization of the household within a 2-km radius of the Bisasar Road landfill site with a view to identify potential environmental and personal risk factors associated with the prevalence of respiratory symptoms using a standard survey instrument.

3.3 Materials and methods

3.3.1 Location of the study

The study was conducted in Durban in KwaZulu-Natal (KZN), South Africa. Research was conducted in the Clare Estate community in the eThekwini Municipality, a Category A (metropolitan council) municipality situated along the east coast of South Africa in KZN. EThekwini Municipality is one of the eleven municipal districts of KwaZulu-Natal. It spans over an area of approximately 2,297 km^2 (eThekwini 2015). It comprises 99 municipal wards, and a population size of 3,442,358 (COGTA 2011).

3.3.2 Sample selection

A sample of households in Clare Estate was selected for the household indoor environment assessment. A purposive sampling strategy was used to sample 157 households. The selected households participating in the indoor assessment were households with children between 6 and 12 years old. These households were participating in the child health screening questionnaire (UKZN questionnaire protocol number BE201/11). Study participants were recruited from their homes by research assistants guided by the inclusion criteria:

- children residing in households situated within a 2-km radius of the landfill sites; recruited to participate;
- children between the age of 6 and years and 12 at the beginning of 2012;
- children who resided within the defined area (2 km) for a period of 5 years or above;
- parents or child caregivers who were 18 years old and older; and
- parents or caregivers who resided with a child for a period of at least 5-years.

Potential households were recruited by house-to-house visits to homes within a 2-km radius of the Bisasar Road landfill site. The indoor assessment was conducted with the parent, child caregiver or other adult person living with the child in that particular household. Written or oral consent was obtained from the participating households before an assessment was conducted in the households. The walkthrough investigation was conducted through observations and questioning.

3.3.3 Data collection

Data were collected by a walkthrough evaluation of the homes using an instrument that was used in the South Durban Health Study (eThekwini Municipality 2007). A walk-through checklist (WTC) (Appendix E) was used to gather data on home characteristics. WTC is a standardised instrument which was previously field tested and used in a Community Action Against Asthma CAAA) project in Detroit in the United States of America (Baldwin 2003). This walkthrough questionnaire was modified to be specific to South African environments, with questions directed at both formal and informal homes included e.g., roofing made of tarpaulin (sail), or asbestos, or corrugated iron, or presence and absence of ceiling; and walls made of materials such as corrugated iron sheets, or cardboard (Jafta 2007). The main purpose for using this questionnaire was to investigate children's exposure to indoor pollutants. Hence, sleep areas, play areas and kitchens were evaluated since children spend more time in these areas.

The WTC comprised questions for room-by-room observations together with oral questions to an adult respondent or child caregiver aimed at collecting data about home characteristics associated with indoor sources of particulate matter. Observational questions were about the type of house, building age, conditions of the resident i.e. water damaged surfaces, moist and damp floors, moisture problems (sources, indicators), ventilation, heating and fungal growth in different areas of the house.

3.3.4 Data analysis

Data collected were captured into Microsoft Excel software by research assistants and double captured by the researcher before they were analyzed. Data were captured as coded in the WTC. In this study "Yes was represented by "1"; "No was represented by "2" and "Don't know was represented by "8". Similarly, other questions were captured as coded in the WTC using codes 1 to 6 (refer to Appendix E). Frequency distributions were presented from data obtained.

3.4 Results and discussion

A total of 157 households where there were children aged between 6 and 12 years old participated in the study. These children had lived in the household for at least five years. The study was conducted in both informal and formal dwellings situated within a 2-km radius of the Bisasar Road landfill site in Clare Estate. Previous studies have associated the respiratory health of children with outdoor pollution. However, children's exposure to air pollution cannot only be attributed to outdoor air pollution. Hence the indoor air quality is equally important. The quality of housing conditions has a major role in the health status of the residents, since many health problems are indirectly or directly related to the building itself. This includes the construction material used and the type of structure of the individual household (Al-Khatib et al. 2001). Poor housing structure can also increase air pollution exposure levels (Shirinde 2014, Muindi et al. 2014).

It is therefore important to understand how the housing structure and social behaviour of the residents contribute to the levels of the indoor pollution exposure. This descriptive study found that most households were built in or prior to 1978. This was the time after the relaxation of the apartheid laws in South Africa to allow black communities to build homes in some parts of Durban where they were previously prevented from doing so. The relaxation of the apartheid laws presented opportunities for the establishment of both formal and informal dwellings closer to the city of Durban.

3.4.1 Home characteristics

Table 3.1 summarizes characteristics of the homesteads which participated in the study. The home characteristics were collected using a WTC survey which was mainly an observational instrument. This instrument made provision for the interviewer to ask questions from participants to substantiate the observed evidence. Out of 157 households, 36.3% were single family homesteads; 20.4% were duplexes or flats; 12.7% were apartment buildings and 30.6% were shacks or informal dwellings. Most (43.9%) houses were built in 1978 or later, whilst 23.6% were built before 1978. About 33% of the respondents did not know when the house was built. This includes those who inherited these houses from relatives, or who were renting, and those who owned houses but could not remember when the house was built. Collectively, about 77% of the respondents knew when their home was built. This shows a high level of awareness of residents about their homes.

Borgini et al. (2015) concluded that personal exposure to indoor pollution is strongly influenced by different microenvironments and should be considered in population studies. Hence, it is vital for this study to reports on type of construction materials used. The study found that 70.7% of the houses were constructed with bricks whilst 14.6% were constructed with wood. Most (52.3%) houses were roofed with roof tiles. About 10.8% were roofed with asbestos and 36.3% with either sails or other roofing material. Thirty percent (30.6%) had their floors covered with cement and 20.4% were covered with carpet. Carpeted floors are capable of trapping dust particles. However, if neglected, carpet can become filled with dust to the extent that it can no longer hold dust anymore. At that point dust is likely to become a releasing source for dust particles and that can cause respiratory health problems. In this study carpeted floors were found to be slightly lower than the 25% reported in a study conducted in Durban (Jafta 2007) and the 34% of reported in a study conducted in Mexico (Escamilla-Nuñez et al. 2008). About 44% were covered with other materials like mats and plastic covers whilst 5% were not covered at all.

Table 3.1 Characteristics of participating homesteads (n = 157)

Variable		**n (%)**
Type of home		
	Single family house	57 (36.3)
	Duplex or flat	32 (20.4)
	Apartment building	20 (12.7)
	Other	48 (30.6)
Number of rooms in a house		
	1	35 (22.3)
	2	34 (21.7)
	3	31 (19.7)
	4	23 (14.6)
	5	17 (10.8)
	6 or more	17 (10.8)
Date when the house was built		
	Before 1978	37 (23.6)
	1978 or after	69 (43.9)
	Don’t know	51 (32.5)
Home construction material		
	Wood	23 (14.6)
	Brick	111 (70.7)
	Other	23 (14.6)
Roof type		
	Roof tiles	83 (52.9)
	Asbestos	17 (10.8)
	Tarpaulin (sail)	17 (3.8)
	Other	51 (32.5)
Type of floor covering		
	Wood	9 (5.7)
	Cement	48 (30.6)
	Earth	9 (5.7)
	Carpet	32 (20.4)
	Other	59 (37.6)

3.4.2 Cooking habits

Most households prepare meals indoors using electricity. Cooking inside the house has been reported in other studies as a potential source of indoor air pollution depending on the type of energy source used. Of the 157 households which participated in the study, an overwhelming 80% cooked inside their houses most of the time in a week, whilst 5% were cooking inside the house occasionally and 15% had never cooked inside the house. Although most (64%) homes did not have a ceiling separating the underside of the roof, most (79%) households had openable windows as a mitigating factor to allow the indoor air pollution to escape from the building. As a result, only 24% of households had evidence of smoke deposits from cooking or heating on walls, ceiling or underside of roof. Of the 24% only 2% had heavy smoke deposits and the remaining 22% had moderate smoke deposits.

This could be attributed to the fact that most (87%) households used electricity for cooking and most (73%) of them did not heat the house during cold days. The few households that used other fuel or energy sources for cooking only used paraffin (10.8%) and wood (0.6%). On the other hand, the majority of those who heated their houses during the cold season used an electric heater (24.2%) with only few (2.5%) using paraffin/kerosene heaters and 1% used other means. The lower number of people heating their homes could also be due to the ever warm environment of Durban. The type of fuel used in households for either cooking or heating the house is determined mainly by the household economic status and determines the potential impact of respiratory health outcomes (Singh et al. 2011). The fuel or energy sources used for either cooking or heating the house are presented in Figures 3.1 and 3.2.

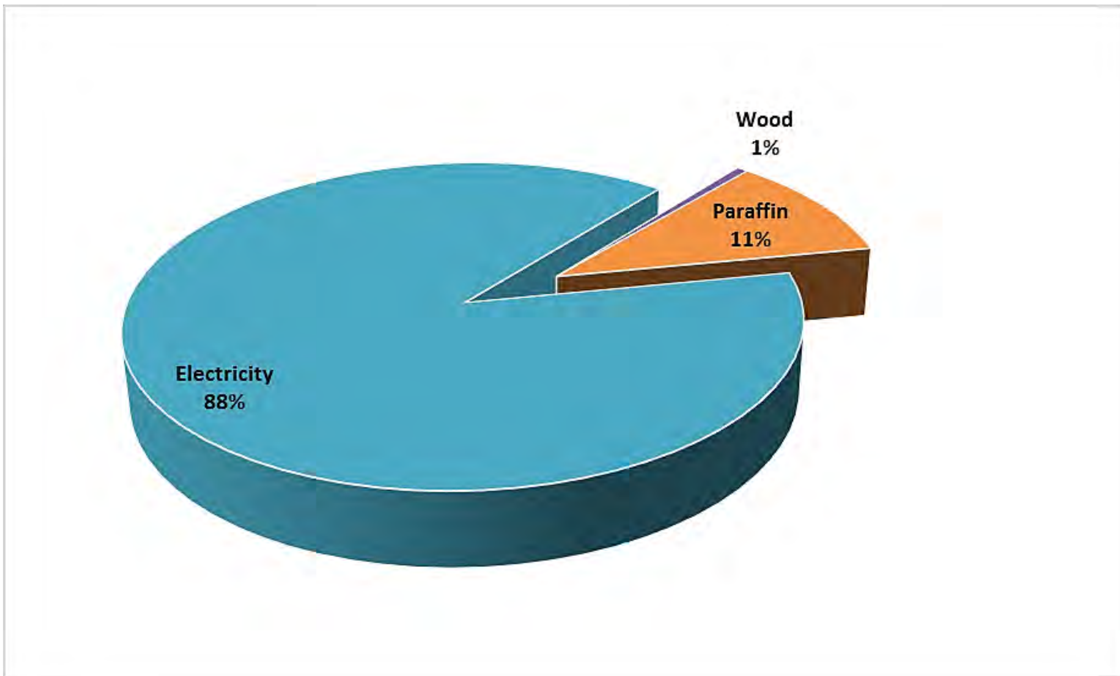

Figure 3.1 Sources of energy used for cooking

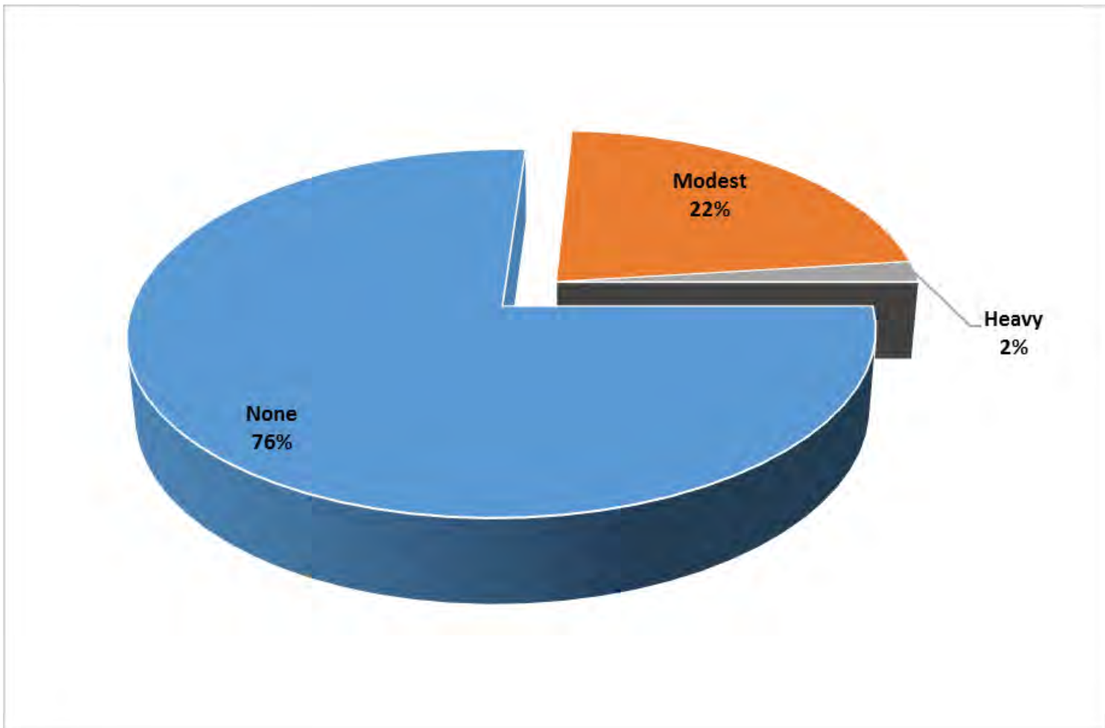

Figure 3.2 The presence of smoke from cooking and heating of the house

3.4.3 Environmental risk factors

Environmental risk factors contribute to the indoor air pollution and may have respiratory health effects for the occupants. The environmental factors in this study include evidence of settling dust, peeling paint, signs of water damage, moisture, or leaks on floors and walls, visible mould or mildew (including musty or mildew smell), tobacco smoke (including cigarette butts and cigarette smell), and presence of cockroaches. The summary of the environmental risk factors is presented in Table 3.2.

Table 3.2 Environmental risk factors

Composite name	Response	n (%)
Settling dust	Yes	88 (56.1)
	No	69 (43.9)
Peeling paint	Yes	46 (29.3)
	No	111 (70.7)
Water damage, moisture, or leaks on wall	Yes	37 (23.6)
	No	120 (76.4)
Water damage, moisture, or leaks on floor	Yes	37 (23.6)
	No	120 (76.4)
Visible mould or mildew	Yes	34 (21.7)
	No	123 (78.3)
Environmental tobacco smoke	Yes	45 (28.7)
	No	112 (71.3)
Cockroaches	Yes	106 (67.5)
	No	47 (29.9)
	Missing	4 (2.6)

Boquette et al. (2006) indicate that fungal growth is not only problematic in developing countries since it has also been observed in first world countries in Europe. However, in this study only 22% had visible mould, which is relatively in the same range as the findings of a study conducted in Durban (Sekhotha et al. 2000), which found an evidence of fungi in 30% of households. Jafta (2007) also found fungal growth in 26% of the homes, which is also in the same range as this study. The results of this study were consistent with the water damage, moisture or leaks on the walls and on the floors. Only 24% of the houses had water damage, moisture or leaks on the walls and floors, respectively. The findings of the study were contrary to the Detroit study which found that most (87%) homes had some water damage on the floors, walls or ceilings (Du et al. 2010). This study confirmed the result by Sekhotha et al. (2000) and Jafta (2007) that the prevalence of fungal growth in Durban homes is limited. On the other hand, the results of this study show more than half (56%) of the households had evidence of settling dust and manifestation of cockroaches, which was reported in 67.5% of the households. Insects such as cockroaches are believed to play a significant role in indoor air quality. Research has proved that cockroaches are strongly linked to asthma and allergic reactions in the upper respiratory tract (Spengler et al. 2001). Environmental tobacco smoke was relatively minimal. About 29% of house households had visible tobacco butts, or cigarette smell, or reported smoking.

3.5 Conclusions

The main aim of this paper was the characterization of the household within a 2-km radius from Bisasar Road landfill site with a view to identify potential environmental and personal risk factors associated with the prevalence of respiratory symptoms using a standard survey instrument. An indoor investigation was conducted using a walkthrough checklist survey. The procedure included both observation and questioning techniques in order to properly characterise the indoor environment. The indoor assessment procedure is a crucial tool since it does not only point to or indicate sources of indoor pollution but is helpful in gauging the extent of indoor environment pollutants when pollutants are identified.

This study presents significant findings in understanding the characteristics of the homes and the possible sources of the indoor air pollution. This is useful in foregrounding the respiratory health of children in those homes. The study found that most households were not heated during cold days and the few who heated their homes used electrical heaters. They also used electricity as a source of energy. Hence very few households had smoke from cooking or heating of the house. Whilst cockroaches and settling dust were found to be possible sources of poor indoor air quality, very little visible mould and moisture or dampness was observed. The associations made about the extent of moisture or dampness with visible fungal growth is vital. In some cases dampness can be observed but no visible fungal growth identified. The study therefore concludes that household pests - cockroaches in this case, and settling dust - could be the possible environmental risk factors that could contribute to the indoor air pollution.

CHAPTER 4: THE RESPIRATORY HEALTH CONDITIONS IN CHILDREN RESIDING NEAR THE LANDFILL SITE (PAPER 3)

4.1 Abstract

The study investigated the respiratory health conditions in children residing in Clare Estate located within a 2-km radius of South Africa's largest landfill site, Bisasar Road landfill site in Durban, South Africa. This cross sectional study was conducted to report parental-reported child health conditions as an indication of the prevalence of respiratory health problems. For this study, chronic symptoms and conditions refer to "wheezing, breathlessness, asthma, reactive airway disease, asthmatic bronchitis, and eczema" Current wheeze was defined as "wheeze" that occurred within the past 12 months period of data collection visit. A standardized respiratory health questionnaire adopted from the American Thoracic Society division of lung disease was modified and utilised to collect data on children's respiratory health conditions from parents or caregivers. It contained questions relating to frequent and chronic respiratory symptoms including cough, phlegm, wheeze and shortness of breath. Before participating in the study, verbal or written consent was obtained from 157 parents or guardians who provided respiratory data about 181 children aged between 6 and 12 years. The study found that 38 (20.9%) children had experienced breathlessness in the past 12 months. About 43 (23.7%) were reported to have had wheeze in their lifetime and 77 (42.5%) had experienced wheeze in the 12-month period. Of the 77 children who were reported to have had current wheeze, 43 (55.8%) had current severe wheeze. About 66% of children were reported having been diagnosed by a doctor for at least one respiratory condition. Asthma recorded the highest proportion (20%) of parent/caregiver report of doctor-diagnosis. Other parent/caregiver report of doctor-diagnosis were allergies (18%), eczema (10%), chronic bronchitis (8%), and reactive airway disease (4%) respectively. Breathlessness, wheeze and asthma were found to be high in children living in Clare Estate.

Keywords: *Asthma, breathlessness, landfill site, particulate matter, respiratory health, wheeze*

4.2 Introduction

Air quality and health of the community are intertwined and are key environmental and public health matters that need protection as affirmed in the Bill of Rights in the Constitution of the Republic of South Africa. The state of air quality depends on the quantities of natural and human-induced emissions in the atmosphere, as well as on its potential for dispersing and removing pollutants from the atmosphere (Department of Environmental Affairs 2009). The World Health Organization (WHO) reported that globally, 7 million deaths are attributed to the joint effects of household and ambient air pollution in 2012 (WHO 2014). Of these deaths, 3.7 million deaths are attributable to ambient air pollution (AAP), whilst 4.3 million are attributed to indoor air pollution (IAP). In Africa alone, 679,000 of the deaths are attributed to both AAP (176,000 deaths) and IAP (581,300).

Reporting on the World Health Organization Ambient Air Pollution Database by countries is still a challenge, particularly in Africa. Out of 194 countries that participate in the WHO Ambient Pollution database, only 47 countries are from Sub-Saharan Africa (WHO 2014). Measuring the impact of air pollution in cities around South Africa is thus still a challenge since there is only partial data on exposure levels to air pollution and adverse effects on health in local settings. Air pollution monitoring efforts tend to focus on 'air pollution priority areas', like Durban South Basin and Vaal Triangle. There are now more air quality monitoring stations around the country that are monitoring $PM_{2.5}$, but they are still situated in air pollution priority areas. Only a few of the air monitoring stations are positioned to monitor population exposure in those areas, which then makes it difficult to assess general exposure to air pollution (Norman et al. 2007). In South Africa, particulate matter (PM) is the pollutant of major concern since reliance on fossil fuels such as coal fired power plants and the use of biomass for cooking and heating is still at its highest level. Particulate matter with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$), that is notorious for its ability to penetrate deep into the lungs and pass into the blood stream, is of particular interest in this investigation.

According to the Department of Environmental Affairs and Tourism (2010), some strides have been made in South Africa in addressing air pollution in recent years. However, more needs to be undertaken in order to identify and reduce air pollution sources. Currently, there are few monitoring stations capable of measuring the ambient $PM_{2.5}$, and little exposure and toxicity (dose-response and health outcomes due to $PM_{2.5}$ exposure) data are available (Environmental Affairs and Tourism 2010). Source identification of air pollution is still a challenge for many countries, including South Africa. Mahajan (2011) indicates that many pollutants remain in the environment for extended periods of time, and are carried away by winds hundreds of kilometres from the source. Hypothetically, communities residing near the source of air pollution are more exposed to pollutants such that the probability of them being highly impacted by pollutants is higher than those further away from the pollutant. This study focuses on the impact of $PM_{2.5}$ on children living in close proximity to Bisasar Road landfill site, which is one of the biggest landfill sites in Africa.

Communities living near air pollution-generating sources such as solid waste disposal sites are exposed to various pollutants in their homes since airborne emissions are carried to the surrounding communities by wind currents. Children are at higher risk than adults for exposure to pollutants emitted from waste sites since they spend more time outdoors and are also likely to inhale higher concentrations of dust, soil, and heavy vapours from the ground, because of their height (Palmiotto et al. 2014). Landfilling is still the main waste disposal method utilised in South Africa, especially in urban areas such as the eThekwini Municipality. Currently, there are no regulations that stipulate the buffer zone between the community and a landfill site.

Bisasar Road landfill site is reputed as Africa's largest formal municipal landfill site which processes up to 5,000 tonnes of solid waste delivered by approximately 1,000 vehicles each business day (Hallowes et al. 2008). Operations commenced in 1980 in the largely Indian suburb of Clare Estate and it is permitted to receive general waste only (GAIA 2011). It is managed by Durban Solid Waste (DSW). The landfill site is located in the western area of the city of Durban. On the fence-line of Bisasar Road landfill site, there is the Kennedy Road informal settlement which houses some 6,000 people in tightly packed shacks made of wood, corrugated iron, tarpaulins and plastic sheeting. The settlement grew after the relaxation of the apartheid laws in the late 1980s (Hallowes et al. 2008). Most of these residents are Africans who were displaced from their ancestral homes subsequent to the infamous Group Areas Act of 1950 (Act 41 of 1905) and more recently, land taken away from them in 1986 without compensation to make way for the Inanda Dam that supplies Durban with water (GAIA 2011). Most children from this settlement are transferred in ten public schools located within one square kilometre from the landfill site (GAIA 2011).

In developed countries, several studies have identified significant associations between air pollution and daily mortality and various markers for acute respiratory morbidity, including hospital admissions, hospital emergencies and outpatient clinic visits, exacerbation of respiratory symptoms, lung function changes (Borgini et al. 2015). The association between air pollution and school absenteeism has been reported in South Africa. However, there are limited studies on the respiratory health effects in children due to landfill sites. Chronic obstructive pulmonary disease (COPD) is a leading cause of morbidity and mortality worldwide (Celli et al. 2015). The objective of this study is to determine the respiratory health outcomes in children living near the Bisasar Road landfill site using both the self-reported, standardised questionnaire and spirometry. This investigation characterises the respiratory health symptoms and spirometric lung function patterns using a standardised questionnaire and spirometer to establish the respiratory effects of being in close proximity to the landfill site.

4.3 Materials and methods

This cross sectional study was conducted in Clare Estate located in Durban at eThekwini Municipality, South Africa. The population of Clare Estate is diverse, comprising a combination of formal and informal dwellers who are mainly Africans and Indians. This settlement is located close to the Bisasar Road landfill site which is approximately 6 km away from the city of Durban.

Although spirometry is recommended as a basis for diagnosing impaired lung function (Global Initiative for Chronic Obstructive Lung Disease 2006), it is not always possible to use it exclusively in field research as it is costly and fragile to transport. Therefore, the respiratory symptom-based questionnaires can be an alternative and cost effective tool to enable the identification and diagnosis of patients with respiratory illnesses (Abbasi et al. 2012). In developing countries, including South Africa, issues of accessibility and scarcity of resources require the use of alternative methods particularly in distant rural areas (Abbasi et al. 2012). Price et al. (2006) urges that symptoms based on questionnaires can be a useful adjunct in the screening of population for respiratory illnesses when used in conjunction with spirometry.

A number of respiratory questionnaires with questions on symptoms of chronic obstructive pulmonary disease (COPD) and asthma were developed (Leite et al. 2008, Shin et al. 2010). The American Thoracic Society Division of Lung Disease questionnaire (ATS-DLD-78A) is a generally used questionnaire for identifying the respiratory symptoms (Ferris 1978). It contains questions relating to frequent and chronic respiratory symptoms including cough, phlegm, wheeze and shortness of breath (Abbasi et al. 2012).

Respiratory health conditions of children were collected without assessing the source of pollution attributed to the presented respiratory conditions. Ideally, the individual sources of pollution must be assessed to eliminate the effects of other variables that could possibly have an impact on the reported respiratory health conditions. During data collection, parents or caregivers were asked questions pertaining the children's respiratory health conditions and allergies. Those conditions include the occurrences of wheeze, breathlessness and the doctor's diagnosis. A parent/caregiver report of doctor-diagnosis included the following respiratory conditions: asthma, asthmatic bronchitis, allergies, eczema, chronic bronchitis, and reactive airway disease. The occurrence of wheeze was categorised into three segments, namely: ever wheezed, current wheeze, and current severe wheeze.

4.3.1 Sample selection

A total of 181 children aged between 6 and 12 years participated in the child health screening questionnaire. Children were recruited from 157 households in Clare Estate, Durban from house to house visits to homes within 2 km radius of the Bisasar Road landfill site. Study participants were recruited from their homes by research assistants guided by the following inclusion criteria:

- children residing in households situated within a 2-km radius of the landfill sites were enlisted to participate;
- children aged between 6 and 12 years at the beginning of 2012 were engaged to participate;
- children who have resided within the defined area (2 km) for a period of 5 years or longer were enlisted to participate;
- parents or child caregivers who were 18 years old and above were allowed to be respondents; and
- parents or caregivers who had resided with the said child for a period of at least 5 years were allowed to participate.

4.3.2 Data collection

A standardised respiratory health screen questionnaire was utilised to collect children's respiratory health data from parents or caregivers. Data was collected for a period of four months (September to December 2012). The study used a modified version of the American Thoracic Society Division of Lung Disease questionnaire (ATS-DLD-78A) to record the occurrence of respiratory symptoms. It comprised questions regarding frequent cough (defined as presence of cough on most days for three consecutive months or more during the year), chronic cough (defined as presence of cough for three consecutive months in a year), frequent phlegm (defined as bringing up phlegm on most days of the month, for three consecutive months or more in a year), chronic phlegm (presence of phlegm for three consecutive months in a year), frequent wheezing (whistling sound heard on expiration), chronic wheezing (whistling sounds heard on expiration for a year), shortness of breath Grade I (shortness of breath when hurrying on ground level or walking up a slight hill) and Grade II (dyspnoea defined as: walking slower than people of the same age on level ground because of breathlessness or having to stop to breath when walking at own pace on level ground), self-reported asthma (defined as respondent having had asthma) and physician-diagnosed asthma (defined as asthma confirmed by a doctor), chronic bronchitis (defined as chronic bronchitis confirmed by a doctor) (eThekwini Municipality. 2007, Abbasi et al. 2012, Reddy et al. 2012).

The Child Health Screening Questionnaire was administered by trained fieldworkers to qualifying parents and caregivers in households where there were children that met the inclusion criteria. The Child Health Screening Questionnaire incorporated questions regarding a child's demographic information and respiratory health symptoms, and a doctor's diagnosis of the respiratory health diseases.

This study used parent/caregiver report of doctor-diagnosis, and chronic symptom and condition recall to define the health outcome. For this study, chronic symptoms and conditions refer to "wheezing, breathlessness, asthma, reactive airway disease, asthmatic bronchitis, and eczema". In this study, the following health outcomes were computed, on the basis of positive answers from the written questionnaire: ever wheeze ["Does (child) ever sound wheezy or whistling], and [Has [child] ever had an attack of wheezing that has made him/her feel short of breath? For both questions, options were "yes" or "no".

Breathlessness of individual was defined as those who, according to the written questionnaire, responded positively (with a 'yes') to all three questions:

1. Is [child] troubled by shortness of breath when hurrying on level ground?
2. Does [child] get short of breath walking with other children of his/her own age on level ground?
3. Does [child] have to stop for breath when walking at his/her own pace on level ground?

Current severe wheeze was defined as those who, according to the written questionnaire, responded positively to all four questions:

1) "In the past 12 months, how often has your child had wheezing (a whistling sound from the chest) with a cold?" For this question, the parent or caregiver could select one of the following four options: a) more than once per month, b) three to 12 times in the whole year, c) once or twice in the whole year or d) never. Included in the definition of severe wheeze were those who wheezed more than once per month. 2) "In the past 12 months, how often has your child had wheezing (a whistling sound from the chest) without a cold?" 3) "In the past 12 months, how often has your child wheezed while exercising, running or playing?"4) "In the past 12 months, how often has your child had an attack of wheezing that made it hard to breathe or catch his or her breath?". For this question, the parent or caregiver could select one of the following three options: a) every day, b) more than two times per week, c) more than once per month d) three to 12 times in the whole year, e) once or two times in the whole year, and f) never. Included in the definition of severe wheeze for questions 2-4 were those who indicated every day or more than twice per week or more than one time per month.

3.3.3 Data analysis

The collected data about children's respiratory health was then captured into Microsoft Excel software by research assistants. Double data entry was performed by the researcher before the data was analysed. Descriptive statistics and frequency distribution were used to analyse and interpret data.

4.3.4 Ethical considerations

Study approval was sourced from the Ethics Review Committee of the Biomedical Research Ethics Committee of the University of KwaZulu-Natal (Ethical clearance number: BE201/11). Verbal and written informed consent was sourced from the participants.

4.4 Results

In this study, 181 children, aged between 6 and 12 years (mean + SD: 8.7 + 2.18) participated in the child health screening questionnaire. Questionnaires were administered to a total of 157 parents or guardians who gave verbal or written consent before participating. Parents or guardians provided data about children who met the inclusion criteria for the study.

4.4.1 Demographic data

The demographic characteristics and self-reported respiratory health conditions are presented (Table 4.1). The demographic data of the study population (n = 181) were gathered through a structured questionnaire to collate demographic characteristics for the participants. All these children had lived in the area from age five or more. These characteristics include basic information of the study population (Table 4.1). The average age of the participating children was 8.7 years and a higher proportion of the children were males (53%) when compared to 47% female counterparts. All children were attending school with a greater proportion (53%) at foundation phase (Grade R - 3). Of the 181 children, 35% were at intermediate phase (Grade 4-6) and 9% at senior phase (Grade 7-9) respectively. About 3% of the respondents did not know which phase children were in. Most children were Africans and Indians, with a marginal difference of 50% and 48% respectively. Only 2% of children were Coloured and none were White.

Table 4.1 Demographic characteristics of the study population (n = 181)

Variable	n (%)
Age (mean, SD)	8.7 (2.18)
Gender	
Male	96 (53)
Female	85 (47)
Educational levels	
Foundation phase (Grade R-3)	96 (53)
Intermediate phase (Grade 4- 6)	63 (35)
Senior phase (7 - 9)	16 (9)
Do not know	6 (3)
Race	
Blacks	90 (50)
Indians	87 (48)
Coloureds	4 (2)
Whites	0

4.4.2 Respiratory health conditions

Of the 181 children that participated in the study, 38 (20.9%) were reported to have experienced breathlessness in the past 12 months and 43 (23.7%) had wheezed (ever wheezed) in their lifetime. When probing, the study found that 77 (42.5%) had current wheeze in the 12-month period. Of the 77 children who were reported to have had current wheeze, 43 (55.8%) had current severe wheeze. About 66% of the participants reported having been diagnosed by a doctor for at least one respiratory condition. The highest proportion of a doctor's diagnosis was asthma 20%. Of those 4% was diagnosed specifically with asthmatic bronchitis. Other doctor's diagnosis were allergies (18%), eczema (10%), chronic bronchitis (8%), and reactive airway disease (4%) respectively. The self-reported respiratory health conditions and doctor's diagnosed conditions are summarised in Table 4.2.

Table 4.2 Respiratory health conditions of children (6 to 12 years) residing near the landfill site (n = 181)

Respiratory conditions	Frequency	Percentage (%)
Breathlessness		
Present	38	21
Absent	143	79
Ever wheezed		
Yes	43	23
No	118	77
Current wheeze		
Present	77	43
Absent	104	57
Current severe wheeze (n = 77)		
Present	43	55
Absent	34	45
Doctor's diagnosis (n = 119)		
Asthma	36	20
Asthmatic bronchitis	8	4
Allergies	33	18
Eczema	19	10
Chronic bronchitis	15	8
Reactive airway disease	8	4

4.5 Discussion

The study investigated the respiratory health outcomes of children living near the Bisasar Road landfill site in Durban, South Africa. The Bisasar Road landfill site is known to be the largest landfill site in southern Africa but little, if anything, is known about the respiratory impact it poses to children living in close proximity to the site. The proximity to the landfill presents challenges such as air pollution, especially particulate matter (Palmiotto et al. 2014). Considering the fact that children are more susceptible to the air pollution (Vrijheid 2000), this study seeks to establish if children (aged between 6 and 12 years) who reside in the vicinity of the landfill site are susceptible to respiratory effects which could be attributed to the landfill site.

In this study a modified version of the American Thoracic Society Division of the Lung Disease questionnaire (ATS-DLD-78A) was utilised to collect respiratory data of children. This tool was previously used in an International Study of Asthma and Allergies in Childhood (ISAAC) Phase One undertaken between 1992 and 1997. It studied the prevalence of symptom and severity of asthma, rhinoconjunctivitis and eczema between populations around the world to elucidate factors influencing these conditions (Asher et al. 2010). From that study, it was noted that the self-reported symptoms by adolescents themselves were higher than the reported symptoms by parents for the same adolescents (Asher et al. 2012). This was attributed to the greater awareness of milder symptoms in the adolescent, or symptoms occurring when the parent is not present and not reported to the parent (Asher et al. 2012). The American Thoracic Society (ATS) developed a questionnaire to be specifically for completion by the parent or guardian of children below l3 years of age. Since the study only included children younger than 13 years old, data about children's respiratory conditions were gathered from parents only.

Epidemiological studies in developed countries have reported on impact of the landfill site on adults. The most common approach to determine such impact is the use of written questionnaires completed by the parent for younger age groups and self-reported by adolescents (Asher et al. 2012). Provided that the information is collected in a standardized manner, any information biases are expected, which could include over- or under-reporting of the symptoms. In view of some of the potential limitations of questionnaires, there has been a search for an objective "asthma test" from which the diagnosis can be made with certainty (Asher et al. 2012).

Altogether 181 children participated in the study. Breathlessness, wheezing, and doctor's diagnosis were used to assess the prevalence of respiratory health conditions. The reporting of these respiratory health conditions are very important in assessing the prevalence of asthma in children. When a child visits a clinician, the diagnosis of asthma is made in clinical practice by characteristic findings on the history of episodic wheeze, cough, or breathlessness (Asher et al. 2012). The doctor's diagnosis included, asthma, asthmatic bronchitis, allergies, eczema, chronic bronchitis, and reactive airway disease. Marginally, more male (53%) than female children participated in this study with an average age of 8.7 collectively. The community of Clare Estate is predominately African and Indian. The participation of the racial groups were fairly representative, comprising of 50% Africans, 48% Indians, and only 2% Coloured.

This study notes that the reported respiratory conditions from the standardised questionnaire were high. The study further shows that many children had been diagnosed of at least one respiratory condition in their lifetime. These results are not surprising considering the close proximity to the landfill site. The study investigated the respiratory health effects in children living within a 2-km radius of the landfill site. The issue of communities living near the landfill site is not a unique phenomenon to South Africa. In Great Britain about 80% of the British population lives within 2 km of known landfill sites (Elliott et al. 2001). Landfill site are well known to be a source of air pollution especially particulate matter (Macklin et al. 2011). Landfilling activities have the potential to produce both fine and coarse particulates, the make-up of which will depend on the activities undertaken on-site and the types of waste being handled (Macklin et al. 2011).

Chalvatzaki et al. (2010) cited that large amounts of solid waste are disposed in landfills and the potential of particulate matter (PM) emissions into the atmosphere is significant. As a result the pre-eminent levels of ambient PM concentrations from the landfill result in elevated human exposure. Children experiencing a respiratory infection may also have increased susceptibility to the effects of air pollution (Chauhan et al. 2003). Studies concerning children concentrate on the effects of $PM_{2.5}$ exposure on asthmatic symptoms (Wu et al. 2005). Despite the fact that all individuals are potentially affected, children are more likely to suffer health effects due to ambient particulate matter, and since their lung structure and immune system are not fully developed compared to adults. Hence a study conducted in Beijing, China, found the children's exposure concentrations of $PM_{2.5}$ were 4 to 5 times greater than other related studies in other countries (Du et al. 2010).

One of the most important conditions we considered in this study was asthma. Asthma is a chronic inflammatory disorder of the airways that results in variable airflow obstruction in response to certain triggers (Australian Institute of Health and Welfare 2010). In 2007, the Working Group of the South African Thoracic Society published the latest guidelines for the management of chronic asthma in adolescents and adults, where they shared a concern that asthma prevalence is increasing worldwide and surveys indicate that the majority of patients in developed and developing countries do not receive optimal care and are therefore not well controlled (Lalloo et al. 2007). This study shares a similar concern that in South Africa little is known about the prevalence of asthma near the prominent areas like landfill site. In their work, they defined asthma as a chronic inflammatory condition of the airways which is usually allergic in origin and is characterized by hyper-responsive airways that constrict easily in response to a wide range of stimuli (Lalloo et al. 2007).

The characteristic symptoms of asthma are cough, wheeze, dyspnoea or shortness of breath, and tightness of the chest. This study has witnessed some of these characteristics from participants, wheeze being the most prominent one. Wheeze is the most frequent symptom of the variable airway obstruction that occurs in asthma (Asher et al. 2012). It is a serious sign of asthma but may be absent at the time of consultation because airway constriction does not always result in detectable signs (Lalloo et al. 2007). According to Sears (2015), wheezing independent of the diagnosis of asthma appears to be an important predictor of poorer pulmonary function. This study has reported wheeze for 33% of participants which is within the range when compared to the 37.6% in Costa Rica but much more higher than 2.4% in Jodhpur (India) (Asher et al. 2012). Epidemiological studies in developed countries have investigated the association between asthma symptoms (e.g. wheeze) and pollution (Morgan et al. 2005, Patel et al. 2008, Mann et al. 2010), however little is known about the strength of such associations in developing countries, such as South Africa.

Asthma is one of the most common non-communicable diseases and depending on severity, the airflow limitation is accompanied by symptoms of breathlessness, wheezing, chest tightness, and cough (Chipps 2015). The increase in asthma prevalence in developed countries seen at the end of the last century has raised concern for the considerable burden of this disease on society as well as individuals (Lai et al. 2009). This study reported that 20% of children had been diagnosed of asthma by the physician, and 4% of those with asthmatic bronchitis. It also found that the prevalence of asthma among children living with a 2-km radius of the landfill site is greater than the prevalence of asthma observed in other studies. These findings strongly affirms the assertion from Phase Three of the International Study of Asthma and Allergies in Childhood (ISAAC) which revealed a marked geographic variation in the prevalence of asthma symptoms, which suggest that environmental factors were likely to be responsible for the observed variations (Lai et al. 2009).

4.6 Conclusion

Characterising respiratory heath conditions is vital in understanding how particulate matter $PM_{2.5}$ affects the lung function patterns in children living near a landfill site. To achieve this, the study focused on the self-reported wheeze and doctor's diagnosis of asthma. Wheeze is a prominent symptom of asthma. Hence it is an important predictor of obstructive and restrictive lung function pattern. An American Thoracic Society questionnaire, which is a validated respiratory questionnaire, was used to describe the respiratory conditions in children. Breathlessness, wheeze and asthma were found to be high in children living in Clare Estate. The study concludes that children living in and near the air pollution emitting sources such as a landfill site have an increased risk of respiratory health conditions including breathlessness and wheeze due to exposure to outdoor air pollution sources. The study also concluded that children who reside near the landfill site are exposed to air pollution, especially particulate matter, and as a result some suffer from asthma.

CHAPTER 5: THE RESPIRATORY HEALTH EFFECTS ASSOCIATED WITH PARTICULATE MATTER ($PM_{2.5}$) IN CHILDREN RESIDING NEAR A LANDFILL SITE (PAPER 4)

5.1 Abstract

Landfill sites are known for their potential of generating particulate matter (PM) which can pose respiratory health problems for people residing in the adjacent communities. Thus the assessment of $PM_{2.5}$ is important in understanding the extent to which such communities are affected. It can help inform the development of the environmental protection programmes by the authorities. South Africa has, to date, no clear guidelines to ensure that landfill sites are located away from the communities, and due to the perennial lack of land and other related economic reasons, communities occupy land in close proximity to landfill sites. To add to the predicament, there is no reliable information on the actual day-to-day and longer term effects of land-filling operations on the lives of residents living near such facilities. $PM_{2.5}$ exposure and its impact on children residing adjacent to landfill sites have not been well investigated in South Africa. One of the main objectives of this study was to examine $PM_{2.5}$ in households adjacent to the Bisasar Road landfill site in Clare Estate, Durban, South Africa and to evaluate its impact on respiratory health outcomes of children residing in those homes. $PM_{2.5}$ and respiratory health outcome data were obtained from a subset of 23 households and children that had initially participated in child-health screening surveys. A Spearman correlation coefficient was computed to determine the association between $PM_{2.5}$ and lung function patterns. The results uncovered a high $PM_{2.5}$ concentration level in those homes. It further demonstrated that most children had restrictive lung function (65%) as compared to the 35% who tested normal. A strong negative correlation between $PM_{2.5}$ concentration levels and lung function test was observed. The findings of the study demonstrated that living in close proximity to the landfill site exposes the community to unacceptable concentration levels of $PM_{2.5}$ and as a result the negative respiratory effects are heightened. Furthermore, it demonstrated that lung function patterns of the vulnerable group (children) of the society are negatively affected. The latter facts necessitate an urgent need for a larger health study which will focus mainly on the respiratory effects of $PM_{2.5}$ in communities who reside near the landfill sites in order to inform the implementation of effective environmental management strategies.

Keywords: *Air pollution, Bisasar Road landfill site, respiratory effects, spirometry, WHO*

5.2 Introduction

The recent demands to cope with economic stresses in the world has resulted in the increasing levels of particulate matter (PM) air pollution in many cities and therefore impacting public health (Feng et al. 2013, Voorhees et al. 2014). Hence, the health effects of air pollution have become a major public health concern in developed countries (Farhat et al. 2013). Epidemiological evidence shows adverse effects of PM following both short and long term exposure; and its public health impact is consistently showing adverse health effects at exposures that are currently experienced by urban populations in both developed and developing countries (WHO 2006).

Most countries focus mainly on ambient air quality in their attempt to control or manage air pollution. Airborne fine particle mass concentrations ($PM_{2.5}$) are used for ambient air quality management worldwide based on known cardiorespiratory health effects (Weichenthal et al. 2013). The World Health Organization (WHO) indicates that it is reasonable to assume that health effects of $PM_{2.5}$ from indoor and outdoor sources are relatively the same. Therefore, the WHO air quality guidelines for PM can also be applied to the indoor environment, specifically in the developing world (WHO 2006). Most countries, including South Africa, do not have the air quality standards or guidelines for the indoor environment. Hence the WHO guidelines were utilised as the basis for the current study.

The current study used $PM_{2.5}$ measurements in an indoor environment to assess its concentration levels and its association with the lung function patterns in children aged between 2 and 6 years residing near the Bisasar Road landfill site, Durban, South Africa. Katsouyanni (2003) argues that, whilst ambient air pollution exposure occurs outdoors, it also penetrates indoors at a rate which depends on the nature of a particular pollutant. In India, nearly 17.8 million disability-adjusted life years are attributable to ambient air pollution (AAP) in the form of fine particulate matter, equal or less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$) (Balakrishnan et al. 2014). The risk for various outcomes due to $PM_{2.5}$ has shown an increase with exposure (WHO 2006). Although the whole population is affected, the susceptibility to pollution is exacerbated by health status and the age of the individual. WHO (2006) reported that health effects of $PM_{2.5}$ are predominant to respiratory and cardiovascular systems. Even though there is little evidence that suggest a threshold below which no adverse health effects would be anticipated, the lowest range of concentrations at which adverse health effects has been demonstrated is estimated to be 3 to 5 $\mu g\ m^{-3}$ (WHO 2006).

In China, a study was conducted to monitor and model PM air quality, and estimated the avoided cases of mortality and morbidity in Shanghai, assuming achievement of China's Class II air quality standards. The investigation estimates that avoided impact on mortality due to $PM_{2.5}$ ranged from 6 to 26 cases per day and from 39 to 1400 per year as compared to the estimated impact of a year exposure of 180 to 3500 per year (Voorhees et al. 2014). Prior 31 December 2015, the South African National Ambient Air Quality Standards (NAAQS) for annual and 24-hour average $PM_{2.5}$ is 25 µg m^{-3} and 65 µg m^{-3}, respectively (Republic of South Africa 2012). From 01 January 2016 to 31 December 2029, the new NAAQS for annual and 24-hour average will be 20 µg m^{-3} and 40 µg m^{-3}, respectively. The current and future NAAQS is much higher than the WHO guidelines which recommends the annual and 24-hour average of 25 µg m^{-3} and 10 µg m^{-3}, respectively (WHO 2006). The above counter factual 24-hour mean $PM_{2.5}$ (65 µg m^{-3}) suggest that there would be substantial health burden remaining even if the NAAQS is met in South Africa.

Environmental studies have reported that landfill sites are some of the sources of $PM_{2.5}$. On the other hand, epidemiological studies have reported $PM_{2.5}$ to be the main cause of respiratory health effects in human beings (Brauer et al. 2012, Gurjar et al. 2010 pg 2, Napoleon et al. 2007, Ostro et al. 2010, Osornio-Vagas et al. 2003, Singh et al. 2011 pg 39). Most studies that investigated the association between waste disposal facilities and $PM_{2.5}$ concentration have been conducted in the developed countries, and they concentrated on hazardous waste landfill sites. There is a need for investigations that will focus on domestic waste disposal facilities from both developed and developing countries. Currently, there are few similar studies conducted in the developing countries such as South Africa and yet the burden of $PM_{2.5}$ exposure is high. Managing PM exposure is critical in avoiding its impact. A study by O'Connor et al. (2008) found the association between $PM_{2.5}$ exposure and lower pulmonary function.

$PM_{2.5}$ exposure and its effects on children residing adjacent to landfill sites have not been investigated nor documented in developing countries including South Africa. The objectives of this study are to determine $PM_{2.5}$ exposures of children living in Clare Estate, and to evaluate its impact on respiratory health outcomes. The study investigated the respiratory health effects of $PM_{2.5}$ in the children residing near the landfill site. The findings of the study contributes to the body of knowledge by investigating the influence of landfill activities on indoor $PM_{2.5}$ levels and its impact on the community, especially children. This investigation characterises the respiratory health symptoms and spirometric lung function patterns using a standardised questionnaire and spirometer to establish the respiratory effects of being in close proximity to the landfill site.

5.3 Materials and methods

This cross-sectional study explores the possible association between $PM_{2.5}$ and the respiratory health in children residing near the Bisasar Road landfill site in Clare Estate, Durban. This study presents a subset of the main study which amassed and analysed data from a child-health screening questionnaire. From the 157 household that participated in the child-health screening questionnaire, 31 (20%) randomly selected households were revisited to gather $PM_{2.5}$ samples and respiratory evaluation, of which 23 (15%) agreed to participate. Spirometric data were collected using a portable, electronic spirometer (SCHILLER SP-260, Baar, Switzerland). The details of data collection methods are discussed separately in 5.3.1 and 5.3.2.

5.3.1 $PM_{2.5}$ sampling

$PM_{2.5}$ samples from homes were collected from 23 homes for a period of three months (November 2013 to January 2014). A real-time particulate monitor (EPAM-5000, Plaistow, USA) was used for sampling. This instrument uses both nephalometric and the gravimetric principle to measure PM, in this case $PM_{2.5}$. EPAM-5000 was deployed in the morning between 8am and 10am and was positioned is a living area within the house so that it collect dust where residents spend their time during the day. EPAM-5000 is a highly sensitive real-time particulate monitor designed for ambient and indoor air quality applications. It combines traditional filter techniques with real-time monitoring methods. It uses the principle of near-forward light scattering of infrared radiation to immediately and continuously measure the concentration in $\mu g\ m^{-3}$ of airborne dust particles (Bu-Olayan 2012). Dust sampling was conducted with $PM_{2.5}$ impactor attached to the EPAM-5000 to allow for the collection of $PM_{2.5}$.

$PM_{2.5}$ samples were collected over in 10 min intervals between measurements for a period of 24 hours in each home, with data stored in the EPAM-5000 for later downloading into a computer using its DustComm Pro software. The software was designed to store and analyse data and create print-ready reports. EPAM-5000's DustComm Pro Software uses a continuous monitoring system to display the minimum, maximum and average concentration values of

$PM_{2.5}$. These concentration levels are expressed in mg m^{-3}. The converted mean concentration values for mg m^{-3} to µg m^{-3} were used to report $PM_{2.5}$ concentration levels.

5.3.2 Spirometry

The spirometry (lung function testing) was performed by the researcher, who is a trained spirometry technician, on a subset of 23 (13%) of the 181 children (aged 6 – 12 years) who initially participated in child-health screening surveys. According to the NHANES (2008), persons aged 6 to 79 years are eligible to participate in the spirometry component since they lungs are developed enough to perform spirometry. In this study, a pre-screening questionnaire was administered to parents or caregiver before the children could participate. This was done to exclude children who had medical conditions that could put a child in a risk. Such conditions include chest injuries, heart attack, high blood pressure, and respiratory infection (Appendix H). All participating children were assessed at their homes and in the presence of the parents or caregivers. The consent was obtained from parents or caregivers before spirometry was performed. Spirometry was performed in a standing position without a nose-clip using a SCHILLER SP-260. Spirometer was calibrated before it was used and measurements were performed following the American Thoracic Society (1995) guidelines.

Spirograms were used to classify participants as normal, having an obstructive pattern and/or a restrictive pattern. According to NHANES (2008), a low forced vital capacity (FVC) is indicative of a restrictive disorder, and typically these individuals will also have a low forced expiratory volume in one second (FEV1), whilst a low FEV1/FVC% ratio may indicate an obstructive impairment. Predicted percentage of more than 80% for FVC; and FEV1 and FEV1/FVC ratio of greater than 0.7 were considered a cut off level for lung function tests to be normal. These limits are commonly used internationally for categorizing lung function as normal or abnormal. Obstructive lung function was defined as having FEV1 < 80% and FEV1/ FVC < 70% and restrictive lung function was defined as having FEV1 < 80% and FEV1/FVC > 70% (Global Initiative for Chronic Obstructive Lung Disease 2006).

Spirometry was conducted to establish the lung function patterns of participating children. Each participant performed at least three technically acceptable tests and each individual test was acceptable if it met both acceptability and repeatability criteria. Tests were accepted if the two largest FVC and FEV1 values were reproducible (variation within 5%), otherwise additional testing was conducted until the acceptance range were achieved (American Thoracic Society 1995). A SCHILLER SP-260 displayed the real time pulmonary test results and provided a clear and comprehensive result analysis. This study considered values of the FVC, FEV1, and the FEV1/FVC ratio to assess the lung pattern in children. SCHILLER SP-260 has data management software for the storage, archiving and instant diagnosis of recordings. Hence, the results from the spirometer were automatically stored in a computer through its PC Spirometry software (SDS-104).

5.3.3 Ethical approval

Prior to the data collection process, the researcher submitted an ethical clearance application for approval by the University of KwaZulu-Natal. Ethical approval for the study was secured from the Biomedical Research Ethics Committee (Ethical clearance number: BE201/11). This study adhered to ethical principles throughout, to protect the rights of the participants. Neuman (1997) mentions that the rights of the participants include: the right not to be harmed, the right to self-determination; the right to privacy; and the right to obtain services. Furthermore, he mentions that these rights are related to: the rights to maintain self-respect and dignity, the right to remain anonymous, and the right to have confidential material remain confidential.

The researcher maintained the rights outlined here.

5.3.3.1 Protection of privacy

The data collectors observed a strict ethical adherence to protect participants' confidentiality, meaning that data provided were not made accessible to anyone who was not directly involved in the study. The clarification on how data were collected, analysed and stored was made known to participants. Data collectors warranted that interviews were conducted in a private/conducive place to participants. In the event of disruptions, the interviewee stopped the interview until the cause of the disturbance was seen to, and only then was the interview continued.

5.3.3.2 Informed consent

The guardians/informants were asked to read and sign the informed-consent form confirming that they voluntarily participated in the study after they had been advised about its purpose, the type of information being collected, and how that information would be used. The guardians/informants retained a signed copy of the informed consent forms.

5.3.3.3 Voluntary participation

Participants were informed that participation in the study was voluntary, and that failure to participate in the study or a withdrawal of consent at any stage was not going to be penalised in any way. Participants were informed that they were not obliged to answer any questions they did not wish to.

5.3.3.4 Avoidance of harm

The study did not place any participant in a potentially harmful situation, whether physically, emotionally, socially, politically, economically, and/or psychologically. All issues were discussed with sensitivity. The times and localities of the interviews was taken into consideration in order to ensure confidentiality. Guardians and participants were given the researcher's contact details and were instructed to call if they felt the need to debrief after the interview had taken place.

5.4 Results

The results present findings of a subset of the main study which collected and analysed data from a child health screening questionnaire. The objectives of this study are to determine $PM_{2.5}$ exposures of children living is Clare Estate, and to evaluate its impact on respiratory health outcomes. The study investigated the respiratory health effects of $PM_{2.5}$ in the children residing near the landfill site. The characteristic data of the study population, $PM_{2.5}$ concentration levels, spirometric data and correlations results between $PM_{2.5}$ and spirometric data are presented.

5.4.1 Characteristics of the study population.

The study population for the present analysis consisted of 23 children aged between 6 and 12 years. This subset included both gender and all age and ethnic groups of study participants. The most frequently occurring age in the study was 12-years (26%). There were more (61%) male participants than females (39%) participants and the majority of ethnic group was African (57%), followed by Indian at (39%). There was only one Coloured participant. This demographic picture represents a true picture of people residing in Clare Estate since prior to the commissioning of the landfill in 1980, the area was largely occupied by Indians (GAIA

2011). Later an African informal shack settlement grew on Kennedy Road around the landfill (GAIA 2011) and hence the area is predominately for African and Indians. Characteristics of the study populations are presented in Tables 5.1. It is worth noting that there are no Whites living in Clare Estate. Norton et al. (2007) reported a similar trend in North Carolina, USA where they observed that solid waste facilities were disproportionately located in communities of colour and low incomes.

Table 5.1 Demographic characteristics showing ages, gender and ethnicity groups of study participants.

Variable name (n = 23)	Frequency	Percent
Ages (years)		
6	1	4
7	2	9
8	3	13
9	5	22
10	4	17
11	2	9
12	6	26
Gender		
Male	14	61
Female	9	39
Ethnicity		
African	13	57
Indian	9	39
Coloured	1	4

5.4.2 $PM_{2.5}$ concentration levels

In this study, only the mean $PM_{2.5}$ concentration levels for a 24-hour measurement were reported. $PM_{2.5}$ concentration levels recorded ranged between 16 to 218 µg m^{-3} from different households with a mean concentration of 76.5 µg m^{-3} with a standard deviation of 60.7 µg m^{-3} and a standard error of 12.6 µg m^{-3}. The mean concentration is above the 24-hour average and an annual average of 65 and 25 µg m^{-3} of the NAAQS, respectively. The results show that there was a large variation (range = 202 µg m^{-3}) of $PM_{2.5}$ measurements. The most recorded $PM_{2.5}$

concentration is 157 µg m^{-3}. $PM_{2.5}$ concentration levels and descriptive statistics are presented in Figure 5.1 and Table 5.2, respectively.

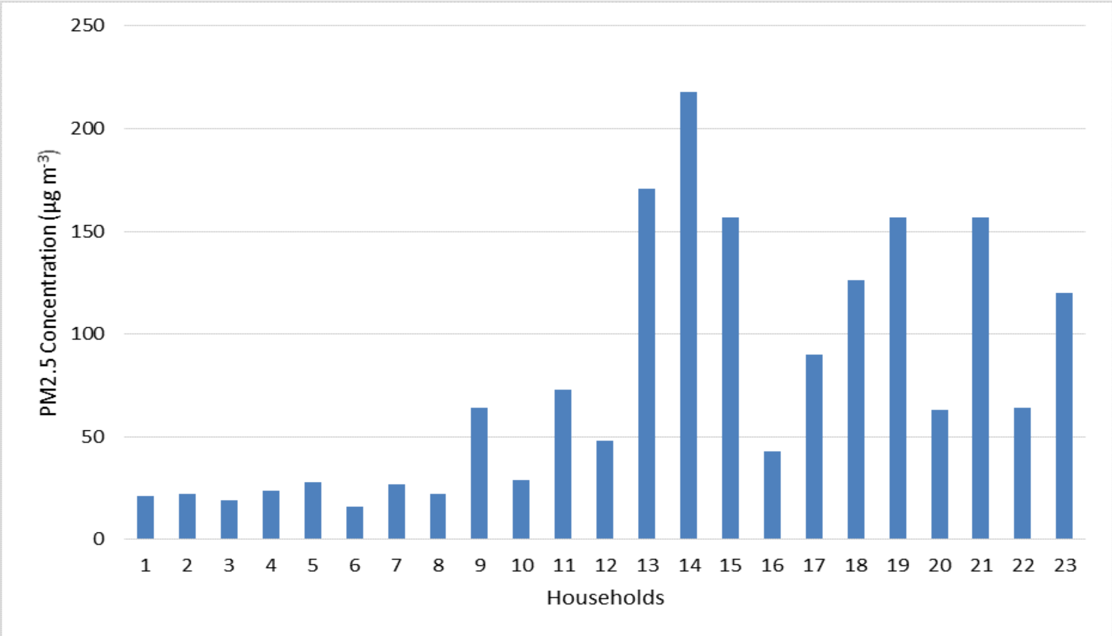

Figure 5.1 Graph showing $PM_{2.5}$ concentrations (µg m^{-3}) in households near the landfill site

Table 5.2 Descriptive statistics for $PM_{2.5}$ concentration

$PM_{2.5}$ concentration (µg m^{-3})	
Mean	76.5
Standard Error	12.7
Median	63.0
Mode	157.0
Standard Deviation	60.7
Sample Variance	3689.2
Range	202.0
Minimum	16.0
Maximum	218.0
Confidence Level (95%)	26.3

5.4.3 Spirometry

Spirometry was conducted in children from the 23 households randomly selected for $PM_{2.5}$ sampling. Spirometric lung function data are summarized in Table 5.3. From a subset of 23 children age between 6 and 12 years, all children were able to perform spirometry successfully. From those, only two respiratory outcomes were observed (35% with "normal" lung function test whilst 65% had "restrictive" test results. None of the children had a "constrictive" result. A mean of FEV1% was 82% (median of 82%, standard deviation of 41), a mean FVC of 75% (median of 75%, standard deviation of 17), and a mean FEV1/FVC of 115% (median of 115%, standard deviation of 8). Evaluation of lung function at the individual level showed that 65% of the children have an impaired lung function (FVC < 80%) of the predicted value. Forty-eight percent of children had FEV1 less than 80% of predicted, although no values were less than 60% of predicted. The common lung function impairment was of restrictive type characterized by the decrease in FVC to less than 80%. Airflow obstruction characterized by the decrease in FEV1/FVC to less than 70% of the predicted value was not found. A combination of both types of lung function decrement was also not found in children. Of all children, only 35% had normal lung function.

Table 5.3 Spirometric lung function measurements

Variable	Male	Female	Total
Body mass index; mean (SD)			
Height (mm)	1380 (±110)	1410 (±110)	1380 (±110)
Weight (kg)	32 (±31)	39 (±13)	33 (±22)
Age (years)	9 (±2)	10 (±2)	10 (±2)
% Predicted spirometric lung volumes in millilitres; Mean (SD)			
FVC	66 (±20)	76 (±15)	75 (±17)
FEV1	76 (±60)	88 (±17)	82 (±41)
FEV1/ FVC	117 (±10)	115 (±6)	115 (±8)
Frequency of lung function patterns (%)			
Normal	2 (9)	6 (26)	8 (35)
Restrictive	7 (30)	8 (35)	15 (65)
Constrictive	0	0	0

5.4.4 Correlations between $PM_{2.5}$ and lung function.

Associations between 24 hour average $PM_{2.5}$ concentration measured at homes and lung function conducted in children are presented in Table 5.5. Associations showed little or no heterogeneity for FEV1/FVC and $PM_{2.5}$ concentration. The indirect correlation coefficient of 0.18 ($r_{\text{\%predicted FEV1/FVC. PM2.5 concentration}} = -0.18$) or indirect coefficient of determination of 0.0324 was observed ($r^2_{\text{\%predicted FEV1/FVC. PM2.5 concentration}} = 0.0324$). However, associations of $PM_{2.5}$ concentration and FVC or FEV1 were more heterogeneous. A strong association was observed between the % predicted FVC and $PM_{2.5}$ concentration with a negative correlation coefficient of -0.60 ($r_{\text{\%predicted FVC. PM2.5 concentration}} = -0.60$) of a coefficient of determination of 0.36 ($r^2_{\text{\%predicted FVC. PM2.5 concentration}} = 0.36$). Also, a moderate association between $PM_{2.5}$ and FEV1 was observed. The results presented an indirect coefficient correlation of -0.41 ($r_{\text{\%predicted FVC. PM2.5 concentration}} = -0.41$) or an indirect coefficient of determination of 0.1681 ($r^2_{\text{\%predicted FEV1. PM2.5 concentration}} = 0.1681$).

Most associations were negative, suggesting decreases in lung function of children with increasing exposure to $PM_{2.5}$. Overall, there were statistically significant negative associations between FEV1 and $PM_{2.5}$ levels. Similarly, we estimated statistically significant negative associations for FVC and $PM_{2.5}$ levels. Table 5.4 presents $PM_{2.5}$ concentration from all 23 participating households and respiratory outcomes from 23 children who participated in the lung function testing (spirometry), and Table 5.5 shows a Spearman's correlation between $PM_{2.5}$ and respiratory outcomes, respectively.

Table 5.4 Results of $PM_{2.5}$ concentration and children's respiratory outcomes

ID	Age	Gender	Ethnic group	% Predicted FVC	% Predicted FEV1	%Predicted FEV1/FVC	Respiratory results	$PM_{2.5}$ level ($\mu g\ m^{-3}$)
1	8	Female	Indian	81	93	117	Normal	21
2	7	Female	Indian	84	88	106	Normal	22
3	10	Female	African	99	109	112	Normal	19
4	11	Female	African	98	110	115	Normal	24
5	10	Female	African	84	93	113	Normal	28
6	8	Male	African	89	95	106	Normal	16
7	12	Male	Indian	120	261	137	Normal	27
8	12	Female	African	99	112	116	Normal	22
9	9	Female	Indian	75	88	118	Restrictive	64
10	12	Female	Coloured	76	85	113	Restrictive	29
11	12	Female	African	56	66	118	Restrictive	73
12	9	Female	African	65	64	100	Restrictive	48
13	9	Female	Indian	60	71	119	Restrictive	171
14	10	Female	Indian	64	64	101	Restrictive	218
15	11	Female	African	64	74	117	Restrictive	157
16	8	Female	African	67	72	110	Restrictive	43
17	10	Male	African	52	61	118	Restrictive	90
18	12	Male	African	59	64	108	Restrictive	126
19	7	Male	Indian	65	75	115	Restrictive	157
20	6	Male	Indian	65	77	119	Restrictive	63
21	9	Male	Indian	79	82	103	Restrictive	157
22	9	Male	African	77	92	119	Restrictive	64
23	12	Male	African	53	63	119	Restrictive	120

Table 5.5 Correlation between $PM_{2.5}$ concentration and lung function outcomes

	% Predicted FVC	% Predicted FEV1	% Predicted FEV1/FVC	$PM_{2.5}$ concentration ($\mu g\ m^{-3}$)
% Predicted FVC	1			
% Predicted FEV1	0.83	1		
%Predicted FEV1/FVC	0.27	0.62	1	
PM 2.5 concentration ($\mu g\ m^{-3}$)	-0.60	-0.41	-0.18	1

5.5 Discussion

Romieu and Hernandez-Avila (2003) claim that concern about the health effects of the high levels of air pollution observed in many megacities of the developing world is growing; and it is likely that this problem will continue to grow because developing countries get trapped in the trade-offs between economic growth and environmental protection. The Bisasar Road landfill site has in the recent past been the subject in courts mainly because authorities chose to prioritise economic growth over environmental and health protection. Saksena and Smith (2003), stated that policy-makers and environmental managers tend to ignore the role of small sources of air pollution like landfill sites, particularly when they do not seem to contribute substantially to ambient emissions. The impact of air pollution is dependent on the dose received by the population. Unfortunately it is difficult to determine the dose for large numbers of people. Therefore, air pollution studies have tended to emphasize exposure, which is usually assumed to be closely proportional to dose (Saksena and Smith 2003).

Saksena and Smith (2003) suggest the importance of measuring air quality in indoor environments where people spend most of their time. Understandably, the impact of air pollution on human health has proved difficult to establish due to questions regarding which pollutant to target, and how to reduce exposure given the high cost associated with environmental interventions (Romieu and Hernandez-Avila 2003). However, the need for the implementation of control programmes cannot be outweighed by such questions.

According to the South African Department of Environmental Affairs and Tourism (2010), there is inadequate South African-specific health evidence to determine the appropriate averaging period for pollutants. It is rather urgent for South Africa to consider seriously reducing levels of pollutant emissions from small stationary air pollution generating sources such as landfill sites. The identification and characterization of air pollution problems, and subsequently the estimation of potential health impacts can serve as a starting point in ensuring that air pollution control programmes are not just implemented, but effectively implemented.

This study noted that South Africa has made some strides in the development of a national ambient standard for $PM_{2.5}$. However, due to trade-off between economic growth and environmental protection, South Africa promulgated a national standard for $PM_{2.5}$ which will take 17 years to achieve its minimum regulated $PM_{2.5}$ concentration. The national standard for $PM_{2.5}$ stipulates different periods for achieving different ambient $PM_{2.5}$ concentration levels, which range between 25 µg m^{-3} from year 2012 to 15 µg m^{-3} 24-hour average in year-2030. Furthermore, the indoor national standard for $PM_{2.5}$ is non-existent in South Africa. It is against this background that the WHO guideline is used in this study to determine if children residing in the close proximity of the landfill site are exposed to $PM_{2.5}$ concentration levels which could cause health effects.

To determine the respiratory effects caused by the close proximity to the landfill site, we measured the concentration of $PM_{2.5}$ within the households. The findings show that most children are exposed to heightened $PM_{2.5}$ concentrations in their households. As alluded to by Romieu and Hernandez-Avila (2003), populations in urban areas are at risk of suffering adverse health effects due to rising problems of severe air pollution but most developing countries do not have data to evaluate the extent of the problem. This reality gives a mirror of a story that will befall South Africa, and the unfortunate part is that although air pollutants are likely to have similar adverse effects on different human populations, the range of exposure, co-exposure to different pollutant mixtures, the population structure, the nutritional status and the lifestyle observed in developing countries suggest that the potential health effects of air pollution may be even greater than those reported for developed nations (Romieu and Hernandez-Avila 2003). It stands to reason that children residing near the Bisasar Road landfill site are exposed to $PM_{2.5}$ concentration levels which may cause respiratory health problems.

The high levels of $PM_{2.5}$ observed in this study are not surprising since landfill sites are characterized as an air pollution source (Department of Environmental Affairs 2009). Considering the fact that $PM_{2.5}$ possess health effects, and that it moves freely in the atmosphere with air currents and remain suspended for days to weeks, and can travel hundreds to thousands of kilometres from the source of origin (Yassin et al. 2012), keeping $PM_{2.5}$ below the national guideline is not an option in both developed and developing countries. In general, air pollution control in South Africa is not easy because South Africa is a dry country with high naturally-occurring dust from various sources (Departmental of Environmental Affairs 2010).

According to Macklin et al. (2011), the coarser dust particles (> 30 µm) are mainly deposited within 100 m of the source, intermediate particles (10 - 30 µm) between 250 and 500 m, fine particles (< 10 µm) could travel up to 1 km whilst ultrafine particles (< 2.5 µm) would be expected to travel considerably further. Paraskaki and Lazaridis (2005), claim that a distance of 1.5 km from the landfill is the minimum downwind distance of the health-risk zone. This study is limited to a 2-km radius from the landfill site and it found heightened $PM_{2.5}$ levels which exceeded the WHO guideline. The study affirms the findings by Paraskaki and Lazaridis (2005), where they found that within 1.5 km from the source, air pollutant concentration was significantly above the WHO reference lifetime exposure health criteria. Paraskaki and Lazaridis (2005), concluded that air pollution emissions from municipal solid waste landfills have the potential to cause health impacts in the surrounding residential areas.

The need to formally address air pollution and appropriate mitigation measures for improved air quality and human health was first recognised in the 1960s in South Africa (Departmental of Environmental Affair 2010). However, the main focus is still with industrial sources since industries in Durban are a major source of air pollutant emissions and large users of fossil fuel based energy (Thambiran and Diab 2011). Focusing exclusively on industrial sources compromise communities residing in close proximity to other sources of air pollution like landfill sites. PM from landfill sites can become airborne and move off-site, and the amount of dust lifted from the surface is dependent on the speed of the wind, the condition of the surface and the size of the dust particles (Macklin et al. 2011).

Since $PM_{2.5}$ tends to escape the point of origin, the result of this study affirm the findings of a study conducted in Greece on $PM_{2.5}$ concentration levels from a landfill site which revealed that the average outdoor concentrations of PM ranged from 42 to 601 $\mu g\ m^{-3}$. Their study also stated that, the high PM concentrations were caused by dust generated by the process of coating residues with suitable earthen materials (soil, rubble) and the movement of trucks at the landfill site (Chalvatzaki et al. 2010). Macklin et al. (2011) also confirms that dust emitted from landfill sites include particles which fall into both the PM10 and $PM_{2.5}$ categories. Landfilling activities have the potential to produce both fine and coarse particulates which depends on the activities undertaken on-site and the types of waste being handled (Macklin et al. 2011).

Palmiotto et al. (2014), argued that most of the human health problems stem from the landfill sites that release PM during landfill operations and uncontrolled emissions. Respiratory health condition such as chronic cough, bronchitis and chest illness have been associated with particulate air pollution (Romieu and Hernandez-Avila 2003). In order to establish the association between $PM_{2.5}$ exposure and respiratory health effects, spirometric assessments were conducted on a subset of 23 children. Children who performed lung function evaluation were residing in households where $PM_{2.5}$ monitoring was conducted. Spirometry revealed that most children who performed spirometry had an impaired lung function. The lung function impairment was a restrictive type which is characterized by the decrease in FVC. Obstructive patterns of lung dysfunction which is characterized by the decrease in the predicted percentage FEV1/FVC was not found.

The purpose of this study was not to diagnose the actual pulmonary disease but to assess the lung function patterns and to determine if such patterns were associated with $PM_{2.5}$ exposure or not. The study revealed that children were suffering from one or more of the following restrictive pulmonary diseases as listed by the American Thoracic Society: interstitial lung diseases, interstitial fibrosis, occupational or environmental lung disease, sarcoidosis, connective tissue diseases, hypersensitivity pneumonitis, lymphangiomyomatosis, ARDS survivors, chest wall diseases, kyphoscoliosis, ankylosing spondylitis, or post-tuberculosis syndrome (Spruit et al. 2013).

The area surrounding the landfill site has an increased rate of reported health impacts (Fielder et al. 2000). Gauderman et al. (2004) found that long-term exposure to elevated concentrations of ambient air pollution is associated with decreased lung function, whilst Pirozzi et al. (2015) reported adverse health effects in the individuals with chronic obstructive pulmonary disease (CODP) associated with exposure to air pollution. In this study, the Spearman correlation coefficient and coefficient of determination were computed to determine the association between $PM_{2.5}$ and the respiratory outcomes. A strong negative correlation between lung function measures and $PM_{2.5}$ exposure was observed. This suggests that emissions from the landfill site have a negative impact on children living in close proximity.

Murray and Lopez (1996) made an assertion that the pattern of disease and competing risk factors differ dramatically between urban populations in high income countries and people exposed to heavy indoor air pollution in low income countries, which are the poorest and most stressed populations in the world. They further claim that the overall risk of acute respiratory infections in young children, one of the main impacts of air pollution in low and middle income countries, is many times higher in South Asia and sub-Saharan Africa than in Western Europe and North America, where most air pollution epidemiology has been carried out. Highly sensitive subpopulations, including asthmatics, the elderly and children, are at an increased health risk when exposed to high levels of $PM_{2.5}$ (Environmental Affairs and Tourism 2010).

Results of this study conclude that there is a substantial public health burden from $PM_{2.5}$ pollution. It is prudent to believe that the reductions in the levels $PM_{2.5}$ depends largely on the detection of $PM_{2.5}$ hotspots and strict management of air pollution sources at landfill sites. In its report, the Department of Environmental Affairs and Tourism (2010) recommends the monitoring $PM_{2.5}$ as a matter of urgency so that PM hotspots can be identified and epidemiological studies carried out. Both epidemiological evidence and advanced detection technology have raised concerns regarding exposure to $PM_{2.5}$ and adverse human health effects (Environmental Affairs and Tourism 2010).

5.6 Conclusions

This study was conducted in a subset of the Clare Estate community who reside in close proximity to the Bisasar Road landfill site. This community is within a 2-km radius of the landfill site. Both $PM_{2.5}$ and spirometry were measured in order to establish if there was any correlation between the two. The study ascertained a strong negative relation between $PM_{2.5}$ and lung function patterns for the participating group. The study also found that children residing in close proximity to this landfill site are exposed to $PM_{2.5}$ concentration levels which are above the minimum accepted by WHO guidelines. The study concludes that the $PM_{2.5}$ from the landfill sites causes the negative respiratory health effects in children.

CHAPTER 6: COMMUNITY APPRAISAL OF AIR QUALITY NEAR A LANDFILL SITE: COMMUNITY PERCEPTIONS (PAPER 5)

6.1 Abstract

This paper presents results from a study of the community perceptions regarding a landfill site in Clare Estate, Durban in South Africa. The purpose of the investigation was to evaluate community perceptions on the impact of dust emanating from the landfill sites in their vicinity. A purposive sampling strategy was used to sample households with children aged between 6 and 12 years who were residing within a 2-km radius of the landfill site. The analysis of in-depth interviews (n = 154) revealed the community discernments on particulate matter emanating from the landfill site, and the factors that shape residents' perceptions and responses about the close proximity of the landfill site. They reported that family members have health issues that were aggravated by the close proximity of the landfill site. Overall, the community reported the discontent about the dust and odour coming from the landfill site. While overall discontent was raised, it was also noteworthy that a sector of the same population had no problem with their close proximity to the landfill site. The one repeatedly suggested community solution to the problem was none other than the relocation or removal of the landfill site. The study also revealed a high degree of residents' discontent due to the close proximity to the landfill site. It was shown that residents perceived that their close proximity to the landfill affected health negatively. Overall, this study significantly advances the understanding of the possible impact of the landfill activities on children residing near such. Furthermore, the study concluded that the community of Clare Estate was not only dissatisfied with the location of this landfill site but had no other residential option and only the relocation of the landfill site could be a proactive way forward. The findings of this study will not only inform future best practices in the location of such sites but also heighten awareness of the long-term negative effects of a reality that can shorten a lifespan of the generation when health considerations are not juxtaposed to progress and industrialization.

Keywords: *Bisasar Road landfill site, community, community perceptions, environmental concerns*

6.2 Introduction

Bisasar Road landfill site is Africa's largest formal waste disposal site, processing up to 5000 tonnes of solid waste per day (Bond and Sharife 2012). It is managed by Durban Solid Waste (DSW) of the eThekwini Municipality. It started operating in 1980 in the largely Indian and Coloured suburb of Clare Estate (GAIA 2011, Bond and Sharife 2012). After the apartheid laws were relaxed in the late 1980s in South Africa, an African informal settlement mushroomed on Kennedy Road near the landfill. Many of these African residents had been displaced from their ancestral homes when land was expropriated from them in 1986 without compensation to make way for the Inanda Dam that supplies Durban with water (GAIA 2011). The landfill site is located in the west wing of the City of Durban and it receives waste from the surroundings of the Durban area.

Due to the shortage of space and other socio-economic reasons, such as being closer to cities for work purposes, communities decided to occupy any land available including the space near the landfill sites. In some developed countries like Great Britain, it is estimated that 80% of its population resides within 2-km of the landfill sites (Elliottt et al. 2001). This situation is not different from other areas in South Africa since there are communities that reside very close to landfill sites as is the case for Bisasar Road landfill site. Apartheid era economic policies led to the rapid increase of urbanization, industrialization, poor land use and poverty. To date, communities still continue to live adjacent to air pollution sources such as landfill sites which increase their vulnerability to air pollution. This is further exacerbated by already existing compromised health status due to health issues and poor nutrition, poverty, unemployment, and poor access to adequate basic social services such as housing, water, electricity, health care, and education (Department of Housing 1997).

The possible adverse environmental impact of landfill sites is well documented in various studies, for example Fielder et al. 2000, Rabl et al. 2008, Zierold and Sears 2014. Studies have reported that a landfill site emits a variety of air pollutants, including emissions of gases and metals to air, water and land from the degradation and treatment of wastes and associated plant and vehicle movements, as well as noise, vibration, litter, vermin, dust, fumes, odour, damage to valuable agricultural/recreational land and historic landscapes (Koshy et al. 2009, De Feo et al. 2013). Higher wind speed results in greater particle re-suspension from the surface within and in the surroundings of the landfill site; whereas increased air temperatures leads to drier soil conditions that favour particle re-suspension (Lazaridis et al. 1998).

Owusu et al. (2012) have identified landfill sites as one of the key challenges associated with rapid urbanization in the developing world. As such, landfill sites have been at the root of numerous conflicts between municipal authorities and communities located near landfills. This has been the case in South Africa, particularly between the Clare Estate community and the eThekwini Municipality. Tuan and Maclaren (2005) reported that communities are concerned about the poor maintenance of landfill sites and the dominant dust exposure that the landfill site presents to the community. A study conducted in South Wales in the United Kingdom revealed that a community near the Trecatti landfill site expressed concerns about odours and health effects which they attributed to landfill site emission (Fielder et al. 2001). An understanding of, and a willingness to listen to the public views on environmental health issues is therefore increasingly important for government officials, politicians, owners and technicians involved in the life cycle of municipal solid waste (MSW) management facilities (De Feo et al. 2013).

People focus on particular risks because of their attachment to place, beliefs, values, social institutions, and moral behaviour, not necessarily on the amount of danger, actual or perceived (Douglas and Wildavsky 1982). Therefore, understanding social context regarding health risks from landfill sites is of paramount importance since it affects how risk is socially constructed. Although there are few studies in developing countries which have investigated the perceptions of communities who live near the landfill site and its impact, the existence of dust from landfill sites has been reported in developed countries (Okeke and Armour 2000). Community opposition to landfill sites and other locally unwanted land uses (LULUs) often leads to the abandonment of such landfill sites (Okeke and Armour 2000). This option, however, has not been the case for the Bisasar Road landfill site, since the community from Clare Estate have opposed the existence of the landfill site in the past and yet the facility is still functional to date. In spite of the vigorous campaign to close down the landfill site due to perceived respiratory health problems, the Department of Water and Forestry extended the landfill site life cycle in 1996 (Bond and Sharife 2012).

In Clare Estate, there has been voluble opposition of the landfill site steered by Sadija Khan, due to it being an unsightly place of rotting garbage spreading obnoxious odours, invasive dust and life-threatening toxins over the surrounding neighbourhood (Bond and Sharife 2012). In 2002, a lawsuit was initiated against the city authorities for failure to close down the landfill site after several attempts by the community to force the then Durban Metro, now Ethekwini

Municipality to close down the landfill site. However, that campaign did not succeed as Bisasar Road landfill site continues to operate. Despite all the futile campaigns, no research has been conducted thus far in the Clare Estate community to solicit the residents' responses and perceptions regarding air quality, particularly particulate matter (PM) from Bisasar Road landfill site. Okeke and Armour (2000) claim that the importance of public opinions should not be overlooked since it is an important factor during the operational phase of any facility.

This study evaluated the public perception of environmental health effects caused by Bisasar Road landfill site in Clare Estate in Durban. The objectives of this study were:

- the exploration of the nature of concerns about the impacts of the landfill site within the broader context of residents' everyday lives;
- the assessment of the level of the communities' environmental health awareness regarding the impact of the landfill site;
- the determination of community perceptions of dust exposure from the landfill sites; and
- the exploration of residents' suggested solutions to the landfill site and air quality challenges.

6.3 Materials and methods

This investigation was one component of a larger research project which investigated the respiratory health impact caused by particulate matter with aerodynamic of less than 2.5 µm ($PM_{2.5}$) in children aged 6 to 12 years who resided within a 2-km radius from the Bisasar Road landfill site. This cross-sectional study was exploratory and descriptive in nature and used a mixture of both quantitative and qualitative methods of data collection. The quantitative part of the study consisted of a survey utilising a questionnaire and the qualitative part used an interview guide. The main aim of the study was primarily to explore and describe community experiences of the landfill site and its impact.

6.3.1 Sample selection

This study used face-to-face interviews in homes to collect data from a total of 154 participants residing within a 2-km radius from Bisasar Road landfill site in Clare Estate. Three respondents who participated in the larger study abstained from participating in this part of the study. The participation rate was 98% of the respiratory health study. Semi-structured interviews were conducted with the community of Clare Estate. A purposive sampling technique was used to allow the researchers to judge who were likely to provide the best information for the research (Quinn-Patton 1980). House-to-house visits were conducted by fieldworkers to gather the opinions of community members who resided with children between the ages of 6 and 12. Since this was also part of a respiratory health study, participants who participated in the respiratory study were automatically included in this study. However they were allowed not to participate in the perception questionnaire or part of the questionnaire if they were not comfortable.

6.3.2 Data collection

Face-to-face interviews were conducted by trained field staff who administered questionnaires and interview guides to participants. The questionnaire went through several stages of the review and revision process by the researcher to ensure that it was comprehensible to the participants. The questionnaire probed several different issues including: greatest local environmental concern; awareness of environmental rights; best and worst air quality; best and worst air quality months; source of poor air quality in the area; air quality issues that have negative effects on heath; involvement in environmental organisation or group; involvement in environmental protest, project or campaign; involvement in air quality organisation; public health issues that are aggravated by the close proximity of the landfill site; strategy to reduce dust exposure, and others. In addition, the questionnaire was designed to be flexible in allowing for the interviewer to follow up on issues raised by participants that were not in the questionnaire during the data collection process.

6.3.3 Data analysis

The interviews, averaging 30 minutes in duration, were coded according to themes in order to accurately capture and represent residents' views. Data were entered into Microsoft Excel for further thematic analysis. The analysis was guided by themes and constructs related to the perceptions of the respondents. To guide against possible biases in credibility and dependability, the key categories of response for questions asked in the interview were created based on a review of the key categories of the larger survey study. This was done prior to line-by-line coding, in order to give a basic structure to the arrangement of the data gathered. Once the key theme codes were identified, the links between the various themes were examined, as were the relationships between these themes and individual differences. Maintaining the integrity of the respondents' words throughout the analysis was imperative and this maintained the credibility of the findings while allowing for all degrees of meaning to be retained.

The quantitative data were captured into Microsoft Excel software before being analyzed. Data were captured as coded in the Perception questionnaire, wherein "Yes was represented by "1"; and "No was represented by "2". For the analysis of this data, frequency distributions were presented from data obtained.

6.3.4 Ethical approval

The perception study formed part of the respiratory health study in children. Hence ethical clearance for this study was received from the Biomedical Research Ethics Committee of the University of KwaZulu-Natal (Ethical clearance number: BE201/11). Permission was also secured from eThekwini Municipality officials. The purpose of the study was clarified to all participants prior to participation. Informed consent was sourced from the informant before conducting the interview. All participants were guaranteed anonymity and the confidentiality of the information received from them.

6.4 Results and discussion

The importance of community perceptions is often overlooked and yet understanding perceptions can play a very important role in harmonising the relationships between municipalities and communities near a landfill site, and also in preventing the impact of air pollution from that landfill site. Since perceptions about waste as an unwanted material with no intrinsic value has dominated attitudes towards disposal (Yoada et al. 2014), perceptions play a major role in understanding whether air quality is perceived as a problem or not, and to solicit possible solutions from the community. Deguen et al. (2012) mentioned that perception of air pollution by the general public is a key issue in the development of comprehensive risk assessment studies as well as in air pollution risk management and policy (Deguen et al. 2012). The results of this study are arranged, presented and discussed in terms of the following areas of specific interest:

- demographic characteristics of study participants;
- residents' opinions about general environmental concerns, air pollution sources, and status of air quality near the landfill site;
- residents' perceptions and attitudes about air quality and its impact near the landfill site;
- residents' awareness of environmental rights and the role the community can play in addressing such environmental issues in the area; and
- suggested solutions to mitigate the impact of environmental problems.

Table 6.1 shows the questions applicable to each focus area of interest.

Table 6.1 Face-to-face questionnaire administered to residents in Clare Estate

Social aspects	Components	No.	Question
Residents' opinion	Pollution	B1	What is your greatest local environmental concern (if any)?
	Air quality	B5	In the past 12 months, would you say you had good air quality in this area?
	Air quality	B6	In the past 12 months, how would you rate air quality where you live?
	Air quality	B7	In your community, what month of the year do you think generally has the worst air quality?
	Air quality	B8	What month of the year do you think generally has the best air quality in your community?
	Pollution sources	B9	I am going to read you a list of items that may be a source contributing to poor air quality in your area. Please rate each item 1 to 6 with '1', does not contribute at all and '6', contributes a great deal.
Residents' perceptions and attitudes	Air quality	B3	What do you consider as best air quality?
	Air quality	B4	What do you consider as worst air quality?
	Health impact of air pollution	B10	Thinking about the effects on you and your family, please rate each of the following types of air quality issues from 1, no negative effect to 6, it has an extreme negative effect
	Health impact of the landfill site	B14	Do you or any of your family members have health issues that are aggravated by the close proximity of the landfill site?
Residents' awareness	Activism	B2	Are you aware of any environmental rights that you hold as a citizen of South Africa?
	Activism	B11	Have you ever been involved in an environmental organisation/group?
	Activism	B12	Have you ever taken part in an environmental campaign/project/protest?
	Activism	B13	Do you currently belong to an organization concerned about air quality and public health?
	Activism	B16	Do you know the number to call if you want to register an air quality complaint?
Mitigation strategies	Behavioural	B15	As a result of air quality issues, please tell me how often in the last 12 months have you shut windows; limited outside activities; skipped a day of work; registered air quality complaint with the municipality; or left town to avoid the poor air quality.
	Solutions	B19	What solutions can you suggest to solve these problems?

6.4.1 Demographic characteristics

The demographic characteristics of the participants in this investigation part of the perception questionnaire are shown in Table 6.1. A total of 154 completed questionnaires were analysed. Al-Khatib et al. (2015) found age of individuals to be an important factor with respect to their awareness of dumpsite problems. In this study, 33% of all participants were 41 years old and above and it constituted the largest percentage. The smallest percentages (7%) were those who were 20 years old and younger. This age distribution is somewhat in line with the study conducted in the West Bank, Palestine where 4.7% were participants younger than 20 years (Al-Khatib et al. 2015).

For this study, the educational level of study participants was considered low. Of all the participants, only 26% were university or college graduates or vocational and technical college graduates. The rest (74%) of participants were either high school graduates (40%) or non-matriculants (34). All participants had stayed in the area for at least 5 years. Close to half (47%) of participants had stayed in the area between eleven and 15 years. This suggests that participants had substantial experience to share regarding the state of air quality in the area. The demographic characteristics of the study participants are presented in Table 6.2.

Table 6.2 Demographic characteristics of respondents showing ages and highest education of study participants

Variable name (n = 154)	Frequency	Percent
Ages (years)		
≤ 20	11	7
21 – 30	44	29
31 – 40	49	32
≥ 41	50	33
Highest education level		
Non-matriculants	53	34
Matriculants	62	40
Vocational school or technical college	7	5
College or university graduate	22	21
Length of stay in Clare Estate (years)		
5	37	24
6 – 10	44	29
11 – 15	73	47

6.4.2 Residents' opinion

In this section, the results relating to the questions about residents' opinions regarding the landfill site and the impact it has on the community are presented and discussed. Ayomoh et al. (2008) mentioned that indiscriminate disposal of municipal solid waste in developing countries poses severe environmental and health threats. Firstly, the residents were asked to indicate their greatest environmental concerns without being specific to either pollution or impact of the landfill site. After they had indicated the environmental concerns, they were then asked specific questions about pollution sources and status of air quality in the area. Participants were also asked to comment openly about dust exposure and about problems they were experiencing due to the close proximity to the landfill site.

The results presenting the environmental concerns of the community are shown in Figures 6.1–6.4. With regards to the greatest environmental concerns, the results reflect unhappiness about the existence of the landfill site (Fig. 6.1). In total, participants mentioned seven environmental concerns, of which the top three were dust and smell from the landfill site (34%), environmental dust (21%), and improper disposal of waste from the landfill site (20%). Collectively, the top three concerns constituted 75% of all the concerns reported by the residents. The remaining 25% were shared amongst five other concerns which the study deemed to be minor. Of the remaining 25%, about 15% indicated that they did not have any concerns.

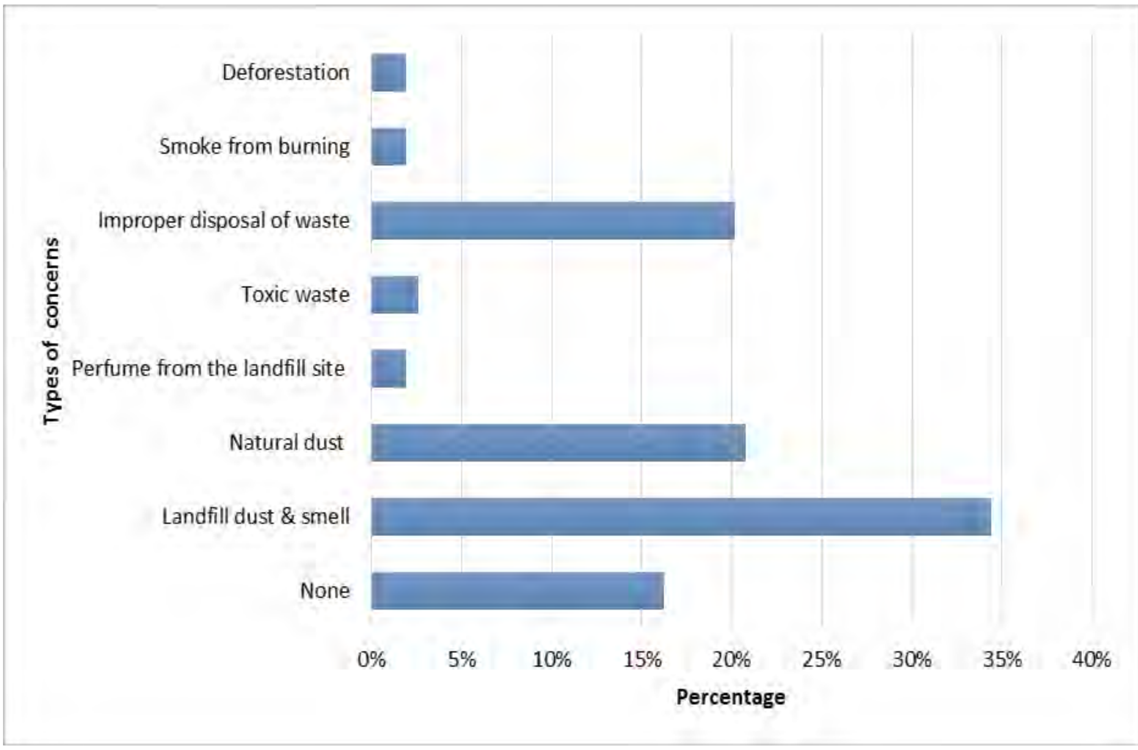

Figure 6.1 A bar graph showing the greatest environmental concerns of participants

When asked to rate the levels of air quality, the majority of respondents (86%) indicated that for the past 12 months, air quality was poor. This is in agreement with the Malaysian study which reported that 91% were bothered by pollution (Sakawi 2011). When asked to rate air quality in the past 12 months (Fig. 6.2), about 72% of the respondents reported that air quality was poor including the 45% who said air quality was very poor and the 27% of those who said it was poor in the area. Only 11% reported that air quality was good. Most (77%) respondents cited the landfill site as the main culprit for poor air quality in the area (Fig. 6.4). The summer season was reported to be that season when they experience worse air quality (45%) and winter was reported to be the season when they experience best air quality (44%) (Fig. 6.3). The results of this study suggest that seasonal variation contributed positively and negatively towards the pollution levels in the area. Of all respondents, 17% indicated that air quality was neither good nor poor. The latter may be attributed to the fact that some residents (8%) were involved in waste picking, and therefore they may have based their responses on the economic benefits from the landfill site.

The results of this study are similar to the Malasian study by Sakawi (2011) which aimed to identify the perception of the community to the source of odour. In addition, the aim of the study was also to look at community perceptions on the impact of odour and dust on human and physical environment, and through the sensory odour intensity and inhalation of dust detected by humans (Sakawi 2011). The study was conducted in the form of a questionnaire, and it was carried out within a 2-km radius of the landfill, similar to this study. The study interviewed people in the vicinity of their homes during the survey to ascertain perception on odour and perceived impact of dust. The Sakawi (2011) study reported that 84.7% of the respondents agreed that the landfill was a source of pollution. According to Tuan and McLaren (2011), even the location of a landfill site has become a very difficult task in both developing and developed countries due to community opposition thereto.

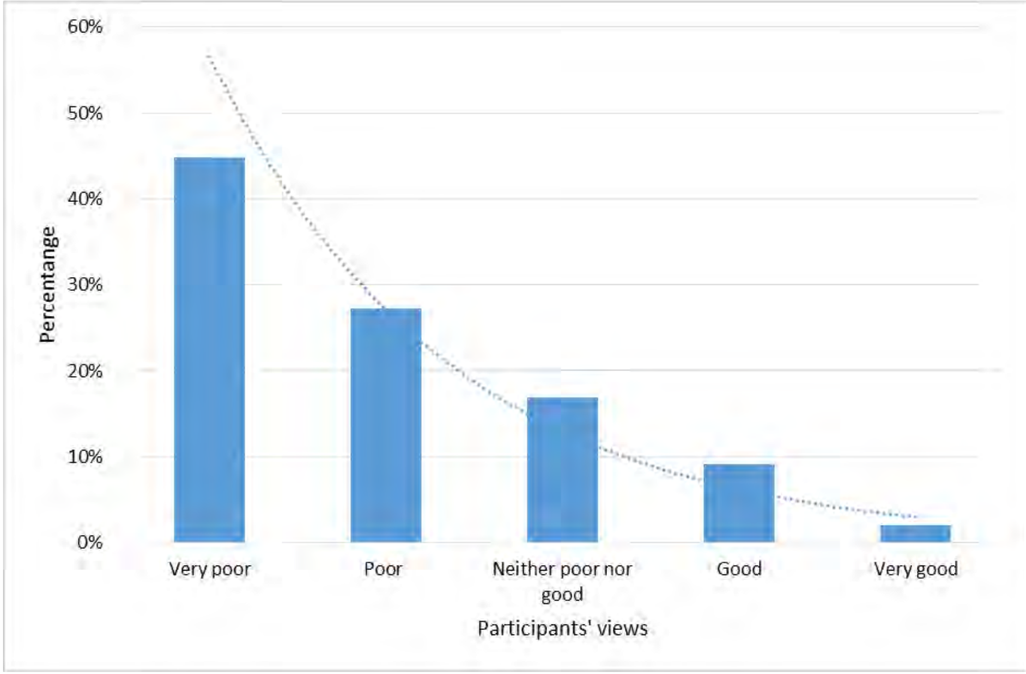

Figure 6.3 A histogram of the air quality ratings by study respondents

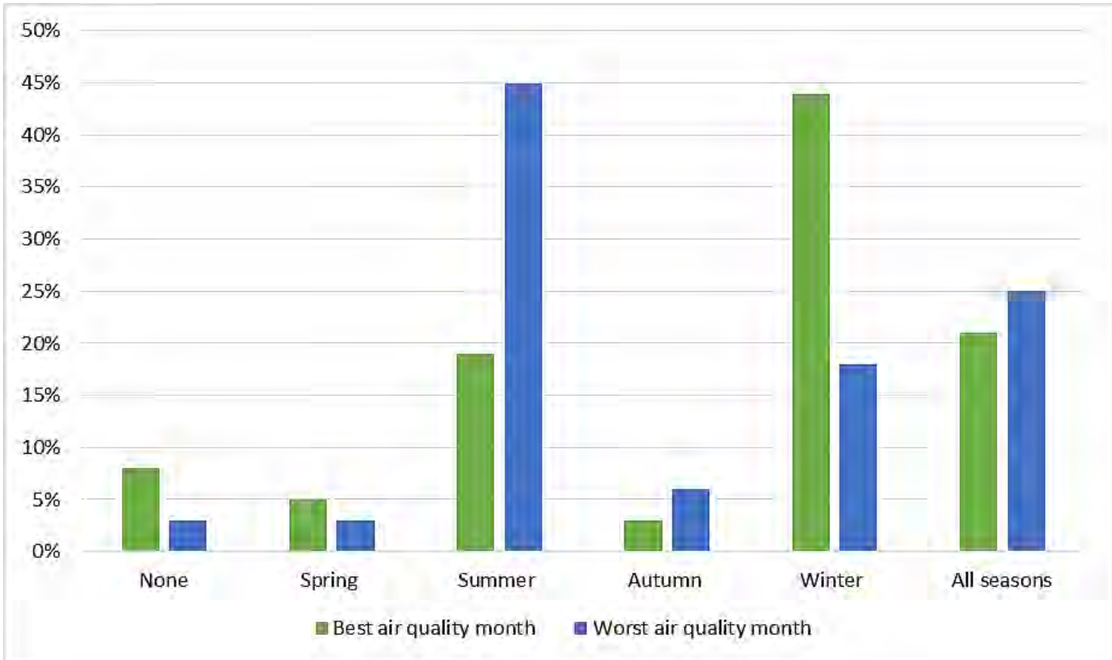

Figure 6.2 A histogram of the best and worst air quality seasons at Clare Estate

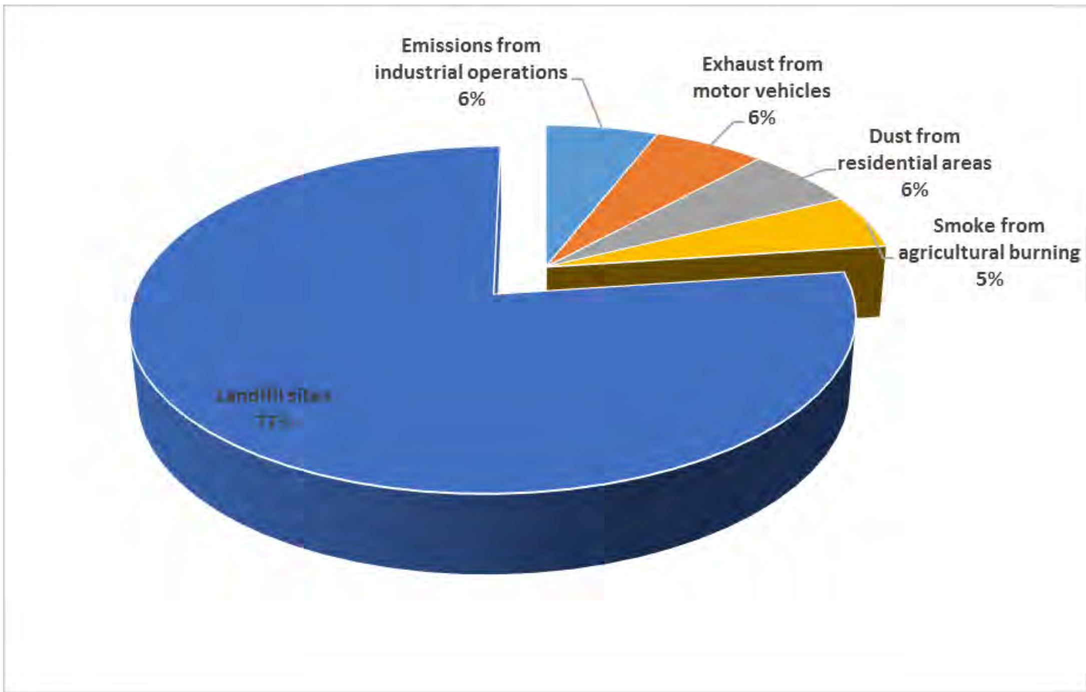

Figure 6.4 A pie chart showing the sources of air pollution

6.4.3 Residents' perceptions and attitudes

London et al. (2006) stated that, "given the potential for landfills to generate a range of toxic agents, attention needs to be given to the potential for these agents to have an impact on the health of nearby residents and communities adjacent to the landfill sites. London et al. (2006) further states that perception of risk has been reported as an important predictor of health problems among residents near landfill sites. In this section, the results relating to the questions about how the residents perceived air quality in the study area are presented and discussed. The study took cognisance of the facts that perception influences how people behave in response to a particular situation. Hence the issue of understanding attitudes is vital. An open ended question was put to residents about what they considered as best and worst air quality in the area. Table 6.3 presents the various responses obtained.

Table 6.3 Perceptions and attitudes about air quality and its impact on residents (n = 154)

Questions and answers	n (%)
What do you consider as best air quality?	
Fresh/clean air with no bad odour	117 (76)
Absence of best air quality	9 (6)
Proper waste disposal	3 (2)
No dust	1 (1)
Don't know	24 (16)
What do you consider as worst air quality?	
Bad smell/bad odour from the landfill site which cause illnesses	128 (83)
Smoke from burning	5 (3)
Manifestation of dust	1 (1)
Don't know	20 (13)
Do you or any of your family members have health issues that are aggravated by the close proximity of the landfill site?	
Yes	48 (31)
No	106 (69)
Thinking about the effects on you and your family, please rate each of the following types of air quality issues from 1, no negative effect to 6, it has an extreme negative effect	
Emissions from industrial operations	10 (6)
Exhaust from motor vehicles	6 (4)
Dust from residential areas	23 (15)
Smoke from agricultural burning	3 (2)
Landfill site	111 (72)
Dust from nature	1 (1)

In this study, most participants considered best air quality as *"Fresh/clean air with no bad odour",* and considered worst air quality as *"Bad smell/bad odour from the landfill site which causes illnesses"* (76% and 83% respectively). Of all respondents, 36% perceived the close proximity to the landfill site as a factor which aggravated some health problems for their families. When asked to rate the air quality issues which they perceived to be contributing to the greatest effects on their families, landfill site (72%) and environmental dust (15%) were reported by most respondents. These two constituted 87% collectively. This study suggests that people perceived the landfill site and its impact as a challenge, and that it contributes a significant knowledge about the cause of the community protests led by the self-taught environmentalist, Sajida Khan (Bond and Dada 2007, Leonard 2012). De Feo et al. (2013) noted that if residents' perceptions, concerns and attitudes towards waste facilities are either not well understood or underestimated, people can produce strong opposition that may include protest demonstrations and violent conflicts such as those experienced in the Campania Region of Italy.

Other community members will go to any lengths necessary to control their exposure, or the exposure of their community as a whole, to dust. For example, Sajida Khan, an environmental activist from the same community of Clare Estate dedicated her life to fight international cooperations and local municipalities on the pollution and environmental degradation of her community. Sajida Khan's perception was that the community was exposed to dust content which led to the people of the community being sick with some developing respiratory symptoms, and others chronic symptoms. Sajida Khan's battle was linked to eco-feminist theory and international feminist, anti-capitalist struggles (Bond and Dada 2007). Sajida battled until the end of her life promoting her point of view about environmental justice and possible ways to create a healthier livelihood of her community members (Bond and Dada 2007).

This study shows that the lack of knowledge regarding the attitudes of the residents by the municipality was in fact the main cause of the dispute. Therefore, if the municipality continues to ignore the importance of the residents' view point of the landfill site, it is possible that we will see more of such protests even after Sajida has passed away. The results of this analysis of the residents' appraisal of the air quality near the Bisasar Road landfill site in eThekwini reveals the residents' unambiguous dissatisfaction. It suggests that community members have developed negative attitudes over time and this is contrary to the notion that positive perceptions of the landfill site increase over time (Elliott et al. 1998).

6.4.4 Residents' awareness of the environmental issues

Omanga et al. (2014) found that the most important factors influencing the respondents' pollution risk perception were environmental awareness and family health status. In this study, participants were asked to indicate their involvement in the environmental activities with the aim of reducing or protecting the community from air pollution-generating sources such as landfill sites. They were also asked about general awareness regarding their rights. Data presented in Table 6.4 indicate that most (60%) respondents were not aware of their environmental rights. Similarly, the majority (94%) of respondents were not aware of the number to call if they wanted to register an air quality complaint. This study reported the opposite when compared to the Malaysian study which reported that only 39% of the respondent did not know where to lay their complaints regarding air quality issues (Sakawi 2011). The findings of this study are not surprising given the low level of education of most of the respondents.

Table 6.4 Awareness and involvement in an environmental activity

Question	Percentage	
	Yes	No
Are you aware of any environmental rights that you hold as a citizen of South Africa?	40	60
Have you ever been involved in an environmental organisation/group?	7	93
Have you ever taken part in an environmental campaign/project/protest?	14	86
Do you currently belong to an organization concerned about air quality and public health?	3	97
Do you know the number to call if you want to register an air quality complaint?	6	94

The community's perception of dust exposure from the landfill depends greatly on the community's level of education (Al-Khatib et al. 2015). Considering their educational level, it is also not surprising that 86% of the respondents had never been involved in an environmental protest, project or campaign. Also 97% do not belong to any organisation concerned with air quality and public health. Al-Khatib et al. (2015) reported education levels as a major factor that affects the awareness of waste dump problems where they found that the individuals with a 2-year college diploma or a masters degree have the highest awareness of the dumpsite problems. It is therefore not surprising that the awareness levels were so low given the low literacy levels of the study population. However, this study indicates the need for concerned authorities to create programs in communities like Clare Estate.

The results indicate that the community of Clare Estate did not see a need to involve themselves in any environmental protest. This could be attributed to the lack of general awareness about the rights they have as South African citizens and the level of education since education contributes, to a great extent, to the awareness of dumpsite problems (Al-Khatib et al. 2015).

De Feo et al. (2013) reported that it is possible that residents of the village nearest to the facilities report lower awareness of and concern about environmental pollution. On the other hand, eThekwini Municipality is not condoned for not disseminating information to the community because media coverage has in the past produced information which influences the manner in which people perceive the landfill site.

A goal of the national government is to promote the education and empowerment of South Africa's people, so as to increase their awareness of and concern for air pollution issues, and to assist in developing the knowledge, skills, values, and commitment necessary to achieve efficient and effective air quality management (Department of Environmental Affairs 2009). This study suggests that eThekwini Municipality has not done enough in disseminating information in the community they work with. The study therefore provided baseline information which the municipality should work on, as far as understanding the residents' opinions, perceptions, and attitudes is concerned.

6.4.5 Mitigating strategies

In this study we believe that the community itself is fundamental in ensuring that the environmental impacts are reduced and for ensuring that their attitudes and perceptions are managed. In order to do this, we felt that it was important to understand the current practices for reducing the environmental impacts, and to understand their suggested future solutions. In this section participants were asked to indicate action they have taken in the last 12 months to reduce their exposure to outdoor pollution. Since perceptions and attitudes are closely linked to social behaviour, this provided valuable information which could assist in developing health education interventions.

The objective of this study is not to develop an intervention but to inform the development of such interventions. These actions were behavioural in nature, and hence participants were asked to comment on the number of times they had to modify their behaviour in order to reduce their exposure to outdoor air problems. Specifically, they were asked to choose from a list of five behavioural actions, which included questions on the number of times they closed their windows, limited outdoor activity, skipped a day of work, registered air quality complaints with the municipality, and left the area to avoid poor air quality.

The prominent cited actions to avoid or reduce outdoor air pollution were shutting windows, doing nothing at all, and limiting outdoor activities. Shutting of windows accounted for 60% whilst doing nothing and limiting outdoor activities accounted for 19% and 17% respectively. The remainder was shared among the other three mitigating strategies, namely, leaving their homes (4%), registering air quality complaint(s) with the municipality (1%), and skipping a day of work (1%). The study shows that residents were aware that air quality was poor in the area and they felt they needed to do something within their means to reduce exposure to it.

Participants were also asked to suggest solutions which in their view would solve the problems they were experiencing due to their being close to the landfill site. Of the 154 participants, 27% abstained from responding to this question and only 112 responded. The suggested solutions are presented in Figure 6.5. Interestingly, 75% of the respondents suggested that either the landfill site or the community must be relocated by the municipality. An overwhelming majority (64%) suggested that the landfill site must be closed down or removed from the area and 8% suggested that the community must be relocated from the area. The latter may be attributed to the fact that despite the previous protest, the municipality has resisted the relocation of the landfill site and therefore community sees the only option as to relocate themselves. A study undertaken by Lester (2006) indicated that a community's main concern in terms of landfills is the removal of waste and that pollutants such as dust will be transported and possibly be elevated and come into contact with other toxic pollutants in the air, as well as the short-term adverse effects that will occur.

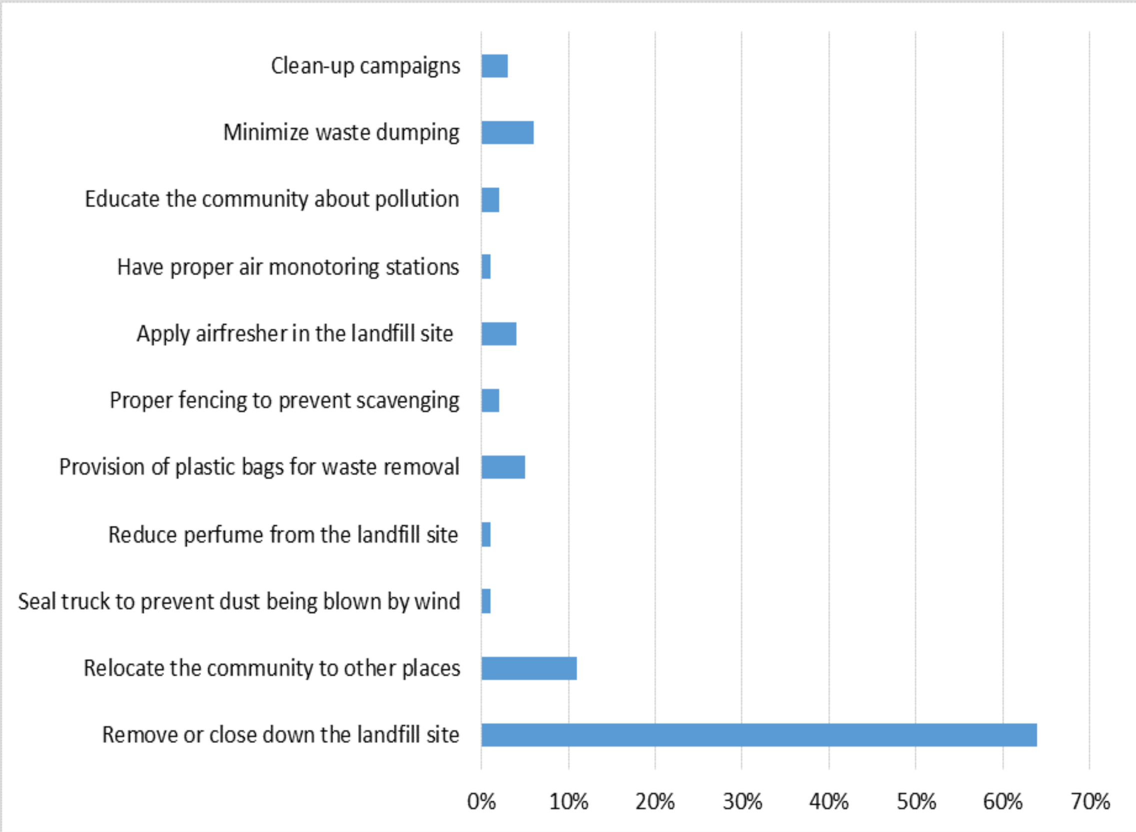

Figure 6.5 Percentage responses to the suggested solutions to mitigate landfill site problems

6.5 Conclusion

This study presented a quantitative approach to environmental risk perception. It investigated relevant environmental risk factors to generate fundamental information on environmental beliefs within the study community through both open ended and closed questions. Perceptions of the community living in and around the landfill site in Durban were sourced with a view to finding out the satisfaction or dissatisfaction levels of those communities. It transpired that the community members viewed the landfill site (which they called "dump site") as the main source of the poor air quality. They attributed the health problems they experienced to existence of the landfill site. The study found low levels of awareness regarding environmental issue. This includes the finding that the community was not aware of the number to call if they wanted to report poor air quality. This is viewed as a serious concern in terms of the community awareness programme from the municipality. They also wanted the eThekwini Municipality to relocate the landfill site as a matter of urgency. The study concludes that, with increased awareness, individual involvement and support, participation by the Clare Estate community could be fundamental in achieving an environmentally friendly and sustainable livelihood. It is hoped that the findings of this study will enable all stakeholders to focus on what is important in mediating the pollution risks in the community as environmental awareness programmes are developed and implemented.

CHAPTER 7: CONCLUSION AND FURTHER PERSPECTIVES

7.1 Introduction

This chapter presents the conclusion of the entire study. Study aims and objectives, limitations of the study, future possibilities, and the summary conclusions are also presented.

7.2 Aims and objectives

The main aim of the research was to determine respiratory health symptoms and outcomes in children aged between 6 and 12 years who reside within a 2-km radius from the Bisasar Road landfill site and to establish if there is a relationship between those respiratory health symptoms and the close proximity to the landfill site. It also intended to determine community experiences regarding the landfill site and its health impacts.

The objectives of the research were the:

- review of the respiratory effects of landfill sites in children;
- identification of the potential environmental and personal risk factors associated with the respiratory symptoms in children;
- determination of the respiratory health symptoms and outcomes of children living near the Bisasar Road landfill site;
- evaluation of the statistical relationship between indoor particulate matter ($PM_{2.5}$) and respiratory health outcomes in children living near the landfill site; and
- determination of the community perceptions about air quality, dust in particular, in relation to the landfill site.

7.3 Limitations of the study

The study had some inherent challenges with respect to data collection. Firstly, the research participants were children aged between 6 and 12 years. These are admittedly very young children, whose conception, understanding and response to questions could be flawed. Hence, the participation of parents, caregivers and guardians was necessary. The information provided may thus be limited or biased; but then the research assistants trained in probing skills minimised this setback. The probing process was vigorous to ensure that sufficient information was obtained from respondents that exposed other aspects related to the investigation.

Secondly, the recruitment was completed simultaneously with the administration of the questionnaires. However, $PM_{2.5}$ monitoring and spirometry (lung function tests) could not be done at the same time due to the limited equipment (spirometer and EPAM-5000). Therefore revisits at a later stage were made in order to conduct air sampling and spirometry tests. Upon revisits, some randomly selected participants were no longer interested in participating or could not be located because they had relocated to outside the study area. To address this limitation, more than the planned percentage was randomly selection to allow the study to retain the planned sample of participants.

Lastly, the lack of health data from health facilities such as clinics, to confirm or contradict respondents' claims was another setback. These claims could however, be corroborated by the health histories given by the parents and caregivers and the series of medical interventions that the children specifically from this area had had to undergo.

7.4 Future possibilities

Currently, there are limited studies in South Africa which have investigated the respiratory health effects of landfill sites. The findings of this study can be used to inform future studies and plans focusing on the impact of the landfill site in vulnerable groups (elderly and children) residing near the landfill sites. The current study focused on the respiratory health effects of children, but could not access the health records from health facilities like clinics to confirm or contradict respondents' claims. These claims could however, be corroborated by the health histories given by the parents and caregivers and series of medical interventions that the children specifically from this area had had to undergo.

A sociological study could also be undertaken based on the findings here. This could include the issues of how health risks are viewed in relation to bread and butter gains. The study could also unpack the same health issues used as a political divide. An interpretivist and critical research paradigm could be adopted. This would further interrogate this social context of information, how it is developed and construed by people and the way in which it is influenced by, and influences that social setting. Landfill sites are a world reality that can never, similarly to the working classes that reside in their proximity, be wished away. They need to be managed properly for the continued existence of all.

7.5 Final comments and summary conclusions

The conclusion of this study is presented according to different sections which are investigated in this study. The study comprises seven chapters, of which five chapters (Chapters 2 to 6) are research papers. Hence, the conclusion focuses only on these chapters.

Paper 1 (Chapter 2) presented a review of respiratory health effects of the landfill sites in children. The review showed a paucity of research in this area of this study. Hence this study fills a gap in the research by investigating the possible influence of landfill site activities, for the largest landfill site in Africa, on indoor $PM_{2.5}$ levels which could pose respiratory health effects on children who are the vulnerable group in post-apartheid South Africa.

Paper 2 (Chapter 3) investigated the environmental and personal risk factors associated with the respiratory symptoms in children residing near a landfill site. The main objective was the characterization of the household within a 2-km radius from the Bisasar Road landfill site with a view to identify potential environmental and personal risk factors associated with the prevalence of respiratory symptoms using a standard survey instrument. This paper presented significant findings in understanding the characteristics of the homes and the possible sources of the indoor air pollution. This was useful in foregrounding the respiratory health of children in those homes. The study found that most households used electricity as a source of energy. It also found that households were not heated during cold days and the few who heated their homes used electrical heaters. The study considered the associations made about the magnitude of moisture or damp damage with visible fungal growth as vital. Although damp was observed in some cases, no visible fungal growth was identified. The study therefore concludes that household pests, cockroaches in this case, and settling dust could be the possible source of the poor indoor air quality in households near the landfill site.

Paper 3 (Chapter 4) investigated the respiratory health conditions in children residing near the landfill site. The main objective was the determination of the respiratory health outcomes in children living near Bisasar Road landfill site using both the self-reported, standardised questionnaire and spirometry. Particulate matter (PM) contributes to the poor indoor air quality, and is a risk factor for respiratory health conditions. Hence, the characterization of the respiratory heath conditions is vital in understanding how particulate matter $PM_{2.5}$ affects the lung function in children living near the landfill site. To achieve this, the study focused on the self-reported wheeze and doctor's diagnosis of asthma. Wheeze is a prominent symptom of asthma. Hence it is an important predictor of obstructive and restrictive lung function. Breathlessness, wheeze and asthma were found to be high in children living in Clare Estate. The study concludes that children living near the air pollution emitting sources such as the landfill site have an increased risk of respiratory health conditions including breathlessness and wheeze due to exposure to outdoor air pollution sources. The study also concluded that children who reside near the landfill site are exposed to air pollution, especially PM, and as a result most suffer from asthma.

Paper 4 (Chapter 5) investigated the respiratory health effects associated with $PM_{2.5}$ in children residing near a landfill site. The objective was the determination of $PM_{2.5}$ exposure to children living in Clare Estate, and to evaluate its impact on respiratory-health symptoms. Since written questionnaires to determine the impact of $PM_{2.5}$ in children were gathered from parents or caregivers, information biases were expected, which could include exaggerated or under reporting of the symptoms. In view of some of the potential limitations of questionnaires, both $PM_{2.5}$ and spirometry were measured in order to establish if there was any correlation between $PM_{2.5}$ exposure and health symptoms. The study established a strong negative relation between $PM_{2.5}$ and lung function. The study also found that children residing in close proximity to this landfill site are exposed to $PM_{2.5}$ concentration levels which are above the minimum accepted by WHO guidelines. The study concluded that the $PM_{2.5}$ emanating from the landfill sites caused the negative respiratory health effects in children.

Given the strong negative correlation between $PM_{2.5}$ concentration and lung function patterns in children, perceptions of the community living in and around the landfill site in Durban were sourced with a view to determine the satisfaction or dissatisfaction levels of those communities. Hence, Paper 5 (Chapter 6) investigated the community appraisal of air quality near a landfill site. The purpose was to evaluate community perceptions on the impact of dust emanating from the landfill sites in their vicinity. It transpired that the community members viewed the landfill site (which they called "dump site") as the main source of the poor air quality. They attributed the health problems to the existence of the landfill. The study found low levels of awareness regarding the environmental issues. The community also wanted the eThekwini Municipality to relocate the landfill site as a matter of urgency. The study concludes that, with increased awareness, individual involvement and support, participation by the Clare Estate community could be fundamental in achieving an environmentally friendly and sustainable livelihood. It is hoped that the findings of this study will enable all stakeholders to focus on what is important in mediating the pollution risks in the community as environmental awareness programmes are developed and implemented.

Overall, this study concluded that the scarcity of research on the impact of the landfill sites in children poses a threat to the well-being of the future generation; that the household pests - cockroaches in this case and settling dust- could be the possible source of indoor air pollution in households near the landfill site; that children living near the air pollution-emitting sources such as the landfill site have an increased risk of respiratory health conditions including breathlessness and wheeze due to exposure to outdoor air pollution sources; that children are exposed to air pollution, especially PM, and as a result most suffer from asthma; that the $PM_{2.5}$ emanating from the landfill sites caused the negative respiratory health effects in children; and that, with increased awareness, individual involvement and support, participation by the Clare Estate community could be fundamental in achieving an environmentally friendly and sustainable livelihood.

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APPENDIX A: PROJECT INFORMATION SHEET

Dear Prospective Participant

My name is Phiwayinkosi Richmond Gumede from School of Agriculture, Earth and Environmental Sciences at the University of KwaZulu-Natal (UKZN). You are being invited to consider participating in a study that involves research on indoor air quality in communities living in and around the Bisasar Road landfill site in eThekwini Municipality.

1. Title of research project

The respiratory health effects associated with particulate matter ($PM_{2.5}$) exposure in children residing near a landfill site: a case of eThekwini Municipality.

2. Purpose of the research

The prime aim of the study is to evaluate the levels of dust exposure around landfills and to assess reported levels of respiratory health of children living near the landfill sites.

3. Name of the researchers

Phiwayinkosi Gumede (Masters)	(031-373 2807; Siphiweg@mut.ac.za)
Prof. MJ Savage	(033- 260 5514; savage@ukzn.ac.za)

4. Description of the research project

If you agree to participate, you also have to consent that your children participate in this study. This study will be carried out in your home at your preferred time. The research is about indoor air as well as other issues in your homes. A visit to your home will involve the following procedures:

4.1 Walkthrough inspection.

A walkthrough inspection will be conducted by the researcher in the houses where the child sleeps. A child caregiver or an adult person who lives with the child will be asked some questions about the house and the child's activity in the house.

4.2 Dust samples.

Dust samples will be taken from the living room or in the child's bedroom where there is no living room. Monitoring equipment will be left to run for 24 hours in your house to monitor and collect dust. Dust samples will be done in an accredited laboratory.

4.3 Lung function test/ Spirometry

Lung function tests will be performed on your child, with your consent (caregivers/parent). Spirometry will be conducted by trained nurses/technician in a sitting position without a nose-clip using a portable, electronic spirometer. Your child will be assessed at home in your presence. Each participant will perform at least three tests.

Spirometry is the procedure that is being performed to measure the lung function. It is sometimes referred to as lung function test. The equipment used to measure lung function is called spirometer. Most spirometers display graphs, called spirograms. It specifically measures the amount (volume) and/or speed (flow) of air that can be inhaled and exhaled by an individual at a given time. It is an important tool in assessing conditions such as asthma, pulmonary fibrosis, cystic fibrosis, and Chronic Obstruction Pulmonary Disease (COPD).

The basic forced volume vital capacity (FVC) test varies slightly depending on the equipment used. Generally, the participant is asked to take the deepest breath they can, and then exhale into the sensor as hard as possible, for as long as possible (preferably at least 6 seconds). It is sometimes directly followed by a rapid inhalation. Sometimes the test will be preceded by a period of quiet breathing in and out from the sensor (tidal volume), or the rapid breath in (forced inspiratory part) will come before the forced exhalation. During the test, soft nose clips may be used to prevent air escaping through the nose and filter mouthpieces may be used to prevent the spread of microorganisms. These filters are changed after each person has performed spirometry. Normal values are based upon your age, height, ethnicity, and sex and normal results are expressed as a percentage.

5. Duration of participation of participant in the study.

If you choose to enrol and remain in the study, the expected duration is three months including revisits if necessary. There will be three visits to your house, the first session will include a walkthrough inspection, taking of dust samples and deploying the equipment in the house which will take a total of up to two (2) hours. The second visit will be for the researcher to remove the deployed equipment that is left in the house which will take ten minutes. The last visit will last about thirty (30) minutes and that will be for the Spirometry Technician to perform lung function test in children.

6. Risks and discomforts of the research

This study will not put you or children in a situation where there might be a risk of harm, whether physically, emotionally, socially, politically, economically, and/or psychologically as a result of your participation. The equipment that will be left in your house will produce a low noise which might take time for people in the house to get used to.

7. Measures to be taken to minimize risks and discomforts:

No measures necessary because there is no risk involved and the noise levels will be very minimal

8. Expected benefits to participants or to others

This study will provide an indication of the indoor dust exposure levels of the communities situated in close proximity to the landfill sites, and it will also give an indication of the possible associated health effects. You will be provided with results and explanation about the state of indoor quality analyzed from your homes unless you indicate that you do not wish to receive this information. Participants will be informed about the importance of the indoor air environment and health effects associated with it. Environmental Health Officers in the area will have an idea about the indoor environment in the area.

9. Costs to participant resulting from participation in the study

You will not pay to take part in this study

10. Payments to participant for participating in the study

The participants will receive no financial benefits from participating in this study.

11. Confidentiality of information collected.

You will not be identified in any reports on this study. The records will be kept confidential to the extent provided by law. Only researchers on this study may have access to your results.

12. Management of Physical Injury

They will be no injuries as a result of participating in the study.

13. Availability of further information

This study has been ethically reviewed and approved by the Ethics Review Committee of the Biomedical Research Ethics Committee of the University of KwaZulu-Natal (Ethical clearance number: BE201/11) (Appendix I). In the event of any problems or concerns/questions you may contact the researcher at (provide contact details) or the UKZN Biomedical Research Ethics Committee, contact details as follows:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus, Govan Mbeki Building, Private Bag X 54001, Durban, 4000

Tel: 27 31 2604769 - Fax: 27 31 2604609 or Email: BREC@ukzn.ac.za

14. Voluntary nature of participation

Your participation in this project is voluntary. Subsequent to your consent, you may refuse to participate in or withdraw from the study at any time without penalty or loss of benefits to which you may otherwise be entitled. If you consent to participate in this project you will have to sign a consent form which will be provided by the data collector.

APPENDIX B: STUDY PERMISSION LETTER

DSW

CLEANSING AND SOLID WASTE
17 Electron Road, Springfield, Durban.
P.O. Box 1038, Durban, 4000.
Tel: +27(0) 31 311 1111
Fax: +27(0) 31 263 1119
Helpline: +27(0) 31 311 8804
Website: www.durban.gov.za

ETHEKWINI MUNICIPALITY

Enquiries : John Parkin
Telephone: 031 311 8820

15 December 2011

Siphiwe Gumede
P O Box 1334
DURBAN
4000

Email: Siphiweg@dut.ac.za

Siphiwe,

RESEARCH DUST EMISSIONS ON LANDFILLS

I refer to our meeting of 19 May 2011 and your subsequent letter dated 21 May 2011.

As discussed each landfill is unique as there are so many variables. Location, climate, geology, waste type, quantity, operation to name a few. Therefore it is not possible to make general conclusion from work on one site. Furthermore Bisasar Rad landfill will be at capacity in 2014 so the usefulness of your research must be in question.

DSW has always supported advancing the understanding of all aspects of waste management and therefore permission will be granted to take samples under the following conditions.

1. The equipment set up does not interfere with daily operations
2. Security of your equipment is your concern. City cannot be hold responsible for damage, vandalism or theft.
3. All safety procedures must be followed whilst on site.
4. You sign an indemnity.

J. PARKIN
DEPUTY HEAD: PLANT & ENGINEERING

C:\Documents and Settings\yvonneon\My Documents\My Documents\John\Research dust emission on Landfill.doc

BATHO PELE — THIS MEANS YOU! LOKHU KUCHAZA WENA

BETTER WITHOUT LITTER

APPENDIX C: ADULT CONSENT FORM

I ____ (Name) have been informed about the study

Titled: ***The respiratory health effects associated with particulate matter ($PM_{2.5}$) exposure in children residing near a landfill site: a case of eThekwini Municipality*** **by Phiwayinkosi Gumede.**

I understand the purpose and procedures of the study

I have been given an opportunity to ask questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any benefits that I would usually be entitled to.

If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at siphiweg@mut.ac.za or 031 907 7576.

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, South Africa
Tel: 27 31 2604769 - Fax: 27 31 2604609
Email: BREC@ukzn.ac.za

_____________________ _____________________
Signature of Participant **Date**

______________________________ _____________________
Name & Signature of Data Collector **Date**

APPENDIX D: CHILD INFORMED ASSENT FORM

IMPORTANT:

1) If you do not understand any words, please ask for an explanation before giving assent.

Title of research project:
The respiratory health effects associated with particulate matter ($PM_{2.5}$) exposure in children residing near a landfill site: a case of eThekwini Municipality

Procedure brief

Lung function tests will be performed if you and your caregivers/parent both consent to participate. Spirometry will be conducted by trained nurses/technician in a sitting position without a nose-clip using a portable, electronic spirometer. Your will be assessed at home in the presence of your guardian. Each participant will perform at least three tests.

Please circle the appropriate answer (child):

1. Have you understood the subject information sheet? YES/NO
2. Did you discuss the study with anyone? YES/NO
3. Who did you discuss it with? ________________________
4. Do you have any questions about the study or about your role in the study? YES/NO
5. Are you worried about any part of this study? YES/NO
6. Have you received enough information about this study? YES/NO
7. Do you understand how you will be involved in this study? YES/NO
8. Do you understand that you are free to withdraw from this study:
   (a) at any time and;
   (b) without having reason to withdraw YES/NO
9. Do you agree to voluntarily take part in this study? YES/NO

If you have answered **NO** to any of the above questions, please obtain the necessary information **BEFORE** signing.

I, __________________________________ (name of child's guardian) hereby give assent for the proposed procedures to be performed on the child participant as part of the above mentioned project.

______________________________ ______________________________

Name & signature of the Guardian **(Date)**

______________________________ ______________________________

Name & Signature of Data Collector **Date**

APPENDIX E: HOME WALKTHROUGH CHECKLIST

INDOOR AIR QUALITY

[**Please note: Some questions in this survey are to be read and others are for you to just observe. In situations where the respondent says something different than what you observe, ask the respondent to explain. "I noticed there are rugs on the floor, and I thought you said before that there are not usually rugs on this floor. Is something unusual going on right now?"**]

[**Read to the occupant**] At this time I would like to walk through several rooms in the house with you. I will be writing down information about these rooms. I will also be asking you questions related to specific items in some of the rooms we will be looking at. This is an important part of the study that will help us give better advice about the indoor environment of your house.

[obs] 1. Type of home:
- ☐1 A single family house
- ☐2 A duplex or flat
- ☐3 An apartment building
- ☐4 Other (explain:______________)

[ask] 2. Total number of rooms in the house [excluding toilets & b/rooms] ________)

[ask] 3. When was this home built?
- ☐1 Before 1978
- ☐2 1978 or later
- ☐3 Don't know

[obs] 4. Home is constructed mostly of:
- ☐1 Wood
- ☐2 Brick
- ☐3 Other (explain:__________)

[obs] 5. Do you have a central air conditioning/fan in your home?
- ☐1 Yes
- ☐2 No

[ask] 6. Did you do anything to prepare for this visit, such as cleaning the house?
- ☐1 Yes
- ☐2 No **[SKIP TO 8]**

[ask] 7. What did you do?________________________________

8. Type of a Home

[obs]A. What are outside walls made of? **CHECK ALL THAT APPLY**	☐1 Corrugated iron sheets ☐2 Wood ☐3 Cement ☐4 Other (Specify:________________________)
[obs] B. What is the roof made of?	☐1 Roof tiles ☐2 Asbestos ☐3 Tauplin (sail) ☐4 Other (Specify:______________________)
[obs] C. Type of floor covering	**[CHECK ALL THAT APPLY]** ☐1 Wood ☐2 Cement ☐3 Earth ☐4 Carpeting ☐5 Other (specify:______________________)
[obs] D. Is there a ceiling in the house (that separate from the underside of the roof	☐1 Yes ☐2 No
[obs] E. Are there visible spaces or gaps between (that is, can sky or obvious light from outside be seen through a gap in:	☐1 Yes ☐2 No (Specify the location______________________)
[obs & ask] F. Cooking is done inside of the house….	☐1 Never…GO TO 28 ☐2 Less than once a week ☐3 Few times each week
[obs & ask] G. The usual fuel or energy source for cooking is…	☐1 Paraffin ☐2 Electricity ☐3 Wood ☐4 Coal Stove ☐5 Other (Specify:___________________________)
[obs & ask] H. Type of ventilation used for cooking…	☐1 None whatsoever ☐2 Only opening of the door and windows ☐3 Hole in the roof or ceiling above cooking area ☐4 Pipe to the outside ☐5 Other Specify:___________________________)
[obs & ask] I. During cold weather, the house is heated by….	☐1 Not heated ☐2 Electric heater ☐3 Paraffin (kerosene) heater ☐4 Wood Stove ☐4 Coal Stove ☐5 Other (Specify:________________________)
[obs] J. Evidence of smoke deposits from cooking or heating on walls, ceiling or underside of roof	☐1 None ☐2 Modest ☐3 Heavy

[obs] K. Evidence of settling dust in the house	☐1 Yes ☐2 No
[obs] N. Peeling paint	☐1 Yes ☐2 No
[obs] M. Is there a window present in every room?	☐1 Yes ☐2 No
[obs or ask] O. Can at least one window in room be opened?	☐1 Yes ☐2 No (If no, why? ____________________________)
[ask] P. Is the window open in spring, summer, or winter?	**[CHECK ALL THAT APPLY]** ☐1 Spring/Autumn ☐2 Summer ☐3 Winter
[obs/ask] Q. Do all the windows in the house appear to have tight seal?	☐1 Yes ☐2 No
[obs] R. Signs of water damage, moisture, or leaks on floors?	☐1 Yes (describe: _______________________) ☐2 No
[obs] S. Signs of water damage, moisture, or leaks on wall?	☐1 Yes (describe: _______________________) ☐2 No
[obs] T. Visible mold or mildew (visible sig ns or musty or mildew smell)	☐1 Yes ☐2 No
[obs or ask] U. Tobacco smoke? (cigarette butts etc.)	☐1 Yes ☐2 No

9. Household Environmental Checklist

[obs or ask] A. Are there cockroaches in your Home?	☐1 Yes ☐2 No ☐8 Don't know
[ask] B. Have you had any problems with cockroaches in your home during the past year?	☐1 Yes ☐2 No ☐8 Don't know
[ask] C. Have you or someone else (your landlord, another family member, a professional) treated your home for cockroaches in the past year?	☐1 Yes ☐2 No **[GO TO F]** ☐8 Don't know **[GO TO F]**
[ask] D. When was the last time it was treated?	☐1 Within last month ☐2 1 to 3 months ago ☐3 3 to 6 months ago ☐4 6 to 12 months ago ☐5 More than 12 months ago ☐8 Don't know

[ask] E. What was used to treat your home for roaches? **[READ EACH CHOICE AND CHECK ALL THAT APPLY]**	☐1 Dry powder ☐2 Spraying ☐3 Gel ☐4 Roach bait trap (**SPECIFY:** ______) ☐5 Boric acid ☐6 Other (**SPECIFY:** _____________) ☐8 Don't know
[ask] F. Have you had any problems with mice or rats in your home during the past year?	☐1 Yes ☐2 No ☐8 Don't know
[ask] G. Have you or someone else (your landlord, another family member, a professional) treated your home for rats or mice in the past year?	☐1 Yes ☐2 No **[END]** ☐8 Don't know **[END]**
[ask] H. When was the last time?	☐1 Within last month ☐2 Between 2 and 6 months ago ☐3 Between 6 and 12 months ago ☐4 More than 12 months ago ☐8 Don't know
[ask] I. How is your home treated for rats or mice? [**READ EACH CHOICE AND CHECK ALL THAT APPLY**]	☐1 Spring traps ☐2 Glue traps ☐3 Poison ☐4 Other (**SPECIFY:** _____________) ☐8 Don't know

Thank you very much!

End Time ___________ AM/PM

APPENDIX F: CHILD HEALTH SCREENING QUESTIONNAIRE

Screening Questionnaire about ____

[*full* name of child]

This questionnaire should be completed by the person who most often takes care of the child. Please put a tick ☑ in the correct box for each question.

A. BACKGROUND INFORMATION

A1. Child's current grade in school	_________
A2. Child's date of birth	_____/_____/________ = ______ day month year age
A3. Is the child:	□1 Male □2 Female
A4. Usual language spoken at home:	□1 English □2 Zulu □3 Xhosa □9 Other (Specify:_____________________)
A5. Your telephone numbers:	home: ____________________ work: _____________________ cell: ______________________ □1 I do not have a telephone
A6. How does the child usually get to school?	□1 walks □2 driven in a private vehicle □3 driven in a taxi □4 takes a bus □9 Other (Specify:_____________________)
A7. Are you the main person who takes care of this child?	□1 Yes □2 No
A8. How are you related to **this child**?	□1 Mother □2 Father □3 Grandmother □4 Grandfather □5 Aunt □6 Uncle □9 Other (**specify:** ________________)

B. CHILD'S SYMPTOMS INFORMATION

B1. In the past 12 months, how often has your child had a **cough that won't go away**?	□1 every day □2 more than 2 times per week □3 more than 1 time per month □4 3 to 12 times in the whole year □5 1 or 2 times in the whole year□ □6 never
B2. In the past 12 months, how often has your child had **wheezing** (a whistling sound from the chest) **with a cold**?	□1 more than 1 time per month □2 3 to 12 times in the whole year □3 1 or 2 times in the whole year □4 never
B3. In the past 12 months, how often has your child had **wheezing** (a whistling sound from the chest) ***without* a cold**?	□1 every day □2 more than 2 times per week □3 more than 1 time per month □4 3 to 12 times in the whole year □5 1 or 2 times in the whole year □6 never
B4. In the past 12 months, how often has your child had an attack of **wheezing** that made it **hard to breathe or catch his or her breath**?	□1 every day □2 more than 2 times per week □3 more than 1 time per month □4 3 to 12 times in the whole year □5 1 or 2 times in the whole year □6 never
B5. In the past 12 months, how often has your child **wheezed while exercising, running or playing?**	□1 every day □2 more than 2 times per week □3 more than 1 time per month □4 3 to 12 times in the whole year □5 1 or 2 times in the whole year □6 never
B6. In the past 12 months, how often has your child **coughed while exercising, running or playing**?	□1 every day □2 more than 2 times per week □3 more than 1 time per month □4 3 to 12 times in the whole year □5 1 or 2 times in the whole year □6 never
B7. In the past 12 months, how often has your child complained that his or her **chest felt tight or heavy**?	□1 every day □2 more than 2 times per week □3 more than 1 time per month □4 3 to 12 times in the whole year □5 1 or 2 times in the whole year □6 never
B8. In the past 12 months, how often has your child's **sleep been disturbed due to wheezing, coughing, chest tightness or shortness of breath**?	□1 most nights □2 more than 1 time per week □3 more than 2 times per month □4 more than 1 time per month □5 3 to 12 times in the whole year □6 1 or 2 times in the whole year □7 never

B9. Has a doctor or nurse **EVER** said that your child had: (check ALL that apply)	□1 Asthma □2 Bronchitis or Bronchiolitis □3 Reactive Airway Disease (RAD) □4 Pneumonia □5 Asthmatic Bronchitis
B10. In the past 12 months has your child **taken any medications, nebulisers, or inhalers (pumps) prescribed by a doctor** for any of the conditions listed above?	□1 Yes □2 No
B11. Does your child take **any of these doctor-prescribed medications every day**, even when he/she is **not** having trouble breathing?	□1 Yes □2 No □8 Does not apply
B12. In the past 12 months how many times has your child **had to make an unplanned visit to a doctor's office for breathing problems?**	□1 0 times □2 1 time □3 2 times □4 3 or 4 times □5 5 or 6 times □6 7 times or more
B13. In the past 12 months how many times has your child **been to the emergency room** (but not stayed overnight in the hospital) **for breathing problems?**	□1 0 times □2 1 time □3 2 times □4 3 or 4 times □5 5 or 6 times □6 7 times or more
B14. In the past 12 months how many times has your child **had to stay in the hospital for one night or more because of breathing problems?**	□1 0 times □2 1 time □3 2 times □4 3 or 4 times □5 5 or 6 times □6 7 times or more
B15. Did a doctor ever say that **[CHILD]** had asthma?	□1 Yes □2 No **[GO TO B19]**
B16. How old was **[CHILD]** when he/she first had this illness?	________ number } □1 months □2 years
B17. Does **[CHILD]** still have this illness?	□1 Yes □2 No □8 don't know
B18. Has **[CHILD]** ever been treated by a Doctor for this illness?	□1 Yes □2 No □8 don't know
B19. Did a doctor ever say that **[CHILD]** had chronic bronchitis?	□1 Yes □2 No **[GO TO C]**
B20. How old was **[CHILD]** when he/she first had this illness?	number ________ } □1 months □2 years
B21. Does **[CHILD]** still have this illness?	□1 Yes □2 No □8 don't know

C. RESPIRATORY CONDITIONS AND ALLERGY

Cough	
C1. Does **[CHILD]** usually cough on most days for 3 consecutive months or more during the year?	□1 Yes □2 No
C2. Does **[CHILD]** usually cough first thing in the morning in the winter?	□1 Yes □2 No **if no to the above, SKIP to PHLEGM**
C3. Does **[CHILD]** usually cough at all during the rest of the day? **[Ignore an occasional cough]**	□1 Yes □2 No
C4. For how many years has **[CHILD]** had this cough?	____________ Number years
Phlegm	
Count phlegm on first going outdoors. Exclude phlegm from the nose. Count swallowed phlegm.	
C5. Does **[CHILD]** usually bring up any phlegm/sputum/mucus from your chest first thing in the morning in the winter?	□1 Yes □2 No
C6. Does **[CHILD]** usually bring up any phlegm/sputum/mucus from his/her chest during the day in the winter?	□1 Yes □2 No
if no to above, SKIP to EPISODES OF COUGH and PHLEGM [C12]	
C7. Does **[CHILD]** bring up phlegm like this on most days for as much as three months each year?	□1 Yes □2 No
C8. Does **[CHILD]** usually bring up phlegm at all on getting up or first thing in the morning?	□1 Yes □2 No
C9. For how many years has **[CHILD]** had trouble with phlegm?	__________ years
C10. Has **[CHILD]** ever coughed up blood?	□1 Yes □2 No
C11. Was this in the past year?	□1 Yes □2 No
Episodes of Cough And Phlegm	
C12. Has **[CHILD]** had periods or episodes of (increased) cough and phlegm lasting for 3 weeks or more each year?	□1 Yes □2 No
Breathlessness	
C13. Is **[CHILD]** troubled by shortness of breath when hurrying on level ground?	□1 Yes □2 No
C14. Does **[CHILD]** get short of breath walking with other children of his/her own age on level ground?	□1 Yes □2 No
C15. Does **[CHILD]** have to stop for breath	□1 Yes

when walking at his/her own pace on level round?	□2 No
Wheezing	
C16. Does **[CHILD]** chest ever sound wheezy or whistling?	□1 Yes □2 No **[GO TO END]**
C17. When **[CHILD]** has a cold?	□1 Yes □2 No
C18. Occasionally apart from colds?	□1 Yes □2 No
C19. Most days or nights?	□1 Yes □2 No
C20. For how many years has this been Present?	_________ years
C21. How many episodes of wheezing or Whistling has **[CHILD]** had in the past 12 Months?	__________ number
C22. How many times in the past 12 Months was **[CHILD]** hospitalised overnight for these episodes of wheezing or whistling?	__________ number
C23. Has **[CHILD]** ever had an ATTACK of wheezing that has made him/her feel short of breath?	□1 Yes □2 No**[GO TO END]**
C24. How old was **[CHILD]** when he/she had your first such attack?_	______ Age in years
C25. Has **[CHILD]** had 2 or more such Episodes?	□1 Yes □2 No
C26. Has **[CHILD]** ever required medicine or treatment for the(se) attack(s)?	□1 Yes □2 No
C27. Is/Was **[CHILD]'s** breathing Absolutely normal between attacks?	□1 Yes □2 No
C28. I am going to read a list of things that might bring on wheezing, tightness in the chest, cough, or shortness of breath in some children. I would like to know whether each of these things brings on these symptoms for **[child]**.	□1 Being active (running, playing, swimming, or exercising) □2 Sprays or strong smells (such as colognes, perfumes, or cleaning supplies) □3 Colds or flu □4 Cold air □5 Change in weather □6 Laughing or crying hard □7 Dust □8 Pets □9 Truck or car exhaust □10 Hot summer days □11 Pollen, trees, fresh cut grass □12 Mold and mildew

	☐13 Smoke ☐14 Cockroaches ☐15 Certain foods ☐16 Nothing causes breathing problems ☐99 Other (**SPECIFY:** _______________)
Has a doctor *ever* told you that **[child]** has.... **[READ ALL CHOICES]**	
C29. Allergies	☐1 Yes ☐2 No
C30. Eczema	☐1 Yes ☐2 No
C31. Reactive airway disease	☐1 Yes ☐2 No
C32. Asthmatic bronchitis	☐1 Yes ☐2 No
C33. Any other lung/breathing condition	☐1 Yes (**SPECIFY:** _______________) ☐2 No

Thank you for your time for these questions.

We may need to contact you again to obtain additional information. Please give me the name, address and telephone number of one relative or friends who would know where you could be reached in case we have difficulty in contacting you.

Name of contact person: ____

Telephone number: ____

Address of first contact person:

_______________ ____

House No. Road/Street

____

Suburb/Township Postal Code

Relationship of contact person to you: ____

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE!

Interview completed at: Time: _ _:_ _ am / pm

APPENDIX G: COMMUNITY PERCEPTION QUESTIONNAIRE

In this questionnaire I am going to ask you questions about the experiences you have with regards to the landfill site. Now I have a few questions about your background that will remain confidential.

Please put a tick ☑ in the correct box for each question.

A. DEMOGRAPHICS

1. What year were you born	____
2. What is the highest level of education you have completed?	□1 Some high school or less □2 High school graduate □3 Vocational school or technical college □4 College or university graduate
3. Are you currently involved in waste picking?	□1 Yes, if yes for how long:_____________ □2 No
4. How long have you lived in this area	____________ Number years
5. Are there any children under the age of 13 who reside with you?	□1 Yes, if yes for how many:_____________ □2 No, if no go to **B1**
6. Are they involved in waste picking in the same landfill site?	□1 Yes □2 No

B. COMMUNITY PERCEPTION

B1. What is your greatest local environmental concern (if any)?	____ ____
B2. Are you aware of any environmental rights that you hold as a citizen of South Africa? Explain.	____ ____ ____ ____ _
B3. What do you consider as best air quality?	____ ____
B4. What do you consider as worst air quality?	____ ____ ____ ____
B5. In the past 12 months, would you say you had good air quality in this area	□1 Yes □2 No if "yes", explain your answer ____ ____

	______________________________________ ______________________________________
B6. In the past 12 months, how would you rate air quality where you live? Would you rate it as	□1 Very poor □2 Poor □3 Neither poor nor good □4 Good □5 Very good
B7. In your community, what month of the year do you think generally has the ***worst*** air quality?	□1 _______________ □2 ______________ □3 All months are the same (don't read)
B8. What month of the year do you think generally has the ***best*** air quality in your community?	□1 _______________ □2 ______________ □3 All months are the same (don't read)
B9. I am going to read you a list of items that may be a source contributing to poor air quality in your area. Please rate each item 1 to 6 with '1', does not contribute at all and '5', contributes a great deal	□1 __ Emissions from industrial operations □2 __ Exhaust from motor vehicles □3 __ Dust from township □4 __ Dust from suburbs □5 __ Smoke from agricultural burning □6 __ Landfill sites □9 __ Other (**specify:** _______________)
B10. Thinking about the effects on you and your family, please rate each of the following types of air quality issues from 1, no negative effect to 6, it has an extreme negative effect	□1 __ Emissions from industrial operations □2 __ Exhaust from motor vehicles □3 __ Dust from township □4 __ Dust from suburbs □5 __ Smoke from agricultural burning □6 __ Landfill sites □9 __ Other (**specify:** _______________)
B11. Have you ever been involved in an environmental organisation/group?	□1 Yes □2 No If yes, which one:______________________ If no, please explain why not: ______________________________________ ______________________________________ ______________________________________ ______________________________________
B12. Have you ever taken part in an environmental campaign/project/protest?	□1 Yes □2 No If yes, which one:______________________ If no, please explain why not: ______________________________________ ______________________________________ __________________________
B13. Do you currently belong to an organization concerned about air quality and public health?	□1 Yes □2 No If yes, which one:______________________

	If no, please explain why: ____ ____ ____________________________
B14. Do you or any of your family members have health issues that are aggravated by the close proximity of the landfill site?	☐1 Yes ☐2 No If yes, list the health issues ____ ____ ____ ____
B15. Next I'll read a list of things people may do to reduce their exposure to outdoor air quality problems from landfill sites. As a result of air quality issues, please tell me how often in the last 12 months have you	☐1 Shut windows ☐2 Limited outside activities ☐3 Skipped a day of work ☐4 Registered air quality complaint with the municipality ☐5 Left town to avoid the poor air quality
B16. Do you know the number to call if you want to register air quality complaint?	☐1 Yes, write the number _______________ ☐2 No

B17. Do you have any other comments you want to add about the dust exposure from landfill site?

____
____
____
____
____

B18. Apart from the dust exposure, what other problems you are experiencing due to the close proximity to landfill site?

____
____
____

B19. What solutions can you suggest to solve these problems?

____
____
____

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE!

Interview completed at: Time: _ _:_ _ am / pm

APPENDIX H: PFT PRESCREENING QUESTIONNAIRE

Completed by a Certified Spirometry Technician Prior to Testing and Attached to the Spirometry Record.

NAME (LAST, FIRST, MIDDLE):____

SITE:____

YES	NO		1	In the last 6 weeks have you had a chest injury or surgery involving the eye, ear, chest, abdomen or been hospitalized for a heart attack? ***If YES, Do not test at this time. Reschedule spirometry test for 6 weeks***
YES	NO		2	Are you under a physicians care for high blood pressure? ***If YES, If blood pressure exceeds action level, obtain Physician clearance before proceeding.***
				Within the last hour have you eaten a full meal? ***If YES to either smoking or eating, if possible wait one hour before testing, otherwise make notation to over reader and proceed.***
YES	NO		3	Have you had a respiratory infection (such as flu, Pneumonia, bronchitis, or chest cold) in the last 3 weeks? ***If YES, Continue with spirometry testing now and schedule to retest in 6 weeks.***
YES	NO		4	Have you used an inhaled bronchodilator (Primatene Mist, Ventolin, etc.) in the last 6 hours?
YES	NO			Have you had more than 2 cups of caffeinated coffee, tea or cola (total) in the last 6 hours? ***If YES, If possible, wait one hour before testing, otherwise make notation to over reader and proceed.***
YES	NO		5	Are you wearing any tight or restrictive clothing?

Certified spirometry technicians initials or ID# ________________ Date:_________________