LIST OF ABBREVIATIONS

Institutional abbreviation

AGA	Anglo Gold Ashanti
ATS – DLD	American Thoracic Society – Division of Lung Diseases
BMRC	British Medical Research Council
CGR	Crown Gold Recoveries
DAAD	Deutscher Akademischer Austausch Dienst
DoE	Department of Education
DRD	Durban Roodepoort Deep
ERPM	East Rand Proprietary Mines
ETS	Environmental Tobacco Smoke
GARD	Global Alliance against Chronic Respiratory Diseases
GINA	Global Initiative for Asthma
ISAAC	International Study of Asthma and Allergies in Childhood
MHSC	Mine Health Safety Council
NRF	National Research Foundation
SHSPH	School of Health Systems and Public Health
SAWS	South African Weather Services
UP	University of Pretoria
WHO	World Health Organisation

Technical abbreviations

AM	Alveolar Macrophages
CI	Confidence Interval
FEV1	Forced Expiratory Volume in 1 second
IL-1β	Interleukin 1β
LRA	Logistic Regression Analysis
MIP-2	Macrophage Inflammatory Protein-2
NOx	Nitrogen Oxides
NO_2	Nitrogen Dioxide
OR	Odds ratio
O_3	Ozone
PM	Particulate Matter
PM2.5	Particulate Matter with an aerodynamic diameter of 2.5 μm or less
PM10	Particulate Matter with an aerodynamic diameter of 10 μm or less
RNS	Reactive Nitrogen Species
ROS	Reactive Oxygen Species
SOx	Sulphur oxides
SO2	Sulphur dioxide
TNF-α	Tumour Necrosis Factor
μg.m-3	Microgram per cubic metre

ABSTRACT

Background: Gold mine dump facilities are the main source of airborne particulate matter pollution. Dust is blown into surrounding communities and can potentially have adverse effects on human health. Communities located close to mine dumps are of lower socio-economic status, often children and the elderly. These communities consist of historically disenfranchised ethnic groups living in government-funded houses, informal settlements and retirement homes.

Aim: To investigate whether the prevalence of respiratory symptoms and diseases among adolescents (13 to 14 year old children) and the elderly (55 years old and above) were associated with community's proximity to mine dumps. This study part of the a collaborative and larger study with Mine Health Safety Council of South Africa.

Methods: Adolescents and elderly persons in communities 1 km – 2 km (exposed) and $\geq$ 5 km (unexposed), from five pre-selected mine dumps in Gauteng and North West Province, South Africa were included in the study. The study was divided into four phases which included a pilot study, cross-sectional studies among adolescents' and the elderly persons, measuring the indoor and outdoor air pollution levels within the school premises in both the exposed and unexposed communities, and lastly panel studies were conducted among adolescents in exposed communities. A pilot study was conducted to test the reliability (internal consistency) of the modified American Thoracic Society-Division of Lung Disease-1978 (ATS-DLD-78) adult respiratory disease questionnaire developed by the British Medical Research Council, among 48 elderly persons in a community located near a mine dump. The International Study of Asthma and Allergies in Childhood (ISAAC) Phase I and II

protocols were applied among 3641 eligible school going children, age between 13 and 14 years, from 22 primary and secondary schools. For the second phase, the outdoor PM10 and SO2 levels were measured along with indoor respirable dust in 10 schools among 100 adolescents that participated in the first phase of the study. Structured interviews were conducted with 2397 elderly people from both the exposed and unexposed communities, using a previously validated ATS-DLD -78 questionnaire. A short-term longitudinal study design with repeated measures was used among 40 children with asthma. Each participant completed a daily symptom diary and performed forced expiratory flows in the morning and at bedtime for 21 consecutive days, and monitored the 24 h ambient air pollution concentrations such as NO_2, NO_x, O_3, $PM_{2.5}$, and PM_{10}. Multiple logistic regression and linear mixed effect models were used in the data analysis.

Results: The ATS-DLD-78 questionnaire was found to be reliable and admissible with overall Cronbach's alpha coefficients of α = 0.74. Children residing in communities that are close to mine dumps had an increased likelihood of current wheeze OR 1.38 (95% CI: 1.10 – 1.71), rhinoconjunctivitis OR 1.54 (95% CI: 1.29 – 1.82), and a protective association with asthma OR 0.29 (95% CI: 0.23 – 0.35). Factors associated with health outcomes included other indoor and outdoor pollution sources. Exposed elderly persons had a significantly higher prevalence of chronic respiratory symptoms and diseases than those who were unexposed. Results from the multiple logistic regression analysis indicated that living close to mine dumps was significantly associated with asthma (OR = 1.57; 95% CI: 1.20 – 2.05), chronic bronchitis (OR = 1.74; 95 CI: 1.25 – 2.39), chronic cough (OR = 2.02; 95% CI: 1.58 – 2.57), emphysema (OR = 1.75; 95% CI: 1.11 – 2.77), pneumonia (OR = 1.38; 95% CI: 1.07 – 1.77) and wheeze (OR = 2.01; 95% CI: 1.73 – 2.54). Residing in exposed communities, current smoking, ex-smoking, use of paraffin as main residential cooking/heating fuel and low level of education emerged as independent significant risk factors for chronic respiratory symptoms and diseases.

Exposed elderly persons had a significantly higher prevalence of cardiovascular and respiratory diseases than those who were not exposed. Multiple logistic regression analysis indicated that living close to mine dumps was significantly associated with asthma + hypertension (odds ratio (OR) 1.67; 95% confidence interval (CI) 1.22 - 2.28), asthma + pneumonia (OR 1.86; 95% CI 1.14 - 3.04), emphysema + arrhythmia (OR 1.38; 95% CI 1.07 - 1.77), emphysema + myocardial infarction (OR 2.01; 95% CI 1.73 - 2.54), emphysema + pneumonia (OR 3.36; 95% CI 1.41 - 7.98), hypertension + myocardial infarction (OR 1.60; 95% CI 1.04 - 2.44) and hypertension + pneumonia (OR 1.34; 95% CI 1.05 - 1.93).There were higher average levels of outdoor PM_{10}, outdoor SO_2 and respirable dust in exposed classrooms compared to unexposed classrooms. The average indoor respirable dust level was 0.17 $mg.m^{-3}$ in exposed and 0.01 $mg.m^{-3}$ in unexposed schools. The corresponding outdoor PM_{10} levels were 16.42 and 11.47 mg.m-3, respectively, while SO_2 levels were 0.02 ppb and 0.01 ppb, respectively.

The mean 24-hour concentration of NO_x and O_3 of the current and previous day were significantly associated with the morning FEV1 decline of 0.762% (95% CI: -1.296 – -0.227), 0.780% (95% CI: -1.461 – -0.099) and 0.716% (95% CI: -1.386 – -0.045) respectively. Single pollutant models showed significant positive associations between chest tightness and cough with NO_2, O_3, NO_x, and SO_2. Medication use such corticosteroids was associated with NO_x (OR = 1.07; 95% CI: 1.00 – 1.28) and β2-agonist with O_3 (OR = 1.57 95% CI: 1.03 – 2.72). Interestingly, a protective significant effect was observed between SO_2 and cough (OR = 0.45; 95% CI: 0.21 – 0.97).

Discussion: The study was able show that there is an association between dust from mine dumps and the prevalence of respiratory symptoms and diseases among adolescents and elderly people residing in communities close to mine dumps in South Africa. The levels of outdoor and indoor air pollution levels measured in schools indicated that children in communities located near mine dumps are exposed to higher pollution levels in the school environment. Elderly in communities located near mine dumps have increased likelihood of having comorbidity of respiratory and cardiovascular diseases than those residing in communities located further away.

Conclusion: The study will contribute to existing literature because very little data is available about the prevalence of respiratory symptoms and diseases in Gauteng and North West, South Africa. The findings of this study provide evidence and add to the current body of knowledge that a community's proximity to mine dumps is associated with increased risk of respiratory symptoms and diseases among the children and the elderly in South Africa. The results of this study will also serve as baseline data for future epidemiological studies in communities located near mine dumps in Africa and South Africa.

Recommendations: A planned birth cohort study should be conducted in these communities where children are followed over a period of time using daily respiratory symptoms and disease diary records in which they record peak expiratory flow rates simultaneously with ambient air monitoring. Effective dust control measures should be implemented to reduce air pollution in these communities. Future plans should seek public solutions and recommendations to reduce the negative environmental impact caused by dust from mine dumps.

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1. Chapter 1: Introduction

1.1 What are mine dumps?

Mining is a major economic activity in many developing countries. In South Africa, gold mining has played a significant role in the development and sustenance of the country's economy, with both positive and negative consenques.[1] The mining industry is often criticised for improper waste disposal attempts which create a significant amount of air, soil and water pollution.[2] The crushed, sand-like by-product refuse material, known as tailings, is produced during extraction, milling or grinding procedures of ground ore during the mining process.[2,3] The tailings are dumped into low-lying areas and constructed into mountain valleys resulting in residue stockpiles or "mine dumps".[4,5] The mine dumps range from a few hundred thousand up to a million cubic metres in size, and are usually situated near mining sites.[6,7] Mining operations generally produce many types of waste, including mine tailings "mine dumps", waste rock and slag. Mine dumps, in particular, act as the main source of environmental contamination.[8]

1.2 Metal composition of mine dumps

Mine dumps consist of a complex mixture of metals, dust particles, or particulate that is released and transported to the surrounding communities. Dust particles or particulate matter are carried by the wind or by soil and/or water.[5,9,10] The degree of environmental pollution depends on the metal element content, mineralogy and physicochemical characteristics of the mine dump material.[11] Generally, gold mine dumps contain a complex mixture of environmentally hazardous chemicals including heavy metals such as gold, cadmium, lead, zinc, copper and selenium which can disperse into the nearby vicinity.[2,12,13] The elemental composition of mine dump material depends on the geology of the mining site, and the mining procedure.[2,14] For example, gold mine dumps release arsenic into the environment[15] and may contain large amounts of mercury[14,] generated by the crushing and spreading of gold bearing rock over liquid mercury to remove gold. The mercury is then evaporated, leaving the gold. Some mercury is lost during this process and accumulates in mine dumps.[14] People living close to a mining site in Campos de Jales, Portugal had a higher prevalence of respiratory symptoms and diseases associated with toxic metals such as gold, lead and cadmium in their blood compared to a control group living 45 km in Vilar de Macada.[16]

1.3 Environmental pollution

Mine dump facilities are major generators of wind-blown dust and one of the main sources of air pollution with potential adverse health implications for nearby communities.[6,9,17,18] The perennial dust problem is brought to the surrounding residents as a result of dying vegetation and reworking of old mine dumps to the for residual gold content.[19,20] Fine dust particles are dispersed into the atmosphere and are carried away large distances. Research studies have shown that mine dumps are the perpetual contributors to the ambient particulate matter (PM) loading of the surrounding atmosphere.[2,21–24] Figure 1.1 indicates a dust storm episode and a non-dusty day in a study area involved in this research.[17]

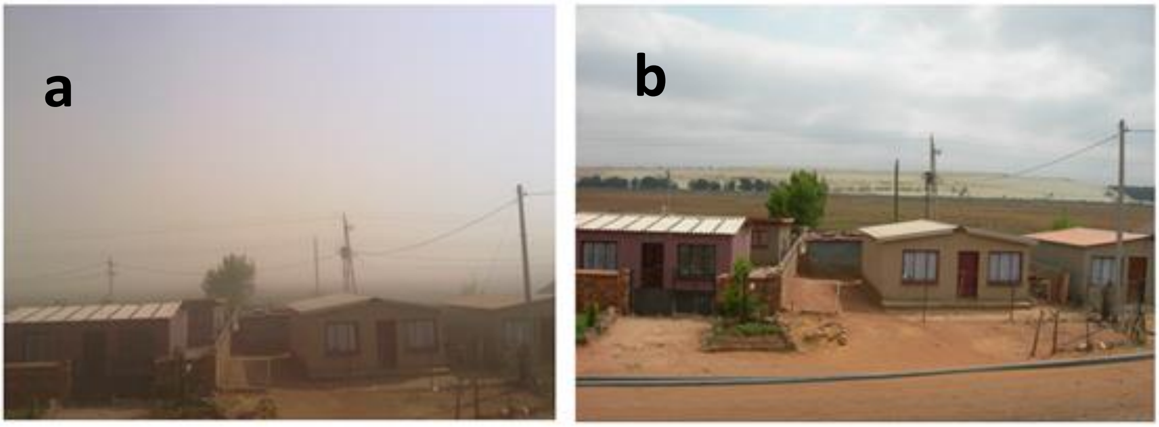

Figure 1.1: Images showing a day with a storm episode (a) and a normal day with low wind speed (b) at the Durban Roodepoort Deep gold mine dump

PM is mixture of variety of many sub-classes of airborne solid particles with different chemical composition, distribution and source of origin.[25,26] PM is divided into three categories based on size: ultrafine, fine and coarse particles. Particulate with an aerodynamic diameter less than 10 µm (PM10) in size may reach the upper respiratory airways and lungs, particulate with an aerodynamic diameter less than 2.5 µm (PM2.5) are able to deposit deep in the lower respiratory tract and reach the alveolar region. Health effects due to PM exposure can be influenced by chemical composition and particle size.[26] A report by Mine Health Safety Council of South African that determined the physiochemical properties of separated dust samples from mine dumps found particles in the nano-range, not only in the PM10 but also in the PM0.1 region (Figure 1.2).[27]

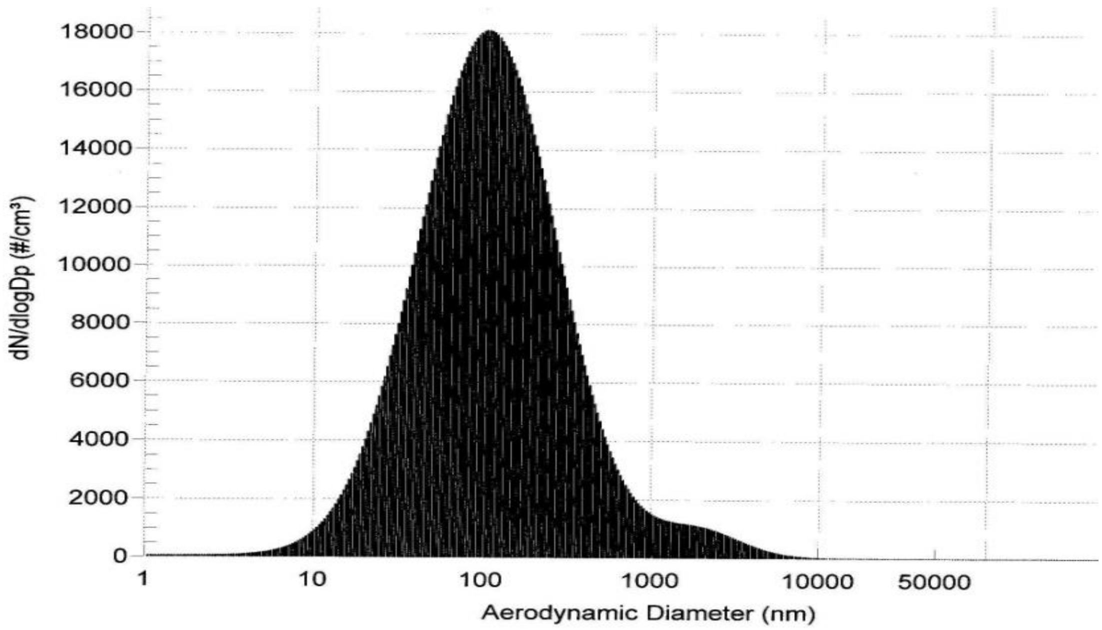

Figure 1.2: A representative dust sample showing fractions of particles with aerodynamic diameters ranging from 1 nm to 10 000 nm[27]

An exposure assessment study conducted in mine dumps (this study) found ambient concentrations of particulate with an aerodynamic diameter less than 10 µm (PM10) which exceeded the 24-hour limit set by the South African Department of Environmental Affairs (180 µg.m-3).[17,28] Communities found downwind of mine dumps experienced higher dust concentrations than those located upwind.[29] Residential developments in some communities are found at the foot of the mine dumps, causing elevated exposure to particulate matter.[17] Dust deposits have a negative effect on visibility when it forms dust plumes, while deposition on fabrics, buildings, skin, eyes, and water tanks constitute a nuisance.[9, 17, 30]

1.4 Toxicity of particulate matter from mine dumps and health effects

Research has linked PM with serious adverse health effects and different types of respiratory and cardiovascular diseases. Exposure to ambient PM can cause premature mortality, chronic cough, wheeze, chronic bronchitis, pneumonia, emphysema, asthma, decreased lung function, chronic obstructive pulmonary diseases, lung fibroids, lung cancer and myocardial infarction.[26,31–42] The elemental composition, size, shape, specific surface area and surface charge may also determine cellular toxicity.[43] Particle size determines deposition patterns in the respiratory tract, and consequently the extent of toxicity.[44] The transport and deposition of PM into respiratory system can be divided into four different categories:[43,44]

- Impact mechanism in the nasopharyngeal region by particles between 5 and 30 µm
- Sedimentation mechanism in the tracheobronchial region by particles between 1 and 5 µm
- Interception mechanism in the alveolar region by particles < 1 µm or ≤ 2.5 µm
- Diffusion mechanism for particles < 0.5 µm

Smaller particles are more toxic since they may infiltrate further into the respiratory system.[44]

1.4.1 Mechanism of particulate matter-induced toxicity

Once PM is deposited in the lungs, pollutants may trigger inflammatory response and induce oxidative stress through the generation of reactive oxygen species (ROS), the ultrafine particles are able to penetrate through the alveoli and cause injury to the cardiovascular system.[45–54] Inhaled particles reach the bronchi and alveoli and come into contact with alveolar macrophages (AMs), the key cells involved in inflammatory responses in the respiratory tract and clearance of bacteria or particles through phagocytosis. Activated AMs secrete a wide range of products including ROS, reactive nitrogen species (RNS), bioactive lipids, cytokines, chemokines, and proteases, which can contribute to lung toxicity. Among these products, ROS and cytokines such as tumour necrosis factor-α (TNF-α), interleukin-1β (IL-1β), and macrophage inflammatory protein-2 (MIP-2), are important mediators of particle induced pulmonary inflammation and toxicity.[55] ROS affect mitochondrial membrane potential and trigger a series of mitochondria-associated events including apoptosis.[56] The release of inflammatory mediators and products is driven by the induction of cellular oxidative stress and activation of redox-sensitive transcription factors such as nuclear factor-κB (NF-κB). NF-κB is an important transcription factor and participates in cell death and in inflammatory responses.[57] Cytokines and chemokines trigger the inflammatory axis via recruitment and activation of inflammatory cells into the lung. ROS triggers signalling pathways involved in inflammatory mediator release and proliferation and in induction of oxidative damage to membrane constituents, intracellular proteins, and genomic DNA.[55] The extent of ROS induced oxidative damage may be exacerbated by a decreased efficiency of antioxidant defence mechanisms.

Endogenous defences against ROS include antioxidant enzymes such as glutathione-S-transferase P1, glutathione peroxidase, catalase, and superoxide dismutase.[58] The ROS and pro-inflammatory cytokines released in the blood stream affect automatic cardiac control (heart rate, heart rate variability and cardiac contractility).[51,59–64] The potential toxicity of mine dump dust particles may involve ROS formation, oxidative damage and inflammation and cause harm to the respiratory and cardiovascular system. Figure 1.3 summarises the mechanism of particulate matter toxicity in the respiratory and cardiovascular system.

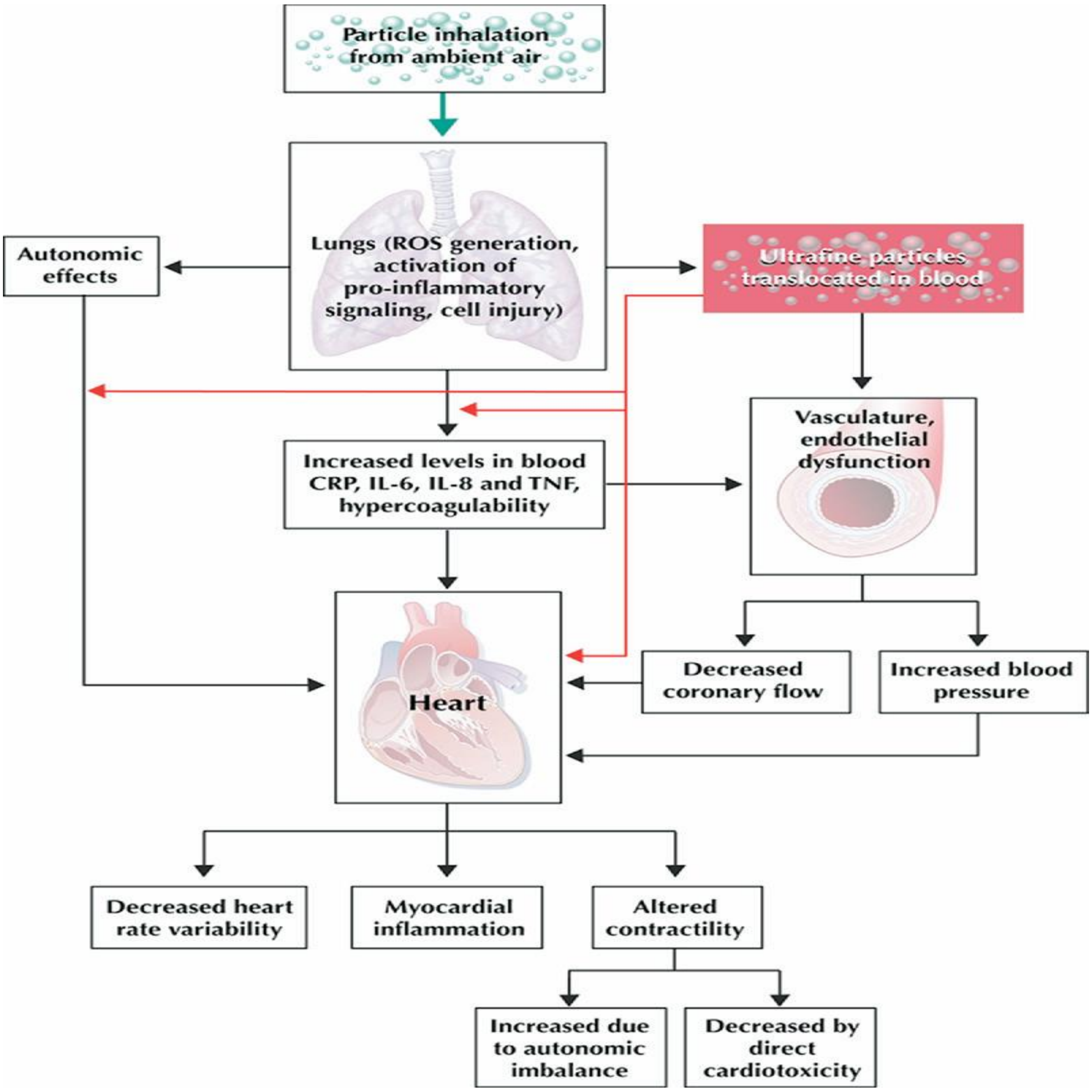

Figure 1.3: Pathophysiological mechanism of lung and circulation – mediated cardiovascular toxicity of particulate air pollutants[51]

1.4.2 Exposure to dust from mine dumps

Pollution associated with mine dumps has been a source of source of concern to communities situated close by.[17] Apart from the wind-blown dust pollution that characterises mine sites, environmental exposure may occur through water, soil and food contamination which presents a public health problem to nearby communities and wildlife.[15,65–67] New residential housing developments at the foot of mine dumps were observed in this study, resulting in an increase in the number of exposed individuals to mine dump pollution.

1.4.3 Children/adolescents and the elderly are most vulnerable to the effects air pollution

The health effects of air pollution among children and the elderly have been subject to intense study in recent years. Epidemiological studies agree that children and the elderly are most susceptible to the negative effects of air pollution associated with respiratory diseases.[68–75] Table 1.1 provides a list of factors that might exacerbate the vulnerability of children to air pollution. The listing begins with preconception exposures and continues through the adolescent years. [76]

Table 1.1: Categories of factors determining susceptibility of children to inhaled pollutants [76]

Factors	Outcomes
Related to lung growth and development	• Vulnerability of developing and growing airways and alveoli • Immature host defence mechanism
Related to time-activity patterns	• Time spent outdoors • Increased ventilation with play and exercise
Related with chronic disease	• High prevalence of asthma • Rising prevalence of cystic fibrosis
Related to acute diseases	• High rates of acute respiratory infections

Children with underlying chronic lung diseases such as asthma may be more vulnerable to the negative effects of air pollution than children without asthma.[76] The elderly are particularly susceptible to air pollution. Elderly people living in areas badly affected by air pollution, have generally had a longer life time exposure. Elderly people generally have weaker immune systems, related to physical weakness. With age the body's ability to filter out and dispel air pollutants from the lungs decreases resulting in vulnerability to respiratory and cardiovascular diseases and mortality.[77–85]

1.4.4 Socio-demographic profile of people living near mine dumps in South Africa.

It is estimated that 1.6 million people live in informal and formal settlements on or directly next to the mine dumps in South Africa.[86,87] People living in these communities tend to be historically marginalised ethnic groups of low socio-economic status, living in government-funded houses, informal settlements and retirement homes.[1,9,88]

Other sources of air pollution in these communities include indoor and outdoor air pollutants from residential cooking and heating i.e. gas, paraffin and wood or coal, environmental tobacco smoke (ETS), traffic air pollution and ETS at schools. These types of air pollution may also cause or exacerbate respiratory symptoms and disease among children and elderly people.[89–107]

1.5 Research question

The main research question addressed in this study was: are there any associations between exposure to dust from gold mine dumps, respiratory symptoms and diseases among adolescents (13 to 14 year old children) and the elderly (55 year old and above), residing in communities close to mine dumps in South Africa?

1.6 Aim

To answer the research question the study investigated whether the prevalence of respiratory symptoms and diseases among adolescents (13 to 14 year old children) and the elderly (55 years old and above) was associated with community proximity to mine dumps.

1.7 Objectives

- To test the reliability of the respiratory symptom questionnaire developed by the American Thoracic Society – Division of Lung Diseases (ATS – DLD – [78]) among the elderly (55 years and above) residing in communities close to mine dumps in South Africa. Chapter 3.
- To describe the prevalence of respiratory symptoms and disease (asthma) among adolescents (13 to 14 year old), residing in communities close to mine dumps in South Africa. Chapter 4.
- To describe the prevalence of chronic respiratory symptoms and diseases among the elderly (55 years and above), residing in communities close to mine dumps in South Africa. Chapter 5.
- To investigate whether the comorbidity of respiratory and cardiovascular diseases among the elderly, are associated with proximity to mine dumps. Chapter 6.
- To investigate whether outdoor air pollution influences indoor air pollution in schools located near mine dumps in South Africa. Chapter 7.
- To investigate the association between acute changes in lung function with ambient air pollutants on asthmatic children (13 to 14 year old). Chapter 8 and 9.

1.8 Study hypothesis

- H_0: There is no association between proximity to mine dumps the risk of respiratory symptoms and diseases among adolescents (13 to 14 year old) and the elderly (55 years and above) in South Africa.

- H_A: Communities close to mine dumps will have a higher prevalence of respiratory symptoms and diseases among adolescents (13 to 14 year old) and the elderly (55 years and above) in South Africa.

1.9 Relevance of the study

The health of children and elderly exposed to indoor and outdoor air pollution is a central focus of research and policy making. The health risks of air pollution may be underappreciated and effective air pollution management measures may be lacking. Children and elderly people may be perpetually exposed to concentration levels that can have negative health impacts in the short and long term. Various risk factors are associated with respiratory symptoms and diseases including gender,[108] socio-economic status,[26] tobacco smoking habits,[109] occupational environment,[110] and polluting fuel used for residential cooking or heating.[111] Most studies conducted in South Africa on the prevalence and risk factors of respiratory diseases have been in industrialised urban areas.[112,113] However, no research has investigated if exposure to dust from mine dumps, or living in close to mine dumps poses an increased risk for respiratory symptoms and diseases, or possible effect modification among children and the elderly people in South Africa.

Using a mixed methods study design (Chapter 2), this study provides evidence for the association between mine dust exposure or community proximity to mine dumps, with respiratory symptoms and diseases (Chapter 4, 5, 6, 7, 8, 9, 10). This study is part of the collaborative capacity building initiated by the Mine Health Safety Council of South Africa (MHSC). The findings of this study will play a major role in efforts by MHSC to rehabilitate the environment, raising awareness about the negative health impacts of mine dump dust, finding recommendations and public solutions to reduce exposure in the affected communities in South Africa.

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2. Chapter 2: Research methodology

2.1 Study location

Communities in urban areas living 1 km – 2 km (exposed) and ≥ 5 km (unexposed) from pre-selected mine dumps (n=11) in Gauteng and North West of South Africa were included in the study (table 2.1). According to literature the maximum distance the dust particles can travel is between 1 – 1.5 km from the mine dumps.

Table 2.1: Eleven communities selected in the study located in Gauteng and North West, South Africa

Mine dump facility	Province	Exposed communities[a]	Unexposed communities[b]
Durban Roodepoort Deep (DRD)	Gauteng	Braamfischerville	Dobsonville
Crown Gold Recoveries (CGR)	Gauteng	Diepkloof, Riverlea, and Noordgesig	Orlando East
East Rand Proprietary Mines (ERPM)	Gauteng	Reiger Park	Windmill Park
Ergo	Gauteng	Geluksdal	Windmill Park
Anglo Gold Ashanti (AGA)	North West	Stilfontein	Jouberton

[a]1 km – 2 km from mine dumps
[b]5 km or more from mine dumps

These mine dumps were included in the study because of their size and population density around them. The socio-demographic profile of exposed and unexposed communities was similar.

2.2 Study design, population and sample selection

This study used a community and school based cross-sectional epidemiological study design and was conducted between 2012 and 2013. The study was divided into four phases (table 2.2). The international Study of Asthma and Allergies in

Childhood (ISAAC) protocol was used for Phase I of this study. ISAAC was founded in 1991, to study asthma and allergic diseases among children by establishing a standardised methodology, and facilitating international collaboration by having studies conducted in different countries. American Thoracic Society – Division of Lung Diseases (ATS – DLD – 78) questionnaire from the British Medical Council (BMRC) was used for the elderly household community surveys, Phase II . Personal and outdoor PM_{10} levels were measured in ten different schools in the communities sampled in this study. Five schools were from exposed and five schools were from unexposed communities. Panel studies were also conducted in Noordgesig and Reiger Park. Each participant completed a daily symptom diary and performed forced expiratory flows in the morning and at bedtime for 21 consecutive days, and data for 24 hour ambient air pollution concentrations were obtained from South African Weather Services (SAWS).

Table 2.2: Phases of the study project

Activity	Measurements	Sample size	Dates
Cross-sectional study: ISAAC questionnaire survey	Questionnaire (See Appendix 4)	Total target population = 6000 Total number of participants = 4300 Participation rate = 71.7% 3641 questionnaires were used in data analysis	May – November 2012
Cross-sectional study: ATS – DLD – 78 community questionnaire survey	Questionnaire (See Appendix 5)	Total target population = 3069 Total number of participation = 2397 Participation rate = 78.0% 2397 questionnaires were used in data analysis	November – December 2012
Personal and outdoor air pollution measurements at schools	PM10 concentration levels	10 schools were included in this phase. Five schools from exposed and five from unexposed communities Total target population = 100	October 2013
Panel studies	Questionnaires: Asthma daily diaries FEV1 NO_2, NOx, O_3, PM2.5, PM10, relative humidity and temperature	40 pupils	August – September 2013

2.2.1 Phase I: Cross-sectional study – ISAAC questionnaire survey

Twenty – two schools were included in the study. Each school was contacted and requested to participate in the study. Following the approval by the principal and governing body, all eligible children between the ages of 13 and 14 years in Grade 8 and 9 were requested to participate. The 13 to 14 year age group was chosen because most adolescents go to school regularly, making data collection easier. This age group is also most likely to be in the study communities during days when wind-blown dust is at the peak. Each school was requested to provide a copy of class lists. The study focused on adolescents who had been residing in the study communities for at least five years. An appointment was scheduled with school to deliver the consent forms to children two weeks prior the study and they were requested to return them within three days. Data were collected from the English version of ISAAC written questionnaires. The questionnaires were completed by the children in the classroom under the supervision of data collectors, who were specifically trained and briefed to avoid explanations that could interfere with the participant's answers. The results are presented in Chapter 4.

2.2.2 Phase II: Cross-sectional study – ATS – DLD – 78 community questionnaire survey

A cross-sectional epidemiological study design was applied among 2397 elderly (55 years old and above) people. This age group was selected in order to increase the power of the study. The study focused on the elderly people who had been residing in the study communities for at least five years. This age group was also chosen because they are most likely to be in the study communities during the day when wind-blown dust is at the peak. Face-to-face interviews were conducted using a previously validated ATS-DLD-78 questionnaire from the British Medical Research Council (BMRC). Streets were randomly selected in each community. Four to five houses were then randomly selected in each street in a radial fashion. The sample size of each community was calculated using Epi Info version 7, with a total sample size of 3069. A knock-on-the-door approach was used to recruit study participants. Twenty-two locally trained fieldworkers were employed, two per community. Each fieldworker received thorough training in conducting the interviews using the respiratory health questionnaire, before the start of the survey. A verbal and written consent was obtained before the interviews commenced. The interviews were mainly in English and were translated into the local language if the respondent did not understand the questions. The results are presented in Chapter 5 and 6.

2.2.3 Phase III: Personal and outdoor air pollution measurements at schools

The study was conducted among 13-14 year old asthmatic pupils from 10 schools in Gauteng and North-West provinces in South Africa. The selected pupils are a subset of the participants of the International Study of Asthma and Allergies in Children (ISAAC) survey conducted earlier in the previous year. In each school, 10 doctor diagnosed asthmatic pupils were randomly selected to participate in the study. Three learners in each of two classrooms and four in one classroom were randomly selected for personal air sampling. Personal air sampling was performed in pupil’s breathing zone during school hours from 8 am to 15 pm using a Gillian Personal Sampler. All the gravimetric sampling was done in accordance with requirements of methods for determination of hazardous substances method 14/3 (General methods for analysis and gravimetric analysis of respirable dust). AEROQUAL mobile air monitoring station was used to measure the ambient PM_{10} on the school premises from 8 am to 15 pm at the height of 1 m. A mobile air monitoring station was placed upwind, in the South-easterly direction, the prevailing wind direction in the study area. Ten filters for each school were weighed in the accredited laboratory. Data from the mobile air monitoring station and the laboratory were merged for analysis. The results are presented in Chapter 7.

2.2.4 Panel studies

Hourly, citywide background air pollution levels were recorded from fixed-site monitors located in the south east, upwind from the prevailing winds. The fixed-site monitoring station provided hourly levels of nitrogen dioxide (NO_2), oxides of nitrogen (NO_x), ozone (O_3), sulphur dioxide (SO_2), particulate matter less than 2.5 ($PM_{2.5}$) and 10 (PM_{10}) µm in diameter. Weather data including temperature and relative humidity were also continuously collected at outdoor sites and expressed in hourly levels. The population lived within 2 and 0.5 km downwind. Forced expiratory volumes in 1 second (FEV1) were measured using a pocket electronic meter (Piko-1). The Piko-1 stored up 96 readings that could be downloaded to a computer. Each participant was trained in the use of the Piko-1, including proper positioning, breathing techniques and maintenance of the instrument. Participants were instructed to perform the Forced Expiratory Volume in 1-second (FEV1) manoeuvre in the standing position three times in the morning and three in the evening prior to use of breathing medication. All participants were issued with daily diary cards to record the presence of asthma symptoms and medication use such as breathlessness, chest tightness, cough, wheeze, short-acting β2-agonist, inhaled corticosteroids and other asthma medication use on the daily diary. The results are presented in Chapter 8 and 9.

2.2.5 Ethical considerations

The study was approved by the Research Ethics Committee, Faculty of Health Sciences, University of Pretoria, Ethics Number: 235/2011 (See Appendix 1).

Approval was sought from the Gauteng Department of Education to access the schools; permission was granted (See Appendix 2).

Approval was sought from the North West Department of Education to access the schools; permission was granted (See Appendix 3).

Letters were sent to the school principals to request permission to conduct the study (See Appendix 7).

Information letters and consent forms were sent to each study participants (parent or guardian of children and the elderly) to request permission to participate in the study before completing the questionnaire (See Appendix 5, 6, 8 and 9).

Children and the elderly were requested to assent before participating in the study (See Appendix 8 and 9).

The participants were informed that should they feel uncomfortable, they could decline to proceed at any stage of research and their decision would not affect them anyway.

The participants were informed that all their information would be kept confidential by the investigators, data collectors and capturers. The results would only be published in aggregate/groups format without revealing their identity or names of participants. No blood, fluids or tissue samples were collected from the children and elderly involved in this study.

2.3 Funding of the project

The project was funded through the help of the following institutions with no intention of profit:

- Mine Health Safety Council of South Africa (MHSC)
- National Research Fundations – Deutscher Akademischer Austausch Dienst (NRF – DAAD).
- University of Pretoria, Faculty of Health Sciences.
- University of Pretoria, School of Health Systems and Public Health.
- EUROSA – Erasmus Mundus Scholarship Programme.

2.4 Reporting of results

Results were reported as follows:

- Progress report to the supervisor twice per year.
- Scientific articles in peer-reviewed journals accredited by the South African Department of Higher Education (DoHE).

Four papers have already been published:

- Nkosi Vusumuzi and Kuku Voyi. Reliability of an adult respiratory symptom questionnaire in a community located near mine dump in South Africa: Pilot Study. South Afr J Infect Dis. 2016;1(1):1-3.
- Vusumuzi Nkosi, Janine Wichmaan and Kuku Voyi. Mine dumps, wheeze, asthma, and rhinoconjunctivitis among adolescents in South Africa: any association? Int J Environ Health Res. 2015;25(6):583-600.
- Vusumuzi Nkosi, Janine Wichmaan and Kuku Voyi. Chronic respiratory disease among the elderly in South Africa: any association with proximity to mine dumps. Environ Health. 2015;14(33):1-8.

- Vusumuzi Nkosi, Janine Wichmaan and Kuku Voyi. Comorbidity of respiratory and cardiovascular diseases among the elderly residing close to mine dumps in South Africa; a cross-sectional study. S Afr Med J. 2016;106(3):290-297.

Two manuscripts have been submitted to accredited Journals (chapters 7 and 8).

- Presentations at University of Pretoria, Faculty of Health Sciences Research day and international conferences (oral and poster presentations).

The research results have been presented at the following conferences:

- European Respiratory Society International Congress, Munich, Germany, 2014. Poster presentations.
- 27th Annual Conference of the International Society for Environmental Epidemiology (ISEE), Sao Paulo, Brazil, 2015. Poster presentation.
- Kyoto Global Conference for Young Public Health Researchers, University of Kyoto, Kyoto, Japan, 2015. Oral presentation.
- Mine Health Safety Council of South Africa, 2012 – 2015.
- Presentations to the Gauteng and North West Department of Education and Mine Health Safety Council of South Africa.

Descriptive results will be published in local media.

The results will be communicated to the International Study of Asthma and Allergies in Childhood (ISAAC), Global Alliance against Chronic Respiratory Diseases (GARD) and Global Initiative for Asthma (GINA). Our research group will also become more involved in the activities of these groups.

3. Chapter 3: Reliability of an adult respiratory symptom questionnaire in a community located near a mine dump in South Africa: Pilot study

3.1 Abstract

Background: Pre-testing a questionnaire is an important activity before the start of the main epidemiological study.

Aim: The study tested the reliability (internal consistency) of the modified ATS-DLD-78 adult respiratory diseases questionnaire developed by the British Medical Research Council.

Methods: Pilot study was conducted among the 48 elderly residing in a community located near mine dump in South Africa.

Results: The questionnaire was found to be reliable and admissible with an overall Cronbach's alpha coefficients of α = 0.74.

Conclusion: The questionnaire is a reliable instrument for data collection and can be a useful tool for collecting data in a developing country. The questionnaire will be used to study the association between respiratory and cardiovascular diseases among older people and community's proximity to mine dumps.

Keywords: Cardiovascular diseases, mine dumps**,** pilot study, respiratory diseases, South Africa

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3.2 Introduction

Pre-testing a questionnaire in a relevant population is an important activity before the start of the main epidemiological study. This is true for all questionnaires including those that have been used many times as well as internationally. A pilot study can be used for pre-testing a particular research instrument in preparation for a major study. This will ensure that the questionnaire is comprehensible, appropriate, and that the questions are well-defined and presented in a consistent manner.[1] Pilot studies can be very informative for both the researchers conducting them, as well as others doing similar work in that they can avoid making the same errors in their studies.[2] One of the benefits of the pilot study is that it might give advanced warning about whether the proposed methods or instruments are unsuitable, understandable or too complicated.[3] Research studies in South Africa have used self-administered modified standard questionnaires to study respiratory and cardiovascular diseases[4,5] but barely mention whether the questionnaire was tested for reliability or not.

The British Medical Research Council approved the American Thoracic Society and the Division of Lung Diseases (ATS – DLD – 78) questionnaire as a standard to conduct epidemiological surveys for chronic respiratory diseases.[6] In this study, the questionnaire was modified by the addition of two questions about arrhythmia and myocardial infarction. To date, no studies in South Africa have tested the reliability of the ATS – DLD – 78 questionnaires. This study is part of the larger project initiated by the Mine Health Safety Council of South Africa (MHSC) on communities located near mine dumps in the Gauteng and North West. The aim of the study was to the test the reliability (internal consistency) of the ATS – DLD – 78 respiratory symptoms and diseases questionnaire among older people (55 years and above).

3.3 Methods

Between January and February 2013, a pilot study was conducted to test the reliability (internal consistency) of the modified ATS-DLD-78 adult respiratory symptoms and diseases questionnaire developed by the British Medical Research Council among older people (55 years and above) in Pennyville, Soweto, Gauteng, South Africa. People that are residing in this township are predominantly black and of lower socio-economic status with a estimated population size of 2757.[7] A unique aspect of the township is that it is located near a mine dump. The questionnaire was self-administered to measure the presence of emphysema, chronic bronchitis, pneumonia, hay fever, asthma, wheezing, cough, family history, chest illness, past illnesses, arrhythmia and myocardial infarction. Each respiratory symptom and disease and cardiovascular diseases had a subset of questions.

A knock-on-the-door approach was used to recruit study participants. The questions were mainly in English. Streets within the community were randomly selected. Four to five houses were then randomly selected in each street. There were 48 participants in this study. The participants that took part in this study were:

- Male or female
- Fifty-five (55) years and above
- Living in Pennyville

If a selected household had no older people or no one at home during the visit, or were unwilling to participate, the researcher proceeded to the next household. This study was approved by the ethics committee of the University of Pretoria (235/2011).

The collected questionnaire data was double entered into a database set up in Epi Info version 3.5.3. Data were analysed using Stata version 12. Data collected during the study was divided into the following categories:

Demographics: Population group, sex, marital status, date of birth, level of education and number of years living in the community being researched.

Respiratory diseases and symptoms: Cough, phlegm, wheezing, cold, asthma, pneumonia, breathlessness, past illnesses, hay fever, bronchitis, emphysema, and chest injuries.

Cardiovascular diseases and symptoms: Arrhythmia, heart trouble, high blood pressure, and myocardial infarction/heart attack.

Family history: Respondents have to report whether their parents had suffered from respiratory and/or cardiovascular diseases.

Home heating and fuel: Coal, wood, liquefied petroleum (LP) gas, electricity, fuel oil, and paraffin.

Occupational history: Respondents had to report whether they have worked in a dusty area, and/or exposed to gas/chemical fumes in their work areas.

In this study, only questions pertaining to the on outcome variables, respiratory and cardiovascular diseases were tested for reliability during analysis. Questions on predictor and outcome variables, for outcome variables such as family history, home heating, fuel, and occupational history, were excluded.

3.4 Statistical analysis

Descriptive statistics were used to explain data, means, frequencies, standard deviations, and Cronbach's alpha statistics to measure internal consistency of the group questions of outcome variables in the questionnaire. A Cronbach's alpha coefficient of $0.7 \leq \alpha < 0.8$ is considered acceptable.[8] In this study, an alpha coefficient of 0.7 and above indicated that the set of questions was reliable. Factor analysis was then further carried out to remove questions from the questionnaire that were correlated. The factor or subset of questions with an Eigenvalue greater than 1.0 was retained.[9]

3.5 Results

A total of 48 predominantly black respondents participated in the questionnaire survey; 67% were females. The majority of the respondents had primary education as the highest form of education level. Respondents' ages ranged from 55 to 100. Table 3.1 summarises the demographic characteristics of the respondents.

Table 3.1: Demographics of the participants

Characteristics	*n = … (%)*
Population	
Participants (n=48)	
Sex	
Females	32 (67)
Males	16 (33)
Marital status	
Divorced	2 (6)
Married	19 (40)
Single	12 (25)
Widowed	14 (29)
Education level	
No schooling	15 (31)
Primary	21 (44)
Secondary	12 (25)
Age (in years)	
Do not know	1 (2)
55-64	21 (44)
65-74	18 (37)
75-84	7 (15)
85-100	1 (2)

Table 3.2 gives a synopsis of the Cronbach's alpha coefficients for questions on outcome variables. All questions were considered acceptable and reliable, except that of past illness.

Table 3.2: Reliability coefficients of the of the outcome variables

Outcome measure	*Test scale (α-coefficient)*	*Average years (SD)**
Cough	0.96	5 (5.3)
Phlegm	0.88	13 (16.0)
Wheezing	0.78	4 (10.5)
Breathlessness	0.79	45 (3.7)
Chest cold and chest	0.91	50 (2.3)
Past illness	0.53	32 (2.3)
Pneumonia	0.72	23 (2.8)
Asthma	0.73	35 (27.8)
Chronic bronchitis	0.76	38 (26.8)
Emphysema	0.80	51 (17.1)
Myocardial	1.00	44 (29.8)
Arrhythmia	0.98	41 (25.9)

SD: Standard deviation

Questions on cough, breathlessness, and wheezing had Cronbach's alpha coefficients of 0.96, 0.88, and 0.78, respectively. The average number of years that the respondents had each condition was 5±5.3, 13±16.0, and 4±10.5, respectively. Questions of two additional outcome variables, namely. Myocardial infarction/heart attack and arrhythmia, were found to be acceptable and reliable with reliability coefficients of 1.00 and 0.98, respectively. Questions regarding past illnesses had a reliability coefficient of 0.53, with each question having an Eigenvalue of 1.08, 0.05, and – 0.26 as shown in Tables 3.3 and 3.5, as shown in the Supplementary Tables.

Table 3.5 (*Supplementary Table*) shows the uniqueness of each question that is not shared with other questions in the questionnaire. The question "Did you have any lung trouble before the age of 16?" had 0.88 uniqueness with an Eigenvalue of 1.08, "Have you had a bronchitis attack?" had the uniqueness of 0.52 with an Eigenvalue of 0.05, and the question "Was the bronchitis attack confirmed by the doctor? "had a uniqueness of 0.45 with an Eigenvalue of – 0.26.

3.6 Discussion

The aim of the pilot study was to the test the reliability of the ATS – DLD – 78 respiratory symptoms and diseases questionnaire among older people (55 years and above) in Pennyville, a community located near a mine dump in Soweto, Gauteng, South Africa. The results of this study confirm that the ATS-DLD-78 questionnaire, with the additional questions, is still a reliable instrument that can be used to collect data, and that the respondents could comprehend the questions contained despite their level of education. All the subset questions for outcome variables such cough, phlegm, wheeze, breathlessness, chest cold and chest illness, pneumonia, asthma, chronic bronchitis, emphysema, myocardial infarction/heart attack and arrhythmia were found to be reliable, except those relating to past illness.

The findings of this study are in agreement with other worldwide studies that have piloted ATS – DLD – 78 respiratory symptoms and diseases questionnaire.[10,11] In all these studies, the ATS – DLD – 78 respiratory symptoms and diseases questionnaire was deemed reliable.

The question: “Did you have any lung trouble before the age of 16?” had 0.88 uniqueness with an Eigenvalue of 1.08 was retained in the questionnaire since it has the Eigenvalue of greater 1.0. A unique variance of 0.88 indicates that 88% of the variance is not shared with any other questions in the questionnaire. The questions: “Have you had a bronchitis attack?” and “Was the bronchitis attack confirmed by the doctor” will be dropped from the questionnaire because they had lower Eigenvalues for the main study. The ATS-DLD-78 respiratory questionnaire is a reliable instrument for data collection, and it will be a useful tool for collecting data in a developing country. Additional questions concerning cardiovascular diseases i.e. heart attack and arrhythmia, were also admissible. The questionnaire will used to study the association between respiratory diseases among older people and their proximity to mine dumps.

Supplementary table 3.3: Reliability coefficient of each question as predictor of past illness

Past illness	*Item-test correlation*	*Item-rest correlation*	*Average inter-item covariance*	*α-coefficient*
Did you have any lung trouble before the age of 16?	0.77	0.37	0.17	0.39
Have you had a bronchitis attack?	0.65	0.19	0.04	0.71
Was the bronchitis attack confirmed by the doctor?	79	0.59	0.38	0.19
Test scale			**0.02**	**0.53**

Supplementary table 3.4: Factor analysis of each question as predictor of past illness

Past Illness	*Eigenvalue*	*Difference*	*Proportion*	*Cumulative*
Did you have any lung trouble before the age of 16?	1.08	1.03	1.24	1.23
Have you had a bronchitis attack?	0.05	0.31	0.06	1.29
Was the bronchitis attack confirmed by the doctor?	- 0.26	0.00	- 0.26	1.00
				P-value = 0.001

Supplementary table 3.5: Factor loading matrix and uniqueness of variances of each question as predictor of Past illness

Past illness	*Uniqueness*
Did you have any lung trouble before the age of 16?	0.88
Have you had a bronchitis attack?	0.52
Was the bronchitis attack confirmed by the doctor?	0.45

3.7 References

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4. Chapter 4: Mine dumps, wheeze, asthma and rhinoconjunctivitis among adolescents in South Africa: any association?

4.1 Abstract

Background: The study investigated the association between community proximity to mine dumps, and current wheeze, rhinoconjunctivitis and asthma among adolescents. This study was conducted during May-November 2012 around five mine dumps in South Africa.

Methods: Adolescents in communities 1 km – 2 km (exposed) and ≥ 5 km (unexposed), from pre-selected mine dumps in Gauteng and North West Province, in South Africa were included in a cross-sectional study. The study participants completed a self-administered questionnaire based on the International Study of Asthma and Allergies in Childhood Phase I protocol.

Results: Communities in close proximity to mine dumps had an increased likelihood of current wheeze OR 1.38 (95% CI: 1.10 – 1.71), rhinoconjunctivitis OR 1.54 (95% CI: 1.29 – 1.82), and a protective association with asthma OR 0.29 (95% CI: 0.23 – 0.35). Factors associated with health outcomes included other indoor and outdoor pollution sources.

Conclusion: Wheeze and rhinoconjunctivitis appear to be a public health problem in these communities. The findings of this study serve as a base for further detailed epidemiological studies for communities in close proximity to the mine dumps e.g. a planned birth cohort study.

Keywords: mine dumps, asthma, wheeze, rhinoconjunctivitis, adolescents, South Africa

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4.2 Introduction

A recent review[1] indicated that current wheeze, asthma and rhinoconjunctivitis prevalence is increasing globally, including developing countries like South Africa.[2] Various lifestyle risk factors have been associated with existing symptoms of asthma (i.e. wheeze) and rhinoconjunctivitis, such as diet,[3,4] lack of physical activity,[5,6] and active smoking.[7,8] Demographic factors such as sex[9], age[10] and ethnicity[11,12] have also been associated with existing symptoms of these health outcomes.

Evidence is also increasing that environmental factors, such as various air pollution sources, significantly increase the risk of existing symptoms of asthma (i.e. wheeze) and rhinoconjunctivitis.[13] Environmental factors are beyond the control of the individual and therefore of great importance. Numerous studies in both developed and developing countries thus far investigated the following air pollution sources: environmental tobacco smoke (ETS) exposure at home or school,[14,15] traffic[16–18] and polluting fuel use for residential cooking/heating.[19–21] Whether air pollution, lifestyle and demographic factors actually are involved in the development of asthma and rhinoconjunctivitis is still being investigated. [22]

Mine dumps facilities are major generators of wind-blown dust and are one of the main sources of air pollution with potential adverse health implications for nearby residents.[23] One of the biggest challenges facing mine industry is inadequate waste disposal. Mine dumps consist of crashed sand-like waste material which is generated by extraction and grinding methods of ground ore during mining[24,25] The material contains a complex mixture of metals, dust particles or particulate matter that is released and transported to the surrounding communities by air, soil or water contamination.[24] Exposed communities are of lower socio-economic status, often elderly people and children.[26] These communities comprise historically marginalised ethnic groups living in government-funded houses, informal settlements and retirement homes.[27] Epidemiological studies have shown that living near mine dumps is a major risk for exposure to particulate matter and metals such as cadmium, manganese, lead and arsenic.[24,28,29] Children are particularly vulnerable because their respiratory system is still developing.[30] Higher prevalence of respiratory diseases was observed and correlated with toxic metals in the blood in people living near mining sites in Campos de Jales, Portugal as compared to a control group living 45 km in Vilar de Macada.[31]

Studies that have reported on the prevalence of asthma symptoms in South Africa applied the International Study of Asthma and Allergies in Childhood (ISAAC) protocol and a wide variability in the prevalence of asthma, wheeze, and rhinoconjunctivitis in residential areas situated near industries was observed.[2,32,33] ISAAC is the largest worldwide collaborative respiratory research project that studies asthma and its symptoms among children. [22]

No studies have investigated whether exposure to dust from mine dumps or living in close proximity to mine dumps pose an increased risk for existing symptoms of asthma (i.e. wheeze) and rhinoconjunctivitis, whether this exposure is involved in the development of these health outcomes or whether there is effect modification between various air pollution sources, including mine dust.

This study is part of the bigger project initiated by Mine Health Safety Council of South Africa (MHSC) around communities located near mine dumps in Gauteng and North West. This study is, to the best of our knowledge, the first study that investigated the prevalence, association between potential risk factors and wheeze and rhinoconjunctivitis among adolescents staying in communities situated near mine dumps in South Africa. The aim of the study was to investigate the prevalence, association between community proximity to mine dumps, and current wheeze, rhinoconjunctivitis, and asthma among adolescents. Effect modification between community proximity to mine dumps and other air pollution sources was also investigated i.e. type of fuel use for residential cooking/heating, frequency of truck traffic near homes, ETS exposure at home and school.

4.3 Methods

4.3.1 Study area and demographics

A cross-sectional epidemiological design was applied. Communities in urban areas living 1 km – 2 km (exposed) and ≥ 5 km (unexposed) from pre-selected five mine dumps in Gauteng and North West of South Africa were included in the study during May to November 2012. Table 4.1 lists the selected communities and Figure 4.1 shows the map of the study area. The socio-economic and demographic profile of exposed and unexposed communities was similar.

Table 4.1: Eleven communities selected in the study, which are located in Gauteng and North West, South Africa

Mine dump facility name	Province located	Exposed communities[a]	Unexposed communities[b]
Durban Roodepoort Deep (DRD)	Gauteng	Braamfischerville	Dobsonville
Crown Gold Recoveries (CGR)	Gauteng	Diepkloof, Riverlea, and Noordgesig	Orlando East
East Rand Proprietary Mines (ERPM)	Gauteng	Reiger Park	Windmill Park
Ergo	Gauteng	Geluksdal	Windmill Park
Anglo Gold Ashanti (AGA)	North West	Stilfontein	Jouberton

[a]1 km – 2 km from mine dumps
[b]5 km or more from mine dumps

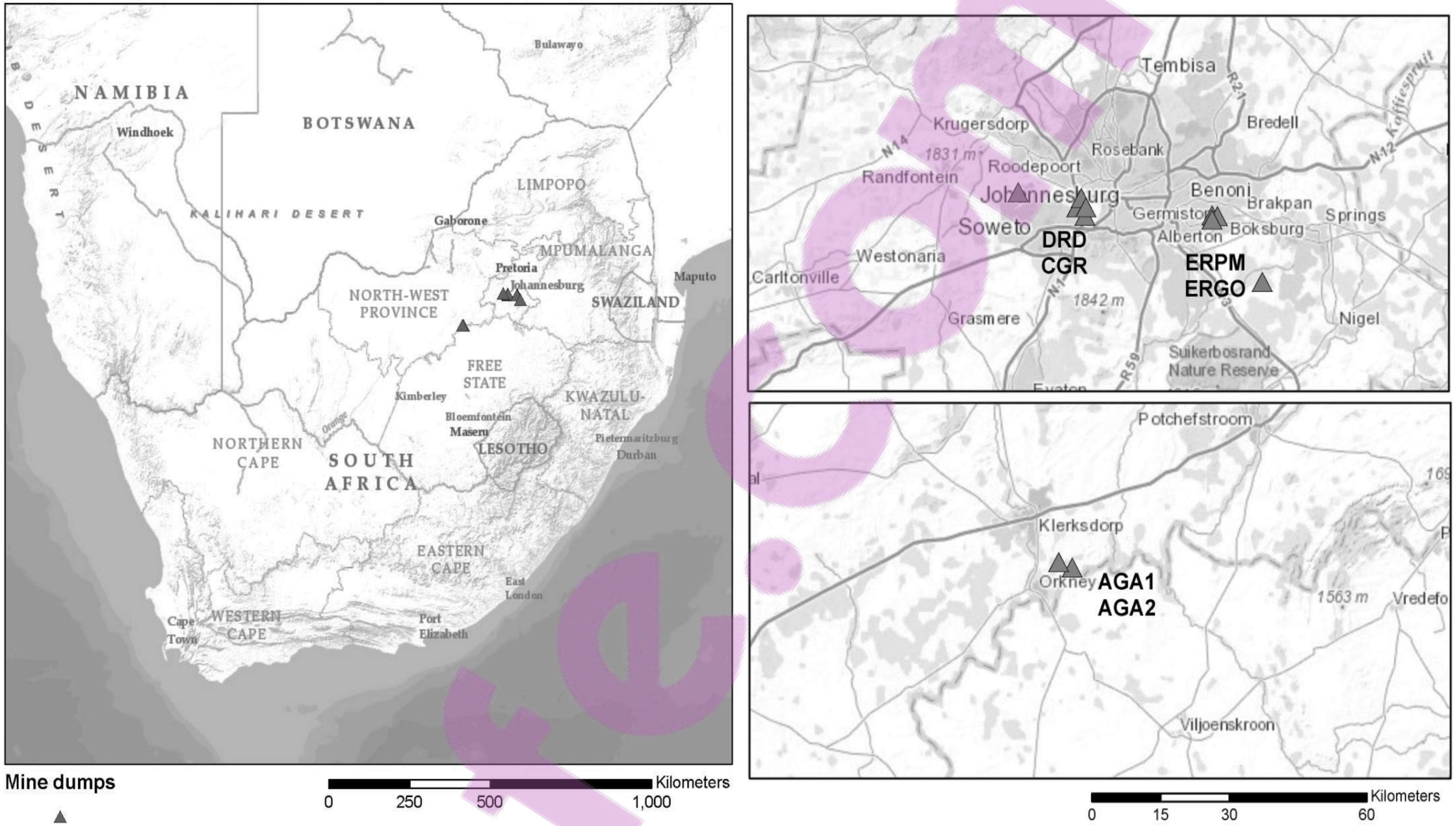

Figure 4.1: Location of mine dumps tailings in South Africa

The study focused on 13–14 year old pupils who attended schools located in the 11 selected communities. The study participants were selected and interviewed during school hours at their respective schools.

Exposed communities had 23 schools (primary and secondary) in total as identified by the investigators. Seven junior primary schools were excluded and 16 schools were contacted and invited to participate. Junior primary schools comprise of pupils under the age of 12 with classes starting from grade zero to four and primary schools pupils from 5 to 15-year olds with classes begin from grade zero to seven. Four of the 16 schools declined and 12 schools participated in the study.

Fourteen schools, both primary and secondary in the unexposed area, were randomly selected to match the number of schools in exposed communities. Four schools declined and 10 schools participated in the questionnaire survey.

Twenty-two schools were included in the study, of which 13 were secondary and nine were primary schools. In each school, all eligible pupils who were 13–14 years old and who resided in one of the selected 11 communities were requested to participate. Each exposure group consisted of 3000 pupils that were invited to participate.

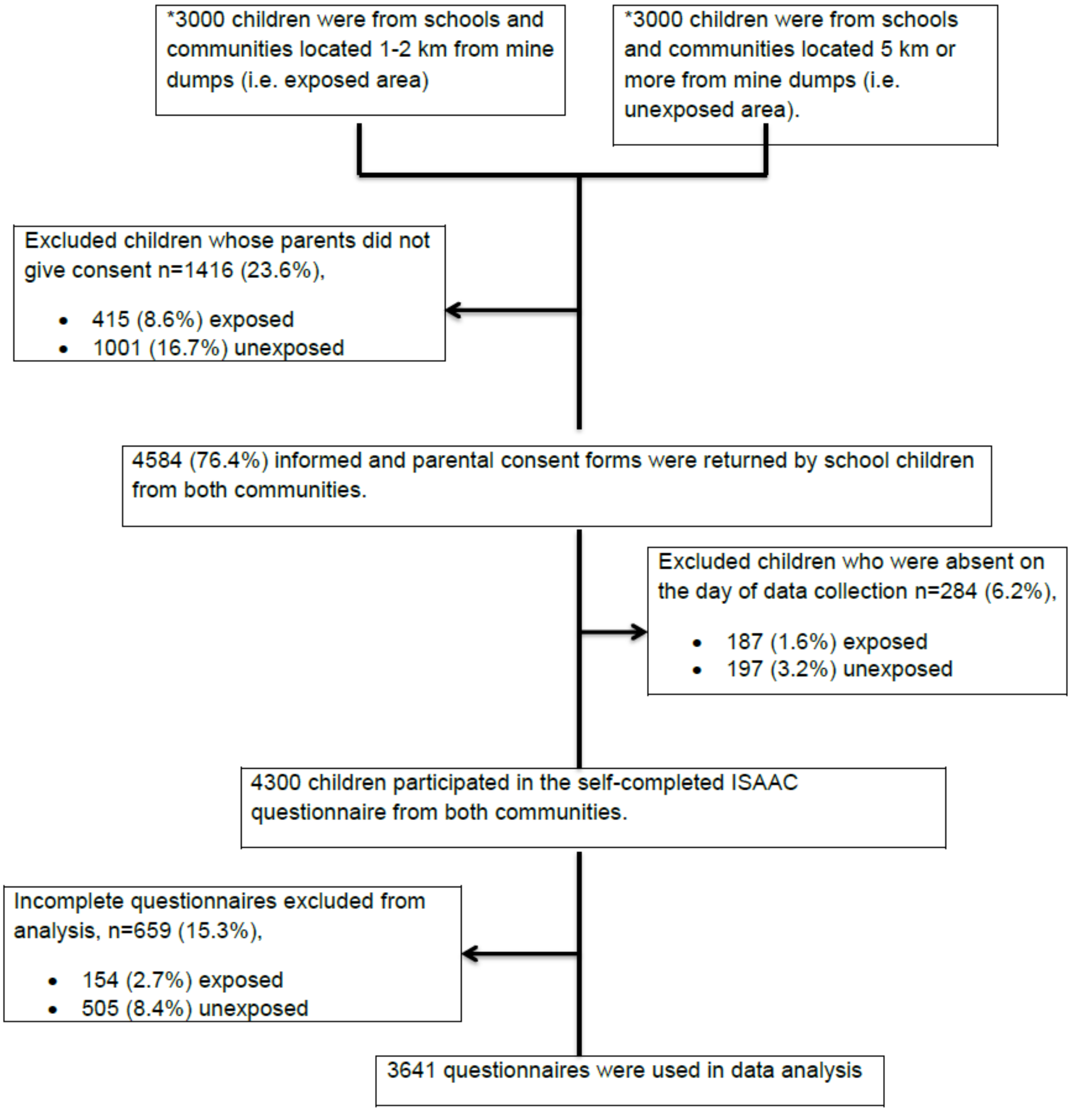

Figure 4.2: Recruitment procedure of study participants and participation rate

*A sample size of 3000 is recommended by the ISAAC steering committee as it is deemed to be representative of children within the general population.[34]

4.3.2 Exclusion criteria

Schools and pupils that did not grant permission prior to the start of the fieldwork, or showed lack of cooperation and pupils residing in communities other than the 11 selected communities (i.e. home and school communities not necessarily the same) were excluded from the study. Figure 2 shows a flowchart of the procedure followed to recruit study participants and the participation rate.

4.3.3 Health outcomes

The study participants completed a self-administered questionnaire based on the (ISAAC) Phase I protocol.[35] Data were collected using the English version of ISAAC written questionnaire composed of modules such as asthma and rhinitis, each comprising up to eight easily understood questions. The medium of instruction in all the schools that participated in the study was English.

According to the ISAAC Phase 1 protocol current wheeze, asthma and rhinoconjunctivitis symptoms were classified on the basis of positive answers to the following questions:

Current wheeze: “Have you had wheeze or whistling in the chest at any time in the past 12 months?”

Asthma: “Have you ever had asthma?”

Rhinoconjunctivitis symptoms: “Have you ever had a problem with sneezing, or a runny, or blocked nose when you did not have a cold or flu?” and “In the past 12 months have you ever had a problem with sneezing, or a runny, or blocked nose when you did not have a cold or flu?” and “In the past 12 months has this nose problem been accompanied by itchy-watery eyes?”

4.3.4 Main exposure factor

The exposure status of a community to mine dust was the main exposure factor. The exposure status was based on the distance between a community and a mine dump (Table 4.1).

Table 4.1. Eleven communities selected in the study, which are located in Gauteng and North West provinces, South Africa

Mine dump facility name	Province located	Exposed communities[a]	Unexposed communities[b]
Durban Roodepoort Deep (DRD)	Gauteng	Braamfischerville	Dobsonville
Crown Gold Recoveries (CGR)	Gauteng	Diepkloof, Riverlea, and Noordgesig	Orlando East
East Rand Proprietary Mines (ERPM)	Gauteng	Reiger Park	Windmill Park
Ergo	Gauteng	Geluksdal	Windmill Park
Anglo Gold Ashanti (AGA)	North West	Stilfontein	Jouberton

[a]1-2km from mine dumps
[b]5km or more from mine dumps

4.3.5 Confounders

Potential confounding variables included other air pollution sources: active smoking by participants (yes/no), ETS exposure at home (yes/no), ETS exposure at school (yes/no), type of residential cooking/heating fuel (electricity, gas, paraffin, wood/coal), mode of transport to school (walking, taxi/bus, car, combination) and the frequency of trucks passing near the residence (never, seldom, frequently through the day, almost all day). Additional confounders considered were: level of mother's education (primary school, secondary school, tertiary education), sex (female/male), vigorous physical activities (never/occasionally, 1 to 2 times/week, $\geq$ 3 times/week), hours spent watching television per day (< 1hr, 1 - 3hrs, 3 - 5hrs, ≥5hrs), frequency of dietary intake of 15 food items (rice, milk, pasta, meat, seafood, fruits, vegetables, pulses, cereal, butter, margarine, nuts, potatoes, eggs, fast food) (never/occasionally, once/twice per week, three or more times a week), type of house (brick, mud, corrugated iron or combination), having running water inside the house (yes/no), and average travel time from home to hospital (15 min walk/5 min drive, 1hr walk/15 min drive, ≥1hrs walk /≥ 30 min drive)

4.3.6 Statistical analyses

Three data technicians entered the collected questionnaire data into a database set up in Epi Info version 3.5.3. Data were analysed in Stata version 12. Prevalence of the health outcome and the proportion of air pollution sources under investigation and confounding variables were calculated by dividing the number of participants who responded affirmatively to a particular question by the number of questionnaires completed. Observations marked as “do not know”, “not stated”, or “other responses” were set as missing, but were included in the descriptive analyses. Therefore, each question had a slightly different sample size. All explanatory variables had some missing observations. A chi-square test was applied to determine the relationship between community type (exposed/unexposed) and confounding variables. Crude and adjusted odds ratios (OR) and 95% confidence intervals (CI) were calculated with univariate and multiple logistic regression analysis (LRA) to estimate the likelihood of having current wheeze, asthma, and rhinoconjunctivitis. Missing values were automatically excluded in each LRA model; therefore, each LRA model will have a different sample size. Air pollution source and confounding variables with $p < 0.20$ obtained in the univariate LRA were included in the multiple LRA. A p-value < 0.05 in the multiple LRA was considered statistically significant.[36] The data were further stratified according to community type, exposed and unexposed to determine if the observed associations for the overall study population applied to the two community types separately. Effect modification between community type (exposed/unexposed) and the other air pollution source variables was investigated by including multiplicative terms in the multiple LRA models.

4.4 Results

From an original 4300, data from 3641 participants were included in the final statistical analysis (a participation rate of 71.7%). The majority 2334 (77.8%) of the study participants lived and attended school in the seven selected exposed communities, whereas 1307 (44.0%) were from the four selected unexposed communities (Table 4.2). The use of paraffin or open fires for residential cooking/heating was more common in the exposed communities. The majority of participants from both the exposed and unexposed communities reported electricity as the main source of residential fuel for cooking/heating, engaged in vigorous physical activities more than once per week and spent more than 5 hours watching television per week. Nearly a half of the participants in both the exposed and unexposed communities reported that their residences were located near roads where trucks were always passing. ETS exposure at home and at school was significantly more common among study participants from exposed communities.

Table 4.2: Demographic characteristics and air pollution sources by type of community

	Community		
	Exposed[a]	**Unexposed[b]**	**P-value[c]**
Sex			
Female	1125(49.5)	620 (50.0)	0.766
Male	1147(50.5)	619 (50.0)	
Missing	62	68	
Residential cooking/heating fuel type			
Electricity	1926 (88.0)	1084 (93.0)	<0.001
Gas	64 (2.9)	29 (2.5)	
Paraffin	95 (4.3)	44 (3.8)	
Open fires	105 (4.8)	8 (0.7)	
Missing	144	142	
Frequency of trucks passing near residence on weekdays			
Never	340 (14.8)	216 (17.4)	0.138
Seldom	478 (20.9)	245 (19.7)	
Frequently	332 (14.5)	159 (12.9)	
Always	1140 (49.8)	621 (50.0)	
Missing	44	66	
ETS exposure at home in the past 30 days			
Yes	572 (25.0)	127 (10.2)	
No	1712 (75.0)	1115 (89.8)	<0.001
Missing	50	65	
ETS exposure at school in the 30 days			
Yes	1058 (55.4)	435 (41.2)	<0.001
No	851 (44.5)	620 (58.8)	
Missing	425	252	
Vigorous physical activities per week			
Never	706 (31.0)	382 (30.7)	0.189

Table 4.2 continues

Once or twice per week	935 (41.1)	546 (43.9)	
Three or more times per week	634 (27.9)	316 (25.4)	
Missing	59	63	
Hours spent watching television per week			
Less than 1 hour	319 (13.8)	179 (14.3)	<.001
1 hour but less than 3 hours	445 (19.3)	177 (14.2)	
3 hours but less than 5 hours	527 (22.9)	228 (18.2)	
5 hours or more	1014 (44.0)	666 (53.3)	
Missing	29	57	

Figures in parentheses are percentages.
[a]Exposed: communities located 1 km – 2 km from mine dumps.
[b]Unexposed: communities located 5 km or more from mine dumps.
[c]p-values of the Chi-square test.

The overall prevalence of current wheeze, asthma, and rhinoconjunctivitis was 675 (18.5%), 596 (17.5%), and 1060 (29.1%), respectively (Table 4.3). The prevalence of current wheeze 429 (21.1%) was significantly higher in the exposed than unexposed communities 183 (14.0%). This trend was also observed for rhinoconjunctivitis. In contrast, asthma 238 (10.8%) was significantly less prevalent in the exposed than unexposed communities 358 (29.6%).

Supplementary tables 4.7 to 4.9 summarise the results from the univariate LRA of all 11-study communities and by community type (exposed/unexposed).

Table 4.3: Prevalence of current wheeze, asthma and rhinoconjunctivitis

		Community		Total
		Exposed[a]	Unexposed[b]	
Current wheeze				
	Yes	492 (21.1)	183 (14.0)	675 (18.5)
	No	1842 (78.9)	1124 (86.0)	2966 (81.5)
	Missing	-	-	-
	Total	2334 (64.1)	1307 (35.9)	3641 (100)
Asthma				
	Yes	238 (10.8)	358 (29.6)	596 (17.5)
	No	1962 (89.2)	851 (70.4)	2813 (82.5)
	Missing	134	98	232
	Total	2200 (64.5)	1209 (35.5)	3409 (100)
Rhinoconjunctivitis				
	Yes	768 (32.9)	292 (22.3)	1060 (29.1)
	No	1566 (67.1)	1015 (77.7)	2581 (70.9)
	Missing	-	-	-
	Total	2334 (64.1)	1307 (35.9)	3641 (100)

Note: Figures in parentheses are percentages.
[a]Exposed: communities located 1 km – 2 km from mine dumps.
[b]Unexposed: communities located 5 km or more from mine dumps.

Table 4.4 summarises the results from the multiple LRA of all 11-study communities. Living in exposed communities significantly increased the likelihood of having current wheeze (38%) and rhinoconjunctivitis (54%). In contrast, those living in the exposed communities had a significant protective association with asthma (OR = 0.29; 95% CI: 0.23 – 0.35). Males were less likely than females to have asthma (OR = 0.73; 95% CI: 0.59 – 0.90) or rhinoconjunctivitis (OR = 0.60; 95% CI: 0.51 – 0.71). Using polluting fuels, such as open fires for residential cooking /heating had a significant detrimental association with current wheeze (OR = 1.98; 95% CI: 1.73 – 2.33) and a dose-response was observed for this factor. None of the other two health outcomes were significantly associated with the fuel use variable.

Those participants who lived near roads where trucks were always passing were 53% and 32% more likely to have wheeze and rhinoconjunctivitis, respectively. Truck traffic was not significantly associated with asthma. ETS exposure at home had a significant detrimental association with current wheeze (OR = 1.33; 95% CI: 1.08 – 1.63) and rhinoconjunctivitis (OR = 1.23; 95 CI: 1.04 – 1.46), but not with asthma. ETS exposure at school significantly increased the likelihood of asthma (63%), but not for current wheeze or rhinoconjunctivitis. Engaging in vigorous physical activities once or more per week had a significant detrimental association with all three health outcomes. More than 5 hours spent indoors watching television had a significant protective association with asthma (OR = 0.73; 95% CI: 0.53 – 0.99), but a significant detrimental association with rhinoconjunctivitis (OR = 1.52; 95% CI: 1.18 – 1.75). Effect modification between community type (exposed/unexposed) and the other air pollution source variables was investigated. No significant effect modification was observed (results not shown).

Table 4.4: Prevalence, adjusted odds ratios of wheeze, asthma, and rhinoconjunctivitis in all 11-study communities

Characteristics	Current wheeze n (%)	Adjusted OR[a] (95% CI)	p-value	Asthma n (%)	Adjusted OR[b] (95% CI)	p-value	Rhino conjunctivitis n (%)	Adjusted OR[c] (95% CI)	p-value
Community									
Unexposed*	183 (14.0)	1		358 (29.6)	1		292 (22.3)	1	
Exposed	492 (21.1)	**1.38 (1.10 – 1.71)**	**0.004**	238 (10.8)	**0.29 (0.23 – 0.35)**	**<0.001**	768 (32.9)	**1.54 (1.29 – 1.82)**	**<0.001**
Sex									
Female*	339 (9.7)	1		314 (9.4)	1		609 (17.4)	1	
Male	321 (9.1)	-		265 (7.9)	**0.73 (0.59 – 0.90)**	**0.004**	437 (12.5)	**0.60 (0.51 – 0.71)**	**<0.001**
Residential heating/cooking fuel type									
Electricity*	574 (17.1)	1		447 (14.0)	1		933 (27.8)	1	
Gas	12 (0.4)	0.48 (0.23 – 1.02)	0.057	18 (0.6)	-		21 (0.6)	-	
Paraffin	31 (0.9)	1.25 (0.78 – 1.99)	0.351	19 (0.6)	-		47 (1.4)	-	
Open fire	29 (0.9)	**1.98 (1.73 – 2.33)**	**0.004**	6 (0.2)	-		36 (1.1)	-	
Frequency of trucks passing near residence on weekdays									
Never*	90 (2.6)	1		89 (2.6)	1		121 (3.4)	1	
Seldom	144 (4.1)	0.96 (0.68 – 1.35)	0.813	95 (2.8)	-		216 (6.1)	1.25 (0.95 – 1.66)	0.105
Frequently	110 (3.1)	1.25 (0.77 – 1.99)	0.448	85 (2.5)	-		150 (4.3)	1.26 (0.93 – 1.71)	0.130

Table 4.4 continues

Always	320 (9.1)	**1.53 (1.28 – 1.97)**	**0.003**	317 (9.4)	-		564 (16.0)	**1.32 (1.07 – 1.75)**	**0.012**
ETS exposure at home in the past 30 days									
No*	228 (7.2)	1		234 (7.7)	1		392 (12.3)	1	
Yes	365 (11.5)	**1.33 (1.08 – 1.63)**	**0.006**	294 (9.7)	-		547 (17.2)	**1.23 (1.04 – 1.46)**	**0.020**
ETS exposure at school									
No*	259 (8.7)	1		199 (7.0)	1		437 (14.7)	1	
Yes	300 (10.1)	**1.63 (1.26 – 2.11)**	**0.030**	265 (9.4)	**1.77 (1.43 – 2.20)**	**<0.001**	462 (15.6)	-	
Vigorous physical activities per week									
Never*	150 (4.3)	1		146 (4.4)	1		268 (7.6)	1	
Once or twice per week	290 (8.2)	**1.37 (1.10 – 1.71)**	**0.014**	245 (7.3)	1.29 (0.99 – 1.68)	0.059	483 (13.7)	**1.51(1.25 – 1.83)**	**<0.001**
Three or more times per week	226 (6.4)	**1.61(1.29 – 2.20)**	**<0.001**	200 (6.0)	**2.02 (1.52 – 2.67)**	**<0.001**	299 (8.5)	**1.54 (1.24 – 1.91)**	**<0.001**
Hours spent watching television									
Less than 1 hr*	83 (2.3)	1		104 (3.1)	1		119 (3.4)	1	
1 hr but less than 3 hrs	114 (3.2)	-		95 (2.8)	0.76 (0.52 – 1.10)	0.151	169 (4.8)	1.26 (0.93 – 1.70)	0.133
3 hrs but less than 5 hrs	121 (3.4)	-		103 (3.0)	**0.59 (0.41 – 0.85)**	**0.005**	221 (6.2)	1.31(0.99 – 1.75)	0.063
5 hrs or more	355 (10.0)	-		291 (8.6)	**0.73 (0.53 – 0.99)**	**0.046**	545 (15.3)	**1.52 (1.18 – 1.75)**	**0.001**

[*] Reference category
[a] Model adjusted for all the variables in this table, except sex
[b] Model adjusted for all the variables in this table, except ETS exposure at home/ frequency of trucks passing near residences
[c] Model adjusted for all the variables in this table and having pets in and around the house, but not adjusted for residential heating/cooking fuel type and ETS at school

Tables 4.5 and 4.6 show results from multiple LRA stratified by community type (exposed/unexposed). In exposed communities, gas frequently used for residential cooking/heating was associated with asthma (OR = 2.2; 95% CI: 1.02 – 4.70). Engaging in vigorous physical activities was consistently associated with current wheeze, asthma, and rhinoconjunctivitis in exposed compared to unexposed communities. More than 5 hours spent indoors watching television had a significant protective association with asthma (OR = 0.49; 95% CI: 0.27 – 0.89), but a significant association with current wheeze (OR = 1.70; 95% CI: 1.17 – 1.82), and rhinoconjunctivitis (OR = 1.69; 95% CI: 1.18 – 1.75) in exposed communities, but a protective a significant protective effect was observed for wheeze (OR = 0.41; 95% CI: 0.22 – 0.77) in unexposed.

Table 4.5: Prevalence, adjusted odds ratios of wheeze, asthma, and rhinoconjunctivitis in exposed communities

Characteristics	Current wheeze n (%)	Adjusted OR[a] (95% CI)	p-value	Asthma n (%)	Adjusted OR[b] (95% CI)	p-value	Rhino conjunctivitis n (%)	Adjusted OR[c] (95% CI)	p-value
Sex									
Female	242 (10.7)	1		123	1		435 (19.2)	1	
Male	237 (10.4)	-		107	**0.71 (0.50 – 0.99)**	**0.048**	333 (14.1)	**0.60 (0.51 – 0.73)**	**<0.001**
Residential heating/cooking fuel type									
Electricity	413 (18.9)	1		170	1		673 (30.7)	1	
Gas	9 (0.4)	-		12 (0.6)	**2.20 (1.02 – 4.70)**	**0.044**	14 (0.6)	-	
Paraffin	22 (1.0)	-		9 (0.4)	1.20 (0.53 – 2.72)	0.667	29 (1.3)	-	
Open fires	29 (1.3)	-		4 (0.2)	0.49 (0.17 – 1.37)	0.172	33 (1.5)	-	
Frequency of trucks passing near residence on weekdays									
Never	56 (2.5)	1		34 (1.6)	1		86 (3.8)	1	
Seldom	108 (4.7)	-		52 (2.4)	-		137 (6.0)	1.09 (0.79 – 1.66)	0.580
Frequently	75 (3.3)	-		32 (1.5)	-		114 (5.0)	1.35 (0.96 – 1.71)	0.088
Always	244 (10.7)	**-**		115	-		423 (18.5)	**1.56 (1.17 – 1.75)**	**0.002**
ETS exposure at home in the past 30 days									
No	148 (7.3)	1		86 (4.5)	1		272 (13.4)	1	

Table 4.5 continues									
Yes	270 (13.3)	**1.44 (1.15 – 1.81)**	**0.002**	126 (6.6)	-		388 (19.2)	-	
ETS exposure at school									
No	161 (8.4)	1		69 (3.8)	1		272 (14.3)	1	
Yes	242 (12.7)	**-**		122 (6.7)	**1.43 (1.01 – 2.02)**	**0.042**	374 (19.6)	-	
Vigorous physical activities per week									
Never	101 (4.4)	1		46 (2.1)	1		204 (9.0)	1	
Once or twice	204 (9.0)	**1.59 (1.20 – 2.10)**	**0.001**	96 (4.4)	1.49 (0.95 – 2.33)	0.059	326 (14.3)	**1.35 (1.05 – 1.61)**	**0.017**
Three or more times per week	178 (7.8)	**2.25 (1.67 – 3.03)**	**<0.001**	94 (4.4)	**2.60 (1.65 – 2.67)**	**<0.001**	228 (10.0)	**1.49 (1.17 – 1.91)**	**0.001**
Hours spent watching television per week									
Less than 1 hr	50 (2.2)	1		42 (1.9)	1		82 (3.6)	1	
1 hr but less than 3 hrs	81 (3.5)	1.22 (0.80 – 1.84)	0.355	41 (1.9)	0.78 (0.44 – 1.40)	0.151	123 (5.3)	1.11 (0.79 – 1.56)	0.545
3 hr but less than 5 hrs	101 (4.4)	1.21 (0.81 –.81)	0.355	44 (2.0)	**0. 49 (0.27 – 0.89)**	**0.020**	171 (7.4)	1.35 (0.98 – 1.87)	0.071
5 hrs or more	259 (11.2)	**1.70 (1.17 – 1.82)**	**0.005**			0.487			**0.001**

*Reference category

[a] Model adjusted for all the variables in this table, except sex
[b] Model adjusted for all the variables in this table, except adjusted for residential heating/cooking fuel type and ETS at school
[c] Model adjusted for all the variables in this table except ETS at school

Table 4.6: Prevalence, adjusted odds ratios of wheeze, asthma, and rhinoconjunctivitis in unexposed communities

Characteristics	Current wheeze %	Adjusted OR[a] (95% CI)	p-value	Asthma%	Adjusted OR[b] (95% CI)	p-value	Rhino conjunctivitis %	Adjusted OR[c] (95% CI)	p-value
Sex									
Female	97 (7.8)	1		191 (16.0)	1		174 (14.0)	1	
Male	86 (6.8)	-		158 (13.3)	-		117 (9.4)	**0.56 (0.42 – 0.76)**	**<0.001**
Residential heating/cooking fuel type									
Electricity	161	1		277 (24.6)	1		260 (22.3)	1	
Gas	3 (0.3)	0.67 (0.20 – 2.28)	0.528	6 (0.5)	-		7 (0.6)	-	
Paraffin	9 (0.8)	1.53 (0.71 – 3.29)	0.280	10 (0.9)	-		18 (1.6)	-	
Open fires	0 (0.0)	-	-	2 (0.2)	-		3 (0.3)	-	
Frequency of trucks passing near residence on weekdays									
Never	34 (2.7)	1		55 (4.6)	1		35 (2.8)	1	
Seldom	36 (2.9)	-		43 (3.6)	0.64 (0.37 – 1.08)	0.095	79 (6.4)	-	
Frequently	35 (2.8)	-		53 (4.4)	**1.70 (1.02 – 2.82)**	**0.043**	36 (2.9)	-	
Always	76 (6.1)	-		202 (16.9)	1.33 (0.88 – 2.00)	0.171	141 (11.4)	-	
ETS exposure at home in the past 30 days									
No	80 (6.9)	1		148 (13.3)	1		120 (10.4)	1	
Yes	95 (8.2)	-		168 (15.1)	-		159 (13.8)	-	

Table 4.6 continues

ETS exposure at school									
No	98 (9.3)	1		130 (12.8)	1		165 (15.6)	1	
Yes	58 (5.5)	-		143 (14.1)	**1.87 (1.39 – 2.49)**	**<0.001**	88 (8.3)	**0.70 (0.52 – 0.94)**	**<0.001**
Vigorous physical activities per week									
Never*	49 (3.9)	1		100 (8.4)	1		64 (5.1)	1	
Once or twice	86 (6.9)	-		149 (12.5)	1.16 (0.82 – 1.65)	0.392	157 (12.6)	**1.77 (1.25 – 2.51)**	**0.001**
Three or more times per week	48 (3.9)	-		106 (8.9)	**1.62 (1.11 – 2.39)**	**0.013**	71 (5.7)	1.47 (0.97 – 2.20)	0.065
Hours spent watching television per week									
Less than 1 hr	33 (2.6)	1		62 (5.2)	1		37 (3.0)	1	
1 hr but less than 3 hrs	33 (2.6)	1.07 (0.62 – 1.87)	0.807	54 (4.5)	0.84 (0.49 – 1.43)	0.521	46 (3.7)	-	
3 hrs but less than 5 hrs	20 (1.6)	**0.41 (0.22 – 0.77)**	**0.005**	59 (4.9)	0.67 (0.40 – 1.11)	0.119	50 (4.0)	-	
5 hrs or more	96 (7.7)	0.81 (0.52 – 1.28)	0.280	181 (15.1)	0.67 (0.44 – 1.01)	0.058	157 (12.6)	-	

* Reference category

[a] Model adjusted for all the variables in this table, except sex, ETS exposure at home, ETS exposure at school, vigorous physical activity per week.

[b] Model adjusted for all the variables in this table, except frequency of trucks passing near residences

[c] Model adjusted for all the variables in this table, but not adjusted for, except ETS exposure

4.5 Discussion

The results of this study suggest that there is a high prevalence of current wheeze and rhinoconjunctivitis in the seven exposed communities (i.e. 1 km – 2 km from mine dumps). A recent report from different centres in African countries that participated in the ISAAC Phase III reported considerable variations in the prevalence of current wheeze (4.0 – 21.5%) and rhinoconjunctivitis (7.2 – 27.3%).[37] The prevalence of current wheeze reported in this study support findings in the ISAAC Phase III for African countries. The prevalence of asthma in exposed communities was consistent with earlier studies conducted in South Africa, i.e. between 10% and 13%.[38–41] However, high prevalence of current wheeze and rhinoconjunctivitis was observed as compared to other studies conducted in the industrialised cities of Cape Town (20.3% and 20.7%)[2] and Polokwane (18.0% and 16.9.%).[33] The 12-month prevalence of wheeze and rhinoconjunctivitis over lifetime prevalence were used as previous studies had shown that this definition is less susceptible to recall bias.

The proximity of a community to mine dumps, residential heating/cooking fuel type, truck traffic frequency and ETS exposure at home and school are all surrogate measures for indoor and outdoor exposure to criteria air pollutants and other pollutants. Criteria air pollutants include particulate matter with an aerodynamic diameter smaller than 10 μm (PM_{10}), $PM_{2.5}$, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ground-level ozone (O_3), carbon dioxide (CO) and lead. Mine dump facilities are major sources of wind-blown dust and smaller PM, e.g. PM_{10}. The mine dust and smaller PM are released and transported to the surrounding communities by air, soil or water contamination.[23,24] Mine dumps contain a complex mixture of metals such as cadmium, manganese, gold, arsenic, selenium, lead.[29,42] In this study, residing in an exposed community was significantly associated with an increased risk of current wheeze and rhinoconjunctivitis among adolescents. A worldwide analysis of ISAAC Phase 1 data of adolescents showed that the urban background PM_{10} has little or no association with current wheeze and rhinoconjunctivitis.[43] These findings are in contrast to those of this study, this may be due to the difference in concentration and chemical composition of PM_{10} and the study setting. Residential developments in some of the selected communities are now at the foot of the mine dumps,[26] and therefore increasing human exposure from the eroded particulate matter of mine dumps.[44]

The results of this study showed increased risk of current wheeze due to the use of open fires for residential heating/cooking. Due to various socio-economic reasons and high unemployment rate in South Africa many households use paraffin and open fires as alternative sources of energy as they are more affordable than electricity.[45] A global analysis of ISAAC data of 13-14 year olds showed a positive association between current wheeze and use of open fires for cooking.[46] In our study a stronger association was observed than that of the ISAAC global analysis.

The association between air pollution derived from truck traffic, asthma, current wheeze and rhinoconjunctivitis is not novel.[43,47–50] People living in close proximity to busy roads are most adversely affected.[51] A strong association between truck traffic frequency and current wheeze was observed in this study.

A recent systematic review of 79 prospective studies found that pre- or postnatal ETS was associated with increased risk of wheezing and rhinoconjunctivitis, [52] our study supports this association. A large number of adolescents reported ETS exposure at schools, which indicated that smoking habits are common in South African public schools. Hence, health promotion programs to reduce smoking at schools should be strengthened; programs that will not only improve knowledge of the dangers of smoking, but also change the attitude towards smoking.

Individual exposure to pollutants depend on the amount of concentration in the exposed environment, duration and time pattern of exposure.[53] A significant association was observed between those who engaged in vigorous physical activities more than once per week, and current wheeze, asthma and rhinoconjunctivitis. During exercise a higher quantity of air inhaled is observed and consequently higher internal dose of air pollution. It is surprising that hours spent indoors watching television had a significant protective effect for asthma, but was a risk factor for rhinoconjunctivitis. Children with asthma are generally less active than their non-asthmatic counterparts[54] and may consequently spend more time indoors and be less exposed to outdoor air pollution.

A possible mechanism to explain the observed detrimental associations between wheeze and the community exposure status and the other indoor or outdoor air pollution sources is that the emitted criteria pollutants may cause air way mucosal damage, disabled mucociliary clearance, enhanced penetration and the access of inhaled allergens to the cells of the immune system and airway sensitisation, thus resulting in airway inflammation.[55,56]

This study has a few limitations. Firstly, the findings are based on self-reported answers from a questionnaire. Self-reported answers may lead to misclassification of the disease and exposure status, which may result in spurious statistical significant associations. E.g., children with asthma might have underestimated how often they engage in vigorous physical activities, while overestimation could have occurred without asthma. Secondly, no quantitative air pollution exposure assessment was conducted. Thirdly, frequency of trucks passing near homes on weekdays maybe misclassified as on weekdays participants are at school. Fourthly, the differential participation rate between exposed and unexposed communities is of concern and may well have introduced selection bias, which is likely to overestimate the prevalence estimates derived from our cross-sectional study and also bias the association in either direction. Fifthly, no data on possible reasons for declining to take part were collected from parents who did not give consent. Sixthly, data on the video questionnaire, which were believed to be more specific for asthma, were not included in the analysis, as the questionnaire could not be completed in some schools, due to logistical problems such as unavailability of electricity, challenges of moving audiovisual equipment from class to class, or lack of a suitable venue where the children could watch the video. Lastly, we did not collect data on how access to healthcare varies between exposed and unexposed communities.

The strength of our study is that an international validated ISAAC questionnaire was used to study the symptoms of wheeze, asthma, and rhinoconjunctivitis. The findings of this study serve as a base for further detailed epidemiological studies for communities in close proximity to the mine dumps e.g. a planned birth cohort study.

4.6 Conclusions

A high prevalence of wheeze, asthma and rhinoconjunctivitis among adolescents in communities located near mine dumps were observed. Detrimental associations between these health outcomes and community proximity to mine dumps, open fire cooking, frequency of truck traffic, ETS and physical activeness were noted. In the era when disease such as asthma is rapidly rising to be leading burden globally and with developments at the base of mine dumps in some communities, the increasing population in these areas will potentially add to the burden of non-communicable diseases in South Africa.

4.7 Conflict of interest

Authors report no conflict of interest.

4.8 Ethical considerations

Ethical approval (number: 235/2011) was obtained from the Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria, Gauteng Department of Education (number: D2012/79) and North West Department of Education (Number: 23-04-2012). School principals and governing bodies were approached and gave their consent for the study. Parents or guardians of participants were sent a letter explaining the details and nature of the study. The parents or guardians of the participants granted consent. Data collectors were instructed to keep all information confidential. Anonymity was maintained and the names of the participants were not recorded.

4.9 Acknowledgements

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4.10 List of abbreviations

CI: Confidence Intervals

ETS: Environmental Tobacco Smoke

ISAAC: International Study of Asthma and Allergies in Childhood

LRA: Logistic Regression Analysis

AGA: Anglo Gold Ashanti

CGR: Crown Gold Recoveries

DRD: Durban Roodepoort Deep

ERPM: East Rand Proprietary Mines

NRF: National Research Foundation

DAAD: Deutscher Akademischer Austausch Dienst

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Supplementary table 4.7: Crude odds ratios of wheeze, asthma, and rhinoconjunctivitis in all 11 study communities

Characteristics	Wheeze	p-value	Asthma	p-value	Rhinoconjunctivitis	p-value
Community						
Unexposed	1		1		1	
Exposed	1.64 (1.36 – 1.97)	<0.001	0.28 (0.24 – 0.34)	<0.001	1.70 (1.45 – 1.99)	<0.001
Sex						
Female	1		1		1	
Male	0.92 (0.78 – 1.09)	0.343	0.81 (0.67 – 0.97)	0.021	0.61 (0.53 – 0.71)	<0.001
Residential heating/cooking						
Electricity	1		1		1	
Gas	0.63 (0.34 – 1.16)	0.138	1.44 (0.84 – 2.44)	0.176	0.65 (0.39 – 1.06)	0.185
Paraffin	1.22 (0.81 – 1.83)	0.345	0.93 (0.57 – 1.53)	0.780	1.14 (0.79 – 1.63)	0.483
Open fires	1.47 (0.95 – 2.26)	0.004	0.33 (0.14 – 0.76)	<0.001	1.04 (0.70 – 1.55)	0.846
Frequency of trucks passing near residence on weekdays						
Never*	1		1		1	
Seldom	1.29 (0.96 – 1.72)	0.088	0.77 (0.56 – 1.05)	0.103	1.53 (1.18 – 1.98)	0.001
Frequently	1.49 (1.09 – 2.03)	0.011	1.04 (0.76 – 1.46)	0.771	1.58 (1.19 – 2.09)	0.001
Always	1.15(0.89 – 1.49)	0.285	1.13 (0.88 – 1.47)	0.341	1.69 (1.35 – 2.12)	<0.001
ETS exposure at home in the past 30 days						
No	1		1		1	
Yes	1.40 (1.16 – 1.67)	<0.001	1.03 (0.85 – 1.24)	0.757	1.43 (1.14 – 1.86)	0.001
ETS exposure at school						
No	1		1		1	
Yes	1.18 (0.98 – 1.42)	0.054	1.41 (1.15 – 1.72)	0.001	1.06 (0.91 – 1.24)	0.464

Supplementary table 4.7 continues

Vigorous physical activities						
Never*	1		1		1	
Once or twice per week	1.37 (1.10 – 1.71)	0.014	1.25 (1.00 – 1.55)	0.051	1.48 (1.24 – 1.76)	<0.001
Three or more times per week	1.61(1.29 – 2.20)	<0.001	1.70 (1.34 – 2.15)	<0.001	1.40 (1.16 – 1.71)	0.001
Hours spent watching television per week						
Less than 1 hour*	1		1		1	
1 hour but less than 3 hours	1.12 (0.82 – 1.53)	0.468	0.70 (0.52 – 0.96)	0.151	1.19 (0.91 – 1.56)	0.213
3 hours but less than 5 hours	0.95 (0.70 – 1.29)	0.764	0.61 (0.45 – 0.82)	0.001	1.32 (1.02 – 1.71)	0.036
5 hours or more	1.33 (1.03 – 1.74)	0.029	0.79 (0.62 – 1.02)	0.073	1.53 (1.21 – 1.92)	0.001

*Reference category

Supplementary table 4.8: Crude odds ratios of wheeze, asthma, and rhino-conjunctivitis in the seven exposed communities

Characteristics	Wheeze	p-value	Asthma	p-value	Rhinoconjunctivitis	p-value
Sex						
Female	1		1		1	
Male	0.95 (0.78 – 1.16)	0.620	0.84 (0.64 – 1.09)	0.198	0.60 (0.51 – 0.73)	<0.001
Residential heating/cooking						
Electricity	1		1		1	
Gas	0.60 (0.29 – 1.22)	0.160	2.45 (1.27 – 4.69)	0.007	0.52 (0.29 – 0.95)	0.033
Paraffin	1.10 (0.68 – 1.80)	0.920	1.14 (0.56 – 2.32)	0.711	0.82 (0.52 – 1.28)	0.378
Open fires	1.40 (0.90 – 2.17)	0.137	0.43 (0.15 – 1.17)	0.098	0.85 (0.56 – 1.30)	0.462
Frequency of trucks passing near residence on weekdays						
Never	1		1		1	
Seldom	1.48 (1.03 – 2.11)	0.032	1.07 (0.67 – 1.69)	0.783	1.19 (0.87 – 1.63)	0.287
Frequently	1.48 (1.01 – 2.18)	0.046	0.91 (0.55 – 1.52)	0.723	1.54 (1.11 – 2.16)	0.287
Always	1.38 (1.02 – 1.90)	0.048	0.99 (0.66 – 1.49)	0.945	1.74 (1.33 – 2.29)	<0.001
ETS exposure at home in the past 30 days						
No	1		1		1	
Yes	1.49 (1.19 – 1.86)	<0.001	1.11 (0.83 – 1.48)	0.492	1.11 (0.92 – 1.34)	0.0274
ETS exposure at school						
No	1		1		1	
Yes	1.27 (0.02 – 1.59)	0.036	1.49 (1.09 – 2.04)	0.012	1.16 (0.96 – 1.41)	0.120

Supplementary table 4.8						
Vigorous physical activities						
Never	1		1		1	
Once or twice per week	1.67 (1.29 – 2.17)	<0.001	1.62 (1.12 – 2.33)	0.010	1.32 (1.07 – 1.63)	0.011
Three or more times per week	2.34 (1.78 – 3.07)	<0.001	2.48 (1.71 – 3.59)	<0.001	1.38 (1.09– 1.73)	0.006
Hours spent watching television per week						
Less than 1 hour*	1		1		1	
1 hour but less than 3 hours	1.20 (0.81 – 1.76)	0.361	0.68 (0.43 – 1.08)	0.100	1.10 (0.79 – 1.52)	0.552
3 hours but less than 5 hours	1.28 (0.88 – 1.85)	0.199	0.60 (0.38 – 0.95)	0.028	1.39 (1.01 – 1.89)	0.038
5 hours or more	1.85 (1.32 – 2.56)	<0.001	0.78 (0.54 – 1.15)	0.217	1.79 (1.35 – 2.37)	<0.001

Supplementary table 4.9: Crude odds ratios of wheeze, asthma, and rhino-conjunctivitis in the four unexposed communities

Characteristics	Wheeze	p-value	Asthma	p-value	Rhino-conjunctivitis	p-value
Sex						
Female	1		1		1	
Male	0.84 (0.62 – 1.19)	0.302	0.79 (0.61 – 1.01)	0.063	0.59 (0.46 – 0.78)	<0.001
Residential heating/cooking						
Electricity	1		1		1	
Gas	0.66 (0.19 – 2.21)	0.502	0.83 (0.33 – 2.09)	0.700	1.01 (0.42 – 2.39)	0.985
Paraffin	1.50 (0.69 – 3.12)	0.311	0.82 (0.39 – 1.67)	0.583	2.19 (1.18 – 4.01)	0.013
Open fires	-	-	0.93 (0.18 – 4.61)	0.926	1.90 (0.45 – 8.01)	0.381
Frequency of trucks passing near residence on weekdays						
Never	1		1		1	
Seldom	0.92 (0.55 –1.53)	0.755	0.60 (0.38 – 0.95)	0.028	2.46 (1.57 – 3.86)	<0.001
Frequently	1.51 (0.89 – 2.55)	0.123	1.41 (0.89 – 2.22)	0.135	1.51 (0.90 – 2.54)	0.117
Always	0.75 (0.48 – 1.16)	0.191	1.41 (0.99 – 2.01)	0.055	1.52 (1.01 – 2.28)	0.044
ETS exposure at home in the past 30 days						
No	1		1		1	
Yes	1.15 (0.84 – 1.59)	0.378	1.11 (0.85 – 1.44)	0.445	1.35 (1.03 – 1.78)	0.027
ETS exposure at school						
No	1		1		1	
Yes	0.82 (0.58 – 1.16)	0.266	1.94 (1.47 – 2.57)	<0.001	0.70 (0.52 – 0.94)	0.017

Supplementary table 4.9 continues						
Vigorous physical activities						
Never	1		1		1	
Once or twice per week	1.27 (0.87 – 1.85)	0.215	1.01 (0.75 – 1.36)	0.051	2.01 (1.45 – 2.78)	<0.001
Three or more times per week	1.22 (0.79 – 1.87)	0.370	1.40 (1.01 – 1.95)	0.044	1.44 (0.99 – 2.01)	0.058
Hours spent watching television per week						
Less than 1 hour	1		1		1	
1 hour but less than 3 hours	1.01 (0.59 – 1.73)	0.960	0.87 (0.56 – 1.36)	0.545	1.35 (0.82 – 2.21)	0.236
3 hours but less than 5 hours	0.43 (0.23 – 0.77)	0.005	0.68 (0.44 – 1.04)	0.073	1.08 (0.66 – 1.74)	0.758
5 hours or more	0.75 (0.45 – 1.15)	0.185	0.73 (0.52 – 1.05)	0.092	1.18 (0.79 – 1.77)	0.413

5. Chapter 5: Chronic respiratory disease among the elderly in South Africa: any association with proximity to mine dumps?

5.1 Abstract

Background: There is increasing evidence that environmental factors such as air pollution from mine dumps, increase the risk of chronic respiratory symptoms and diseases. The aim of this study was to investigate the association between proximity to mine dumps and prevalence of chronic respiratory disease in people aged 55 years and older.

Methods: Elderly persons in communities 1 km – 2 km (exposed) and ≥ 5 km (unexposed), from five pre-selected mine dumps in Gauteng and North West Province, in South Africa were included in a cross-sectional study. Structured interviews were conducted with 2397 elderly people, using a previously validated ATS-DLD-78 questionnaire from the British Medical Research Council.

Results: Exposed elderly persons had a significantly higher prevalence of chronic respiratory symptoms and diseases than those who were unexposed., Results from the multiple logistic regression analysis indicated that living close to mine dumps was significantly associated with asthma (OR = 1.57; 95% CI: 1.20 – 2.05), chronic bronchitis (OR = 1.74; 95 CI: 1.25 – 2.39), chronic cough (OR = 2.02; 95% CI: 1.58 – 2.57), emphysema (OR = 1.75; 95% CI: 1.11 – 2.77), pneumonia (OR = 1.38; 95% CI: 1.07 – 1.77) and wheeze (OR = 2.01; 95% CI: 1.73 – 2.54). Residing in exposed communities, current smoking, ex-smoking, use of paraffin as main residential cooking/heating fuel and low level of education emerged as independent significant risk factors for chronic respiratory symptoms and diseases.

Conclusion: This study suggests that there is a high level of chronic respiratory symptoms and diseases among elderly people in communities located near to mine dumps in South Africa.

Keywords*:* Mine dumps, chronic respiratory diseases, elderly, South Africa

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5.2 Background

Chronic respiratory diseases are among the leading causes of death worldwide.[1] A literarure review indicated that developing countries are experiencing an increase in the prevalence of respiratory diseases[2] and projected trends of severity and frequency are likely to pose a public health challenge.[3] Studies have shown that both indoor and outdoor air pollution are the main risk factors for the burden of respiratory diseases[4,5] and elderly people are mostly affected[6] as a result of normal and pathological ageing.[7] A higher burden of respiratory diseases among the elderly could be of concern to South Africa's rapidly increasing population aged 60 years and above, currently the second largest in sub-Saharan Africa.[8]

In developing countries where health risks of air pollution may be underappreciated and effective air pollution abatement techniques are lacking, people are continually exposed to concentrations that can have negative health effects in both the short and long term. Various risk factors have been associated with chronic respiratory diseases, including gender[9], socio-economic status[10], tobacco smoking habits[11], occupational environment[12] and polluting fuel used for residential cooking/heating.[13] Studies conducted in South Africa on the prevalence of respiratory diseases have been in industrialised urban areas.[14,15]

Mine dump facilities are the main source of airborne particulate matter pollution, the dust is blown into the surrounding communities and can potentially have adverse health effects on human health and ecology.[16,17] Communities located close to mine dumps are of lower socio-economic status, often children and the elderly. These communities consist of historically disenfranchised ethnic groups living in government-funded houses, informal settlements and retired homes.[18] Epidemiological studies have shown that residing near mines is a major risk for exposure to particulate matter and metals such as cadmium, lead, silica, manganese, lead and arsenic.[19–21] Exposure to mine dump dust that is that is rich in silica has been linked to the development of chronic bronchitis, emphysema and airflow obstruction.[22] Settle-able dust has a negative effect on visibility, when it forms dust plumes while its deposition on fabrics, buildings, vehicles and water tanks constitutes a nuisance.[23] The ongoing reclamation of mine dumps for gold recovery observed during the survey, is worsening dust pollution with further deterioration of ambient air quality in the study populations. Many epidemiological studies have linked the effects of ambient air pollution with respiratory diseases.[24,25] Elderly people are potentially highly vulnerable to the effect of ambient air pollution, due to normal and pathological ageing.[26]

No studies have investigated whether exposure to mine dust or living in close proximity to mine dumps poses an increased risk for respiratory diseases among elderly people or possible effect modifications between various air pollution sources, including mine dust.

This study is part of the bigger project initiated by Mine Health Safety Council of South Africa (MHSC) around communities located near mine dumps in Gauteng and North West. It is, to the best of our knowledge, the first study that has investigated the association between potential risk factors and chronic respiratory diseases among elderly people staying in communities situated near mine dumps in South Africa. The aim of the study was to investigate whether the prevalence of chronic respiratory symptoms and diseases among the elderly community were associated with proximity to mine dumps. Effect modification between proximity to mine dumps and other air pollution sources was also investigated, for instance the type of fuel use for residential cooking/heating, tobacco smoking and history of occupational exposure to dust or chemical fumes.

5.3 Methods

5.3.1 Study area and demographics

Communities living 1 km – 2 km (exposed) and $\geq$ 5 km (unexposed) from five pre-selected mine dumps in Gauteng and North West of South Africa were studied during November and December in 2012. Table 5.1 lists the selected communities and Figure 5.1 shows a map of the study area. The socio-economic and demographic profile of exposed and unexposed communities was similar.

Table 5.1: Eleven communities selected in the study located in Gauteng and North West, South Africa during November-December 2012

Mine dump facility	Province	Exposed communities[a]	Unexposed communities[b]
Durban Roodepoort Deep (DRD)	Gauteng	Braamfischerville	Dobsonville
Crown Gold Recoveries (CGR)	Gauteng	Diepkloof, Riverlea, and Noordgesig	Orlando East
East Rand Proprietary Mines (ERPM)	Gauteng	Reiger Park	Windmill Park
Ergo	Gauteng	Geluksdal	Windmill Park
Anglo Gold Ashanti (AGA)	North West	Stilfontein	Jouberton

[a]1 km – 2 km from mine dumps.
[b]5 km or more from mine dumps.

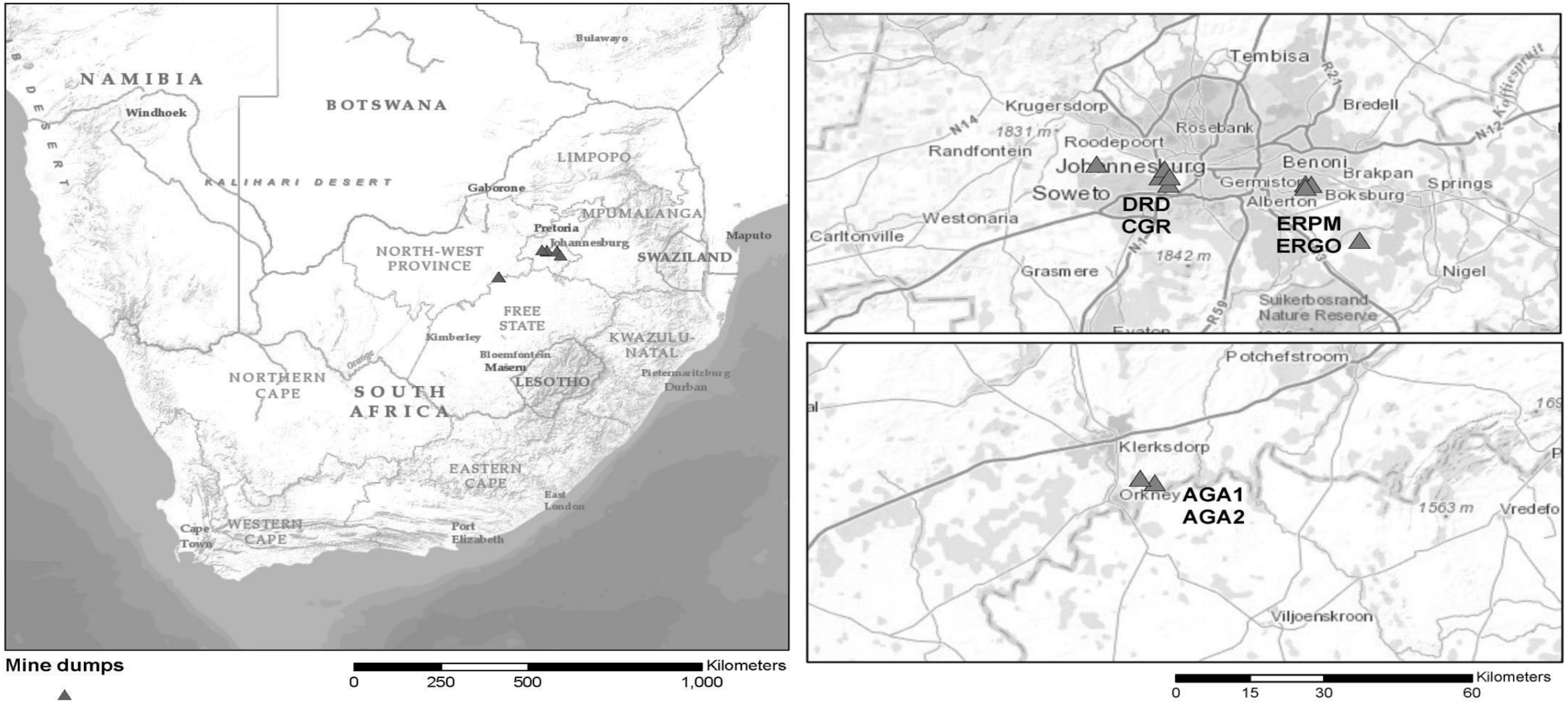


Figure 5.1: Location of mine dumps tailings in South Africa

5.3.2 Study design and sample selection

A cross-sectional epidemiological study design was applied. Face-to-face interviews were conducted using a previously validated ATS-DLD-78 questionnaire from the British Medical Research Council (BMRC).[27] The study focused on elderly people (55 years old and above) who had been residing for a period of five years or more, in the study communities. A knock-on-the-door approach was used to recruit study participants. The interviews were mainly in English and were translated into the local language if the respondent did not understand the questions.

Streets were randomly selected in each community. Four to five houses were then randomly selected in each street in a radial fashion. The sample size of each community was calculated using Epi Info version 7, with a total sample size of 3069. The population sizes were based on the 2001 census from Statistics South Africa because the results for census 2011 were not released when the study commenced. Twenty-two locally trained fieldworkers were employed, two per community listed in Table 5.1. Each fieldworker received thorough training in conducting the interviews using the respiratory health questionnaire, before the start of the survey.

5.3.3 Exclusion criteria

If a selected household had no elderly people or no one at home during the visit, or were unwilling to participate, the fieldworker proceeded to the next household.

5.3.4 Quality control

To maintain the quality of the interviews, different fieldworker per each community randomly selected 10% of homes and re-administered the same questionnaire to the same previously interviewed participants to verify their responses. This was performed 15 to 20 days after the first interview. Ten percent deviations within the interviews were deemed unacceptable.

5.3.5 Health outcomes

Having asthma, chronic bronchitis, chronic cough, emphysema, pneumonia and wheeze were classified on the basis of positive answers to the following questions:

- Asthma: "Was the asthma confirmed by the doctor?"
- Chronic bronchitis: "Was the chronic bronchitis confirmed by the doctor?"
- Chronic cough: "Do you cough most days for three consecutive months or more during the year?"
- Emphysema: "Was the emphysema confirmed by the doctor?"
- Pneumonia: "Was the pneumonia confirmed by the doctor?"
- Wheeze: "Does your chest ever sound whistling most days or nights?"

5.3.6 Main exposure factor

The main exposure factor of interest in this study was based on the distance between the study population and a mine dump (Table 5.1).

5.3.7 Confounders

Potential confounding variables included other air pollution sources: active smoking by participants (yes/no), main type of residential cooking/heating fuel (electricity, gas, paraffin, wood/coal). Additional confounders considered were: age (years), level of education (no schooling, primary, secondary, tertiary), sex (female/male), occupational exposure history to dust/chemical fumes (yes/no).

5.3.8 Statistical analyses

Two technicians entered the collected questionnaire data into a database set up in Epi Info version 3.5.3. Data were analysed using Stata version 12. Prevalence of the health outcome; the proportion of air pollution sources under investigation; and confounding variables, were calculated by dividing the number of participants who responded affirmatively by the number of questionnaires completed. Therefore, each question had a different sample size. Observations marked as “do not know”, “not stated”, or “other responses” were set as missing, but were included in the descriptive analyses. Only two explanatory variables such as age and main residential heating and cooking fuel type had missing observations. Responses to the number cigarettes smoked per day were very low and not included in the analysis. A chi-square test was applied, to determine the relationship between community (exposed/unexposed) and confounding variables. Crude and adjusted odds ratios (ORs) and 95% confidence intervals (CI) were calculated using univariate and multiple logistic regression analysis (LRA) to estimate the likelihood of having asthma, chronic bronchitis, chronic cough, emphysema, pneumonia and wheeze. Missing values were automatically excluded in each LRA model; therefore each multiple LRA model had a different sample size. To obtain adjusted ORs for the effect of “community (exposed/unexposed)” on the outcomes were placed in an initial LRA model. This was followed by the addition of a potential confounder in a stepwise manner starting with the most statistical significant from the univariate analysis. Each time a new potential confounder was added to the model if the effect estimate between the exposure of interest and respiratory outcome already in the models changed by more than 5%, the additional variable was retained in the final multiple LRA otherwise the variable was removed and a different one was added.[28] The most parsimonious multiple LRA models were reported, i.e. those with variables having a p-value < 0.05.[29] Community (exposed/unexposed) was considered as the main exposure factor and therefore was included in all models for each outcome of interest regardless of whether it was statistically significant in the univariate analyses.

Effect modification between community (exposed/unexposed) and other air pollution source variables, such as smoking habits, occupational exposure history to dust/chemical fumes, and residential cooking/heating fuel type, was investigated by including a multiplicative term in the model.

5.3.9 Ethics approval

Ethical approval (number: 235/2011) was obtained from the Research Ethics Committee, Faculty of Health Sciences, University of Pretoria. A verbal and written consent was obtained before commencement of the interviews.

5.4 Results

Only completed questionnaires (2397) were used for data analysis. This included 1499 (63%) study participants from exposed and 898 (37%) from unexposed communities (Table 5.2). The number of females in the study was slightly higher than males. Most of the study participants were in the age group 55 to 59 years. Overall, the majority of participants from both study communities had obtained secondary level education. The proportion of current smokers and those with a history of occupational exposure history to dust/chemical fumes, in exposed communities, was double that of the unexposed. A majority of participants from both exposed and unexposed communities reported electricity as the main source of residential fuel for heating/cooking.

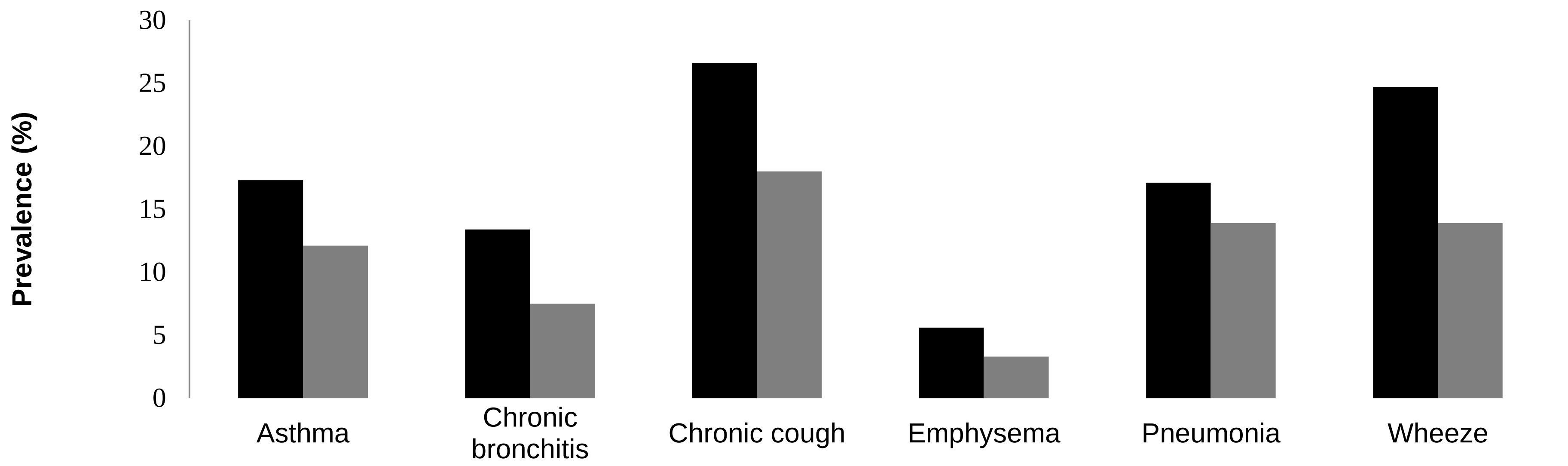
Table 5.2: Demographic characteristics and air pollution variables by type of community in Gauteng and North West, South Africa during November-December 2012

	Community		
	Exposed[a] (n = 1499)	Unexposed[b] (n = 898)	p-value[c]
Sex			
Female	774 (51.6)	472 (52.3)	
Male	725 (48.4)	426 (47.4)	0.66
Age (in years)			
55-59	500 (33.4)	225 (25.1)	
60-64	405 (27.0)	221 (24.6)	
65-69	228 (15.2)	125 (13.9)	<0.001
70-84	309 (20.6)	278 (31.0)	
≥85	48 (3.2)	29 (3.2)	
Missing	9 (0.6)	20 (2.2)	
Population group			
Black	1006 (41.9)	695 (29.0)	
Coloured	493 (20.6)	203 (8.5)	< 0.001
Level of education			
No schooling	262 (17.5)	271 (30.2)	
Primary	479 (32.0)	287 (32.0)	
Secondary	691 (46.1)	332 (37.0)	<0.001
Tertiary	67 (4.5)	8 (0.8)	
Smoking habits			
Non-smoker	888 (59.2)	598 (66.6)	
Ex-smoker	234 (15.6)	187 (20.8)	
Current smoker	377 (25.2)	113 (12.6)	<0.001
Occupational exposure history to dust/chemical fumes			
Yes	637 (42.5)	149 (16.6)	
No	862 (57.5)	749 (83.4)	<0.001
Main residential heating/cooking fuel type			
Electricity	1422 (94.9)	783 (87.2)	
Gas	31 (2.1)	67 (7.5)	<0.001
Paraffin	25 (1.7)	6 (0.7)	
Open fires	1 (0.07)	13 (1.5)	
Missing	20 (1.3)	29 (3.2)	

Figures in parentheses are percentages.
[a]Exposed: communities located 1 km – 2 km from mine dumps.
[b]Unexposed: communities located 5 km or more from mine dumps.

[c]p-values of the Chi-square test

The prevalence of asthma (17.3%), chronic bronchitis (13.4%), chronic cough (26.6%), emphysema (5.6%), pneumonia (17.1%) and wheeze (24.7%), in the exposed communities was higher than that of the unexposed communities, where the proportions were 12.1%, 7.5%, 18%, 3.3%, 13.9% and 19.3%, respectively (Figure 5.2).



	Asthma	Chronic bronchitis	Chronic cough	Emphysema	Pneumonia	Wheeze
■ Exposed	17.3	13.4	26.6	5.6	17.1	24.7
■ Unexposed	12.1	7.5	18	3.3	13.9	13.9

Figure 5.2: Prevalence of chronic respiratory symptoms and diseases stratified by type of community located 1 km – 2km and ≥5 km from mine dumps in Gauteng and North West, South Africa during November-December 2012

The prevalence of asthma, chronic bronchitis, chronic cough, emphysema, pneumonia, and wheeze per each risk factor considered in this study are shown in Supplementary Table 5.1. Crude and adjusted ORs for all risk factors except the main exposure factor are shown in Supplementary Tables 5.5 and 5.6.

Table 5.3: Univariate and multivariate analyses of chronic respiratory symptoms/diseases and diseases in all 11-study communities located 1 km – 2 km and ≥5 km* from mine dumps in Gauteng and North West, South Africa during November-December 2012

Chronic respiratory symptoms/diseases	*Crude OR*	*(95% CI)*	*p-value*	*Adjusted OR*	*(95% CI)*	*p-value*
Asthma[a]	**1.49**	**(1.17 – 1.90)**	0.001	**1.57**	**(1.20 – 2.05)**	0.001
Chronic bronchitis[b]	**1.92**	**(1.44 – 2.57)**	<0.001	**1.74**	**(1.26 – 2.39)**	0.001
Chronic cough[c]	**1.77**	**(1.43 – 2.20)**	<0.001	**2.02**	**(1.58 – 2.57)**	<0.001
Emphysema[d]	**1.72**	**(1.12 – 2.63)**	0.013	**1.75**	**(1.11 – 2.77)**	0.016
Pneumonia[e]	**1.25**	**(1.01 – 1.58)**	0.018	**1.38**	**(1.07 – 1.77)**	0.014
Wheeze[f]	**1.96**	**(1.65 – 2.32)**	<0.001	**2.01**	**(1.73 – 2.54)**	<0.001

[*]Communities located ≥5 km (unexposed) from mine dumps used as reference category.
[a-f:] Models adjusted for sex, age, population group, smoking habits, occupational exposure history to dust/chemical fumes and main residential heating/cooking fuel type

Results from the multiple LRA (Table 5.3) indicated that living in the exposed communities was significantly associated with asthma (OR = 1.57; 95% CI: 1.20 – 2.05), chronic bronchitis (OR = 1.74; 95% CI: 1.25 – 2.39), chronic cough (OR = 2.02; 95% CI: 1.58 – 2.57), emphysema (OR = 1.75; 95% CI: 1.11 – 2.77), pneumonia (OR = 1.38; 95% CI: 1.07 – 1.77) and wheeze (OR = 2.01; 95% CI: 1.73 – 2.54). Sex was not associated with any of the health outcomes considered in this study. The study participants who were in the age group between 70–84 years were at an increased likelihood of having chronic bronchitis (67%), emphysema (81%) and pneumonia (36%). Coloured participants were less likely to experience cough (OR= 0.55; 95% CI: 0.42 – 0.71) and wheeze (OR= 0.54; 95% CI: 0.44 – 0.66) as compared to black. Participants with primary level as their highest education were 50% more likely to have asthma. Having secondary education was associated with chronic bronchitis (OR = 1.45; 95% CI: 1.01 – 2.22) and wheeze (OR = 1.54; 95% CI: 1.54 – 1.98). Current and ex-smoking significantly increased the likelihood of having chronic cough, wheeze, asthma, emphysema, pneumonia, and were not associated with chronic bronchitis respectively. Occupational exposure history to dust/chemical fumes was significantly associated with chronic bronchitis (OR = 1.43; 95% CI: 1.07 – 1.91). Using polluting fuels, such as paraffin or gas for residential cooking/heating had significant detrimental association with chronic cough (OR = 2.03; 95% CI: 1.13 – 4.78) and pneumonia (OR = 2.40; 95% CI: 1.11 – 5.17) (Supplementary Table 5.5).

No significant effect modification between community type (exposed/unexposed) and other air pollution source variables was observed (results not shown).

5.5 Discussion

This is the first study that investigated the prevalence and risk factors associated with chronic respiratory symptoms and diseases and among elderly people in communities exposed to mine dumps in South Africa. The results of this study suggest that there is a high prevalence of asthma, chronic bronchitis, chronic cough, emphysema, pneumonia and wheeze in the seven exposed communities. Residing in exposed communities, smoking habits, use of paraffin for residential cooking/heating, and having a low level of education emerged as significant risk factors for chronic respiratory symptoms and diseases.

The risk of exposure to particulate matter from mine dumps is well documented by international research studies.[30–32] An exposure assessment study done in one of the mine dumps in this study showed that the ambient concentration of particulate matter with an aerodynamic diameter less than 10 μm (PM_{10}) exceeded by far the 24-hour limit set by the South African Department of Environmental Affairs (180 $\mu g.m^{-3}$).[16,33] Residential developments in some communities are a stone throw from the mine dump, resulting in elevated exposure to particulate matter.[34] Therefore, respiratory diseases and symptoms could be aggravated or originated as a result of exposure to dust emanating from mine dumps.

No significant differences were observed between the prevalence of chronic respiratory symptoms and diseases in males and females, and sex was not associated with any of the health outcomes considered in this study. Previous studies have reported that males were at increased risk for respiratory diseases.[35,36] This difference may result from differential occupational exposure rates and smoking between males and females.

Ageing is normally associated with an increased risk of respiratory symptoms and diseases,[36,37] this might be attributed to anatomical, physiological and immunological changes that occur in the respiratory system during ageing.[38] In this study increase in age was not significantly associated with having chronic respiratory symptoms and diseases, survivor effect could be a possible explanation for these observations. A research study conducted in South Africa showed being coloured was associated with the presence chronic lung diseases among the elderly people.[39] However, in this study a significant protective effect was observed. Primary and secondary education levels were significant risk factors for respiratory symptoms and diseases. Lower education levels are known to be linked to low socio-economic status and have been identified as a risk factor for respiratory symptoms and diseases.[40] A national household survey conducted in South Africa reported higher education level as a protective factor for respiratory diseases.[41] The findings of this study support this association.

Association of smoking habits with respiratory diseases and symptoms is not novel.[42–44] Current and ex-smoking was significantly associated with chronic cough, wheeze, asthma, emphysema and pneumonia. Ex-smokers were at a higher risk than current smokers of having the latter. Being diagnosed as having chronic respiratory symptoms and disease might be the reason why respondents stopped smoking. Another possibility might have been advice from doctors, as it has been shown that physician's advice could contribute to smoking cessation.[45]

The respiratory system is susceptible to harm from occupational exposures due to direct contact with the ambient environment, and inhalation of possible toxic substances.[46] Occupational exposure history to dust/chemicals was not associated with respiratory diseases or symptoms. The findings of this study are in contrast to those of other research studies in this respect.[47–49] Domestic use of paraffin or gas appliances has been associated with respiratory symptoms and diseases in children, less consistently with adults and elderly people.[50,51] In this study domestic use of paraffin and gas was associated with an increased risk of respiratory symptoms and diseases, possibly caused by oxides of nitrogen or carbon monoxide generated when gas or paraffin is burnt.[51]

This study has some limitations inherent to cross-sectional epidemiological designs. Firstly, the study cannot provide any evidence of causality. Secondly, no quantitative air pollution exposure assessment was conducted. Thirdly, we relied on doctor-diagnosed respiratory diseases, which, although specific, can cause an underestimation of disease prevalence. Therefore it is assumed that several individuals with respiratory diseases were missed due to restrictive definitions employed in this study, as a result of poor access to health care facilities associated with black poor communities.[52] The possibility of estimating falsely low prevalence figures cannot be ignored. However, the observed high prevalence of respiratory diseases in exposed communities cannot only be attributed to a strict definition used, but to a complex interaction of social, economic, and behavioural factors such as air pollution, undernutrition, poor access to healthcare, or lifestyle behaviours.[53,54] Fourthly, the interviewer error might have occurred in the translation of the questions to the local language during the interview of some study participants who did not understand English. Fifthly, unwillingness of the respondents to provide honest answers or giving socially desirable responses should be taken into account in the interpretation of the results. Sixthly, no lung function tests and/ or spirometry, were conducted during the study. Lastly, the differential participation rate between exposed and unexposed communities is of concern and may well have introduced response bias, which is likely to overestimate or underestimate the prevalence estimates derived from our cross-sectional study and also bias the association in either direction.

An advantage of this study is that when 10% of the study participants were interviewed twice, with 96% repeatability observed.

5.6 Conclusion

The study findings suggest that there is a high prevalence chronic respiratory symptoms and diseases among the elderly in communities located near mine dumps. The significant risk factors are proximity to mine dump, smoking habits, low level of education and domestic use of gas or paraffin.

5.7 Acknowledgements

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5.8 Contributors

VN and KV participated in the design of the study, data collection, statistical analysis and interpretation of the results, drafted and critically revised the manuscript. JW participated in the statistical analysis and interpretation of the results, drafted and critically revised the manuscript. All authors have read and approved the final manuscript.

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5.10 Competing interest

None.

5.11 Abbreviations

CI: Confidence Intervals

MLRA: Multilevel Logistic Regression Analysis

AGA: Anglo Gold Ashanti

CGR: Crown Gold Recoveries

DRD: Durban Roodepoort Deep

ERPM: East Rand Proprietary Mines

Statistics South Africa (SSA)

National Research Fund – Deutscher Akademischer Austausch Dienst (NRF – DAAD)

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Supplementary table 5.4: Prevalence of chronic respiratory symptoms and diseases in relation to independent variables in all 11-study communities located 1 km – 2 km and ≥5 km from mine dumps in Gauteng and North West, South Africa during November-December 2012

	Chronic respiratory symptoms and diseases, *n (%)*					
	Asthma	**Chronic**	**Chronic cough**	**Emphysema**	**Pneumonia**	**Wheeze**
Sex						
Male	175 (7.3)	125 (5.2)	292 (12.2)	56 (2.3)	125 (5.2)	255 (10.6)
Female	194 (8.1)	143 (6.0)	268 (11.2)	58 (2.4)	143 (6.0)	288 (12.0)
Age (in years)						
55 – 59	10.1 (4.2)	75 (3.1)	153 (6.4)	27 (1.1)	102 (4.3)	149 (6.2)
60 – 64	98 (4.1)	58 (2.4)	141 (5.9)	25 (1.0)	104 (4.3)	147 (6.1)
65 – 69	61 (2.5)	36 (1.5)	97 (4.1)	24 (1.0)	56 (2.3)	74 (3.1)
70 – 84	97 (4.1)	86 (3.6)	148 (6.2)	37 (1.5)	106 (4.4)	148 (6.2)
85 and above	9 (0.4)	12 (0.5)	18 (0.8)	1 (0.04)	12 (0.5)	18 (0.8)
Occupational exposure history to dust/chemical fumes						
No	229 (9.6)	158 (6.6)	356 (14.9)	71 (3.0)	158 (6.6)	344 (14.4)
Yes	140 (5.8)	110 (4.6)	204 (8.5)	43 (1.8)	110 (4.6)	199 (8.3)
Level of education						
No schooling	7.5 (3.1)	44 (1.8)	110 (4.6)	26 (1.1)	80 (3.3)	81 (3.4)
Primary	153 (6.4)	82 (3.4)	220 (9.2)	44 (1.8)	131 (5.5)	155 (6.5)
Secondary	292 (12.2)	138 (5.8)	219 (9.1)	43 (1.8)	159 (6.6)	219 (9.1)
Tertiary	15 (0.6)	6 (0.3)	11 (0.5)	1 (00.4)	12 (0.5)	11 (0.5)

Supplementary Table 5.4						
Smoking habits						
Non-smoker	211 (8.8)	165 (6.9)	299 (12.5)	230 (9.6)	230 (9.6)	293 (12.2)
Ex-smoker	80 (3.3)	45 (1.9)	127 (5.3)	86 (3.6)	87 (3.6)	108 (4.5)
Current smoker	78 (3.3)	58 (2.4)	134 (5.6)	66 (2.8)	58 (2.4)	142 (5.9)
Main residential heating/cooking fuel type						
Electricity	335 (14.0)	242 (10.1)	522 (21.8)	108 (4.5)	344 (14.4)	509 (21.2)
Gas	20 (0.8)	13 (0.5)	20 (0.8)	3 (0.1)	19 (0.8)	17 (0.7)
Paraffin	8 (0.3)	4 (0.2)	13 (0.1)	2 (0.08)	10 (0.4)	10 (0.4)
Open fires	2 (0.08)	1 (0.04)	2 (0.08)	0 (0.0)	4 (0.2)	1 (0.04)

1:Reference category

Supplementary table 5.5: Crude odds ratios with 95 % confidence intervals of chronic respiratory symptoms and diseases in all 11-study communities located 1 km – 2 km and ≥5 km from mine dumps in Gauteng and North West, South Africa during November-December 2012

	Asthma[a]	Chronic bronchitis[b]	Chronic cough[c]	Emphysema[d]	Pneumonia[e]	Wheeze[f]
Sex						
Male	1	1	1	1	1	1
Female	1.02 (0.81 – 1.27)	1.06 (0.82 – 1.37)	**0.78 (0.63 – 0.95)**	0.95 (0.66 – 1.39)	0.93 (0.744 – 1.15)	0.86 (0.73 – 1.01)
Age (in years)						
55 – 59	1	1	1	1	1	1
60 – 64	1.14 (0.85 – 1.55)	0.88 (0.62 – 1.27)	0.98 (0.75 – 1.29)	1.08 (0.62 – 1.87)	1.22 (0.91 – 1.65)	0.97 (0.78 – 1.21)
65 – 69	1.29 (0.92 – 1.83)	0.98 (0.65 – 1.50)	1.34 (0.98 – 1.82)	**1.88 (1.07 – 3.31)**	1.16 (0.81 – 1.65)	0.99 (0.76 – 1.27)
70 – 84	1.23 (0.91 – 1.67)	**1.48 (1.07 – 2.07)**	1.30 (0.90 – 1.55)	**1.74 (1.05 – 2.89)**	**1.35 (1.01 – 1.82)**	0.86 (0.69 – 1.07)
85 and above	0.82 (0.39 – 1.71)	1.60 (0.82 – 3.09)	1.19 (0.66 – 2.14)	-	1.12 (0.59 – 2.15)	0.74 (0.46 – 1.21)
Population group						
Black	1	1	1	1	1	1
Coloured	**0.74 (0.57 – 0.96)**	**1.74 (1.34 – 2.26)**	**0.61 (0.49 – 0.77)**	0.78 (0.51 – 1.21)	1.15 (0.90 – 1.44)	**0.70 (0.55 – 0.84)**
Level of education						
No schooling	1	1	1	1	1	1
Primary	**1.46 (1.08 – 1.97)**	1.30 (0.88 – 1.91)	**1.36 (1.02 – 1.80)**	1.19 (0.72 – 1.96)	1.12 (0.83 – 1.52)	**1.43 (1.14 – 1.80)**
Secondary	0.84 (0.62 – 1.15)	**1.73 (1.21 – 2.48)**	0.87 (0.81 – 1.36)	0.86 (0.52 – 1.41)	0.99 (0.74 – 1.34)	**1.27 (1.02 – 1.57)**
Tertiary	0.99 (0.50 – 1.97)	0.97 (0.40 – 2.35)	0.60 (0.30 – 1.20)	0.26 (0.04 – 1.97)	1.03 (0.53 – 1.99)	1.41 (0.87 – 2.30)

Supplementary Table 5.5 continues						
Smoking habits						
Non-smoker	1	1	1	1	1	1
Ex-smoker	**1.39 (1.05 – 1.84)**	0.96 (0.68 – 1.36)	**1.47 (1.14 – 1.89)**	**2.07 (1.31 – 3.29)**	**1.38 (1.05 – 1.82)**	0.84 (0.68 – 1.05)
Current smoke	1.12 (0.85 – 1.49)	1.07 (0.78 – 1.48)	**1.43 (1.16 – 1.83)**	**1.83 (1.16 – 2.88)**	0.85 (0.63 – 1.14)	**1.34 (1.11 – 1.67)**
Occupational exposure history to dust/chemical fumes						
No	1	1	1	1	1	1
Yes	**1.39 (1.05 – 1.84)**	**1.52 (1.15 – 1.94)**	**1.21 (1.01 – 1.51)**	1.33 (0.85 – 1.85)	0.80 (0.67 – 1.07)	**1.35 (1.05 – 1.58)**
Main residential heating/cooking fuel type						
Electricity	1	1	1	1	1	1
Gas	1.41 (0.85 – 2.36)	1.21 (0.68 – 2.26)	0.80 (0.50 – 1.36)	0.6 (0.19 – 1.97)	1.31 (0.77 – 2.16)	0.68 (0.40 – 1.15)
Paraffin	2.01 (0.89 – 4.57)	1.24 (0.42 – 3.46)	**2.30 (1.13 – 4.78)**	1.3 (0.32 – 5.68)	**2.60 (1.19 – 5.49)**	1.62 (0.71 – 3.24)
Open fires	0.93 (0.21 – 4.15)	0.61 (0.81 – 4.79)	0.91 (0.24 – 3.16)	-	2.20 (0.67 – 6.89)	0.22 (0.03 – 1.89)

1:Reference category

Supplementary table 5.6: Adjusted odds ratios with 95 % confidence intervals of chronic respiratory symptoms and diseases in all 11-study communities located 1 km – 2 km and ≥5 km from mine dumps in Gauteng and North West, South Africa during November-December 2012

	Asthma[a]	Chronic bronchitis[b]	Chronic cough[c]	Emphysema[d]	Pneumonia[e]	Wheeze[f]
Sex						
Male	1	1	1	1	1	1
Female	1.13 (0.88 – 1.42)	1.08 (0.82 – 1.41)	0.87 (0.70 – 1.08)	1.07 (0.72 – 1.61)	0.87 (0.69 – 1.10)	0.97 (0.82 – 1.16)
Age (in years)						
55 – 59	1	1	1	1	1	1
60 – 64	1.14 (0.83 – 1.55)	0.93 (0.82 – 1.27)	0.95 (0.72 – 1.25)	1.04 (0.60 – 1.82)	1.23 (0.91 – 1.66)	1.04 (0.83 – 1.30)
65 – 69	1.28 (0.89 – 1.82)	1.06 (0.69 – 1.62)	1.33 (0.97 – 1.83)	**1.78 (1.07 – 3.16)**	1.15 (0.81 – 1.65)	1.05 (0.84 – 1.37)
70 – 84	1.30 (0.95 – 1.78)	**1.67 (1.17 – 2.36)**	**1.40 (1.05 – 1.86)**	**1.81 (1.08 – 3.08)**	**1.36 (1.01 – 1.85)**	1.08 (0.85 – 1.34)
85 and above	0.73 (0.33 – 1.59)	1.89 (0.96 – 3.77)	1.38 (0.74 – 2.54)	-	1.07 (0.54 – 1.51)	0.79 (0.47 – 1.33)
Population group						
Black	1	1	1	1	1	1
Coloured	0.77 (0.58 – 1.03)	**1.47 (1.09 – 1.97)**	**0.55 (0.42 – 0.71)**	0.76 (0.46 – 1.23)	1.16 (0.89 – 1.51)	**0.54 (0.44 – 0.66)**
Level of education						
No schooling	1	1	1	1	1	1
Primary	**1.50 (1.09 – 2.06)**	1.29 (0.87 – 1.93)	1.25 (0.93 – 1.67)	1.10 (0.66 – 1.83)	1.04 (0.75 – 1.42)	**1.53 (1.20 – 1.95)**
Secondary	0.90 (0.64 – 1.27)	**1.45 (1.01 – 2.22)**	1.03 (0.75 – 1.39)	0.83 (0.48 – 1.45)	0.86 (0.61 – 1.19)	**1.54 (1.20 – 1.98)**
Tertiary	1.02 (0.51 – 2.08)	0.93 (0.37 – 2.32)	0.54 (0.26 – 1.11)	0.26 (0.03 – 1.99)	0.87 (0.44 – 1.74)	1.28 (0.77 – 2.15)

Supplementary Table 5.6 continues						
Smoking habits						
Non-smoker	1	1	1	1	1	1
Ex-smoker	**1.40 (1.04 – 1.89**)	0.98 (0.68 – 1.42)	**1.54 (1.16 – 1.99)**	**2.00 (1.24 – 3.24)**	**1.31 (1.04 – 1.82)**	0.93 (0.74 – 1.18)
Current smoke	1.04 (0.77 – 1.42)	0.97 (0.69 – 1.39)	**1.30 (1.01 – 1.71)**	**1.57 (1.15 – 2.59)**	0.82 (0.59 – 1.12)	**1.31 (1.05 – 1.65)**
Occupational exposure history to dust/chemical fumes						
No	1	1	1	1	1	1
Yes	1.22 (0.94 – 1.57)	**1.43 (1.07 – 1.91)**	0.93 (0.73 – 1.18)	1.02 (0.66 – 1.57)	0.80 (0.61 – 1.04)	0.94 (0.77 – 1.14)
Main residential heating/cooking fuel type						
Electricity	1	1	1	1	1	1
Gas	1.65 (0.97 – 2.79)	1.69 (0.91 – 3.16)	0.76 (0.45 – 1.29)	0.71 (0.21 – 1.57)	1.35 (0.79 – 2.29)	0.57 (0.35 – 1.14)
Paraffin	1.81 (0.79 – 4.18)	1.19 (0.41 – 3.48)	**2.03 (1.13 – 4.78)**	1.19 (0.27 – 5.12)	**2.40 (1.11 – 5.17)**	0.86 (0.41 – 1.79)
Open fires	1.06 (0.23 – 4.83)	1.29 (0.61 – 4.79)	0.94 (0.25 – 3.53)	-	2.18 (0.67 – 7.13)	0.14 (0.02 – 1.12)

1:Reference category

6. Chapter 6: Comorbidity of respiratory and cardiovascular diseases among the elderly residing close to mine dumps in South Africa: A cross-sectional study

6.1 Abstract

Background: Pollution arising from mine dumps in South Africa has been a source of concern to nearby communities.

Objective: To investigate whether comorbidity of respiratory and cardiovascular diseases among elderly persons (≥55 years) was associated with proximity to mine dumps.

Methods: Elderly persons in communities 1 – 2 km (exposed) and ≥ 5 km (unexposed) from five pre-selected mine dumps in Gauteng and North West in SA were included in a cross-sectional study.

Results: Exposed elderly persons had a significantly higher prevalence of cardiovascular and respiratory diseases than those who were unexposed. Multiple logistic regression analysis indicated that living close to mine dumps was significantly associated with asthma + hypertension (odds ratio (OR) 1.67; 95% confidence interval (CI) 1.22 – 2.28), asthma + pneumonia (OR 1.86; 95% CI 1.14 – 3.04), emphysema + arrhythmia (OR 1.38; 95% CI 1.07 – 1.77), emphysema + myocardial infarction (OR 2.01; 95% CI 1.73 – 2.54), emphysema + pneumonia (OR 3.36; 95% CI 1.41 – 7.98), hypertension + myocardial infarction (OR 1.60; 95% CI 1.04 – 2.44) and hypertension + pneumonia (OR 1.34; 95% CI 1.05 – 1.93).

Conclusion: Detrimental associations between comorbidity of the health outcomes and proximity to mine dumps were observed among the elderly in SA.

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6.2 Introduction

Pollution arising from mine dumps that serve as depositories for waste materials produced during gold mining processes, has been a source of concern to communities located in close proximity in South Africa (SA). [1,2] The crushed sand-like refuse material is generated during extraction and milling of ground ore during the mining process.[(3,4)] The material contains a complex mixture of heavy metals and trace elements such as gold, copper, lead, zinc, arsenic, cadmium and selenium.[2,3,5] Mine dumps are generally located in low-lying areas near mining sites, and dust particles or particulate matter are transported to nearby communities by air or by soil and water contamination.[3] The major routes of entry to the body upon exposure include contact with skin or eyes, inhalation and ingestion. Exposed communities tend to be historically marginalised ethnic groups of low socio-economic status and living in government-funded houses, informal settlements and retirement homes,[6] and are often elderly persons and children.[2,7,8] Moreover, some of the exposed communities also live near highways where there is heavy traffic flow and industries, so are exposed to the effects of ambient particulate matter air pollution, resulting in an increased risk of developing respiratory and cardiovascular diseases.[9–14] Elderly people are potentially highly susceptible to the effects of ambient air pollution as a result of normal and pathological ageing.[15] An increased prevalence of respiratory disease was observed in people living near mining sites in both South Africa and Portugal, compared with a control group living further away. [7,8,16]

No studies have investigated whether exposure to mine dust or living in close proximity to mine dumps poses an increased risk for comorbidity of respiratory and cardiovascular diseases among elderly people, and none have investigated the effects between combinations of various air pollution sources, including mine dust. Comorbidity was defined in the present study as having more than one respiratory or cardiovascular disease. One possible reason for the overlap between these two diseases is that they share the same risk factors, which may cause or exacerbate respiratory or cardiovascular diseases in vulnerable individuals. [17]

This study is part of a larger project initiated by the Mine Health Safety Council of South Africa (MHSC) around communities located near mine dumps in Gauteng and North West. No studies have investigated the association between potential risk factors and the comorbidity of respiratory and cardiovascular diseases among elderly people living near mine dumps in SA.

6.3 Objectives

To investigate whether comorbidity of respiratory and cardiovascular diseases among the elderly was associated with proximity to mine dumps. Effect modification between proximity to mine dumps and other air pollution sources was also investigated, e.g. the type of fuel used for cooking/heating in the home, tobacco smoking, and a history of occupational exposure to dust or chemical fumes.

6.4 Methods

The study methods have been described in detail elsewhere and a summary of the methods has been provided.[7] Ethical approval (ref. no. 235/2011) was obtained from the Research Ethics Committee, Faculty of Health Sciences, University of Pretoria. Verbal and written consent was obtained from the participants before commencement of interviews.

6.4.1 Population and study design

A cross-sectional study of 2 397 elderly (≥55 years) people from communities living 1 – 2 km (exposed) and ≥5 km (unexposed) from five pre-selected mine dumps in Gauteng and North West was conducted during November and December 2012. Table 6.1 lists the selected communities, and Table 6.2 the population size of the elderly people and the targeted sample size in each community under study.

Table 6.1: Eleven communities selected in the study located in Gauteng and North West, SA during November – December 2012

Mine dump facility	Province	Exposed	Unexposed
Durban Roodepoort Deep	Gauteng	Braamfischerville	Dobsonville
Crown Gold Recoveries	Gauteng	Diepkloof, Riverlea and	Orlando East
East Rand Proprietary Mines	Gauteng	Reiger Park	Windmill Park
Ergo	Gauteng	Geluksdal	Windmill Park
Anglo Gold Ashanti	North	Stilfontein	Jouberton

Exposed = communities located 1 – 2 km from mine dumps; Unexposed = communities located ≥5 km from mine dumps.

Table 6.2: Population sizes of elderly (≥55 years) people in the 11 communities under study

Location	**Population size (*N*)**	**Sample size (*n*)**
Geluksdal	430	197
Windmill Park	371	184
Reiger Park	155	109
Diepkloof	10 789	351
Dobsonville	4 629	337
Noordgesig	668	235
Orlando East	5 702	334
Jouberton	8 202	348
Stilfontein	2 974	324
Riverlea	1709	299
Braamfischerville	10 789	351

The mine dumps were selected before the study by the MHSC because of large population densities around these dumps. Eleven communities were included in the study. A previously validated ATS-DLD-78 questionnaire from the British Medical Research Council was used for face-to-face interviews.[18] The study focused on elderly people who had been living in the study communities for ≥5 years. A ‘knock-on-the-door’ approach was used to recruit study participants. In each community, streets were randomly selected and then four to five houses were randomly selected in each street. The sample size of each community was calculated using Epi Info version 7, with a total sample size of 3 069. Population sizes were based on the 2001 census from Statistics South Africa, because the results of census 2011 were not released when the study commenced.

6.4.2 Questionnaire administration

Twenty-two locally trained fieldworkers were employed, with two assigned to each community. Each fieldworker received thorough training in conducting the interviews using the respiratory health questionnaire before the start of the survey. The interviews were mainly in English and were translated into the local language if the respondent did not understand the questions. The questionnaire included sections on demography, medical history, type of fuel use for residential cooking/heating, tobacco smoking habits, and history of occupational exposure to dust or chemical fumes. The outcomes of interest, e.g. arrhythmia, asthma, emphysema, hypertension, myocardial infarction and pneumonia, were based on positive answers indicating diagnosis of the conditions by a doctor. The main exposure factor of interest in this study was the distance between the study population and the mine dump. For quality control of the interviews, fieldworkers randomly selected 10% of the homes and re-administered the same questionnaire to the same previously interviewed respondents to verify their responses. This verification was done 15 – 20 days after the first interview. Within the interviews, a >10% deviation was deemed unacceptable.

6.4.3 Statistical analysis

Two technicians entered the collected questionnaire data into a database set up in Epi Info version 3.5.3. Data were analysed using Stata version 12. Prevalence of the health outcome, the proportion of air pollution sources under investigation, and confounding variables were calculated by dividing the number of participants who responded affirmatively by the number of questionnaires completed. Each question therefore had a different sample size. Observations marked as 'do not know', 'not stated' or 'other

responses' were set as missing, but were included in the descriptive analyses. Only two explanatory variables, age and main type of fuel used for heating and cooking in the home, had missing observations. Responses to the number of cigarettes smoked per day were very low and were not included in the analysis. Pearson's χ^2 test was applied to determine the relationship between community (exposed/unexposed) and confounding variables. Using univariate and multiple logistic regression analysis (LRA) to estimate the likelihood of having asthma, chronic bronchitis, chronic cough, emphysema, pneumonia and wheeze, crude and adjusted odds ratios (Ors) and 95% confidence intervals (Cis) were calculated. Missing values were automatically excluded in each LRA model, so each multiple LRA model had a different sample size. To obtain adjusted Ors for the effect of 'community (exposed/unexposed)', outcomes were placed in an initial LRA model. This was followed by the addition of a potential confounder in a stepwise manner, starting with the most statistically significant from the univariate analysis. Each time a new potential confounder was added to the model, if the effect estimate between the exposure of interest and comorbidity outcome already in the models changed by more than 5.0%, the additional variable was retained in the final multiple LRA; otherwise, the variable was removed and a different one was added.[19] The most parsimonious multiple LRA models were reported, i.e. those with variables having a *p*-value of <0.05.[20] Community (exposed/unexposed) was considered as the main exposure factor and was therefore included in all models for each outcome of interest, regardless of whether it was statistically significant in the univariate analyses.
Effect modification between community (exposed/unexposed) and other air pollution source variables (smoking habits, occupational exposure history to dust/chemical fumes, and residential cooking/heating fuel type) was investigated by including a multiplicative term in the model.

6.5 Results

6.5.1 Demographic characteristics and air pollution variables by type of community

Detailed demographic characteristics of the respondents and air pollution variables by community type have been published previously (Table 6.3).[6] There were 1 499 study participants from exposed and 898 from unexposed communities.

Table 6.3: Demographic characteristics and air pollution variables by type of community in Gauteng and North West, South Africa during November-December 2012

	Community		
	Exposed[a] (n = 1499)	**Unexposed[b] (n = 898)**	**p-value[c]**
Sex			
Female	774 (51.6)	472 (52.3)	
Male	725 (48.4)	426 (47.4)	0.66
Age (years)			
55-59	500 (33.4)	225 (25.1)	
60-64	405 (27.0)	221 (24.6)	
65-69	228 (15.2)	125 (13.9)	<0.001
70-84	309 (20.6)	278 (31.0)	
≥85	48 (3.2)	29 (3.2)	
Information missing	9 (0.6)	20 (2.2)	
Population group			
Black	1006 (41.9)	695 (29.0)	
Coloured	493 (20.6)	203 (8.5)	< 0.001
Level of education			
No schooling	262 (17.5)	271 (30.2)	
Primary	479 (32.0)	287 (32.0)	
Secondary	691 (46.1)	332 (37.0)	<0.001
Tertiary	67 (4.5)	8 (0.8)	

Table 6.3 continues

Smoking habits			
Non-smoker	888 (59.2)	598 (66.6)	
Ex-smoker	234 (15.6)	187 (20.8)	
Current smoker	377 (25.2)	113 (12.6)	<0.001
History of occupational exposure to dust/chemical fumes			
Yes	637 (42.5)	149 (16.6)	
No	862 (57.5)	749 (83.4)	<0.001
Main heating/cooking fuel type			
Electricity	1422 (94.9)	783 (87.2)	
Gas	31 (2.1)	67 (7.5)	<0.001
Paraffin	25 (1.7)	6 (0.7)	
Open fires	1 (0.07)	13 (1.5)	
Missing	20 (1.3)	29 (3.2)	

Figures in parentheses are percentages.
[a]Exposed: communities located 1 km – 2 km from mine dumps.
[b]Unexposed: communities located 5 km or more from mine dumps.
[c]p-values of the Chi-square test

6.5.2 Prevalence of comorbidity stratified by type of community

The prevalences of asthma + emphysema (1.7%), asthma + hypertension (12.6%), asthma + pneumonia (5.0%), emphysema + myocardial infarction (0.8%), emphysema + pneumonia (2.5%), hypertension + myocardial infarction (6.5%), hypertension + pneumonia (11.9%) and pneumonia + arrthymia (1.9%) in the exposed communities were higher than those in the unexposed communities, where the percentages were 1.1%, 8.0%, 4.3%, 0.7%, 0.8%, 4.1%, 8.9% and 1.8%, respectively (Table 6.4).

Table 6.4: Prevalence of comorbidity by type of community in Gauteng and North West, South Africa, during November – December 2012

	Community		
	Exposed ***n* (%)**	**Unexposed** ***n* (%)**	**Total** ***n* (%)**
Asthma + arrhythmia			
Yes	66 (4.4)	44 (4.9)	110 (4.6)
No	1 432 (95.5)	836 (93.1)	2 268 (94.6)
Missing information	1 (0.1)	18 (2.0)	19 (0.8)
Total	1 499 (62.5)	898 (37.5)	2 397 (100.0)
Asthma + emphysema			
Yes	26 (1.7)	10 (1.1)	36 (1.5)
No	1 473 (98.3)	888 (98.9)	2 361 (98.5)
Missing information	-	-	-
Total	1 499 (62.5)	898 (37.5)	2 397 (100.0)
Asthma + hypertension			
Yes	189 (12.6)	72 (8.0)	261 (10.9)
No	1 292 (86.19)	797 (88.6)	2 089 (87.1)
Missing information	18 (1.2)	29 (3.2)	47 (2.0)
Total	1 499 (64.1)	898 (37.5)	2 397 (100.0)
Asthma + pneumonia			
Yes	75 (5.0)	28 (3.1)	103 (4.3)
No	1 421 (94.8)	853 (95.0)	2 274 (94.9)
Missing information	3 (0.2)	17 (1.9)	20 (0.8)
Total	1 499 (64.1)	898 (37.5)	2 397 (100.0)
Emphysema + arrhythmia			
Yes	31 (2.1)	20 (2.2)	51 (2.1)
No	1 468 (97.9)	878 (97.8)	2 346 (97.9)
Missing information	-	-	-
Total	1 499 (64.1)	898 (37.5)	2 397 (100.0)
Emphysema + myocardial infarction			
Yes	12 (0.8)	7 (0.7)	19 (0.8)
No	1 487 (99.2)	891 (99.3)	2 378 (99.2)
Missing information	-	-	-
Total	1 499 (64.1)	898 (37.5)	2 397 (100.0)
Emphysema + pneumonia			
Yes	38 (2.5)	7 (0.8)	45 (1.9)
No	1 461 (97.46)	891 (99.2)	2 352 (98.1)
Missing information	-	-	-
Total	1 499 (64.1)	898 (37.5)	2 397 (100.0)
Hypertension + myocardial infarction			
Yes	98 (6.5)	37 (4.1)	135 (5.6)
No	1 394 (93.0)	839 (93.4)	2 233 (93.2)
Missing information	7 (0.5)	22 (2.5)	29 (1.2)
Total	1 499 (64.1)	898 (37.5)	2 397 (100.0)

Table 6.4 continues			
Hypertension + pneumonia			
Yes	178 (11.9)	80 (8.9)	258 (10.8)
No	792 (88.2)	1 311 (87.5)	2 103 (87.7)
Missing information	10 (2.9)	26 (2.9)	36 (1.5)
Total	1 499 (64.1)	898 (37.5)	2 397 (100.0)
Pneumonia + arrhythmia			
Yes	74 (4.9)	52 (5.8)	126 (5.2)
No	1 422 (94.9)	831 (92.5)	2 253 (94.0)
Missing information	3 (0.2)	15 (1.7)	18 (0.8)
Total	1 499 (64.1)	898 (37.5)	2 397 (100.0)
Pneumonia + myocardial infarction			
Yes	29 (1.9)	1.7 (1.8)	46 (1.9)
No	1 470 (98.1)	867 (96.7)	2 337 (97.5)
Missing information	-	14 (1.5)	14 (0.6)
Total	1 499 (64.1)	898 (37.5)	2 397 (100.0)

Exposed = communities located 1 - 2 km from mine dumps; Unexposed = communities located ≥5 km from mine dumps.

6.5.3 Multivariate analyses of comorbidity in all 11 study communities

Crude and adjusted ORs for all risk factors except for the main exposure factor are shown in Tables 6.5 and 6.6.

Table 6.5: Crude ORs with 95% CIs of risk factors for chronic respiratory and cardiovascular diseases in all 11 study communities located 1 - 2 km and ≥5 km* from mine dumps in Gauteng and North West, SA, during November - December 2012

Risk factors†	Asthma + arrhythmia	Asthma + emphysema	Asthma + hyper-tension	Asthma + pneumonia	Emphysema + arrhythmia	Emphysema + myocardial infarction	Emphysema + pneumonia	Hypertension + myocardial infarction	Hypertension + pneumonia	Pneumonia + arrhythmia	Pneumonia + myocardial infarction
Gender											
Male	1	1	1	1	1	1	1	1	1	1	1
Female	0.98 (0.67 - 1.44)	1.16 (0.60 - 2.24)	1.19 (0.92 - 1.55)	1.40 (0.94 - 2.09)	1.57 (0.89 - 2.79)	1.59 (0.62 - 4.05)	1.06 (0.59 - 1.91)	1.05 (0.74 -1.49)	1.19 (0.92 - 1.55)	0.97 (0.67 - 1.39)	0.63 (0.35 – 1.15)
Age (years)											
55 - 59	1	1	1	1	1	1	1	1	1	1	1
60 - 64	0.75 (0.43 - 1.32)	0.77 (0.27 - 2.18)	1.26 (0.87 - 1.81)	0.82 (0.45 - 1.48)	0.96 (0.41 - 2.25)	0.29 (0.03 - 2.59)	0.52 (0.18 - 1.51)	0.81 (0.48 - 1.39)	1.26 (0.87 - 1.81)	1.09 (0.66 - 1.81)	0.77 (0.27 - 2.18)
65 - 69	1.10 (0.60 - 2.00)	2.08 (0.82 - 5.29)	**1.69 (1.13 - 2.52)**	1.42 (0.78 - 2.58)	1.55 (0.65 - 3.72)	2.07 (0.51 - 8.31)	1.70 (0.69 - 4.14)	1.03 (0.57 - 1.87)	**1.69 (1.13 - 2.52)**	1.10 (0.60 - 2.00)	1.61 (0.59 - 4.36)
70 - 84	1.29 (0.78 - 2.13)	1.66 (0.69 - 3.97)	**1.57 (1.10 - 2.24)**	1.49 (0.89 - 2.49)	**2.09 (1.02 - 4.32)**	3.12 (0.97 - 10.01)	**2.17 (1.02 - 4.59)**	**2.02 (1.29 - 3.14)**	**1.57 (1.10 - 2.24)**	**1.68 (1.04 - 2.69)**	**3.10 (1.41 - 6.78)**
≥85	1.83 (0.73 - 4.52)	-	1.26 (0.58 - 2.74)	0.66 (0.16 - 2.84)	-	-	-	1.73 (0.70 - 4.27)	1.26 (0.58 - 2.74)	1.50 (0.57 - 3.98)	2.12 (0.45 - 10.00)
Population group											
Black	1	1	1	1	1	1	1	1	1	1	1
Coloured	0.72 (0.46 - 1.13)	1.21 (0.61 - 2.43)	0.76 (0.57 - 1.03)	1.12 (0.74 - 1.72)	1.22 (0.68 - 2.18)	1.12 (0.42 - 2.94)	1.47 (0.81 - 2.70)	0.86 (0.58 - 1.27)	0.76 (0.57 - 1.03)	0.96 (0.64 - 1.42)	1.46 (0.80 - 2.65)
Level of education											
No schooling	1	1	1	1	1	1	1	1	1	1	1
Primary	1.06 (0.63 - 1.76)	1.50 (0.60 - 3.71)	**1.44 (1.02 - 2.03)**	1.62 (0.94 - 2.77)	1.10 (0.53 - 2.29)	2.80 (0.59 - 13.24)	0.93 (0.43 - 1.97)	0.67 (0.41 - 1.07)	**1.44 (1.02 - 2.13)**	1.27 (0.74 - 2.17)	0.78 (0.37 - 1.65)
Secondary	0.86 (0.52 - 1.43)	0.97 (0.38 - 2.44)	0.76 (0.53 - 1.09)	0.83 (0.47 - 1.44)	0.86 (0.42 - 1.78)	2.36 (0.51 - 10.94)	0.69 (0.32 - 1.47)	0.80 (0.52 - 1.23)	0.76 (0.53 - 1.09)	1.35 (0.81 - 2.24)	0.66 (0.31 -1.36)
Tertiary	0.82 (0.24 - 2.78)	1.01 (0.12 - 8.37)	0.86 (0.38 - 1.96)	1.03 (0.29 - 3.56)	-	-	0.58 (0.08 - 4.56)	1.17 (0.47 - 2.87)	0.86 (0.38 - 1.96)	1.61 (0.59 - 4.38)	0.52 (0.06 - 4.08)
Smoking habits											
Non-smoker	1	1	1	1	1	1	1	1	1	1	1
Ex-smoker	**1.70 (1.05 - 2.72)**	**2.23 (1.01 - 4.96)**	1.32 (0.96 - 1.83)	0.91 (0.53 - 1.57)	**3.45 (1.79 - 6.63)**	**4.17 (1.39 - 12.45)**	**2.97 (1.45 - 6.08)**	1.23 (0.77 - 1.96)	1.32 (0.96 - 1.83)	1.50 (0.96 - 2.36)	1.56 (0.68 - 3.62)
Current smoker	1.39 (0.86 - 2.24)	1.91 (0.86 - 4.25)	0.96 (0.69 - 1.34)	0.97 (0.56 - 1.60)	**2.27 (1.13 - 4.56)**	3.05 (0.98 - 9.52)	**2.54 (1.24 - 5.19)**	**1.64 (1.09 - 2.46)**	0.96 (0.69 - 1.34)	1.42 (0.92 - 2.20)	**3.43 (1.80 - 6.55)**

History of occupational exposure to dust/chemical fumes											
No	1	1	1	1	1	1	1	1	1	1	1
Yes	1.31 (0.88 - 1.94)	1.02 (0.51 - 2.06)	**1.44 (1.11 - 1.88)**	0.94 (0.61 - 1.44)	1.57 (0.89 - 2.75)	1.50 (0.60 - 3.73)	1.25 (0.68 - 2.30)	**1.67 (1.17 - 2.37)**	**1.44 (1.11 - 1.88)**	1.13 (0.77 - 1.64)	**2.12 (1.18 - 3.80)**
Main type of fuel used for heating/ cooking in the home											
Electricity	1	1	1	1	1	1	1	1	1	1	1
Gas	1.63 (0.74 - 3.61)	-	1.04 (0.55 - 1.98)	2.09 (0.98 - 4.43)	0.94 (0.22 - 3.91)	-	0.53 (0.07 - 3.90)	1.06 (0.46 - 2.49)	1.04 (0.55 - 1.98)	0.97 (0.39 - 2.43)	1.10 (0.26 - 4.61)
Paraffin	0.71 (0.09 - 5.24)	2.13 (0.28 -16.06)	**2.35 (1.00 - 5.51)**	1.68 (0.39 - 7.15)	-	-	1.72 (0.23 -12.88)	1.13 (0.27 - 4.79)	**2.35 (1.01 - 5.51)**	1.23 (0.29 - 5.21)	3.64 (0.84 - 15.76)
Open fires	-	-	-	1.81 (0.23 - 13.96)	-	-	-	-	-	-	-

*Communities located ≥5 km (unexposed) from mine dumps used as reference category.
†Models adjusted for gender, age, population group, smoking habits, level of education, occupational exposure history to dust/chemical fumes and main type of fuel used for heating/cooking in the home.

Table 6.6: Adjusted ORs with 95% CIs of risk factors for chronic respiratory and cardiovascular diseases in all 11 study communities located 1 - 2 km and ≥ 5 km* from mine dumps in Gauteng and North West, SA, during November - December 2012

Risk factors†	Asthma + arrhythmia	Asthma + emphysema	Asthma + hyper-tension	Asthma + pneumonia	Emphysema + arrhythmia	Emphysema + myocardial infarction	Emphysema + pneumonia	Hyper-tension + myocardial infarction	Hyper-tension + pneumonia	Pneumonia + arrhythmia	Pneumonia + myocardial infarction
Gender											
Male	1	1	1	1	1	1	1	1	1	1	1
Female	1.13 (0.75 - 1.70)	1.30 (0.63 - 2.63)	1.29 (0.98 - 1.70)	1.34 (0.87 - 2.06)	2.02 (0.97 - 3.72)	2.27 (0.83 - 6.27)	1.13 (0.59 - 2.13)	1.18 (0.81 - 1.71)	1.06 (0.81 - 1.40)	1.04 (0.71 - 1.54)	0.77 (0.41 - 1.48)
Age (years)											
55 - 59	1	1	1	1	1	1	1	1	1	1	1
60 - 64	0.75 (0.43 - 1.32)	0.76 (0.21 - 2.60)	1.22 (0.84 - 1.77)	0.81 (0.45 - 1.47)	0.90 (0.38 - 2.12)	0.28 (0.03 - 2.53)	0.51 (0.18 - 1.49)	0.83 (0.71 - 1.51)	1.03 (0.71 - 1.51)	1.11 (0.66 - 1.85)	0.75 (0.26 - 2.14)
65 - 69	1.10 (0.60 - 2.03)	2.00 (0.77 - 5.10)	1.61 (1.07 - 2.41)#	1.34 (0.73 - 2.45)	1.47 (0.61 - 3.57)	2.13 (0.52 - 8.70)	1.61 (0.65 - 3.95)	1.08 (0.59 - 1.98)	1.33 (0.88 - 2.02)	1.11 (0.61 - 2.04)	1.54 (0.56 - 4.23)
70 - 84	1.29 (0.77 - 2.17)	1.62 (0.65 - 4.01)	1.61 (1.11 - 2.32)#	1.41 (0.82 - 2.40)	1.91 (0.90 - 4.05)	3.29 (0.97 - 11.12)	2.20 (1.01 - 4.81)#	2.31 (1.45 - 3.69)#	1.82 (1.28 - 2.60)#	1.73 (1.06 - 2.04)#	2.99 (1.32 - 6.74)#
≥85	1.72 (0.63 - 4.67)	-	1.01 (0.43 - 2.32)	0.27 (0.03 - 2.01)	-	-	-	2.09 (0.83 - 5.29)	1.23 (0.56 - 2.71)	1.48 (0.50 - 4.39)	2.55 (0.52 - 12.54)
Population group											
Black	1	1	1	1	1	1	1	1	1	1	1
Coloured	0.60 (0.36 - 1.10)	1.17 (0.53 - 2.57)	0.82 (0.59 - 1.13)	1.29 (0.80 - 2.09)	1.21 (0.90 - 4.05)	0.69 (0.21 - 2.18)	1.48 (0.74 - 2.93)	0.7 (0.46 - 1.09)	0.98 (0.72 - 1.34)	0.79 (0.50 - 4.39)	1.57 (0.78 - 3.13)
Level of education											
No schooling	1	1	1	1	1	1	1	1	1	1	1
Primary	1.18 (0.69 - 1.99)	1.33 (0.53 - 2.57)	1.49 (1.04 - 2.12)#	1.57 (0.90 - 2.73)	1.23 (0.58 - 2.62)	3.41 (0.70 - 16.56)	0.80 (0.36 - 1.75)	0.75 (0.45 - 1.23)	1.31 (0.90 - 1.89)	1.37 (0.80 - 2.35)	0.88 (0.40 - 1.91)
Secondary	1.07 (0.61 - 1.87)	0.75 (0.27 - 2.09)	0.80 (0.54 - 1.19)	0.65 (0.35 - 1.23)	0.87 (0.38 - 1.95)	2.93 (0.57 - 15.21)	0.46 (0.19 - 1.10)	1.04 (0.64 - 1.70)	0.98 (0.66 - 1.45)	1.61 (0.93 - 2.77)	0.71 (0.31 - 1.62)
Tertiary	1.18 (0.33 - 4.13)	0.96 (0.11 - 8.43)	0.92 (0.39 - 2.16)	0.83 (0.23 - 3.00)	-	-	0.45 (0.05 - 3.85)	1.58 (0.61 - 4.05)	1.26 (0.57 - 2.75)	2.22 (0.79 - 6.27)	0.79 (0.09 - 6.64)
Smoking habits											
Non-smoker	1	1	1	1	1	1	1	1	1	1	1
Ex-smoker	1.74 (1.06 - 2.88)#	2.02 (1.01 - 4.71)#	1.32 (0.94 - 1.87)	0.83 (0.46 - 1.50)	3.50 (1.77 - 6.89)#	4.24 (1.32 - [illegible])#	2.77 (1.30 - 5.88)#	1.25 (1.01 - 2.46)#	1.21 (0.85 - 1.71)	1.43 (0.88 - 2.31)	1.27 (0.52 - 3.11)
Current smoker	1.51 (0.89 - 2.55)	1.83 (0.77 - 4.37)	0.87 (0.61 - 1.26)	0.83 (0.59 - 1.78)	2.37 (1.11 - 5.07)#	4.03 (1.16 - 14.06)#	1.92 (0.87 - 4.24)	1.57 (0.97 - 2.11)	0.91 (0.64 - 1.32)	1.52 (0.94 - 2.46)	2.89 (1.40 - 5.98)#

Table 6.6 continues

History of occup-ational exposure to dust/ chemical fumes											
No	1	1	1	1	1	1	1	1	1	1	1
Yes	1.31 (0.84 - 2.04)	0.89 (0.42 - 1.92)	1.31 (1.01 - 1.76)[#]	0.80 (0.50 - 1.29)	1.71 (0.91 - 3.23)	1.66 (0.60 - 4.60)	0.91 (0.46 - 1.79)	1.43 (0.97 - 2.86)	0.94 (0.69 - 1.27)	1.16 (0.76 - 1.77)	1.81 (0.92 - 3.58)
Main type of fuel used for heating/ cooking in the home											
Electricity	1	1	1	1	1	1	1	1	1	1	1
Gas	1.54 (0.67 - 3.50)	-	1.16 (0.55 - 2.25)	2.38 (1.08 - 5.23)[#]	0.96 (0.22 - 4.20)	-	0.70 (0.09 - 5.33)	1.02 (0.50 - 2.86)	1.11 (0.57 - 2.14)	0.99 (0.39 - 2.54)	1.14 (0.26 - 4.97)
Paraffin	0.74 (0.09 - 5.55)	1.92 (0.25 - 14.77)	2.18 (0.91 - 5.22)	1.57 (0.36 - 5.23)	-	-	1.53 (0.20 -11.89)	1.16 (0.27 - 5.07)	2.82 (1.23 - 6.43)[#]	1.32 (0.31 - 5.63)	3.81 (0.84 - 17.51)
pen fires	-	-	-	2.37 (0.30 - 19.25)	-	-	-	-	-	-	-

*Communities located ≥5 km (unexposed) from mine dumps used as reference category.
[†]Models adjusted for gender, age, population group, smoking habits, level of education, occupational exposure history to dust/chemical fumes and main type of fuel used for heating/cooking in the home.

Results from the multiple LRA (Table 6.9) indicated that living in the exposed communities was significantly associated with asthma + hypertension (OR 1.67; 95% CI 1.22 - 2.28), asthma + pneumonia (OR 1.86, 95% CI 1.14 - 3.04), emphysema + arrhythmia (OR 1.38, 95% CI 1.07 - 1.77), emphysema + myocardial infarction (OR 2.01; 95% CI 1.73 - 2.54), emphysema + pneumonia (OR 3.36; 95% CI 1.41 - 7.98), hypertension + myocardial infarction (OR 1.60; 95% CI 1.04 - 2.44) and hypertension + pneumonia (OR 1.34; 95% CI 1.05 - 1.93).

Table 6.7: Univariate and multivariate analyses of respiratory and cardiovascular diseases comorbidity in all 11 study communities located 1 - 2 km and ≥5 km* from mine dumps in Gauteng and North West, SA, during November - December 2012

Respiratory and cardiovascular diseases†	Crude OR (95% CI)	*p*-value	Adjusted OR (95% CI)	*p*-value
Asthma + arrhythmia	0.88 (0.59 - 1.29)	0.506	0.82 (0.53 - 1.27)	0.373
Asthma + emphysema	1.57 (0.75 - 3.27)	0.230	1.41 (0.64 - 3.10)	0.390
Asthma + hypertension	**1.77 (1.43 - 2.20)**	<0.001	**1.67 (1.22 - 2.28)**	0.001
Asthma + pneumonia	**1.72 (1.12 - 2.63)**	0.013	**1.86 (1.14 - 3.04)**	0.016
Emphysema + arrhythmia	**1.25 (1.01 - 1.58)**	0.018	**1.38 (1.07 - 1.77)**	0.014
Emphysema + myocardial infarction	**1.96 (1.65 - 2.32)**	<0.001	**2.01 (1.73 - 2.54)**	<0.001
Emphysema + pneumonia	**3.31 (1.47 - 7.45)**	0.004	**3.36 (1.41 - 7.98)**	0.006
Hypertension + myocardial infarction	**1.59 (1.08 - 2.34)**	0.018	**1.60 (1.04 - 2.44)**	0.033
Hypertension + pneumonia	**1.34 (1.01 - 1.78)**	0.037	**1.43 (1.05 - 1.93)**	0.022
Pneumonia + arrhythmia	0.83 (0.58 - 1.19)	0.322	0.73 (0.48 - 1.09)	0.130
Pneumonia + myocardial infarction	1.01 (0.55 - 1.84)	0.984	0.77 (0.39 - 1.50)	0.441

*Communities located ≥5 km (unexposed) from mine dumps used as reference category.
†Models adjusted for gender, age, population group, smoking habits, level of education, occupational exposure history to dust/chemical fumes and main type of fuel used for heating/cooking in the home.

Population group was not associated with any of the health outcomes considered in this study. The study participants in the age groups 65 - 69 and 70 - 84 years were at an increased likelihood (61.0%) of having asthma + hypertension. Female participants were at an increased risk of having emphysema + arrhythmia (OR 2.02; 95% CI 1.10 - 3.72). Participants with primary school as their highest level of education were 49.0% more likely to have asthma + hypertension. Current smoking and being an ex-smoker significantly increased the likelihood of having asthma + arrhythmia, asthma + emphysema, emphysema + arrhythmia and emphysema + myocardial infarction, and were not associated with asthma + hypertension and asthma + pneumonia. A history of occupational exposure to dust/chemical fumes was significantly associated with asthma + hypertension (OR 1.31; 95% CI 1.01 - 1.76). Using polluting fuels such as paraffin or gas for cooking/heating in the home had a significant detrimental association with asthma + pneumonia (OR 2.38; 95% CI 1.08 - 5.23) (Table 6.8).

No significant effect modification between community type (exposed/unexposed) and other air pollution source variables investigated was observed.

6.6 Discussion

This is the first study to investigate the risk factors associated with comorbidity of respiratory and cardiovascular diseases among elderly people in exposed communities in SA. The results suggest that there was a high prevalence of comorbidity in exposed communities. Living in exposed communities, age, smoking habits, a history of occupational exposure to dust/chemical fumes, and use of gas for cooking/heating in the home were found to be significant risk factors for comorbidity of respiratory and cardiovascular diseases.

Mine dumps are considered to be major sources of wind-blown dust that not only constitutes a nuisance but represents a risk to human health.[2,16,21–25] Size distribution analysis of dust particles from mine dumps has revealed high levels of respirable components. According to previous research done on one of the mine dumps in this study, the ambient concentration of particulate matter with an aerodynamic diameter of <10 μm (PM_{10}) greatly exceeded the 24-hour limit set by the SA Department of Environmental Affairs (180 μg/m^3).[2,26] Residential developments are encroaching on the bases of mine dumps,[1] and ongoing reclamation of gold from mine dumps observed during the survey increased exposure to particulate matter. Respiratory and cardiovascular diseases were therefore caused or aggravated by exposure to dust from mine dumps.

Ageing is an intricate process associated with an increased risk of cardiovascular and respiratory diseases[27–29] as a result of changes in cellular and organ function.[30,31] In this study, an increase in age was not associated with comorbidity of cardiovascular and respiratory diseases. A possible explanation for this finding could be a survivor effect. Contrary to findings reported elsewhere,[32] population group was not associated with the comorbidity outcomes considered in this study. Lower levels of education were also not significantly associated with outcomes of interest in this study, although they are generally known to be linked with lower socio-economic status and have previously been identified as a risk factor for cardiovascular and respiratory diseases.[33,34] Current and ex-smoking was significantly associated with respiratory and cardiovascular diseases. Ex-smokers were at higher risk than current smokers of having cardiovascular and respiratory disease comorbidity. Having being diagnosed with cardiovascular and or respiratory disease may have been the reason why study participants stopped smoking. Another possibility could have been advice from doctors, which has been shown to contribute to smoking cessation.[35]

The cardiovascular and respiratory systems are vulnerable to occupational exposures owing to direct contact with the ambient environment and inhalation of toxic substances.[36,37] Occupational exposure to dust or chemicals was significantly associated with cardiovascular and respiratory diseases. The findings of this study are in agreement with other research in this respect.[38,39] Domestic use of gas and paraffin (kerosene) was significantly associated with cardiovascular and respiratory diseases, possibly caused by the oxides of nitrogen or carbon monoxide generated when gas or paraffin is burnt.[40,41]

6.7 Study limitations

Some limitations and advantages of this study have been published previously.[(6)] The study has additional limitations inherent to cross-sectional epidemiological study designs: (*i*) it cannot provide any evidence of causality; (*ii*) no quantitative air pollution exposure assessment was conducted; and (*iii*) it relied on doctor-diagnosed respiratory and cardiovascular diseases, which, although specific, can underestimate disease prevalence. It is therefore assumed that several individuals with respiratory and cardiovascular diseases were missed as a result of restrictive definitions employed in

this study or poor access to healthcare facilities.[(42)] The possibility of estimating falsely low prevalence figures cannot be ignored. However, the observed high prevalence of respiratory and cardiovascular diseases in exposed communities cannot be attributed only to the strict definition used, but is also likely to be due to a complex interaction of social, economic, and behavioural factors such as air pollution, undernutrition, poor access to healthcare or lifestyle behaviours.[43,44] Further limitations are that: (*iv*) interviewer error may have occurred during translation of the questions into the local language during interviews with study participants who did not understand English; (*v*) unwillingness of the respondents to provide honest answers, or their giving socially desirable responses, should be taken into account in the interpretation of results; and (*vi*) no data were collected on possible reasons for declining to take part – the differential participation rate between exposed and unexposed communities is of concern and may well have introduced response bias, which is likely to overestimate the prevalence estimates derived and bias the association in either direction; and (*vii*) data on how access to healthcare varied between exposed and unexposed communities were not collected. Interviewing 10% of the study respondents twice resulted in 96% repeatability.

6.8 Conclusion

The findings of this study suggest a high prevalence of respiratory and cardiovascular diseases, with detrimental associations observed between comorbidity of the health outcomes and proximity to mine dumps, among the elderly in SA. The significant risk factors were proximity to mine dumps, age group, occupational exposure history to dust/chemical fumes, and main type of fuel used for heating/cooking in the home.

6.9 Acknowledgments

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7. Chapter 7: Indoor and outdoor PM10 levels at schools located near mine dumps in Gauteng and North West, South Africa

7.1 Abstract

Background: Few studies in South Africa have investigated the exposure of asthmatic learners to indoor and outdoor air pollution at schools.

Aims: This study compared outdoor PM_{10} and SO_2 exposure levels in exposed (1 km – 2 km from gold mine dumps) and unexposed schools (5 km or more from gold mine dumps). It also examined exposure of asthmatic children to indoor respirable dust at exposed and unexposed schools.

Methods: The study was conducted between 1−31 October 2012 in five schools from exposed and five from unexposed communities. Outdoor PM_{10} and SO_2 levels were measured for 8-hrs at each school. Ten asthmatic learners were randomly selected from each school for 8-hr personal respirable dust sampling during school hours.

Results: The average level of outdoor PM_{10} for exposed was 16.42 and 11.47 $mg.m^{-3}$ for the unexposed communities ($p < 0.001$). The outdoor SO_2 for exposed was 0.02 ppb and 0.01 ppb for unexposed communities ($p < 0.001$). Indoor respirable dust in the classroom differed significantly between exposed (0.17 $mg.m^{-3}$) and unexposed (0.01 $mg.m^{-3}$) children with asthma at each school ($p < 0.001$).

Conclusion: The significant differences between exposed and unexposed schools could reveal a serious potential health hazard for school children, although they are lower than published standards. The indoor respirable dust levels in exposed schools could have an impact on children with asthma, as they were significantly higher than the unexposed schools, although there are no published standards for environmental exposure for children with asthma.

Key words: Mine dumps, schools, air pollution, asthma, South Africa

[This chapter is currently under peer review]

7.2 Introduction

Acute or chronic exposure to particulate matter <10μm in diameter (PM_{10}) is a worldwide concern. It is associated with the exacerbation of asthma attacks, decline in lung function, preterm birth and an increase in hospital visits and deaths among children with pre-existing asthma conditions or respiratory diseases. [1–9] Children are the most susceptible population since they can receive a higher dose of PM_{10} in the lungs as compared to adults. This may be due to greater fractional deposition with each breath and/or larger minute ventilation relative to lung size.[10] Children spend approximately seven or more hours per day at school, mostly in classrooms. This is the second highest time spent in the indoor environment after home, so makes the school an interesting area to assess air pollution exposure.[11,12] Children's personal exposure to indoor air pollutants, including PM_{10}, is largely determined by pollutant concentration outdoors.[13–15] Research studies have shown that mine dumps are a major contributor of particulate matter air pollution to surrounding communities, and that proximity is associated[16] with increased risk asthma symptoms.[17,18] Taking into consideration that school children spend one-third of their total time inside school buildings, it is evident that air quality inside the classrooms should be of concern.[5,19,20] Whether it is indoor or outdoor, PM_{10} may have adverse biological effects when exposures are prolonged in children.[21] Children who have asthma are a group that is particularly vulnerable to airborne pollutants such as PM_{10}, SO_2 and respirable dust.[22–27] In order to estimate the risk to children, particularly those with asthma; and develop a mitigation strategy, the actual levels of these air pollutants at schools near mine dumps need to be measured.

No studies appear to have investigated whether proximity to mine dumps influences outdoor air pollution and indoor respirable dust levels in South African schools. Thus, the aim of this study was to measure levels of PM_{10} and SO_2 outside, as well as respirable dust indoors in schools exposed and unexposed to mine dust between 1 and 31 October 2012.

This study forms part of a bigger project initiated by Mine Health Safety Council of South Africa (MHSC) around communities located near mine dumps in Gauteng and North West, provinces in South Africa.

7.3 Methods

7.3.1 Study area, study period and demographics

Schools located 1 – 2 km (exposed) and 5 km or more (unexposed) from pre-selected five mine dumps in Gauteng and North West of South Africa were included in the study. The study was conducted between 1 and 31 October 2012. Table 7.1, lists the selected schools and Figure 7.1 shows a map of the study area. The socio-economic and demographic profile of exposed and unexposed schools was similar.

Table 7.1: Ten schools selected in the study located in Gauteng and North West, South Africa during 1 and 31 October 2012

Mine dump facility	Province	Exposed school[a]	Unexposed school[b]
Durban Roodepoort Deep (DRD)	Gauteng	Kgatelopele secondary	PJ Simelane secondary
Crown Gold Recoveries (CGR)	Gauteng	Noordgesig secondary	Job Rathebe secondary
Ergo	Gauteng	Geluksdal primary	Windmill Park primary
East Rand Proprietary Mines (ERPM)	Gauteng	Lakeside primary	Windmill Park secondary
Anglo Gold Ashanti	North West	Vaal Reefs secondary	Inkangmahlale secondary

[a]1 km – 2 km from mine dumps.
[b]5 km or more from dumps.

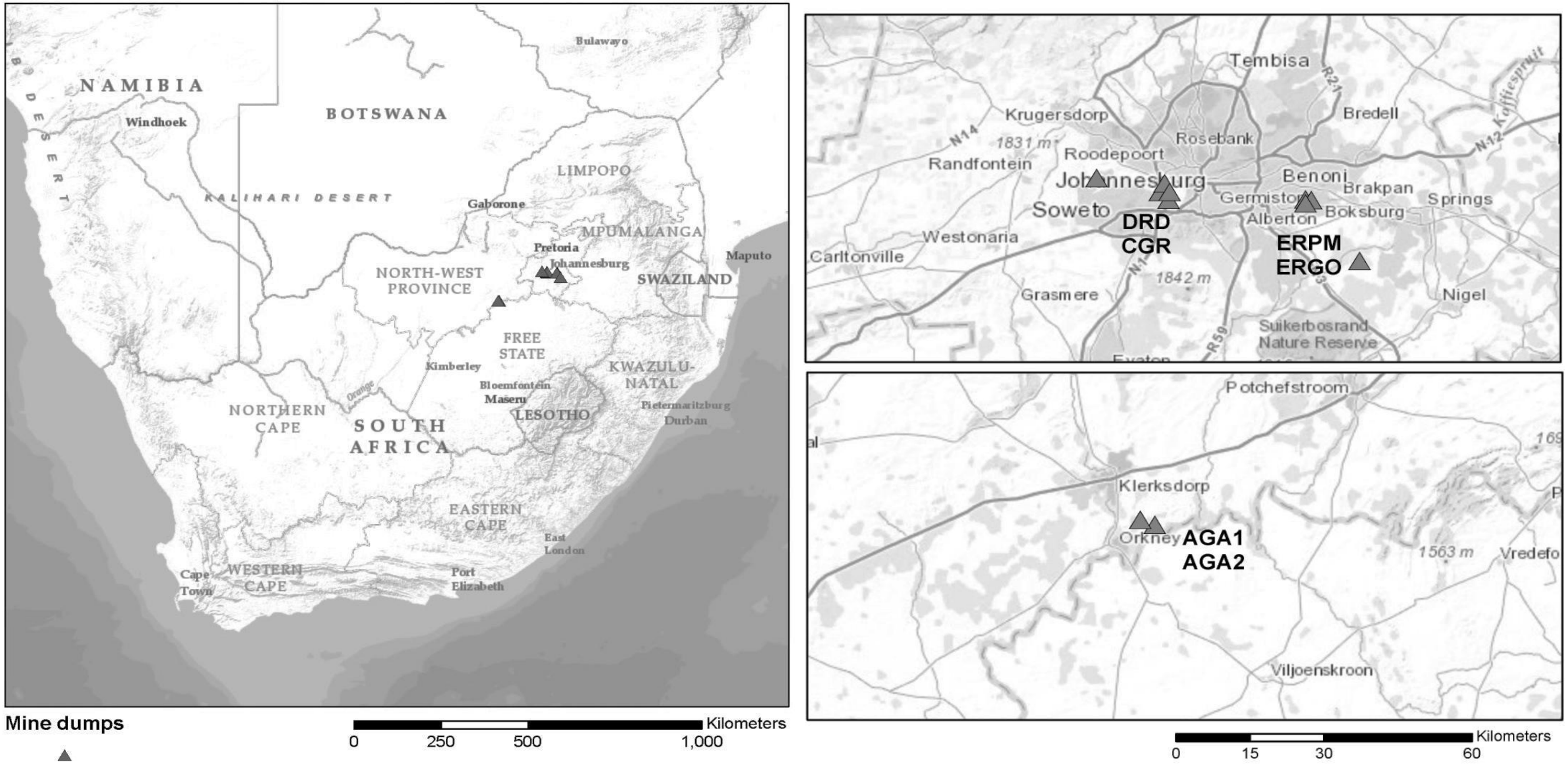

Figure 7.1: Location of mine dumps tailings in South Africa

7.3.2 Study participants

The study participants were 13-14 year old asthmatic learners. Ten of these learners were randomly selected from each of from 10 schools (five exposed and five unexposed) in Gauteng and North West in South Africa. They form a subset of participants in the International Study of Asthma and Allergies in Children (ISAAC), 2012 survey. The study participants had reported in the ISAAC 2012 survey that their asthma was diagnosed by the doctor/physician. Three learners in each of two classrooms and four in one classroom were randomly selected for personal air sampling; Figure 7.2 shows the seating position of learners within the classroom.

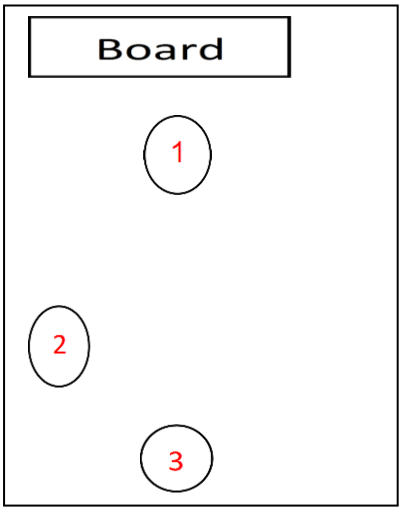

Figure 7.2: Seating positions of sampled pupils

7.3.3 Personal air sampling

Personal air sampling was performed in the breathing zone of asthmatic learners during school hours from 8 am to 15 pm using a Gillian Personal Sampler. All the gravimetric sampling was done in accordance with the requirements of General

Methods for Sampling and Gravimetric Analysis of Respirable, Thoracic and Inhable Dust, Regulation 14/3.[28]

7.3.4 Ambient air monitoring

An AEROQUAL mobile ambient air monitoring station was used to measure the ambient PM_{10} and SO_2 within the school premises, between 08h00 and 15h00, at a height of 1 m, on an open space or ground. The mobile air monitoring station was placed downwind, in the South-easterly direction, where the wind is predominately blowing in the study areas,

7.3.5 Statistical analyses

All statistical analyses were performed using Stata ™ version 14. Eight hour mean concentration of ambient air pollutants such as PM_{10}, SO_2 and respirable dust were determined. Pearson correlations coefficients were estimated to better understand their interrelationship of PM10, SO2 and respirable dust. Descriptive statistics were used to explain data; standard deviations, percentiles and ranges were to illustrate data as appropriate. The t-test was using was used to compare the mean levels of respirable dust, PM_{10} and SO_2 of exposed and unexposed schools. Ten filters for each school were weighed in the accredited laboratory. Data from the mobile air monitoring station and the laboratory were merged for analysis.

Crude and adjusted β-coefficients and 95% confidence intervals (CI) were calculated with univariate and multiple backward hierarchical standard regression analysis to estimate the association between of respirable dust and independent variables such as PM_{10} outdoor concentration, SO_2 outdoor concentration, school location, day of sampling. Independent variables with p-value <0.2 obtained in the univariate regression analysis were included in the multivariable regression analysis. A p-value < 0.05 in the multivariate regression analysis was considered statistically significant.[29] The most parsimonious multivariate model is reported, i.e. the model with variables having a p-value < 0.05.

7.4 Results

A total of 100 learners' age between 13 to 14 years took part in the study. Fifty were from the communities exposed and other 50 from the unexposed communities. October encompassed part of the wet season in South Africa; Figure 7.3 shows the percentage precipitation during the sampling period. [30]

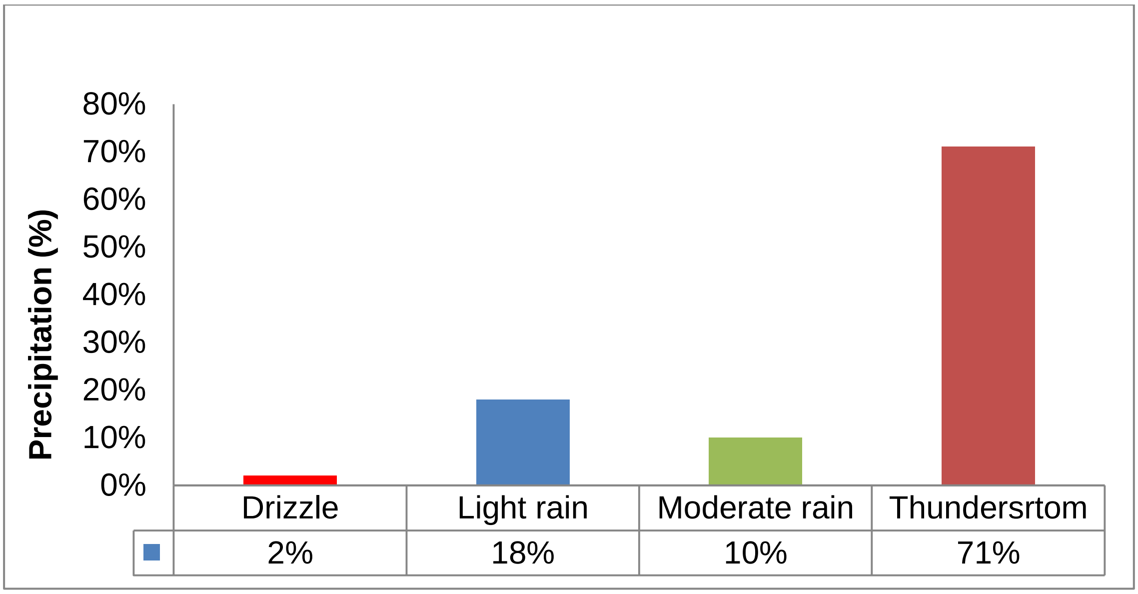

Figure 7.3: The percentage precipitation during the sampling period for exposed and unexposed community, October 2012.

The mean outdoor 8-hour concentrations of PM_{10} and SO_2 for both exposed and unexposed schools, were well below the South African Air Quality Standards' set by the Department of Environmental Affairs.[31] However, there was a significantly higher

8-hour mean concentration of PM_{10} ($p < 0.001$), SO_2 ($p < 0.001$) and respirable dust ($p < 0.001$) observed in schools located near mine dumps, as compared to unexposed schools (Table 7.2).

Table 7.2: Distribution of the daily 8-h mean concentrations of PM10 and SO2 and indoor respirable dust in ten selected

Exposed[a]	**Mean + SD**	**95 CI**	**p-value**[c]	**25th percentile**	**Median**	**75th percentile**	**Range**
Respirable dust ($\mu g/m^3$)	0.17 + 0.10	(0.14 – 1.99)	<0.001	0.10	0.17	0.20	0.02 – 0.7
PM_{10} ($\mu g/m^3$)	16.42 + 3.67	(15.37 – 17.46)	< 0.001	17.30	18.00	18.10	9.30 – 19.40
SO_2 (ppb)	0.02 + 0.01	(0.01 – 0.03)	<0.001	0.10	0.10	0.04	0.00 – 0.05
Unexposed[b]							
Respirable dust ($\mu g/m^3$)	0.06 + 0.03	(0.05 – 0.07)	<0.001	0.05	0.06	0.08	0.01 – 0.15
PM_{10} ($\mu g/m^3$)	11.47 + 4.90	(10.08 – 12.87)	< 0.001	9.30	13.30	15.20	3.10 – 16.50
SO_2 (ppb)	0.01 + 0.01	(0.001 – 0.02)	<0.001	0.00	0.01	0.02	0.00 – 0.20

[a]Exposed: schools located 1 – 2 km from mine dumps.
[b]Unexposed: schools located 5 km or more from mine dumps.
[c]p-values of the t-test. PM_{10}: particulate matter <2.5 µm in diameter; SO_2: sulphur dioxide

Table 7.3 shows the Spearman correlation coefficients of the indoor and outdoor pollutants. PM_{10} and respirable dust were significantly positively correlated with each other ($p < 0.001$). The strongest correlation coefficient observed was r = 0.41 (p-value = 0.02) between PM_{10} and respirable dust. No significant correlation was observed between SO_2 and PM10, SO_2 and respirable dust.

Table 7.3: Spearman's correlation coefficients for outdoor PM10 and SO2 and indoor respirable dust in ten selected schools in the study located in Gauteng and North West, South Africa between 1 and 31 October 2012

Pollutants	**Spearman correlation coefficients**		
	Respirable dust	**PM_{10}**	**SO_2**
Respirable dust (µg/m³)	1.00		
PM_{10} (µg/m³)	0.41 (<0.001)*	1.00	
SO_2 (ppb)	0.02 (0.675)	0.29 (0.004)*	1.00

*p<0.05; SO_2: sulphur dioxide; PM_{10}: particulate matter <10 µm in diameter.

Results from the multivariate standard regression model (Table 7.4) indicated significant associations between respirable dust and PM_{10} (β = 0.27; 95% CI: 0.05 – 0.49); SO_2 (β = -0.31; 95% CI: -0.57 – -0.05) and school location (β = -0.95; 95% CI: -1.18 – -0.71) respectively. The day of sampling was significantly associated with the indoor respirable in schools located near mine dumps in the univariate analysis (β = -11.59; 95% CI: -18.57 – -5.6), but not in the multivariate analysis

Table 7.4: Univariate and multivariate β coefficients of standard regression analysis with 95 % confidence intervals of respirable dust in 10 schools located 1 km – 2 km and ≥5 km from mine dumps in Gauteng and North West, South Africa between 1-31 October 2012.

	Univariate analysis			Multivariate analysis*		
	β coefficients	**95% CI**	**P-value**	**β coefficients**	**95% CI**	**P-value**
Independent variables						
PM_{10} outdoor concentration	0.56	0.31 – 0.80	<0.001	0.27	0.05 – 0.49	0.018
$S0_2$ outdoor concentration	-0.31	-0.57 – -0.05	0.018	-11.59	-18.57 – -5.60	0.001
School location	-0.93	-1.15 – -0.72	<0.001	-0.95	-1.18 – -0.71	<0.001
Day of sampling	-0.11	-0.15 – -0.06	<0.001	-	-	-

*****Model adjusted for all variables in this Table, except day of sampling and number of asthmatic per school

7.5 Discussion

The results of this study suggest that school located near mine dumps in South African are exposed to higher levels of concentration of outdoor air pollutants such as outdoor PM_{10} and SO_2 and indoor respirable as compared to those located further away. Children with increased vulnerability to air pollution would be more likely to experience exacerbated asthma symptoms and attacks on both low and high air polluted days. [32,33] The mean 8-hr concentration levels of PM_{10} and SO_2 were well below the South African Air Quality Standards' set by the Department of Environmental Affairs.[31] However, such low levels might have a negative impact on the respiratory health of the susceptible individuals, since there is no threshold limit for pollutants to trigger an asthma symptoms and attack.[34] Amenity deficiencies in school such as poor maintenance and structural damage which may due to lack of funding observed during the survey. This may cause pollutants to infiltrate from the outdoor environment inside the classrooms. Research studies have shown that asthmatic children miss more days at school than those without.[35–37] This indicates that children attending schools in communities located near mine dumps, their respiratory health is not only compromised but also their academic performance might be negatively affected.

In assessing the school environment both indoor and outdoor air pollution contribution should be considered, since children often play outside their classrooms during breaks.[38] In this study, a statistically significant correlation between PM_{10} and indoor respirable dust was observed; this is agreement with other research studies that the outdoor PM_{10} can infiltrate and influence the indoor concentration levels of respirable dust.[39–42] The exposure assessment study conducted during the dry season in one of the mine dumps included in this study showed that the average 24-hr ambient air pollution levels were 20 times high than what is recommended by the South African Air Quality Standards' set by the Department of Environmental Affairs.[17,31] Therefore, suggesting that mine dumps can have an influence on the indoor air pollution levels in the houses and schools of the nearby communities. A cross-sectional conducted in the communities located close to mine dumps in South Africa, showed that a significant number of residents still use coal or fossil fuel as the main residential heating or cooking fuel type;[18,43] which might contribute to the ambient levels of SO_2 in these communities. Research studies have indicated that asthmatics are very sensitive to inhaled SO_2, and experience changes in pulmonary function and respiratory symptoms after periods of exposure to SO_2 as short as 10 minutes is sufficient to induce broncho-constriction.[44–47]

Limitations of the study were that only SO_2 was determined. Other gaseous pollutants were not included due the mobile air monitoring station which only had one SO_2 sensor. Only 10 schools were included in the study, due to limited funds. The study was conducted only in spring wet season and measurements were done once per school in each community. Therefore, it is suggested that further studies should be conducted to contrast indoor and outdoor levels in dry and wet seasons for longer duration.

7.6 Conclusion

The significant differences between exposed and unexposed schools could reveal a serious potential health hazard for schoolchildren, although they are lower than published standards. The indoor respirable dust levels in exposed schools could have an impact on children with asthma, as they were significantly higher than the unexposed schools, although there are no published standards for environmental exposure for children with asthma.

7.7 Ethical considerations

Ethical approval (number 235/2011) for the study was obtained from the Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria, Gauteng (reference number: D2012/79) and North West Department of Education (reference number: 24-04-12). School principals and governing bodies were approached and gave their consent for the study. Parents or guardians of the participants granted consent.

7.8 Contributors

VN and KV participated in the design of the study, data collection, statistical analysis and interpretation of the results, drafted and critically revised the manuscript. JW participated in the statistical analysis and interpretation of the results, drafted and critically revised the manuscript. All authors have read and approved the final manuscript.

7.9 List of abbreviations

CI: Confidence Intervals

SRA: Simple Regression Analysis

AGA; Anglo Gold Ashanti

CGR: Crown Gold Recoveries

DRD: Durban Roodepoort Deep

ERPM: East Rand Proprietary Mine

NRF- DAAD: National Research Fund – Deutscher Akademischer Austausch Dienst

$\mu g/m^3$: Microgram per cubic metre

PM_{10}: particulate matter with size less than 10µm in diameter

SO_2: Sulphur dioxide

7.10 Acknowledgements

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7.11 Conflict of interest

Authors and the Mine Health and Safety Council of South Africa (MHSC) declare no conflict of interest.

7.12 Funding

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8. Chapter 8: Acute respiratory health effects of air pollution on asthmatic adolescents residing in a community close to Crown Gold Recoveries mine dump in South Africa: Panel study

8.1 Abstract

Background: Air pollution arising from mine dumps has been a major public health concern to communities located in close proximity to these facilities in South Africa.

Objective: The study investigated the association between acute changes in lung function and ambient air pollutants on asthmatic children in Noordgesig, Gauteng, South Africa.

Methods: A panel study design with repeated measures was used to carry-out the investigation which involved 15 asthmatic children. Each participating child completed an asthma daily symptom diary and performed forced expiratory flows in one second (FEV1) for 21 consecutive days. The 24 h ambient air pollution concentrations were monitored over this period. Linear mixed effect models adjusted for temperature, relative humidity, day of the week, first order autocorrelation and 10 $\mu g.m^{-3}$ increase of the mean of pollutant concentrations were used to determine the association between morning FEV1 and air pollutants. The association between air pollutants, respiratory symptoms and medication use were evaluated with logistic mixed effect models.

Results: The mean 24-hour concentration of NO_x for current day was 0.762% (95% CI: -1.296 – -0.227), and for O_3, the respective current and previous days were 0.780% (95% CI: -1.461 – -0.099) and 0.716% (95% CI: -1.386 – -0.045), all of these were significantly associated with the morning FEV1 decline. Single pollutant models showed significant positive associations between chest tightness, cough and NO_2, O_3, NO_x, and SO_2 pollutants. Medication use such as corticosteroids and short-acting β_2 agonist were associated with NO_x (OR = 1.07; 95% CI: 1.00 – 1.28) and O_3 (OR = 1.57 95% CI: 1.03 – 2.72) respectively. Interestingly, a protective significant effect was observed between SO_2 and cough (OR = 0.45; 95% CI: 0.21 – 0.97).

Conclusion: The findings of this study provide evidence that an acute change of gaseous air pollutants in communities situated near mine dumps exacerbates lung function in vulnerable children.

Keywords*:* Mine dumps, Panel study, Respiratory effects, Asthma, Noordgesig, South Africa.

[This chapter is currently under peer review]

8.2 Introduction

Air pollution arising from mine dumps has been a major public health concern for communities located in close proximity to these facilities. These facilities serve as a waste depository for materials formed by extraction and grinding methods of during mining process.[1–3] The material consist of a complex mixture of metals such lead, cadmium, manganese, silver, arsenic, dust particles and particulate matter measured in fractions of $\leq$ 10 µm (PM_{10}) and $\leq$ 2.5 µm ($PM_{2.5}$) in diameter.[3–7] These metals and particulate matter constitute a serious health hazard on the human respiratory system.[8–11] As a result of these mine dumps, ambient air quality is deteriorating due to dust particles that are released and transported via aeolian dispersion to nearby communities.[6,12] In dry windy seasons for instance the ambient air concentration of dust particles can reach the maximum of 2160 µg/m^3, which is several times higher than the 24-hour limit value suggested by the World Health Organization South African Department of Environmental Affairs.[13] In communities where mine dumps are located, those are likely to be major contributors of air pollution, thus posing serious health risks to the people living within those communities.[12] Usually people living in exposed communities are found mainly in informal settlements and government-funded houses of historically marginalised ethnic groups and are of lower socio-economic status. The most vulnerable in such communities are the elderly and children.[14] Children are particularly more at risk because their respiratory system is still developing.[15] Epidemiological studies have linked short-term exposure to particulate matter with adverse health effects such as decreased lung function and premature death in people with lung diseases.[16–19] In South Africa, higher prevalence of asthma symptoms were observed in children residing in communities situated close to the mine dumps than those located further away.[16] So far no studies have been reported in the extant literature of whether air pollution as the result of mine dumps pose an increased risk for children who are asthmatic. The study reported here is part of a larger project on health related issues initiated by Mine Health Safety Council of South Africa (MHSC) around communities located near mine dumps in Gauteng and North West, South Africa. The purpose of the study was to investigate the association between acute changes in lung function with ambient air pollutants on asthmatic children in Noordgesig, Gauteng, South Africa.

8.3 Methods

8.3.1 Study population

The study was conducted in Noordgesig, Gauteng, South Africa, with estimated with an population of about 12,155 in 2011[17]. A unique aspect of the township is that it is located at the base of the mine dump. Children with asthma were identified from a self-administered questionnaire survey based on the International Study of Asthma and Allergies in Childhood (ISAAC).[18] The ISAAC study was carried out in the previous year, It included 400 secondary school children in Noordgesig.[16] For the present study, children who had given a positive response to the question “Has a doctor/physician ever told you that you had asthma?” and whose parent or guardian had agreed to be contacted about future research were selected. Fifteen asthmatic children between 13 and 14 years old and lived in homes where no one was smoking cigarette participated in the study.

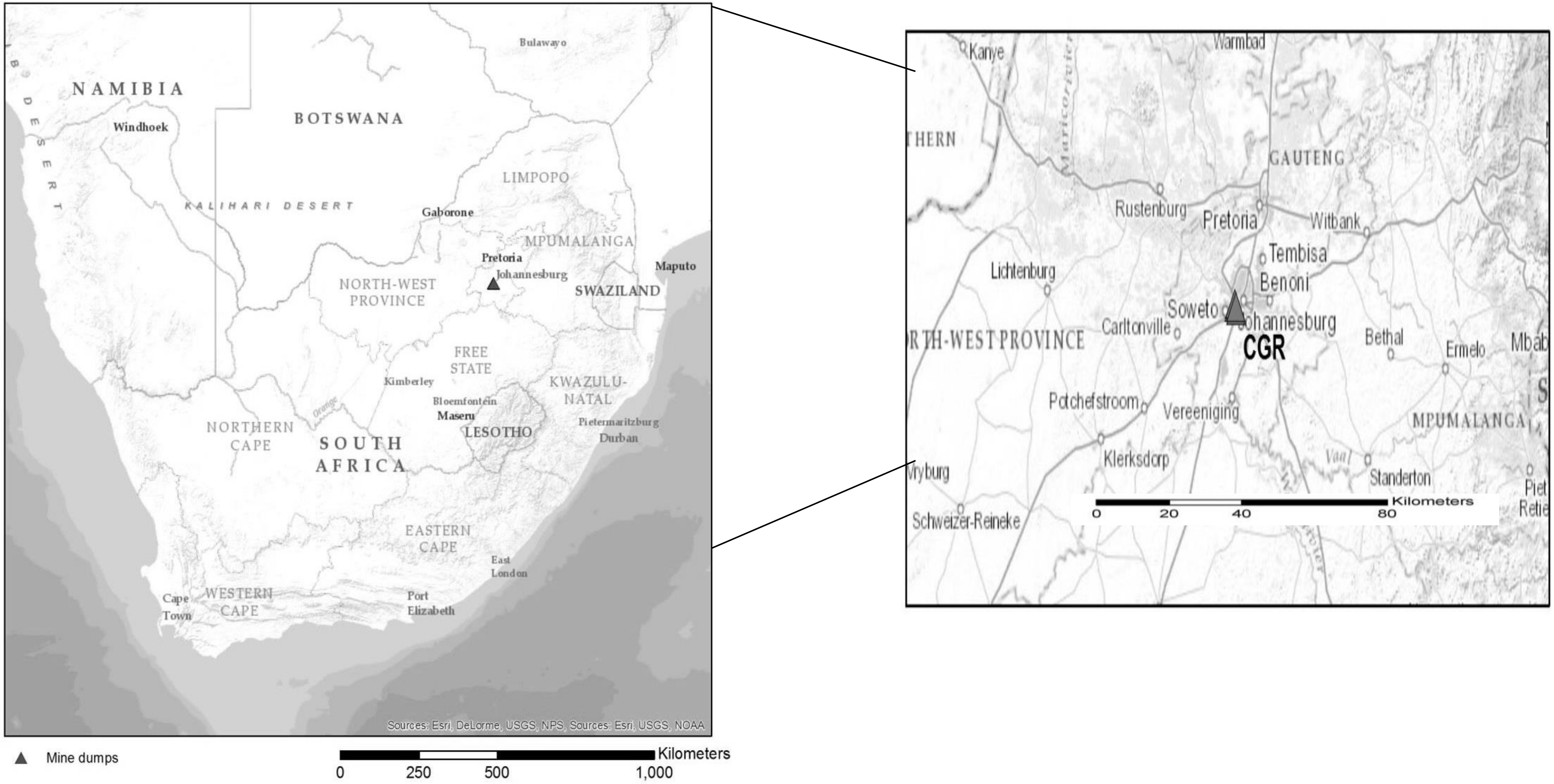


Figure 8.1: Location of mine dumps tailings in Noordgesig.

The institutional review board of the participating school approved the study protocol. The parent or guardian of each child gave a written informed consent before the child could participate in the study.

8.3.2 Study design

A panel study design with repeated measures was used to carry-out the investigation which involved 15 asthmatic children. Each participant completed an asthma symptom daily diary, and performed forced expiratory flows for 21 consecutive days. Children were studied in a dry season from 18 August to 8 September 2013.

8.3.3 Air pollution monitoring

Citywide background air pollution hourly levels were obtained from fixed-site monitor located in in the south east of area, upwind from the prevailing winds. The fixed-site monitoring station belongs to South African Weather Services. Hourly levels of pollutants data such as nitrogen dioxide (NO_2), oxides of nitrogen (NO_x), ozone (O_3), sulphur dioxide (SO_2), particulate matter less than 2.5 ($PM_{2.5}$) and 10 (PM_{10}) μm in diameter were retrieved from the monitoring station. Weather data for the duration of the study including temperature and relative humidity were also retrieved from the monitoring station.

8.3.4 Lung function assessment

Forced expiratory volumes in 1 second (FEV1) were measured using a pocket electronic flow meter (Piko-1). Each participant was trained to use Piko-1. The training also included the proper standing position during the use of Piko-1, breathing techniques and maintenance of the instrument. Participants were instructed to perform the FEV1 maneuver in the standing position three times in the morning and three in the evening prior use of breathing medication. For each participant the mean morning FEV1 was calculated. Percentage morning FEV1 decrements variability was expressed as 100 % × (individual morning FEV1 measured on that day – individual mean of morning FEV1 throughout the study period)/ individual mean of morning FEV1 throughout the study period.

8.3.5 Diary cards

All study participants were issued with asthma daily diary cards to record the presence of asthma symptoms and medication use such as breathlessness, chest tightness, cough, wheeze, short-acting β_2-agonist, inhaled corticosteroids and other asthma medication use on the diary.

8.3.6 Statistical analyses

All statistical analyses were performed using SAS statistical software package version 9.4. Prevalence of health outcomes were calculated by dividing the number of participants who recorded the presence of asthma symptoms divided by number of completed diaries. Daily mean concentration of air pollutants, temperature and relative humidity were calculated by adding the hourly levels and dividing by 24 hours per day. Pearson correlation coefficients were estimated to better understand the interrelationship between air pollutants and weather variables.

The results obtained from linear mixed effect models were expressed as the percentage of morning FEV1 decrements corresponding to 10 $\mu g.m^{-3}$ increase in air pollutants concentration. Autoregressive covariance structure (AR1) was used to allow for a greater within-subject autocorrelation for FEV1 measures taken more closely in time. A random intercept and fixed slope was assumed. The effect of air pollutants concentration of the current day (lag 0), previous day (lag 1) and 2 days after the exposure (lag 2) on the lung function, asthma symptoms and asthma medication use were analysed separately.

The association between air pollutants, respiratory symptoms and asthma medication use were evaluated with logistic mixed effect models. Odds ratios (OR) were calculated for an increase of 10 $\mu g.m^{-3}$ in air pollutant levels. The final models with outcome variables were adjusted for daily mean temperature, relative humidity and day of the week for both linear and logistic mixed effect are reported in this study. The *p-value* < 0.05 obtained in both models for air pollutants, respiratory symptoms and asthma was deemed statistically significant. Two pollutant models were used to characterise pollutants that were more strongly associated with associated with FEV1, respiratory symptoms and asthma medication use.

8.4 Results

8.4.1 Demographic characteristics

A total of 15 pupils were involved in the study, 60% were females and 40% males with the mean age of 13 years. All participants that were included in the study had a history of “doctor-diagnosed asthma”. Of the participants, the mean morning FEV1 was 2.49. During the study period, 40% reported the use of inhaled corticosteroids, 40% short-acting β_2 agonist, 7% other asthma medication and 14% no asthma medication.

The prevalence of respiratory symptoms reported by children were breathless (67%), chest tightness (47%), cough (73%) and wheeze (87%).

Table 8.1: Demographic characteristics of the 15 participating children, by period of study in Noordgesig (Gauteng, South Africa) in 2013

	Study period	
Characteristics	**August 18-September 08**	**% (n)**
Sex		
Female		60 (9)
Male		40 (6)
Age (years)		
Age; mean (SD)[*]		13 (0.4)
Height (m)		
Height; mean (SD)[*]		1.6 (0.1)
Weight (kg)		
Weight; mean (SD)[*]		59.5 (18.5)
BMI (kg/m^2)		
BMI; mean (SD)[*]		24.9 (7.0)
Respiratory symptoms prevalence during the study *period*		
Breathlessness		67 (10)
Chest tightness		47 (7)
Cough		73 (11)
Wheeze		87 (13)
Medication use during the study period		
Inhaled corticosteroid		40 (6)
Short-acting β_2-agonist		40 (6)
Other asthma medication		7 (1)
No asthma medication		14 (2)
MFEV1[+]; mean (SD)[*]		2.49 (0.37)

Figures in parentheses are the number of participants unless otherwise stated.
[*]SD: Standard deviation
[‡]MFEV1: Morning forced expiratory volume in 1 second

8.4.2 Air pollution

The mean 24-hour concentration of air pollutants were well below the South African Air Quality Standards set by the Department of Environmental Affairs (Table 8.2).[13] SO_2 and PM_{10} remained stable over the study period (Figure 8.2). NO_2, NO_x, $PM_{2.5}$, PM_{10} and SO_2 were positively correlated with each other, whereas ozone was negatively correlated with all these five ambient air pollutants (Table 8.2).

The strongest correlation between two pollutants was 0.65 ($p = 0.001$), It was observed between $PM_{2.5}$ and PM_{10}.

Table 8.2: Distribution of the daily 24-h mean concentrations of selected outdoor air pollutants and meteorological characteristics in Noordgesig between 18 August and 08 September 2013

Pollution/weather variables[#]	Days (n)	Mean± SD (range)	25th percentile	Median	75th percentile	Interquartile range
NO_2 (ppb)	21	32.3 ± 8.4 (16.3 – 49.9)	28.0	31.8	38.3	10.3
NO_x (ppb)	21	47.0 ± 22.3 (13.5 – 99.6)	36.6	41.2	58.5	21.9
O_3 (ppb)	21	33.7 ± 13.5 (12.9 – 74.2)	24.7	32.6	40.3	14.6
$PM_{2.5}$ (µg/m^3)	21	21.0 ± 6.0 (9.1 – 32.9)	16.1	22.4	23.2	7.1
PM_{10} (µg/m^3)	21	45.0 ± 12.2 (20.8 – 63.9)	38.8	46.7	52.1	13.3
SO_2 (ppb)	21	5.9 ± 4.3 (0.2 – 14.9)	3.1	4.9	8.0	4.9
Relative humidity (%)	21	37.9 ± 11.0 (15.2 – 60.2)	33.8	39.0	40.5	6.7
Temperature (^{o}C)	21	12.2 ± 1.8 (9.1 – 18.2)	11.4	12.0	12.8	1.4

NO_2: nitrogen dioxide; NO_x: oxides of nitrogen; O_3: ozone; $PM_{2.5}$: particulate matter <2.5 µm in diameter; PM_{10}: particulate matter <10 µm in diameter; SO_2: sulphur dioxide. [#]: Data were obtained from South African Weather Services.

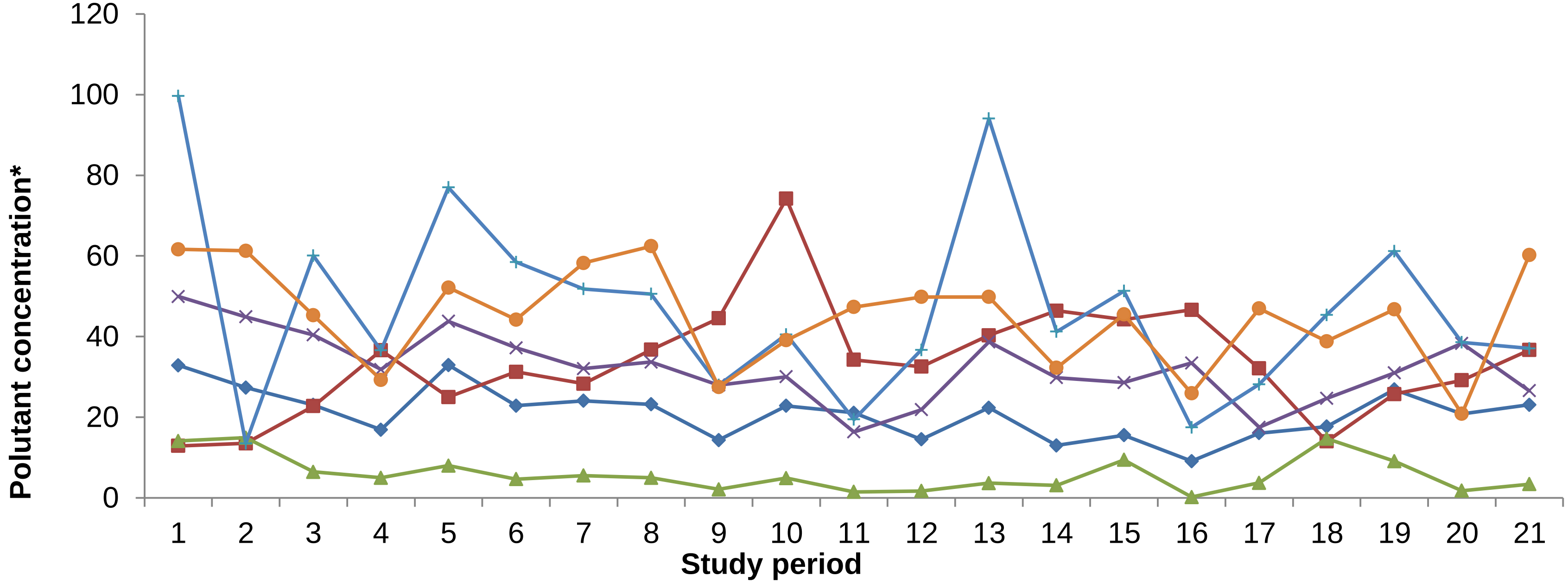


Figure 8.2: The 24-h mean concentrations of air pollutants during the study period August 18 to September 08, 2013, in Noordgesig, Gauteng, South Africa. x: nitrogen dioxide; +: oxides of nitrogen; ■: ozone; ♦: particulate matter <2.5μm in diameter; ●: particulate

Table 8.3: Pearson's correlation coefficients for the pollutants (daily means) and meteorological characteristics in Noordgesig between 18 August and 08 September 2013

	Pearson correlation coefficients							
Pollutants/weather variables	**NO_2**	**NO_x**	**O_3**	**$PM_{2.5}$**	**PM_{10}**	**SO_2**	**Relative humidity**	**Temperature**
NO_2 (ppb)	1.00							
NO_x (ppb)	0.56**	1.00						
O_3 (ppb)	-0.35**	-0.24**	1.00					
$PM_{2.5}$ (µg/m^3)	0.62**	0.59**	-0.46**	1.00				
PM_{10} (µg/m^3)	0.20*	0.35**	-0.39**	0.65**	1.00			
SO_2 (ppb)	0.45**	0.33**	-0.60**	0.54**	0.44**	1.00		
Relative humidity (%)	-0.25**	-0.38**	-0.24**	0.10	-0.13	-0.03	1.00	
Temperature (^{o}C)	-0.03	-0.19*	0.13*	-0.29**	-0.04	-0.30**	-0.29	1.00

*: $p<0.05$; **: $p<0.001$. NO_2: nitrogen dioxide; NO_x: oxides of nitrogen; O_3: ozone; $PM_{2.5}$: particulate matter <2.5 µm in diameter;

8.4.3 Pollutant and FEV1 % change

Adjusted for temperature, relative humidity and day of the week and 10µg.m^{-3} increases of pollutants concentration. The mean 24-hour concentration of NO_x of the previous day (lag 0) was associated with the morning FEV1 decline of 0.762% (95% CI: -1.296 – -0.227). The mean 24-hour concentrations of ozone (O_3) of the current (lag 0) and previous day (lag 1) were also significantly associated with the morning FEV1 decline of 0.780% (95% CI: -1.461 – -0.099) and 0.716% (95% CI: -1.386 – -0.045) respectively. Interestingly, SO_2 of the current day (lag 0) and one day later (lag 1) was associated with improved morning FEV1 of 0.248% (95% CI: 0.028 – 0.468) and 0.234% (95% CI: 0.013 – 0.467) respectively. Increases of 10µg.m^{-3} in NO_2, NO_x, O_3 and $PM_{2.5}$ two days later (lag 2) were associated with the decrease in morning FEV1, but no significant relationship was observed.

Table 8.4: The effects of 10µg.m-3 increase of pollutants on morning forced expiratory volume in 1 second (MFEV1) expressed as percentages among children with asthma in Noordgesig between 18 August and 08 September 2013‡

Pollutants#	FEV 1 % change+	95% CI	p-value
Single pollutant			
NO_2:			
Lag 0	0.252	-1.095 –.1.600	0.712
Lag 1	0.095	-1.277 – 1.467	0.892
Lag 2	-0.602	-1.948 – 0.745	0.379
NO_x:			
Lag 0	-0.426	-0.880 – 0.028	0.066
Lag 1	-0.762	-1.296 – -0.227	0.005*
Lag 2	-0.448	-1.030 – 0.135	0.131
O_3:			
Lag 0	-0.780	-1.461 – -0.099	0.025*
Lag 1	-0.716	-1.386 – -0.045	0.036*
Lag 2	-0.375	-1.053 – 0.303	0.277
PM_{10}:			
Lag 0	0.566	-0.197 – 1.329	0.145
Lag 1	0.511	-0.265 – 1.286	0.196
Lag 2	0.201	-0.558 – 0.960	0.603
$PM_{2.5}$:			
Lag 0	0.129	-1.513 – 1.772	0.877
Lag 1	-0.123	-1.836 – 1.589	0.887
Lag 2	-0.645	-2.280 – 0.989	0.438

Table 8.4 continues

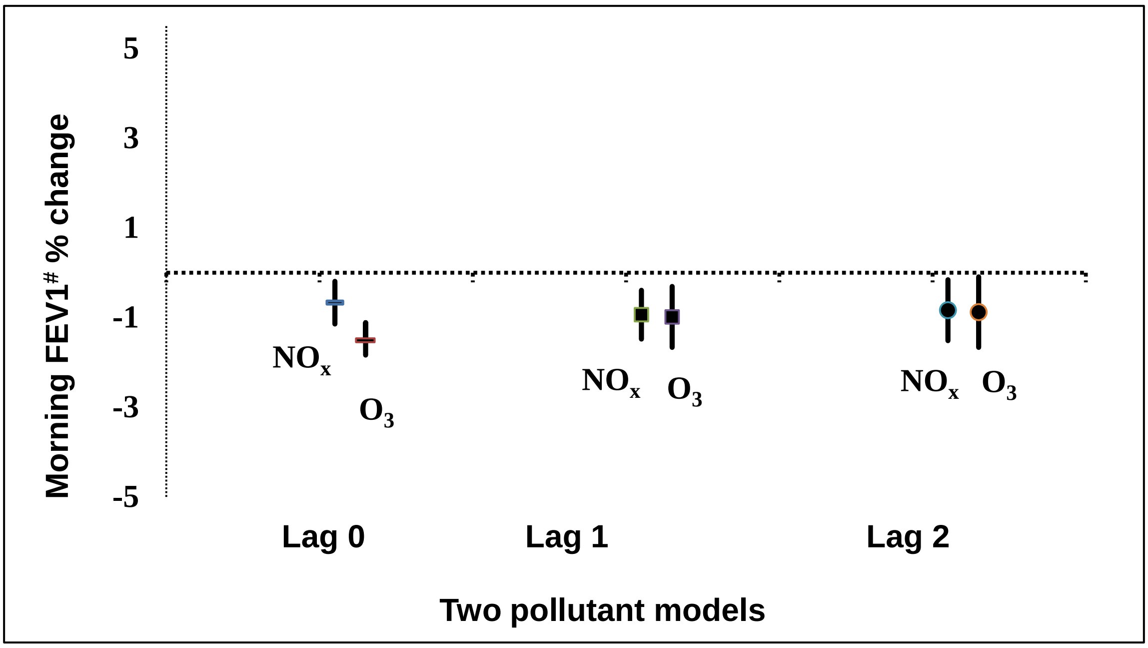
SO_2:			
Lag 0	0.248	0.028 – 0.468	0.027*
Lag 1	0.234	0.013 – 0.467	0.039*
Lag 2	0.064	-0.193 – 0.322	0.623

NO_2: nitrogen dioxide; NO_x: oxides of nitrogen; O_3: ozone; $PM_{2.5}$: particulate matter <2.5 µm in diameter; PM_{10}: particulate matter <10 µm in diameter; SO_2: sulphur dioxide. #: Data were obtained from South African Weather Services. *: p<0.05. +: FEV1 % change = 100 % x (individual morning FEV1 measured on that day – individual mean of morning FEV1 throughout the study period)/ individual mean of morning FEV1 throughout the study period. ǂ: a mix model was used with random intercept and fixed slope and autoregressive covariate structure adjusted for daily temperature, relative humidity, day of the week, sex, age and body mass index.

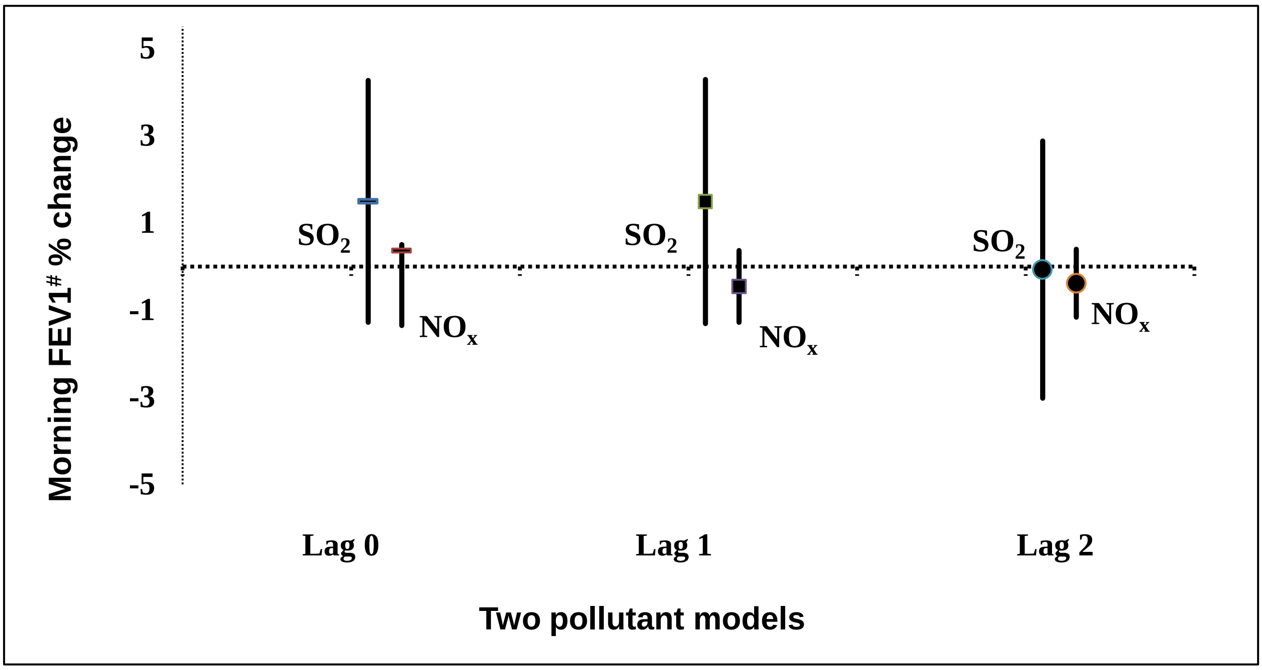
8.4.4 Two pollutant models and MFEV1 % change

In the two pollutant models that included NO_x and O_3 as predicators for MFEV1, all lags were significantly associated with MFEV1 (Fig 8a) and the other combinations were not significantly associated with MFEV1 (Fig 8a – e).

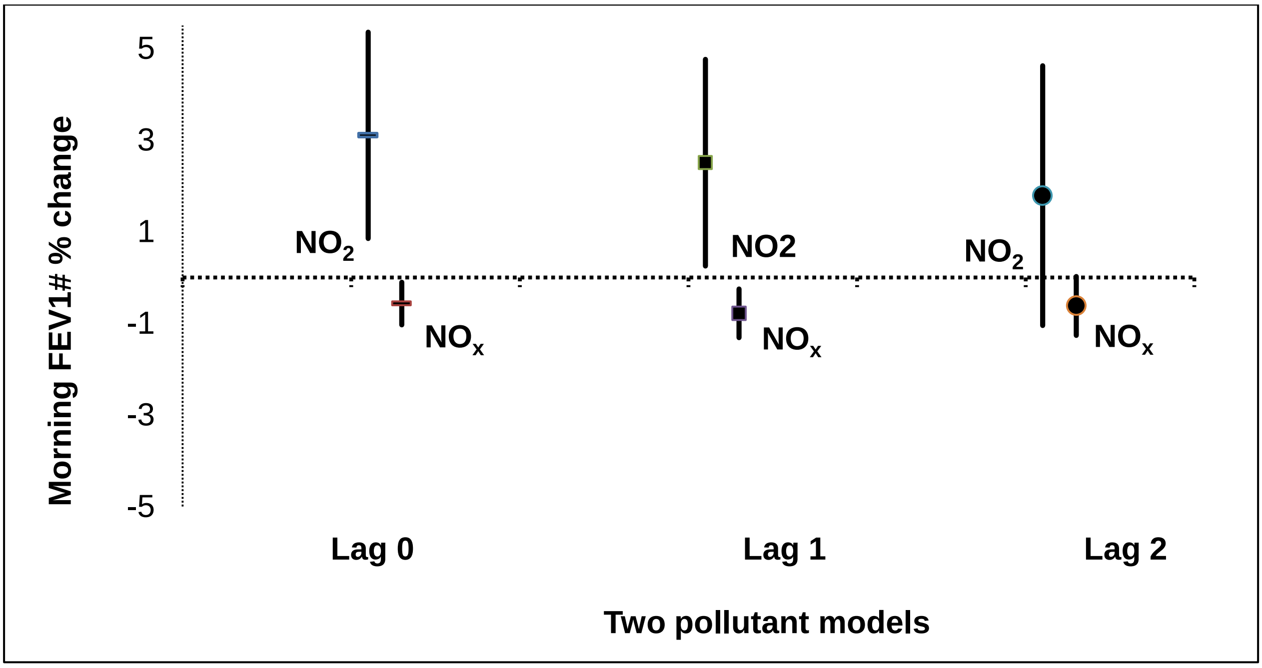
a)

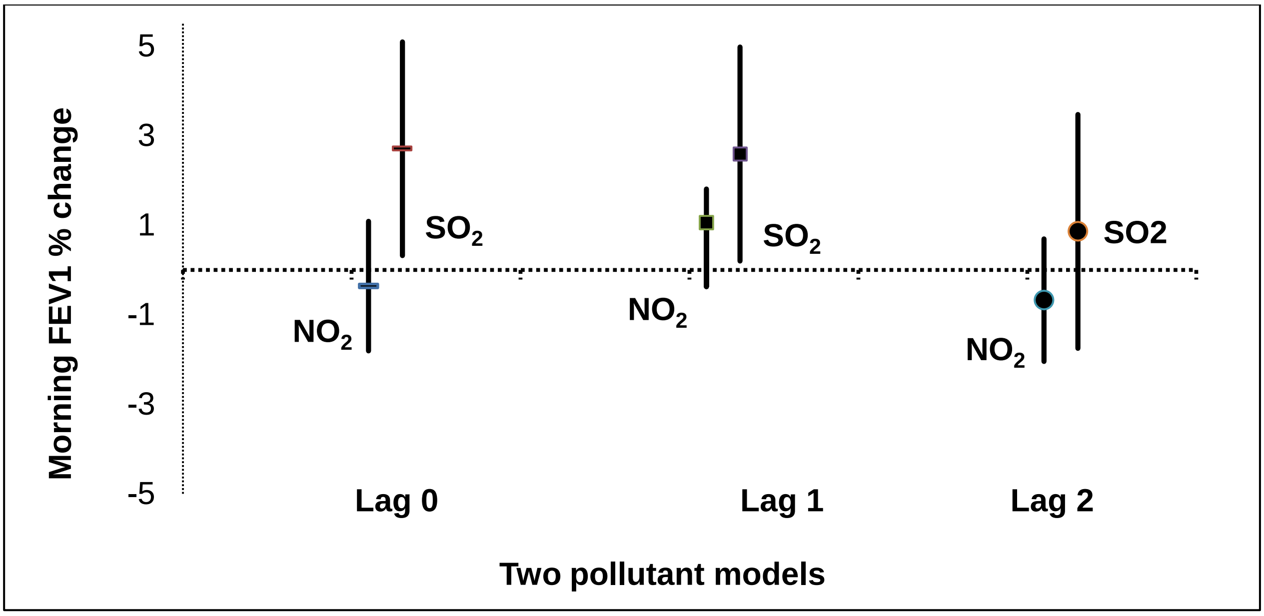


b)

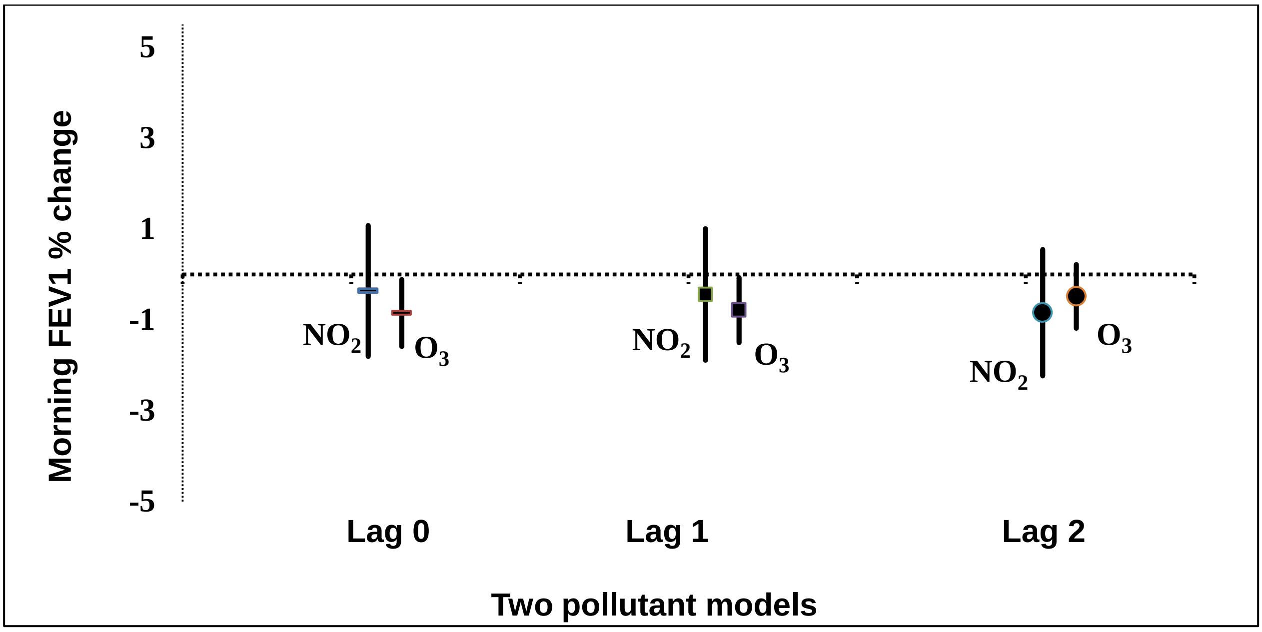

Morning FEV1# % change
5
3
1
-1
-3
-5
SO2
NOx
SO2
NOx
SO2
NOx
Lag 0
Lag 1
Lag 2
Two pollutant models

c)


Morning FEV1# % change
5
3
1
-1
-3
-5
NO2
NOx
NO2
NOx
NO2
NOx
Lag 0
Lag 1
Lag 2
Two pollutant models



d)



e)

Figure 8.3: Morning forced expiratory volume in 1 s associated with 10µg.m-3 increase of air pollutants concentration averaged for 24 hours on the test day, previous day and two previous days.

For the data in Figure 8.3, a mix model was used with random intercept and fixed slope and autoregressive covariate structure adjusted for daily temperature, relative humidity, day of the week, sex, age and body mass index.

8.4.5 Single pollutant models and health outcomes

For asthma-related symptoms and medication use, single pollutant models revealed significant positive associations between chest tightness and cough with NO_2, O_3, NO_x, and SO_2. Asthma medication use such as corticosteroids was associated with NO_x (OR = 1.07; 95% CI: 1.00 – 1.28) and short-acting β_2-agonist with O_3 (OR = 1.57 95% CI: 1.03 – 2.72). Interestingly a protective significant effect was observed between SO_2 and cough (OR = 0.45; 95% CI: 0.21 – 0.97). (Table 8.5)

Table 8.5: The effects of an increase of 10µg.m-3 of pollutants on respiratory symptoms among children with asthma in Noordgesig between 18 August and 08 September 2013‡

	Lag days	NO_2	NO_x	O_3	PM_{10}	$PM_{2.5}$	SO_2
Respiratory symptoms							
Breathlessness							
	0	1.16 (0.81 – 1.66)	0.95 (0.83 – 1.08)	0.95 (0.79 – 1.34)	1.01 (0.82 – 1.25)	0.95 (0.61 – 1.49)	1.02 (0.56 – 1.87)
	1	1.00 (0.73 – 1.55)	0.87 (0.75 – 1.01)	0.99 (0.81 – 1.19)	0.98 (0.79 – 1.21)	0.84 (0.53 – 1.34)	0.86 (0.46 – 1.61)
	2	0.99 (0.62 – 1.36)	0.94 (0.79 – 1.11)	1.08 (0.88 – 1.33)	0.91 (0.73 – 1.13)	0.75 (0.47 – 1.19)	**0.45 (0.21 – 0.97)***
Chest tightness							
	0	**1.54 (1.08 – 2.19)***	1.05 (0.93 -1.19)	**0.81 (0.70 - 0.99)***	1.00 (0.97 – 1.01)	1.33 (0.86 – 2.03)	**1.94 (1.09 – 3.44)***
	1	**1.38 (1.00 – 2.01)***	0.96 (0.83 – 1.11)	0.88 (0.73 – 1.07)	0.93 (0.76 – 1.14)	1.14 (0.72 – 1.79)	1.61 (0.87 – 2.98)
	2	1.24 (0.84 – 1.83)	1.06 (0.90 – 1.25)	0.95 (0.77 – 1.16)	0.87 (0.70 – 1.07)	1.03 (0.65 – 1.64)	1.12 (0.54 – 2.33)
Cough							
	0	0.80 (0.55 – 1.18)	0.94 (0.82 – 1.08)	0.96 (0.79 – 1.18)	1.07 (0.86 – 1.34)	0.84 (0.52 –1.37)	1.87 (0.92 – 3.81)
	1	0.80 (0.53 – 1.21)	**1.11 (1.01 – 1.41)***	0.95 (0.67 – 1.29)	1.09 (0.87 – 1.36)	0.85 (0.50 – 1.42)	**2.24 (1.00 – 4.99)***
	2	0.77 (0.50 – 1.18)	0.93 (0.77 – 1.12)	0.85 (0.76 -1.19)	1.08 (0.81 – 1.37)	0.83 (0.49 – 1.40)	2.87 (1.09 – 7.52)*
Wheeze							
	0	1.26 (0.74 – 2.11)	0.99 (0.81 – 1.20)	1.07 (0.79 – 1.43)	1.05 (0.79 – 1.40)	1.23 (0.64 – 2.33)	0.76 (0.32 – 1.78)
	1	1.30 (0.75 – 2.25)	1.00 (0.79 – 1.24)	1.06 (0.78 – 1.44)	1.06 (0.80 – 1.42)	1.28 (0.65 – 2.52)	0.75 (0.31 – 1.84)
	2	1.22 (0.70 – 2.14)	1.04 (0.82 – 1.32)	1.14 (0.81 – 1.58)	1.03 (0.76 – 1.38)	1.19 (0.61 – 2.36)	0.56 (0.21 – 1.49)
Medication use							
corticosteroids							
	0	1.05 (0.78 – 1.42)	0.99 (0.87 – 1.12)	1.03 (0.85 – 1.24)	1.01 (0.83 – 1.25)	1.20 (0.78 – 1.83)	1.09 (0.60 – 1.99)
	1	1.01 (0.98 – 1.05)	1.02 (0.88 – 1.19)	1.00 (0.82 – 1.22)	1.05 (0.84 – 1.30)	1.38 (0.86 – 2.22)	1.27 (0.66 – 2.44)
	2	1.00 (0.97 – 1.03)	**1.07 (1.00 – 1.28)***	1.04 (0.84 – 1.29)	1.02 (0.81 – 1.28)	1.33 (0.81 – 2.19)	1.13 (0.51 – 2.49)

Table 8.5 continues

β₂-agonist							
	0	0.80 (0.29 – 2.19)	1.06 (0.76 – 1.48)	1.31 (0.80 – 2.14)	0.88 (0.48 – 1.64)	0.65 (0.19 – 2.22)	0.77 (0.16 – 3.77)
	1	0.61 (0.20 – 1.81)	0.92 (0.61 – 1.38)	1.49 (0.89 – 2.50)	0.81 (0.43 – 1.50)	0.44 (0.12 – 1.70)	0.47 (0.08 – 2.84)
	2	0.58 (0.19 – 1.83)	0.89 (0.55 – 1.43)	**1.57 (1.03 – 2.72)***	0.79 (0.41 – 1.51)	0.45 (0.12 – 1.71)	0.33 (0.04 – 3.09)

NO_2: nitrogen dioxide; NO_x: oxides of nitrogen; O_3: ozone; $PM_{2.5}$: particulate matter <2.5 µm in diameter; PM_{10}: particulate matter <10 µm in diameter; SO_2: sulphur dioxide. #: Data were obtained from South African Weather Services. *: $p<0.05$. ‡: a mix model was used with random intercept and fixed slope and autoregressive covariate structure adjusted for daily temperature, relative humidity, day of the week.

8.4.6 Two pollutant models and health outcomes

Cough was only the significant health outcome considered in this study for the following air pollutants combination that included SO_2+O_3, NO_x+SO_2 and NO_2+SO_2 (Table 8.6).

Table 8.6: The effects of 10µg.m-3 increase of two pollutants on respiratory symptoms among children with asthma in Noordgesig between 18 August and 08 September 2013‡

	Lag days	NO_x+O_3	SO_2+O_3	NO_x+SO_2	NO_2+SO_2	NO_2+O_3
Respiratory symptoms						
Breathlessness						
		0.93 (0.80 – 1.07)	1.06 (0.51 – 2.22)	0.99 (0.87 – 1.12)	1.17 (0.80 – 1.73)	1.13 (0.77 – 1.66)
	0	0.91 (0.74 – 1.11)	0.91 (0.73 – 1.13)	1.32 (0.72 – 2.42)	0.94 (0.49 – 1.79)	0.97 (0.79 – 1.17)
		0.86 (0.73 – 1.01)	0.83 (0.39 – 1.76)	0.89 (0.77 – 1.03)	1.10 (0.74 – 1.63)	1.06 (0.71 – 1.57)
	1	0.94 (0.76 – 1.14)	0.93 (0.75 – 1.17)	0.97 (0.51 – 1.82)	0.82 (0.43 – 1.59)	0.99 (0.81 – 1.21)
		1.01 (0.85 – 1.22)	0.40 (0.17 – 0.94)	1.07 (0.89 – 1.28)	0.98 (0.66 – 1.47)	0.95 (0.64 – 1.42)
	2	1.10 (0.88 – 1.39)	0.97 (0.78 – 1.22)	**0.38 (0.17 – 0.85)***	**0.45 (0.21 – 0.98)***	1.08 (0.87 – 1.33)
Chest tightness						
		0.99 (0.88 – 1.13)	1.52 (0.74 – 3.10)	1.00 (0.89 – 1.13)	1.38 (0.94 – 2.02)	1.41 (0.97 – 2.07)
	0	0.86 (0.71 – 1.04)	0.93 (0.75 – 1.17)	1.74 (0.97 – 3.10)	1.59 (0.85 – 2.96)	0.90 (0.74 – 1.09)
		0.94 (0.81 – 1.09)	1.35 (0.64 – 2.85)	0.96 (0.83 – 1.02)	1.30 (0.88 – 1.92)	1.31 (0.89 – 1.95)
	1	0.88 (0.73 – 1.06)	0.95 (0.75 – 1.19)	1.52 (0.82 – 2.80)	1.42 (0.74 – 2.70)	0.92 (0.76 – 1.12)
		0.99 (0.82 – 1.18)	1.14 (0.50 – 2.61)	0.99 (0.84 – 1.18)	1.24 (0.83 – 1.84)	1.22 (0.82 – 1.83)
	2	0.93 (0.74 – 1.17)	0.96 (0.76 – 1.20)	1.25 (0.56 – 2.77)	1.05 (0.50 – 2.22	0.97 (0.79 – 1.19)

Table 8.6 continues

Cough						
		0.93 (0.80 – 1.08)	2.35 (0.98 – 5.62)	0.90 (0.77 – 1.04)	0.67 (0.45 – 1.02)	0.75 (0.49 – 1.14)
	0	0.92 (0.74 – 1.14)	1.13 (0.86 – 1.49)	**2.22 (1.03 – 4.80)***	**2.45 (1.13 – 5.38)***	0.91 (0.74 – 1.13)
		0.92 (0.78 – 1.10)	**2.74 (1.07 – 6.99)***	0.92 (0.77 – 1.09)	0.69 (0.46 – 1.07)	0.76 (0.49 – 1.17)
	1	0.92 (0.74 – 1.15)	1.11 (0.84 – 1.47)	**2.41 (1.05 – 5.54)***	**2.70 (1.15 – 6.30)***	0.91 (0.73 – 1.13)
		0.90 (0.73 – 1.11)	**3.39 (1.15 – 9.94)***	0.84 (0.70 – 1.03)	0.71 (0.46 – 1.09)	0.74 (0.47 – 1.16)
	2	0.89 (0.70 – 1.16)	1.02 (0.84 – 1.45)	**4.24 (1.38 – 13.01)***	**3.27 (1.19 – 8.96)***	0.92 (0.73 – 1.16)
Wheeze						
		1.04 (0.87 – 1.25)	0.91 (0.31 – 2.71)	1.04 (0.87 – 1.24)	1.34 (0.77 – 2.35)	1.33 (0.77 – 2.30)
	0	1.03 (0.78 – 1.37)	0.99 (0.71 – 1.39)	0.89 (0.38 – 2.08)	0.67 (0.28 – 1.62)	1.12 (0.81 – 1.54)
		1.01 (0.82 – 1.24)	0.80 (0.26 – 2.44)	0.99 (0.81 – 1.22)	1.37 (0.77 – 2.44)	1.36 (0.77 – 2.39)
	1	1.05 (0.78 – 1.41)	1.01 (0.71 – 1.43)	0.79 (0.32 – 1.94)	0.69 (0.27 – 1.73)	1.19 (0.80 – 1.54)
		1.20 (0.92 – 1.56)	0.48 (0.15 – 1.56)	1.20 (0.92 – 1.57)	1.28 (0.71 – 2.30)	1.28 (0.73 – 2.27)
	2	1.33 (0.89 – 2.00)	1.04 (0.73 – 1.49)	**0.33 (0.12 – 0.98)***	0.54 (0.19 – 1.45)	1.17 (0.82 – 1.66)

Table 8.6 continues

Medication use						
corticosteroids						
		0.99 (0.86 – 1.14)	1.28 (0.59 – 2.78)	0.98 (0.86 – 1.11)	1.04 (0.74 – 1.46)	1.09 (0.78 – 1.53)
	0	1.03 (0.84 – 1.25)	1.08 (0.85 – 1.37)	1.13 (0.60 – 2.09)	1.06 (0.54 – 2.07)	1.05 (0.86 – 1.29)
		1.02 (0.88 – 1.21)	1.43 (0.64 – 3.19)	1.02 (0.88 – 1.20)	1.12 (0.78 -1.61)	1.17 (0.81 – 1.68)
	1	1.01 (0.82 – 1.24)	1.07 (0.84 – 1.36)	1.26 (0.65 – 2.44)	1.18 (0.59 – 2.37)	1.03 (0.84 – 1.27)
		1.12 (0.92 – 1.36)	1.27 (0.52 – 3.12)	1.08 (0.89 – 1.30)	1.09 (0.75 – 1.61)	1.12 (0.76 – 1.65)
	2	1.11 (0.87 – 1.41)	1.07 (0.84 – 1.37)	1.00 (0.42 – 2.35)	1.10 (0.50 – 2.45)	1.05 (0.85 – 1.31)
β_2-agonist						
		1.17 (0.81 – 1.69)	1.67 (0.29 – 11.73)	1.09 (0.78 – 1.54)	1.04 (0.74 – 1.46)	1.00 (0.33 – 3.03)
	0	1.37 (0.81 – 2.31)	1.39 (0.76 – 2.53)	0.77 (0.16 – 3.78)	1.06 (0.54 – 2.07)	1.34 (0.76 -2.35)
		0.97 (0.63 – 1.49)	0.95 (0.11 – 7.81)	0.92 (0.61 – 1.38)	1.12 (0.78 – 1.61)	1.17 (0.82 – 1.68)
	1	1.47 (0.87 – 2.49)	1.47 (0.81 – 2.68)	0.48 (0.08 – 2.80)	1.18 (0.59 – 2.38)	1.03 (0.84 – 1.27)
		1.07 (0.64 - 1.79)	0.62 (0.05 – 737)	0.97 (0.59 – 1.59)	1.09 (0.75 – 1.62)	1.12 (0.76 – 1.65)
	2	1.62 (0.88 – 2.98)	1.49 (0.82 – 2.72)	0.35 (0.03 – 0.96)	1.10 (0.50 – 2.46)	1.05 (0.84 – 1.31)

NO_x: oxides of nitrogen; O_3: ozone; SO_2: sulphur dioxide. #: Data were obtained from South African Weather Services. *: $p<0.05$. ǂ: a mix model was used with random intercept and fixed slope and autoregressive covariate structure adjusted for daily mean temperature, relative humidity, day of the week.

8.5 Discussion

The findings of this study showed significant association between short-term gaseous air pollution exposure and respiratory health outcomes in children residing in a community situated near mine dump, despite the fact that the daily ambient pollutants concentration were all well below Air Quality Standards set by the World Health Organization and South African Department of Environmental Affairs. These findings suggest that the currently accepted air pollution standards for public safety should be revisited. Concentrations of NO_x, O_3, and SO_2 were significantly associated with decrements with FEV1, NO_x and O_3 had stronger effects. NO_x is considered to be a good marker of traffic-related air pollution.[20] The community included in the study is located near a busy highway, indicating that traffic is also a major contributor of ambient air pollution in this area. A cross-sectional study conducted in South Africa showed that heavy truck was a risk factor for asthma symptoms in communities located nearby mine dumps than those far away.[16] All children in the study area are exposed to the ambient air pollution, resulting in a large number of children affected. Suppose that there is a population distribution of asthma severity and of sensitivity to air pollution, children with increased vulnerability to air pollution would be more likely to experience exacerbated asthma attacks on low or high air pollution days.[21,22]

A recent systematic review showed the negative impact of the short-term effects NO_2 on respiratory health in children with asthma, NO_2 showed statistically significant associations with asthma symptoms when considering all possible lags[23] and decrements in lung function.[13,24,25] These findings are in contrast to those of this study, although NO_2 had the strongest effect on chest tightness and not for all the lags. The effects of SO_2 on the lung function of the asthmatics are well documented by research studies[26–28] In this study SO_2 was associated with asthma symptoms but improved lung function. In addition, two pollutant models indicated that SO_2 effect were not strong on the lung function. Due to various socio-economic reasons and high employment rate in South Africa, many households use paraffin and open fires for residential heating or cooking as alternative sources of energy as they are more affordable than electricity[29] and this might contribute immensely to the SO_2 indoor and outdoor air pollution in this area. These findings are supported by the International study of Asthma and Allergies in Childhood that was conducted in communities that are located in close proximity to mine dumps in South Africa.[20] However, it could not be explained as to why SO_2 had improved FEV1. Summer pollution is quantitatively different from winter air pollution, O_3 levels are higher and air pollution mixture is strongly influenced by photochemical reaction. Although this study was conducted in winter, high concentration of O_3 was observed and consistently associated with decrements in lung function and use of asthma medication. There were no significant associations observed between FEV1 and $PM_{2.5}$ and PM_{10}. Nevertheless, $PM_{2.5}$ decreased FEV1. Ambient particulate matter is one the environmental risk factor that has been associated with respiratory morbidity.[28,30–32] The major effect of ambient particulate matter on the pulmonary system is the exacerbation of inflammation, mainly on vulnerable individuals. One of the mechanisms by which ambient particulate matter exerts its pro-inflammatory effects is the generation of oxidative stress by its chemical compounds. The particulate matter-induced oxidative stress include inflammation.[33,34]

8.6 Study limitation

First, it was assumed that personal exposure to ambient air pollutants could be characterised using the measurements of one fixed measurement site, and therefore it may have caused an underestimation of the effect. Second, no quantitative indoor air pollution exposure assessment was conducted; only children living in smoke-free homes were included. Third, days when an individual spent outside the study area were not included in the analyses to avoid misclassification of exposure. Fourth, the forced vital capacity manoeuvre for necessary for the FEV1 measurement was observed only during the training periods. Increased variability of the test could have reduced the power to detect true association with ambient air pollutants.

8.7 Study strengths

The strength of this study is that adverse biological effect on the lungs from low levels ambient air pollutants on a small number of study participants was observed. The generalizability of the results may be restricted to Noordgesig, because of the different composition of air pollutants caused by different sources in other communities.

8.8 Conclusion

The findings of this study provide evidence that an acute change of gaseous air pollutants in communities situated near mine dumps exacerbates lung function in vulnerable children.

8.9 Conflict of interest

None declared

8.10 Ethical considerations

Ethical approval (number: 235/2011) was obtained from the Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria, and Gauteng Department of Education (number: D2012/79). School principals and governing bodies were approached and gave their consent for the study. Parents or guardians of participants were sent a letter explaining the details and nature of the study. All information was kept confidential. Anonymity was maintained and the names of the participants were not recorded

8.11 Contributors

VN and KV participated in the design of the study, data collection, statistical analysis and interpretation of the results, drafted and critically revised the manuscript. GH and JW participated in the statistical analysis and interpretation of the results, drafted and critically revised the manuscript. All authors have read and approved the final manuscript.

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9. Chapter 9: Acute respiratory health effects of air pollution on asthmatic adolescents residing in a community close to East Rand Proprietary Mine dump in South Africa: Panel study

9.1 Abstract

Background: Air pollution has been known as one of the important contributor to the exacerbation of asthma symptoms. However, evidence is limited in South Africa, especially in communities exposed to dust from mine dumps.

Aim: The study investigated the association between acute changes in lung function and ambient air pollutants on asthmatic children in Reiger Park, Gauteng, South Africa.

Methods: A panel study design with repeated measures was used to carry-out the investigation which involved 25 asthmatic children. Each participating child completed an asthma daily symptom diary and performed forced expiratory flows in the morning and at bedtime for 21 consecutive days. The 24 h ambient air pollution concentrations were monitored over this period. Linear mixed effect models adjusted for temperature, relative humidity, day of the week, first order autocorrelation and 1µg.m^{-3} increase of the mean of pollutant concentrations were used to determine the association between morning FEV1 and ambient air pollutants. The association between air pollutants, respiratory symptoms and asthma medication use were evaluated with logistic mixed effect models

Results: The mean 24-hour concentration of SO_2 of the current day was significantly associated with the morning FEV1 decline of 58.534% (95% CI: 17.012 – 100.061). Single pollutant models showed that wheeze (OR = 1.77; 95% CI: 1.12 – 2.78) and medication use such as short-acting β_2 agonist (OR = 2.93; 95% CI: 1.14 – 7.53) were significantly associated with NO_2 and respectively. A significant association between chest tightness and $PM_{2.5}$ was also observed (OR = 1.26; 95% CI: 1.02 – 1.55).

Conclusion

The findings of this study provide evidence that an acute change of gaseous and particulate matter air pollutants in communities situated near mine dumps exacerbates lung function among the asthmatics children.

Keywords: Mine dumps, panel study, respiratory effects, asthma, Reiger Park, South Africa.

9.2 Introduction

Adverse respiratory effects of air pollution on the asthmatic children have been reported by research studies.[1–6] The majority of epidemiological studies in South Africa have studied particulate matter air pollution from traffic-related pollutants, petrochemical refinery environment, silicon smelting and automobile industry.[7–10] However, mine dumps which are a significant source of ambient air pollution in the surrounding communities have not been studied.[11–13] The dust consists of particulate matter measured in fractions of $\leq$ 10 µm (PM_{10}) and $\leq$ 2.5 µm ($PM_{2.5}$) in diameter.[14–16] These particulate matters have been linked with the cause or exacerbation of asthma symptoms among children.[17–21] The exposure assessment study conducted in a community around mine dump during a dry windy season showed that the dust air pollution levels, can be 20 times higher than the recommended 24-hour limit value suggested by the South African Department of Environmental Affairs.[12] Settle-able just often have negative effect on visibility when dust plumes forms, while its deposition on fabrics, house, vehicles and water constitute irritation.[11] New residential developments are now at the base of the mine dump, this might result in more children being exposed to dust from mine dumps which rich in silica and has been linked to air flow obstruction in and respiratory diseases.[22]

No studies have investigated whether air pollution as the result of mine dumps pose an increased risk for children who are asthmatic. This study is part of the larger project initiated by Mine Health Safety Council of South Africa (MHSC) around communities located near mine dumps in Gauteng and North West, South Africa. This study is, to the best of our knowledge the first study that has investigated the acute effects of air pollution on asthmatic children who are residing in a community located near mine dump in South Africa. The aim of the study was to investigate the association between acute changes in lung function and ambient air pollutants on asthmatic children in Reiger Park, Gauteng, South Africa.

9.3 Methods

9.3.1 Study population

The study was conducted in Reiger Park, Gauteng, South Africa. Reiger Park Township is located near the mine dump. Children with asthma were identified from a self-administered questionnaire survey based on the International Study of Asthma and Allergies in Childhood (ISAAC).[18] The ISAAC study was conducted in the previous year, the study included 600 secondary school children in Reiger Park.[16]

For the present study, children who had given a positive response to the question "Has a doctor/physician ever told you that you had asthma?" and whose parent or guardian had agreed to be contacted about future research were selected. Twenty five asthmatic children between 13 and 14 years old and lived in homes without cigarette smoke participated in the study. The institutional review board of the participating school approved the study protocol. The parent or guardian of each child gave a written informed consent before the child could participate in the study.

9.3.2 Study design

A panel study design with repeated measures was used to carry-out the investigation which involved 25 asthmatic children. Each participant completed an asthma symptom daily diary, and performed forced expiratory flows in the morning and at bedtime for 21 consecutive days. Children were studied in a dry season from 18 August to 8 September 2013.

9.3.3 Air pollution monitoring

Citywide background air pollution hourly levels were obtained by using an AEROQUAL mobile ambient air monitoring station, upwind from the prevailing winds. The mobile ambient air monitoring station is part of the University of Pretoria, provided hourly levels of nitrogen dioxide (NO_2), particulate matter less than 2.5 ($PM_{2.5}$) in diameter and sulphur dioxide (SO_2). Weather data including temperature and relative humidity were also collected using AEROQUAL mobile ambient air monitoring station.

9.3.4 Lung function assessment

Forced expiratory volumes in 1 second (FEV1) were measured using a pocket electronic flow meter (Piko-1). Each participant was trained to use Piko-1. The training also included the proper positioning during the use of (Piko-1), breathing techniques and maintenance of the instrument. Participants were instructed to perform the FEV1 maneuver in the standing position three times in the morning and three in the evening prior use of breathing medication. For each participant the mean morning FEV1 was calculated. Percentage morning FEV1 decrements variability was expressed as 100 % × (individual morning FEV1 measured on that day – individual mean of morning FEV1 throughout the study period)/ individual mean of morning FEV1 throughout the study period.

9.3.5 Diary cards

All study participants were issued with asthma daily diary cards to record the presence of asthma symptoms and medication use such as breathlessness, chest tightness, cough, wheeze, short-acting β_2 agonist, inhaled corticosteroids and other asthma medication use on the daily diary for the entire duration of the study.

9.3.6 Statistical analyses

All statistical analyses were performed using SAS statistical software package version 9.4. Prevalence of health outcomes were calculated by dividing the number of participants who recorded the presence of asthma symptoms divided by number of completed diaries. Daily mean concentration of ambient pollutants, temperature and relative humidity were calculated by adding the hourly levels and dividing by 20 hours per day. Pearson correlation coefficients were estimated to better understand their interrelationship between air pollutants and weather variables.

The results obtained from linear mixed effect models were expressed as the percentage morning FEV1 decrements corresponding to 1µg.m^{-3} increase in air pollutants concentration. Autoregressive covariance structure (AR1) was used to allow for a greater within-subject autocorrelation for FEV1 measures taken more closely in time. A random intercept and fixed slope was assumed. The effect of air pollutants concentration for current day (lag 0) exposure on lung function, asthma symptoms and asthma medication use were analysed separately.

The association between air pollutants, respiratory symptoms and asthma medication use were evaluated with logistic mixed effect models. The final models with outcome variables controlled for daily mean temperature, relative humidity and day of the week for both linear and logistic mixed effect are reported in this study. The p-value < 0.05 obtained in both models was deemed statistically significant.

9.4 Results

9.4.1 Demographic characteristics

A total of 25 pupils participated in the study, 60% were females and 40% males with the mean age of 13 years. All participants that were included in the study had a history of “doctor-diagnosed of asthma”. Of the participants, the mean morning FEV1 was 2.47. During the study period, 24% reported to have use inhaler corticosteroids, 60% short-acting β_2 agonist, 4% other asthma medication and 12% no asthma medication during the period on the study. The prevalence of respiratory symptoms reported by children during the study was breathless (64%), chest tightness (48%), cough (76%) and wheeze (72%).

Table 9.1: Demographic characteristics of the 25 participating children, by period of study in Reiger Park (Gauteng, South Africa) in 2013

	Study period	
Characteristics	**August 18-September 08**	**% (n)**
Sex		
Female		60 (15)
Male		40 (10)
Age (years)		
Age; mean (SD)*		13 (0.4)
Height (m)		
Height; mean (SD)*		1.4 (0.2)
Weight (kg)		
Weight; mean (SD)*		52.6 (17.6)
BMI **(kg/m^2)**		
BMI; mean (SD)*		24 (5.6)
Respiratory symptoms prevalence during the study period		
Breathlessness		64 (15)
Chest tightness		48 (12)
Cough		76 (19)
Wheeze		72 (18)

Table 9.1 continues

Medication use during the study period	
Inhaled corticosteroid	24 (6)
Short-acting β_2-agonist	60 (15)
Other asthma medication	4 (1)
No asthma medication	12 (3)
MFEV1‡; mean (SD)*	2.47 (0.35)

Figures in parentheses are the number of participants unless otherwise stated.
*SD: Standard deviation
‡MFEV1: Morning forced expiratory volume in 1 second

9.4.2 Air pollution

The study was conducted from the end of August to early September 2014, encompassing a dry and windy season in South Africa. The mean 24-hour concentrations of air pollutants were well below the South African Air Quality Standards set by the Department of Environmental Affairs (Table 9.2). SO_2 and NO_2 remained stable over the study period (Figure 9.1). A significant negative correlation was observed between $PM_{2.5}$ and NO_2, $r = -0.46$ ($p = 0.021$) (Table 9.3).

Table 9.2: Distribution of the daily 24-h mean concentrations of selected outdoor air pollutants and meteorological characteristics in Reiger Park between 18 August and 08 September 2013

Pollution/weather variables#	Days (n)	Mean ± SD (range)	25th percentile	Median	75th percentile	Interquartile range
NO_2 (ppb)	21	0.63 ± 0.73 (0.02 – 2.81)	0.17	0.35	0.84	0.67
$PM_{2.5}$ (µg/m^3)	21	27.31 ± 9.36 (14.96 – 57.07)	21.83	24.35	35.35	13.52
SO_2 (ppb)	21	2.34 ± 2.33 (0.02 – 10.29)	1.10	1.54	2.85	1.75
Relative humidity (%)	21	34.38 ± 11.46 (20.24 – 62.20)	25.28	31.94	40.14	14.86
Temperature (^{o}C)	21	20.06 ± 3.52 (10.54 – 29.71)	18.05	20.94	21.68	3.63

NO_2: nitrogen dioxide; O_3: ozone; $PM_{2.5}$: particulate matter <2.5 µm in diameter; SO_2: sulphur dioxide. #: Data were obtained by AEROQUAL mobile monitoring station.

Table 9.3: Pearson's correlation coefficients for the pollutants (daily means) and meteorological characteristics in Reiger Park between 18 August and 08 September 2013

Pollutants/weather variables	Pearson correlation coefficients					
	NO_2	O_3	$PM_{2.5}$	SO_2	Relative humidity	Temperature
NO_2 (ppb)	1.00					
$PM_{2.5}$ (µg/m^3)	-0.46*	-0.21	1.00			
SO_2 (ppb)	0.32	-0.13	-0.28	1.00		
Relative humidity (%)	0.63	-0.13	0.01	-0.17	1.00	
Temperature (^{o}C)	0.31	0.14	-0.33	-0.14	0.03	1.00

*: $p<0.05$; NO_2: nitrogen dioxide; O_3: ozone; $PM_{2.5}$: particulate matter <2.5 µm in diameter; SO_2: sulphur dioxide.

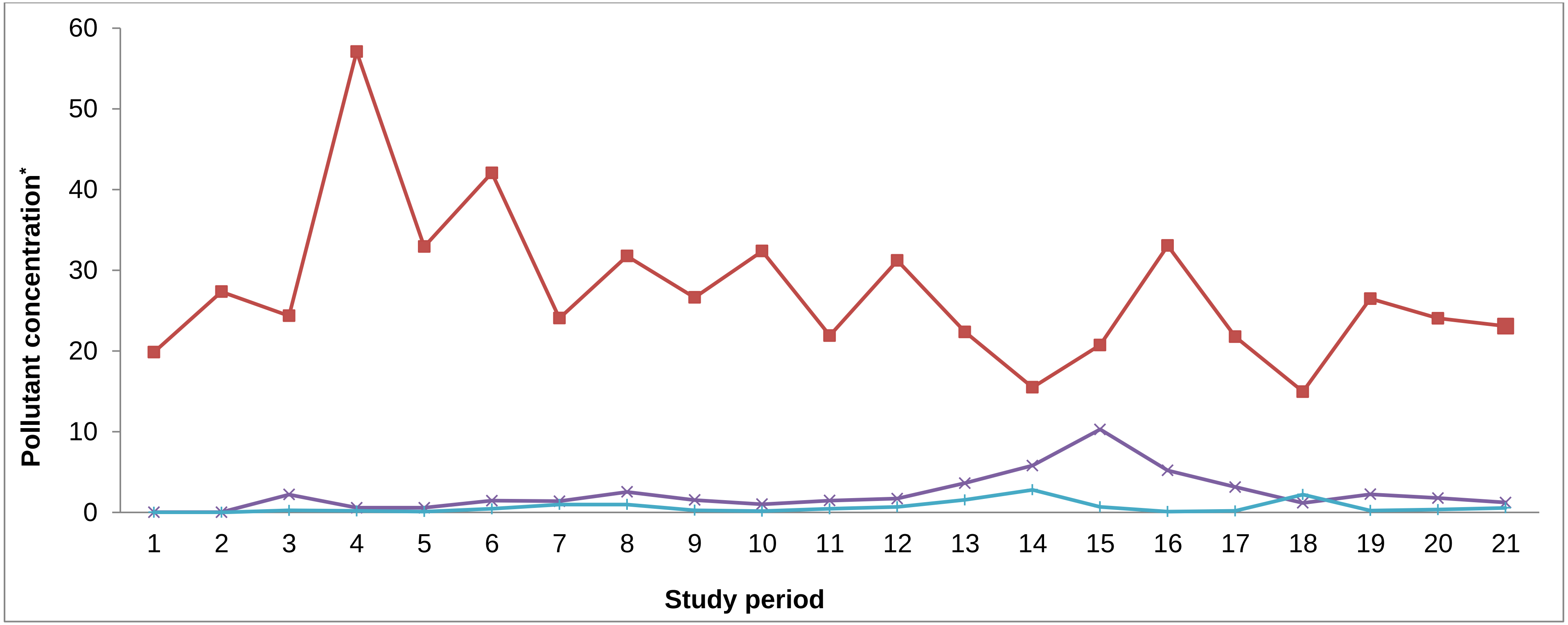

Figure 9.1: The 24-h mean concentration of air pollutants during the study period 18 August to September 08, 2013, in Reiger Park, Gauteng, South Africa

Legend: ■: Particulate matter <2.5µm in diameter; x: Nitrogen dioxide; +: sulphur dioxide, * all pollutant concentrations are expressed in ppb except $PM_{2.5}$ which is in µg/m^3.

9.4.3 Pollutant and FEV1 % change

The mean 24-hour concentration of SO_2 of the current day (lag 0) was interestingly associated with the morning FEV1 improvement of 58.534% (95% CI: 17.012 – 100.061). The NO_2 [4.964%; 95% CI: (-12.570 – 2.640)] and $PM_{2.5}$ [1.574%; 95% CI: (-5.904 – 2.756) were associated with the decline in lung function, although no significant relationship was observed (Table 9.4).

Table 9.4: The effects of pollutants on morning forced expiratory volume in 1 second (MFEV1) expressed as percentages among children with asthma between 18 August and 08 September 2013

Pollutants#	FEV 1 % change+	95% CI	p-value
Single pollutant models			
NO_2:			
Lag 0	-4.964	-12.570 – 2.640	0.200
$PM_{2.5}$:			
Lag 0	-1.574	-5.904 – 2.756	0.475
SO_2:			
Lag 0	58.534	17.012 – 100.061	0.006*

NO_2: nitrogen dioxide; $PM_{2.5}$: particulate matter <2.5 µm in diameter; SO_2: sulphur dioxide. #: Data were obtained by using AEROQUAL mobile ambient air monitoring station. *: $p<0.05$. +: FEV1 % change = 100 % x (individual morning FEV1 measured on that day – individual mean of morning FEV1 throughout the study period)/ individual mean of morning FEV1 throughout the study period. A mix model was used with random intercept and fixed slope and autoregressive covariate structure adjusted for daily temperature, relative humidity, day of the week, sex, age and body mass index.

9.4.4 Pollutant models and health outcomes

For asthma-related symptoms and medication use for 21 days study period, single pollutant models revealed significant associations between NO_2 and wheeze (OR = 1.77; 95% CI: 1.12 – 2.78) and the use of short-acting β_2 agonist (OR = 2.93; 95% CI: 1.14 – 7.53). A significant association between $PM_{2.5}$ and an asthma symptom such as chest tightness was observed (OR = 1.26; 95% CI: 1.02 – 1.55).

Table 9.5: The effects of pollutants on respiratory symptoms among children with asthma in Reiger Park between 18 August and 08 September 2013

	Lag days	NO_2	$PM_{2.5}$	SO_2
Respiratory symptoms				
Breathlessness	0	1.31 (0.89 – 1.92)	0.87 (0.71 – 1.08)	1.09 (0.89 – 1.36)
Chest tightness	0	1.40 (0.92 – 2.13)	**1.26 (1.02 – 1.55)***	0.89 (0.71 – 1.09)
Cough	0	0.79 (0.50 – 1.25)	0.98 (0.77 –1.23)	0.99.(0.78 – 1.28)
Wheeze	0	**1.77 (1.12 – 2.78)***	0.68 (0.51 – 1.90)	1.01 (0.75 – 1.32)
Medication use				
corticosteroids	0	1.61 (0.89 – 2.92)	0.85 (0.65 – 1.11)	1.03 (0.76 – 1.36)
Short –acting β_2-agonist	0	**2.93 (1.14 – 7.53)***	0.76 (0.29 – 1.05)	0.69 (0.44 – 1.09)

NO_2: nitrogen dioxide; $PM_{2.5}$: particulate matter <2.5 µm in diameter; SO_2: sulphur dioxide. #: Data were obtained by using AEROQUAL mobile ambient air monitoring station. *: $p<0.05$. +: FEV1 % change = 100 % x (individual morning FEV1 measured on that day – individual mean of morning FEV1 throughout the study period)/ individual mean of morning FEV1 throughout the study period. A mix model was used with random intercept and fixed slope and autoregressive covariate structure adjusted for daily temperature, relative humidity, day of the week, sex, age and body mass index.

9.5 Discussion

The findings of this study showed significant association between short-term gaseous and particulate matter air pollution and respiratory health outcomes in children residing in a community situated near mine dump, despite the fact that the daily ambient pollutant concentrations were all well below by the South African Air Quality Standards set by the World Health Organization and the Department of Environmental Affairs. These findings suggest that the currently accepted air pollution standards for public safety should be revisited. Collaborative effort between the mining companies and government is needed to reduce air pollution in the affected communities. In this study, NO_2 was significantly associated with wheeze and use of asthma medication such as short-acting β_2-agonist. NO_2 is a ubiquitous atmospheric pollutant due to wide spread prevalence of both of natural and man-made sources, and it can be a respiratory irritant when inhaled.[24,25] Man-made NO_2 emission are derived from fossil fuel burning.[24] Although many houses are electrified in South Africa; research studies has shown that communities located near mine dumps are of low socio-economic status and depend on gas, paraffin, coal and open fires as the main residential heating or cooking fuel type.[26–28] These fuel types are the major source of $NO_{2.}$ This suggest that children in living in these communities exposed to more than one source of air pollution. Persons suffering from respiratory disease, especially asthma are sensitive to NO_2 even at lower concentration levels.[29–32] The findings of this study are consistent with other studies that were conducted in other parts of world.[33–35] NO_2 was also associated with the asthma medication as a result of reduced lung capacity this is similar to other studies.[36–38]

Ambient particulate matter is an environmental risk factor that has been associated with increased respiratory morbidity and mortality.[39–42] One of the major effect of particulate matter on the respiratory system is the exacerbation of inflammation, especially among the asthmatics. One of the ways that particulate matter exerts its pro-inflammatory effects is through the generation of oxidative stress by its chemical compounds and metals, this subsequently lead to a susceptible individual to experience asthma symptoms.[17] Mine dumps are the source of ambient particulate air pollution and has been a source of concern to the population in the nearby communities.[11,12] The findings of this suggest that the particulate matter from the mine dumps might have a negative impact on the respiratory health of the asthmatic individuals.

9.6 Study limitations

First, mobile air monitoring station with few sensors was used; thus other gaseous and particulate matter could not be monitored. Second, it was assumed that personal exposure to ambient air pollutants could be characterised using the measurements of one fixed measurement site, and therefore it may have caused an underestimation of the effect. Third, no quantitative indoor air pollution exposure assessment was conducted; only children living in smoke-free homes were included. Fourth, days when an individual spent outside the study area were not included in the analyses to avoid misclassification of exposure. Fifth, the forced vital capacity maneuver for necessary for the FEV1 measurement was observed only during the training periods. Increased variability of the test could have reduced the power to detect true association with ambient air pollutants.

9.7 Study strengths

The strength of this study is that adverse biological effect on the lungs from low levels ambient air pollutants on a small number of study participants was observed. The generalizability of the results may be restricted to Reiger Park, because of the different composition of air pollutants caused by different sources in other communities.

9.8 Conclusion

The findings of this study provide evidence that an acute change of gaseous and particulate matter air pollutants in communities situated near mine dumps exacerbates lung function in vulnerable children.

9.9 Conflict of interest

None declared

9.10 Ethical considerations

Ethical approval (number: 235/2011) was obtained from the Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria, and Gauteng Department of Education (number: D2012/79). School principals and governing bodies were approached and gave their consent for the study. Parents or guardians of participants were sent a letter explaining the details and nature of the study. All information was kept confidential. Anonymity was maintained and the names of the participants were not recorded.

9.11 Contributors

VN and KV participated in the design of the study, data collection, statistical analysis and interpretation of the results, drafted and critically revised the manuscript. JW participated in the statistical analysis and interpretation of the results, drafted and critically revised the manuscript. All authors have read and approved the final manuscript.

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10. Chapter 10: Conclusion and recommendations

10.1 Background

The study reported here was conducted in Gauteng and North West, South Africa in communities located near six mega gold mine dumps. This is the first study that was conducted in these areas using ISAAC and ATS methodology. Three previous South African studies applied the ISAAC methodology; one in ekuRhuleni, Gauteng Province, a heavily industrialised urban area; the second one in Cape Town, Western Cape Province, an industrialised coastal city; and the third one in Polokwane, Limpopo Province.[1–3] To the best of our knowledge, no previous study has applied the ATS methodology in South Africa. Mine dumps are the source of air pollution in these communities;[4–7] the dust consists of particulate matter that can be inhaled and deposited inside the lungs. The exposure assessment study conducted in one of the mine dumps in this study showed that PM_{10} levels exceeded by far the 24-hour limit set by the South African Department of Environmental Affairs.[8,9] It is estimated that 1.6 million people live in informal and formal settlements on or directly next to the mine dumps in South Africa,[10,11] and with new residential developments encroaching the base of the mine dumps, the increasing population in these areas will potentially add to the burden of respiratory diseases in South Africa. The ongoing reclamation of mine dumps for gold recovery observed during the survey is worsening dust pollution and that leads to further deterioration of ambient air quality in the study areas. Many epidemiological studies have linked the negative effects of air pollution to respiratory health.[12–18] It was justifiable to conduct research in these communities, as they are faced with a unique air pollution source that is dust from gold mine dumps.

10.2 Main findings

The aim of the study was to investigate whether the prevalence of respiratory symptoms and diseases among adolescents (13 to 14 year old children) and the elderly (55 years old and above) was associated with community proximity to mine dumps. This thesis describes:

- The reliability of the respiratory symptom questionnaire developed by the American Thoracic Society – Division of Lung Diseases (ATS – DLD – 78) among the elderly (55 years and above) residing in a community close to mine dumps in South Africa.
- The prevalence of respiratory symptoms and disease (asthma) among adolescents (13 to 14 year old), residing in communities close to mine dumps in South Africa.
- The prevalence of chronic respiratory symptoms and diseases among the elderly (55 years and above), residing in communities close to mine dumps in South Africa.
- The association between comorbidity of respiratory and cardiovascular diseases and proximity to mine dumps among the elderly.
- Comparison between the indoor and outdoor air pollution in exposed and unexposed schools in South Africa.

- The acute changes in lung function with ambient air pollutants on asthmatic children (13 to 14 year old).

Chapter 3 focused on testing the reliability (internal consistency) of the modified ATS-DLD-78 adult respiratory diseases questionnaire developed by the British Medical Research Council, among the elderly residing in a community near a mine dump. Epidemiological research studies in South Africa have used self-administered modified standard questionnaires to study the respiratory and cardiovascular diseases, but do not mention whether the questionnaire used was tested for reliability or not. [19,20] The ATS-DLD-78 questionnaire was found to be a reliable instrument for data collection, and it is also a useful tool that can be used for collecting data in a developing country. The findings of this chapter were in agreement with other worldwide studies that have piloted the ATS-DLD-78 questionnaire[21,22]

Chapter 4 investigated whether exposure to dust from mine dumps or living in close proximity to mine dumps pose an increased risk for existing asthma, asthma symptoms (i.e. wheeze) and rhinoconjunctivitis among adolescents; whether this exposure is involved in the development of these health outcomes or whether there is effect modification between various air pollution sources, including mine dump dust. The findings of this chapter suggested that there was a higher prevalence of current wheeze and rhinoconjunctivitis in exposed than unexposed communities. The prevalence of asthma in exposed communities was consistent with earlier studies conducted in South Africa.[3,19,23,24] However, high prevalence of current wheeze and rhinoconjunctivitis was observed as compared to other studies conducted in the industrialised cities of Cape Town and Polokwane, South Africa.[2,25] Residing in exposed communities was significantly associated with an increased risk of current wheeze and rhinoconjunctivitis among adolescents.

The association between community proximity to mine dumps and prevalence of chronic respiratory symptoms and diseases in people aged 55 years and older was investigated in chapter 5. Elderly persons living in exposed communities had a significantly higher prevalence of chronic respiratory symptoms and diseases than those that were unexposed. Residing in exposed communities, current smoking, ex-smoking, use of paraffin as main residential cooking/heating fuel and low level of education emerged independent significant risk factors for chronic respiratory symptoms and diseases.

To add to the complex story of chronic respiratory symptoms, diseases and community proximity to mine dumps. Detrimental associations between comorbidity of respiratory and cardiovascular diseases and community proximity to mine dumps were observed among the elderly in chapter 6.

Chapter 7 outdoor PM_{10} and SO_2 exposure levels in exposed and unexposed schools were compared. The average level of outdoor PM_{10} and SO_2 were high in exposed schools. This chapter also examined exposure of asthmatic children to indoor respirable dust at exposed and unexposed schools. Indoor respirable dust in the classroom differed significantly between exposed and unexposed children at each school. The indoor respirable dust levels in the exposed schools could have an impact on children with asthma.

Chapter 8 and 9, panel study designs with repeated measures were used to carry out investigations which involved asthmatic children to determine the acute changes in lung function and ambient air pollutants in Noordgesig and Reiger Park, Gauteng, South Africa. The findings of these chapters provided evidence that an acute change of gaseous air pollutants in Noordgesig and Reiger Park and particulate matter in Reiger Park exacerbated lung function in vulnerable children.

10.3 Potential bias and limitations

The study has additional limitations inherent to cross-sectional epidemiological study designs: (*i*) it cannot provide any evidence of causality; and (*ii*) it relied on doctor diagnosed respiratory and cardiovascular diseases, which, although specific, can under estimate disease prevalence. It is therefore assumed that several individuals with respiratory and cardiovascular diseases were missed as a result of restrictive definitions employed in this study or poor access to healthcare facilities. The possibility of estimating falsely low prevalence figures cannot be ignored. However, the observed high prevalence of respiratory and cardiovascular diseases in exposed communities cannot be attributed only to the strict definition used, but is also likely to be due to a complex interaction of social, economic, and behavioural factors such as air pollution, undernutrition, poor access to healthcare or lifestyle behaviours. Further limitations are that: (*iii*) interviewer error may have occurred during translation of the questions into the local language during interviews with study participants who did not understand English; (*iv*) unwillingness of the respondents to provide honest answers, or giving socially desirable responses, should be taken into account in the interpretation of results; and (*vi*) no data were collected on possible reasons for declining to take part – the differential participation rate between exposed and unexposed communities is of concern and may well have introduced response bias, which is likely to overestimate the prevalence estimates derived from the answers and bias the association in either direction; *(vii)* data on the video questionnaire, which were believed to be more specific for asthma among adolescents, were not included in the analysis, as the questionnaire could not be completed in some schools, due to logistical problems such as unavailability of electricity, challenges of moving audiovisual equipment from class to class, or lack of a suitable venue where the children could watch the video; *(vii)* the results of this study showed lower for inhaled short-acting β_2-agonist and higher for inhaled corticosteroids. This observation might be explained by the fact that the study participants comprised of more severely affected asthmatics that were using anti-inflammatory medication regularly; *(viii)* was assumed that personal exposure to ambient air pollutants could be characterised using the measurements of one fixed measurement site, and therefore it may have caused an underestimation of the effect; *(ix)* no quantitative indoor air pollution exposure assessment was conducted, only children living in smoke free homes were included; *(x)* days when an individual spent outside the study area were not included in the analyses to avoid misclassification of exposure; *(xi)* the forced vital capacity maneuver necessary for the FEV1 measurement was observed only during the training periods, and increased variability of the test could have reduced the power to detect true association with ambient air pollutants.

10.4 Study strengths

Despite the limitations discussed in 10.4, there are areas of strength that should be recognised: *(i)* the study used a validated ISAAC questionnaire among the adolescents, the ISAAC core questionnaires have been used extensively worldwide in studies of childhood asthma, and the study had a large sample of more than 3500 children as required by ISAAC centres, which increased the statistical power for the study, *(ii)* a previously validated ATS questionnaire was also used among the elderly people, 10% study participants were interviewed twice resulting in 96% repeatability, *(iii)* The findings of this study provided evidence that an acute change of gaseous and particulate air pollutants in the atmosphere in communities situated near mine dumps exacerbates lung function in vulnerable children.

10.5 Conclusion and recommendations for future studies

An association was observed between dust from gold mine dumps, respiratory symptoms and diseases among adolescents and the elderly. Current smoking, ex-smoking, use of paraffin as main residential cooking/heating fuel and low level of education emerged as independent significant risk factors for respiratory symptoms and diseases. Detrimental association between the comorbidity of respiratory and cardiovascular diseases among the elderly and community proximity to mine dumps was observed. Current policies and legislation by the Department of Environmental Affairs should be enforced to the mine companies to reduce air pollution emission. New long-term strategies to reduced air pollution should be researched and be implemented. The current implemented strategies such as spraying the mine dumps with water and planting grass in the mine dumps are not effective, because the grass quickly withers and mine dumps quickly absorb water during spraying and become dry again. A monitoring station to measure air pollution emitted by mine dumps should be placed around them by the mining companies to ensure compliance as stipulated in the Department of Environmental Affairs. We acknowledge that air pollution migration strategies may be costly; therefore, a combined effort by the mining companies and the government is necessary in order to address the challenge of environmental pollution. Mining companies should develop their own policies and regulations that will address the challenges of air pollution. It is also recommended that there should be collaboration between the affected communities and the mining companies, where the community members are invited to contribute in finding the solutions to mitigate air pollution. The people living in these communities should be made aware of the negative effects of dust from mine dumps on their respiratory and cardiovascular health. People in these communities should be given other protective measures by the mining companies e.g. dust masks to be worn during windy and high polluted days. The results of this study showed also that besides the home, school is another environment where children are exposed to high levels of air pollution and that acute change of gaseous air pollutants in the atmosphere as a result of burning of fossil fuels exacerbate lung function in vulnerable children. Many South African households still rely on biomass fuel, gas and paraffin as an alternative source of energy. It is recommended that the country should promote and encourage the use of cleaner energy such as solar energy, which is cost effective compared to the expensive and ever rising cost of electricity. South Africa is currently facing the challenges of shortage of power and the electricity outages are common as part of the load-shedding plan introduced by the government. More and more people are resorting to the use of fossil fuels as a source of energy; this may increase the prevalence on respiratory symptoms and diseases among the vulnerable people such as children and the elderly. The study will contribute to existing literature because very little data is available about the prevalence of respiratory symptoms and diseases in Gauteng and North West, South Africa. The findings of this study provide evidence and add to the current body of knowledge that a community's proximity to a mine dump is associated with an increased risk of respiratory symptoms and diseases among the children and the elderly in South Africa. The results of this study will also serve as baseline data for future epidemiological studies in communities located near mine dumps in Africa and South Africa. A planned birth cohort study should be conducted in these communities where children would be followed over a period of time using daily respiratory symptoms and diseases dairy records in which they record peak expiratory flow rates simultaneously with ambient air monitoring. Cohort studies with larger sample sizes are known to give more support to the strength of the association between the exposure and health. Time series studies should be conducted in the exposed and unexposed areas to contrast both indoor and outdoor air population levels in dry and wet seasons and repeated for longer duration, in order to get enough data to further the correlation of health outcomes and exposure to air pollutants.

10.6 Future perspective

The results of this thesis have been shared to the Mine Health Safety Council of South Africa. It is the intension of the author of this thesis to follow up on the recommendations of this work and use this work to foster more collaborative work with scientists in the area of air pollution as the problem is likely to affect future generations. Epidemiological studies of ambient air pollution should utilise high quality exposure modelling to separate the health effects of different types and sources of air pollution. The researcher planning to pursue a postdoctoral study that will focus on the distribution and spatial modelling of gold mine dust particles. This approach will give an insight about the extent of exposure and air pollution in the atmosphere as result of mine dump dust. In addition, longitudinal exposure assessment studies will be conducted in these areas. This will be done in collaboration with the University of Kyoto. High tech air monitoring stations will be provided by the University of Kyoto. The results from the longitudinal studies will lead to the establishment of policy framework for the mining companies pertaining to the mine dust air pollution.

10.7 References

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Appendix 1: Letter of approval from the Academic Advisory Committee

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Denkleiers • Leading Minds • Dikgopolo tša Dihlalefi

Faculty of Health Sciences
School of Health Systems and Public Health

23 February 2016

Mr V Nkosi
24282788
PhD (Public Health)

Dear Mr Nkosi

Approval Academic Advisory Committee

This serves to confirm that your new title: ***Association between dust from gold mine dumps, respiratory symptoms and diseases among adolescents and the elderly in South Africa*** was served and approved via round robin on 23 February 2016.

You can now submit to ethics.

Sincerely

Prof S Feresu
Chairperson
SHSPH Academic Advisory Committee

cc Prof K Voyi

School of Health Systems and Public Health
University of Pretoria
Private Bag x323
Pretoria South Africa 0001

Tel Number +27 12 354 1472
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http://www.facebook.com/SHSPH

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Appendix 2: Letter of approval from the Research Ethics Committee

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 20 Oct 2016.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 22/04/2017.

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Faculty of Health Sciences Research Ethics Committee

21/04/2016

Approval Certificate
Amendment
(to be read in conjunction with the main approval certificate)

Ethics Reference No.: 235/2011

Title: Association between dust from gold mine dumps, respiratory symptoms and diseases among adolescents and the elderly in Gauteng and Northwest Provinces, South Africa

Dear Mr Vusumuzi Nkosi

The **Amendment** as described in your documents specified in your cover letter dated 15/04/2016 received on 19/04/2016 was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 20/04/2016.

Please note the following about your ethics amendment:

- Please remember to use your protocol number (**235/2011**) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committe may ask further questions, seek additional information, require further modification, or monitor the conduct of your research.

Ethics amendment is subject to the following:

- The ethics approval is conditional on the receipt of 6 monthly written Progress Reports, and
- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Professor Werdie (CW) Van Staden
MBChB MMed(Psych) MD FCPsych FTCL UPLM
Chairperson: Faculty of Health Sciences Research Ethics Committee

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

◆ Tel:012-3541330 ◆ Fax:012-3541367 Fax2Email: 0866515924 ◆ E-Mail: fhsethics@up.ac.za
◆ Web: http://www.up.ac.za/healthethics ◆ H W Snyman Bld (South) Level 2-34 ◆ Private Bag x 323, Arcadia, Pta, S.A., 0007

Appendix 3: Letter of approval from the Gauteng Department of Education

For administrative use:
Reference no. D 2016 / 412 A
Enquiries: Diane Buntting 011 843 6503

GAUTENG PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

GDE AMENDED RESEARCH APPROVAL LETTER

Date:	24 February 2016
Validity of Research Approval:	24 February 2016 to 30 September 2016
Previous GDE Research Approval letter reference number	D2012 / 79 dated 9 June 2011
Name of Researcher:	Nkosi V.
Address of Researcher:	Olympus; Rm No. D3-21; University of Pretoria; Hatfield; 0083
Telephone / Fax Number/s:	076 968 0522
Email address:	s24382788@tuks.co.za
Research Topic:	Association between dust from mine dumps, respiratory symptoms and diseases among adolescents and the elderly in South Africa
Number and type of schools:	FORTY Primary and FORTY Secondary Schools
District/s/HO	Ekurhuleni North; Ekurhuleni South; Gauteng East; Gauteng North; Gauteng West; Johannesburg East; Johannesburg North; Johannesburg South; Johannesburg West; Sedibeng East and Sedibeng West

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved. A separate copy of this letter must be presented to the Principal, SGB and the relevant District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted. However participation is VOLUNTARY.

The following conditions apply to GDE research. The researcher has agreed to and may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

2016/02/25

1

Making education a societal priority

Office of the Director: Education Research and Knowledge Management ER&KM)
9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506

CONDITIONS FOR CONDUCTING RESEARCH IN GDE

1. *The District/Head Office Senior Manager/s concerned, the Principal/s and the chairperson/s of the School Governing Body (SGB.) must be presented with a copy of this letter.*
2. *The Researcher will make every effort to obtain the goodwill and co-operation of the GDE District officials, principals, SGBs, teachers, parents and learners involved. Participation is voluntary and additional remuneration will not be paid;*
3. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal and/or Director must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
4. *Research may only commence from the second week of February and must be concluded by the end of the THIRD quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
5. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
6. *It is the researcher's responsibility to obtain written consent from the SGB/s; principal/s, educator/s, parents and learners, as applicable, before commencing with research.*
7. *The researcher is responsible for supplying and utilizing his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institution/s, staff and/or the office/s visited for supplying such resources.*
8. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research title, report or summary.*
9. *On completion of the study the researcher must supply the Director: Education Research and Knowledge Management, with electronic copies of the Research Report, Thesis, Dissertation as well as a Research Summary (on the GDE Summary template). Failure to submit your Research Report, Thesis, Dissertation and Research Summary on completion of your studies / project – a month after graduation or project completion - may result in permission being withheld from you and your Supervisor in future.*
10. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned;*
11. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director/s and school/s concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

Dr David Makhado

Director: Education Research and Knowledge Management

DATE: 2016/02/25

Appendix 4: Letter of approval from North West Department of Education

Education and Sport Development
Department of Education and Sport Development
Departement van Onderwys en Sport Ontwikkeling
Lefapha la Thuto le Tlhabololo ya Metshameko
NORTH WEST PROVINCE

1st Floor, East Wing,
Garona Building, Mmabatho
Private Bag X2044,
Mmabatho 2735
Tel.: (018) 388-3429
Fax.: (018) 388-3430
e-mail: ptyatya@nwpg.gov.za

OFFICE OF THE SUPERINTENDENT-GENERAL

Enquiries: Mpiliso Tyatya	Tel:(018) 388 3071 / e-mail lptyatya@nwpg.gov.za	Fax: 018 388 3430

04 March 2016

To: University of Pretoria
Faculty of Health Sciences

Attention: Prof. Feresu
o.b.o. Mr. V. Nkosi (24282788)

From: Dr. I.S. Molale
Superintendent-General

REQUEST FOR PERMISSION TO CONDUCT RESEARCH:

ASSOCOATION BETWEEN DUST FROM GOLD MINE DUMPS, RESPIRATORY SYMPTOMS AND DESEASES AMONG ADOLESCENTS AND THE ELDERLY IN SOUTH AFRICA

Reference is made to your correspondence dated 23 February 2016 regarding the above matter. The content is noted and accordingly, approval is granted for you to conduct the research as per your request, subject to the following provisions: -

- That you contact the relevant District Manager as well as principals of your target schools about your request and this subsequent letter of permission.
- That participation in your project will be voluntary.
- That, as far as possible, the general school functionality should not be compromised.
- That the outcome of your research work will be shared with be made available to the North West Department of Education & Sports Development upon request.
- That, in undertaking this exercise, the general principles of confidentiality and privacy of information will apply in the strictest terms.

With our best wishes.

DR. I.S. MOLALE
SUPERINTENDENT GENERAL

"Towards Excellence in Education and Sport Development"

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Appendix 5: Research request letter to the school principals

UNIVERSITEIT VAN PRETORIA
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YUNIBESITHI YA PRETORIA

Faculty of Health Sciences
School of Health Systems and Public Health

11/04/2012

Re: information letter for schools

Dear Principal/ Chairman of School Governing Body/Teachers

We are inviting some children at your school to participate in an important international study on child health with the approval of their parents. Many schools around the world took part in this study since 1992. Your school has been selected to participate by simple random sampling techniques. The study will focus on 12-13 year old school going children in Ekurhuleni Metropolitan area. Before the children can participate, informed consent will be sought from their parents.

The purpose of the study is to understand more about the increasing problem of respiratory health symptoms in children of this age group. Attached to this letter is an information leaflet explaining the detailed procedures of the study. This study has the approval of the University of Pretoria Ethics Committee and Gauteng Department of Education Research Committee. You may contact the committee directly about ethical matters if necessary; see contact details on the information leaflet.

If you have further questions about this project please contact the investigator Mr Vusumuzi Nkosi on 076 968 0522.

Yours Sincerely

Vusumuzi Nkosi
Principal Investigator

Professor Kuku Voyi
Supervisor

School of Health Systems and Public Health
University of Pretoria
Private Bag X323
Pretoria South Africa 0001

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Appendix 6: Consent forms to the parents

UNIVERSITEIT VAN PRETORIA
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Faculty of Health Sciences
School of Health Systems and Public Health

CONSENT FORM

<u>REQUEST FOR YOUR CHILD TO PARTICIPATE IN A REASEARCH PROJECT IMPORTANT INFORMATION</u>

STUDY TITLE: Association between dust from gold mine dumps, respiratory symptoms and diseases among adolescents and the elderly in South Africa.

Investigator: Mr Vusumuzi Nkosi
Supervisor: Professor Kuku Voyi

Dear Parent;

Introduction

Your child is invited to participate in a study of respiratory health symptoms in children. The study will focus on 12-14 years old school going children in Gauteng and Northwest province. This information leaflet is to help you to decide if you would like your child to participate. Before you agree you should fully understand what is involved. If you have any questions, which are not fully explained in this leaflet, do not hesitate to ask the investigator. You should not allow your child to participate unless you are completely happy about all the procedures involved.

Background

The occurrence of respiratory diseases such as asthma and allergic disease remains poorly understood, and therefore considerable research and comparisons between populations may help us to understand how these diseases occur. The International Study of Asthma and Allergies in Childhood, ISAAC was founded to study asthma and allergic disease among children by establishing a standardized methodology and facilitating international collaboration by having studies conducted in different countries. The purpose of the study is to understand more about the increasing problem of respiratory health symptoms in children of this age group and to further compile information on the asthma in your area through employment of an internationally standardized methodology.

Description of procedures (your child involvement)

The study will be carried out in two Phases.

Phase I: Your child will be asked to complete a simple five page double sided ISAAC questionnaire which is designed to assess the respiratory symptoms and potential environmental factors associated with these symptoms, a 10 minutes video about exercise and breathing will be shown to your child in order to answer some of the questions in the questionnaire. This questionnaire will be completed at school under the supervision of the investigator. The entire process of watching the video and completing the questionnaire will

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www.up.ac.za

take up to 40 minutes.

Phase II: After completion of Phase I, a subgroup of children from the initial sample will be randomly selected to participate in Phase II of the study. Should your child be selected you will receive letter notifying you of the date when the team will be visiting the school. The tests will be conducted at school and all three will take 25 minutes per child. A medical team comprising of Registrar's from the Department of Paediatrics and Child Health, University of Pretoria will conduct the following tests on the selected children:

Lung function tests

An instrument called a piko-1 meter will be used to measure amount and rate of air that the child breathes within specified seconds. Each child will receive an instrument. They will take three readings (3) two (2) times a day in the mornings (5am to 8am) and in the evenings (5pm to 8pm) for three weeks. The readings obtained from the Piko-1 meter will be recorded on a daily asthma diary, which will be provided. A child will be requested to breathe in fully and seal the mouth around the mouthpiece of Piko-1 meter, and then blow as fast as he/she can until the lungs are empty, this can take several seconds. The reading on the instrument will then be recorded. The children's height and weight without shoes will be measured before Piko-1 meters are issued out.

Air pollution measurements

In addition to the questionnaire and clinical tests outdoor pollution measurements of PM2.5, SO_2, NO_2, and O_3 will be conducted in the school.

What will happen to those children who test positive for any of the tests?

Should any child test positive for any tests the parents will be informed and issued with a referral letter for medical attention.
What are the risks?

There is no significant risk to the children. There may be mild pain from scratching or pricking during the skin test. The itching usually goes away shortly after washing the arm at the end of the test. Emergency care will be available should there be any treatment needed.

What is the duration of this study?

Phase I of the study will be conducted during the months of April to August 2012; and Phase II from February to April 2013.

Appendix 7: Assent form

UNIVERSITEIT VAN PRETORIA
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Faculty of Health Sciences
School of Health Systems and Public Health

ASSENT FORM

REQUEST FOR YOUR CHILD TO PARTICIPATE IN A REASEARCH PROJECT
IMPORTANT INFORMATION

STUDY TITLE: Association between dust from gold mine dumps, respiratory symptoms and diseases among adolescents and the elderly in South Africa.

Investigator: Mr Vusumuzi Nkosi
Supervisor: Professor Kuku Voyi

Dear Learner;

Introduction

Your child is invited to participate in a study of respiratory health symptoms in children. The study will focus on 12-14 years old school going children in Gauteng and Northwest province. This information leaflet is to help you to decide if you would like your child to participate. Before you agree you should fully understand what is involved. If you have any questions, which are not fully explained in this leaflet, do not hesitate to ask the investigator. You should not allow your child to participate unless you are completely happy about all the procedures involved.

Background

The occurrence of respiratory diseases such as asthma and allergic disease remains poorly understood, and therefore considerable research and comparisons between populations may help us to understand how these diseases occur. The International Study of Asthma and Allergies in Childhood, ISAAC was founded to study asthma and allergic disease among children by establishing a standardized methodology and facilitating international collaboration by having studies conducted in different countries. The purpose of the study is to understand more about the increasing problem of respiratory health symptoms in children of this age group and to further compile information on the asthma in your area through employment of an internationally standardized methodology

Description of procedures (your child involvement)

The study will be carried out in two Phases.

Phase I: Your child will be asked to complete a simple five page double sided ISAAC questionnaire which is designed to assess the respiratory symptoms and potential environmental factors associated with these symptoms, a 10 minutes video about exercise and breathing will be shown to your child in order to answer some of the questions in the questionnaire. This questionnaire will be completed at school under the supervision of the investigator. The entire process of watching the video and completing the questionnaire will

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take up to 40 minutes.

Phase II: After completion of Phase I, a subgroup of children from the initial sample will be randomly selected to participate in Phase II of the study. Should your child be selected you will receive letter notifying you of the date when the team will be visiting the school. The tests will be conducted at school and all three will take 25 minutes per child. A medical team comprising of Registrar's from the Department of Pediatrics and Child Health, University of Pretoria will conduct the following tests on the selected children:

Lung function tests

An instrument called a piko-1 meter will be used to measure amount and rate of air that the child breathes within specified seconds. Each child will receive an instrument. They will take three readings (3) two (2) times a day in the mornings (5am to 8am) and in the evenings (5pm to 8pm) for three weeks. The readings obtained from the Piko-1 meter will be recorded on a daily asthma diary, which will be provided. A child will be requested to breathe in fully and seal the mouth around the mouthpiece of Piko-1 meter, and then blow as fast as he/she can until the lungs are empty, this can take several seconds. The reading on the instrument will then be recorded. The children's height and weight without shoes will be measured before Piko-1 meters are issued out.

Air pollution measurements

In addition to the questionnaire and clinical tests outdoor pollution measurements of PM2.5, SO2, NO2, and O3 will be conducted in the school.

What will happen to those children who test positive for any of the tests?

Should any child test positive for any tests the parents will be informed and issued with a referral letter for medical attention.

What are the risks?

There is no significant risk to the children. There may be mild pain from scratching or pricking during the skin test. The itching usually goes away shortly after washing the arm at the end of the test. Emergency care will be available should there be any treatment needed.

What is the duration of this study?

Phase I of the study will be conducted during the months of April to August 2012; and Phase II from February to April 2013.

Confidentiality

All information obtained during the course of this study will be kept strictly confidential. No names or other identifying information will be used in any publication or presentations that may result from this study.

Has the study received ethical approval?

This survey has the approval of the University of Pretoria Ethics Committee (235/2011) and Gauteng Department of Education Research Committee (D2012/79). You may contact the committee directly about ethical matters if necessary. **If you have any questions regarding ethics, contact the ethics committees.**

31 Bophelo Road, Medical Campus,
HW Snyman Building (South) Level 2-34.
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9th floor, Commissioner Street
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2001

Tel: 011 355 0506
Email: David Mkhado@gauteng.gov.za

Informed consent

I hereby confirm that the investigator, about the nature of this study, has informed me. I have also received, read and understood the above written information regarding the study. I am aware that the results of the study, including personal details regarding my child's sex, age, date of birth, initials will be anonymously processed into a study report. I may, at any stage, without prejudice, withdraw my consent and my child's participation in the study. I have had sufficient opportunity to ask questions and (of my own free will) allow my child to participate in the study.

Learner/Pupil(s) Name: ____________________ (Please print)

Appendix 8: ISAAC questionnaire

Faculty of Health Sciences
School of Health Systems & Public Health

&

Mine Health and Safety Council

INSTRUCTIONS

1. **Use English to fill-in the questionnaire**
2. **Use a black pen to fill –in the questionnaire**
3. **Follow the instruction**

NOTE: ***RESPONSES IN THESE QUESTIONNAIRES WILL BE TREATED AS CONFIDENTIAL AND ANONYMOUS***

1

INFORMTION LEAFLET

Research topic: Association between dust from gold mine dumps, respiratory symptoms and diseases among adolescents and the elderly in South Africa.

You are invited to take in a research project conducted by the University of Pretoria and the School of Health System and Public Health (SHSPH), Mine Health and Safety Council. The research project is a requirement for accomplishment of the degree Phillosophiae Doctor (PhD) in Public Health. You are invited to participate after fully understanding all procedures involved. Information will be collected by means of completing the questionnaire which shall take not more than 20 minutes. Note that you can withdraw from the study at any stage. Furthermore, your contribution will be highly appreciated and relevant to the existing knowledge concerning the research topic. So, please try to be as honest and precise as possible during the interview.

WHAT IS THE PURPOSE OF THE STUDY?

The purpose of the study is to determine the number of existing cases with respiratory attributable to exposure to dust from mine dumps.

HAS THE STUDY RECEIVED ETHICAL APPROVAL?

Written protocol was submitted to the Research Ethics Committees and written approvals have been granted.

WHAT ARE MY RIGHTS AS A PARCIPANTS IN THIS STUDY?

Your participation in this trial is entirely voluntary and you can refuse to participate or stop at any time without stating any reason. The investigator retains the right to withdraw you from the study if it is considered to be in your best interest.

WHAT ARE THE RISKS IN THIS STUDY?

No risk associated with the study.

CONFIDENTIALITY?

All information obtained during the course of this study is strictly confidential. Data that may be reported in scientific journals will not include any formation which identifies you as a patient in this study.

ANY QUESTIONS PLEASE CONTACT:

Mr NKOSI V – Phillosophae Doctor (PhD) in Public Health student
E-mail: s24382788@tuks.co.za /vnkosi334@gmail.com
Mobile: 076 968 0522
University of Pretoria (SHSPH)

INFORMED CONSENT

I hereby confirm that I have been informed by the researcher, Mr Vusumuzi Nkosi about the nature of the nature of the research, possible benefits and risks of being part of the study. I confirm having read and understood the information given in the above informed consent sheet. I am aware that the findings of the study shall be kept confidential and that I may withdraw at any stage from participating. I have had enough time to ask question concerning the study, and out of my own free will I voluntarily agree to participate in the study.

Signature of the participants……………………………….
Date…………………………………………………….

Signature of investigator ……………………………………………
Date ………………………………………………………………

3

ISAAC
Questionnaire for 13/14 year olds

Instructions for completing the questionnaire
Examples of instructions for completing questionnaire and demographic questions are given below.

On this sheet are questions about your name, school, and birth dates. Please write your answers to these questions in the space provided.

All other questions require you to tick your answer in a box. If you make a mistake put a cross in the box and tick the correct answer. Tick only one option unless otherwise instructed.

Examples of how to mark questionnaires: Age [13] years

To answer Yes/No, put a tick in the appropriate box as per example below:

YES	
NO	X

SUBURB/ TOWNSHIP/SECTION WHERE YOU LIVE: [ ]

SCHOOL: [ ]

TODAY'S DATE: [ ]

YOUR NAME: [ ]

YOUR AGE: [ ] years

YOUR DATE OF BIRTH: [ ]

HOW TALL ARE YOU? [ ] Metres /centimeters

HOW LONG HAVE YOU BEEN LIVING IN THE SAME PART OF TOWN? [ ] Years

(Cross your answers for the rest of the questionnaire)

Are you a: [ ] **MALE** [ ] **FEMALE**

4

Core questionnaire for asthma

1. Have you ever had wheezing or whistling in the chest at any time in the past?

YES	
NO	

IF YOU HAVE ANSWERED "NO" PLEASE SKIP TO QUESTION 6

2. Have you had wheezing or whistling in the chest in the past 12 months?

YES	
NO	

IF YOU HAVE ANSWERED "NO" PLEASE SKIP TO QUESTION 6

3. How many attacks of wheezing have you had in the past 12 months?

NONE	
1 TO 3	
4-14	
More than 12	

4. In the past 12 months, how often, on average, has your sleep been disturbed due to wheezing?

Never woken with wheezing	
Less than one night per week	
One or more nights per week	

5. In the past 12 months, has wheezing ever been severe enough to limit your speech to only one or two words at a time between breaths?

YES	
NO	

×

6. Have you ever had asthma?

YES	
NO	

7. In the past 12 months, has your chest ever sounded wheezy during or after exercise?

YES	
NO	

5

8. In the past 12 months, have you had a dry cough at night, apart from a cough associated with a cold or chest infection?

YES	
NO	

Core questionnaire for rhinitis

9. Have you ever had a problem with sneezing, or a runny, or blocked nose when you DID NOT have a cold or the flu?

YES	
NO	

IF YOU HAVE ANSWERED "NO" PLEASE SKIP TO QUESTION 14

10. In the past 12 months, have you had a problem with sneezing, or a runny, or blocked nose when you DID NOT have a cold or the flu?

YES	
NO	

IF YOU HAVE ANSWERED "NO" PLEASE SKIP TO QUESTION 14

11. In the past 12 months, has this nose problem been accompanied by itchy-watery eyes?

YES	
NO	

12. In which of the past 12 months did this nose problem occur? (Please tick any which apply)

January		January	
February		February	
March		March	
April		April	
May		May	
June		June	

13. In the past 12 months, how much did this nose problem interfere with your daily activities?

Not at all	
A little	
A moderate amount	
A lot	

14. Have you ever had hayfever?

YES	
NO	

Core questionnaire for eczema

15. Have you ever had an itchy rash, which was coming and going for at least six months?

YES	
NO	

IF YOU HAVE ANSWERED "NO" PLEASE SKIP TO QUESTION 21

16. Have you had this itchy rash at any time in the past 12 months?

YES	
NO	

IF YOU HAVE ANSWERED "NO" PLEASE SKIP TO QUESTION 21

17. Has this itchy rash at any time affected any of the following places:

the folds of the elbows, behind the knees, in front of the ankles, under the buttocks, or around the neck, ears or eyes?

YES	
NO	

18. At what age did this itchy rash first occur?

Age 2-4 years	
Age 5 or more	
Can't remember	

19. Has this rash cleared completely at any time during the past 12 months?

YES	
NO	

20. In the past 12 months, how often, on average, have you been kept awake at night by this itchy rash?

Never in the past 12 months	
Less than one night per week	
One or more nights per week	

21. Have you ever had eczema?

YES	
NO	

General questionnaire

1. How long have you lived in this SUBURB/ TOWNSHIP/SECTION?

Less than 6 months	
6 to 12 months	
1 to 2 years	
3 years or longer	

2. How do you usually get to school?

Walk	
Taxi/Bus	
Motor car	
Combination	
Other	

3. How far is the nearest Clinic or Hospital from your home?

15 minutes walk or 5 minute drive	
1 hour walk or 15 minute drive	
more than an hour's walk or more than 30 minute drive	

4. What type of house do you live in?

Brick	
Mud	
Corrugated iron	
Combination	
Other	

5. How many rooms are in your house? (Excluding bathrooms)

6. Do you have running water in the house?

YES	
NO	

7. In the past 12 months, how often, on average, did you eat or drink the following?: (Please leave blank if you do not know what a food is)

Type of food	Never or occasionally	Once or twice per week	Three or more times per week
Meat (e.g. beef, lamb, chicken, pork)			
Seafood (including fish)			
Fruit			
Vegetables (green and root)			
Pulses (peas, beans, lentils)			
Cereal (including bread)			
Pasta			
Rice			
Butter			
Margarine			
Nuts			
Potatoes			
Milk			
Eggs			
Fast food/burgers			

8. How many times a week do you engage in vigorous physical activity long enough to make you breathe hard?

Never or occasionally	
Once or twice per week	
Three or more times a week	

9. During a normal week, how many hours a **day (24hours)** do you watch television?

Less than 1 hour	
1 hour but less than 3 hours	
3 hours but less than 5 hours	
5 hours or more	

10. In your house, what fuel is usually used for cooking?

Electricity	
Gas	
Paraffin	
Open fires	
Other – Please specify	

11. In your house, what fuel is usually used for heating?

Electricity	
Gas	
Paraffin	
Open fires (wood,coal)	
Other – Please specify	

12. In the past 12 months, how often, on average, have you taken paracetamol (e.g. Panadol, Pamol)?

Never	
At least once a year	
At least once per month	

13. How many older brothers and sisters do you have?

Brothers	
Sisters	

14. How many younger brothers and brothers sisters do you have?

Brothers	
Sisters	

15. Were you born in this township/suburb?

YES	
NO	

16. What level of education has your mother received?

Primary school	
Secondary school	
College, university or other form of tertiary education	

17. How often do trucks pass through the street where you live, on weekdays?

Never	
Seldom	
Frequently through the day	
Almost everyday	

18. Do you currently have a cat in your home?

YES	
NO	

19. In the past 12 months, have you had a cat in your home?

YES	
NO	

20. Do you currently have a dog in your home?

YES	
NO	

21 In the past 12 months, have you had a dog in your home?

YES	
NO	

22. Does your mother (or female guardian) smoke cigarettes?

YES	
NO	

23. Does your father (or male guardian) smoke cigarettes?

YES	
NO	

24. How many people living in your house smoke cigarettes?

[ ] People

25. Does someone living in your house (other than you) smoke cigarettes?

YES	
NO	

26. In the past 30 days about how many days would you say you were in a place where someone smoked close to you (no complete physical barrier i.e. smoke got to you)?

	Never	1-6 days	7-10 days	16-20 days	More than 20 days
At home					
At school					
In the car or transport					
Restaurant					

27 Do you smoke cigarette?

YES	
NO	

ISAAC International Video Questionnaire answer sheet

SCENE ONE: The first scene is of a young person at rest.

QUESTION ONE: Has your breathing been like this, at any time in your life?

YES	
NO	

if **YES:** has this happened in the past year?

YES	
NO	

if **YES:** has this happened one or more times a month?

YES	
NO	

SCENE TWO: The second scene is of two young people exercising. One is in a dark shirt and the other is in a white shirt.

QUESTION TWO: Has your breathing been like the boy in the dark shirt during or following exercise at any time in your life?

YES	
NO	

if **YES:** has this happened in the past year?

YES	
NO	

if **YES:** has this happened one or more times a month?

YES	
NO	

SCENE THREE: The third scene is of a young person waking at night.

QUESTION THREE: Have you been woken at night like this at any time in your life?

YES	
NO	

12

if **YES:** has this happened in the past year?

YES	
NO	

if **YES:** has this happened one or more times a month?

YES	
NO	

SCENE FOUR: The fourth scene is also of a young person waking at night.

QUESTION FOUR: Have you been woken at night like this at any time in your life?

YES	
NO	

if **YES:** has this happened in the past year?

YES	
NO	

if **YES:** has this happened one or more times a month?

YES	
NO	

SCENE FIVE: The final scene is of another person at rest.

QUESTION FIVE: Has your breathing been like this at any time in your life?

YES	
NO	

if **YES:** has this happened in the past year?

YES	
NO	

if **YES:** has this happened one or more times a month?

YES	
NO	

Thank you!

Appendix 9: ATS questionnaire

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

School of Health Systems & Public Health

&

Mine Health and Safety Council

INSTRUCTIONS

1. Use English to fill-in the questionnaire
2. Use a black pen to fill -in the questionnaire
3. Follow the instruction

NOTE: RESPONSES IN THESE QUESTIONNAIRES WILL BE TREATED AS CONFIDENTIAL AND ANONYMOUS

Page 1 of 14

INFORMTION LEAFLET

Research topic: Association between dust from gold mine dumps, respiratory symptoms and diseases among adolescents and the elderly in South Africa.

You are invited to take in a research project conducted by the University of Pretoria and the School of Health System and Public Health {SHSPH), Mine Health and Safety Council. The research project is a requirement for accomplishment of the degree Phillosophiae Doctor {PhD) in Public Health

You are invited to participate after fully understanding all procedures involved. Information will be collected by means of completing the questionnaire which shall take not more than 20 minutes. Note that you can withdraw from the study at any stage. Furthermore, your contribution will be highly appreciated and relevant to the existing knowledge concerning the research topic. So, please try to be as honest and precise as possible during the interview.

WHAT IS THE PURPOSE OF THE STUDY?

The purpose of the study is to determine the number of existing cases with respiratory attributable to exposure to dust from mine dumps.

HAS THE STUDY RECEIVED ETHICAL APPROVAL?

Written protocol was submitted to the Research Ethics Committee and written approval has been granted by that committee.

WHAT ARE MY RIGHTS AS A PARCIPANTS IN THIS STUDY?

Your participation in this trial is entirely voluntary and you can refuse to participate or stop at any time without stating any reason. The investigator retains the right to withdraw you from the study if it is considered to be in your best interest.

WHAT ARE THE RISKS IN THIS STUDY?

No risk associated with the study.

CONFIDENTIALITY?

All information obtained during the course of this study is strictly confidential. Data that may be reported in scientific journals will not include any formation which identifies you as a patient in this study.

ANY QUESTIONS PLEASE CONTACT:

Mr NKOSI V - Phillosophae Doctor {PhD) in Public Health student

E-mail: s24382788@tuks.co.za /vnkosi334@gmail.com

Mobile: 076 968 0522

University of Pretoria {SHSPH)

INFORMED CONSENT

I hereby confirm that I have been informed by the researcher, Mr Vusumuzi Nkosi about the nature of the nature of the research, possible benefits and risks of being part of the study. I confirm having read and understood the information given in the above informed consent sheet.

I am aware that the findings of the study shall be kept confidential and that I may withdraw at any stage from participating.

I have had enough time to ask question concerning the study, and out of my own free will I voluntarily agree to participate in the study.

Signature of the participants................

Date......................

Signatureofinvestigator................

Date ....

1 -DEMOGRAPHICS

1. Population group?

{Cross: X)

1-Asian ☐ 2-Black ☐ 3-Coloured ☐ 4-White ☐

{Cross: X)

2. Sex?

1-Female ☐ 2-Male ☐

3. Maritalstatus?

{Cross: X)

1- Single	2- Married	3- Widowed	4- Divorced

4. Date of birth?

{Fill-in)

Y	Y	Y	Y	M	M	D	D

5. Levelofeducation?

{Fill-in)

4.1-Noschooling	4.2-Primary	4.3-Secondary	4.4-Tertiary

6. Place of birth?

{Fill-in)

....

7. How long have you been living in the same part of town? ☐ years

Page 4 of 14

SECTION2-COUGH

{Cross: X)

2.1 Do you usually have cough? {excluding clearing of throat)	Yes	No
2.2 Do you usually cough as 4 to 6 times a day, 4 or more day out the week?	Yes	No
2.3 Do you usually cough on getting up, or first thing in the morning?	Yes	No
2.4 Do you usually cough at all during the day or night?	Yes	No

If Yes to any of the above {2.1, 2.2, 2.3, and 2.4) answer the following

2.5 Do you usually cough like this on most days for 3 consecutive months or more during the year?

{Cross: X)

2.5.1. Yes- ☐ 2.5.2. No- ☐

2.6 For how many years have you had this cough?

Indicate the number of years ☐

SECTION3-PHLEGM

{Cross: X)

3.1 Do you usually bring up phlegm? {excluding phlegm from the nose)	Yes	No
3.2 Do you usually bring up phlegm like this twice per day, 4 or more day out the week?	Yes	No
3.3 Do you usually bring up phlegm at all on getting up, or first thing in the morning?	Yes	No
3.4 Do you usually bring up phlegm at all during the day or night?	Yes	No

If Yes to any of the above {3.1, 3.2, 3.3, and 3.4)

3.5 Do usually bring up phlegm like this on most days for 3 consecutive months or more during the year?

{Cross: X)

3.5.1 Yes- ☐ 3.5.2. No- ☐

3.6 For how many years have you had trouble with phlegm?

Indicate the number of years ☐

SECTION 4- EPIOSDEOFCOUGHANDPHLEGM

{Cross: X)

4.1 Have you had periods or episodes of Phlegm and cough lasting for 3 weeks or more each year?	Yes	No

If Yes to 4.1 answer the following question

{Fill-in)

4.1.1 How long have you had at least 1 such episode per year? [ ]

SECTION 5- WHEEZING

{Cross: X)

5.1 Does your chest ever sound whistling when you have a cold?	Yes	No
5.2 Does your chest ever sound whistling occasionally apart from cold?	Yes	No
5.3 Does your chest ever sound whistling most days or nights?	Yes	No

5.4 If Yes to the any of the above {5.1, 5.2, and 5.3)

{Cross: X)

5.4.1.1 Have you ever had attack of wheezing that has made you feel short of breath?	Yes	No

5.5 If Yes to 5.4.1.1 answer the following

5.5.1 How old were you when you had your first such attack? Number of years [ ]

5.5.2 Have you had 2 or more such episodes? Yes- [ ] No- [ ]

5.5.3 Have you ever required medicine or treatment for the {se) attack{s)? Yes- [ ] No- [ ]

5.6 BREATHLESSNESS

5.6.1 Are you troubled by shortness of breath when hurrying on the level or walking up the slight hill?

{Cross: X)

5.6.1.1 Yes- ☐ 5.6.1.2 No - ☐

5.6.2 If Yes to 5.6.1 answer the following

{Cross: X)

5.6.2.1 Do you have to walk slower than people of your age on the level because of breathless?	Yes	No
5.6.2.2 Do you ever have to stop for breath when walking at your pace on the level?	Yes	No
5.6.2.3 Do you have to stop for breath after walking about few minutes on the level?	Yes	No
5.6.2.4 Are you breathless to leave the house or breathless on dressing or undressing?	Yes	No

5.7. CHEST COLD AND CHEST ILLNESS

5.7.1 If you get cold, does it usually go to your chest? Yes- ☐ No- ☐

5.7.2 In the past 3 years have you had any chest illness that kept off work, indoors at home, or in home? Yes- ☐ No- ☐

If Yes to 5.7.2 answer the following questions

5.7.2.1 Did you produce phlegm with any of these chest illnesses?	Yes	No

5.7.2.2 In the last 3, years how many such illnesses with phlegm, did you have which lasted a week or more? ☐

5.8 PASTILLNESS

{Cross: X)

5.8.1 Did you have any lung trouble before the age of 16?	Yes	No
5.8.2 Have you had a bronchitis attack?	Yes	No
5.8.3 Was the bronchitis attack confirmed by the doctor?	Yes	No

5.8.4 At what age was your first attack? ☐

SECTION- 6 PNEUMONIA

6.1 Have you had Pneumonia? Yes - No -

If Yes to 6.1 answer the following questions

6.1.1 Was the pneumonia confirmed by the doctor?	Yes	No

6.1.2 At what age did you first have it?

SECTION - 7 HAYFEVER

7.1 Have you had Hay fever? Yes- No-

If Yes to 7.1 answer the following questions

7.1.1 Was the Hay fever confirmed by the doctor?	Yes	No

7.1.2 At what age did it start?

SECTION - 8 CHRONICBRONCHITIS

8.1 Have you ever had chronic bronchitis? Yes- No-

If yes to 8.1 answer the following questions

8.1.1 Was it confirmed by the doctor?	Yes	No

8.1.2 At what age did it start?

SECTION -9 EMPHYSEMA

9.1 Have you ever had emphysema? Yes- No-

If yes to 9.1 answer the following questions

9.1.1 Was it confirmed by the doctor?	Yes	No

9.1.2 At what age did it start?

SECTION 10- ASTHMA

10.1 Have you ever had asthma? Yes- No-

If yes to 10.1 answer the following questions

10.1.1 Do you still have it?	Yes	No
10.1.2 Was it confirmed by the doctor?	Yes	No

10.2.1 At what age did it start? ☐

10.2.2 If you no longer have it, at what age did it stop? ☐

SECTION 11- OTHERINCIDENTS

11.1 Have you had any other chest illness? Yes- ☐ No- ☐

If yes please specify ....

11.2 Have you had any chest operations? Yes- ☐ No- ☐

If yes please specify..

11.3 Have you had any chest injuries? Yes- ☐ No- ☐

11.4 Has the doctor told you that you have a heart trouble? Yes - ☐ No- ☐

If yes to 11.4 answer the following question

11.4.1 Have you ever had treatment for heart trouble in the past 10 years? Yes- ☐ No- ☐

11.5 Has the doctor told you that you have high blood pressure? Yes- ☐ No- ☐

If yes to 11.5 answer the following question?

11.5.1 Have you ever had treatment for high blood pressure? Yes- ☐ No- ☐

SECTION 12- TOBACCOSMOKING

12.1 Have you ever smoked cigarettes? Yes- ☐ No - ☐

If yes to 12.1 answer the following question

12.1.1 Do you now smoke cigarettes? Yes- ☐ No - ☐

12.1.2 How old were you when you started to smoke cigarettes? ☐

12.1.3 if you stopped smoking cigarettes completely, how old were you when you stop ? ☐

12.1.4 How many cigarettes do you smoke per day? ☐

12.1.5 Do or did you inhale the cigarette smoke

12.1.5.1 Not at all	12.1.5.2 Slightly	12.1.5.3 Moderately	12.1.5.4 Deeply

SECTION 13-PIPESMOKING

13.1 Have you ever smoked pipe? Yes- ☐ No - ☐

If yes to 13.1 answer the following question

13.1.1 Do you now smoke pipe? Yes- ☐ No - ☐

13.1.2 How old were you when you started to smoke pipe? ☐

13.1.3 if you stopped smoking pipe completely, how old were you when you stop ? ☐

13.1.4 How many pipes do you smoke per day? ☐

13.1.5 Do or did you inhale the pipe smoke

13.1.5.1 Not at all	13.1.5.2 Slightly	13.1.5.3 Moderately	13.1.5.4 Deeply

SECTION 14-FAMILYHISTORY

14.1 Were either of your natural parents ever told by the doctor that they that they had chronic lung condition suchas,

FATHER

{Cross: X)

14.1.1 Chronic bronchitis?	Yes	No	Don't know
14.1.2 Emphysema?	Yes	No	Don't know
14.1.3 Asthma?	Yes	No	Don't know
14.1.4 Lung cancer?			
14.1.5 Other conditions? Specify..			
14.1.5 Is the parent alive	Yes	No	Don't know
Specify the cause of death..			

MOTHER

{Cross: X)

14.1.1 Chronic bronchitis?	Yes	No	Don't know
14.1.2 Emphysema?	Yes	No	Don't know
14.1.3 Asthma?	Yes	No	Don't know
14.1.4 Lung cancer?			
14.1.5 Other conditions? Specify..			
14.1.5 Is the parent alive	Yes	No	Don't know
Specify the cause of death..			

SECTION 15- HOMEHEATINGANDFUEL

15. How is your home heated?

{Cross: X)

15.1 Steam or hot water	
15.2 Warm air furnace	
15.3 Floor, wall, or pipe less furnace	
15.4 Built in electric units	
15.5 Other means with fuel	
15.6 Other means without fuel	

16 What fuel is most used for heating your home?

{Cross: X)

16.1 Coal or Coke	
16.2 Wood	
16.3 Utility gas	
16.4 Bottled tank, or LP gas	
16.5 Fuel oil, Kerosene, etc.	
16.6 Electricity	
16.7 other	
16.8 No fuel	

17 What is the fuel that is used in your home most for cooking?

{Cross: X)

16.1 Coal or Coke	
16.2 Wood	
16.3 Utility gas	
16.4 Bottled tank, or LP gas	
16.5 Fuel oil, Kerosene, etc.	
16.6 Electricity	

SECTION 16- OCCUPATIONALHISTORY

16.1 Have you worked full time for 6 months or more? Yes- ☐ No- ☐

If yes to 16.1 answer the following question

16.1.1 Have you ever worked for a year or more in any dusty job? Yes - ☐ No- ☐

16.1.2 Was the dust exposure?

{Cross: X)

16.1.2.1 Mild	16.1.2.2 Moderate	16.1.2.3 Severe

16.2.1 Have you ever been exposed to gas or chemical fumes at work? Yes- ☐ No- ☐

16.2.2 if Yeswastheexposure?

{Cross: X)

16.1.2.1 Mild	16.1.2.2 Moderate	16.1.2.3 Severe

SECTION 17 - MYOCARDIAL INFARCTION/HEART ATTACK

{Cross: X)

17.1 Have you ever had a heart attack before?	Yes	No

If Yes to 17.1 answer the following questions

17.1.2 How old were you when you had your first such attack? Number of years ☐

17.1.3 Have you had 2 or more such episodes? Yes- ☐ No- ☐

17.1.4 Have you ever required medicine or treatment for the {se)attack{s)? Yes- ☐ No- ☐

Page 13 of 14

SECTION 18 - ARRYTHMIA/IRREGULAR HEART BEATS

{Cross: X)

18.1 Have you ever had a irregular heart beats/arrhythmia?	Yes	No

If Yes to 18.1 answer the following questions

18.1.2 How old were you when you had your first such attack? Number of years ☐

18.1.3 Have you had 2 or more such episodes? Yes-☐ No-☐

18.1.4 Have you ever required medicine or treatment for the{se) attack{s)? Yes- ☐ No- ☐

Appendix 10: Asthma daily diaries

Faculty of Health Sciences
School of Health Systems & Public Health

&

Mine Health and Safety Council

My Daily Health Diary

INSTRUCTIONS

- Use a black pen to fill a diary.
- Take three (3) readings two (2) times a day, in the mornings, and at night.

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MONDAY

Write the down the number in the box of symptoms

0 = None, 1 = Occasionally, 2 = Frequent, 3 = Continuous.

Personal best														
PEAK FLOW METER														
RANGE	Green Zone			Yellow Zone			Red Zone							
										Cough	Wheeze	Breathlessness	Sputum production	Chest tightness

Indicate (Cross: X) type medication reliever used during the last 24hrs

Inhaled corticosteroids	Short acting β_2-agonist	Other asthma medication	No asthma medication

TUESDAY

Write the down the number in the box of symptoms

0 = None, 1 = Occasionally, 2 = Frequent, 3 = Continuous.

Personal best														
PEAK FLOW METER														
RANGE	Green Zone			Yellow Zone			Red Zone							
										Cough	Wheeze	Breathlessness	Sputum production	Chest tightness

Indicate (Cross: X) type medication reliever used during the last 24hrs

Inhaled corticosteroids	Short acting β_2-agonist	Other asthma medication	No asthma medication

WEDNESDAY

Write the down the number in the box of symptoms

0 = None, 1 = Occasionally, 2 = Frequent, 3 = Continuous.

Personal best								
PEAK FLOW METER								
RANGE	Green Zone	Yellow Zone	Red Zone	Cough	Wheeze	Breathlessness	Sputum production	Chest tightness

Indicate (Cross: X) type medication reliever used during the last 24hrs

Inhaled corticosteroids	Short acting β_2-agonist	Other asthma medication	No asthma medication

THURSDAY

Write the down the number in the box of symptoms

0 = None, 1 = Occasionally, 2 = Frequent, 3 = Continuous.

Personal best								
PEAK FLOW METER								
RANGE	Green Zone	Yellow Zone	Red Zone	Cough	Wheeze	Breathlessness	Sputum production	Chest tightness

Indicate (Cross: X) type medication reliever used during the last 24hrs

Inhaled corticosteroids	Short acting β_2-agonist	Other asthma medication	No asthma medication

FRIDAY

Write the down the number in the box of symptoms

0 = None, 1 = Occasionally, 2 = Frequent, 3 = Continuous.

Personal best								
PEAK FLOW METER								
RANGE	Green Zone	Yellow Zone	Red Zone					
				Cough	Wheeze	Breathlessness	Sputum production	Chest tightness

Indicate (Cross: X) type medication reliever used during the last 24hrs

Inhaled corticosteroids	Short acting β_2-agonist	Other asthma medication	No asthma medication

SATURDAY

Write the down the number in the box of symptoms

0 = None, 1 = Occasionally, 2 = Frequent, 3 = Continuous.

Personal best								
PEAK FLOW METER								
RANGE	Green Zone	Yellow Zone	Red Zone					
				Cough	Wheeze	Breathlessness	Sputum production	Chest tightness

Indicate (Cross: X) type medication reliever used during the last 24hrs

Inhaled corticosteroids	Short acting β_2-agonist	Other asthma medication	No asthma medication

SUNDAY

Write the down the number in the box of symptoms

0 = None, 1 = Occasionally, 2 = Frequent, 3 = Continuous.

Personal best								
PEAK FLOW METER								
RANGE	Green Zone	Yellow Zone	Red Zone	Cough	Wheeze	Breathlessness	Sputum production	Chest tightness

Indicate (Cross: X) type medication reliever used during the last 24hrs

Inhaled corticosteroids	Short acting β_2-agonist	Other asthma medication	No asthma medication

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