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BASELINE ASSESSMENT OF CHILD RESPIRATORY HEALTH IN THE HIGHVELD PRIORITY AREA

by

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Declaration

I, PN Albers, hereby declare that the work which I hereby submit as fulfilment for the degree MSc (Community Health) is original (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been submitted, or is being submitted for another degree at this or any other university.

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Abstract

Children are a highly susceptible population to the effects of air pollution. To establish a current baseline of child respiratory health and associated risk factors in the Highveld Priority Area, a quantitative questionnaire was carried out among parents or guardians of children aged between 9 and 11 years in Witbank and Middelburg. Key health outcomes of interest were asthma and upper and lower respiratory tract complications. Air quality data were obtained for Witbank and Middelburg and compared with recently gazetted National Standards to establish potential risks. The prevalence of health outcomes and associated risk factors, such as indoor fossil fuel burning and parental smoking were considered and key risk factors identified. A unique method for the analysis of poor quality responses was introduced in order to derive the most meaning from the data. The study findings showed the air quality to be of concern particularly in Witbank; however, it also showed a similarity between the air quality in both towns. The health outcome with the highest prevalence was hay fever (occurring in the previous 6 months) with 31.7%. The use of non-electric heating sources, parental smoking and mould in the house were risk factors of most concern for respiratory health. During bivariate analysis mould was found to be associated with a number of health outcomes, most notably having bronchitis, with a crude OR of 4.74. An adjusted odds ratio of 4.05 was found for smoking in the house and having bronchitis. An adjusted OR of 6.32 was found for using gas or paraffin and having episodes of wheezing. These results may be used to direct future research studies as well as assist air quality management practices in the area. Finally, a technique to handle contradictions in questionnaire responses was developed to maximise use of data collected for application in under-resourced research environments.

Samevatting

Kinders is baie vatbaar vir die effek van lugbesoedeling. Om die huidige basislyn van respiratoriese gesondheid van kinders, asook die risikofaktore daarvan in die Hoëveld Prioriteitsarea, te bepaal, is n kwantitatiewe vraelys gebruik wat deur ouers of voogde van kinders tussen die ouderdomme van 9 tot 11 jaar in Witbank en Middelburg ingevul moes word. Belangrike gesondheidstoestande wat ondersoek is, was asma en boonste- en onderstelugwegkomplikasies. Lugkwaliteitsdata vir Witbank en Middelburg is verkry en vergelyk met nasionale standaarde wat onlangs in die Staatskoerant verskyn het, om sodoende risikos te bepaal. Die voorkoms van gesondheidstoestande en hul geassosieerde risikofaktore, soos die gebruik van soliede brandstowwe binnenshuis en ouers wat rook, is in aanmerking geneem en hieruit is belangrikste risikofaktore bepaal. ‘n Unieke metode vir die ontleding van bedorwe of swak gehalte terugvoering is ingebring om sodoende die beste betekenis aan die data te gee. Die studie het gevind dat daar n ooreenkoms is in die luggehalte van die twee dorpe, maar dat die die luggehalte, in veral Witbank, kommerwekkend is. Die gesondheidstoestand met die hoogste voorkoms, was hooikoors (voorkoms in voorafgaande ses maande) met 31.7%. Die gebruik van verhitting wat nie deur elektrisiteit verskaf word nie, ouers wat rook in die huis asook swamme wat binnenshuis groei, was die mees kommerwekkende risikofaktore. Gedurende tweevoudige ontleding is gevind dat swamme met verskeie gesondheidstoestande geassosieer kon word, waarvan die ooglopendste bronchitis was met n basiese waarskynlikheid van 4.74. ‘n Aangepasde waarskynlikheid van 4.05 is gevind vir bronchitis in n huis waar gerook word. ‘n Aangepaste waarskynlikheid van 6.32 is gevind vir ‘n fluitende bors en die gebruik van gas of paraffin. Hierdie navorsing kan gebruik word om die rigting van toekomstige navorsing te bepaal en ook om te help met die bestuurspraktyke van lugkwaliteit in the area. ‘n Tegniek wat gebruik kan word in die hantering van teenstrydighede in die antwoorde op vraelyste is ontwikkel om sodoende maximum voordeel te trek uit die toepassing van versamelde data in navorsingsareas waar hulpbronne skaars is.

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List of Abbreviations

ALRI	Acute Lower Respiratory Infection
APPA	Atmospheric Pollution Prevention Act
ARI	Acute Respiratory Infection
C_6H_6	Benzene
CI	Confidence Interval
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CVD	Cardio Vascular Disease
ETS	Environmental Tobacco Smoking
HPA	Highveld Priority Area
INT	Integer
ISAAC	International Study of Asthma and Allergies in Childhood
KAP	Knowledge, Attitudes and Perspectives
MEC	Member of the Executive Council
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
O_3	Ozone
OR	Odds Ratio
Pb	Lead
pe	Probability for entry
PM	Particulate Matter
ppb	Parts per billion
SO_2	Sulphur Dioxide
TSP	Total Suspended Particulates
US	United States
USEPA	United States Environmental Protection Agency
VAPS	Vaal Air Pollution Study
VOC	Volatile Organic Compound
WHO	World Health Organization

Chapter 1: Background

1.1 Introduction

This chapter provides an introduction to the research that will be presented in this dissertation. The most relevant or recent scientific literature will be explored. The literature will be presented in a top-down format, where air quality will be introduced and specific pollutants will be defined and explained. The health effects of air pollution exposure will also be covered, with a specific examination of child health. The South African situation of child health in relation to air quality will then be investigated. The literature from the Highveld region, the study area for this research project, will also be reviewed.

The particulars of this specific study will then be set out, including the relevance of the study and the aim and objectives. This dissertation is constructed according to the aims and objectives of the study.

1.2 Air pollution

Air pollution can be explained as harmful emissions into the atmosphere which are either anthropogenic or natural. These pollutants vary in their impacts, the severity of these impacts as well as their lifetime in the atmosphere [1]. As a result of increased global awareness regarding air pollution and its impacts, a number of pollutants were identified as being ubiquitous. These pollutants are known as criteria pollutants. Guidelines and standards for these specific chemicals have been set around the world, to alleviate human health impacts. As a result of this, in 2005, the World Health Organization (WHO) set a number of guidelines for specific pollutants, in order to significantly reduce health risks [2].

According to the WHO [3] more than half of the world's population relies on burning different solid fuels such as wood and coal for heating and cooking. This is often done using open fires or stoves without chimneys. Pollution from these sources can have severe impacts on the health of exposed individuals, thus, the WHO placed air pollution as the 8th highest contributor to global burden of disease [3].

Women, children and the elderly are the subpopulations most highly affected by indoor air pollution. Women often spend many hours a day cooking and are therefore exposed. In their first years of life, children are more likely to be near their mother as well as kept in the warmest part of the house, often near the pollution source [3]. It is then no surprise that the WHO reports that 56% of deaths resulting from indoor air pollution exposure occur in children under five years of age.

This indoor fossil fuel burning also contributes to outdoor pollution levels, through chimneys, open windows and doors. Burning fossil fuels is also the primary cause of poor outdoor air quality and the sources are chiefly from motor vehicle exhausts, power plants and other industrial or commercial activities [4 & 5].

In the atmosphere there are numerous harmful contaminants, these are divided into two groups, that of primary and secondary air pollutants [6]. Primary pollutants include; Particulate Matter (PM), such as solid carbon particles, and gaseous pollutants, such as Sulphur Dioxide (SO_2), Nitric Oxide (NO), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO) and Carbon Dioxide (CO_2). Secondary pollutants are formed in the atmosphere as a result of the presence of other pollutants or other factors. A secondary pollutant of concern is Ozone (O_3); it is formed by the presence of mono-nitrogen oxides (NO_X) or volatile organic compounds (VOCs) and sunlight. PM is typically characterised into three groups, those with a diameter equal to or less than 10µm (PM_{10}), those with a diameter of 2.5µm ($PM_{2.5}$) and those with a diameter of equal to or less than 1µm (PM_1) [6].

SO_2, NO_2, O_3, PM_{10} and $PM_{2.5}$ will be examined in greater detail below as these are the pollutants of interest for this study.

1.2.1 Particulate matter (PM)

PM is a mixture of solid particles and liquid droplets which vary in size, composition and origin [7]. The smaller particles ($PM_{2.5}$) are mostly derived from the combustion of fossil fuels whereas the larger particles (PM_{10}) are mostly derived from soil materials [7]. The smaller particles pose a greater health risk not only as a result of their composition but also because they can be inhaled more deeply into the lungs.

PM_{10} is sometimes referred to as thoracic particles as these can penetrate into the lower respiratory system, while $PM_{2.5}$ is sometimes referred to as respirable particles as these can easily enter into the gaseous exchange region of the lungs [8]. PM_1, however, also known as ultrafine particles, are abundant in the atmosphere and can infiltrate deepest into the lungs causing many adverse health effects [8].

1.2.2 Sulphur dioxide (SO_2)

SO_2 is a colourless gas with a pungent odour [9]. It is primarily released into the atmosphere through the burning of fossil fuels, metal-smelters and other industrial activities [6]. Coal-fired power plants are often large contributors to ambient SO_2 and for this reason they require strict emission control measures [6]. Some natural processes that release SO_2 into the atmosphere are volcanoes, forest fires and decomposition [6]. SO_2 is a primary contributor to secondary PM, as SO_2 can dissolve in water to form acid aerosols, such as sulphuric acid. SO_2 can also interact with other gasses or particles, forming particulate sulphates. These sulphate particles have a further influence on the environment in that they have a diameter similar to that of the optimum visible wavelength of sunlight, thus blocking light and causing a milky haze. These particles reflect light and heat back into the atmosphere, while trapping heat closer to the earth's surface [10]. Koening and Mar explain that SO_2 is a highly water soluble gas and is easily inhaled through the nose during normal breathing, and penetration into the lungs is deeper during mouth breathing or exercise [11]. The authors further explain that in people with allergic rhinitis and asthma, they often experience nasal congestion and therefore breathe through their mouths more frequently. Bronchoconstriction occurs so dramatically that it limits the amount of gas reaching the bronchial airways [11]. Nasal influences from SO_2 inhalation are congestion and inflammation [11].

1.2.3 Nitrogen dioxide (NO_2)

NO_2 is a gas with an irritating odour and is reddish and brown in colour. This gas is primarily released into the atmosphere through the burning of fuels or materials containing nitrogen [6]. It is mostly insoluble in water, thus allowing it to have greater health impacts. As a result of this insolubility, there is little irritation of the mucous membranes such as in the throat, nose and eyes. The gas can then travel further into the lungs, where it reacts with water forming nitric acid, the disassociation reactions associated with this, form nitrates and nitrites which can cause extensive tissue damage [12].

NO_2 and the other nitrogen oxides are the main contributors to surface level O_3 formation [6]. NO_2, like SO_2, can cause visibility impairment, acid rain and contribute to global warming [6]. Majority of outdoor NO_X is attributed to motor vehicles. Other sources of NO_X are power plants, industry and domestic fuel burning.

1.2.4 Ozone (O_3)

O_3 is not directly released into the atmosphere, but, is formed through the presence of VOCs, NO_X and SO_2 [6]. The O_3 that comprises the ozone layer has the same chemical structure as that which occurs at ground level; therefore, it is the location of the O_3 in the atmosphere that determines whether it is harmful or not to human health [6]. The 'good' O_3 forms naturally in the stratosphere; this layer protects the earth from the most harmful of the sun's rays [6]. The O_3 found at ground level is mostly not natural and can pose human health risks when inhaled [6]. O_3 is primarily an outdoor pollutant because when it enters a building it rapidly reacts with furniture and walls. This occurs because O_3 molecules are very unstable and quickly break down double carbon bonds such as those in plastics. O_3 is formed in the presence of sunlight; therefore, there are elevated levels of O_3 during day light hours and summer months. Brunekreef and Holgate explain that there tends to be lower levels of O_3 over city centres than suburbs as a result of nitric oxide (NO) originating from vehicle exhausts removing O_3 [8].

1.3 Air pollution and climate

The climate of an area is a very important aspect in the management and understanding of air pollution. The pressure system residing over the area in question is one of the most important climatic aspects to take into consideration. A persistent high pressure can cause a trapping of air pollutants on the surface, therefore, not allowing the pollutants to disperse or rise and thereby having a greater influence on the human health of residents [13].

Up until recently, there has been limited evidence of seasonal changes in mortality from air pollution. Qian *et al* reported statistically significant mortality increases, including all natural, cardiovascular, stroke, respiratory and cardio-pulmonary, from air pollution during the winter months [14]. These findings are explained largely by the higher pollutant levels during these months as a result of the colder air temperatures and the increased domestic fossil fuel burning during the winter months.

1.4 Indoor air pollution

In developing countries, the use of biomass fuels indoors contributes strongly to the mortality rates [8]. Indoor mould has also been found to be associated with respiratory complications. Brunekreef *et al* showed an association between self-reported mould or mildew in the house and child respiratory health, with odds ratios (ORs) going as high as 2.16 [15]. Children between the ages of 8 and 12 years were studied, and lung function tests were conducted. However, the association between lung function and home dampness was weak. The WHO guidelines for indoor air quality dampness and mould state that occupants of damp or mouldy buildings can be at greater risk for respiratory symptoms, infections and exacerbation of asthma [16]. Asthma is a chronic inflammatory disorder of the air ways, which can result in restricted airflow and the results can worsen over time as can the disorder [17].

Furthermore, there is evidence which supports that the risk of certain rare conditions is increased by the presence of indoor mould. Some of these include; hypersensitivity, pneumonitis, allergic alveolitis, chronic rhinosinusitis and allergic fungal sinusitis [16]. These results have been observed in non-atopic people; however, allergic or atopic populations would be even more sensitive to these effects.

1.5 Health effects from outdoor air pollution

The major sources of outdoor air pollution are mining, industrial activity, electricity generation, fossil fuel burning and vehicle traffic. There are complex interactions between the different pollutants, their sources and the overlapping health effects. For instance the primary constituents of traffic-related air pollution are NO_2 and PM [18], while the key components of pollution from electricity generation are SO_2 and PM

[11]. Similar health effects can be seen for all three of these pollutants. In epidemiological studies, it is usually difficult to separate the effects of SO_2 and PM. This is demonstrated through the mortality increase that is often seen with an increase in SO_2. The strength of this association is frequently reduced when PM is accounted for [11].

1.5.1 Outdoor air pollution and respiratory complications

A number of varying health effects have been associated with air pollution, the most direct association would be respiratory complications such as asthma, bronchitis and sinusitis.

In a study conducted by Brunekreef *et al* they demonstrated that an increase in mortality and hospital admissions due to asthma, reduced lung function and acute respiratory symptoms was as a result of PM_{10} and $PM_{2.5}$ exposure [19]. The study demonstrated that there was evidence of increased mortality and hospital admissions due to asthma at concentrations of below 100μg/m^3 as a 24hourly average for PM_{10}. For a PM_{10} 24hourly average not exceeding 115μg/m^3, lung function and acute respiratory symptoms were found. The current Standard in South Africa is 120μg/m^3 in 24hours [20].

It was also established that when people exercise in outdoor environments where O_3 hourly concentrations exceed 120μg/m^3 they experience lung function changes. This is because O_3 swiftly reacts with the lining of the respiratory tract directly damaging the proteins and lipids in the cells [21]. The current O_3 Standard for South Africa is 120μg/m^3 as a running 8 hourly average.

1.5.2 Outdoor air pollution and cardio pulmonary disease

Cardio pulmonary diseases include complications that affect the normal functioning of the heart and lungs. A study conducted in the United States, found an association between fine particulates, including sulphates, and an increase in cardio pulmonary disease [7]. A large cohort study conducted between 1986 and 1994 in the Netherlands showed that persons residing near major roads were at greater risk for cardio pulmonary mortality [22]. This association was still strong after accounting for various confounding factors such as diet and poverty. The authors also established that people residing closer to major roads tended to have slightly higher education levels, were involved in less blue collar work and tended to smoke less.

Pope *et al* found that there was an association between particulate air pollution and mortality, more specifically with cardio pulmonary mortality and lung cancer [23]. In 2002, results were published that showed with a 10µg/m^3 increase in fine particulates ($PM_{2.5}$) there was also a 4% increased risk in all-cause mortality, a 6% increase risk for cardio pulmonary mortality and an 8% increased risk in lung cancer mortality [24].

Another study found that increases in O_3 levels were associated with increases in all natural deaths, respiratory disorders, diabetes, cardiovascular disease, heart disease, acute myocardial infarction and stroke [25]. Neither socioeconomic status nor individual characteristics were found to alter these results significantly. [25]

1.5.3 Outdoor air pollution and Cardio Vascular Disease (CVD)

Cardio vascular disease (CVD) refers to any complications that affect the normal functioning of the heart. Cardio vascular disorders form part of cardio pulmonary disorders. The American Heart Association published an update to the scientific statement of 2004 in 2010, where they reviewed all literature examining the relationship between PM and CVD [26]. It was noted that there is a causal relationship between $PM_{2.5}$ exposure and morbidity and mortality from cardio vascular complications. Some of these complications included myocardial ischemia, infarctions, heart failure, arrhythmias and strokes. All the literature and research examined for this scientific statement showed that short term exposure to $PM_{2.5}$ (a few hours to a few weeks) can cause cardio vascular morbidity and mortality. Relating to this, a further study found a relationship between PM_{10} exposure and non-malignant respiratory mortality [27]. It has been estimated that up to 2 years of life shortening can occur; however, this could be greater for vulnerable population groups, such as children [8].

A time series study was conducted in the Canary Islands examining the relationship between respiratory and cardiac mortality; and daily changes in PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO and O_3 [28]. The Canary Islands have a number of conditions which complicate the air pollution problem. Some of these conditions include; trade winds (blowing from May till October), scarce rainfall, mild temperatures and its proximity to Africa which increases the amount of natural (mostly from deserts) PM in the area [28]. It was found that the only pollutant associated with total mortality was SO_2, and O_3 was associated with heart disease [28]. PM_{10} and $PM_{2.5}$ were both associated with respiratory mortality and cardiovascular mortality [28].

1.5.4 Outdoor air pollution and cancer

In a large quantity of reviewed literature, the association with cancer has often been noted. Cancer can be understood as the uncontrolled division of abnormal cells in a specific area of the body. A major source of outdoor air pollution is traffic and one primary component of traffic related air pollution is NO_2. A review by Brunekreef and Holgate showed that there is a growing body of evidence suggesting a greater link between traffic-related air pollution and lung cancer [8]. An association was found between fine particulates ($PM_{2.5}$), including sulphates, and lung cancer in the United States (US) [7]. An older study also found increased risk of lung cancer as a result of Total Suspended Particulates (TSP) and SO_2; however, the trend was less significant for females [29]. The risk of lung cancer as a result of air pollution may be underestimated in relation to cigarette smoking because; it is not possible to have a comparison group of individuals that are not exposed to air pollution. They also note, with regard to ambient air pollution monitoring, that it is not possible to know the exposure on an individual level.

1.5.5 Outdoor air pollution and foetal development damage

Apart from all the health effects felt by the general adult population or sensitive populations, increasing evidence is revealing the dangers of air pollution on foetal development.

A recent study showed that prenatal NO_2 exposure was associated with reduced foetal birth weight and development [30]. Earlier studies showed a similar association whereby, exposure to SO_2 and PM during the third trimester of pregnancy were associated with low birth weight [31-33].

1.6 Air pollution and child health

1.6.1 Children as a susceptible population

Children are a vulnerable population group to the effects of air pollution. They are said to be more susceptible as a result of their greater breath to body weight ratio, meaning that children have a greater gaseous exchange region in the lungs [11]. Children are more likely to spend additional time outdoors and participate in physical activities causing them to breathe deeper and often through their mouths; this can cause them to be predisposed to adverse effects from air pollution [34-35]. In the absence of physical exercise, it has also been explained that children tend to give preference to breathing through their mouths. This may increase exposure as most pollutants get removed when inhaled through the nose [36]. Children with allergies and bronchial hyper responsiveness will often be more vulnerable to the effects of air pollution [37]. A study which examined indoor environments and child respiratory health in urban China used children between the ages of one and six because, the physical lung development would make them most sensitive to air pollution [38]. A South African study, known as the Vaal Air Pollution Study conducted in the 1990s explained that the effects of air pollution can be more easily studied in children, not only because the effects might be greater, but also because they are unlikely to have started smoking [39].

1.6.2 Indoor air quality factors

A study of indoor conditions and child respiratory health, explained the importance of including home decor, pets, indoor smoking, fossil fuel burning for heating or cooking, ventilation, mould, pests and their proximity to busy roads as risk factors [38]. Pets in the home have been shown in many studies to be protective of respiratory ill health [40-41]; however, Dong *et al* showed in an urban Chinese population, where their study was based, dog ownership was a risk factor for children, rather than being protective. An OR of 1.45 (95% CI, 1.03- 2.06) was found. In these urban areas most pets will be kept indoors at all times, therefore, resulting in greater exposure, as well as increased pet-related pests [38]. Both of these factors were related to asthma diagnosis and asthma symptoms. The association between pets and respiratory health is complex, results often show that children without pets have more respiratory health complications; however, it is plausible that the household was advised or they perceived it best to remove the pets as a result of the respiratory health complications [42-43]. Custovic conducted a review of studies that examined the relationship between pet ownership and respiratory health [44]. They found that the results were generally inconsistent, particularly for cat ownership. According to the author some studies found cat ownership to be a risk while others found it to be protective [44]. The results for dog ownership were more consistent, studies found that owning a dog may have no effect or be slightly protective.

1.6.3 Traffic related air pollution

In the previous section regarding air pollution and health effects on the general adult population it was seen that there is an association between traffic-related pollution and health outcomes. For this reason, when considering child respiratory health in relation to outdoor air quality, traffic-related effects and pollution needs mention.

Reduced child lung function was found to be associated with truck-traffic density; the association was stronger in children living closest to motor ways [18]. Another association was found between diesel exhaust particles (where black carbon was used as a proxy) and lung function [18]. This association was stronger in girls than in boys.

A study conducted in South Holland examined respiratory health outcomes of children living in close proximity to major roads [45]. Traffic counts were collected and questionnaires were delivered to schools in close proximity to these major roads [45]. It was found that children living within 100m of the major roads were significantly more likely to report doctor diagnosed asthma, wheezing, coughing and runny nose [45]. Truck-traffic and smoke at the schools were significantly more likely to be associated with chronic respiratory symptoms, such as chronic cough, asthma, wheeze and rhinitis. NO_2 and smoke concentrations were found to decrease with distance from the motorways, but not PM_{10} and $PM_{2.5}$. Furthermore it was found that all of these associations were more pronounced for females. Statistically significant associations between truck-traffic and bronchitis were found for children living within 300m of the highways [45].

An association between traffic-related air pollution and self-reported wheezing, ear, nose or throat infections, asthma and colds and flu were reported by Brauer et al [46]. The children used in this cohort were 2 years of age, for this reason the authors explained that the association between asthma and exposure needs to be better explored [46].

Another study was conducted in the Netherlands where the relationship between truck exhaust fumes and child respiratory health was examined [47]. It was found that $PM_{2.5}$ and elemental carbon increased significantly with the increase of truck-traffic. NO_2 concentrations were found to increase significantly with total traffic increases. One of the data collection mechanisms that the authors used was a questionnaire for the parents of the children. Results indicated a prevalence of having asthma to be 8%, chest wheeze 9.4%, hay fever 7.2% and bronchitis 7.7%. The study used the pollutant measures, distances to major roads, traffic densities and truck-traffic densities as risk factors for various self-reported respiratory health outcomes and measured bronchial hyper responsiveness and allergies. Through this they found an association between truck-related air pollution and chronic respiratory complications in children living close to motorways.

In 2006, a direct link between traffic-related air pollution and otitis media (earache) in children was found [48]. This finding was significant as otitis media is one of the primary reasons for doctor visits and surgery in developed countries [48]. Also, otitis media may cause speech, language and cognitive delays in children, which may put a strain on a country's medical and education systems [48].

The study conducted by Dong *et al* found an association between respiratory morbidity in children and their proximity to traffic pollution, they obtained an adjusted OR of 1.48 (95% CI: 1.19- 2.36) [38]. This was adjusted for age, sex, breast feeding, living in city, school, house type, area of residence, number of rooms, indoor coal use, current exposure to Environmental Tobacco Smoking (ETS), exposure to ETS before 2-years-old and during pregnancy, pet keeping, home decoration, parents' education and parents' atopy.

1.6.4 Diet

Ellwood *et al* conducted a study to estimate or establish a relationship between some respiratory health conditions and diet [49]. The focus was on wheeze, asthma, allergic rhinoconjuncitivits and atopic eczema. The data used was collected through the International Study of Asthma and Allergies in Childhood (ISAAC). The age groups of 6-7 years and 13-14 years were used. Results showed a decrease in symptoms with an increase in caloric intake of cereal and rice, protein from cereal and nuts, starch, vegetables and vegetable nutrients.

A second study found an association between low intake of fish, fruit and vegetables and coughing and wheezing; the strongest association was seen between low intake of fish and coughing [50]. Chatzi *et al* found that consumption of fresh fruit and vegetables were protective of wheezing and rhinitis, while high consumption of nuts and margarine were associated with the occurrence of wheezing and allergic rhinitis [51].

1.6.5 Children with asthma

Koening and Mar examined SO_2 air quality standards with regards to child health. It was noted by the authors that children and adults with asthma are particularly sensitive to the effects of SO_2. Exposure to SO_2 may cause symptoms such as shortness of breath, coughing, wheezing and decreased lung function [11]. Also, increased coughing, wheezing and infectious respiratory disease (excluding pneumonia) have been associated with SO_2 exposure in children who do not have asthma [52-54].

An association was found between high levels of PM_{10}, $PM_{2.5}$ and O_3 and having reduced lung function in children with asthma [55]. Similar findings were also found by Mann *et al*. NO_2, PM_{10} and $PM_{2.5}$ were independently associated with wheezing in children with asthma [56]. This association was stronger in children with allergies to cats and common fungi.

A time series study was conducted in Athens, Greece; where it was found that elevated PM_{10} concentrations increased the number of paediatric asthma exacerbations and hospital admissions [57]. This risk was doubled for asthmatic children aged between 0 and 4 years. A four day lag period from the time of exposure was more strongly associated with the occurrence of asthma attacks in older children [57].

1.6.6 Socio-economic status

There is some evidence to suggest that socio-economic status may impact upon children's exposure to air pollution and subsequent adverse health outcomes. A study was carried out by Wilhelm *et al*, whereby the associations between outdoor air quality, childhood asthma and neighbourhood quality (using socio-economic status) were examined [58]. A weak association between neighbourhood quality decrease and an increase in CO and NO_2 levels, and a decrease in O_3 levels was found. However, children residing in areas with higher O_3 were found to have a greater chance of having doctor diagnosed asthma, but they did not have higher odds of having an attack in the past 12 months.

Another study examined the relationship between Acute Lower Respiratory Infection (ALRI) hospital admissions in Nigerian pre-school children [59]. A strong association between the fuel used for cooking and being hospitalised for ALRIs was found. Additionally most of the children who died were exposed to wood smoke.

In the South African environment, lower socio-economic status may indicate greater chance of having prefabricated housing, presence of mould, making use of dirty fuels for heating and cooking and having lower nutritional status. The use of dirty fuels may contribute to ambient pollution levels in a community. Having mould in the house or using dirty fuels may contribute to poor indoor air quality. Nutritional status may influence or be indicative of a person's general health or ability to cope with ill health.

1.7 The South African situation

1.7.1 Sources of air pollution

Although it is understood that in South Africa the industrial, mining, agricultural, transport and residential sectors contribute to air pollution, their individual contribution is not yet known [60]. It has been shown that the primary contributors to the total PM_{10}, SO_2 and NO_X in South Africa were industrial activities, mining and power generation [60]. The impacts of these activities on the environment (human or natural) are dependent on not only the amount of emissions but also the locations. For example, the contribution of emissions from power generation to poor human health is complicated since the emissions from power generation are often released higher up in the atmosphere compared to ground level fossil fuel burning.

1.7.2 Air pollution control

South Africa has been identified as having an air pollution problem resulting mostly from the burning of fossil fuels as an energy source [61]. The first air pollution control act that came into effect was the Atmospheric Pollution Prevention Act (Act 45 of 1965) (APPA) [62]. This act focussed on factory emissions and gross smoke; visible pollution control and non-industry air pollution, such as vehicle emissions, were largely ignored.

APPA was later repealed by the National Environmental Management: Air Quality Act (Act 39 of 2004) [63]. This act was created to regulate air quality for the protection of the environment and health, by providing measures for the prevention of pollution and ecological damage while securing ecologically sustainable development.

The act requires that emission standards and local ambient air quality, such as substances in ambient air that may be harmful to human health and well-being, be identified and documented through the Government Gazette. Other air quality management measures discussed in the act include the identification of and control of pollutants in priority areas.

1.7.2.1 Criteria pollutants

In South Africa, there are 8 criteria pollutants for the effective management of air quality, namely O_3, NO_2, SO_2, lead (Pb), PM_{10}, CO and benzene (C_6H_6). On 24 December 2009, the standards for the criteria pollutants were gazetted (Government Gazette 32816, 2009) [20]. In 2011, proposed standards for the control of $PM_{2.5}$ were also gazetted for public comment on 5 August 2011 (Government Gazette 34493, 2011) [64]. Table 1 below shows the South African standards for these criteria pollutants as well as the guidelines set by the WHO.

Table 1. Standards for criteria pollutants used by South Africa and WHO

Substance	South Africa		WHO	
	Averaging Period	Concentration ($\mu g/m^3$)	Averaging Period	Concentration ($\mu g/m^3$)
SO_2	1hour	350	24hours	20
NO_2	1hour	200	1hour	200
PM_{10}	24hours	120	24hours	50
$PM_{2.5}$	24hours	65	24hours	25
O_3	8hours	120	8hours	100
C_6H_6	1year	10		
Pb	1year	0.5		
CO	1hour	$30mg/m^3$		

Note: There are different averaging periods for SO_2 standards used by SA and WHO

For some of the criteria pollutants, future guidelines have been set with specific dates for when they will take effect. Three of the criteria pollutants have future guidelines, specifically PM_{10}, $PM_{2.5}$ and Benzene. For PM_{10} and Benzene the new guideline will come into effect on 1 January 2015. At that time the PM_{10} 24 hourly average cannot exceed $75\mu g/m^3$ and for Benzene the yearly average cannot exceed $5\mu g/m^3$. The proposed future $PM_{2.5}$ guideline will come into effect on 1 January 2016, and will define that the $PM_{2.5}$ 24 hourly average cannot exceed $40\mu g/m^3$.

1.7.3 Priority areas

A priority area is an area declared by the Minister or a Member of the Executive Council (MEC) through notice in the Government Gazette. There are five primary reasons for an area being declared. Firstly, it must be reasonably believed that the ambient air quality standards of an area are being or may be exceeded. Secondly, a situation of concern must exist which may cause or is causing a significant negative effect on the air quality of the area. Thirdly, a specific air quality management action is required to rectify a situation. Fourthly, the air quality in the area affects the population or the poor air quality has or may affect another country. Lastly, an area may be declared a priority area when the affected area is distributed over provincial boundaries, or when the area falls within a province and the province requests it be declared a priority area. The MECs of two adjoining provinces may by joint action declare an area falling within those provinces as a priority area. A consultative process must be followed before an area gets declared as a priority area. The Minister or MEC may by notice in the Government Gazette withdraw the declaration of an area, if the area has been in compliance (with the National air quality standards) for at least two years. Currently there are two Priority Areas in South Africa, the Vaal Triangle Priority Area and the Highveld Priority Area (HPA). There is a third proposed Priority area, namely that of the Waterberg district (Government gazette 34631) [65]. The HPA is the site of this study.

1.7.4 Indoor air pollution and health

The epidemiological data of child health and indoor fuel use for South Africa shows a cause for concern. Barnes *et al* conducted a study examining indoor fossil fuel burning and child respiratory health [66]. Various biomass fuels were placed in a hierarchy. Biomass fuels such as wood were ranked the least favourite for indoor air, followed by transition fuels (e.g. coal). Modern fuels (e.g. electricity) were ranked most ideal for indoor air. Between 1994 and 1999, 2.5 million houses were electrified. From 1996 to 2007, there was an increase in the number of households using electricity for cooking and heating, with a slight decrease in coal, wood and paraffin use, while the use of gas remained similar. It was noted that although this is a good trend, it does not allow one to examine households using multiple fuels to meet their needs, as the data were collected for the primary fuel. This “good” trend also does not account for people continuing to use other fuels for cooking and heating [66].

A number of studies examining indoor air quality noted that numerous households were in exceedence of the United States Environmental Protection Agency (USEPA) guidelines for SO_2, NO_2, PM_{10} and CO, and that children were present around the fire for 52- 61% of the time that it was burning [67-68].

A comparative risk assessment was conducted by Norman *et al* to establish the burden of respiratory health in South Africa due to indoor air pollution [69]. The assessment found that approximately 24% of Acute Respiratory Infections (ARI) in children under the age of five years was attributable to indoor air pollution. This study adjusted for ventilation. This shows that for children in South Africa, indoor fossil fuel use has a significant contribution to respiratory morbidity. However, the contribution of outdoor air should not be neglected.

1.7.5 Outdoor air pollution and health

Numerous studies have assessed the relationships between outdoor air pollutants and health. In South Africa, Norman *et al* conducted a comparative risk assessment examining outdoor air pollution (specifically PM_{10} and $PM_{2.5}$) and mortality from cardio pulmonary disease and lung cancer in adults over 30 years and ARIs in children less than 4 years [70]. This showed that the annual average PM_{10} concentration in urban areas in South Africa was approximately 46.9µg/m^3, and the concentration of $PM_{2.5}$ was approximately 26.6 µg/m^3. Outdoor air pollution was responsible for approximately 3.7% of deaths due to cardiopulmonary disease in adults over 30 years [70]. They found 5.1% of mortality from cancer of the trachea, bronchus and lung in adults of over 30 years was attributable to outdoor air pollution. Outdoor air pollution contributed to 1.1% of ARI mortality in children.

ISAAC studies use a specific method that aims to determine the prevalence of asthma and allergies in populations around the world. These studies do not specifically examine the causes of these health outcomes; however, they may be attributed to outdoor or indoor air pollution. Asher *et al* reported results from an ISAAC Phase 1 and 3 studies [71]. The Phase 3 results were collected and presented in order to show prevalence changes from Phase 1, there were approximately 5years between the phases. In Phase 1, there was only one African country used (Nigeria) for the age group of 6-7 years. The prevalence for asthma was recorded at 4.8%, this prevalence increased in Phase 3 to 5.6%. For the 13-14 years age group, for the same country, the prevalence was recorded at 10.7% for Phase 1, while for Phase 3 there was an increase to 13%. For South Africa, data were collected from a centre in Cape Town. There was, however, no data for the 6-7 years age group, but there was data collected for the 13-14 years age group. The prevalence of asthma in Phase 1, for this age group, was recorded at 16.1%, and 20.3% in Phase 3. This prevalence was the highest of all the African countries included.

Ait- Khaled *et al* examined ISAAC phase 3 data for asthma, rhinitis and eczema for different centres in different African countries [72]. In South Africa, there were two centres; Cape Town and Limpopo. The prevalence of wheeze in Cape Town was 20.3% while Limpopo had a prevalence of 18%. The prevalence of severe wheeze in

Cape Town was 5% while in Limpopo it was 6.6%. The centre in Cape Town had the highest prevalence for wheeze out of all the included centres in Africa, while Limpopo had the highest prevalence for severe wheeze out of all the centres used. For rhinoconjunctivitis, the Cape Town sample had a prevalence of 20.7% while Limpopo had a prevalence of 18.2%. The highest prevalence for this was recorded in Brazzaville, Congo at 33.3%.

The information used by Ait- Khaled *et al* for Limpopo Province was reported by Wichmann *et al*. This study was the first to use children aged between 6 and 7 living in South Africa [73]. Wheeze, severe wheeze and associated risk factors were examined. In addition to the prevalence reported above, they found a prevalence of 11.2% for wheeze and 5.7% for severe wheeze.

The Vaal Air Pollution Study was a large comprehensive study whereby the effectiveness of air pollution management and the potential child respiratory health effects were quantified [39]. The study considered outdoor and indoor exposure and monitoring. Physiological monitoring was done as well as the use of a quantitative questionnaire. The study identified two primary risk factors for child respiratory health, namely, indoor coal use and indoor smoking. Results showed a prevalence for upper respiratory disease of 65.9% and lower respiratory of 28.9%.

A study examining the relationship between asthma and outdoor air pollution in an industrialised area of Durban, South Africa was conducted [74]. It found a strong association between SO_2 and PM_{10} and respiratory illness, both individually and combined. A prevalence of 52% for asthma of any severity was found. It was also demonstrated that air pollution concentrations measured at the selected schools never exceeded the South African Standards.

These studies present a profile of the respiratory health of children throughout the country. It is important to be cognisant of these studies when examining the child respiratory health in a different region.

1.8 The Highveld region

1.8.1 Location

The Highveld region includes the eastern part of Gauteng and the Western part of Mpumalanga. This region has for many years been involved in much industrial activity, particularly electricity generation. Some of the major industrial towns in the Highveld region are Witbank, Middelburg, Secunda and Ermelo. The map below shows the Highveld region, shown using a dotted line ring (Figure 1).

Figure 1. Highveld region of South Africa

1.8.2 Highveld Priority Area

The HPA was declared a priority area on 23 November 2007. The HPA includes the eastern part of Gauteng and the western part of Mpumalanga. The selected study area for this research was in Mpumalanga. The HPA was declared a priority area as, there is a recognised air pollution problem in the area and it is believed that the populations living and working in the area are exposed to air that is harmful to their health and wellbeing [75]. Over an area of approximately 31 000 km^2 there is a population of ~3.6 million [76]. Some of the primary contributors to the poor air quality in the area are coal-fired power production plants, petrochemical plants and coal mines.

As a result of the HPA being declared, a baseline air quality report as well as a management plan was required. A draft of this became available in March 2010 [77]. This report notes some of the sources of pollutants in the area such as PM, NO_2 and SO_2. Some of the sources of these are listed as power generation, mines, mine haul roads, other industrial activities and domestic fuel burning. The modelled and monitored data allowed 10 pollution hotspots within the HPA to be identified [77]. These include Emalahleni (Witbank), Kriel, Steve Tshwete (Middelburg), Ermelo, Secunda, Ekurhuleni, Lekwa, Balfour, Delmas and Pixley ka Seme.

1.8.3 Demographics

In 2008, Mpumalanga had a population of 3.5 million people, while the national population was about 48.5 million. In the same year, there were less than 1 million households in Mpumalanga and there were about 13.5 million households in the entire country. In 2008, approximately 11% of households in Mpumalanga were informal. In the same year, about 83% of households in Mpumalanga reportedly had electricity; however, 31.5% reported using paraffin or wood for cooking. This was the only province that did not show a substantial decrease in the percentages of people using paraffin or wood for cooking between 2002 and 2008. About 6% of households in the province had no toilet system and were using the bucket system; this was the third lowest percentage by province. Only 38.2% of households in the province had their waste removed by the municipality, the only province worse off was Limpopo. Just fewer than 90% of households had access to piped water; there were three other provinces with less access to piped water. In 2008, over 62% of households reported having water interruptions to their piped water supply at least once a month; this was the highest in the whole country. [78].

These factors show that Mpumalanga is one of the poorer provinces in the country and they are currently struggling with essential service delivery. This may result in people being exposed to poor living environments, and increased environmental pollution.

In the Mpumalanga State of the Environment report it is explained that of all 11 operational coal fired power stations nation-wide, 8 are found in Mpumalanga and these generate approximately 70% of all electricity in South Africa [79]. Coal fired power plants primarily emit PM, SO_2 and NO_2.

1.8.4 Climate of the Highveld region

In the winter months there is a presiding high pressure cell over the Highveld region of South Africa. This high pressure cell causes an inversion layer which traps pollutants close to the surface [80].

The southern hemisphere is dominated by recurrent, semi-permanent anticyclone cells. The atmosphere is very stable as a result of the downwards movement of air, particularly during winter. The inversion layers that are present in the area allow near surface winds with little dispersion power, however, these are able to transport pollutants over a long distance. There is less stable air above the surface inversion where horizontal movement of pollution is maximised. Just above this mixing layer and below the subsidence inversion is a pollution-trapping area. [81]

Wells *et al* explained that inversion layers were an important meteorological factor contributing to the accumulation and dispersion of air pollutants [82]. It was noted that inversion layers also contribute to ambient air pollution concentration during the summer months; however, the winter months are the most severe.

The contribution of air pollution sources is not only dependent on the amount of their emissions but also their location [59]. As was mentioned previously; the effects felt from power generation emissions would be less than ground source emissions as a result of the height of the power generation emission stack [59]. However, given the climatic condition of the area these emissions are forced lower to the ground, worsening their effects.

In the State of Air report it is explained that there are five possible routes for air pollution dispersion, seen in Figure 2. These include a direct path towards the Indian Ocean, Atlantic Ocean, south Indian Ocean, equatorial Africa and least favourable a circulation over the African sub-continent to arrive back in the same place [1].

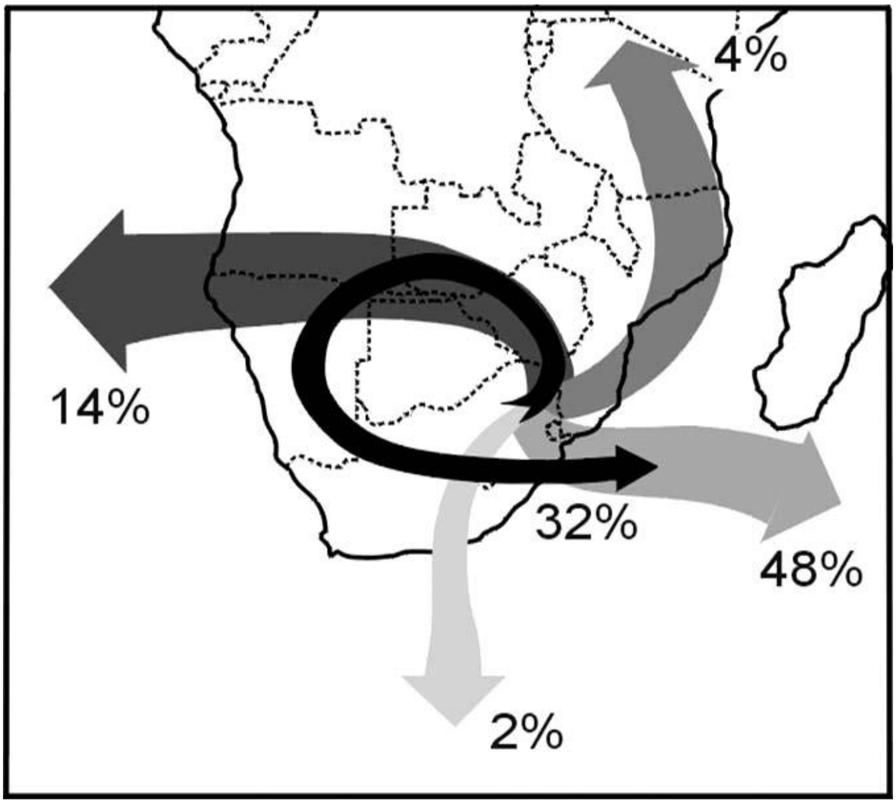

Figure 2. Five identified pathways of pollution movement from the Highveld region [1pg 86]

These climatic conditions must be taken into account when examining health or air quality data and they must be considered for management and control purposes.

1.8.5 Air pollution

The area defined as the HPA is similar in location to the original Eastern Transvaal Highveld area, now called Mpumalanga Province. The Highveld region, previously the eastern Transvaal, had (and still has) one of the worst pollution problems in the country as a result of electricity generation and domestic coal burning [80]. This document warned against the construction of additional mines and coal fired power plants in the area. In 2007, work began on a new coal fired power plant in the Kendal area of the Highveld; the construction process may also create additional pollution.

In a study to examine various gaseous pollutants over the HPA, the distribution of SO_2, NO_2, O_3, Benzene, toluene, ethylbenzene and xylene were investigated [83]. Results showed that there was a mixture of pollution sources such as metallurgic, mining, coal fired power stations and petro chemical plants. The area also has domestic fossil fuel burning and during the dry, cold winters, natural fires are common. It was found that SO_2 and NO_2 concentration were highest at industrial sites such as Witbank, while O_3 was highest at more rural points [83]. The results indicate that sites with the highest NO_2 and SO_2 concentrations had the lowest O_3 concentrations, while sites with the highest O_3 concentrations had lower SO_2 and NO_2 concentrations. Out of all the sampling points used around the HPA, Witbank had the highest NO_2 and SO_2 concentrations. From the results, Witbank generally had the worst concentration so it was recommended that Witbank should be seen as a localised hotspot [83].

A study examining dry deposition of sulphur in Mpumalanga was conducted [84]. The average SO_2 concentration during the winter months was recorded at 10.7parts per billion (ppb), and the highest recorded value was 92.3ppb [84]. This equates to 28µg/m^3 and 241.6µg/m^3, respectively. For the summer months, an average of 5.4ppb was recorded, and 45.5ppb was the highest recorded value [84]. This equates to 14.1µg/m^3 and 119.1µg/m^3, respectively. Similar deposition rates for sulphur, for both summer and winter, were found. The majority of dry deposition occurs during the day, indicating limited vertical mixing at night.

1.8.6 Air pollution and health in the Highveld region

Zwi *et al* conducted a cross-sectional study in the Highveld region examining child respiratory health and air pollution [85]. Two child samples were used: one from an area deemed “polluted” and another from an area deemed “clean”. The clean areas or control areas were selected using air quality data. Primary school children in “Standard 2 and 3”, now known as Grade 4 and 5, were included.

Children in these Grades would typically be between the ages of 9 and 11 years. A questionnaire completed by the child’s mother was used to determine respiratory health status. Height, weight and lung function were also measured. Children in the non-polluted areas were statistically significantly taller than those from the polluted areas; this was still significant after adjusting for age. They found coughing in the morning or during the day or night to be statistically significant, but only for girls. The same was found for wheezing. Having asthma was reported to have been statistically significant for boys. The results suggested little association between bronchitis, pneumonia and other chest illnesses. Smoking in the home was related to chest colds, but in girls. Asthma was more prevalent in children from polluted areas. Results suggest that boys residing in homes that did not use electricity for cooking were more likely to have a chest illness that kept the child away from school for a week or more, compared to boys living in homes that did use electricity. Earache was found to be more common in girls when there was smoking in the home. Children from the cleaner areas were more likely to have hay fever. While, vital capacity and peak expiratory flow rate, were found to be lower in boys living in the polluted areas and only vital capacity was lower in girls from the polluted areas. However, after adjusting for important variables and confounders, these differences were eliminated.

These results show that the respiratory health of children from the polluted area was worse than the cleaner area. This is the only study to have considered child respiratory health in the Highveld region. The results of this study were published 21 years ago. Given the changing nature of the South African industrial and economic situation and the introduction of stricter air quality management, it is prudent that this topic be revisited.

1.9 Relevance of study

There is little known about air pollution and its impacts on the respiratory health of the children in the HPA. For this reason, a basic investigative study needed to be completed in order to begin to better understand the respiratory health of children in the area.

1.10 Aim and objectives of the study

The aim of this study was to complete a baseline of child respiratory health and associated risk factors for children aged between 9 and 11 years in the HPA, in the towns of Witbank and Middelburg.
Four specific objectives were identified:

- Determine, using proportions, the respiratory health status of children aged between 9 and 11 years in the HPA;
- Show associations between possible risk factors and child respiratory health;

- In relation to measured child respiratory health status, describe air quality in Middelburg and Witbank and make comparisons with the National Air Quality Standards and other health- based guidelines or standards; and
- Provide recommendations to assist in current development of the Air Quality Management Plan for the Highveld Priority Area.

Chapter 2: Methods

2.1 Introduction

The respiratory health data for children aged between 9 and 11 years were obtained through the use of a quantitative questionnaire, completed by consenting parents, guardians or caregivers. Data were entered, prepared and checked before being analysed. The air quality data were first scrutinised for quality and then prepared and used to illustrate the extent of the possible air pollution problem. Chemicals of interest that were focused on were SO_2, O_3 and NO_2. PM_{10} and $PM_{2.5}$ were also examined.

The study was set in the HPA; however, it focused exclusively on the Middelburg and Witbank regions. The towns of Witbank and Middelburg were chosen as they were similar and are 25 km apart. They are known to experience some of the poorest air quality in the HPA. There is a National Air Quality Monitoring Station situated in each of these towns. They are the only National Monitoring Stations in these towns; however, they are not the only National Monitoring Stations in the HPA.

2.2 Study design

This study of child respiratory health was designed as a cross-sectional study. An epidemiological cross-sectional study is one where the exposure and health outcomes are measured at a single point in time and they are measured simultaneously [86]. Cross-sectional studies are used to determine the prevalence of a particular health outcome at a given point in time and they identify possible associated risk factors [86]. These study designs are typically used to direct the aims of further analytical studies in order to better understand or confirm these identified associations [86].

The current study examined child respiratory health and air pollution in the HPA using a questionnaire. The questionnaire collected quantitative data regarding respiratory health outcomes and possible risk factors. In this way, baseline respiratory health data were attained, as well as possible risk factors examined, such as parental smoking and indoor fossil fuel use. The study also examined air quality data from the Witbank and Middelburg National Monitoring Stations, with specific interest in SO_2, NO_2, PM_{10}, $PM_{2.5}$ and O_3.

2.3 Study population

The study population included any Grade 4 or 5 pupils attending public primary schools in the two areas. Grade 4 and 5 children are typically between the ages of 9 and 11.

Children between the ages of 9 and 11 years were used because at this age, males and females have similar but high breath rates, with; 14m^3/day and 13m^3/day, respectively [87]. After this age, the female breathing rate lowers until reaching adulthood, with a rate of 11.3m^3/day. The male breath rate increases up till 17m^3/day before dipping slighting to 15.2m^3/day in adulthood [87]. The rate is the same for males and females from infancy to 8 years of age, starting at 4.5m^3/day to 10m^3/day [87].

Schools closest to the national monitoring stations in Witbank and Middelburg were selected. Clusters of potential schools around the monitoring stations were identified. A 10 km radius around each monitoring station was used as a guide for school selection and inclusion. Only as many schools as were required to meet the calculated sample size were included. Only public primary schools were used. No further inclusion or exclusion criteria were used.

Within these primary schools, all children in the selected grades were asked to participate. All children present in the classes on the day of distribution were given questionnaires in their home language (where possible) to be taken home and completed by their parents This was done in order to obtain the majority of the school's children within the age range while causing the least disruption and ensuring that the appropriately-aged children received a questionnaire.

In order to obtain a sample large enough to successfully calculate statistically significant associations, a sample size was calculated.

This can be calculated using the following formula, where n is the number of questionnaires required to be distributed, π is variance, CI is the desired confidence interval and Response Rate is the estimated number of questionnaires that will be returned.

$$n= [4\pi(1-\pi) \div (1-(CI\div100))^2] \div [\text{Response Rate}/100]$$

The result of this calculation dictates how many questionnaires need to be distributed, so as to receive the correct number, using an approximated Response Rate.

For this study, the value of π was not known, it was assumed to be 0.5 as this allows for the largest sample size. The confidence interval chosen for this was 95% with a response rate of approximately 30%. The calculation follows below.

$$n= [(4\times0.5)(1-0.5) \div (1-(95\div100))^2] \div [30\div100]$$

$$n= [1\div0.0025] \div [0.3]$$

$$n= 400 \div 0.3$$

Therefore $n= 1333.33$

Therefore in total, a minimum number of 1334 questionnaires had to be distributed.

2.3.1 School selection

A multi-stage random sampling approach was used in this study.

a) A complete and up-to-date list of all the schools (including public, private, primary, secondary, high, combined and special) for the entire country was obtained. This data set was prepared, by first removing all the schools labelled “private”. Private schools do not use a zoning system for admission therefore students may be from a wider geographic area meaning that they may not be exposed to similar ambient air. Following this, all the schools that have since closed were removed. Then all non-primary schools were removed (i.e. secondary and high schools) however, combined schools were not removed. Schools listed in the document that did not have recorded GPS coordinates could not be used, as the location of schools was required in order to determine if the schools fell within the defined radius around the monitoring stations. A number of unwanted columns of information were also removed. The remaining schools were then sorted according to their magisterial district.

b) The GPS coordinates of the schools falling within the Witbank or Middelburg magisterial district were then plotted in Google Earth. The GPS coordinates of the two national air quality monitoring stations were also plotted. After plotting the coordinates of all the remaining schools, only the schools that fell within the 10 km radius around each monitoring station could be considered for inclusion (Figure 3). 35 and 19 schools were located in the 10 km radius around the Witbank and Middelburg Monitoring Stations, respectively. Using this, the 10 closest schools to the each monitoring station were shortlisted.

Figure 3. 10km radius around monitoring stations (shown with flags), including the plotted schools (shown with tear drop markers)

c) The number of children in Grades 4 and 5 at each school was required in order to ensure the correct number of children to be sampled. This information was not available; however, the total number of learners in each school was available. As a result, the number of Grade 4 and 5 pupils were estimated using the total number of learners. As there are seven grades within a primary school, the total number of learners was divided by seven, in order to gain an estimate of learners in each grade. This was then multiplied by two to account for Grades 4 and 5.

d) Out of the 10 shortlisted schools, those with the largest estimate of Grades 4 and 5 learners were selected until reaching over 700 learners for both Witbank and Middelburg.

These schools were then telephonically contacted and asked if they would be interested in participating and if so, a meeting was scheduled. When a school declined, a replacement school from within the already identified shortlisted group of schools was contacted.

2.4 Measuring tools

A structured questionnaire was used to collect quantitative data regarding respiratory health as well as possible risk factors for child respiratory health. Also included in the questionnaire were some variables collecting information regarding indicators of socio-economic status. The questionnaire was based on questionnaires previously used in other scientific studies of this nature. These include that used by Oosthuizen *et al* [88], and the Vaal Triangle Air Pollution and Health Study [39]. These two questionnaires were based on those used by Ferris [89] (ATS-DLD-78) the Canadian air quality and health study (NHW/HPB-190-03040) and the Harvard School of Public Health's Children's Health Study (NHW/HPB-190-03210).

The questionnaire (Appendix A) was modified, shortened and created to obtain specific information required for this study. The resultant questionnaire consisted of 42 independent questions, estimated to take 40 minutes to complete. Parents or guardians were fully informed as to what was expected of them and the confidentiality of this questionnaire through the use of a covering letter.

The first seven questions collected information regarding demographics which included gender, date of birth, language, town where the child lives, how long they have been living in the town, if and where they lived before and for how long. These questions were all nominal apart from a question regarding the previous town which was open; this was done for practicality purposes.

The following section collected information on the child's home environment. These included the type of home (such as pre-fabricated or brick), overcrowding, water sources, heating systems, frequency of heating system use, fuel used for cooking, circulation of fresh air, mould, pets and smoking. Although this study focussed on outdoor air pollution, factors within the child's home (such as indoor air pollutants) are often risk factors as well as potential confounding factors and therefore were included. Most of these questions were ordinal or nominal; two were open, requesting the number of bedrooms in the house and the number of people in the house.

The next section comprised only one question which asked about eating habits and this was also a nominal question. This examined the frequent eating of chicken or fish, red meat, vegetable, fruit and processed foods.

One Knowledge, Attitude and Perspectives (KAP) question was included. It was designed to ascertain if the parents or guardians view the health of the child to be better, the same or worse than other children in their peer group.

The health outcomes of interest were examined in a series of questions. In this section, two questions, designed to ascertain prevalence, were included and these asked if a number of conditions, such as bronchitis, had been experienced in the previous six months or two weeks. Asthma was examined in a section specifically set out with linked or stem and branch questions for respondents who reported having asthma. There were six questions included to acquire information regarding chest cough, phlegm and wheezing and patterns and severity thereof. There were two questions investigating hospitalisation for respiratory illness and using prescription medication. All of the health outcome questions were nominal or ordinal, with four open questions for counts or specifications.

The predominant languages of the schools were obtained, and this informed translation and printing. The questionnaire was translated into Afrikaans and Zulu. A backwards translation procedure was also carried out to ensure no meaning was lost. Following this, the translated questionnaires were given to someone with the language as their home language to read. The people were asked to relay the meaning of each question and where necessary slight alterations were made, in order to ensure better comprehension of the questions. Based on the predominant languages of the scholars, obtained from the schools, sufficient copies of the questionnaires were made.

Blank questionnaires were placed in A4 envelopes and personally delivered to each school and responses were personally collected one week later.

2.5 Ethical considerations

The questionnaires were created for the parents, guardians or caregivers to complete regarding their Grade 4 or 5 child's health. The questionnaire was completely anonymous and participation was voluntary. Consent to participate was given by the return of a completed questionnaire. This information was explained in detail in a covering letter which was the first page of the questionnaire.

The protocol for this study was approved by the Academic Advisory Committee of the University of Pretoria on 20-07-2010. This study was given provisional approval from the University of Pretoria Ethics Committee on 18-10-2010 depending on the consent given by the Principals of the approached schools. This study was approved by the Department of Education on 07-07-2010 and the Department of Environmental Affairs on 24-06-2010. Final ethical clearance was given on 12-04-2011 (S152/2010) (Appendix B).

2.6 Data management

Prior to data entry, a database was created using Epidata 3.1. In the database, each question was numbered according to the questionnaire and each variable was given a unique name. The entries were monitored by using various checks. Each respondent was given a unique code, there was a variable included in the database for this code. The unique code was manually written in two places on the returned questionnaires prior to data entry. Data entry assisted with verification of this unique code. In the questionnaire, all quantitative questions were numerically coded. The open-ended questions (3) were not coded immediately, but were stored separately and returned to later. This was necessitated by the different languages used to answer the questionnaire. Once the Epidata database was complete, several tests were run to ensure its effectiveness and ease of use; when necessary a few alterations were made and a test was done again. When these tests were completed and the researcher was satisfied with the database, data entry began.

Each question was entered exactly as it was on the questionnaire, however, a log of the questionnaire's unique code was kept when challenges were encountered so that if they were encountered again the same action was taken and this ensured consistency in data entry.

A 10% random double entry was done due to budget constraints. It was revealed that out of the 10% double entry there were two questions entered incorrectly, and one date of birth, and there were five questions that had consistency errors. For all the questions where consistency errors occurred, the entire database was checked and further errors were amended.

2.6.1 Questionnaire data analysis

The complete data set was then exported from Epidata into Microsoft Excel where the age of the child was calculated using the integer (INT) command. The children's age was calculated using the first day that field work took place and the date of birth completed on the questionnaire. Respondents that fell outside the age range of 9 to 11 years were removed from the data set. Some respondents did not provide a date of birth and so their age could not be calculated and they were therefore also removed from the dataset. There were some respondents that did not provide the full date of birth, some provided only the year and month while some provided only the year. In cases where only the year was given, the first of January for that year was used (i.e. 01-01), and in cases where only the day was missing the first day of that month (i.e. 01) was used.

All responses that were coded as "missing" were re-coded to be a blank cell, because Stata recognises a blank cell as a "missing" response. Before exporting to Stata all the text fields were removed and saved in a separate file, they were examined separately in Microsoft Word. Some of these included the town where the child previously lived, what illness caused absence at school and what prescription medication the child was using. The remaining data were then exported to Stata.

Following this, all the independent and dependent variables were identified and where possible dependent variables were re-coded into binary. For majority of dependent variables that were not binary, this was not done so as not to lose the value of the collected information. Next, all ordinal dependent variables (where possible) were re-coded so that the “healthiest” option for selection appeared first. This was done because of the way ordinal variables are managed in Stata, where by the proceeding categories are run against the most ideal. For example, the ‘healthiest option for allergies is not having allergies, while the second healthiest option would be having allergies and using medication bought over the counter. This ordering would continue until the least favourable.

After the preparation of the data, univariate analysis was carried out. This included calculating the frequencies for all the variables remaining in the data set. Missing data was also examined in this process.

The second stage was that of bivariate analysis whereby p-values for all the risk factor- health outcome relationships were calculated and tabulated. This was calculated using the Chi Squared test; however, if any cells had 5 or less observations, the Fishers Exact test was used. Using these p-values, the ORs of only significant risk factor- health outcome relationships were calculated and tabulated, along with their corresponding confidence intervals. A p-value of less than or equal to 0.05 was used to determine significance. All variables were included at this stage.

The third stage entailed multivariate analysis to determine possible risk factor relations for specific health outcomes. All health outcomes were tabulated with their significant risk factors these were determined using a p-value of 0.25 from the bivariate analysis. The exact risk factors used were determined using the bivariate results as well as examining the biological plausibility of the relationships [90].

Models were run on both the prevalence questions, therefore the same health outcome, this was done in order to examine the potential risk factors and examine their similarities.

As the study set out to examine possible risk factors for specific health outcomes, a multivariate model was not run on the KAP question. The 'number of days absent' variable was not modelled, although it could indicate the severity of an illness or other health problems, it only had one associated variable and that was the demographic factor of language.

For the asthma section, only the questions asking if the child had asthma were modelled. This was done because the other questions in the section were asking more details of the disease. The study aimed to examine the risk factors for the health outcomes.

Forwards stepwise regression was conducted using a pe (probability for entry) value of 0.05. Models were originally run using a pe value of 0.2, however, the outcomes were insignificant and the entrants significantly affected the models, thus it was decided to use a stricter pe value.

After running the models the R^2 value was the first to be interpreted value. This value explains how much of the variation seen in the dependent variable is due to the independent variables in the model. After this, the F-test value along with the corresponding p-value was examined. A high F-test with a low corresponding p-value shows the overall significance of the model. Lastly, the individual coefficients included in the model were examined in terms of their role and significance, a negative coefficient indicates a protective association.

2.6.1.1 Stem and branch question analysis

During data entry, it became evident that respondents did not answer a question in a way that correlated with their previous answers. These responses are termed spoiled responses [91]. Typically, inconsistent or spoiled responses would be disregarded [92- 93]. As a result of the questionnaire design and the number of inconsistent responses it was decided not to disregard these responses. Naeim *et al* discuss innovative ways of dealing with missing and "do not know" responses [94]. For this reason a novel solution for the challenges seen here was sought.

Firstly, all questions that were directly related to other questions were identified. As all data was entered exactly as it appeared in the questionnaire and no judgements regarding previous answers were made, all questions could then be seen as standalone. However, some questions were linked to previous questions, without removing the standalone version of the variable, a new variable was created. This new variable, termed a 'linked' variable, only included responses where they corroborate the response seen in the linking question. For example, a question was included to determine if pets were allowed inside the house, this question was linked to whether or not the child had pets. Therefore, another version of the pets being allowed inside question was created. This version (linked version) included only responses from those who originally said they had pets.

This was done for all questions that were correlated with previous questions. The situation regarding asthma-related questions requires special mention here. In the questionnaire, there was a section devoted specifically to asthma. The first question of this section asked if the child had ever been diagnosed with asthma. If the answer was 'no' the respondents were instructed to skip the rest of the section. Therefore the positive response to having asthma is then linked to the proceeding questions regarding asthma. After this question there was a question which asked if the child 'still had asthma attacks'. The answer to this question then further linked to the remaining questions in the section, such as 'how often the child has attacks'.

A linked version of the 'still have asthma' question was then created, this linked version, only included responses for respondents that originally selected having asthma. The questions that proceeded the 'still have asthma' question were then examined according to if the respondent reported that they still have asthma attacks. It, however, did not take into consideration if they originally reported doctor diagnosed asthma. This second tier of linking was then accounted for by taking into account the linked version of the 'still have asthma' question. Figure 4 illustrates this process schematically.

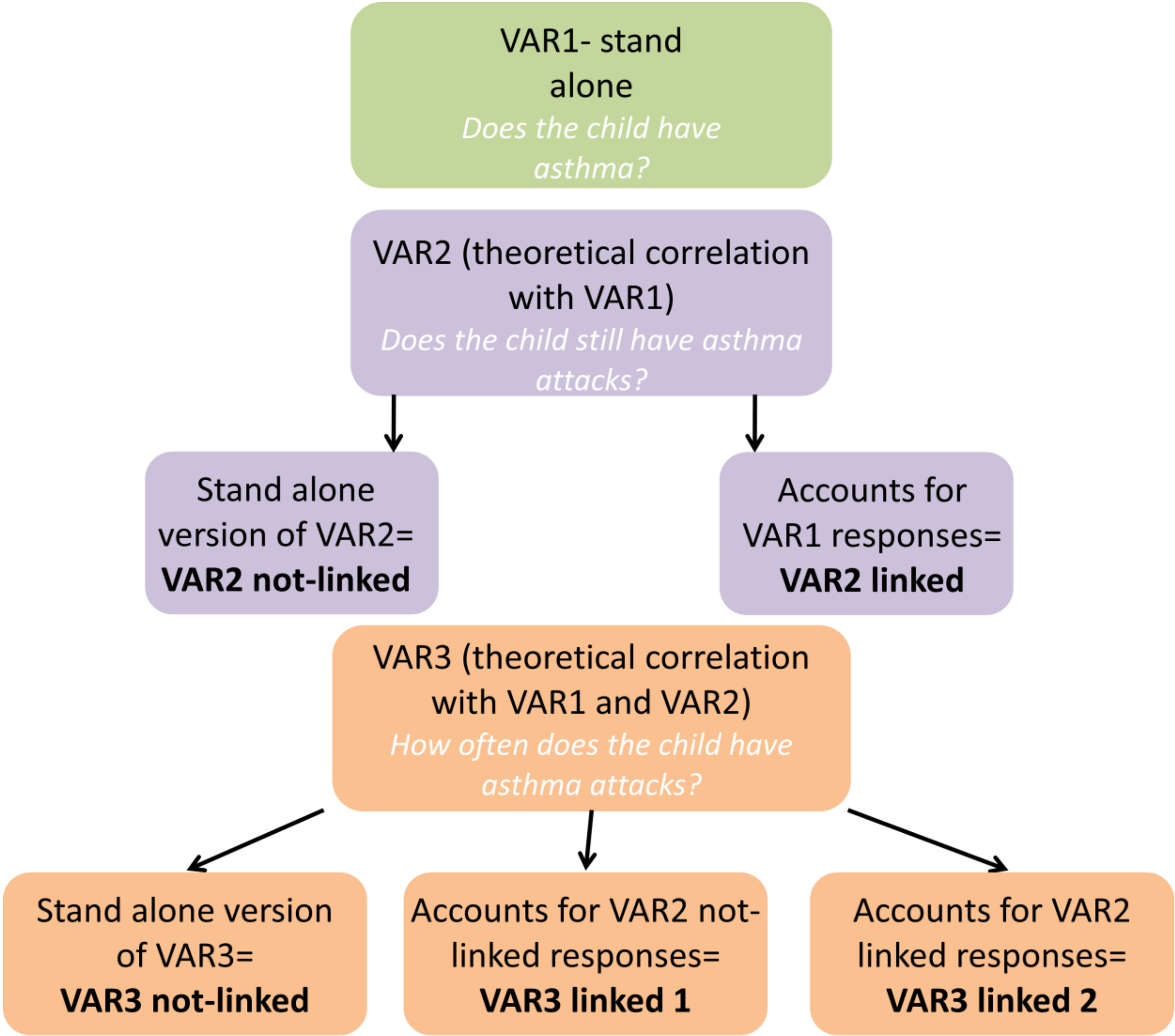

Figure 4. Schematic diagram for linked variables

2.6.2 Air quality monitoring data

The purpose of the air quality data was to illustrate a potential problem rather than determine a direct association between the air quality and child respiratory health.

Permission was obtained from the National Department of Environmental Affairs in order to obtain air quality monitoring data from the Witbank and Middelburg monitoring stations. Data for the most recent complete year was requested, however, only data for 10 months was provided for both monitoring stations. The data for the period August 2008 to May 2009 were provided in Microsoft Excel spread sheets with one month per sheet. The obtained data were in a raw format, where 10 minute readings were recorded for each pollutant. It was not possible to obtain data for the same period when the questionnaire was distributed. The questionnaire was distributed in the month of September. The air quality data included the month of September 2008. One could assume that the data would be similar for September 2010 as no large industries were added during the two years, and the climatic factors would be similar. However, a potential limitation is that one cannot know of any changes in the pre-existing industries, such as expansion or filter damage.

The instruments used to collect the air quality data are owned and maintained by the Department of Environmental Affairs according to their standard procedures for calibration and maintenance.

All metadata were removed from each sheet leaving only the pollutants of interest. Columns were added for hourly averages for each substance, as well as a column for the 24 hourly averages for PM_{10}, $PM_{2.5}$ and SO_2. A column for the 8 hourly averages for O_3 was also added. The SO_2, NO_2 and O_3 data were received in ppb. A pollutant-specific conversion was used to convert these to $\mu g/m^3$. All the hourly averages were then calculated using the “AVERAGE” command. The same was done for the 24 hourly averages and 8 hourly averages.

As a result of the poor quality of the data, it was decided that no formal guidelines such as those set by the EPA would be used to manage the missing data.

The following guidelines were used to clean the data; they were used consistently throughout data preparation. It was decided that 70% was the minimum amount of data to be present in order for an average to be calculated. For every hourly average there were six ten minute readings, it was calculated that if there were two or more missing then the hourly average was then also missing. For the substances that require 24 hourly averages, it was calculated that for seven or more missing hourly averages, the 24 hourly averages would then also be missing. For O_3, that requires an 8 hourly average, it was calculated that two or more missing hourly averages resulted in a missing 8 hourly average. For a monthly average, either the hourly, 8 hourly or 24 hourly averages were calculated and discarded if there was 30% or more of the data missing.

In some of the data, there were large strings where the same readings were recorded for a length of time. These were then marked as missing. Also all readings of “0” were marked as missing as these were deemed to be more likely missing than a true reading and can adversely influence the data.

2.6.3 Air quality data analysis

For both monitoring stations, all the monthly averages of the hourly averages (where available) were tabulated for all five substances, as well as the 24 hourly monthly average for PM_{10}, $PM_{2.5}$ and SO_2 and the 8 hourly monthly average for O_3.

The 99th percentiles were calculated for all substances for all months and for both monitoring stations. These were tabulated and shown in accordance with the South African National Standards and the WHO guidelines (Table 1).

Following this, for both monitoring stations, the months that appeared to be the worst but still had sufficient data, for PM_{10}, $PM_{2.5}$ and O_3 were selected and plotted. This was used to illustrate the monthly pollution pattern and to show exceedences. The most complete month for SO_2 and NO_2 were selected and monthly averages for each hour were calculated and plotted. This was used to illustrate a daily pattern for SO_2 and NO_2. All the air quality data was compared by monitoring station. Data for the month of September were examined as this was the month when the questionnaires were distributed.

Chapter 3: Results

This chapter presents the descriptive results of the child respiratory health questionnaire. The bivariate and multivariate analysis results that aimed to explore the potential associations between risk factors and health outcomes will be presented. The prevalence of health outcomes will also be described. The air quality data from Witbank and Middelburg will be presented using graphs and tables.

3.1 Response rate

A total of 1400 questionnaires were distributed, of which 859 responses were returned, 358 (41.7%) of these were from Witbank and 501 (58.3%) from Middelburg, even though equal numbers (700) of questionnaires were distributed in both towns.

In the sample size calculation, a response rate of 30% was estimated; however, 61.4% was received. For Witbank alone, the response rate was just over 51% and for Middelburg it was 71.6%.

After removing those that were not within the age range there were 189 respondents from Witbank and 438 from Middelburg. Witbank, therefore, had a usable response rate of 27% and Middelburg had a usable response rate of 62.6%. Therefore, a total usable response rate of 44.8% was obtained.

3.2 Demographic information from questionnaire

Table 2 shows the demographic information obtained through the questionnaire, explanation of some of these demographic variables follows.

3.2.1 Age

The questionnaire asked for the child's date of birth. This was then used to calculate the child's age on the first day that field work took place (13-09-2010), for more detail see Chapter 2 (Section 2.6.1). The majority of respondents that fell outside this age range were older than 11 years. Of the total respondents that were not included in the age range of 9 to 11 years, 2 were younger and 208 were older. 22 respondents did not provide their child's date of birth.

Table 2. Demographic information from questionnaire

Demographic variable	Variable options	Number of respondents n(%)
Age	9 years	143 (22.8)
	10 years	270 (43.1)
	11 years	214 (34.1)
	Total	627
Gender	Male	268 (43)
	Female	349 (57)
	Total	617
	Missing	10
Language	Afrikaans	13 (2.1)
	English	10 (1.6)
	Sotho	72 (11.6)
	Xhosa	7 (1.1)
	Zulu	436 (70.2)
	Swazi	40 (6.4)
	Other	43 (6.9)
	Total	621
	Missing	6
Town where child lives	Middleburg	438 (69.9)
	Witbank	189 (30.1)
Type of home	Detached brick house	338(58.9)
	Attached brick house	138(24)
	Flat	12(2.1)
	Prefabricated house	86(15)
	Total	574
	Missing	53
Water source	Municipality	573 (92.7)
	Private borehole	12 (1.9)
	Community borehole	33 (5.3)
	Total	618
	Missing	9

For those within the age range, there were 143 respondents of 9 years of age, 270 of 10 years and 214 of 11 years. The mean age was 10 years, while the mean age of all the respondents, including those falling outside the age range was 13.5 years.

All data analyses were completed using the sample of respondents falling within the age group of 9 to 11 years i.e. 627.

3.2.2 Language

For language, less than 1% was missing and 6.9% of respondents selected ‘other’. Majority (70.2%) of respondents selected Zulu as their home language, followed by Sotho (11.6%).

3.2.3 Town where the child lives

The majority of the respondents in the correct age group were from Middelburg (69.9%). Before removing those that were not part of the specified age group of 9 to 11 years, only 58.3% were from Middelburg.

3.2.4 Water sources

This section examined where the household got its water from. The respondents were asked to select ‘yes’ or ‘no’ for the three different options: municipality, private borehole and community borehole, and if neither of these, they were given an opportunity to specify an alternative. Some respondents did not answer the question at all while others did not answer it properly, meaning that people tended to select ‘yes’ for one option and not select no for the others but rather left them blank. For this reason, the number of people responding ‘yes’ to any option is of most importance. The results of this can be seen in Table 2.

3.3 Risk factor frequencies from questionnaire

Table 3 shows the percentage of respondents who selected the options for the different variables. Explanation of these findings can be found below.

Table 3. Risk factor responses from questionnaire

Risk factor variable	Variable options	Number of respondents n(%)
Heating system	Wood, coal stove or imbhawula	324 (64)
	Fireplace	47 (9.3)
	Gas or Paraffin heater	104 (20.6)
	Asbestos heater	31 (6.1)
	Total	506
	Missing	121
Frequency of gas or paraffin use	About every day	43 (48.9)
	2 to 3 times a week	28 (31.8)
	2 to 3 times a month	6 (6.8)
	Seldom	11 (12.5)
	Total	88 (100)
Frequency of wood, coal or imbhawula use	About every day	257 (85.4)
	2 to 3 times a week	23 (7.6)
	2 to 3 times a month	11 (3.7)
	Seldom	10 (3.3)
	Total	301 (100)
Frequency of fire place use	About every day	14 (38.9)
	2 to 3 times a week	13 (36.1)
	2 to 3 times a month	3 (8.3)
	Seldom	6 (16.7)
	Total	36 (100)
Fuel used for cooking	Electricity	459 (74.8)
	Gas	5 (0.8)
	Paraffin	43 (7)
	Wood	8 (1.3)
	Coal	99 (16.1)
	Missing	13
	Total	614
Circulation of fresh air	Yes	499 (81.5)
	No	113 (18.5)
	Total	612
	Missing	15
Mould in the house	Yes	149 (26.5)
	No	414 (73.5)
	Total	563
	Missing	64

Risk factor variable	Variable options	Number of respondents n(%)
Pets	Yes	86 (14.5)
	No	508 (85.5)
	Total	594
	Missing	33
Pets inside	Yes	17 (20)
	No	68 (80)
	Total	85
Smoking inside	Yes	51 (8.3)
	No	562 (91.7)
	Missing	77
	Total	613
Eats chicken or fish	Yes	495 (95.6)
	No	23 (4.4)
	Total	518 (100)
Eats red meat	Yes	309 (74.5)
	No	106 (25.5)
	Total	415 (100)
Eats processed food	Yes	321 (78.7)
	No	87 (21.3)
	Total	408 (100)
Eats vegetables	Yes	458 (93.3)
	No	33 (6.7)
	Total	491 (100)
Eats fruit	Yes	420 (92.7)
	No	33 (7.3)
	Total	453 (100)

3.3.1 Heating system

For this question, the same format as the water source question was used whereby respondents select ‘yes’ or ‘no’ to each option. However, as was the case in the previous question, this often did not happen or the question was omitted altogether. The range of these responses for the whole sample can be seen in Table 3.

Figure 5 shows the percentage of responses for heating options by town. Both towns have a similar distribution of respondents using wood, coal stoves or imbhawulas and gas or paraffin heaters. While for fireplace use and asbestos heater use, the pattern is inverted. Witbank had more people using asbestos heaters and Middelburg had more respondents using fireplaces.

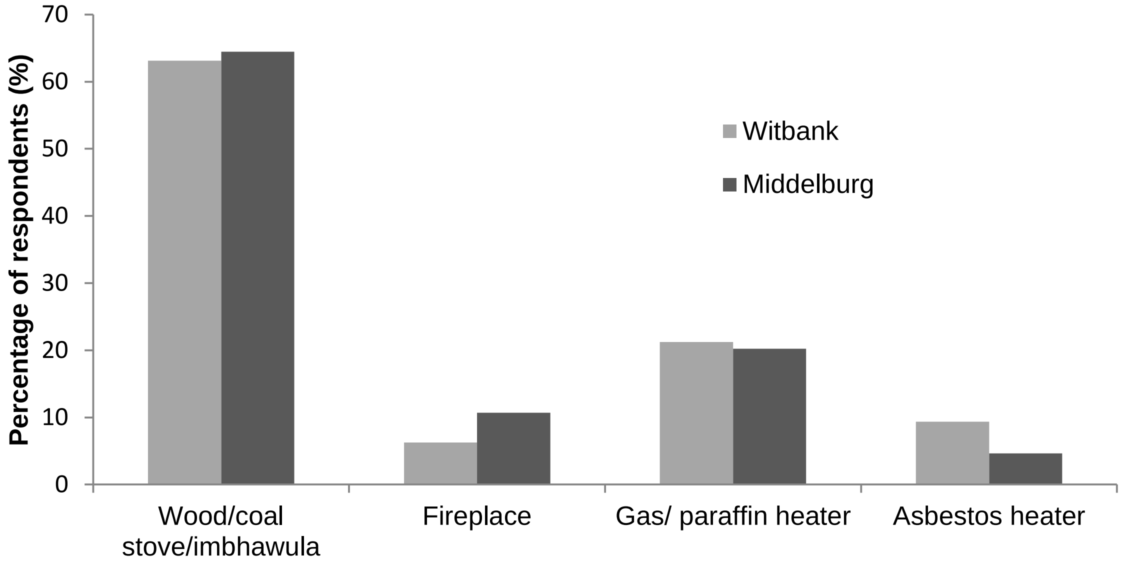

Figure 5. Fuel used for heating in Witbank and Middelburg

3.3.2 Frequency of gas or paraffin use

This question was a linked question, i.e. a respondent who responded ‘yes’ to using a gas or paraffin heater in the previous question would answer this question too. For the non-linked responses, 254 out of a total 452, selected ‘never’. This equates to 56.2% of respondents, indicating that the linked variable needs to be examined. For the linked version, 48.9% selected option 1 (‘about every day’). This was followed by 31.8% selecting option 2 (‘2 to 3 times a week’). The frequency of gas or paraffin use for the entire sample can be seen in Table 3.

3.3.3 Frequency of wood, coal stove or imbhawula use

This variable, like gas and paraffin use, was linked to the previous question regarding which fuel was used for space heating. For the linked version of this variable, 85.4% said they used it ‘about every day’, this was followed by 7.6% who said they used it ‘2 to 3 times a week’. These results can be seen in Table 3.

3.3.4 Frequency of fireplace use

This variable was also linked as mentioned above. For the linked version, majority of respondents said they used it 'about every day' (39%). This was closely followed by '2 to 3 times a week' (36%) These results can be seen in the Table 3.

3.3.5 Fuel used for cooking

There were 13 (2%) missing responses for the question regarding the fuel used for cooking. There were five different options provided, those were electricity, gas, paraffin, wood and coal. In Table 3 the distribution of responses for the entire sample can be seen.

Table 4 shows a comparison between the house type and fuel used for cooking for Witbank and Middelburg. From Table 4, it can be seen that for Witbank 12.5% of people using electricity for cooking stayed in prefabricated housing, while only 6.8% of people using electricity from Middelburg stay in prefabricated houses. Majority of respondents from Witbank and Middelburg who used paraffin for cooking stayed prefabricated housing, although the numbers were low for Middelburg. No respondents from Witbank reported using wood. Of the few that reported using wood for Middelburg majority resided in detached brick housing. For Witbank majority (66.67%) of respondents, who reported using coal, resided in prefabricated houses. While for Middelburg, the majority (50%) of respondents who reported using coal resided in detached brick housing. Only 8.33% of coal users in Witbank resided in detached brick housing and only 15.15% of coal users from Middelburg resided in prefabricated housing.

Table 4. Comparison between house type and fuel used for cooking for both towns

Home type	Electricity		Gas		Paraffin		Wood		Coal	
	Witbank n (%)	Middelburg n (%)	Witbank n (%)	Middelburg n (%)	Witbank n (%)	Middelburg n (%)	Witbank n (%)	Middelburg n (%)	Witbank n (%)	Middelburg n (%)
Detached brick	61 (58.65)	217 (67.81)	1 (50)	0	10 (29.41)	1 (25)	0	4 (57.14)	2 (8.33)	33 (50)
Attached brick	28 (26.92)	72 (22.5)	1 (50)	1 (100)	5 (14.71)	0	0	1 (14.29)	5 (20.83)	23 (34.85)
Flat	2 (1.92)	9 (2.81)	0	0	0	0	0	0	1 (4.17)	0
Prefabricated	13 (12.5)	22 (6.88)	0	0	19 (55.88)	3 (75)	0	2 (28.57)	16 (66.67)	10 (15.15)
Total	104	320	2	1	34	4	0	7	24	66

3.3.6 Mould in the house

This question attempted to ascertain whether respondents had any form of mould or mildew inside the home. Of all the responses 149 (26.5%) of respondents said they had mould or mildew inside the house.

3.3.7 Pets

This question asked if the child or family had any pets, as this would indicate if the child was in regular contact with the pet. Only 14.5% of respondents said they had pets.

A linked question followed this, to establish, of the children with pets, how many had the pets inside the house. Using the linked variable, 17 respondents of 85 (20%) said the pets were allowed inside the house.

3.3.8 Smoking

Of all the respondents who answered this question; only 8.3% said there was smoking (cigarette, cigar or pipe) occurring inside the house almost daily.

3.3.9 Eating habits

Diet may be of importance as it can influence a person's immune system, potentially making them more susceptible to illness or the effects of environmental pollution [50]. For the sample, more people reported eating chicken or fish and vegetables, followed by fruit, processed foods and red meat.

3.4 Prevalence of health outcomes from the questionnaire

3.4.1 General health

This question was the only opinion-based question in the questionnaire; it asked the parents how they would rate their child's health in relation to the child's peer group: better, the same or worse. For the entire sample, 57.6% of respondents said better, 40.7% said the same and 1.7% said worse. Parents of children in Witbank were more likely than parents of children in Middelburg to think that their child had the same general health or worse general health compared to their peers.

3.4.2 Allergies

This question had four options to select from; one 'no' answer and three 'yes' answers with varying degrees of severity. Table 5 shows the numbers and percentages for each option, for the entire sample as well as for Witbank and Middelburg.

For the entire sample, the prevalence of having allergies in general was just over 24%. The prevalence for Witbank was just under 22%, and for Middelburg, just over 25%. There was a higher prevalence for allergies in Middelburg than Witbank. However, 9.5% of those with allergies in Witbank had allergies which were being treated using prescription medication from a doctor. For Middelburg, 9.6% of children with allergies were being treated using prescription medication from a doctor.

Table 5. Number and percent of respondents that selected the various options from entire sample, Witbank and Middelburg

	Number of responses for entire sample n (%)	Number of responses for Witbank n (%)	Number of responses for Middelburg n (%)
No	461 (75.8)	140 (78.2)	321 (74.8)
Yes, not using medication	64 (10.5)	19 (10.6)	45 (10.5)
Yes, using over counter medication	25 (4.1)	3 (1.7)	22 (5.1)
Yes, prescription medication	58 (9.5)	17 (9.5)	41 (9.6)
Total	608 (100)	179 (29.4% of total)	429 (70.6% of total)

3.4.3 Absent in the past 6 months

This question asked for the number of days the child had been absent from school in the past 6 months; it had 5 different options: '0 days', '1-10 days', '11-20 days', '21-30 days' and '> 30 days'. The majority of respondents selected "0 days" (70.8%), followed by “0 to 10 days” (28.5%). Only 0.6% of respondents selected option 3 and 0.2% selected option 4. No respondents selected option 5.

3.4.4 Illness in the past 2 weeks or 6 months

These are two of the most important health outcome questions in the questionnaire. They were designed to determine the prevalence of six respiratory health outcomes. The first used a period of 6 months and the other a period of 2 weeks. For every option, the respondents had to select ‘yes’ or ‘no’. These results can be seen in Table 6. The data for Witbank and Middelburg are also provided. Asthma was not included in the 6 month question as the prevalence of asthma in general could be calculated from the asthma section.

Table 6. Period prevalence of specific health outcomes over the past 2 weeks or 6 months for entire sample, Witbank and Middelburg

Health outcome	Prevalence (%) for entire sample, (95% CI)		Prevalence (%) for Witbank, (95% CI)		Prevalence (%) for Middelburg, (95% CI)	
	Past 2 weeks	Past 6 months	Past 2 weeks	Past 6 months	Past 2 weeks	Past 6 months
Bronchitis	4.9 (2.8- 6.9)	15.6 (12.2-19.1)	4.9 (1.02- 8.7)	19.5 (12.6- 26.5)	4.9 (2.5- 7.3)	13.9 (10- 17.9)
Pneumonia	1.5 (0.3- 2.7)	1.7 (0.36- 3.3)	1.7 (-0.7- 4.2)	1.8 (-0.7- 4.4)	1.4 (0.03- 2.7)	1.7 (0.03- 3.3)
Earache	8.1 (5.4- 10.8)	7.3 (4.6- 10)	9.3 (4- 14.6)	6.3 (1.7-10.9)	7.6 (4.5- 10.7)	7.8 (4.4- 11.2)
Hay fever	16 (12.5- 19.6)	31.7 (27.2- 36.2)	21.6 (14.3- 28.9)	26.6 (18.7- 34.5)	13.7 (9.7- 17.6)	34 (28.4- 39.4)
Sinusitis	7.9 (5.3-10.6)	15.3 (11.6- 19.1)	9.2 (4- 14.5)	15.4 (8.7- 22)	7.4 (4.3- 10.4)	15.3 (10.8- 19.8)
Asthma	4 (2.1- 5.9)	/	3.5 (0.08- 6.9)	/	4.2 (1.9- 6.6)	/

3.4.5 Mostly breathe

This question asked how the child mostly breathes, i.e. through the mouth or nose. For the entire sample, 19.3% said they mostly breathed through their mouths. For Middelburg, more parents reported their child as having breathed through their mouths.

3.4.6 Asthma

This was the first question of the asthma section in the questionnaire; it was used to determine the prevalence of asthma. This was the variable to which the "linked 1" variables linked to, for more information see Chapter 2 (Section 2.6.1). Of all the respondents 7.1% (95% CI: 4.9- 9.2) said they had ever been diagnosed with asthma. The prevalence's for Witbank and Middelburg were 6.4% (95% CI: 2.5-10.3) and 7.3% (95% CI: 4.8- 9.9), respectively.

3.4.7 Age asthma was diagnosed

This question aimed to ascertain when the children were diagnosed with asthma. For the not-linked version of the variable, the majority of respondents (28.6%) selected 'between 0 and 1 years', followed by '2 to 3 years' (23.4%), followed by those who selected 'do not know' (20.8%). For the linked version, 32.4% selected 'between 0 and 1 years', 26.5% selected between '2 and 3 years' and 14.7% selected '10 years and older'. Only 5.9% of respondents said they did not know.

3.4.8 Still have asthma attacks

This was used to determine how many respondents still had attacks among those who said that they had been diagnosed with asthma. For the not-linked version of this variable, 2.9% said they still had asthma attacks. For the linked version of this variable, 35.3% said they still had asthma attacks. Only 3 (42.9%) of 7 people from Witbank with asthma and 9 (33.3%) of the 27 respondents from Middelburg with asthma, said they still had attacks. This was the second variable used to link those to follow, for more information see Chapter 2 (Section 2.6.1).

3.4.9 Frequency of asthma attacks

This question was linked to having asthma and still having asthma, for this reason a not linked variable exists as do the linked 1 and linked 2 versions. The distribution of the results can be seen in the Table 7. For this question, there were low numbers of responses, however, it does appear that children in Witbank who still had asthma tended to have attacks during exercise or play and monthly, while for Middelburg the most respondents selected occasionally.

Table 7. Frequency of asthma attacks for the three not-linked, linked1 and linked2 variables

Frequency of asthma attacks	Number of respondents for not-linked version n (%)	Number of respondents for linked 1 version n (%)	Number of respondents for linked 2 version n (%)
Occasionally	17 (37.8)	6 (37.5)	5 (41.7)
During exercise or play	17 (37.8)	7 (43.8)	5 (41.7)
Monthly	4 (8.9)	2 (12.5)	2 (16.7)
Weekly	7 (15.6)	1 (6.3)	0
Total	45 (100)	16 (35.6 % of total)	12 (26.7% of total)

3.4.10 Treatment for asthma

This was a 'yes' or 'no' question determining if the child was currently receiving treatment for asthma. This question was linked to having asthma and still having asthma. For the not linked version, 2.2% of respondents said they were getting treatment for asthma. For the linked 1 version, 2.9% of respondents reported getting treatment and for the linked 2 version, 30% said they were getting treatment, however, there were only 10 observations.

3.4.11 Months with asthma attacks

Table 8 shows the number of respondents who selected having asthma attacks in the different months of the year. This has not been examined for the two towns separately because of the very low numbers and because seasonal patterns (if any) were unlikely to change for the two towns as they are situated geographically close together. From Table 8, it can be observed that of the people who reported having being diagnosed with asthma, and who reported still having asthma, majority selected the winter months as the period when they experienced attacks most frequently. Once again low numbers prevail, however, using the linked 1 variable it can be seen that more respondents selected experiencing attacks over May, June, July and August.

Table 8. Number of respondents who reported having asthma attacks in the different months for the not-linked, linked 1 and linked 2 variables

Months	Number of respondents for not-linked variable n	Number of respondents for linked 1 variable n	Number of respondents for linked 2 variable n
January	4	1	0
February	3	0	0
March	6	1	0
April	4	1	0
May	8	2	2
June	29	8	6
July	24	7	4
August	12	5	4
September	7	3	2
October	6	1	1
November	2	1	0
December	6	1	1

3.4.12 Coughs when waking up

This question asked if a child coughs most mornings when waking up. There were three different options to select: ‘no’; ‘yes, during previous 3 months’; and ‘yes, longer than 3 months’. The prevalence of saying yes to having a cough regardless of duration for the entire sample was just over 10%. The prevalence for saying yes regardless of duration was 15.5% and 7.9% for Witbank and Middelburg, respectively. The prevalence for having the chest cough for longer than 3 months for Witbank was 4.7% and Middelburg was 1.3%.

3.4.13 When coughing mostly occurs

This question was a linked question, linking to the previous one, trying to determine when coughing mostly occurs. Table 9 shows the percentage of respondents that selected the various options for both the linked and not linked variables.

Table 9. Number and percentage of respondents who reported the occurrence of coughing using both the linked and not-linked variable

	Not-linked responses n (%)	Linked responses n (%)
During the day	13 (10.3)	3 (7)
During the night	65 (51.6)	21 (48.8)
During the day and night	17 (13.5)	6 (14)
Only when waking up or going to bed	31 (24.6)	13 (30.2)
Total	126	43

3.4.14 Phlegm on the chest

This item asked if the child usually had phlegm on the chest. There were three options: ‘no’; ‘yes, with a cold’; and ‘yes, without a cold’. For the entire sample, 21.2% said ‘yes, with a cold’ while 4.4% said ‘yes, without a cold’, and 77.4% said no. For further analysis, this variable was re-coded, into a binary variable, whereby the category ‘yes, with a cold’ was also coded as ‘no’.

3.4.15 Having phlegm for longer than 3 months

This question was linked to the previous question. For the not-linked variable, 4.2% said ‘yes’ to having phlegm for longer than 3 months. For the linked version, 11% said they had had phlegm for longer than 3 months.

3.4.16 Wheeze

This was a ‘yes’ or ‘no’ question asking if the children had experienced wheezing. A total of 11.4% reported having had incidences of wheezing. There was a linking question which attempted to ascertain when wheezing episodes occur most, when not in conjunction with a cold. Table 10 shows the distribution of the percentage of responses for each category for linked and not linked.

Table 10. Breakdown of responses for occurrence of wheezing episode using both the linked and not-linked variables

	Not-linked responses n (%)	Linked responses n (%)
Never	42 (38.8)	15 (28.9)
During the day	8 (7.4)	3 (5.8)
During the night	34 (31.5)	18 (34.6)
During the day and night	24 (22.2)	16 (30.8)
Total	108	52

3.5 Questionnaire bivariate analysis

Using bivariate analysis, all possible risk factor-health outcome associations were explored. This was done using the Chi Squared test or Fishers Exact (when cell numbers were equal to or less than 5); the p-value was of interest. For all significant ($\alpha \leq 0.05$) associations, the corresponding crude ORs were calculated, where α represents statistical power. Results of this can be seen in Appendix C. Only the significant associations of interest have been included in this table in Appendix C. The table provides p-values, crude ORs and 95% confidence intervals, for each included associations. For ordinal risk factors, the crude ORs could not be calculated and therefore have not been included in the Appendix C table. Some independent variables were found to be statistically significantly protective, these have also been shown.

Table 11 shows some of the most relevant results from the bivariate analysis, it includes the p-value, OR and 95% CI. From the table it can be seen that having mould in the house was protective of having allergies, but where the individual was not using any medication.

Bivariate results show having mould in the house and using a fireplace for heating to be associated with having asthma.

These results also show bronchitis to be associated with smoking in the house, having mould in the house, using an imbhawula for heating and breathing through the mouth.

Chest wheeze was seen to be associated with mouth breathing, the use of gas or paraffin for space heating and having pets inside the house.

These bivariate results further showed an association between having earache and smoking in the house, having mould in the house and mouth breathing.

Hay fever was the only health outcome that was statistically significantly associated with the town where the child lives, in this case Witbank. Other factors that were significant were mouth breathing, smoking in the house, having mould in the house and the use of an imbhawula for space heating. The confidence intervals for associations with pneumonia were wide, however, it was found to be associated with smoking in the house, having mould in the house and using a fireplace for space heating.

Sinus was seen to be associated with smoking in the house, breathing through the mouth or using gas or paraffin for heating.

Table 11. Most relevant results from the bivariate analysis

Health Outcome	Risk Factor	P-value	OR	95% CI
Allergies (no medication)	Mould in the house	0.004	0.45	0.25-0.79
Allergies (prescribed medication)	Male	0.013	0.49	0.28-0.87
Asthma	Mould in the house	0.008	2.66	1.25-5.67
Asthma (2 weeks)	Heating system (fireplace)	0.029	6	1.23-29.31
Asthma (2 weeks)	Heating system (gas or paraffin)	0.02	6.25	1.19-32.89
Bronchitis (2 weeks)	Breathes through mouth	0.002	3.88	1.54-9.74
Bronchitis (2 weeks)	Mould in the house	0.00	4.74	1.85-12.16
Bronchitis (2 weeks)	Smoking allowed inside	0.001	7.71	2.62-22.69
Bronchitis (6 months)	Breathes through mouth	0.00	3.76	2.05- 6.91
Bronchitis (6 months)	Heating system (imbhawula)	0.008	3.02	1.29-7.09
Bronchitis (6 months)	Mould in the house	0.005	2.24	1.25-4.01
Bronchitis (6 months)	Smoking allowed inside	0.00	3.92	1.82-8.42
Chest wheeze	Breathes through mouth	0.0004	3.02	1.59- 5.71
Chest wheeze	Heating system (gas or paraffin)	0.01	2.82	1.24-6.41
Chest wheeze	Pets allowed inside [linked]	0.018	6.38	1.32-30.71
Coughs when waking	Lives in Witbank	0.016	2.14	1.14- 4.02
Earache (2 weeks)	Breathes through mouth	0.02	2.55	1.12-5.78
Earache (2 weeks)	Smoking allowed inside	0.001	4.38	1.68-11.4

Health Outcome	Risk Factor	P-value	OR	95% CI
Earache (6 months)	Breathes through mouth	0.00	6.1	2.49- 14.91
Earache (6 months)	Mould in the house	0.021	2.63	1.12-6.18
Earache (6 months)	Smoking allowed inside	0.001	5.05	1.77-14.4
Hay fever (2 weeks)	Lives in Witbank	0.043	1.74	1.01-3
Hay fever (2 weeks)	Smoking allowed inside	0.042	2.3	1-5.29
Hay fever (6 months)	Breathes through mouth	0.025	1.86	1.07- 3.23
Hay fever (6 months)	Heating system (imbhawula)	0.03	1.92	1.05-3.49
Hay fever (6 months)	Mould in the house	0.04	1.65	1.02-2.68
Phlegm on the chest	Breathes through mouth	0.02	3.04	1.15-8.3
Pneumonia (2 weeks)	Heating system (fireplace)	0.029	12.27	1.17-128.9
Pneumonia (2 weeks)	Mould in the house	0.029	6.8	1.2-38.48
Pneumonia (6 months)	Smoking allowed inside	0.03	11.74	1.79-77.23
Sinusitis (2 weeks)	Breathes through mouth	0.001	3.74	1.62-8.64
Sinusitis (6 months)	Heating system (gas or paraffin)	0.001	3.64	1.6-8.27
Sinusitis (6 months)	Smoking allowed inside	0.021	2.74	1.12-6.73
Still has asthma	Breathes through mouth	0.00	6.94	2.36-20.37

3.6 Multivariate analysis results

Independent variables were listed against dependent variables where they were seen to have a p-value equal to or less than 0.25. The results from the bivariate analysis were used to inform this stage (Appendix D). Forwards stepwise regression models were then run in order to gain a better understanding of how the variables interact, a pe value of 0.05 was used. Adjusted ORs were calculated (where possible) for the variables that were entered into each model. Not-linked versions of the variables were not included on the models. The results of this analysis follow below.

3.6.1 Allergies

Being male, using an imbhawula for space heating, using a fireplace for space heating, having mould in the house and breathing through the mouth were modelled with this outcome.

Only being male and using a fireplace for space heating was returned as significant. Being male was returned as being protective, while the use of a fireplace was found to be associated. The R^2 value for this model was 0.0662. The F-test value was 5.14, with a p-value of 0.007. Overall the model is not highly predictive of this variable. The adjusted ORs for the two variables can be seen in Table 12 below. The associations presented below are statistically weak as for both the 95% CI include the null (i.e. 1).

Table 12. Adjusted ORs or risk factors for allergies

Variable	P-Value	Adjusted OR	95% CI
Being male	0.13	0.44	0.15- 1.28
Using a fireplace for space heating	0.51	1.68	0.36- 7.88

3.6.2 Having bronchitis in the past 6 months

Living in Witbank, time spent in the town, the use of a fireplace or imbhawula for space heating, having mould in the house, smoking in the house, eating chicken, eating processed foods, the frequency of imbhawula use and breathing through the mouth were modelled with the outcome. One protective factor was also included, 'circulating fresh air'.

When running the model Stata dropped the imbhawula use variable. Of the remaining only breathing through the mouth and smoking in the house came out as significant. These two variables were then adjusted for each other and the results are presented in Table 13. The R^2 value for the model was 0.3193, meaning that the model only explains 32% of the variation in the health outcome. The F-test value was 12.43 and corresponding p-value was 0.000. Although this is not the most explanatory model the significance, interaction and role of these variables should not be discarded.

Table 13. Adjusted ORs for having bronchitis in the past 6 months

Variable	P-Value	Adjusted OR	95% CI
Smoking in the house	0.001	4.05	1.81- 9.05
Mouth breathing	0	3.5	1.9- 6.45

3.6.3 Having bronchitis in the past 2 weeks

Variables that were run in the model were smoking and having mould in the house, having pets, breathing through the mouth and eating processed foods. The model was run and only smoking and breathing through the mouth were returned as significant. This model had an R^2 value of 0.0757, an F-test value of 9.74 and a p-value of 0.0001. This means that a small degree of the variation in the outcome is explained by these variables. This model is significantly less explanatory than that for having had bronchitis in the previous six months. The adjusted ORs are presented in Table 14.

Table 14. Adjusted ORs for having bronchitis in the past 2 weeks

	P-value	Adjusted OR	95% CI
Breathing through the mouth	0.012	3.59	1.35- 9.55
Smoking in the house	0.00	8.26	2.75- 24.82

3.6.4 Having pneumonia in the past 6 months

Forwards stepwise regression model was run with the following variables: heating systems (imbhawula, fireplace, gas or paraffin and asbestos), the presence of mould and smoking in the house, owning pets, breathing through the mouth, being male and eating red meat, vegetables or fruit.

Of all the variables run, five came out significant, these include using an asbestos heater, smoking in the house, using a fireplace, owning pets and eating vegetables. Eating vegetables was the only protective variable in the model. The overall R^2 value for this model was 0.4370, implying that these factors can explain 43% of the disparity in the outcome. The F-test value that was received was 14.6, with a corresponding p-value of 0.00.These results inform of a relatively illustrative model, although no adjusted ORs for these variables could be calculated.

3.6.5 Having pneumonia in the past 2 weeks

The following were modelled with the outcome: gender, time spend living in the town, using a fireplace for heating, circulating fresh air, having mould in the house, having pets, eating chicken or fish and breathing through the mouth.

Only having mould in the house and using a fireplace for heating were returned as significant. The R^2 value of the model was not very high with 0.0898, the F-test value was 6.56 and the corresponding p-value was 0.0019. This shows that the model is slightly weak and significantly weaker than that for having pneumonia over the past 6 months. The adjusted ORs for using a fireplace for heating and having mould in the house are provided in Table 15. The CIs are wide for both due to the low numbers; also having mould in the house is not significant as the 95% CI includes the null (i.e. 1).

Table 15. Adjusted ORs for having pneumonia in the past 2 weeks

	P-value	Adjusted OR	95% CI
Using a fireplace for heating	0.026	14.39	1.37- 151.37
Having mould in the house	0.063	9.35	0.88- 98.93

3.6.6 Having earache in the past 6 months

A forwards stepwise regression model with: gender, using an imbhawula for space heating; using an asbestos heater; circulating fresh air; having mould in the house; smoking in the house; eating chicken or fish, red meat, or fruit; having pets inside the house; and breathing through the mouth, was then run.

None of the variables were entered into the model.

3.6.7 Having earache in the past 2 weeks

This model was run with time spent in the town; having mould in the house; smoking in the house; eating red meat; eating fruit; and mouth breathing.

Eating red meat and the amount of time spent in the town were returned as being statistically significant. The model appears weak with an R^2 value of 0.0592, an F-test value of 7.42 and a p-value of 0.007. The adjusted ORs of these are provided below in Table 16. Both these variables were returned as being protective of having earache in the past 2 weeks.

Table 16. Adjusted ORs for having earache in the past 2 weeks

	P-value	Adjusted OR	95% CI
Time spent in town	0.008	0.68	0.51- 0.9
Eating red meat	0.004	0.26	0.11- 0.64

3.6.8 Having hay fever in the past 6 months

Living in Witbank; time spent in the town; using an imbhawula and gas or paraffin for heating, fuels used for cooking, having mould and smoking inside the house, owning pets; eating chicken or fish, eating processed foods and mouth breathing were modelled with the outcome.

Only two variables were returned, both of which were protective. The variables returned were fuel used for cooking and eating chicken or fish. The R^2 value was 0.1474, the F-test value was 9.59 and the associated p-value was 0.0001. In general the model is not very strong.

The adjusted ORs for these are presented in Table 17. The fuel used for cooking variable, was an ordinal variable. The adjusted OR for each category is also presented in the table. The table shows that only the use of coal for cooking is protective over having hay fever over the last 6 months.

Table 17. Adjusted ORs for having hay fever in the past 6 months

	P-value	Adjusted OR	95% CI
Using gas for cooking	0.939	1.09	0.11- 10.68
Using paraffin for cooking	0.617	0.8	0.32- 1.95
Using wood for cooking	0.98	1.03	0.086- 12.47
Using coal for cooking	0.002	0.38	0.21- 0.71
Eating chicken or fish	0.004	0.039	0.16- 0.95

3.6.9 Having hay fever in the past 2 weeks

Town where the child lives; time spent in this town; using an imbhawula or gas or paraffin for heating, owning pets, having mould, pets and smoking in the house; eating chicken or fish, red meat or processed foods; and mouth breathing were modelled with the outcome. Stata dropped the owning pets variable. Two variables were returned as significant, namely; using an imbhawula for space heating and having mould in the house. This model had an R^2 value of 0.4185, and F-test of 7.84 with a corresponding p-value of 0.0039. The adjusted ORs for returned variables are presented below in Table 18. It can be seen that neither of these two variables are highly significant as both include the null (i.e. 1) in the 95% CI.

Table 18. Adjusted ORs for having hay fever in the past 2 weeks

	P-value	Adjusted OR	95% CI
Imbhawula for space heating	0.074	2.04	0.93- 4.45
Having mould in the house	0.205	1.56	0.78- 3.12

3.6.10 Having sinusitis in the past 6 months

The use of a fire place and gas or paraffin for heating, along with mould and smoking inside the house, eating fruit and mouth breathing were modelled for this health outcome.

Only smoking and eating fruit were returned as significant. The model had a R^2 value of 0.1220, F-test value of 8.27 and a consequent p-value of 0.0004. This shows that the significant variables can explain a degree of the change witnessed in the health outcome. The adjusted ORs for these can be seen in the Table 19. These ORs have been adjusted for each other. Eating fruit has a protective relationship with the variable; however, the 95%CI includes the null, so is therefore statistically weak.

Table 19. Adjusted ORs for having sinusitis in the past 6 months

Variable	P-value	Adjusted OR	95% CI
Eating fruit	0.279	0.54	0.18- 1.65
Smoking in the house	0.029	3	1.12- 8.08

3.6.11 Having sinusitis in the past 2 weeks

This model was run with gender, time spent in the town, all four space heating options, smoking, eating fruit and breathing through the mouth. Only the variable 'eating fruit' was returned as significant. The model had a R^2 value of 0.0334, and F-test value of 4.39 and a corresponding p-value of 0.0382. This indicated that the model is not highly explanatory. As a result of there only being one variable the adjusted OR could not be calculated. The crude OR, however, was 0.33 (95% CI: 0.11- 0.95), the p-value for this was 0.039.

3.6.12 Having asthma in the past 2 weeks

The applicable variables for this model were the use of fireplace, gas or paraffin or asbestos heater for space heating, having mould in the house and breathing through the mouth. None of the variables in the model were returned as significant.

3.6.13 Having asthma

For ever having asthma, the following variables were run: gender, using a fireplace or gas or paraffin for space heating, having mould and smoking in the house, and breathing through the mouth.

Only smoking in the house was returned as significant. The R^2 value for the model was 0.0372, the F-test value was 5.18 with a p-value of 0.0244. This shows that the model was not highly explanatory of the outcome. The adjusted OR for asthma could not be calculated as there was only one variable that was returned as significant.

3.6.14 Coughing

The town where the child lives, the house type, the use of an imbhawula for space heating, the fuel used for cooking, eating processed foods, the frequency of imbhawula use and mouth breathing were modelled with the health outcome.

Imbhawula use was dropped by Stata due to its colineararity between it and the frequency of its use.

None of the remaining variables were returned as significant.

3.6.15 When coughing mostly occurs

This variable was linked to the question regarding coughing. There were only two variables that were run in a model these were; circulating fresh air and mouth breathing. Only mouth breathing was returned as significant. The R^2 value for the model was 0.1457, the F-test value was 5.8 with a corresponding p-value of 0.0216. As there is only one significant variable the adjusted OR could not be calculated.

3.6.16 Having phlegm on the chest without a cold

Only three variables were run in the model, these were the town where the child lives, the use of fireplace for heating and breathing through the mouth. None of these was returned as significant.

3.6.17 Having phlegm on the chest for longer than three months

This variable is linked to the previous whereby respondents stating that the child experienced phlegm on the chest without having a cold, were asked if they experience it for longer than three months.

The variables to be modelled against this outcome were gender, fuel used for cooking, circulation of fresh air, having mould in the house and eating red meat.

In this model only mould was returned as significant. The R^2 value for the model was 0.0974, the F-test value was 6.26 and the associated p-value was 0.0152. This shows that the model is not very explanatory of the outcome

3.6.18 Chest wheeze

The variables that were run in this model were gender, the town where the child lives, fireplace and gas or paraffin used for heating, having mould and pets in the house, eating chicken or fish, eating vegetables, eating fruit and breathing through the mouth.

The model could not be run. As a result, the same model was run excluding the three dietary factors. This was done because the three dietary factors were found to be protective during bivariate analysis, so for exploratory purposes this model could provide an indication of some of the possible risk factors for having chest wheeze.

This model returned two variables as significant; using gas or paraffin for space heating and using a fireplace for space heating. The R^2 value for the model was 0.5833, the F-test value was 11.9 and the associated p-value was 0.0006. This indicates that the variables were highly expounding, however, it must be considered that the dietary related variables were removed. The adjusted ORs for these are presented in Table 20. Using a fireplace for heating is not significant as the 95% CI includes the null value of 1.

Table 20. Adjusted ORs for having chest wheeze

Variable	P-value	Adjusted OR	95% CI
Fireplace used for space heating	0.216	2.2	0.63- 7.68
Using gas or paraffin for space heating	0.00	6.32	2.26- 17.64

3.6.19 When wheezing mostly occurs

This variable is linked to the previous, whereby respondents who reported having wheezing episodes then reported when these mostly took place. There were four variables modelled with this. These include; the amount of time spent residing in the town, the fuel used for cooking, circulating fresh air and eating red meat.

No variables were returned as significant.

3.6.20 Breathing through the mouth

This is not a direct health outcome, but rather has a complex relationship with risk factors and health outcomes. Up to this point it has often been associated with different health outcomes as a risk factor. A number of factors were also seen as being risk factors for it. For this reason, a model was needed to better understand this complex interaction.

The child's home, the use of a fireplace for heating, eating processed foods and the frequency of imbhawula use were modelled with this variable. None of the variables were returned as significant. Although the model does not conclusively indicate what factors influence a child breathing through their mouth it does seem apparent that the type of fuel used may be important.

3.7 Air quality data results

3.7.1 PM_{10}

In South Africa, there is no PM_{10} one hourly average standard; there is only a 24 hourly average standard (see Table 1). This guideline was set at 120µg/m^3. The WHO also has a PM_{10} 24 hourly guideline which is set at 50µg/m^3. As of 1 January 2015, the new South African standard for PM_{10} will come into effect; this standard is set at 75µg/m^3.

For Witbank, for PM_{10}, there were 9 months of sufficient data and one month of insufficient data. For Middelburg, four months had insufficient data. Table 21 shows an average of the 24 hourly averages, 99th percentile and the highest reading for each month for Witbank and Middelburg.

Table 21. Average 24 hourly average, 99th percentile and highest 24 hourly average for PM_{10} in both towns

Month	Monthly average µg/m^3		99th percentile		Highest 24 hourly average µg/m^3	
	Witbank	Middelburg	Witbank	Middelburg	Witbank	Middelburg
08-2008	No data	No data	No data	No data	No data	No data
09-2008	85.42	94.26	170.66	205.88	173.47	207.66
10-2008	40.80	49.75	71.36	99.63	72.92	99.85
11-2008	27.59	No data	55.19	No data	55.77	No data
12-2008	24.99	No data	57.43	No data	59.22	No data
01-2009	21.05	No data	45.58	No data	48.65	No data
02-2009	21.94	19.4	35.75	34.67	35.82	34.86

03-2009	33.59	31.25	70.16	74.93	76.17	81.6
04-2009	57.22	47.08	118.38	107.62	123.59	116.97
05-2009	68.87	49.41	144.09	98.83	145.32	101.24

For Witbank, the 99^{th} percentiles and highest recorded 24 hourly averages for the months were examined and compared to the South African National Standard as well as the WHO guideline. Two of the 99^{th} percentiles were in exceedence of the South African Standard, while seven were in exceedence of the WHO guideline (this includes the two that were in exceedence of the South African Standard). For the highest 24 hourly averages, three were in exceedence of the South African Standard and seven (including the three exceeding the South African Standard) were in exceedence of the WHO guideline.

For Middelburg, for the 99^{th} percentiles, one exceeded the South African Standard and four exceeded the WHO guideline. For the highest PM_{10} averages recorded for each month, three were in exceedence of the South African Standard, and only one was not in exceedence of the WHO guideline.

A monthly profile of PM_{10} concentrations for Witbank and Middelburg for the month of September 2008 was plotted (Figure 6).

This graph shows the 24 hourly averages for the months for both towns. The graph also illustrates the WHO and South African guidelines. There are three peaks exceeding the South African Standard visible in this graph. Majority of the data for the entire month sat above the WHO guideline, with only three minor dips below. The South African Standard allows for four PM_{10} 24 hour average exceedences in a year. For the month of September, in Witbank, five exceedences were counted and six were counted for the same month in Middelburg. Middelburg had one day of missing data.

All of the data were used to plot a diurnal distribution of PM_{10} for both towns, presented in Figure 7. From Figure 7 two peaks can be observed for both towns at similar points in time and to similar concentrations for both towns. Both peaks occur between five and 10, in both the morning and evening, however, a slight time lag is seen between the two towns. The evening peaks for both Witbank and Middelburg were higher than the morning peaks. The night time trough for Middelburg was approximately 15µg/m^3 higher than that of Witbank.

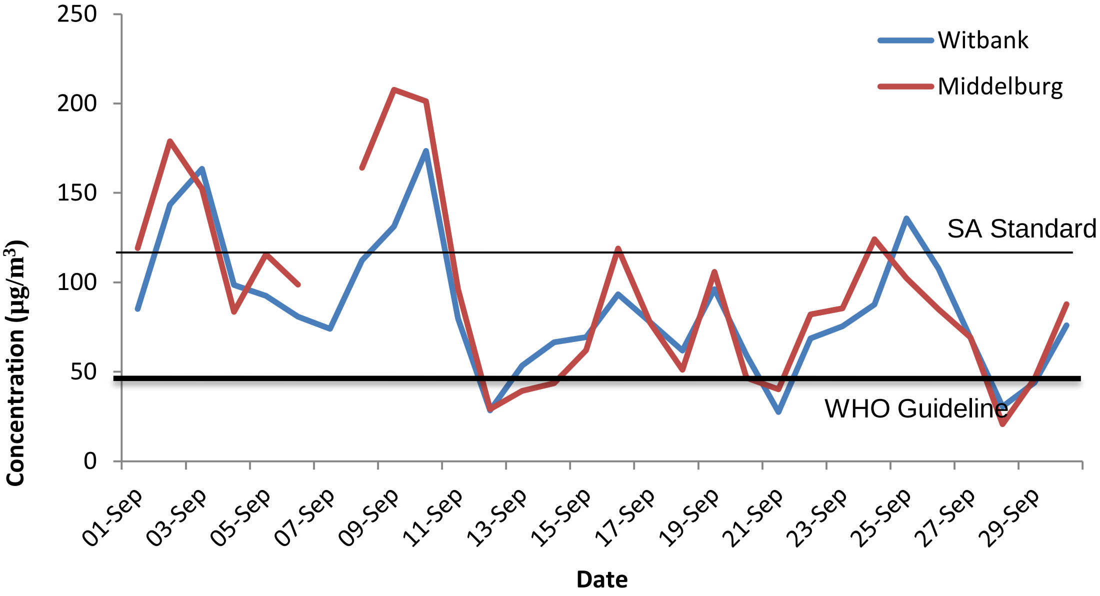

Figure 6. PM_{10} distribution over September 2008 for both towns

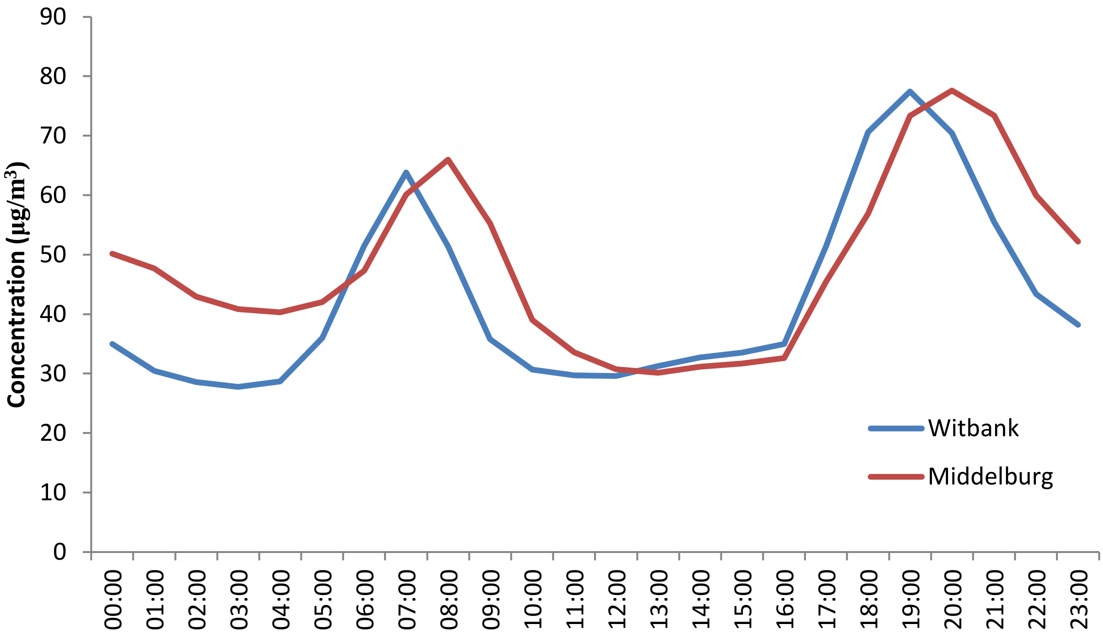

Figure 7. Diurnal distribution of PM_{10} in both towns

3.7.2 $PM_{2.5}$

South Africa recently gazetted a $PM_{2.5}$ Standard for public comment. The Standard is set at 65µg/m^3 as a 24 hourly average. This standard is enforceable until 31 December 2015, at which point the new standard will be introduced. This standard will be set at 40µg/m^3. The current South African Standard allows for no exceedences. The WHO uses a 24 hourly average guideline of 25µg/m^3.

As with PM_{10}, one month for Witbank had insufficient data, while four months for Middelburg had insufficient data. Table 17 provides the averaged $PM_{2.5}$ 24 hourly averages, the 99th percentiles and the highest recorded 24 hourly averages for each month for both towns.

Two of the 99th percentiles for Witbank were in exceedence of the South African standards, and one from Middelburg. Like the 99th percentiles, two from Witbank were in exceedence and one from Middelburg was in exceedence. With regard to the WHO guidelines, three of Witbank's average 24 hourly averages were in exceedence and two from Middelburg. Eight of Witbank's 99th percentiles were in exceedence of the WHO guideline; five of Middelburg's were in exceedence. All of the highest recorded averages for Witbank were in exceedence and only one for Middelburg was not.

Table 22. Monthly averages, 99th percentiles and the highest 24 hourly averages for $PM_{2.5}$ for both Witbank and Middelburg

Month	**Monthly average (µg/m^3)**		**99th percentile**		**Highest value (µg/m^3)**	
	Witbank	Middelburg	Witbank	Middelburg	Witbank	Middelburg
08-2008	No data	No data	No data	No data	No data	No data
09-2008	40.05	37.34	91.17	92.98	93.91	101.51
10-2008	22.67	22.77	38.68	42.3	39.47	42.95
11-2008	17.27	No data	30.49	No data	30.78	No data
12-2008	13.85	No data	24.4	No data	25.43	No data
01-2009	13.66	No data	26.45	No data	27.9	No data
02-2009	14.31	11.76	27.78	22.93	29.58	23.37
03-2009	20.26	17.14	38.73	35.4	42.13	36.92
04-2009	32.29	23.99	61.1	48.91	62.46	51.31
05-2009	45.04	27.28	88.41	54.27	90.22	55.1

Figure 8 shows a monthly distribution pattern for $PM_{2.5}$ for both Witbank and Middelburg. This was done for the month of September 2008. In Figure 8 it can be seen that the concentrations were higher at the start of the month. It is further evident that the plot for both towns was similar with both experiencing peaks and troughs of similar magnitudes at the same points in time.

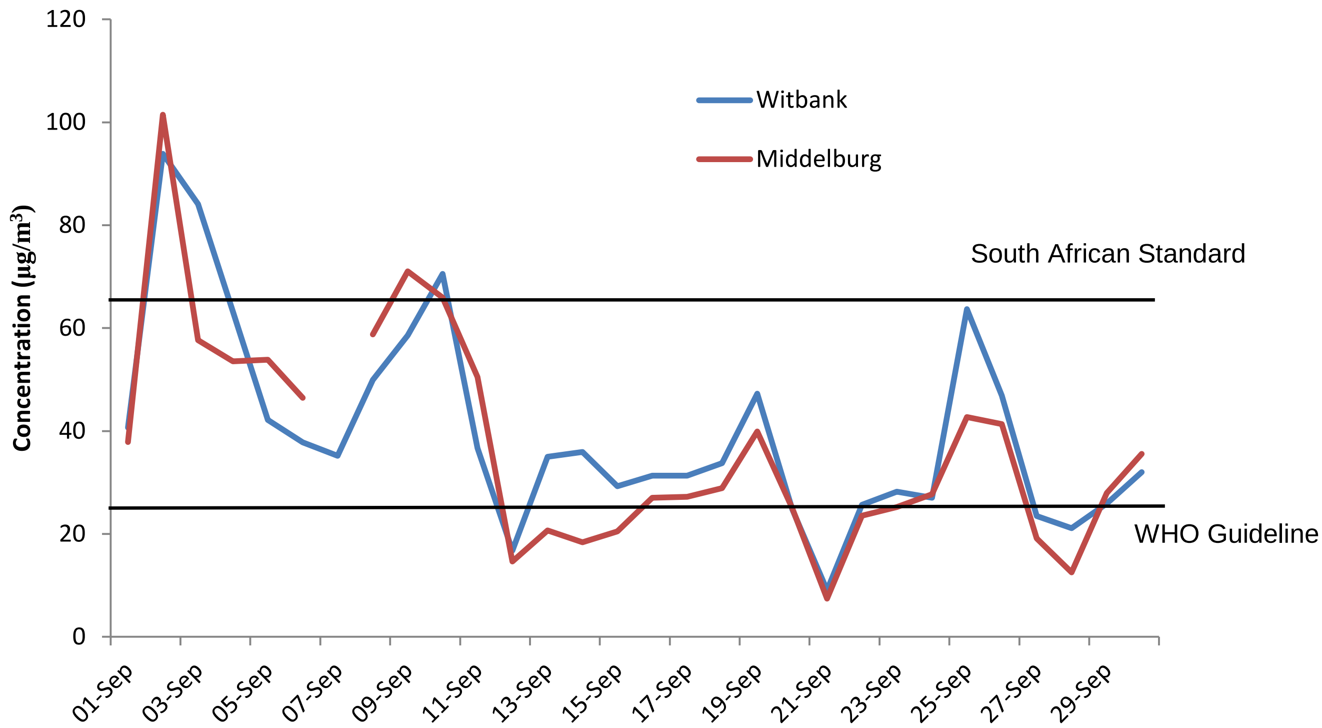

Figure 8. Distribution of $PM_{2.5}$ for September 2008 for both towns

As with PM_{10}, all of the data for $PM_{2.5}$ were used to plot a daily distribution of the pollutant. This can be seen in Figure 9. The diurnal pattern observed in Figure 9, shows a similarity to the plot for PM_{10}. It also had two peaks, these occurred between five and nine o'clock in the morning and evening. Also similar to what was observed in the PM_{10} graph; $PM_{2.5}$ levels for Middelburg did not drop at night as much as they did for Witbank or as much as they did during the day time. Also noticeable were the higher peaks for Witbank than Middelburg. The Standard states that zero exceedences are allowed, and for this month in Witbank, three were counted while three were also counted for the same month in Middelburg.

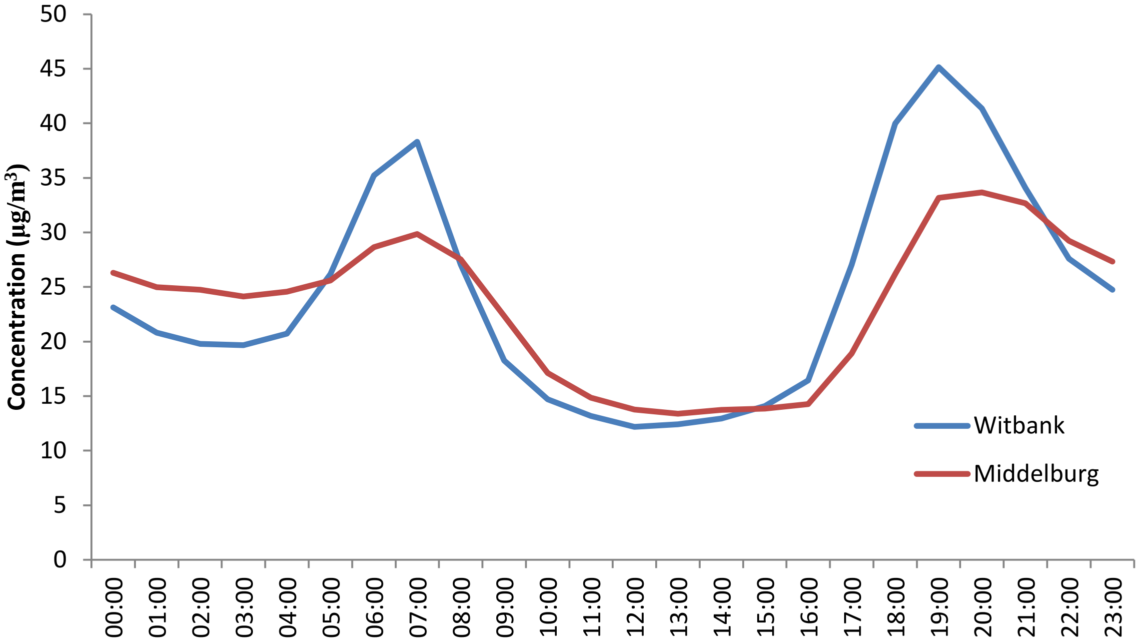

Figure 9. Daily distribution for $PM_{2.5}$ for both towns

3.7.3 SO_2

For SO_2, South Africa has a 10 minute average Standard, hourly average Standard, 24 hourly average Standard and yearly average Standard. In this study, the data were examined using the hourly (350µg/m^3) and 24 hourly average (125µg/m3) Standard. The hourly Standard allows for 88 exceedences and the 24 hourly allows for four exceedences. The data were also compared with the WHO 24 hourly guideline of 20µg/m^3.

For Witbank, data for two out of the 10 months were missing, while for Middleburg, data for one month were missing. The hourly averages aggregated for each month, the 99th percentiles for these and the highest hourly average for each month are presented in Table 23. Table 24 shows the same information but for the 24 hourly averages, for comparison with the WHO guideline.

Table 23. Monthly averages, 99th percentiles and highest hourly averages for SO_2 for Witbank and Middelburg

Month	Monthly average (μg/m³)		99th percentile		Highest value (μg/m³)	
	Witbank	Middelburg	Witbank	Middelburg	Witbank	Middelburg
08-2008	No data	34.43	No data	200.44	No data	292.24
09-2008	54.13	33.52	231.59	200.45	323.28	568.64
10-2008	35.53	30.37	261.27	123.1	493.23	233.97
11-2008	15.13	6.74	85.64	24.34	108.97	74.97
12-2008	33.23	11	195.92	58.51	491.55	90.18
01-2009	24.36	No data	222.9	No data	567.9	No data
02-2009	No data	8.04	No data	52.63	No data	135.67
03-2009	35.34	8.76	242.04	47.16	411.6	228.07
04-2009	43.22	23.44	262.6	72.71	878.91	130.46
05-2009	59.96	39.20	407.35	231.81	647.58	586.27

The monthly averages show that the data for both towns were similar, however, the concentration in Witbank were slightly higher. One of the 99th percentiles for SO_2, for Witbank, was in exceedence of the South African Standard and none for Middelburg were in exceedence of this Standard. Of the highest values recorded for each town, six and two were in exceedence of the South African Standard, respectively. The South African Standard allows for 88 exceedences per year. Based on the highest 99th percentiles, May 2009 appeared to be the worst month for SO_2 for both Witbank and Middelburg. For Witbank, during May, 12 exceedences were counted. While for Middelburg no exceedences of the South African guideline were counted.

For the South African 24 hourly average standard, one of the 99th percentiles was in exceedence of the South African Standard for Witbank, and none of the 99th percentiles for Middelburg were in exceedence. All of the 99th percentiles for Witbank were in exceedence of the WHO guideline and seven of the 99th percentiles for Middelburg were in exceedence of the WHO guideline. All of the highest averages for each month for Witbank were in exceedence of the WHO guideline and one was in exceedence of the South African Standard. For Middelburg seven of the highest recordings exceeded the South African Standard, one exceeded the WHO and two did not exceed either.

Table 24. Monthly averages, 99th percentiles and highest 24hourly averages for SO_2 in both towns

Month	Monthly average (µg/m³)		99th percentile		Highest value (µg/m³)	
	Witbank	Middelburg	Witbank	Middelburg	Witbank	Middelburg
08-2008	No data	34.18	No data	84.19	No data	84.22
09-2008	55.07	33.76	84.42	110.81	84.46	125.41
10-2008	35.7	30.44	84.57	57.91	85.29	59.03
11-2008	14.94	6.73	34.66	16.27	35.97	18.36
12-2008	33.22	11.01	64.58	22.37	66.95	23.48
01-2009	24.28	No data	89.97	No data	96.4	No data
02-2009	No data	8.19	No data	20.24	No data	20.24
03-2009	35.47	8.87	71.80	18.19	72.09	18.8
04-2009	43.15	23.38	89.92	33.81	91.27	34.3
05-2009	60.07	39.23	157.86	103.47	160.38	108.21

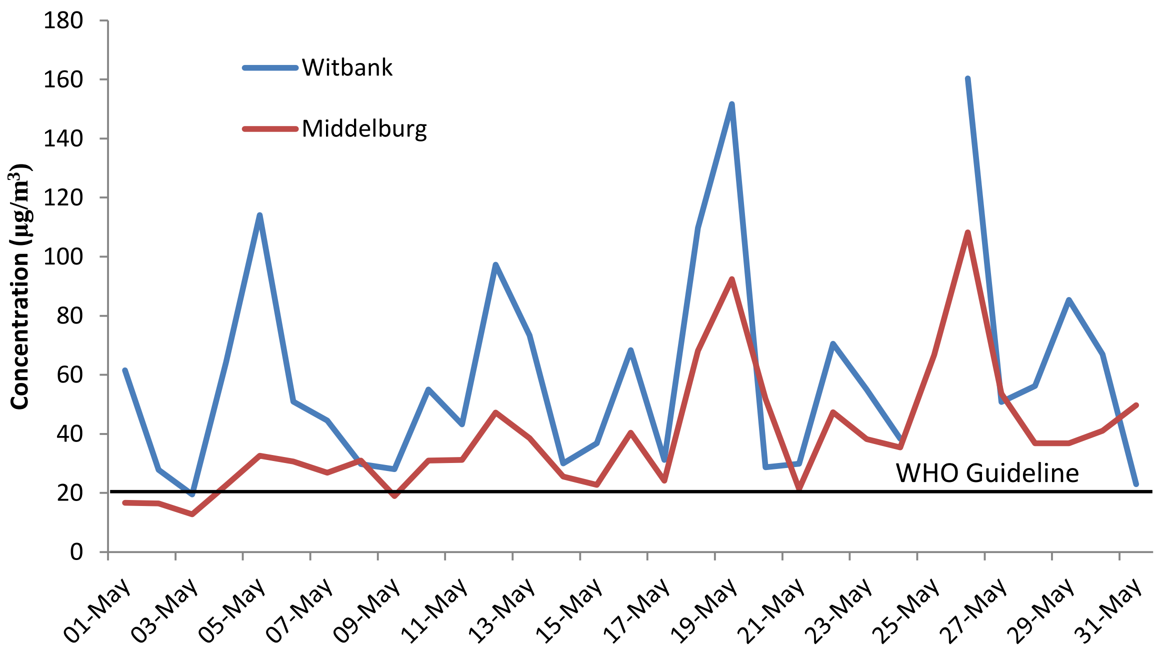

Figure 10. Monthly distribution for SO_2 for the month of May 2009

A monthly distribution of SO_2 for May 2009 was plotted and demonstrated in Figure 10. The WHO guideline, which is a 24 hourly guideline, is shown. Since South Africa uses an hourly Standard, it has not been included on this graph. It is evident in this graph that majority of the data for both towns lay above the WHO guideline. There was a similar pattern for both towns, with Middelburg's peaks and troughs following those of Witbank. The two highest peaks were for Witbank and they were seven times the WHO guideline. Witbank had one day of missing data.

Figure 11 shows the monthly distribution for the month of September 2008. From here it can be seen that the concentrations were higher at the beginning of the month. There was also a similar pattern evident for both towns. There were eight days of missing data for Witbank and one for Middelburg.

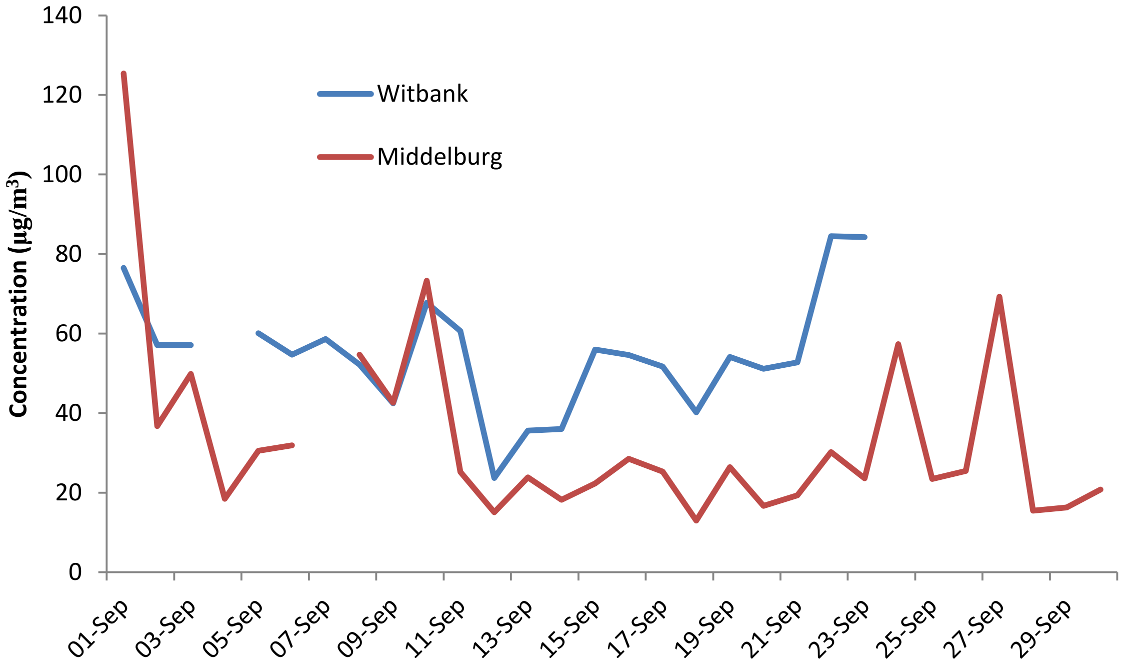

Figure 11. Monthly distribution for the month of September 2008

Figure 12 shows the diurnal pattern for SO_2 for both towns. Slight increases in the SO_2 concentrations were visible over the day time hours. This pattern was similar for both towns, except for a peak visible in the evening for Witbank. Witbank appears to have experienced higher concentrations of SO_2 than Middelburg.

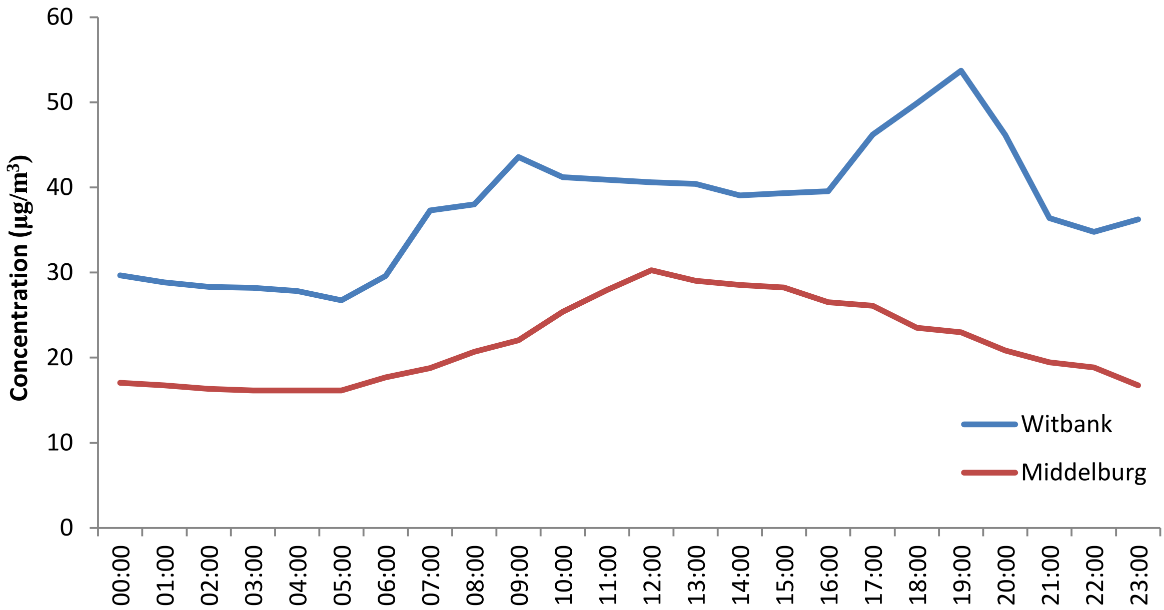

Figure 12. Daily distribution for SO_2 for both towns

3.7.4 NO_2

For NO_2, the South Africa Standard is the same as the guideline value set by the WHO; 200µg/m^3 for an hourly average. For Witbank, one of the months had insufficient data while for Middelburg four of the months had insufficient data for analysis purposes. As for the previous pollutants, the aggregated hourly averages for each month, the 99th percentiles and highest hourly average are presented for both towns in Table 25.

Two of the 99th percentiles for Witbank were in exceedence of the South African Standard and only one for Middelburg was in exceedence of the South African Standard. For the highest averages recorded, five of the months were in exceedence of the South African Standard; the highest was recorded at 1754.65µg/m^3. The 99th percentile for that month was 234.34µg/m^3.

Table 25. Average hourly average, 99th percentile and highest hourly average for NO_2 for both towns

Month	Monthly average ($\mu g/m^3$)		99th percentile		Highest value ($\mu g/m^3$)	
	Witbank	Middelburg	Witbank	Middelburg	Witbank	Middelburg
08-2008	52.56	No data	106.32	No data	121.95	No data
09-2008	37.08	21.42	106.97	56.4	131.89	62.64
10-2008	124.19	183.47	150.17	223.59	254.4	275.2
11-2008	20.12	27.29	60.58	84.04	123.5	190.2
12-2008	19.33	17.76	67.8	61.62	93.39	78.92
01-2009	No data	No data	No data	No data	No data	No data
02-2009	47.6	No data	147.4	No data	243.74	No data
03-2009	94.6	No data	213.32	No data	608.65	No data
04-2009	63.96	58.66	234.34	93.88	1754.65	115.56
05-2009	77.56	41.74	181.19	73.23	1008.68	128.14

A monthly distribution of NO_2 was not plotted because the guidelines for NO_2 for both South Africa and WHO are for hourly averages. The daily distribution of NO_2 was plotted for both Witbank and Middelburg, as seen in Figure 13

The diurnal paternal for Middelburg can be seen as an almost constant concentration, however, with slight peaks in the morning and evening. The diurnal patter for Witbank is quite different with two notable peaks in the morning and evening and the evening peak was slightly higher than the morning peak. There is also a small peak noticeable over the lunch time hours.

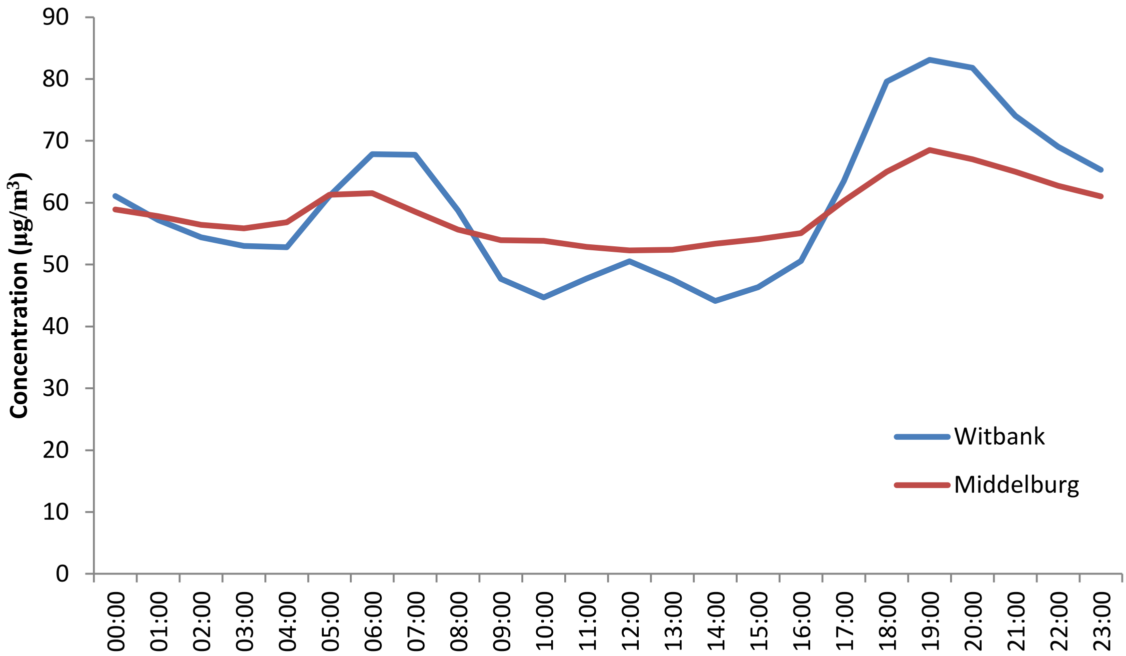

Figure 13. Daily distribution in both towns for NO_2

3.7.5 O_3

Both South Africa and the WHO use a running 8 hourly average. South Africa uses a Standard of 120µg/m^3, while the WHO uses a guideline of 100µg/m^3. For three of the months for Witbank, there were insufficient data while Middelburg had insufficient data for two months. The 8 hourly averages aggregated for each month, the corresponding 99th percentiles and the highest recorded 8 hourly averages are presented in Table 26.

One of Witbank's 99th percentiles for O_3 exceeded the South African Standard and three exceeded the WHO guideline. For Middelburg two of the 99th percentiles exceeded the South African Standard and five exceeded the WHO guideline. For the highest values recorded for Witbank, three were in exceedence of the South African Standard and WHO guideline. For Middelburg, three exceeded the South African Standards and five exceeded the WHO. For both towns the O_3 levels in September 2008 appeared to be some of the worst, the guidelines stipulate that 8 exceedences are allowed. For this month alone, for Middelburg; 27 exceedences were counted.

Table 26. Monthly averages, 99th percentiles and highest 8 hourly averages for O_3 for both towns

Month	Monthly average (µg/m³)		99th percentile		Highest value (µg/m³)	
	Witbank	Middelburg	Witbank	Middelburg	Witbank	Middelburg
08-2008	No data	61.38	No data	129.8	No data	141.83
09-2008	No data	106.6	No data	154.8	No data	159.36
10-2008	No data	100.47	No data	157.78	No data	159.09
11-2008	72.61	69.25	132.5	108.42	133.44	109.45
12-2008	68.66	73.02	115.16	109.63	142.1	109.7
01-2009	59.76	No data	116.45	No data	121.89	No data
02-2009	39.06	26.62	91.21	70.2	94.16	71.93
03-2009	43.26	No data	81.41	No data	85.32	No data
04-2009	36.82	29.41	76.1	65.06	78.33	65.67
05-2009	32.34	24.54	71.53	63.3	76.79	64.41

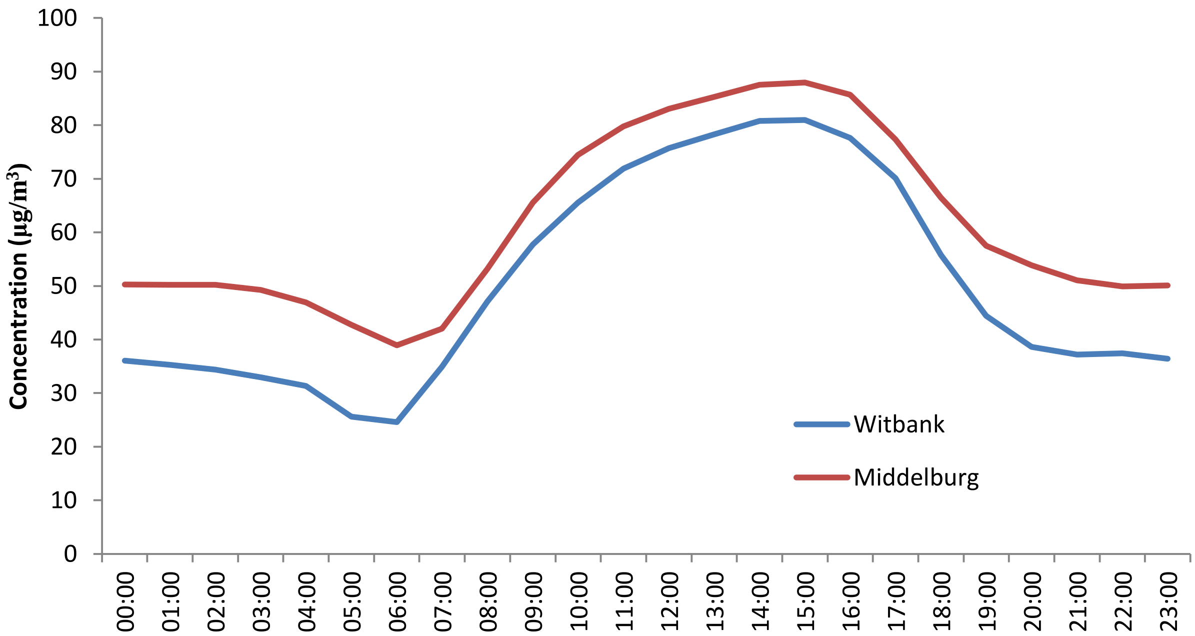

Figure 14. Daily distribution for O_3 over Witbank and Middelburg,

As with NO_2, no monthly distribution was plotted. A daily distribution was plotted and is shown in Figure 14. This is a typical diurnal pattern for O_3, with the day time increase. This occurs because O_3 is formed in the presence of sunlight. There is a slight trough before the day-time increase, this is also typical. This occurs because of the titration effect of NO, whereby it breaks down O_3 in the atmosphere [95].

Chapter 4: Discussion

4.1 Linked question analysis technique

An innovative analysis technique to handle a questionnaire design challenge and subsequent responses was created and used in this study. The questionnaire included some questions with skips or stem and branch questions. In this study, it was observed that respondents would answer the question in a way that would require them to apply the skip; however, they would continue to answer the next question without skipping. Joubert and Ehrlich explain that when this occurs one would code the response as missing [86]. However, given the frequency of the occurrence of this in the data set, it was decided that much valuable information would be lost and therefore an alternate method to handle this conflict was created. The exact methods are detailed in Chapter 2 (Section 2.6.1).

Previous studies in which a questionnaire was administered, typically discard occasional inconsistencies between responses to stem and branch questions [92-93]. In this study, an innovative method, defined as linked and not linked, proved invaluable during data analysis as it was a means for demonstrating important information regarding responses and how these related to previous responses. The significance of this method was best demonstrated in the analysis of the asthma related questions.

This method separates the responses, allowing for all the data to be maintained and no data to be lost. The first option for one variable would be the not-linked option whereby all of the responses are examined regardless of the responses to previous questions. The number of responses for this variable will always be highest.

For the frequency of asthma attacks, there were 45 responses in total, 16 of these had originally responded ‘yes’ to having asthma and 12 of the 45 had responded ‘yes’ to having asthma and ‘yes’ to still having asthma attacks. The large difference in the number of responses shows that some valuable information could be lost. Because the source of the potential error is not evident, it is unknown whether the respondents who answered this question, but responded ‘no’ to having asthma, truly do not have asthma or if the question was potentially misunderstood. Further, the question asked specifically if a “doctor” diagnosed asthma, it is possible that respondents did not have a doctor diagnosis, however, were confident they had asthma and therefore felt it was important to answer the questions.

Through the use of the linked / not linked technique, it was also seen that for the question regarding whether a child was receiving treatment for asthma, for the not-linked version, 2.2% reported receiving treatment and for the linked 1 version (linked only to having doctor diagnosed asthma) 2.9% said they were receiving treatment. This shows that of the respondents who reported not having doctor diagnosed asthma, there are a number receiving treatment for asthma.

This discussion highlights the importance of the unique linked / not linked analysis method. It showed that instead of coding the data as missing and potentially losing valuable information, the illogical responses may be included and examined and analysed, and meaning can be derived. If it is clear that nothing of value exists then only the linked variables should be used for further analysis. This technique is particularly valuable in a developing country research environment, where resources are limited and community-targeted data collection is not carried out routinely. The technique allows for full interpretation of the respondents’ input but also allowing for consideration of results using the traditional approach for inter-study comparisons.

4.2 Demographics

Demographic factors are of importance when studying respiratory health and ambient air quality. Demographic factors may indicate socio-economic status and this may indicate potential indoor air quality risks. In South Africa, in 2006, 73% of households had access to electricity [66]. Households that do not have electricity may have to rely on other fuels to meet their needs such as wood or coal [96]. Furthermore, although a house may have electricity they may not use electricity solely to meet all their needs, for example, a large proportion of households in Gauteng still use coal for cooking or heating even though they have electricity [96].

According to the National State of the Environment Report (2009), 4.3 million households do not have access to water services. The house type and water source can indicate poverty and therefore potentially poor indoor air exposure.

The sample for this study had a higher number of females, which could be explained by the slightly higher number of females in Mpumalanga. Mpumalanga has the fourth lowest ratio of men to women which decreased slightly from 94.7:100 in 1996 to 92.1:100 in 2001 [97].

In South Africa, the most prominent languages spoken in the home are Zulu and Xhosa [98]. For Mpumalanga, the most prominent languages spoken are siSwati and Zulu [99]. For this study, the most prominent languages were Zulu and Sotho. The reason for the higher percentage of Sotho speaking respondents was that one of the selected schools was a Sotho speaking school. There was also an Afrikaans medium school used in Witbank, accounting for the higher percentage of Afrikaans spoken in the Witbank sample. The low percentage of English in the sample would be expected. However, one of the schools in Middelburg was an English medium school, but the percentage of English speakers was still very low, indicating that despite it being an English medium school, a large percentage of the children do not use English as their home language.

Just over half of the sample was from Middelburg, however, after removing those that were outside the age range, a much larger proportion were from Middelburg. This suggests that the schools used in Witbank had a higher number of children in Grades 4 and 5 who were not between the ages of 9 and 11, compared to the schools included from Middelburg.

The type of house in which most of the subjects reside in was detached brick housing, followed by attached brick housing and then prefabricated housing. When examining the data for each town, it was seen that Witbank had 20% more respondents who said that they resided in prefabricated houses compared to Middelburg.

4.3 Indoor risk factors

It was seen that a high percentage (80%) of respondents from Middelburg had electricity, yet a large portion use other means to warm the house. This corroborates findings from Barnes *et al,* whereby they explained that although more and more households now have access to electricity, many still continue to use other fuels to meet all their needs, particularly with regard to space heating [66].

Of the respondents who reported using gas or paraffin for space heating, most used it every day or 2 to 3 times a week.

Of those who said they used an imbhawula, which was a high proportion of the sample, they reported that they used it about every day. The proportion of those that said they used it almost every day was higher than those who said they used gas or paraffin almost every day.

For the entire sample who said they used a fireplace, majority said they used it about every day; however, this was very closely followed by those who said they used it 2 to 3 times a week.

Imbhawulas and wood or coal burning stoves are often the worst contributors to poor indoor air [66]. These results suggest that imbhawulas or wood or coal burning stoves were the most popular choice, and they were also the most frequently used.

When examining these results by town it can be seen that 20% more households in the Middelburg sample used electricity than households in Witbank. Middelburg had 20% more households residing in detached brick housing. Witbank and Middelburg had a similar percentage of households using coal for cooking. For Middelburg there were primarily two fuels used for cooking, while in Witbank paraffin was used more than coal. This difference could be because of financial reasons; paraffin can sometimes be cheaper than coal, or it could be because of convenience since, paraffin is generally quicker and easier to use. Further, paraffin is correctly perceived as being cleaner than coal [66], and therefore people might voluntarily use paraffin for this reason.

From the comparison between the fuel used for cooking and the house type, as well as the space heating related questions, it appeared that for cooking, people tended to prefer to use whatever means was easiest, for example, the use of paraffin over coal. For heating, it appears that people tend to prefer to use whatever is cheapest as it needs to be sustained for a long period of time, for example, coal over electricity. These results suggest that the type of housing does not always influence the type of fuel used for cooking or space heating. It can be speculated that other factors may be contributing to fuel choices such as costs, traditional or personal preference.

When examining the circulation of fresh air versus the type of fuel used for cooking, the greatest proportion (71%) of people not circulating air were using electricity for cooking. This was followed by people using coal (20%). Of the people who reported using coal for cooking, 22.7% do not circulate any air through the house. Circulation of air through the house when burning fossil fuels indoors may reduce possible exposure.

Mould spores within a household are a major contributor to adult and child respiratory ill health [16]. When examining this variable in accordance with house type, it was seen that 26.7% of people living in prefabricated housing reported having mould in the house. While 24.8% of people living in detached brick housing reported having mould in the house. This shows that there seems to be very little variation between house type and reported mould.

Smoking is well known for its harmful effects not only on the smoker but also those exposed, particularly children [43]. For the entire study sample and for both towns individually, the percentages of smoking inside the child’s home were all low with the lowest being the 5.8%, recorded for Middelburg. It is possible that this value is under reported as a result of the public awareness regarding the dangers of tobacco smoke.

Breathing through the mouth is not a direct risk factor or health outcome; however, it has a complex relationship with respiratory disease. Ill children may frequently breathe through their mouths and mouth breathing may make a child more susceptible to respiratory illness. During multivariate analysis when running a model for mouth breathing none of the variables were returned as significant. However, during bivariate it was seen that indoor fossil fuel use may have an impact. The higher number of respondents for Middelburg reporting that their child breathes through their mouth might correlate with the higher prevalence of hay fever in the town.

4.4 Respiratory health outcomes and their associated risk factors

4.4.1 Absenteeism

Although this is not a health outcome it may indicate the severity of the illness or illnesses influencing the child. There was a very similar pattern of absenteeism for both groups; however, Witbank had slightly higher levels of absenteeism than Middelburg.

4.4.2 Allergies

The overall prevalence of allergies for the entire sample, Witbank and Middelburg were all slightly lower than the prevalence found by Terblanche *et al*, stated as 27% [39]. The general prevalence for allergies was higher in Middelburg; however, the prevalence of severe allergies was the same for both towns.

Results of the bivariate analysis showed, four variables were protective of having allergies. Having mould in the house was found to be protective of having allergies but not using any medication, this may be as a result of the reverse relationship between the two variables. Whereby people with allergies may have been informed of the effects of mould and are therefore more likely to clean mould or reduce its growth. This association is possibly similar to that seen with pet ownership and allergies as was explained by Brunekreef *et al* [42].

Breathing through the mouth was found to be protective of having allergies and using medication bought over the counter, as well as using prescribed medication for the allergies. Being male was found to be protective of having allergies and using prescription medication. Jensen-Jarolim and Untersmayr explain that in children, the risk for allergies in boys is greater, despite the identical immunological systems that cause the reactions [100]. Clougherty conducted a review, where all studies that examined the relationship between the effects on respiratory health and gender were examined [101]. The article shows, that although a number of studies have found the effects of air pollution on respiratory health to be modified by sex, the results are inconsistent. It is unclear whether these differences are as a result of physiological differences, or as a result of socially determined gender roles which influence exposure [101]. There may also be a complex interaction between these two factors [101]. As a result of typical gender roles in South African communities, girls and women often spend more time indoors around cooking sources [69, 3]. Therefore, in this study the protective relationship between being male and having allergies may not be accurate but rather an effect of socially determined gender roles.

4.4.3 Bronchitis

For bronchitis, the prevalence for Witbank was higher than that of Middelburg, although the sample was slightly smaller resulting in a slightly wider confidence interval. The bottom limit of the confidence interval was only marginally lower than the prevalence of Middelburg. The prevalence for the entire sample is comparable to that found by Zwi *et al*, although Zwi *et al*'s results were stratified by gender [85]. As this study contained more females it was decided to compare these findings to reported exposed girl prevalence. The reported exposed girl prevalence in Zwi *et al* was 15.7% [85]. The prevalence for this study's entire sample was the same as Zwi *et al* but Middelburg was lower and Witbank higher. These are all higher than that recorded in the VAPS study, which found a prevalence of 14% [39].

As expected the prevalence of bronchitis over the past 2 weeks was lower than that over the past 6 months. Both towns reported the same prevalence.

During bivariate analysis it was seen that the use of an imbhawula for space heating was strongly associated with having bronchitis over the past 6 months, as was having mould in the house, smoking in the house and breathing through the mouth. Multivariate analysis showed that only breathing through the mouth and smoking in the house were significant.

During multivariate analysis two variables were revealed as being significantly associated with having bronchitis over the past 2 weeks. These were breathing through the mouth and smoking in the house. For both models, the same risk factors were identified.

4.4.4 Pneumonia

For pneumonia, the prevalence for both periods was very similar, although as a result of low numbers these results lack strength. Zwi *et al* found a prevalence of

1.9% for exposed girls, which was similar to the finding in this study [85]. The prevalence over the past 2 weeks was very similar to that over the past 6 months, although the numbers were also very low.

During bivariate analysis statistically significant associations ($p \leq 0.05$) were found between having pneumonia in the past 6 months and eating red meat, as well as smoking inside the house. Multivariate analysis revealed only one variable to be statistically significant for having pneumonia in the past 6 months. It was the protective variable of eating vegetables.

For having pneumonia in the past 2 weeks, associations between using a fireplace for heating and having mould in the house were found. Mould was returned as significant, however, the 95% CI showed it not to be. Yet, its contribution to the variable should not be ignored. The study was conducted at the end of September. September is the first month of spring in the southern hemisphere. Domestic animals typically moult in spring. In the WHO report on home dampness and mould they explain that the concentrations of fungi in a cubic meter of indoor air can vary greatly due to factors such as climate and season [16]. In the graph presented by Vismer *et al* whereby the Penicillium/ Aspergillus spore counts were plotted for two years from an area in the Vaal triangle, the peak periods were found to be between March and May, however, increases in the counts are also visible from mid-September [102]. It is possible that the change in season influenced these two factors making them the important risk factors at that point in time.

4.4.5 Earache

For earache, Middelburg had a higher prevalence than Witbank by 1.5%. Zwi *et al* found that earache was more common in children from less polluted areas [85].

For having earache in the past two weeks, the prevalence had increased from that of past 6 months. However, this finding should be discounted due to data reliability issues, as the prevalence over 2 weeks cannot be higher than that of 6 months.

For earache in the past 6 months, bivariate analysis revealed breathing through the mouth, having mould, pets and smoking in the house as significantly associated with the outcome.

Two of these were found as significant for having earache over 2 weeks, namely breathing through the mouth and smoking in the house. Eating fruit and red meat were also associated with having earache over the past two weeks.

Although no factors were returned as being significant for having earache over the past six months, some of the associations found during bivariate analysis should be considered. For example; smoking in the house, Otitis media is a well-documented effect of ETS [103, 48].

4.4.6 Hay fever

For hay fever over the past 6 months, Middelburg also had a higher prevalence than Witbank by almost 10%. This finding corroborates that of Zwi *et al* who found that lesser exposed areas tended to have higher prevalence for hay fever [85]. It is possible that variations in pollens through the different areas may affect this. Respondent definitions or understandings of hay fever may also influence this.

The prevalence for hay fever over 2 weeks was lower than that of 6 months by almost half. However, Witbank had a higher prevalence of hay fever over the last 2 weeks than Middelburg.

For having hay fever over the past 6 months only one variable was returned during multivariate analysis as being significant, that was fuel used for cooking. This variable would have been returned as protective as a result of the intra-variable comparisons between dirtier fuels and electricity. So as a whole, the cleaner the fuel the more protective it would be over having hay fever. Some of the associations that were revealed during bivariate analysis were breathing through the mouth, using an imbhawula and having mould in the house.

The bivariate associations that were revealed for having hay fever over the past 2 weeks were living in Witbank, having pets and smoking inside the house. Having mould in the house was returned as being significantly associated with having hay fever during the past 2 weeks. This may also be associated with the spring time patterns of mould as was explained earlier.

4.4.7 Sinusitis

For sinusitis, the prevalence for Witbank and Middelburg were the same with only 0.1% difference.

The prevalence of sinusitis over the past 2 weeks was almost half of that for the past 6 months. Over the past 2 weeks, Witbank had a higher prevalence of sinusitis than Middelburg, however, over 6 months the prevalence were very similar.

Some of the important associations seen in bivariate analysis were with using gas or paraffin for space heating and having smoking inside the house. During multivariate, smoking was returned as significant, as well as eating fruit. Eating fruit was seen to be protective, and this may be related to immune system functions [49, 51].

One of the variables that having sinusitis over the past 2 weeks was associated with during bivariate analysis was breathing through the mouth. During multivariate analysis, only one variable was returned as significant, namely eating fruit. This variable was found to be protective. This result was similar to what was found for having sinus over the past 6 months.

4.4.8 Asthma

Zwi *et al* found the prevalence of asthma amongst exposed girls to be 4.6% [85]. The prevalence for the entire sample in this study was higher than this with 7.1%. The prevalence for Middelburg was higher than Witbank, and almost double that found by Zwi *et al* [85].

In the two prevalence questions, the prevalence of asthma over the past two weeks was determined. The prevalence for the entire sample was 4.9%, which was similar to that found by Zwi *et al* [85]. And as expected, lower than that of ever having asthma. For the 2 week prevalence, Witbank had a lower prevalence than Middelburg.

The results are lower than those collected during phase 1 and 3 of the ISAAC study in Cape Town [72]. However, the age used for the ISAAC study was 13 to 14 years, compared to the age (9-11 years) used in this study.

During bivariate analysis, two risk factors were found to be significantly associated with ever having asthma; these being breathing through the mouth and having mould in the house. Three risk factors were found to be associated with having asthma in the past 2 weeks, one of which was also breathing through the mouth. The other two were using a fire place or gas or paraffin for space heating. Mouth breathing can make a child more susceptible to the effects of air pollution, which might in turn have an influence on asthma.

No variables were found to be significant during multivariate analysis for having asthma in the past 2 weeks. For ever having asthma, only smoking in the house was found to be significant.

It was seen through the frequencies that majority of the respondents who had asthma reported having asthma attacks most frequently in the winter months. One would expect these results because of the inversion layers in the area. These inversion layers trap pollutants near the surface. Also there is no winter rainfall, so the area's microclimate is dry and cold which can also trigger asthma attacks.

The question examining the age that asthma was diagnosed revealed that children were being diagnosed either very early in life or they were diagnosed recently.

4.4.9 Coughing

There was a noticeably higher prevalence for having a cough when waking regardless of duration for Witbank than Middelburg. There was also a higher prevalence for Witbank to have the cough for longer than three months. In the study by Zwi *et al* a prevalence of 5.5% was found [85]. It can be seen that the prevalence for the entire sample from this study was significantly higher than that of Zwi *et al*. The prevalence for Witbank was about 3 times higher.

It can be seen that majority of respondents, in both the linked and not-linked variable and in both Witbank and Middelburg selected coughing most at night. This was followed by those selecting coughing only when waking up or going to bed.

From the bivariate analysis it was apparent that some of associated factors were; living in Witbank and indoor fossil fuel use. Although, no variables were returned as significant in multivariate analysis, the possible contribution of those found in bivariate should not be ignored.

The multivariate model run to determine what may influence when this coughing mostly occurs found that only mouth breathing was significant.

4.4.10 Phlegm on the chest

Witbank had a higher prevalence of respondents saying that they had phlegm on the chest when they had a cold; however, Middelburg had a higher prevalence of people saying they had phlegm on the chest even without a cold. While for the linked variable of having phlegm for longer than 3 months, Witbank had about 5% more people saying they had it for longer than 3 months than Middelburg.

Amongst the associations seen during bivariate analysis the use of indoor fossil fuels and residing in Witbank where pollution levels are slightly higher, appear to be the most understandable. However, during multivariate analysis no variables were returned as statistically significant.

Having mould in the house was found to be statistically significantly associated with having phlegm on the chest for over three months.

4.4.11 Wheeze

The respondents of Witbank were about 7% more likely to say they had experienced wheezing than those in Middelburg. Our data found that the prevalence of asthma was higher in Middelburg. It has also been shown through our data that the socio-economic status of the sample from Witbank appears to be lower than that of the sample from Middelburg. There may be a potential for under diagnosis of asthma in Witbank, due to not seeking medical care as a result of socio-economic conditions, perceptions of when medical care needs to be sought and the quality or availability of medical care. Rubel and Garro explained some of the factors that influence the successful control of tuberculosis to be cultural understandings that influence people's acknowledgement of changes to their physical or mental well-being, affecting when people seek medical attention [104]. Adherence to medical treatment is often subject to the cost of the treatment, lack of access to or cost of transport, the poor distribution of clinical facilities and the lack trained staff [104]. This possible explanation of the lower prevalence of asthma may be further substantiated by the higher prevalence of wheeze in Witbank than Middelburg.

For the entire sample using the linked variable, a majority of respondents selected having episode of wheeze during the night, followed by those who selected having wheezing episodes during the day and night. For Witbank, majority selected having wheezing during the night. While for Middelburg, majority selected having wheezing episodes during the day and night. Night time inversion layers may trap high concentrations of pollutants which may result in respiratory effects; this will be more noticeable with night time fossil fuel burning.

Zwi *et al* found a prevalence of 6.2% for having ever wheezed [85].The prevalence for the sample in this study was almost twice that found by Zwi *et al*.

From multivariate analysis it was seen that the most important factor influencing the occurrence of chest wheeze was the use of gas or paraffin for space heating. Although, using a fireplace for space heating was also returned as significant, its 95% CI was not significant. However, the contribution of this variable on the outcome should not be ignored. No relationships with when this wheezing occurs were found during multivariate analysis. However, from bivariate results it appears that indoor fossil fuel use and circulation of fresh air might impact this.

4.5 Air quality data

Overall the air quality data was highly variable for both towns throughout the months; however, typical diurnal patterns were seen for most of the pollutants. The air quality was similar for both towns; however, for most of the pollutants Witbank had higher ambient concentrations. In general, both towns experienced exceedences over the 10 month period for different pollutants at different times, therefore it can be concluded the ambient air in the two towns is of poor quality.

This study found the monthly averages for PM_{10} to be similar for both towns. The monitored and modelled data for PM_{10} from the Draft Air Quality Baseline Assessment for the Highveld Priority Area [77], matched the findings reported here. They determined what pollution sources influenced the Witbank monitoring station (the same as the one used in this study), they found industrial activities in the north and mining activities in the south. They also noted that domestic fuel burning had an influence. However, the obtained air quality data did not include the primary winter months of June and July, when the domestic fuel burning contribution would have been most evident.

The daily distributions of PM_{10} for Witbank and Middelburg showed that both towns had the same daily distribution pattern with two peaks, one in the morning and one in the afternoon, most likely associated with traffic. The higher peak in the evening might be attributed to domestic coal burning. It was also seen that the night-time trough from Middelburg did not go as low as the daytime trough. And that it was higher than the night-time trough of Witbank. This may be explained by industrial activities at night or climatic factors which inhibit the movement of air cells.

The $PM_{2.5}$ data for Witbank and Middelburg showed that the pattern for both towns was not as consistent as it was for PM_{10}; this indicates possible separate sources of $PM_{2.5}$ in each area. $PM_{2.5}$ concentrations were slightly elevated for Witbank.

The daily distribution of $PM_{2.5}$ concentrations for both towns, like that for PM_{10}, has two possible traffic related peaks. However, the peaks for Witbank were higher than that of Middelburg, while for PM_{10} the peaks were similar in height. For PM_{10} both traffic peaks for Witbank appeared to occur slightly earlier than those for Middelburg, however, the afternoon peak appeared to occur earlier. The night-time trough for Middelburg was higher than the daytime trough, as mentioned for PM_{10} this might have been as a result of less dispersion than Witbank or night-time emissions.

The PM_{10} concentrations for Witbank and Middelburg over a selected month were similar. The $PM_{2.5}$ concentrations showed slight deviation and Witbank was seen to have slightly higher concentrations of $PM_{2.5}$. Given the presented results it is apparent that there may be a regional pattern for PM_{10} and $PM_{2.5}$.

The data suggests a relationship between both these PM_{10} and $PM_{2.5}$ concentrations. This possible association may be associated with a primary pollution source. There may have been climatic impacts in the region such as inversion layers, limited rainfall and a predominant wind speed and direction that contributed to the observed regional patterns.

A relation between the SO_2 pollution levels in Witbank and Middelburg was evident, although it can be seen that the SO_2 concentrations were higher in Witbank and exceedences were more common, meaning that SO_2 was potentially more of a problem in Witbank than Middelburg. This may have been due to the industrial and mining activities that are more prolific around Witbank than Middelburg.

In the Draft Air Quality Baseline Assessment for the HPA it was noted that the Witbank area was regarded a hotspot area as a result of the frequent exceedences of SO_2, NO_2, PM, and O_3 [77]. In this report, it was noted that the most common source of SO_2 in this region was from industrial coal burning. However, there could also be an impact from domestic coal burning. Middelburg was also noted as a hotspot area, as a result of its SO_2 and PM exceedences.

NO_2 is predominantly associated with traffic. All three peaks could probably be attributed to traffic or industrial emissions. The daytime trough for Witbank went lower than the NO_2 concentration in Middelburg at any point, while the peaks for Witbank extended above the Middelburg concentration. The slightly higher peak for NO_2 in the evenings could also be attributed to fossil fuel burning. As the results from the questionnaire showed, fossil fuel burning appeared to be more prevalent in Witbank. This might explain the higher peaks that were visible in Witbank, particularly in the evenings. For the distribution data, Witbank experienced very high outliers. However, the data suggests that although that individual reading was very high, this was not a trend but rather a once off. For Middelburg only one of the highest values was above the South African National Ambient Air Quality Standard, this was for the same month where the exceeding 99th percentile was recorded.

O_3 is known to be one of the most harmful pollutants to human health. In the Draft Air Quality Baseline Assessment for the HPA, it was explained that one of the reasons Witbank was seen as a hotspot in the area was as a result of the frequent exceedences of O_3 concentrations.

4.6 Conclusion

This discussion shows that there may be a potential human health risk in the area related to ambient air quality. However, it also showed a number of risk factors, including indoor fossil fuel burning, indoor smoking and having mould, to be associated with child respiratory health.

The ambient air quality in the area was seen to be poor. The residents may experience respiratory illness as a result of this. However, the quantification of this relationship is not yet known.

Chapter 5: Conclusions and Recommendations

5.1 Introduction

This chapter will briefly highlight some of the key finding and observations made during the study, in terms of the risk factors for child respiratory health, health prevalence and the air quality in the towns where the children resided. Some of these key findings pave the way for a number of future studies that should be carried out and these will also be discussed in this chapter. The research process encountered a few challenges and limitations and these will also be presented and discussed in this chapter.

5.2 Summary of key findings

The first objective of the study was to determine the prevalence of respiratory health outcomes in children between the ages of 9 and 11 years in the area. This was done and the results were contextualised using those found by Zwi *et al*. This was the only other study of a similar nature to the study reported here that was carried out in the same study area. Compared to the results reported by Zwi *et al* the prevalences found in this study were comparable. The prevalences for bronchitis, pneumonia and wheezing in this study versus Zwi *et al* were; 15.6% versus 15.7%, 1.7% versus 1.9% and 11.4% versus 9.3%, respectively.

Study results show a relatively low asthma prevalence of 7.1%, however, a prevalence of 11.4% for wheezing was found. A prevalence of coughing was found to be 10%; more respondents from Witbank (4.7%) reported having a cough for more than three months, as compared to Middelburg (1.3%). This is important as coughing is often a symptom of asthma in children [105]. These results indicate that there is possibly a respiratory health problem in the area; the exact causes have not yet net been determined. Other factors such as social characteristics and the prevailing medical system may have an influence on these results, for example it appears that the prevalence of asthma may be under reported.

With regard to the Zwi *et al* study, there appeared to be limited change from what was measured 20 years ago. This study had a higher prevalence of asthma than that of Zwi *et al*. This is substantiated by the general trend of increasing asthma prevalence around the world [105]. Low to middle-income countries tend to have more severe asthma [105]. Although this study did not have a high prevalence of asthma, severity of the cases is not known. When examining the results of this study in relation to that of the Cape Town ISAAC study the prevalence of asthma was significantly lower in this study [72]. The study findings are also significantly lower than those found by the ISAAC study conducted in Limpopo [73]. This study also found a higher prevalence of chest wheeze than that of Zwi *et al*; this is understandable as chest wheeze can be associated with asthma. The results presented in this study also showed a significantly higher prevalence of coughing compared with results in Zwi *et al*.

The differences seen between this study and the Zwi *et al* study might be explained by the similar air quality, meaning that the air quality in the area may not have changed very much since the early 1990s [85]. However, it is likely that the levels of domestic fuel burning have decreased [66], this could indicate an increase in industrial or traffic related emissions. Also, the differences in medical care, as well as, possible perception around medical care and ill health should be considered [104]. Further, the effects of HIV/AIDs and TB also need to be considered as they may influence a person's susceptibility to the effects of air pollution [106].

The second objective of the study was to show associations between risk factors and child respiratory health. This was done using bivariate and multivariate analyses on identified risk factors and health outcomes. The majority of the indoor risk factors included in the questionnaire were statistically significant with a number of the health outcomes, either in bivariate or multivariate analysis. Of note, is the continued re-occurrence of the fossil fuels used in the house, smoking and having mould inside the house were also frequently demonstrated as being significant. Some of the following associations were found during multivariate analysis; the use of a fireplace for space heating was associated with having chest wheeze; having phlegm on the chest; pneumonia; and allergies. The use of gas or paraffin for space heating was associated with having sinusitis. Using an asbestos heater was associated with pneumonia. Smoking in the house was found to be associated with asthma, sinusitis, earache, pneumonia and bronchitis. Mould also repeatedly came up as being strongly associated with health outcomes such as bronchitis and pneumonia. Hay fever was found to be associated with the type of fuel used for cooking and owning pets was associated with having pneumonia.

The third objective was to describe the air quality in the two towns and compare it to the South African National Air Quality Standards and the WHO guidelines. The air quality data suggests that the air quality is similar in both towns (Witbank and Middelburg), with there being a slightly higher concentration for one pollutant in Witbank. For both towns, all pollutants did at some point during the 10 months exceed the South African Standards. The WHO guidelines, which are more stringent than the South African Standards, were frequently exceeded in both towns for all pollutants. For Witbank, the pollutants of most concern were SO_2 and the PMs. For Middelburg, the pollutants of most concern were the PMs. The higher levels of SO_2 seen in Witbank can most likely be attributed to the town's closer proximity to the nearby power stations.

The second part of the third objective was to examine measured child respiratory health in relation to the air quality. The respiratory related health outcomes for both towns appeared similar; there was limited evidence from the data to support worse health in Witbank. However, using the prevalence reported for both towns it would appear that Witbank had a greater degree of lower respiratory disease (bronchitis, pneumonia and asthma), while Middelburg had a greater degree of upper respiratory diseases (otitis media, hay fever and sinus). The reasons behind this observation cannot be known with certainty at present; however, differing ambient situations and differing indoor pollutant profiles may have a role to play.

5.3 Limitations

Several limitations were encountered during the study. The first of which was the quality of the responses as a result of the inclusion of skips or stem and branch questions, in the questionnaire. However, these challenges were dealt with through the use of an innovative linked / not linked analysis technique. The quality of these responses may have been influenced by technicalities, such as a person having not been formally diagnosed with asthma but regard themselves as having the disease and therefore feel the need to report their information. Some of the difficulties may also have been as result of literacy levels. The use of this method highlights that the utilisation of self-completed questions may have further challenges in social environments similar to those used in this study. This study used a novel method for obtaining the most value for a complicated dataset, however, in future alternate and more accurate methods for obtaining this data should be examined.

Self-completed or self-reported data also has a degree of inaccuracy as people's recollection of events may not be accurate. There is also no means to verify the truth of their responses. In this questionnaire, it became evident during data entry that some responses did not always correlate to their previous responses to preceding questions. For example, a respondent would answer "no" for having being diagnosed with asthma. However, the following question, designed for those who answered "yes" to the previous question, would ask about the age of diagnosis and the respondent that responded "no" would now provide an age.

Some of the questions (e.g. water and heating system) used a method whereby respondents select 'yes' or 'no' to each option, however, it was found that respondents often did not do that and it was suspected that possibly resulted in a greater percentage of the respondents omitting the question completely.

There were 3 open questions where the respondents were required to fill in one word or possibly a sentence. These questions were omitted from analysis as a result of the poor and missing responses. The open questions were further complicated by language differences, as majority of respondents, responded in Zulu.

The questionnaire used for this study was a tested questionnaire from previous studies; it was designed to answer the aim and objectives of the study. However, from the results of this study it can be seen that a few modifications for future studies are appropriate. This would include the removal of the KAP question and the open ended questions.

There were also limitations seen in the air quality data. Firstly this air quality data was not for the same time period that the questionnaire was conducted. This data was also limited as it contained gaps of missing data, as was not long enough to properly see trends. Importantly, it was also missing the winter months.

This study did not look at outdoor risk factors, such as the proximity of the child's house or school to main roads. Questions covering aspects such as these could be included in the questionnaire for future studies.

5.4 Future studies

As previously detailed, a unique process was created to deal with inconsistent responses to stem and branch questions so as not to lose any valuable information. In future studies, where similar data issues are also encountered, this data management and analysis technique should also be tested rather than automatically coding mistaken responses as missing.

Further epidemiological studies should be carried out in the HPA; however, the studies need to be more specific than this cross-sectional study. Future studies should focus on specific exposures such as traffic-related pollution or specific industry-related pollution. They should also focus on specific health outcomes such as asthma, allergies or otitis media. The data found in this study can be used to compliment or form a basis for further future studies.

From the study's findings, it is evident that indoor environments in the area need further attention. Indoor air quality monitoring should be carried out to quantify and explore the indoor exposures.

A further future study could also do comparisons between areas either within the HPA or the country, and, in greater detail, examine and explain the differing health profiles as seen in Witbank and Middelburg.

Future studies should also aim at quantifying the relationship between exposure and outcome, by specifically running statistical analyses on exposure measurements and specific health outcomes. Future studies could also analyse clinic or hospital data with exposure data to try and map past relationships.

Another study could determine the sources of air pollution and track them around the area in an attempt to determine what communities are at greatest risk. Protection or management strategies could then be directed at those communities.

Time-activity pattern studies could be used to examine gender exposure differences and subsequently differing disease profiles. A study of the gender roles in the country and the HPA would need to supplement this study.

5.5 Recommendations for management

In ten months of air quality data, a number of exceedences of the South African Standards and WHO guidelines were observed. This demonstrates that the air quality is poor in the area. It is recommended that air quality monitoring continues in the area but also occurs in different areas such as industrial sites, residential areas and near or along large roads. This will better explain source contributions of the air pollution and potential individual's exposure. Stricter and more frequent assessment of the industries' air quality emissions should be conducted. Although the ambient air quality in the area is poor, the indoor environment also needs to be taken into account and appropriate strategies are required to improve the indoor air quality environment. This should be done not only to protect human health but also to reduce indoor fossil fuel burning as a source contributor to ambient concentrations.

5.6 Final conclusions

This dissertation provides the results of a cross-sectional study of ambient air quality and child respiratory health for children living in the HPA. The study aimed to determine the baseline prevalence for child respiratory health outcomes in the area. The results showed that the respiratory health in the area is comparable to that of similar studies. This study also set out to determine potential indoor risk factors for child respiratory health. Two primary risk factors were identified (indoor fossil fuel burning and indoor smoking), both of which are known risk factors and are described in literature. This study also planned to examine air quality data for the area and describe it in terms of potential exposure. The air quality data showed exceedences and therefore a potential risk for sensitive populations, including children. Lastly, it was planned that the study contributes scientific evidence for the management of the area. Recommendations for management of the area have been made as well as providing direction for future studies.

Through the execution of this study some challenges with the responses as well as questionnaire design were faced, however, the most significant of these were the inconsistent responses as a result of the stem and branch questions. A unique method was created to deal with these responses so as not to lose any valuable information. The applicability of this method for other studies with similar data issues should be tested and or modified to allow for future studies to accommodate data issues rather than automatically coding mistaken responses as missing. This method allowed different tiers of the responses to be examined and preserved all forms of the data.

In conclusion, the overall air quality of the area was found to be poor and there were respiratory health effects reportedly being experienced by the children in the area. However, the contribution of ambient air pollution levels to these health effects is unknown, since the study aim was not to prove causation. This study showed that there were a number of indoor risk factors for the examined health outcomes; however, this does not exclude outdoor risk factors that were not assessed in this study.

The study showed that there are respiratory health effects being experienced and there are harmful concentrations of pollutants in the ambient air. It also found a number of risk factors for child respiratory health. The direct relationship between child respiratory health and ambient air quality in the area is an important next step. Future studies should endeavour to quantify this in order to protect child health and create an environment that is not harmful to their well-being.

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Appendix A: Questionnaire

INFORMED CONSENT FOR ANONYMOUS QUESTIONNAIRE

Patricia Albers
26025869
School of Health Systems and Public Health, Faculty of Health Sciences
University of Pretoria

Dear Parent or Guardian

Baseline assessment of child respiratory health in the Highveld Priority Area

I am a Masters student in Community health in the School of Health Systems and Public Health, University of Pretoria. You are invited to volunteer to participate in my research project on child respiratory health in the Highveld Priority Area. Your participation is important to me, as it will improve my data allowing me to make more meaningful conclusions.

This letter gives information to help you to decide if you want to take part in this study. Before you agree you should fully understand what is involved. If you do not understand the information or have any other questions, do not hesitate to contact me. You should not agree to take part unless you are completely happy about what we expect of you.

The purpose of the study is to evaluate child respiratory health in the Highveld Priority Area, through the use of a questionnaire**.** We would like you, as parent or guardian to complete a questionnaire, regarding the child's health. This may take about 40 minutes. I will collect the questionnaire from your child's teacher. It will be kept in a safe place to ensure confidentiality. Please do not write your name on the questionnaire.

The Research Ethics Committee of the University of Pretoria, Faculty of Health Sciences granted written approval for this study. Your participation in this study is voluntary. The department of Education has also granted written permission for this study to be conducted.

You can refuse to participate without giving any reason. As you do not write your name on the questionnaire, you give us the information anonymously. Once you have given the questionnaire back to us, you cannot recall your consent. We will not be able to trace your information. Therefore, you will also not be identified as a participant in any publication that comes from this study.

We sincerely appreciate your participation.

Yours truly,
Patricia Albers
Tel: 012 841 4540 or Cell: 072 857 9951

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Please mark your answers using an X

CHILD's PERSONAL INFORMATION (Demographics)

1. What is the child's gender?

a) Male	b) Female

2. What is the child's date of birth?

YEAR: MONTH: DAY:

3. What is the child's home language?

		a) Afrikaans			e) Zulu
		b) English			f) Swazi
		c) Sotho			g) Other
		d) Xhosa			

4. In which town does the child live?

a) Witbank	b) Middleburg

5. How long has the child been living in this town (where he/she now lives most of the time)?

a) Since birth	b) Less than 2 years	c) 2 – 4 years
d) 5 – 10 years	e) More than 10 years	

6. In what town did the child live before living in this town?

____

7. How long did the child live in the previous town?

a) Since birth	b) Less than 2 years	c) 2 – 4 years
d) 5 – 10 years	e) More than 10 years	

THE FOLLOWING QUESTIONS RELATE TO THE HOME WHERE THE CHILD LIVES

8. Which of the following best describes the child's home?

a) A single family brick house, not attached to any other house	
b) A single family brick house, attached to another house (or houses)	
c) A flat	
d) Pre-fabricated home (asbestos/wood/clay)	

9. How many bedrooms are there in this home? _______________________

10 How many people live in this home? __________________________

11. From where do you get the water used in the child's home? (Mark Yes or No for each one)

a) Municipality	Yes	No
b) Private borehole	Yes	No
c) Community borehole	Yes	No
d) Other (Specify) ______________________________		

12. Are any of the following heating systems used in the child's home? (Mark Yes or No for each one)

a) Wood/coal stove/ imbhawula	Yes	No
b) Fireplace	Yes	No
c) Gas or paraffin heater	Yes	No
d) Asbestos heater	Yes	No

13. If there is a portable gas or paraffin heater in the child's home, how often is it used during the winter?

a) About every day
b) 2 to 3 times a week
c) 2 to 3 times a month
d) Seldom
e) Never

14. If there is a coal stove/ imbhawula in the child's home, how often is it used during the winter?
a) About every day
b) 2 to 3 times a week
c) 2 to 3 times a month
d) Seldom
e) Never

15. If there is a fireplace in the child's home, how often is it used during the winter?
a) About every day
b) 2 to 3 times a week
c) 2 to 3 times a month
d) Seldom
e) Never

16. What fuel is mostly used for cooking? (Mark only one)
a) Electricity
b) Gas
c) Paraffin
d) Wood
e) Coal

17. Are windows or doors opened often to circulate fresh air into the child's home during the winter months? Yes | No

18. Is there mould or mildew (usually black or brown spots) growing on any damp or moist surface inside the child's home (e.g. on walls, wallpaper, carpets, ceilings, shower, curtains, etc.)?

Yes | No

19 a) Does household where the child lives or stays most of the time have any pets?
Yes | No

b) Are any animals allowed inside the home? Yes | No

20. Does smoking (cigarettes, cigars or pipe) happen on a regular basis (almost daily) inside the home where the child lives? Yes | No

EATING HABITS

21. Which of the following does the child eat on a regular basis (at least three times a week)? Mark Yes or No for each one)

a)	Chicken or fish	Yes	No
b)	Red meat	Yes	No
c)	Processed food (e.g. polony, meat pies)	Yes	No
d)	Vegetables	Yes	No
e)	Fruit	Yes	No

THE FOLLOWING QUESTIONS ARE ABOUT THE CHILD's HEALTH

22. How would you describe the child's health compared to the health of other children of the same age group?

a)	Better	
b)	The same	
c)	Worse	

23. Does the child have any allergies?

a) No
b) Yes, but the child is not using any medication
c) Yes, and the child is using medication bought over the counter
c) Yes, and the child is using medication prescribed by a doctor

24. During the last <u>2 weeks,</u> how many **days** has the child been absent from school because of illness? [ ][ ] days

25. During the past <u>6 months</u>, how many **days** has the child been absent from school due to illness?

a)	0 days		c)	21-30 days	
b)	1-10 days		d)	>30 days	
c)	11-20 days				

26. If absent from school during the past 6 months, please specify which illness mostly caused this absence ______________________________

27. Has the child been diagnosed with any of the following illnesses during the <u>past 6 months</u>? (Mark Yes or No for every illness)

a) Bronchitis	Yes	No	<u>Symptoms</u>: severe coughing, fever, sometimes chest pains and shortness of breath.
b) Pneumonia	Yes	No	
c) Earache	Yes	No	
d) Hay fever	Yes	No	<u>Symptoms</u>: sneezing, itchy and watery eyes, runny nose and a burning throat
e) Sinus problems	Yes	No	

28. How does the child mostly breathe?

a) Through the mouth	b) Through the nose

ASTHMA

29. Has a <u>doctor</u> ever said that the child has asthma?

Yes	No

If the answer was NO, go to question 34.

30. How old was the child when <u>asthma</u> was diagnosed by the doctor?

a)	0 – 1 years		e)	8 – 9 years	
b)	2 – 3 years		f)	10 years and older	
c)	4 – 5 years		g)	Do not know	
d)	6 – 7 years				

31. a) Does the child still have <u>asthma</u> attacks? Yes | No

b) If you answered **yes**, how often does the child have <u>asthma</u> attacks?

Weekly	
Monthly	
Occasionally	
During exercise or play	

32. Is the child taking medicine or getting treatment for <u>asthma</u> currently?

Yes	No

33. Which months of the year does the child have <u>asthma</u> attacks most often? (Mark Yes or No for each one)

a) January	Yes	No	g) July	Yes	No
b) February	Yes	No	h) August	Yes	No

c) March	Yes	No	i) September	Yes	No
d) April	Yes	No	j) October	Yes	No
e) May	Yes	No	k) November	Yes	No
f) June	Yes	No	l) December	Yes	No

CHEST COUGH

34. Does the child cough most mornings when he/she wakes up? (Mark one)
a) No **(go to question 36)**
b) Yes, has been coughing during the previous 3 months
c) Yes, has been coughing for longer than the previous 3 months

35. When does the child cough mostly? (Mark one)
a) During the day
b) During the night
c) During the day and the night
d) Only when waking up or going to bed

PHLEGM (phlegm on the chest is a thick, sticky substance that causes coughing)

36. Does the child usually have phlegm on the chest? (Mark one)
a) No **(go to question 38)**
b) Yes, when he/she has a cold
c) Yes, with and without having a cold

37 If "Yes", is this phlegm usually present for longer than 3 months continuously or non-stop?

Yes | No

WHEEZE OF THE CHEST (whistling sound of the chest)

38. Does the child's chest sound wheezy or make a whistling sound when he/she inhales or breathes in?

Yes | No

If NO, go to question 40.

39. When the child does **not** have a cold, when does the wheezing mostly occur?
a) Never
b) During the day
c) During the night
d) During the day and the night

40. Has the child ever been hospitalised for respiratory illnesses?

Yes | No If yes, please provide the following information:

c) How many times has the child been hospitalised for respiratory illnesses? __________
d) If possible, specify month and year of each time the child was admitted to hospital:
i) month ________________________ year ________
ii) month ________________________ year _______
iii) month ________________________ year________
iv) month ________________________ year ________
v) month ________________________ year ________
e) What respiratory illnesses were the child admitted to hospital for?
____

OTHER ILLNESSES AND CONDITIONS

41. Is the child currently using any medication prescribed by a doctor?

Yes | No

If yes, please specify ____________________

42. Within the **past two weeks**, has the child been diagnosed with any of the following? (Mark Yes or No for each one)

a) Bronchitis	Yes	No
b) Pneumonia	Yes	No
d) Earache	Yes	No
e) Hay fever	Yes	No
f) Sinusitis	Yes	No
g) Asthma	Yes	No

THANK YOU!

Once the questionnaire has been completed, please return it to the child's teacher in the enclosed envelope

Appendix B: Ethics approval certificate

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Faculty of Health Sciences Research Ethics Committee

12/04/2011

Number	:	**S152/2010**
Title	:	Baseline assessment of child respiratory health in the Highveld Priority Area
Investigator	:	Patricia Nicole Albers, School of Health Systems and Public Health, University of Pretoria (SUPERVISORS: Prof K Voyi / Dr C Wright)
Sponsor	:	None
Study Degree:		MSc Community Health

This Student Protocol was reviewed by the Faculty of Health Sciences, Student Research Ethics Committee, University of Pretoria on 12/04/2011 and found to be acceptable. The approval is valid for a period of 3 years.

Prof M J Bester	BSc (Chemistry and Biochemistry); BSc (Hons)(Biochemistry); MSc (Biochemistry); PhD (Medical Biochemistry)
Prof R Delport	(female)BA et Scien, B Curationis (Hons) (Intensive care Nursing), M Sc (Physiology), PhD (Medicine), M Ed Computer Assisted Education
Prof J A Ker	MBChB; MMed(Int); MD – Vice-Dean (ex officio)
Dr M L Likibi	MBChB; Med.Adviser (Gauteng Dept.of Health)
Dr MP Mathebula	Deputy CEO: Steve Biko Academic Hospital
Prof T S Marcus	(Female) BSc (LSE), PhD (University of Lodz, Poland)
Prof A Nienaber	(Female) BA (Hons) (Wits); LLB (Pretoria); LLM (Pretoria); LLD (Pretoria); PhD; Diploma in Datametrics (UNISA)
Prof L M Ntlhe	MBChB(Natal); FCS(SA)
Mrs M C Nzeku	(Female) BSc(NUL); MSc Biochem(UCL,UK)
Snr Sr J. Phatoli	(Female) BCur (Et.Al); BTech Oncology
Dr R Reynders	MBChB (Pret), FCPaed (CMSA) MRCPCH (Lon) Cert Med. Onc (CMSA)
Dr T Rossouw	(Female) MBChB (cum laude); M.Phil (Applied Ethics) (cum laude), MPH (Biostatistics and Epidemiology (cum laude), D.Phil
Mr Y Sikweyiya	MPH (Umea University Umea, Sweden); Master Level Fellowship (Research Ethics) (Pretoria and UKZN); Post Grad. Diploma in Health Promotion (Unitra); BSc in Health Promotion (Unitra)
Dr L Schoeman	(Female) BPharm (NWU); BAHons (Psychology)(UP); PhD (UKZN); International Diploma in Research Ethics (UCT)
Dr R Sommers	**Vice-Chair** (Female) - MBChB; MMed (Int); MPharMed.
Prof T J P Swart	BChD, MSc (Odont), MChD (Oral Path), PGCHE
Prof C W van Staden	**Chairperson** - MBChB; MMed (Psych); MD; FCPsych; FTCL; UPLM; Dept of Psychiatry

Student Ethics Sub-Committee

Prof R S K Apatu	MBChB (Legon,UG); PhD (Cantab); PGDip International Research Ethics (UCT)
Mrs N Briers	(female) BSc (Stell); BSc Hons (Pretoria); MSc (Pretoria); DHETP (Pretoria)
Prof M M Ehlers	(female) BSc (Agric) Microbiology (Pret); BSc (Agric) Hons Microbiology (Pret); MSc (Agric) Microbiology (Pret); PhD Microbiology (Pret); Post Doctoral Fellow (Pret)
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Dr A L Vlok	MBChB, MMed MPhil

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Appendix C: Table of bivariate results

Health Outcome	Risk Factor	P-value	OR	95% CI
Age asthma diagnosed (2 to 3 years) [not linked]	Eating processed food	0.02	26	0.46-
Allergies (no medication)	Mould in the house	0.004	0.45	0.25-0.79
Allergies (over counter medication)	Breathes through mouth	0.01	0.26	0.1- 0.63
Allergies (prescribed medication)	Breathes through mouth	0.003	0.37	0.19- 0.72
Allergies (prescribed medication)	Male	0.013	0.49	0.28-0.87
Asthma	Breathes through mouth	0	3.3	1.62-6.7
Asthma	Mould in the house	0.008	2.66	1.25-5.67
Asthma (2 weeks)	Breathes through mouth	0	10.55	2.95-37.67
Asthma (2 weeks)	Heating system (fireplace)	0.029	6	1.23-29.31
Asthma (2 weeks)	Heating system (gas or paraffin)	0.02	6.25	1.19-32.89
Asthma attack frequency [not linked]	Owns pets	0.048	0.1	0.009-1.25
Asthma in April [not linked]	Eating chicken or fish	0.01	0.04	0.005-0.32
Asthma in August [not linked]	Circulating fresh air	0.043	0.29	0.089-0.93
Asthma in December [not linked]	Breathes through mouth	0.041	7.15	1.16-44.08
Asthma in December [not linked]	Lives in Witbank	0.008	12.86	1.46- 113.35
Asthma in December [not linked]	Mould in the house	0.016	12.17	1.32-112.31
Asthma in July [not linked]	Breathes through mouth	0.008	3.32	1.3-8.45
Asthma in July [not linked]	Mould in the house	0.025	2.76	1.09-7
Asthma in June [not linked]	Breathes through mouth	0.001	4.03	1.79-9.06

Health Outcome	Risk Factor	P-value	OR	95% CI
Asthma in June [not linked]	Water source (municipal)	0.018	0.23	0.062- 0.88
Asthma in March [not linked]	Water source (municipal)	0.005	0.027	0.003- 0.22
Asthma in November [not linked]	Eating chicken or fish	0.08	0.04	0.002-0.7
Asthma in October [not linked]	Breathes through mouth	0.02	13.93	1.4-138.78
Asthma in October [not linked]	Mould in the house	0.015	12.31	1.3- 113.6
Asthma in September [not linked]	Eating chicken or fish	0.024	0.08	0.014-0.49
Asthma treatment [not linked]	Heating system (fireplace)	0.036	11.08	1.07- 114.72
Asthma treatment [not linked]	Water source (community borehole)	0.023	14.09	1.29- 153.76
Asthma treatment [not linked]	Water source (municipal)	0.041	0.13	0.02- 0.64
Bronchitis (2 weeks)	Breathes through mouth	0.002	3.88	1.54-9.74
Bronchitis (2 weeks)	Mould in the house	0	4.74	1.85-12.16
Bronchitis (2 weeks)	Smoking allowed inside	0.001	7.71	2.62-22.69
Bronchitis (6 months)	Breathes through mouth	0	3.76	2.05- 6.91
Bronchitis (6 months)	Eating processed food	0.003	0.36	0.18-0.73
Bronchitis (6 months)	Heating system (imbhawula)	0.008	3.02	1.29-7.09
Bronchitis (6 months)	Mould in the house	0.005	2.24	1.25-4.01
Bronchitis (6 months)	Smoking allowed inside	0	3.92	1.82-8.42
Bronchitis (6 months)	Water source (community borehole)	0.033	3.08	1.03-9.19
Bronchitis (6 months)	Water source (private borehole)	0.029	5.49	1.25-24.01
Chest wheeze	Breathes through mouth	0.0004	3.02	1.59- 5.71

Health Outcome	Risk Factor	P-value	OR	95% CI
Chest wheeze	Heating system (gas or paraffin)	0.01	2.82	1.24-6.41
Chest wheeze	Pets allowed inside [linked]	0.018	6.38	1.32-30.71
Chest wheeze	Pets allowed inside [not linked]	0	5.4	2.32- 12.8
Chest wheeze	Water source (community borehole)	0.01	3.71	1.2- 11.45
Chest wheeze	Water source (municipal)	0.0002	0.16	0.05-0.48
Coughs when waking	Breathes through mouth	0.001	3.12	1.53- 6.35
Coughs when waking	Fuel used for cooking (paraffin)	0.0026	0.27	0.11- 0.66
Coughs when waking	Fuel used for cooking (wood)	0.034	0.12	0.03-1.1
Coughs when waking	Heating system (imbhawula)	0.049	3.22	0.94- 11
Coughs when waking	Lives in Witbank	0.016	2.14	1.14- 4.02
Coughs when waking	Water source (community borehole)	0.006	5.44	1.59- 18.61
Coughs when waking	Water source (municipal)	0.012	0.21	0.067- 0.63
Earache (2 weeks)	Breathes through mouth	0.02	2.55	1.12-5.78
Earache (2 weeks)	Eating fruit	0.025	0.26	0.09-0.79
Earache (2 weeks)	Eating red meat	0.004	0.29	0.12-0.71
Earache (2 weeks)	Smoking allowed inside	0.001	4.38	1.68-11.4
Earache (6 months)	Breathes through mouth	0	6.1	2.49- 14.91
Earache (6 months)	Mould in the house	0.021	2.63	1.12-6.18
Earache (6 months)	Pets allowed inside [not linked]	0.03	4.32	1.28-14.56
Earache (6 months)	Smoking allowed inside	0.001	5.05	1.77-14.4

Health Outcome	Risk Factor	P-value	OR	95% CI
General health (same)	Eating fruit	0.006	2.84	1.31-6.12
General health (same)	Eating red meat	0.04	1.63	1.03-2.58
General health (worse)	Eating chicken or fish	0	17.38	3.28-92.16
General health (worse)	Eating fruit	0.001	11.27	1.77-71.15
General health (worse)	Eating red meat	0.04	5.59	0.89-35.03
General health (worse)	Eating vegetable	0.003	9.27	1.59-59.48
General health (worse)	Mould in the house	0.013	0.22	0.06-0.82
Hay fever (2 weeks)	Eating processed food	0.023	0.47	0.24-0.91
Hay fever (2 weeks)	Eating red meat	0.014	0.46	0.24-0.87
Hay fever (2 weeks)	Lives in Witbank	0.043	1.74	1.01-3
Hay fever (2 weeks)	Pets allowed inside [not linked]	0.001	4.27	1.7-10.73
Hay fever (2 weeks)	Smoking allowed inside	0.042	2.3	1-5.29
Hay fever (2 weeks)	Water source (other)	0.002	10.67	1.73- 65.74
Hay fever (6 months)	Breathes through mouth	0.025	1.86	1.07- 3.23
Hay fever (6 months)	Eating chicken or fish	0.028	0.38	0.16-0.93
Hay fever (6 months)	Heating system (imbhawula)	0.03	1.92	1.05-3.49
Hay fever (6 months)	Mould in the house	0.04	1.65	1.02-2.68
Hay fever (6 months)	Water source (other)	0.006	4.93	1.39- 17.49
Phlegm for longer than 3 months [linked]	Male	0.036	3.8	1.06- 13.62
Phlegm for longer than 3 months [not linked]	Breathes through mouth	0.032	3.03	1.04- 8.81

Health Outcome	**Risk Factor**	**P-value**	**OR**	**95% CI**
Phlegm for longer than 3 months [not linked]	Circulating fresh air	0.001	0.23	0.09-0.57
Phlegm for longer than 3 months [not linked]	Lives in Witbank	0.004	3.49	1.44- 8.54
Phlegm for longer than 3 months [not linked]	Mould in the house	0	4.87	1.85-12.86
Phlegm for longer than 3 months [not linked]	Owns pets	0.022	2.9	1.12-7.45
Phlegm for longer than 3 months [not linked]	Pets allowed inside [not linked]	0.015	5.33	1.62-17.53
Phlegm for longer than 3 months [not linked]	Water source (municipal)	0.015	0.13	0.034- 0.54
Phlegm on the chest	Breathes through mouth	0.02	3.04	1.15-8.3
Pneumonia (2 weeks)	Heating system (fireplace)	0.029	12.27	1.17-128.9
Pneumonia (2 weeks)	Mould in the house	0.029	6.8	1.2-38.48
Pneumonia (6 months)	Eating red meat	0.021	0.36	0.02-5.9
Pneumonia (6 months)	Smoking allowed inside	0.03	11.74	1.79-77.23
Sinusitis (2 weeks)	Breathes through mouth	0.001	3.74	1.62-8.64
Sinusitis (2 weeks)	Eating fruit	0.048	0.33	0.11-0.95
Sinusitis (6 months)	Heating system (gas or paraffin)	0.001	3.64	1.6-8.27
Sinusitis (6 months)	Smoking allowed inside	0.021	2.74	1.12-6.73
Still has asthma	Breathes through mouth	0	6.94	2.36-20.37
Still has asthma	Pets allowed inside [not linked]	0.05	4.34	1.16-16.28
Still has asthma	Water source (private borehole)	0.02	25.56	1.82- 359.58
Wheezes most often (day)	Eating red meat	0.006	0.05	0.0026-1.02

Appendix D: Table informing multivariate analysis

Health outcome	Risk factor	P-value
Age asthma diagnosed [linked]	Eating processed food	0.009
Age asthma diagnosed [linked]	Fuel used for cooking	0.032
Age asthma diagnosed [linked]	Language	0.029
Age asthma diagnosed [linked]	Mould in the house	0.161
Age asthma diagnosed [linked]	Smoking allowed inside	0.029
Age asthma diagnosed [not linked]	Circulating fresh air	0.082
Age asthma diagnosed [not linked]	Eating processed food	0.024
Age asthma diagnosed [not linked]	Fuel used for cooking	0.116
Age asthma diagnosed [not linked]	Heating system (imbhawula)	0.175
Allergies	Breathes through mouth	0.000
Allergies	Eating processed food	0.136
Allergies	Eating red meat	0.248
Allergies	Gender	0.053
Allergies	Heating system (fireplace)	0.090
Allergies	Heating system (imbhawula)	0.119
Allergies	Mould in the house	0.041
Allergies	Water source (private borehole)	0.244
Asthma	Breathes through mouth	0.000
Asthma	Eating chicken or fish	0.138
Asthma	Gender	0.098
Asthma	Heating system (fireplace)	0.217
Asthma	Heating system (gas or paraffin)	0.249
Asthma	Mould in the house	0.008
Asthma	Pets allowed inside [not linked]	0.138
Asthma	Smoking allowed inside	0.243
Asthma	Water source (municipal)	0.117
Asthma	Water source (private borehole)	0.151
Asthma (2 weeks)	Breathes through mouth	0.000
Asthma (2 weeks)	Frequency of paraffin use [not linked]	0.139
Asthma (2 weeks)	Heating system (asbestos heater)	0.020
Asthma (2 weeks)	Heating system (fireplace)	0.029
Asthma (2 weeks)	Heating system (gas or paraffin)	0.020
Asthma (2 weeks)	Mould in the house	0.198
Asthma (2 weeks)	Water source (other)	0.131
Asthma (2 weeks)	Water source (private borehole)	0.220
Asthma attack frequency [linked]	Eating chicken or fish	0.167
Asthma attack frequency [not linked]	Circulating fresh air	0.045
Asthma attack frequency [not linked]	Eating chicken or fish	0.201
Asthma attack frequency [not linked]	Eating red meat	0.211
Asthma attack frequency [not linked]	Heating system (asbestos heater)	0.143
Asthma attack frequency [not linked]	Heating system (fireplace)	0.236
Asthma attack frequency [not linked]	Owns pets	0.048

Health outcome	Risk factor	P-value
Asthma attack frequency [not linked]	Water source (municipal)	0.083
Asthma in April [linked1]	Eating chicken or fish	0.250
Asthma in April [linked1]	Eating red meat	0.250
Asthma in April [linked1]	Gender	0.250
Asthma in April [linked1]	Town where child lives	0.250
Asthma in April [not linked]	Eating chicken or fish	0.010
Asthma in April [not linked]	Fuel used for cooking	0.069
Asthma in April [not linked]	Heating system (gas or paraffin)	0.052
Asthma in April [not linked]	Heating system (imbhawula)	0.249
Asthma in April [not linked]	Mould in the house	0.157
Asthma in April [not linked]	Water source (municipal)	0.115
Asthma in August [linked2]	Heating system (imbhawula)	0.250
Asthma in August [not linked]	Breathes through mouth	0.059
Asthma in August [not linked]	Circulating fresh air	0.043
Asthma in August [not linked]	Fuel used for cooking	0.210
Asthma in August [not linked]	Heating system (gas or paraffin)	0.029
Asthma in August [not linked]	Heating system (imbhawula)	0.228
Asthma in December [not linked]	Breathes through mouth	0.041
Asthma in December [not linked]	Fuel used for cooking	0.115
Asthma in December [not linked]	Gender	0.090
Asthma in December [not linked]	Mould in the house	0.016
Asthma in December [not linked]	Time spent living in town	0.022
Asthma in December [not linked]	Town where child lives	0.008
Asthma in December [not linked]	Water source (municipal)	0.143
Asthma in February [not linked]	Eating chicken or fish	0.239
Asthma in February [not linked]	Fuel used for cooking	0.039
Asthma in February [not linked]	Language	0.187
Asthma in January [linked1]	Eating chicken or fish	0.250
Asthma in January [linked1]	Eating red meat	0.250
Asthma in January [linked1]	Gender	0.250
Asthma in January [linked1]	Town where child lives	0.250
Asthma in January [not linked]	Eating chicken or fish	0.154
Asthma in January [not linked]	Eating red meat	0.154
Asthma in January [not linked]	Fuel used for cooking	0.065
Asthma in January [not linked]	Heating system (gas or paraffin)	0.052
Asthma in January [not linked]	Heating system (imbhawula)	0.148
Asthma in January [not linked]	Mould in the house	0.016
Asthma in January [not linked]	Time spent living in town	0.037
Asthma in January [not linked]	Town where child lives	0.007
Asthma in January [not linked]	Water source (municipal)	0.115
Asthma in January [not linked]	Water source (private borehole)	0.142
Asthma in July [linked1]	Gender	0.167
Asthma in July [linked1]	Smoking allowed inside	0.222

Health outcome	Risk factor	P-value
Asthma in July [linked1]	Type of house	0.214
Asthma in July [linked1]	Water source (municipal)	0.222
Asthma in July [not linked]	Breathes through mouth	0.008
Asthma in July [not linked]	Fuel used for cooking	0.093
Asthma in July [not linked]	Heating system (gas or paraffin)	0.079
Asthma in July [not linked]	Heating system (imbhawula)	0.136
Asthma in July [not linked]	Mould in the house	0.025
Asthma in July [not linked]	Town where child lives	0.170
Asthma in June [linked2]	Eating chicken or fish	0.250
Asthma in June [linked2]	Smoking allowed inside	0.200
Asthma in June [linked2]	Smoking allowed inside	0.250
Asthma in June [linked2]	Type of house	0.089
Asthma in June [linked2]	Water source (municipal)	0.200
Asthma in June [linked2]	Water source (municipal)	0.250
Asthma in June [not linked]	Breathes through mouth	0.001
Asthma in June [not linked]	Frequency of fireplace use [not linked]	0.003
Asthma in June [not linked]	Frequency of imbhawula use [not linked]	0.248
Asthma in June [not linked]	Fuel used for cooking	0.084
Asthma in June [not linked]	Gender	0.089
Asthma in June [not linked]	Heating system (fireplace)	0.070
Asthma in June [not linked]	Heating system (gas or paraffin)	0.155
Asthma in June [not linked]	Mould in the house	0.217
Asthma in June [not linked]	Water source (municipal)	0.052
Asthma in March [linked1]	Smoking allowed inside	0.200
Asthma in March [linked1]	Type of house	0.200
Asthma in March [not linked]	Breathes through mouth	0.221
Asthma in March [not linked]	Eating chicken or fish	0.222
Asthma in March [not linked]	Fuel used for cooking	0.116
Asthma in March [not linked]	Heating system (fireplace)	0.212
Asthma in March [not linked]	Heating system (imbhawula)	0.160
Asthma in March [not linked]	Language	0.105
Asthma in March [not linked]	Mould in the house	0.172
Asthma in March [not linked]	Time spent living in town	0.054
Asthma in March [not linked]	Town where child lives	0.059
Asthma in March [not linked]	Water source (municipal)	0.005
Asthma in May [not linked]	Fuel used for cooking	0.141
Asthma in May [not linked]	Heating system (imbhawula)	0.062
Asthma in May [not linked]	Mould in the house	0.070
Asthma in May [not linked]	Town where child lives	0.232
Asthma in May [not linked]	Water source (municipal)	0.218
Asthma in November [linked1]	Eating chicken or fish	0.250
Asthma in November [linked1]	Eating red meat	0.250
Asthma in November [linked1]	Gender	0.250

Health outcome	Risk factor	P-value
Asthma in November [linked1]	Town where child lives	0.250
Asthma in November [not linked]	Eating chicken or fish	0.080
Asthma in November [not linked]	Fuel used for cooking	0.028
Asthma in November [not linked]	Heating system (gas or paraffin)	0.137
Asthma in November [not linked]	Heating system (imbhawula)	0.059
Asthma in November [not linked]	Mould in the house	0.063
Asthma in November [not linked]	Town where child lives	0.081
Asthma in November [not linked]	Water source (municipal)	0.060
Asthma in November [not linked]	Water source (private borehole)	0.142
Asthma in October [not linked]	Breathes through mouth	0.020
Asthma in October [not linked]	Fuel used for cooking	0.103
Asthma in October [not linked]	Gender	0.090
Asthma in October [not linked]	Heating system (fireplace)	0.129
Asthma in October [not linked]	Heating system (gas or paraffin)	0.067
Asthma in October [not linked]	Language	0.140
Asthma in October [not linked]	Mould in the house	0.015
Asthma in October [not linked]	Town where child lives	0.058
Asthma in October [not linked]	Type of house	0.203
Asthma in October [not linked]	Water source (municipal)	0.169
Asthma in September [not linked]	Breathes through mouth	0.224
Asthma in September [not linked]	Eating chicken or fish	0.024
Asthma in September [not linked]	Fuel used for cooking	0.131
Asthma in September [not linked]	Gender	0.248
Asthma in September [not linked]	Heating system (gas or paraffin)	0.149
Asthma in September [not linked]	Mould in the house	0.103
Asthma in September [not linked]	Water source (municipal)	0.193
Asthma in September [not linked]	Water source (private borehole)	0.142
Asthma treatment [not linked]	Circulating fresh air	0.241
Asthma treatment [not linked]	Frequency of paraffin use [not linked]	0.147
Asthma treatment [not linked]	Fuel used for cooking	0.057
Asthma treatment [not linked]	Heating system (fireplace)	0.036
Asthma treatment [not linked]	Heating system (gas or paraffin)	0.034
Asthma treatment [not linked]	Pets allowed inside [not linked]	0.125
Asthma treatment [not linked]	Water source (community borehole)	0.023
Asthma treatment [not linked]	Water source (municipal)	0.041
Breathes through mouth	Eating processed food	0.144
Breathes through mouth	Frequency of imbhawula use [linked]	0.213
Breathes through mouth	Heating system (fireplace)	0.097
Breathes through mouth	Pets allowed inside [not linked]	0.239
Breathes through mouth	Type of house	0.185
Breathes through mouth	Water source (other)	0.222
Bronchitis (2 weeks)	Breathes through mouth	0.002
Bronchitis (2 weeks)	Eating processed food	0.089

Health outcome	Risk factor	P-value
Bronchitis (2 weeks)	Mould in the house	0.000
Bronchitis (2 weeks)	Owns pets	0.092
Bronchitis (2 weeks)	Smoking allowed inside	0.001
Bronchitis (6 months)	Breathes through mouth	0.000
Bronchitis (6 months)	Circulating fresh air	0.199
Bronchitis (6 months)	Eating chicken or fish	0.223
Bronchitis (6 months)	Eating processed food	0.003
Bronchitis (6 months)	Frequency of fireplace use [not linked]	0.063
Bronchitis (6 months)	Frequency of imbhawula use [linked]	0.031
Bronchitis (6 months)	Frequency of imbhawula use [not linked]	0.194
Bronchitis (6 months)	Heating system (fireplace)	0.118
Bronchitis (6 months)	Heating system (imbhawula)	0.008
Bronchitis (6 months)	Mould in the house	0.005
Bronchitis (6 months)	Smoking allowed inside	0.000
Bronchitis (6 months)	Time spent living in town	0.138
Bronchitis (6 months)	Town where child lives	0.146
Bronchitis (6 months)	Water source (community borehole)	0.033
Bronchitis (6 months)	Water source (municipal)	0.107
Bronchitis (6 months)	Water source (other)	0.142
Bronchitis (6 months)	Water source (private borehole)	0.029
Chest wheeze	Breathes through mouth	0.000
Chest wheeze	Eating chicken or fish	0.124
Chest wheeze	Eating fruit	0.183
Chest wheeze	Eating vegetable	0.054
Chest wheeze	Gender	0.170
Chest wheeze	Heating system (fireplace)	0.157
Chest wheeze	Heating system (gas or paraffin)	0.010
Chest wheeze	Mould in the house	0.221
Chest wheeze	Pets allowed inside [linked]	0.018
Chest wheeze	Pets allowed inside [not linked]	0.000
Chest wheeze	Town where child lives	0.026
Chest wheeze	Water source (community borehole)	0.014
Chest wheeze	Water source (municipal)	0.000
Chest wheeze	Water source (private borehole)	0.174
Coughs when waking	Breathes through mouth	0.001
Coughs when waking	Eating processed food	0.093
Coughs when waking	Frequency of imbhawula use [linked]	o.109
Coughs when waking	Frequency of imbhawula use [not linked]	0.182
Coughs when waking	Fuel used for cooking	0,009
Coughs when waking	Heating system (imbhawula)	0.049
Coughs when waking	Language	0.179
Coughs when waking	Pets allowed inside [not linked]	0.054

Health outcome	Risk factor	P-value
Coughs when waking	Town where child lives	0.016
Coughs when waking	Type of house	0.110
Coughs when waking	Water source (community borehole)	0.006
Coughs when waking	Water source (municipal)	0.012
Days absent in last 6 months	Language	0.068
Earache (2 weeks)	Breathes through mouth	0.020
Earache (2 weeks)	Eating fruit	0.025
Earache (2 weeks)	Eating red meat	0.004
Earache (2 weeks)	Frequency of fireplace use [not linked]	0.114
Earache (2 weeks)	Mould in the house	0.051
Earache (2 weeks)	Smoking allowed inside	0.001
Earache (2 weeks)	Time spent living in town	0.072
Earache (2 weeks)	Water source (community borehole)	0.114
Earache (6 months)	Breathes through mouth	0.000
Earache (6 months)	Circulating fresh air	0.076
Earache (6 months)	Eating chicken or fish	0.134
Earache (6 months)	Eating fruit	0.237
Earache (6 months)	Eating red meat	0.226
Earache (6 months)	Gender	0.232
Earache (6 months)	Heating system (asbestos heater)	0.202
Earache (6 months)	Heating system (imbhawula)	0.133
Earache (6 months)	Language	0.104
Earache (6 months)	Mould in the house	0.021
Earache (6 months)	Pets allowed inside [linked]	0.180
Earache (6 months)	Pets allowed inside [not linked]	0.030
Earache (6 months)	Smoking allowed inside	0.001
Earache (6 months)	Water source (municipal)	0.238
General health	Breathes through mouth	0.205
General health	Eating chicken or fish	0.003
General health	Eating fruit	0.002
General health	Eating processed food	0.096
General health	Eating red meat	0.018
General health	Eating vegetable	0.017
General health	Mould in the house	0.056
General health	Smoking allowed inside	0.211
General health	Town where child lives	0.020
General health	Water source (community borehole)	0.149
Hay fever (2 weeks)	Breathes through mouth	0.082
Hay fever (2 weeks)	Eating chicken or fish	0.119
Hay fever (2 weeks)	Eating processed food	0.023
Hay fever (2 weeks)	Eating red meat	0.014
Hay fever (2 weeks)	Frequency of fireplace use [not linked]	0.160
Hay fever (2 weeks)	Heating system (asbestos heater)	0.175

Health outcome	Risk factor	P-value
Hay fever (2 weeks)	Heating system (gas or paraffin)	0.175
Hay fever (2 weeks)	Heating system (imbhawula)	0.100
Hay fever (2 weeks)	Mould in the house	0.083
Hay fever (2 weeks)	Owns pets	0.140
Hay fever (2 weeks)	Pets allowed inside [linked]	0.244
Hay fever (2 weeks)	Pets allowed inside [not linked]	0.001
Hay fever (2 weeks)	Smoking allowed inside	0.042
Hay fever (2 weeks)	Time spent living in town	0.191
Hay fever (2 weeks)	Town where child lives	0.043
Hay fever (2 weeks)	Water source (community borehole)	0.093
Hay fever (2 weeks)	Water source (other)	0.002
Hay fever (6 months)	Breathes through mouth	0.025
Hay fever (6 months)	Eating chicken or fish	0.028
Hay fever (6 months)	Eating processed food	0.231
Hay fever (6 months)	Frequency of paraffin use [not linked]	0.214
Hay fever (6 months)	Fuel used for cooking	0.140
Hay fever (6 months)	Heating system (gas or paraffin)	0.185
Hay fever (6 months)	Heating system (imbhawula)	0.030
Hay fever (6 months)	Language	0.002
Hay fever (6 months)	Mould in the house	0.040
Hay fever (6 months)	Owns pets	0.093
Hay fever (6 months)	Pets allowed inside [not linked]	0.100
Hay fever (6 months)	Smoking allowed inside	0.163
Hay fever (6 months)	Time spent living in town	0.140
Hay fever (6 months)	Town where child lives	0.144
Hay fever (6 months)	Water source (other)	0.006
Phlegm for longer than 3 months [linked]	Circulating fresh air	0.178
Phlegm for longer than 3 months [linked]	Eating red meat	0.192
Phlegm for longer than 3 months [linked]	Fuel used for cooking	0.109
Phlegm for longer than 3 months [linked]	Gender	0.036
Phlegm for longer than 3 months [linked]	Language	0.144
Phlegm for longer than 3 months [linked]	Mould in the house	0.105
Phlegm for longer than 3 months [linked]	Pets allowed inside [not linked]	0.109
Phlegm for longer than 3 months [linked]	Water source (community borehole)	0.204
Phlegm for longer than 3 months [not linked]	Breathes through mouth	0.032
Phlegm for longer than 3 months [not linked]	Circulating fresh air	0.001
Phlegm for longer than 3 months [not linked]	Eating red meat	0.041
Phlegm for longer than 3 months [not linked]	Fuel used for cooking	0.101
Phlegm for longer than 3 months [not linked]	Gender	0.127
Phlegm for longer than 3 months [not linked]	Heating system (asbestos heater)	0.165

Health outcome	Risk factor	P-value
Phlegm for longer than 3 months [not linked]	Heating system (fireplace)	0.067
Phlegm for longer than 3 months [not linked]	Mould in the house	0.000
Phlegm for longer than 3 months [not linked]	Owns pets	0.022
Phlegm for longer than 3 months [not linked]	Pets allowed inside [linked]	0.143
Phlegm for longer than 3 months [not linked]	Pets allowed inside [not linked]	0.015
Phlegm for longer than 3 months [not linked]	Smoking allowed inside	0.225
Phlegm for longer than 3 months [not linked]	Town where child lives	0.004
Phlegm for longer than 3 months [not linked]	Water source (community borehole)	0.076
Phlegm for longer than 3 months [not linked]	Water source (municipal)	0.015
Phlegm on the chest	Breathes through mouth	0.020
Phlegm on the chest	Heating system (fireplace)	0.163
Phlegm on the chest	Heating system (gas or paraffin)	0.220
Phlegm on the chest	Language	0.208
Phlegm on the chest	Owns pets	0.201
Phlegm on the chest	Time spent living in town	0.039
Pneumonia (2 weeks)	Breathes through mouth	0.194
Pneumonia (2 weeks)	Circulating fresh air	0.241
Pneumonia (2 weeks)	Eating chicken or fish	0.229
Pneumonia (2 weeks)	Gender	0.226
Pneumonia (2 weeks)	Heating system (fireplace)	0.029
Pneumonia (2 weeks)	Mould in the house	0.029
Pneumonia (2 weeks)	Owns pets	0.162
Pneumonia (2 weeks)	Time spent living in town	0.059
Pneumonia (2 weeks)	Water source (municipal)	0.200
Pneumonia (2 weeks)	Water source (private borehole)	0.170
Pneumonia (6 months)	Breathes through mouth	0.111
Pneumonia (6 months)	Eating fruit	0.186
Pneumonia (6 months)	Eating red meat	0.021
Pneumonia (6 months)	Eating vegetable	0.053
Pneumonia (6 months)	Gender	0.234
Pneumonia (6 months)	Heating system (asbestos heater)	0.099
Pneumonia (6 months)	Heating system (fireplace)	0.008
Pneumonia (6 months)	Heating system (gas or paraffin)	0.112
Pneumonia (6 months)	Heating system (imbhawula)	0.175
Pneumonia (6 months)	Mould in the house	0.118
Pneumonia (6 months)	Owns pets	0.212
Pneumonia (6 months)	Pets allowed inside [not linked]	0.238
Pneumonia (6 months)	Smoking allowed inside	0.030

Health outcome	Risk factor	P-value
Pneumonia (6 months)	Water source (municipal)	0.218
Sinusitis (2 weeks)	Breathes through mouth	0.001
Sinusitis (2 weeks)	Eating fruit	0.048
Sinusitis (2 weeks)	Frequency of fireplace use [not linked]	0.235
Sinusitis (2 weeks)	Gender	0.127
Sinusitis (2 weeks)	Heating system (asbestos heater)	0.115
Sinusitis (2 weeks)	Heating system (fireplace)	0.225
Sinusitis (2 weeks)	Heating system (gas or paraffin)	0.115
Sinusitis (2 weeks)	Heating system (imbhawula)	0.095
Sinusitis (2 weeks)	Smoking allowed inside	0.113
Sinusitis (2 weeks)	Time spent living in town	0.114
Sinusitis (6 months)	Breathes through mouth	0.087
Sinusitis (6 months)	Eating fruit	0.056
Sinusitis (6 months)	Frequency of fireplace use [not linked]	0.228
Sinusitis (6 months)	Heating system (fireplace)	0.060
Sinusitis (6 months)	Heating system (gas or paraffin)	0.001
Sinusitis (6 months)	Mould in the house	0.174
Sinusitis (6 months)	Smoking allowed inside	0.021
Sinusitis (6 months)	Water source (private borehole)	0.128
Still has asthma [linked]	Breathes through mouth	0.065
Still has asthma [linked]	Heating system (imbhawula)	0.179
Still has asthma [linked]	Owns pets	0.266
Still has asthma [not linked]	Breathes through mouth	0.000
Still has asthma [not linked]	Eating chicken or fish	0.102
Still has asthma [not linked]	Eating fruit	0.229
Still has asthma [not linked]	Heating system (gas or paraffin)	0.110
Still has asthma [not linked]	Mould in the house	0.048
Still has asthma [not linked]	Pets allowed inside [linked]	0.105
Still has asthma [not linked]	Pets allowed inside [not linked]	0.050
Still has asthma [not linked]	Water source (community borehole)	0.165
Still has asthma [not linked]	Water source (private borehole)	0.020
Wheezes most often [linked]	Circulating fresh air	0.130
Wheezes most often [linked]	Eating red meat	0.018
Wheezes most often [linked]	Fuel used for cooking	0.034
Wheezes most often [linked]	Language	0.249
Wheezes most often [linked]	Pets allowed inside [not linked]	0.108
Wheezes most often [linked]	Time spent living in town	0.153
Wheezes most often [not linked]	Breathes through mouth	0.160
Wheezes most often [not linked]	Eating red meat	0.410
Wheezes most often [not linked]	Fuel used for cooking	0.058
Wheezes most often [not linked]	Heating system (fireplace)	0.186
Wheezes most often [not linked]	Language	0.120
Wheezes most often [not linked]	Pets allowed inside [not linked]	0.141

Health outcome	Risk factor	P-value
Wheezes most often [not linked]	Time spent living in town	0.068
Wheezes most often [not linked]	Town where child lives	0.135
When coughing mostly occurs [linked]	Breathes through mouth	0.072
When coughing mostly occurs [linked]	Circulating fresh air	0.070
When coughing mostly occurs [linked]	Water source (municipal)	0.092
When coughing mostly occurs [not linked]	Eating processed food	0.082
When coughing mostly occurs [not linked]	Language	0.038
When coughing mostly occurs [not linked]	Mould in the house	0.205
When coughing mostly occurs [not linked]	Time spent living in town	0.129