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Health in the Waterberg, Up in Smoke?

By: Adela Itzkin (Student no: 319735)

A dissertation submitted to the School of Animal, Plant and Environmental Sciences, University of Witwatersrand, for consideration of the award of MSc.

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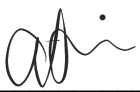
Signature:  **Date:** September 22, 2015

Abstract

High levels of existing and projected future air pollution in the Waterberg region make it South Africa's most recently declared air pollution hotspot. The perceived and real impacts of air pollution on human health may not be equally distributed among all members of society. The distribution of air pollution related perceptions and impacts is necessary to inform government's management policies. This study includes the collection of self-reported respiratory-related health outcomes, using surveys among different segments of society, which can be correlated to air quality and other factors, and used to identify possible modes of intervention, including policies, within the Waterberg National Priority Area. Three sites of human settlement, namely Lephalale, Marapong and Steenbokpan, occurring within the Waterberg region were sampled. The history of these sites; with Lephalale (previously Ellisras) being a formerly white residential area and town, Marapong providing accommodation for labourers, and the Steenbokpan site consisting of an informal settlement lacking electrification; suggests that comparisons of air pollution perceptions and self-reported health outcomes on the basis of socio-economic characteristics could be made. Chi-squared tests of the survey results showed 12 out of 15 of the socio-economic and energy-related indicators tested, including poverty and qualification levels, to be significantly different between the three sites, strongly reinforcing the hypothesis that the three sites represent three distinct socio-economic profiles which can be classified in descending order of wealth status as Lephalale, Marapong and Steenbokpan. Air pollution perceptions and self-reported health outcomes were found to vary with socio-economic profile. These associations sometimes follow the expected linear relationship, as is the case for factors such as air pollution awareness (χ^2 (2, N=215) =24.45, P<0.001) and perceived pollution levels (χ^2 (6, N = 211) = 16.13, $p < 0.05$); where awareness of air pollution and perceived pollution level are highest at Lephalale and lowest in Steenbokpan. This is, however, not always the case; Steenbokpan displays an understanding of air pollution that is higher than might be expected based on the site's socio-economic profile; and the largest proportion of respondents from Marapong perceive their household health over the last two years as having improved. There are two ambient air quality monitoring stations in the study area, positioned in Lephalale and Marapong respectively. The

annual, hourly and 24 hour average of SO_2, NO_2, PM_{10} and $PM_{2.5}$ measured were higher in Marapong than in Lephalale. The annual averages of SO_2 at Marapong (9.87 $\mu g/m^3$) is almost ten times that of Lephalale (1 $\mu g/m^3$), and the average PM_{10} concentration of 88.7$\mu g/m^3$ in Marapong is shown to exceed the NAAQS value of 50$\mu g/m^3$. In contrast with air quality reality of Marapong having the higher pollution levels than Lephalale, 25% of residents from Lephalale perceive the overall health of their households as worse, compared to only 11% from the other two areas. This may correspond to Marapong having the most people with a low understanding of air pollution. The set of scenarios being compiled for the Regional Environmental and Social Assessment of Coal-Based Energy Projects (RESA) predicts that the area and magnitude of air pollution exceedances and adverse impacts in the Waterberg will increase over time till 2035. There are no RESA scenarios that consider feasible emission reductions. Qualification of respondent, subscription to medical aid and presence of a ceiling on the home came up as associated with 'air pollution understanding', as well as 'overall rating of household health over the last two years'. This points to education, formal job creation and dwelling modifications as possible modes of intervention.

Key Words: Waterberg, air quality, health perceptions.

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Chapter One: Introduction

The World Health Organization's 2012 report attributes one in eight deaths worldwide to air pollution, making it the single greatest environmental health risk on Earth (World Health Organisation 2012). Air pollution comprises of outdoor (ambient) pollution and indoor pollution. The report estimates that 88% of premature deaths caused by outdoor pollution occurred in low- and middle-income countries. South Africa is a developing country with a coal-based energy economy (Cook 1994, Nteo *et al.* 2011). The three main anthropogenic sources of air pollution in South Africa are industrial combustion of fossil fuels, domestic burning of fossil fuels and exhaust fumes from motor vehicles (Wright *et al.* 2011). The high level of fossil fuel based industry together with apartheid infrastructure, poverty, and inadequate air quality legislation have resulted in a number of 'air pollution hotspots' in the country (*ibid* 2011).

The Waterberg region of South Africa contains more than 40% of the country's *in-situ* coal reserves, and is to be host to a number of current and future coal mines and power stations (Corbett *et al.* 2008, Moodley *et al.* 2014). As the Waterberg region is home to a number of human settlements in different stages of development, the effects of close proximity domestic burning is also of importance when considering human health status.

Concerns about high levels of existing and projected future air pollution in the Waterberg have resulted in its 2012 pronouncement as a National Priority Area (NPA), making it the country's most recently declared air pollution hotspot (Department of Environmental Affairs 2012). The perceived and real impacts of air pollution on human health may not be equally distributed among all members of society. Knowledge of the distribution of air pollution related perceptions and impacts is necessary to inform government and corporate management policies.

The conceptual framework of this study, adapted from the city of Tshwane's air quality management plan, recognizes that an effective air quality monitoring system must link environmental reporting, air quality monitoring, health assessments, policy and planning (Figure 1). The study

therefore includes the collection of self-reported respiratory-related health outcomes, using mixed methods surveys and key stakeholder interviews among three communities, namely Ellisras, Marapong and Steenbokpan, which represent different segments of society. Findings from these surveys can then be linked to air quality and other factors, and used to identify possible modes of intervention within the Waterberg NPA.

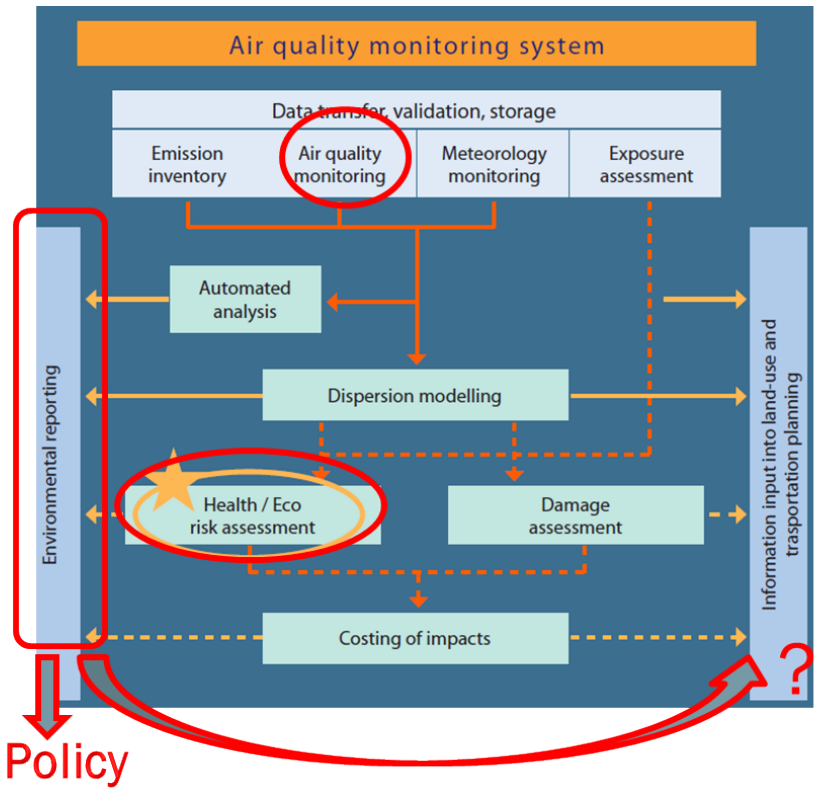


Figure 1. Conceptual Framework for this study, adapted from Air Quality Management plan for city of Tshwane 2006-2008. Red circles indicate areas of focus of this study, and arrows point to linkages that the air quality management plan does not explicitly make, which this study will.

Aim

To conduct an assessment of the perceived state of air quality (framed as an ecosystem service which in turn supports respiratory health) as a result of fossil fuel burning and domestic activities in the Waterberg NPA, using stakeholder surveys and scenario analysis.

Objectives and Key Questions

1. To conduct a socio-economic and energy analysis at three sites within the Waterberg district municipality.

- How do the three sites differ with regards to household size, qualification, poverty levels, grants, family structure, medical aid, home ownership, electricity access, presence of a ceiling, smokers, and whether smoking happens inside the home?

2. To describe current distribution and burden of air pollution perceptions and self-reported respiratory-related health outcomes.

- How do air pollution and health perceptions differ between sites?
- Can perceptions and/or quantitative data be linked to the socio-economic indicators analyzed in Objective 1?

3. To access ambient air quality data available for the last 5 years.

- What are the trends in SO_2, NO_2, PM_{10} and $PM_{2.5}$ data available for the last 5 years?
- What are the exceedances in the SO_2, NO_2, PM_{10} and $PM_{2.5}$ data available for the last 5 years?

4. To identify and describe current health and environmental policies and measures designed to reduce the burden of respiratory-related health outcomes.

- What are the health and environmental policies currently in place?

5. To estimate future potential air pollution related health impacts, using scenarios of future change.

- What are the described scenarios set out for the region in terms of air quality and human health?

Chapter Two: Literature Review

The purpose of Chapter Two is to expand on concepts from the literature that form the theoretical framework within which the distribution of air pollution related perceptions in the Waterberg will be determined in this study. The interdisciplinary nature of this study requires that information from a broad range of disciplines be brought together. The structure of the chapter thus comprises, firstly, of the sources and effects of air pollution on health, air quality regulation as an ecosystem service, and man-made air-quality regulatory systems internationally. A South African perspective of these issues and other studies conducted around the air quality and health in the Waterberg will then be discussed. The chapter will conclude by expanding on air quality and health interventions; and the concept of scenario building as an effective tool to inform future decision making in this field and defining various concepts as used in this study.

2.1. Sources of Air Pollution and Effects of Air Pollution on Health

Air pollution comprises of outdoor (ambient) pollution and indoor pollution. Outdoor pollution comes chiefly from fossil fuel burning, transport, industrial non-fossil fuel emissions and natural emissions. Indoor pollution typically comes from burning coal, wood and paraffin for heating, cooking and lighting (World Health Organization 2009). There is a wide range of pollutants present in both outdoor and indoor air. These include several types of particulates, sulfur oxides, nitrogen oxides, carbon monoxide, ozone, toxic compounds, lead and other heavy metals, and a variety of volatile organic compounds (VOCs) (McGranahan and Murray 2003). The many variations in the sources, distribution and effects of the different compounds make it preferable to avoid over-generalization. The spatial distribution and concentrations of the various air pollutants vary considerably but most air pollutants are a local phenomenon, with concentrations at any particular location varying with local site geography, climate combinations, emission rate, and meteorological dispersion factors (McGranahan and Murray 2003).

The World Health Organization (WHO) develops and produces "Air quality guidelines" recommending exposure limits to key air pollutants, namely particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) (WHO 2014). Since the production of particulates, sulfur and nitrogen oxides all arise out of the burning of fossil fuels, and have all been identified by the WHO as being of concern with regard to human health, more information on the sources and effects of these pollutants is provided below.

Particulates

Particulate air pollution, measured in micrometers of diameter (μm), refers to the presence in air of small solid and liquid particles of various physical dimensions and chemical properties. Although particulate matter (PM) is often grouped by the size of the particles, their sources, distribution and effects can be highly variable (McGranahan and Murray 2003). The major components of PM are sulphates, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water (WHO 2014). It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. Some particles such as biological particles, fine soil particles, wildfire smoke particles, salt, and volcanic ash, are of natural origin. Some originate from a range of anthropogenic sources that include industrial combustion processes, vehicle emissions, and domestic heating and cooking. Other particles can be produced in air as a result of slow atmospheric reactions among gases emitted at distant locations, and transported by atmospheric processes (McGranahan and Murray 2003).

The importance of each source varies with economic, geographical and meteorological conditions. Areas that experience low rainfall with soils prone to wind erosion are, for example, susceptible to periods of high soil particulate levels (McGranahan and Murray 2003). Regions that are heavily dependent on solid fuels are prone to smoke and sulphur dioxide pollution, particularly those that use coal products for industrial production, electricity generation and domestic heating. People in rural areas and low-income communities of many developing countries may experience high

concentrations of indoor particulate and other air pollution caused by the burning of biomass fuels. Particulate matter has been shown to be harmful to human health, with the 2014 WHO proclamation that PM affects more people than any other pollutant. The most health-damaging PM particles are those with a diameter of 10 microns or less, (≤ PM 10 μm or PM_{10}), which can penetrate and lodge deep inside the lungs (WHO 2014). Even smaller particles with a diameter of 2.5 microns or less (≤ PM 2.5 μm or $PM_{2.5}$) can penetrate deeper and are deemed extremely damaging. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer (WHO 2014). A study conducted by Pope and others (2002) for the American Cancer Society showed a 6% (95% confidence interval 2% to 11%) increase in mortality per 10 $\mu g/m^3$ increase in fine particle ($PM_{2.5}$) exposure.

Sulfur oxides

Sulfur dioxide (SO_2) is a colourless gas with a sharp odour. The main anthropogenic source of SO_2 is the burning of sulfur-containing fossil fuels for power generation, domestic cooking and heating, and motor vehicle emissions (WHO 2014). Sulfur dioxide can react catalytically or photochemically with other pollutants or natural components of the atmosphere to produce sulfur trioxide, sulfuric acid and sulfates. Sulfur dioxide is usually a local pollutant, especially in moist atmospheres, but in its oxidized forms it can persist and be transported substantial distances as a fine particulate (McGranahan and Murray 2003).

Sulfur dioxide is damaging to human respiratory functioning, increasing both the prevalence of chronic respiratory disease, and the risk of acute respiratory disease. Sulfur dioxide can affect the respiratory system and the functions of the lungs, as well as cause inner eye irritation. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to respiratory tract infections (WHO 2014). Being highly soluble, SO_2 is more likely to be absorbed in the upper airways rather than penetrate to the pulmonary region (Corbett *et al.* 2008). The WHO's 2014 ambient air quality fact sheet found an increase in hospital admissions for cardiac disease and mortality on days with higher SO_2 levels.

Nitrogen oxides

Although there are a number of chemical forms of nitrogen oxides, the most significant from a human health perspective is nitrogen dioxide (NO_2) (McGranahan and Murray 2003). Nitrogen oxide exposure can come from industrial, domestic and personal activities. The major anthropogenic sources of NO_2 are combustion processes such as heating, power generation, and vehicle engines (WHO 2014). Urban concentrations of NO_2 tend to be highest close to major roads during peak traffic conditions, in the vicinity of major industrial sources. Nitrogen oxides are also important indoor air pollutants because they are produced by domestic and commercial combustion equipment such as stoves, ovens and unflued gas fires. The smoking of cigarettes is a key source of personal exposure (*ibid* 2003).

As an air pollutant, NO_2 has several correlated effects. At short-term concentrations exceeding 200 $\mu g/m^3$, it is a toxic gas which causes significant inflammation of the airways. Oxides of nitrogen are particularly harmful to children and can lead to respiratory diseases. Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NO_2 (WHO 2014). Nitrogen dioxide is also the main source of nitrate aerosols, which form an important fraction of $PM_{2.5}$.

2.2. Air quality regulation: An Ecosystem Service

An ecosystem is a dynamic complex of social, physical and biological components of an environment. These organisms form complex sets of relationships and function as a unit. The WHO defines ecosystem services as the benefits that humans obtain from ecosystems. Ecosystem services are produced by interactions within the ecosystem. These services can be provisioning, regulating or cultural and can be effective on a local, regional or global scale (Figure 2). An example of a regulating ecosystem service is that of air quality regulation, which in turn supports health.

Anthropogenic activities such as fossil fuel burning can disrupt normal ecosystem functioning, in turn disrupting the services that they provide to humans.

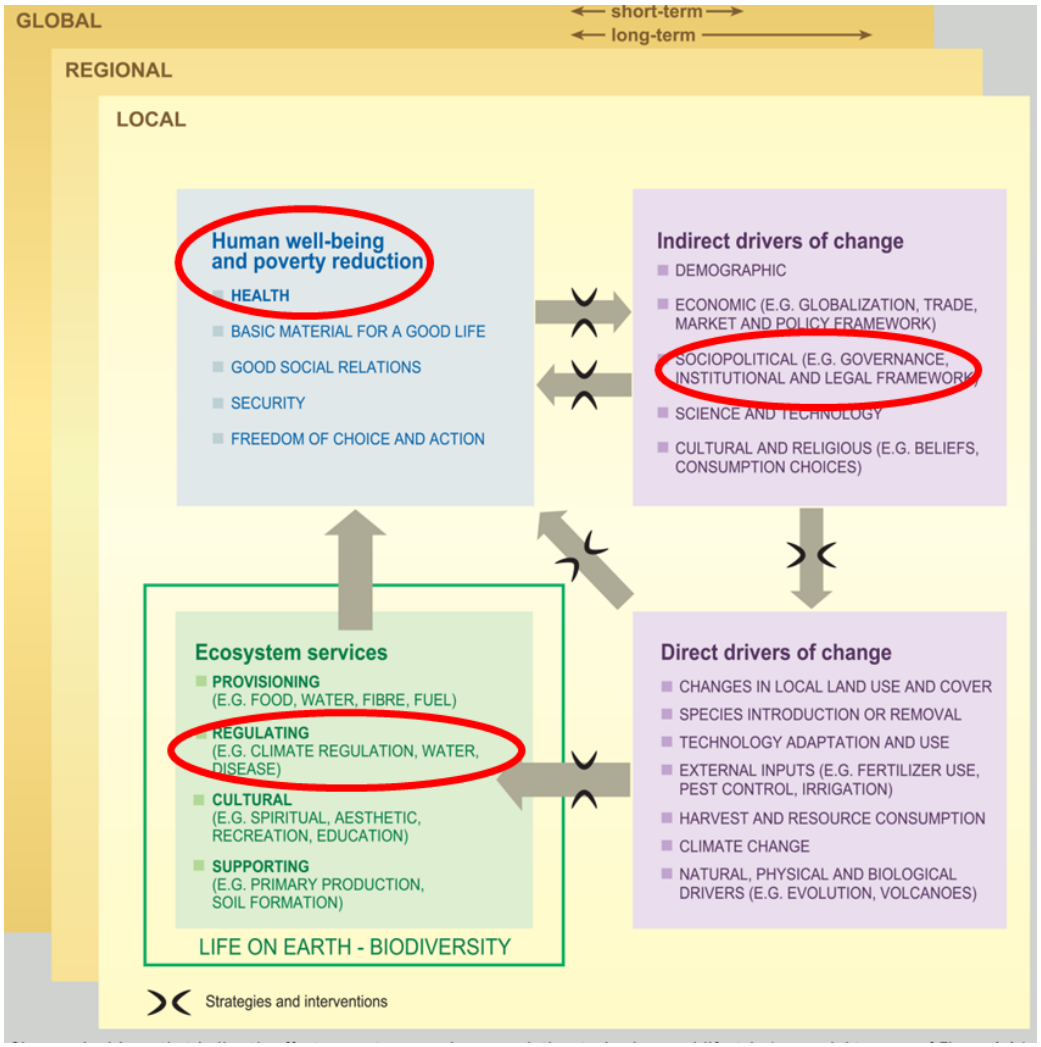


Figure 2 . Ecosystem services are categorized as provisioning, regulating, cultural or supporting; and act to promote human well-being. A number of direct and indirect drivers of change can affect ecosystem services either positively or negatively. In the case of air quality, the ecosystem acts to regulate the air, which in turn enables respiratory health. The emission of copious pollutants disrupts this service, and can have negative implications with regards to human health. Man-made strategies and interventions can also regulate the effectiveness of ecosystem services (WHO Millennium Assessment 2005).

Butler and Oluoch-Kosura (2006) suggest that although the links between ecosystems and aspects of human well-being, including health, may have been long obvious to ecologists; they have been less well understood among the social science community. The Millennium Ecosystem

Assessment, in which a health synthesis report of ecosystems and human well-being was conducted, aims at starting to change that situation (Corvalan, Hales and McMichael 2005). The report outlined some of the pathways in which environmental change and eco-system impairment could have consequences for health.

2.3. Air Quality Research and Regulation: Global Picture

Linking air emissions to human illness requires an understanding of the air dispersion patterns, human exposure to air quality risks, and the dose–response functions that relate human health to air pollutant levels (Spalding-Fecher and Matible 2003). Natural ecosystem regulatory services are disrupted when emissions are of a level where air pollution transport through dispersion patterns would no longer be sufficient to protect against negative health impacts. When this happens, man-made interventions may need to be introduced (World Health Organization Millennium Assessment 2005). Such interventions can come in the form of guidelines such as the World Health Organisation (WHO) air quality guidelines, which recommend exposure limits to key air pollutants, minimizing damage to human health. The guidelines are based on expert evaluation of current scientific evidence for: nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter (PM) and ozone (O_3). The WHO guidelines are aimed to be broad and applicable worldwide but are not legally binding within national jurisdictions. They can, however, serve to inform air quality standards within national jurisdictions

The 2005 "WHO Air quality guidelines" long term and short term globally recommended limits for the following pollutants, in micrograms per cubic metre ($\mu g/m^3$), are as follows:

NO_2: 40 $\mu g/m^3$ annual mean, 200 $\mu g/m^3$ 1-hour mean

SO_2: 20 $\mu g/m^3$ 24-hour mean, 500 $\mu g/m^3$ 10-minute mean

$PM_{2.5}$: 10 $\mu g/m^3$ annual mean, 25 $\mu g/m^3$ 24-hour mean

PM_{10}: 20 $\mu g/m^3$ annual mean, 50 $\mu g/m^3$ 24-hour mean

The PM_{10} guidelines are based on findings to suggest that reducing PM_{10} pollution from 70 to 20 μg/m^3 metre could cut air pollution-related deaths by around 15%. The WHO's 2005 revision of the 24-hour guideline for SO_2 concentrations from 125 to 20 μg/m^3 was based on findings that health effects are associated with much lower levels of SO_2 than previously believed. Although the causality of the effects of low concentrations of SO_2 is still uncertain, reducing SO_2 concentrations is also likely to decrease exposure to co-pollutants. The recommendation that SO_2 concentrations of 500 μg/m^3 should not be exceeded over average periods of 10 minutes duration is informed by studies indicating that a group of people with asthma experience changes in pulmonary function and respiratory symptoms after periods of exposure to SO_2 as short as 10 minutes (WHO 2014). In conjunction with the air quality guidelines, the WHO conducts research regarding the linkage of air pollution to specific diseases, such as respiratory and cardiovascular conditions, as well as burden of disease estimates from existing air pollution exposures, which is used to inform recommendations.

In addition to international guidelines, national and local governance structures and policies can take relevant conditions and priorities into account. Various forms of intervention can be enforced on national, regional, local, or individual scales (Spalding-Fecher and Matible 2003). These range from large-scale policy changes and investments associated with power generation, industrial limitations, clean transport and energy-efficient housing, to better municipal waste management and healthcare as well as community and individual behavioural changes.

Research is an important step in understanding what legislation is required to ensure that the air quality standards work towards maintaining human health. Most of the research around these issues is, however, still focussed on North America and Europe, for instance, a framework was recently developed by Likhvar and others (2015) to model air-quality and human health across three geographical scales (namely: Global, European and French) and assess future (2030-2050) health impacts of ozone and $PM_{2.5}$ under two emissions scenarios: Current Legislation Emissions (CLE), and Maximum Feasible Reductions (MFR). The study found consistently fewer deaths under the MFR scenario compared to CLE, with a possible 1.5 million cardiovascular-related deaths delayed each

year from 2030 compared to 2010 under the MFR scenario, 84% of which would occur in Asia, especially in China. In Europe, the benefits under the MFR scenario are noticeably larger than those under CLE. In France, more than 2830 annual cardiovascular related deaths associated with PM2.5µm changes could be delayed under MFR but in Paris, ozone-related respiratory mortality is expected to increase under both scenarios (Likhvar *et al.* 2015). Likhvar's findings point towards multi-scale health impact assessments being necessary to illustrate the differences in direct consequences of various mitigation policies and help decision-makers choose between policy alternatives at various scales. It is thus important to consider differences between the developed and developing world, as well as regional and local differences when making policy decisions. There is some work in this regard now taking place in the developing world. A recent study that was conducted in Delhi, India, for instance, shows that under the current national policies scenario $PM_{2.5}$ concentrations for Delhi will be too high to reach the recommended national ambient air quality standards by 2030 (Dholakia et al. 2013).

2.4. Air Quality and Health Research: South Africa

There have, similarly, been some studies and reports which are intended to inform decision and policy making in South Africa. A report conducted for the for the Department of the Environment and Water Affairs by Edkins and others in 2010, bases the external costs on health impacts from coal-fired power stations on two South African studies conducted by van Horen (1996) and Spalding-Fecher & Matible (2003). The van Horen study (1996) done to link human illness to air dispersion patterns, human exposure to air quality risks, and the dose–response functions that relate human health to air pollutant level in South African, adapted a model developed by Rowe and others (1994) in the United States. The fact that these studies do not have the own customized models is, however, a limitation.

The Department of Environmental and Water Affairs report also concluded that South African studies (such as Blignaut and King 2002, and Spalding-Fetcher and Matible 2003) on the external costs of climate change from coal-fired power generation are out-dated compared to

international estimates due to those studies using very low damage estimates for climate change (Edkins *et al.* 2010). International studies on the costs of air pollution related health damages were found to out-cost local studies by a factor of 10 for health impacts, mainly because of different approaches in valuing health between developing and developed countries (*ibid* 2010).

Cost-benefit analyses can also be a useful tool in weighing up which measures, policies and scenarios would result in the largest benefit at the lowest cost. While most developed-world studies of externalities in the electricity sector have focused on the costs of air pollution on human health and the environment, electricity also has a variety of positive impacts in developing countries. Electrification creates significant health benefits for the poor by displacing indoor air pollution caused by 'dirtier' fuels such as wood, coal and paraffin (Spalding-Fecher 2005).

The mass electrification programme initiated by Eskom in 1991 and included as a key government programme after 1994 has been one of the most successful elements of the Reconstruction and Development Programme (Spalding-Fecher and Matible 2003). It has increased the share of South Africa's population with access to electricity from 35% in 1990 to 66% at the end of 1999, providing ''cleaner'' and ''safer'' forms of energy than coal and wood, which when burnt indoors causes high levels of indoor air pollution for low-income households (*ibid* 2003).

As low-income households receive electricity access, they commonly reduce, but not eliminate, the consumption of other household fuels in a process which is complex, involving many social and cultural as well as economic factors (Annecke 1999; Mehlwana and Qase 1999). Within the South African context, Government is conventionally held responsible for upholding the socio-economic rights of citizens, including the right to health and the shift towards electrification is likely to have significant environmental and health benefits for low-income households in South Africa. A study conducted by Röllin and others, for instance, found that concentrations of PM_{10} and CO, measured in kitchens and in children in rural South African villages, were significantly higher in un-electrified homes compared to homes where electricity was used (Röllin *et al.* 2004).

While electrification is a measure which can reduce exposure to air pollutants on a household level, proximity to industrial sources of pollution affects whole communities. A study regarding ambient pollution and respiratory outcomes among schoolchildren in Durban found that children from industrially exposed communities in South Durban experienced a higher prevalence of persistent asthma than those from communities distant from industrial sources (Naidoo *et al.* 2013).

2.5. Air Quality and Health Regulation: South Africa

Following the new democratic dispensation in 1994, air quality was included in the South African Constitution, which is enshrined as the country's highest level of law with regard to socio-economic rights (South African Constitution 1994). The lack of adequate air quality legislation until fairly recently, together with other socio-economic factors affecting South African society have, however, contributed to the development of a number of air pollution hotspots across the country (Wright, Garland and Thambiran 2011). These include the South Durban Industrial Basin, Secunda in the Highveld region and Zamdela in the Vaal triangle (*ibid* 2011).

The Air Quality Management Act (No 39 of 2004) (the AQA) aims to control all major sources of pollution and is managed by local government. Tools under the AQA include regulation of emissions from point sources, ambient air quality standards for priority pollutants such as SO_2, NO_2, PM_{10}, O_3, C_2H_2, Pb and CO (Table 1), and the development and implementation of air quality management plans at all spheres of government.

The South African Government is, however, also faced with the responsibility of fulfilling various development goals, including economic growth, poverty alleviation and job creation. The fact that coal makes up 90% of South Africa's energy mix and is one of the country's top commodities, with a total sales value higher than both platinum and gold for 2010 and 2011 (South African Chamber of Mines, Department of Mineral Resources 2012), places government in a challenging position when it comes to balancing health-related issues with its developmental agenda. The Department of Environment and Tourism (DEAT) acknowledged, in 2008, that the development path that South Africa is currently pursuing has elements of being unsustainable and that South Africa is

characterized by the inequitable distribution of wealth and resources, and has consequently set up a national framework for sustainable development.

Table 1. Ambient air quality standards for priority pollutants in South Africa, as written into law in 2009. A prescribed number of exceedances, as stipulated by the frequency of exceedance column, are allowed for each standard (CSIR 2012, Reconstructed from Government Gazette of 24 December 2009).

Averaging Period	Concentration	Frequency of Exceedence	Compliance Date
National Ambient Air Quality Standards for Sulphur Dioxide (SO_2)			
10 minutes	500 µg/m³ (191 ppb)	526	Immediate
1 hour	350 µg/m³ (134 ppb)	88	Immediate
24 hours	125 µg/m³ (48 ppb)	4	Immediate
1 year	50 µg/m³ (19 ppb)	0	Immediate
The reference method for the analysis of sulphur dioxide shall be ISO 6767			
National Ambient Air Quality Standards for Nitrogen Dioxide (NO_2)			
1 hour	200 µg/m³ (106 ppb)	88	Immediate
1 year	40 µg/m³ (21 ppb)	0	Immediate
The reference method for the analysis of nitrogen dioxide shall be ISO 7996			
National Ambient Air Quality Standards for Particulate Matter (PM_{10})			
24 hours	120 µg/m³	4	Immediate – 31 December 2014
24 hours	75 µg/m³	4	1 January 2015
1 year	50 µg/m³	0	Immediate – 31 December 2014
1 year	40 µg/m³	0	1 January 2015
The reference method for the determination of the particulate matter fraction of suspended particulate matter shall be EN 12341			
National Ambient Air Quality Standards for Ozone (O_3)			
8 hours (running)	120 µg/m³ (61 ppb)	11	Immediate
The reference method for the analysis of ozone shall be UV photometric method as described in SANS 13964			
National Ambient Air Quality Standards for Benzene (C_6H_6)			
1 year	10 µg/m³ (3.2 ppb)	0	Immediate – 31 December 2014
1 year	5 µg/m³ (1.6 ppb)	0	1 January 2015
The reference methods for the sampling and analysis of benzene shall either be EPA compendium method TO-14 A or method TO-17			
National Ambient Air Quality Standards for Lead (Pb)			
1 year	0.5 µg/m³	0	Immediate
The reference method for the analysis of lead shall be ISO 9855			
National Ambient Air Quality Standards for Carbon Monoxide (CO)			
1 hour	30 mg/m³ (26 ppm)	88	Immediate
8 hour (calculated on 1 hourly averages	10 mg/m³ (8.7 ppm)	11	Immediate

In 2008 the South African government also announced its aim to develop a national climate change response policy that will map a socio-economic transition to a climatic resilient and low-carbon South African economy and society (DEA 2008). In the 2011 South African Environmental Stakeholder Report, government presents the effort to peak emissions by 2025, to stabilize for ten years, followed by a decline; as a fair and meaningful contribution to the global effort, conditional on

the provision of international funding and technology (Nteo *et al.* 2011). Within this framework, the energy-intensive South African economy is therefore currently in its increasing phase leading up to the envisioned 2025 peak (*ibid* 2011). There is a risk here, that this statement is used as a justification of increased emissions ahead of supposed reductions, for which there is no guarantee.

The trajectory that this increase takes and the manner in which South Africa makes the transition to a low-carbon economy will have environmental, economic and social impacts which may be positive or negative. Business decisions and government policies, as well as mitigation and adaptation measures will affect how these impacts play out. A world-wide appreciation that these issues are integrated, along with a much needed focus on innovation that cuts across traditional disciplinary boundaries is now emerging.

2.6. Air Quality and Health Regulation: Waterberg Bojanala

In June 2012 the Department of Environmental Affairs (DEA) declared the Waterberg and Bojanala District Municipalities collectively the "Waterberg Bojanala Priority Area (WBPA)" making it South Africa's third "National Priority Area". This priority area status moves policy control of the area from Provincial to National government (DEA 2012). The priority area covers district municipalities in two provinces, to include nine local municipalities (Figure 3). Topographically, the area which consists of the Waterberg Mountains and Plateau, the Limpopo Depression, the Pilansberg, Magaliesberg and Bushveld Basin and the Merensky Reef; varies between approximately 1000 and 2100m (Moodley *et al.* 2014).

The declaration of the WBPA was based, primarily, on concerns over declining air quality from a myriad of current and proposed future activities in the region, as well as trans-boundary air pollution impacts from South Africa's neighbour, Botswana (DEA 2012). "The premise is precautionary where air quality may become degraded, especially in the Waterberg District Municipality", which contains 40% of national coal reserves and 70% of Limpopo's platinum (Moodley *et al.* 2014). Following on from this, South African Minister of Water and Environmental

affairs, Bomo Edna Edith Molewa, has stated that the area requires specific national air quality management action to ensure that air pollution levels remain within the national ambient air quality standards (DEA 2012). The emphasis of this declaration is on air quality.

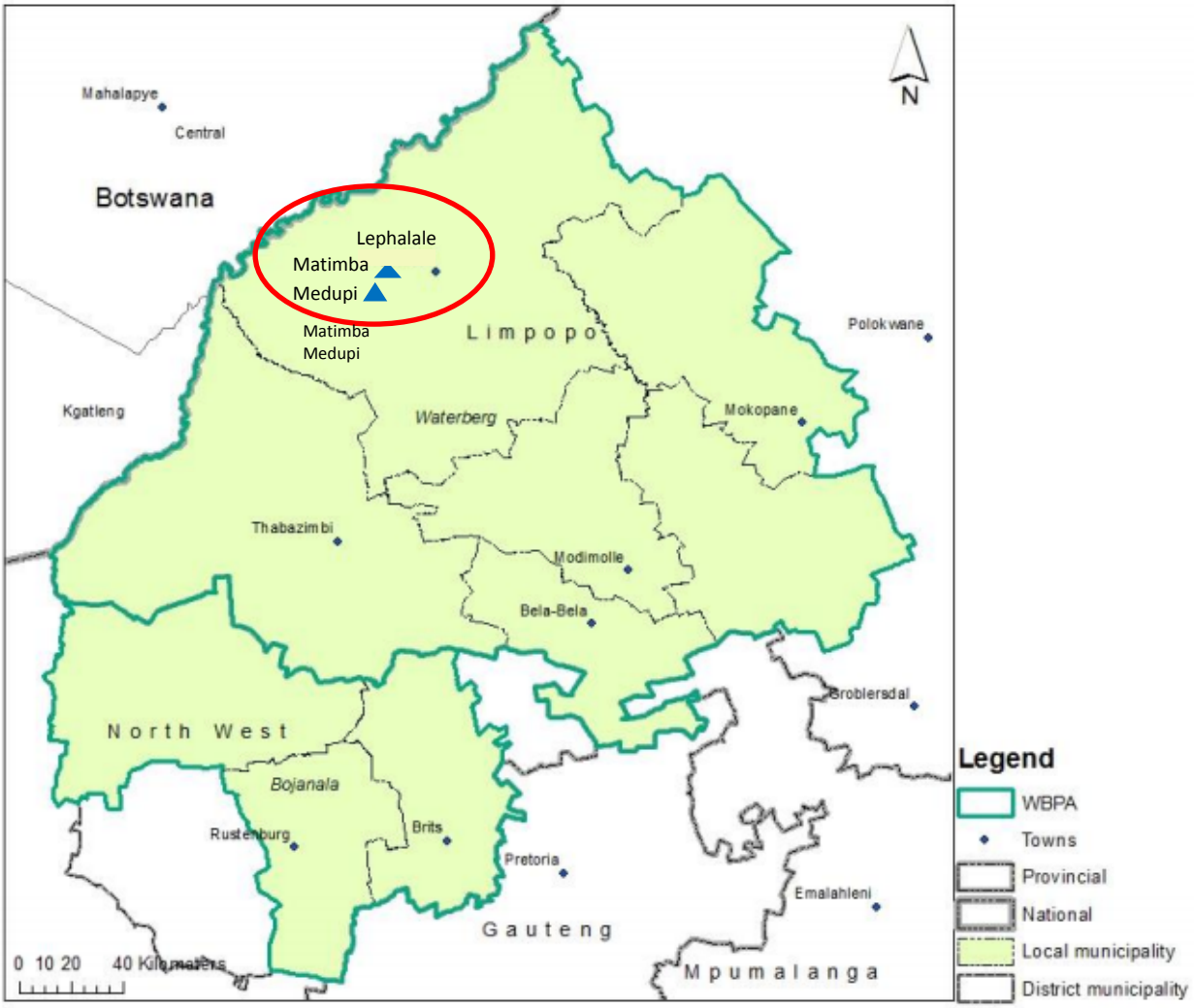


Figure 3. Political demarcation of the Waterberg Bojanala Priority Area (WBPA) includes the Waterberg District Municipality consisting of Thabazimbi, Modimolle, Mogalakwena, Bela-Bela, Mookgopong and Lephalale in Limpopo Province and the Bojanala Platinum District Municipality consisting of Moses Kotane, Rustenburg and Madibeng in the North West Province (DEA 2012). This study focuses on the region around the Town of Lephalale (demarcated in red), wherein Eskom's Matimba and Medupi coal-power stations (blue triangles) as well as a number of human settlements occur. (Adapted from Moodley *et al.* 2014).

In response to this declaration, the Department of Environmental Affairs (DEA) has commissioned the development of the "Waterberg Bojanala Priority Area Air Quality Management Plan (WBPA AQMP)" to an environmental consultancy, uMoya-nilu. The WBPA AQMP aims to cover emissions inventories, air quality management capacity assessments, ambient air quality information, dispersion modelling results and a threat assessment of the Waterberg-Bojanala region projecting into the future (Moodley *et al.* 2014).

In order to predict how emissions will affect the air quality of the region, the climatology and atmospheric transport patterns must be known. Climatology is determined mainly by a place's latitude, which controls the amount of solar radiation it receives, its relative position from the sea and its height above sea level. The general circulation of the atmosphere, perturbations from that mean, the nature of the underlying surface, vegetation cover and orientation relative to topographical features are secondary features determining climatology (*ibid* 2014).

According to the WBPA AQMP, the WBPA lies between latitudes 22º 16' S and 26º 05' S in the central interior of Southern Africa and is bordered on the north-western side by the Limpopo River where the altitude varies between 800 m and 900 m above sea level, increasing to between 1 100 m and 1 300 m above sea level in the east. The mean circulation of the atmosphere over southern Africa is dominated by high pressure systems (anticyclones) which make up semi-permanent sub-tropical high-pressure cells throughout the year (Tyson and Preston-Whyte 2012). The frequency of occurrence of anticyclones reaches a maximum over the interior plateau in the winter months with the minimum in summer (Moodley *et al.* 2014).

The predominant winds in Lephalale blow from the north east (Feig 2010). The region experiences summer rainfall with an annual average of 350 to 400 mm. During summer time average sunshine duration is 65%, and the temperature averages around 32 ºC (Lephalale Local Municipality Integrated Development Plan 2012 – 2013).

Little material has been published on atmospheric transport into and out of the Waterberg but it is known that most air is transported off of the Southern African subcontinent into the southwest

Indian Ocean (Tyson *et al.*1996). An 8-year trajectory climatology conducted by Freiman and Piketh (2003) verifies and advances such observations in the lower troposphere, further indicating that over a third of the air from the industrial heartland of South Africa is re-circulated over the subcontinent (Figure 4). The main pathways out of the Highveld observed in this research are transport to the Atlantic Ocean (14%), the South Indian Ocean (6%), the Indian Ocean (39%), equatorial Africa (8%) and the re-circulated transport (33%). The re-circulated transport moves over the subcontinent towards the point of its origin, on a regional or sub-continental scale.

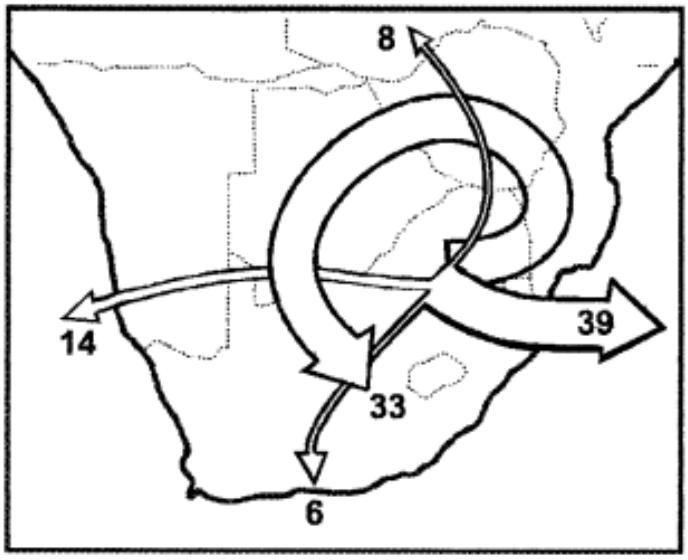


Figure 4. An eight-year transport trajectory showing 95% of the trajectories exiting the Highveld region at 800-700 hPa. The transport paths are drawn in approximate proportion to the percentage of transport occurring (Freiman and Piketh 2003).

The ambient air quality in the WBPA will be affected by air transport of pollutants both in and out of the region. Atmospheric transport to the Waterberg could occur directly as it move towards the Atlantic Ocean mode or via the recirculation mode. The air might also pass over other sources areas (such as Johannesburg) and accumulate pollutants (Moodley *et al.* 2014).

Atmospheric transport out of the WBPA can happen through dispersion. The WBPA Air Quality Management Plan states that the dispersion potential of the Waterberg is expected to be relatively good during the day in both winter and summer as days are hot and windy. Dispersion potential will, however, be better in summer because summer rainfall is an important removal mechanism for air pollutants, thermal mixing is stronger and night-time temperature inversions are weaker and less persistent. There is also a higher frequency of stronger winds in summer than in winter, resulting in higher ambient air pollution concentrations expected in winter than in the summer (Moodley *et al.* 2014).

Thus far, emission estimations were made for listed industrial activities, residential fuel burning, mining, biomass burning and motor vehicles in both district municipalities. Fourteen ambient air quality stations have been set up within the WBPA, four of which are currently in operation within the Waterberg District Municipality (*ibid* 2014). Dispersion modelling of SO_2, NO_X and PM_{10} was undertaken using CALPUFF for Lephalale and Botswana, as well as the Rustenburg Platinum Belt at 1km spacing (*ibid* 2014).

What has however, been lacking from government discourse, is the study of the impacts that declining air quality will have on the surrounding ecosystems. Operation of the Medupi power station will, for example, add to the sulfur and nitrogen oxides being emitted into the atmosphere of the WBPA; which will affect air quality, and have impacts that may be positive or negative. In order to compile an Air Quality Management Plan, these impacts must be assessed by being compared to baseline values. Baseline data of the social, physical and biological components of the area expected to be impacted should therefore be collected prior to emissions from additional developments such as Medupi. Baseline data covering a range of environmental factors in the Waterberg consequently being collected by various parties will be expanded on in section 2.8.

2.7. Background into latest National Priority Area

The Lephalale region in the Waterberg District Municipality is an important area in which air quality issues could play out in various ways. The area is host to Eskom's Matimba power station (3990 MW capacity), Eskom's newly built Medupi coal-fired power station (which is not yet operational and will be a projected 4800 MW), and Exxaro's Grootgeluk coal mine which will supply coal to both Medupi and Matimba. Medupi will be the largest dry-cooled coal power station (and third largest coal power station) in the world (Eskom 2012). Eskom's CEO, Brian Dames (2012), has stated that the new capacity from Medupi will relieve constraints on the power supply, enabling higher rates of economic growth. Dames also listed local job creation and skills development as being amongst the benefits of the development (*ibid* 2012).

At the same time, there will also be impacts on environmental and human health. Emissions from Medupi and related Eskom expansions will introduce significant amounts of nitrogen and sulfur oxides; affecting air quality and contributing to acid deposition and the disruption of ecosystem services. Two more colossal coal-fired power stations, of 5400 MW each, referred to as Coal 3 and Coal 4, have been proposed to be placed within the municipality, approximately 40 km west of Lephalale town and other developments in the region are being considered by Transnet, Exxaro and Sasol.

Short-term air quality limits for SO_2 , NO_2 and PM_{10} in the area were found to be exceeded from emissions before the operation of Medupi, yet the environmental authorisation of the Medupi Power Station was issued with the condition that both Medupi and Matimba need only be fitted with SO_x abatement technology "if monitoring in populated areas at a later stage indicates non-compliance with South African ambient air quality standards" (Corbett *et al.* 2008). This Environmental Impact Assessment mitigation measure is not adequate, and it is unclear whether it will be enforced since air quality was already exceeding those standards at certain times without emissions from the Medupi Power Station, and there has, to date, been no confirmation of Eskom incorporating SO_x abatement technology at Medupi. In addition to this, the abatement technology would only decrease sulfur

emissions. Other air quality indicators such as predicted PM_{10} concentrations were also found to exceed the South African National Standards (SANS) and European Union limit values in the vicinity.

The predominant winds in the area blow from the north east (Figure 4). As a result of predominant winds the estimated annual SO_2 concentrations, originating from the emissions of Medupi and Matimba have been projected to be highest in the "green" area south west of the power stations (as shown in Figure 4 overleaf). The atmospheric chemistry reaction rates of the wide range of nitrogen species are slower than those of sulfur, and therefore the major zones of nitrogen deposition may be further to the south west along the same axis (Moodley *et al.* 2014).

The formal human settlement marked as Onverwacht on Figure 6, is part of the former town of Ellisras, recently renamed Lephalale Town, and is situated south east of the power stations. Another settlement, Marapong, is located less than two kilometers upwind of Matimba and approximately eight kilometers upwind of Medupi (Figure 6). Marapong currently consists of a mixture of planned and informal areas, so while some segments of the Marapong community have access to electricity, sewage, and other services; others do not. Growth of Marapong is rapidly occurring, which corresponds to the economic growth and development of the region in general (Dames 2012). This growth is, however, often informal, and as such is not accompanied by infrastructure. Factors other than industrial emissions that contribute to declining air quality in the area include fuel wood burning, refuse burning and vehicle emissions. Sulfur dioxide concentrations for both the Marapong and Ellisras/Onverwacht settlements were projected at 1µg/m^3 (Figure 5). Ambient air quality monitoring has however more recently shown that while this estimate may be accurate for Lephalale town, Marapong has a much higher annual average SO_2 concentration at 9.8 µg/m^3 (Table 2).

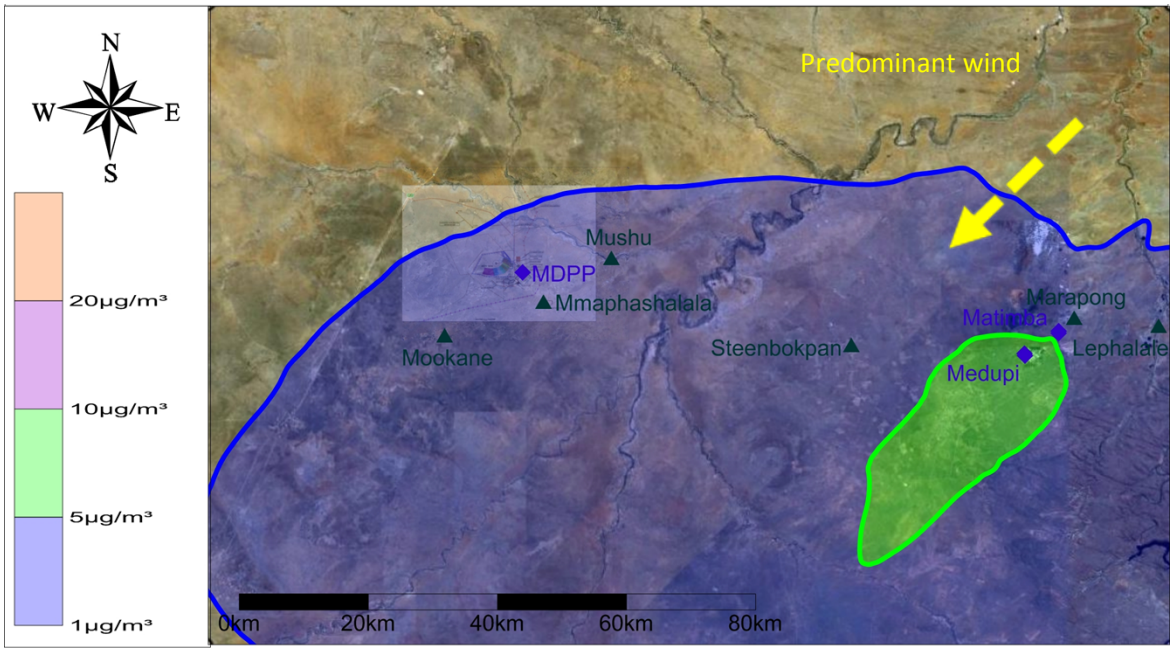


Figure 5. Annual SO_2 concentration predicted in the Waterberg area as a result of the emissions of Medupi and Matimba. The different colour shading denotes how heavily impacted the area is expected to be, is based on the fact that predominant winds blow from the North East, as indicated by the yellow arrow. The "green" area South West of Matimba Power station is expected to be most heavily impacted. (Feig 2010).



Figure 6. Satellite image of the study area with predicted SO_2 concentrations superimposed. The location of the Matimba and Medupi Power Stations; the Grootgeluk coal mine and the Marapong and Onverwacht (part of the current day Lephalale town) human settlements, are all labeled respectively. Sulfur dioxide concentrations for both the Marapong and Onverwacht settlements are projected at 1µg/m^3 (Adapted from Google Earth 2012).

Table 2. Ambient air quality monitoring showing annual averages of various pollutants as measured at the Marapong and Lephalale continuous monitoring stations, as well as National Ambient Air Quality Standards (NAAQS) (Moodley *et al.* 2014). The annual average of sulfur dioxide at Marapong is almost ten times that of Lephalale town, and the average PM_{10} concentration of 88.7µg/m^3 in Marapong is shown to exceed the NAAQS value of 50µg/m^3.

Annual average (µg/m^3)	SO_2	NO_2	PM_{10}	$PM_{2.5}$
Marapong	9.8	12.5	88.7	37.7
Lephalale	1.0	8.8	25.5	7.5
NAAQS	50	40	50	65

2.8. Previous and Current Impact Studies in the Waterberg

In response to the need to understand impacts, many researchers have started projects in the region, and the intention is for there to be a designated research transect across which data should be collected by all parties. Researchers in various fields have therefore been working towards an integrated research platform, with the overall objective of establishing an environmental baseline assessment and long-term monitoring sites to evaluate the impact of the expanding industrial activity in the Waterberg region. Scientists from Wits University, North West University and the CSIR held an integrated research project meeting, together with Eskom representatives on 27 May 2013 (Sasol and the Department of Environmental Affairs were invited but did not attend). The aim of the meeting was the establishment of a transect of monitoring sites to suit a wide range of monitoring, from which to evaluate the upwind and downwind impact from the increased industrial activity around Lephalale. The four thematic areas of investigation under consideration were the hydrosphere, biosphere, atmosphere and anthroposphere.

A biosphere study, entitled "Baseline data (soils, lichens and EIAs) needed to measure impacts of Eskom's Medupi Power Station in the Waterberg Priority Area", has been completed to date. The study was conducted in 2012 at the University of Witwatersrand, by Adela Itzkin, under the supervision of Professor Mary Scholes. The overall objective of the study was the collection of environmental baseline data on lichens and soils, both upwind and downwind of the Matimba and

Medupi power stations, as well as a compilation of data from EIAs, which could be used to develop mitigation strategies, and for post-installation comparisons. Findings included that for all soil properties measured, data showed that element contents were higher upwind than downwind (Mann-Whitney tests $p<0.001$). Neither texture, nor organic content correlated strongly to sulfur (S) and nitrogen (N) and so deposition was considered as a possible explanatory factor for S and N content. The carbon to nitrogen ratio upwind of 7.8:1 fitted the expected ratio of between 8:1 and 15:1, but the downwind ratio 2.4:1 indicated increased nitrogen. The upwind site had a greater foliose lichen diversity. Overall, the data indicated that the downwind site is already impacted by emissions, with the upwind site also possibly showing signs of impacts. EIA documents revealed that, prior to the operation of Medupi, short term SO_2 limits in the area were exceeded on several occasions.

Within the research platform, two on-going atmosphere projects, one hydrosphere project, two biosphere projects, and this anthroposphere project, are all currently being conducted along the proposed transect line.

2.9. Eskom Marapong Air Quality Perceptions Study: findings, limitations, point of comparison

In 2009, Eskom commissioned a questionnaire to determine the socio-economic status of the residents of Marapong and to identify air quality perceptions (Warnier *et al.* 2009). A thousand households were questioned regarding demographic profile, overall health, energy usage and impressions regarding air quality. A separate survey was used to interview a group of 40 teachers. This represented an 'educated component of the community', whose responses could then be compared with those of the general population. The main findings of this study are outlined below:

Income and Skills:

In 586 of households interviewed (60%), it was reported that none of the household members are employed. Thirty per cent of the interviewees stated an average monthly household income of between R500 and R1400, followed by a group of 28% earning between R1400 and R2499 a month,

and 22% fitting themselves into the above R4000 a month bracket. None of the teachers thought their student's parents earn on average more than R4000 a month. A suggested explanation of the elevated reporting of income by residents was the inclusion of monthly government child grants and pensions. Most interviewees categorised themselves as unskilled, with an average of 37.5% of the households interviewed listing themselves as semi-skilled and 8% as having achieved a higher level of education.

Energy usage:

Around 56% of the Marapong residents were shown to have access to electricity. For residents with electricity, that is the energy source most used for lighting and cooking. Paraffin is most often used for heating. Almost 30% of the residents that have electricity pay over R250 a month, and about 20% pay between R100 and R150 a month for this utility.

Health:

To be able to compare the respondent's answers to the questions on air quality, their understanding of what air quality is had to be established. Resident's answers such as 'the goodness of air' 'the freshness of air' and a lack of smells in the air led Wanier and others (2009) to the conclusion that the respondents were not able to express well what air quality is. When teachers were asked the same question they referred to the level of pollution in the air and the health effects related to this poor air quality illustrating a deeper understanding of the issue. When asked what the air quality was like in Marapong, almost 48% of the residents responded that it was excellent and 33% consider the quality of the air to be good. Only 20% thought it to be poor to fair. However, the same question asked to the teachers in Marapong provides a totally different image of the air quality with 84% placing air quality in the poor to fair bracket, and only 3% placing it as excellent. The predominant cause of poor air quality was listed by residents as the power station (28%), fumes from the mines (2%) and fumes from the coal (domestic fuel burning) (9%) and sources resulting in bad smells (19%). Only 12% of the Marapong residents believe that the making of electricity in the area has an effect on the air quality in Marapong. This indicates a potential lack of understanding of the links between power generation and air pollution. Without this understanding, the further link to health impacts cannot be made. The predominant cause of poor air quality listed from the teachers indicated a similar source grouping with the power station (42%) listed as the main reason for poor air quality

in the region. Other sources of concern were the coal mine (21%), dusty roads (8%), and domestic fuel burning (8%). About 40% of teachers reported to have noticed health problems (coughing, eye problems and occasionally lung and breathing problems and headaches) apparently related to the use of paraffin at home.

The residents and the teachers of Marapong have contrasting views on the effect that power station fumes have on health. A large majority of the residents, namely 87%, do not think the fumes affect their health, compared to 26% of the teachers. When asked why, the teachers responded that the smoke that is released by the power station stays in the air and this leads to poor air quality which as a result causes many lung problems for the students. Responses around the time of year that sickness occurred was also disparate between residents, who reported no seasonality in occurrence of illness and teachers, who reported that 77% of their students get sick in winter.

The largest age group of ill people is between 41 and 50 years. The second highest incidence of illness was seen to occur in adults between 31 and 41 years. This may also be an indication of the impacts HIV/AIDS may be having on the community with these economically mobile individuals being highly susceptible to this type of infection. Once their immunity is compromised this will result in them being more at risk to infection. The age of ill people differs from expectation created in other studies (SCHER 2007) of very old and very young being most vulnerable.

Suggestions for Addressing the Issue of Poor Air Quality:

Limiting fumes from power stations was the most common suggestion coming from teachers (41.7%) and second most common from residents (26.9%). Increasing the distance between the village and the power station was the most prevalent suggestion among residents (41.8%) and second most prevalent suggestion from teachers (11.1%). Teachers presented a number of suggestions that did not feature in residents responses to this question, such as: Building tarred roads (8.3%), checking health and offering treatment (8.3%), providing everyone with electricity (8.3%) and educating people around this issue (5.6%).

The 2009 Warnier study can be used to provide a baseline of conditions and health perceptions in the Marapong settlement only. It is noteworthy that the study was conducted for Eskom. The question of ethical clearance is also unknown.

2.10. Linking perceptions and "real" air quality, taking into account socio-economic status and other factors

It is worth noting that the 2009 Eskom study includes air quality and health perceptions. Hunter and others (2003) suggest that conducting health studies that focus on the measurement of specific pollutants or mixes of pollutants alone has the risk of missing out on an important aspect of disease aetiology, that of personal and community belief about the quality of their environment and the risks this may pose to their health. This notion is reinforced by the fact that many respiratory illnesses have been found to have their causation totally or in part in psychological factors including beliefs about illness (Butani and O'Connell 1997, Muncer *et al.* 2001). Butani and O' Connell's (1997) study indicated that effective treatment of respiratory symptoms should be directed toward underlying stressors, which can include perceptions and source of these perceptions. They go on to outline that possible psychogenic stressors must be inquired into and, when identified, treated in a multidisciplinary manner (*ibid* 1997). It is also worth stating, that self-reported illness should not be viewed as necessarily being less valid than formally diagnosed illness, because for someone to report symptoms they must believe themselves to have suffered from those symptoms, and Hunter *et al.* (2003) argue that such beliefs are valid. Despite this, few studies have sought to link illness to subjective perceptions of environmental pollution. Even Eskom's 2009 study, which includes perceptions, does not attempt to link these perceptions to actual air quality. Making these links can fit into a conceptual model linking beliefs, perceptions, pollution and ill health (Figure 7 overleaf).

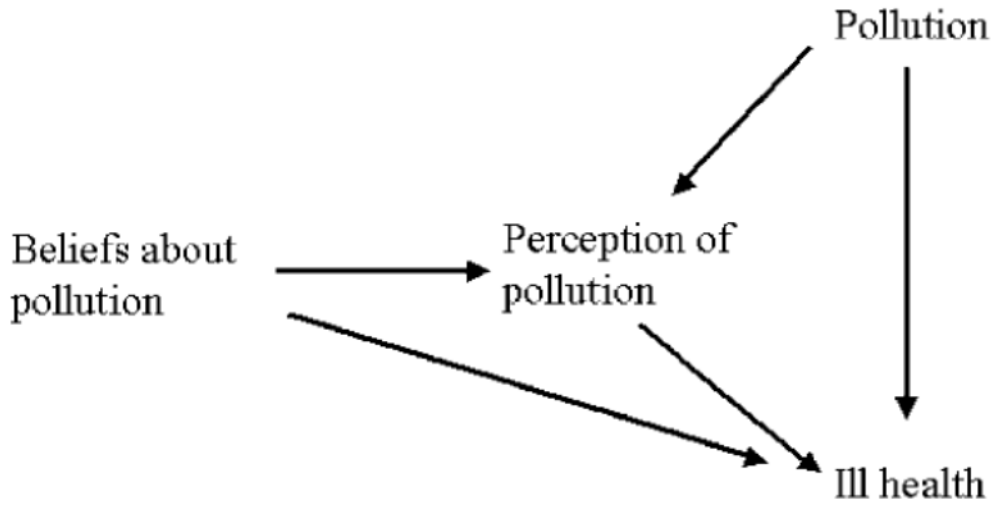


Figure 7. Conceptual Model of the relationship between air pollution and self-reported respiratory illness (Hunter *et al.* 2003).

Education and understanding around issues of air quality and health can influence perceptions. The results from surveys related to air quality and human health among a low income community in the Highveld Priority Area indicate that 77% of households perceived their health to be good (Wright *et al.* 2011). This corroborates the results of a previous study in which 90% of respondents considered the health of family members living in their household to be good (John *et al.* 2008). A qualitative evaluation using focus group discussions among an intervention and a control group was conducted by Barnes (2010). The intervention group was given an educational presentation, as well as follow-up door-to-door visits. Post-intervention discussions with the two groups illustrated a noticeable improvement in health understanding among caregivers in the intervention group, highlighting the role of education in shifting perceptions in this field.

In order to achieve a better understanding of the dynamics of the Waterberg region as well as sets of scenarios that could inform decision making processes at different levels, the differences between communities with various sets of socio-economic conditions in the region must be known. There is the need for a study that links air quality, socio-economic standing, perceptions, health, policy and governance; to allow for adaptive management that will pave the way for a positive future for the Waterberg.

2.11. Modes of Intervention at the Local Scale

If air quality standards are not adhered to, other forms of intervention to reduce the negative impacts of air pollution on human health would need to be implemented. A study reviewing an international multi-disciplinary workshop on air quality management found that regulatory interventions are essential in reducing exposure to pollutant levels and, consequently, health impacts (Giles *et al.* 2011). The study indicates that to complement progress made through regulation (or compensate for a lack thereof), interventions implemented at the community and individual levels should also be given attention.

Current large scale data collection efforts are largely disconnected from smaller-scale studies in health sciences. There is, however, a largely separate body of literature investigating the technical as well as behavioural and socio-economic factors that influence air pollutant exposure (Ezzati *et al.* 2005, Barnes, Mathee and Thomas 2011 and Giles *et al.* 2011). Some studies, such as Mehta and Shahpar's (2004) paper evaluating the health benefits of interventions to reduce indoor air pollution in South and South-east Asia, Africa, and the Americas, consider cost-effectiveness. Wisham (2011), writing on mitigating interventions of air pollutants in North America, argues that cities can improve residents' health by considering air quality during land-use planning. In developing countries, a special focus is placed on mitigating the effects of indoor pollution. Efforts in this regard can be technical, ranging from access to cleaner burning fuels and the use of improved cook stoves to the modification of housing characteristic, or behavioural ranging from improved understanding of air pollution, to cooking outside and avoidance of exposure to fumes. A study conducted by Barnes (2010) emphasized improved perceptions and understanding of health as one of the motivators for caregivers to protect their children from indoor air pollution exposure, and a community counselling study conducted by Barnes and others (2011) in the rural North-West Province of South Africa provides evidence to suggests that a health behaviour change is associated with reductions in child indoor air pollution exposure. Furthermore, behavioural change as an intervention is relatively inexpensive and easy to replicate.

2.12. Scenarios

The United Nations Environmental Programme (UNEP 2002) defines scenarios as "plausible accounts of future events against which one can test ideas, or check assumptions." Scenarios can be used as a tool to identify possible consequences in a set of each of the diverse courses of action or inaction. In this way scenarios can be used as a tool to identify the best possible modes of intervention. The scenarios working group of the Millennium Assessment considered four global scenarios (namely: Global Orchestration, Order from Strength, Adapting Mosaic and Techno-Garden), in order to identify pathways that would minimize vulnerability of societal and environmental systems to unfavourable events, and enhance their resilience. Human well-being and ecosystem services were shown to vary substantially over these four scenarios, which differ according to their evolution of policies, ecosystem services, and institutions (Butler and Oluoch-Kosura 2006). Human well-being was found to be highest in the Global Orchestration scenario, which assumes the fastest evolution of beneficial institutions, and lowest in the Order from Strength scenario, which assumes that the world fragments into regional markets and alliances and most categories of ecosystem services, especially those in developing countries, decline (*ibid* 2006). Human well-being was found to be intermediate in the other two scenarios (Adapting Mosaic and Techno-Garden) even though these scenarios share a much greater recognition of the importance of ecosystem services to human well-being.

Scenarios are a useful tool in which evidence based information can be utilized in order to set out plausible outcomes and to inform decision-making processes. It is, however, important to remember that insufficient information on both the current state of a system and on forces governing its dynamics, lead to inevitable uncertainties over possible future states (Amann *et al.* 2004). There is also the possibility that surprises and extreme occurrences may change the outlook. Furthermore, the future is unpredictable because it is subject to human choices that have not yet been made, which does negate the value of scenario forecasting, to some extent.

Table 3. Human well-being varies substantially over these four global scenarios considered in the Millennium Ecosystem Assessment (Butler and Oluoch-Kosura 2006).

Global Orchestration	Free trade and a good heart reign in this scenario. There is a determined effort to fight poverty and inequality. As a result, there is a huge boost in food and other provisioning services in developing countries. However, the general approach to ecosystem services is reactive, rather than preventative. The costs are borne by regulating services—such as climate change—and a loss in cultural services.
Order from Strength	The world fragments into regional markets and alliances. Nations are obsessed with security issues, and the tragedy of the commons deepens. Most categories of ecosystem services decline, especially in developing countries.
Techno-Garden	This is a globally connected world, with abundant green technology, and a focus on preventing ecosystem problems. Food and other provisions increase, although they are not maximized. Climate change, floods, and disease are of less concern. Biodiversity continues to decline.
Adapting Mosaic	The emphasis here is on local solutions. Regional politicians and institutions focus on watershed-scale ecosystems to maximize benefits and prevent problems. If it catches on widely, it pays off. Every type of ecosystem service improves in both developing and industrialized nations.

Other than the Adapting Mosaic scenario, which broadly considers local solutions (Table 3); the Millennium Assessment scenarios are all top down, statist approaches. In contrast to this, in all the historical air pollution hot spots of South Africa (the Durban Industry Basin, Secunda in the Highveld and Zamdela district of the Vaal triangle), community led bottom-up protests and air-pollution campaigns have played a major role in prompting industries and government to take action to reduce air pollution emissions (Wright, Garland and Thambiran 2011). Questions that should, perhaps, therefore be asked when developing scenarios in this field are: whether the political environment allows for protest, whether the population is educated, and what other factors might take priority over air quality concerns; for example poor communities may be more concerned over wages, as these pose a more tangible and immediate threat to survival.

A case study of the scenario analysis approach being designed to incorporate, inform and drive legislation is the Baseline Scenarios for the Clean Air for Europe (CAFE) Programme commissioned by the European Commission in 2004 (Amann *et al.* 2004). The scenarios in this study were set out to take into account the impacts of the presently decided legislation on emission controls,

and to explore the necessity, scope and cost-effectiveness of further action to achieve the long-term environmental policy objectives for air quality of the European Union. The CAFE program recognizes the inherent uncertainties in the predictions of some of the drivers that influence future emissions (such as economic development, energy prices and policy preferences), and thus incorporates a variety of baseline projections that reflects a plausible range of future development. All CAFE scenarios assume full implementation of all source-related emission legislation of the European Union. The policy debate that follows the scenario and modelling exercises then focuses on environmental targets that lead to further improvements of air quality and will explore the implications of alternative baseline projections on achieving these targets (*ibid* 2004). Once scenarios with different emissions levels and standards were set out, they were inserted into a model to identify sets of emission control measures that could efficiently lead to further improvements of European air quality.

2.13. Concepts: Vulnerability, Resilience, Adaptation and Mitigation

Within scenarios, the appropriate targeting of interventions requires an understanding of the demographic or geographical subpopulations most at risk, the factors that contribute to their vulnerability, and factors that potentially may be modified within the context of a particular time and setting. Individuals and communities that cannot or will not adapt are most vulnerable; and individual, community and geographical factors determine vulnerability (MA 2005). Some population subgroups may not have the resilience to adapt because of a lack of material resources, relevant information, and public health infrastructure, as well as a lack of effective governance and civil institutions. Resilience refers to the ability to absorb disturbances, to be changed and then to re-organise and still retain the same basic structure and ways of functioning (Resilience Alliance 2002). The resilience perspective is increasingly used as an approach for understanding the dynamics of social–ecological systems (Allen and Holling 2010, Folke 2006, Folke *et al.* 2010). Attempts to integrate the social dimension are

currently taking place in resilience work, and scenario building is being utilized as a tool in this process of setting out pathways of adaptive governance that allow for management of essential ecosystem services in such a manner so as to increase social and environmental resilience (Folke 2006). Once the current state of vulnerability and the capacity for future adaptation of populations, subgroups and systems have been assessed, scenarios can be set out. Two possible courses of action to avoid disease caused by ecosystem disruption are mitigation and adaptation. The one avenue, mitigation strategies, involves the prevention, limitation, or management of environmental damage. The second course of action, adaptation strategies, involves making necessary changes to protect individuals and populations from the consequences of ecosystem change (MA 2005).

2.14. Working definitions

Perception: is the process by which people interpret and organise sensory impressions to produce a meaningful experience of the world. Perception is the ultimate experience of the world and although it is, by its nature based on incomplete information, perception is the lived reality and guides human behaviour in general (Linsay and Norman 1977).

Socio-economic status: Socio-economic status is an economic and sociological combined total measure of a person's work experience and of an individual's or family's economic and social position relative to others based on income, education and occupation (Cirino *et al.* 2002).

Household: According to the Oxford Online Dictionary (2014) a household consists of a house and its occupants, regarded as a unit. For the purposes of this study, the occupants living together in a unit make up a household.

Respiratory Health: Respiration refers to the act of breathing (Oxford Online Dictionary 2014). Respiration in humans is done by the chest wall, diaphragm and lungs. Health denotes the state of being free of illness or injury, and can also refer to a person's mental or physical condition (Oxford Online Dictionary 2014). Respiratory Health is thus used in this study to refer to a person's condition regarding issues related to breathing.

Chapter Three: Materials and Methods

3.1. Study Area

The area of interest for this study is located within the Lephalale Local Municipality of the Waterberg Bojanala Priority Area (WBPA). According to the 2011 Census data, the estimated population of the Municipality is 115 768 (Lephalale CBD Plan 2013). Eskom's Matimba Power Station has been operational since 1993, with Medupi being constructed a mere 6 km away (Eskom 2012). Predominant winds blow from the North East, and areas occurring downwind of emissions sources are expected to be impacted most by the emissions plume. The Lephalale Local Municipality (LM) area comprises two urban nodes, namely Lephalale/Onverwacht and Marapong; as well as the surrounding areas such as Steenbokpan (Figure 8).

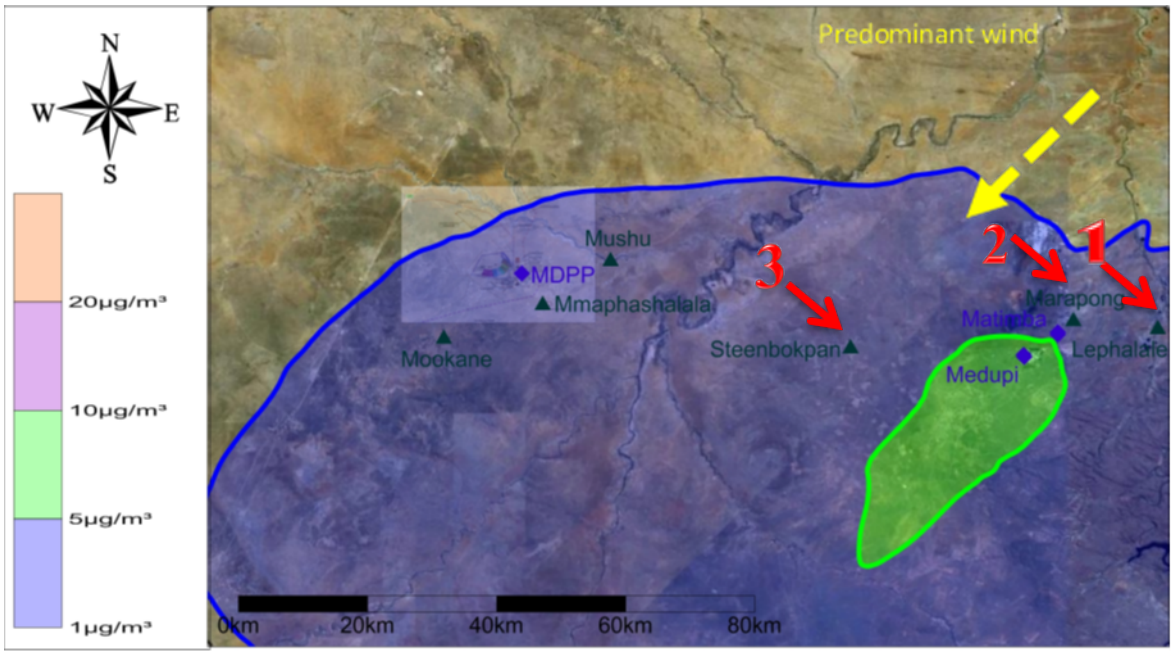


Figure 8. Satellite image of the study area. The location of the Matimba and Medupi Power Stations, and the human settlements of Lephalale (Site 1), Marapong (Site 2) and Steenbokpan (Site 3) are labeled respectively. The entire region is predicted to have an annual SO_2 concentration of at least 1µg/m^3 as a result of the emissions of Medupi and Matimba (Feig 2010).

Three human settlement areas, namely Lephalale/Onverwacht Town, Marapong Township and Leseding Location of Steenbokpan, were selected for sampling (Figure 7). The three settlements occur within 40km of the Medupi and Matimba Coal Power Stations and the Grootgeluk Coal Mine. Although the settlements occur within a similar geographic region, they have very different socio-economic characteristics. All three settlements were thus chosen to be sampled, to allow for comparisons, inter alia, on the basis of socio-economic characteristics.

3.1.1. Site 1: Lephalale Town (Formerly Ellisras and Onverwacht)

Lephalale is a coal mining town in the Limpopo province of South Africa immediately east of the Waterberg Coalfield. The town was established as Ellisras in 1960, and renamed Lephalale by the provincial government of Limpopo in 2002. As an effect of the growth of Lephalale, a previously adjoining residential suburb, formerly called Onverwacht has now been assimilated into the town (Lephalale CBD Plan 2013). The population of Lephalale Town and Onverwacht was estimated by the 2011 Census data to comprise of 13 500 residents (Statistic South Africa 2012). The town is the closest urban node to the rapidly developing coal and energy related industries in the region. Economically, the town is booming. Assis Pontes, holder of the Pam Golding Properties franchise in town, reported that before construction started in 2008, rentals were half what they are now. Pontes says that eight years ago he would rent out a normal-sized three-bed house for R3 500 per month, whereas it could now go for R14 000. Gross yields as high as 13% are the norm on a two-bed, two-bath unit and, rental agreements carry a 10% annual escalation clause (Mantshantsha 2013). Other spin off industries, such as retail, are also benefitting from this growth. In the past two years four shopping malls, tenanted by big chain stores such as Clicks, Mr Price, Checkers and Game, have opened to cash in on the influx of money, visitors and newcomers. The 32 000m² Lephalale Mall is the newest one, and is to be accompanied by 1 000 parking bays (*ibid* 2013).

3.1.2. Site 2: Marapong Township

While Lephalale is enjoying the boom times linked with the construction of Eskom's R120bn Medupi power station, Financial Mail Journalist Sikhonathi Mantshantsha (2013) says that very little money is flowing into Marapong. He points to the big Spar supermarket close to the township's hostels as the only sign of new money in Marapong. Marapong accommodates contractors from the Grootegeluk Mine and Matimba power station, and is still referred to by the pejorative term "township" which refers to an underdeveloped urban living area that, from the late 19th century until the end of Apartheid, was reserved for non-whites (Statistics South Africa 2004). The township is made up of a mixture of formal and informal areas, and only the main roads are paved. The formal part of Marapong consists mainly of government-built housing, and has basic services. The ever-expanding informal part of the township lacks basic services such as electricity, sewage and waste disposal. The 2009 study commissioned by Eskom places the number of households at 3000 households (Warnier et al. 2009), and the 2011 Census data places the population of Marapong at around 13 800 people (Lephalale CBD Plan).

3.1.3. Site 3: Leseding Location, Steenbokpan

A number of self-generated and self-regulating human settlements have 'popped up overnight' in the region. Astrid Basson, Democratic Alliance councillor for the Waterberg District Municipality, lists the 'Leseding Location' of Steenbokpan, which formed the third sampled area, as an example of such a settlement (Basson 2013). The word 'location' was also pejoratively used by the old Apartheid government to describe non-white suburbs. Settlements in Steenbokpan are currently classified as historical rural villages, but are still bi-enlarge referred to as locations (Lephalale CBD Development Plan 2013). The Leseding settlement has only been there for approximately five years (*ibid* 2013). The settlement does not have services and the area is unregulated but is estimated by the local councillor to have a population size of approximately 500 people (Basson personal communication).

3.2. Sampling Design

3.2.1 Proposal Writing and the Development of Surveys

The study area comprising of three human settlements within the Waterberg NPA, was identified and research questions related to socio-economics, air quality perceptions and self-reported health outcomes were developed.

Surveys (Appendix 1) were designed to take self-reported respiratory health perceptions and symptoms, as well as socio-economic factors into account, and to yield results that could be comparable and complimentary to a previous study commissioned by Eskom, which was only conducted in Marapong (Warnier *et al.* 2009).

The surveys were targeted at households at three sites, Lephalale, Marapong and Steenbokpan, and were translated into Afrikaans and Sepedi by the Wits Language School.

Ethical clearance was obtained from the University's ethics committee on Tuesday 13 August 2013 (Ethics clearance certificate no. H13/05/11-Appendix 2).

3.2.2. Dissemination of Surveys

The first site visit was undertaken on 14-16 August 2013. During this scoping trip, the three study sites were identified. As there are no established methods of communication or entry points into most communities included in the study, it was decided that household surveys would be sent out through schools as satellite points for their respective communities. This decision was reinforced by the fact that the study commissioned by Eskom also incorporated schools by using school-teachers as a component of their study group. It must, however, be kept in mind that the largest component of the participants in this study thus consists of households that include at least one child of school-going age. Various schools (both semi-private "Model C" schools and public rural farm schools) in each study site were identified and approached. The Department of Education's Limpopo School Program was also approached. Public and private medical institutions across an economic (wealth) and spatial

gradient within the study area were also identified, in conjunction with the Department of Health. Key stakeholders were identified and approached for interviews.

Permission was obtained from four schools in the region, consisting of two "model C" schools in Lephalale Town, one public school in Marapong Township and one farm school near the Leseding Location of Steenbokpan. Permission was also obtained from the Marapong Private Medi-Clinic and various private health care practitioners in the region. An application to include public clinics in the study, was lodged with the Department of Health.

Field work took place between 4 and 20 November 2013. During fieldwork, an excess of 200 surveys were collected, 3 focus group meetings were arranged and a number of key stakeholder interviews were undertaken. Surveys were sent home with learners at schools identified within the three target areas that made up the study site. School size was taken as a proxy for community size and a minimum of ten percent return was obtained from each school, as a representative sample of the school's community. Focus group meetings took place at schools and community centers, two of the meetings were well attended, with an excess of 50 people at Nelsonskop School in Marapong, and 18 people at Leseding Location community center. Nobody attended the focus group meeting at Bosveld Primary in Lephalale Town.

Permission to survey at public clinics was granted by the Department of Health on 13 January 2014 (Appendix 4), and a subsequent trip to the study area took place in March 2014. Surveys were disseminated to and collected from patients in the waiting rooms of various public and private healthcare institutions in the region. In this way two main sample groups, namely households and patients were collected, for each study site. A small number of staff at healthcare institutions, and teachers at schools also responded to surveys, yielding two subsets of respondents who are presumably better acquainted than the general public with the issues under discussion.

3.2.3. Collection of other information:

In order to meet Objective Three, ambient air quality data for the region were requested and received from Eskom, as well as uMoya-nilu Environmental Consultancy. Health and environmental policies and legislation were collected for review, to be presented and critically appraised with a focus on both policy itself as well as modes of implementation, as set out in Objective Four.

Many other sources of information, such as newspaper articles, government documents, environmental impact assessments, strategic development plans for the region, and key stakeholder interview findings were reviewed to be taken into account when drawing up the scenarios of future change required to meet Objective Five.

A number of meetings, courses and conferences also attended in relation to this study are listed below:

- The Environment Sector Science Policy Seminar hosted by The Department of Environmental Affairs in Pretoria, March 2013.
- "Integrated Research Platform in the Waterberg" Meeting held at Wits University, 27 May 2013.
- 1-week Masters level course run by Professor Rosemary Falcon of the Wits School of Chemical and Metallurgical Engineering entitled, "Coal and the Environment", 19-23 August 2013.
- Health and Energy Policy Roundtable hosted by the National Institute for Occupational Health, SAMA (Gauteng branch) and Groundwork, 12 September 2013.
- Waterberg Bojanala Priority Area Multi-stakeholder National Air Quality Management Plan meeting, in Modimolle, 26 June 2014.
- National Association for Clean Air (NACA) 2014 Conference, held in Umhlanga, 9-10 October 2014.
- Waterberg Bojanala Priority Area Multi-stakeholder reference group meeting, In Modimolle, 21 October 2014.

- Global Change Conference, where findings of this project were presented, Port Elizabeth, 1-5 December 2014.

3.3. Data Analyses

Data collected were designed to be compatible with a previous extensive study carried out in Marapong, to allow for comparison. Data were also constructed to be comparable with Statistics South Africa (Stats SA) Poverty lines and the Stats SA "Perceived health and other health indicators in South Africa" report which examines the perceived health status of individuals and links it to individual circumstances such as gender, age, population group, place of residence and employment status.

Data collected in order to meet Objective One were summarized by calculating averages and standard error. As data were not normally distributed, Kruskal–Wallis and Friedman's tests were used to determine whether there were differences in each outcome for the three sites. Pearson Correlations were used to reveal trends between various socio-economic properties and respiratory health perceptions at all three sites, which were then used to highlight possible relationships.

Air quality data were presented in terms of current, past and projected future temporal trends, where possible. Data collected for inclusion in the scenario building process were summarised and presented as appropriate to allow for current and future scenarios to be set out, as required by Objective Five.

3.4 Report Back

This project is aimed at informing decision making and interventions at different scales. An important aspect of this project is therefore to report findings of the study back to stakeholders including the impacted communities, different levels of government, and NGOs. Key findings of the study will thus be reported on at the Waterberg Bojanala Priority Area Multi-stakeholder reference group meetings, which a variety of stakeholders are invited to attend. These findings will also be communicated directly to uMoya-Nilu, the company commissioned with the task of compiling the Waterberg Bojanala Priority Area Air Quality Management Plan (WBPA AQMP); as well as Earthlife Africa, an NGO that is involved in community education programs in the region.

Chapter Four: Results

The results will be laid out in the following order: first, the survey results comprising of socio-economic, energy, health and air pollution perceptions analyses; followed by the findings of focus group meetings and key stakeholder interviews; and lastly, the sections placing the survey findings within the context of air quality data from ambient air quality monitoring stations, and policy and future plans for the region, as well as a description of future scenarios and projected trade-offs between development and air quality and health outcomes.

4.1 Surveys

A collation of surveys representing between eight and fourteen percent of respective student and teacher numbers at schools, and daily patient numbers at healthcare institutions were captured for analysis. A total of 91 surveys representing households in Lephalale (site 1); 62 from schools, 10 from teachers, 14 from private clinics and 4 from public clinics were analysed. A total of 106 surveys representing households in Marapong (site 2) were analyzed; 71 from schools, 8 from teachers, 10 from private clinics and 17 from public clinics. As the school and community surveyed in Steenbokpan (site 3) was much smaller, there were a total of 30 surveys representing households in Steenbokpan; 19 of which were from schools and 10 from public clinics. Only 1 Steenbokpan resident was found at a private clinic and none of the teachers of the Lerekhureng Combined School in Steenbokpan lived at the site.

4.1.1. Socio-Economic Analysis:

This section outlines the socio-economic situation of the respondents. These results aim to outline and compare the demographic profile of the residents within the various categories, with the objective of providing context/insight into the type of concerns the residents may have with respect to air quality and health at the site. A number of factors including employment, grants, education, income, family structure, medical aid, and home ownership can be used to measure a household's socio-economic status.

Gender and Age Profiles

The overall gender profile of respondents from the three sites is skewed towards female respondents, with only 35%, 27% and 31% of male respondents in Lephalale, Marapong and Steenbokpan, respectively (Figure 9). Of the ten sub-categories, seven have more female respondents, with the three exceptions being Lephalale Public Clinics, Marapong Teachers and Marapong Private Clinics (Table 4). Two of the three exceptions, namely Lephalale Public Clinics and Marapong Teachers had only four responses on the question of gender.

There were significant differences in age profile (χ^2 (4, N = 173) = 13.65, $p < 0.01$) between Lephalale and the other two sites, with more middle aged respondents in Lephalale (36-50 years), while Marapong and Steenbokpan had a higher proportion of younger respondents (18-35 years). The populations of areas with poorer socio-economics are expected to be skewed towards younger people.

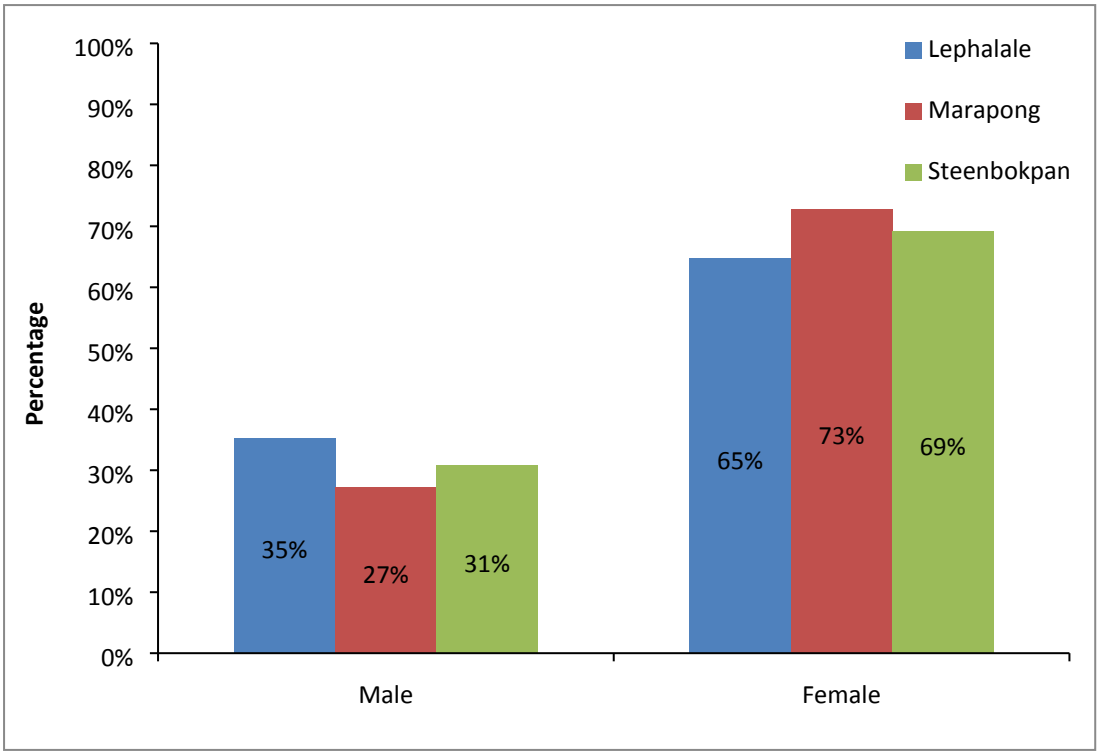


Figure 9. Percentage of male and female respondents in Lephalale, Marapong and Steenbokpan.

All ten teachers living in Lephalale are female, which is not unusual considering that teaching is traditionally a female dominated profession (Warnier 2009). The high proportion of female respondents living in Marapong (82%) and Steenbokpan (90%) who were surveyed at public clinics may be a reflection of the gynaecological, obstetric and paediatric services offered at public clinics (Table 4). It is also possible that the men in these areas who are employed in the power plant construction will receive basic first aid and health care through work clinics. It can be concluded that the females represent a larger percentage of respondents in this survey than their male counterparts, and a higher percentage than the national average of 52% (Statistics South Africa 2012).

Table 4. A comparison of the gender profiles of respondents in ten sub-categories. The number in brackets indicates the number of respondents within the relevant sub-category, who completed the gender category.

Site and Sub-category	Lephalale				Marapong				Steenbokpan	
	Schools (62)	Teachers (10)	Private Clinics (14)	Public Clinics (4)	Schools (71)	Teachers (4)	Private Clinics (10)	Public Clinics (17)	Schools (15)	Public Clinics (10)
Percentage of female respondents	62%	100%	58%	50%	80%	50%	20%	82%	53%	90%

Household Size, Employment and Grants

Households in all three sites have an average occupancy of between four and five people. Although average household size is similar across all three sites, it should be remembered that some households in an area such as Marapong may be expected to be migrant labor hostels rather than traditional family unit homes.

All sub-categories in Lephalale show average overall employment greater or equal to 1.75 people, and a low number of grants (less than one member) per household. Teachers in Lephalale have the smallest households (average size of 2.6 people) with high levels of employment (average 2.1) and are not dependent on government grants. Teachers in Marapong showed the highest number employed, at 3.25, but also represented the sub-category with the largest households with an average of 7.25 people per household (Table 5). Steenbokpan has high levels of unemployment, and it was the only site in which the number of household members receiving government grants was greater than the number of those employed.

Table 5. A comparison of the total numbers of people living in the household, people employed and people receiving grants, for households in each sub-category (Mean ± SD). Employment here refers to either full time, part time, skilled or unskilled work.

Total per Household:	**Lephalale**				**Marapong**				**Steenbokpan**	
	Schools	**Teachers**	**Private Clinics**	**Public Clinics**	**Schools**	**Teachers**	**Private Clinics**	**Public Clinics**	**Schools**	**Public Clinics**
Occupancy	4.48 ± 4.80				4.94 ± 2.60				4.17 ± 2.47	
	4.45 ± 2.31	2.6 ± 0.70	3.73 ± 1.53	4.75 ± 2.63	5.12 ± 2.05	7.25 ± 5.37	2.7 ± 0.95	4.44 ± 2.50	4.61 ± 2.95	3.3 ± 1.05
Employed	1.88 ± 0.83				1.62 ± 1.46				0.86 ± 0.92	
	1.78 ± 0.80	2.10 ± 0.57	2.13 ± 1.06	1.75 ± 1.26	1.54 ± 1.11	3.25 ± 3.41	1.90 ± 1.37	1.00 ± 0.79	0.94 ± 0.94	0.6 ± 0.84
Grants	0.24 ± 0.62				1.50 ± 1.49				1.89 ± 1.78	
	0.25 ± 0.44	0.00 ± 0.00	0.56 ± 1.13	0.67 ± 1.15	1.88 ± 1.53	0.40 ± 0.89	0.11 ± 0.33	1.33 ± 1.23	1.90 ± 2.08	2.14 ± 1.35

Income

Correlating the combined income of households in the three sites shows a moderate relationship ($r=-0.53$, $p<0.001$), with the majority of households in Steenbokpan (sixty-six percent) declaring a combined monthly income of below R1400, thirty-three percent of which report a monthly revenue of below R500 (Figure 10). Forty-five percent of households in Marapong, and eighty-four percent of those in Lephalale town, fall into the highest income bracket of greater than R4000 (Figure 8). The patterns of household income in the three sites correspond with the three sites' respective levels of employment (Table 4).

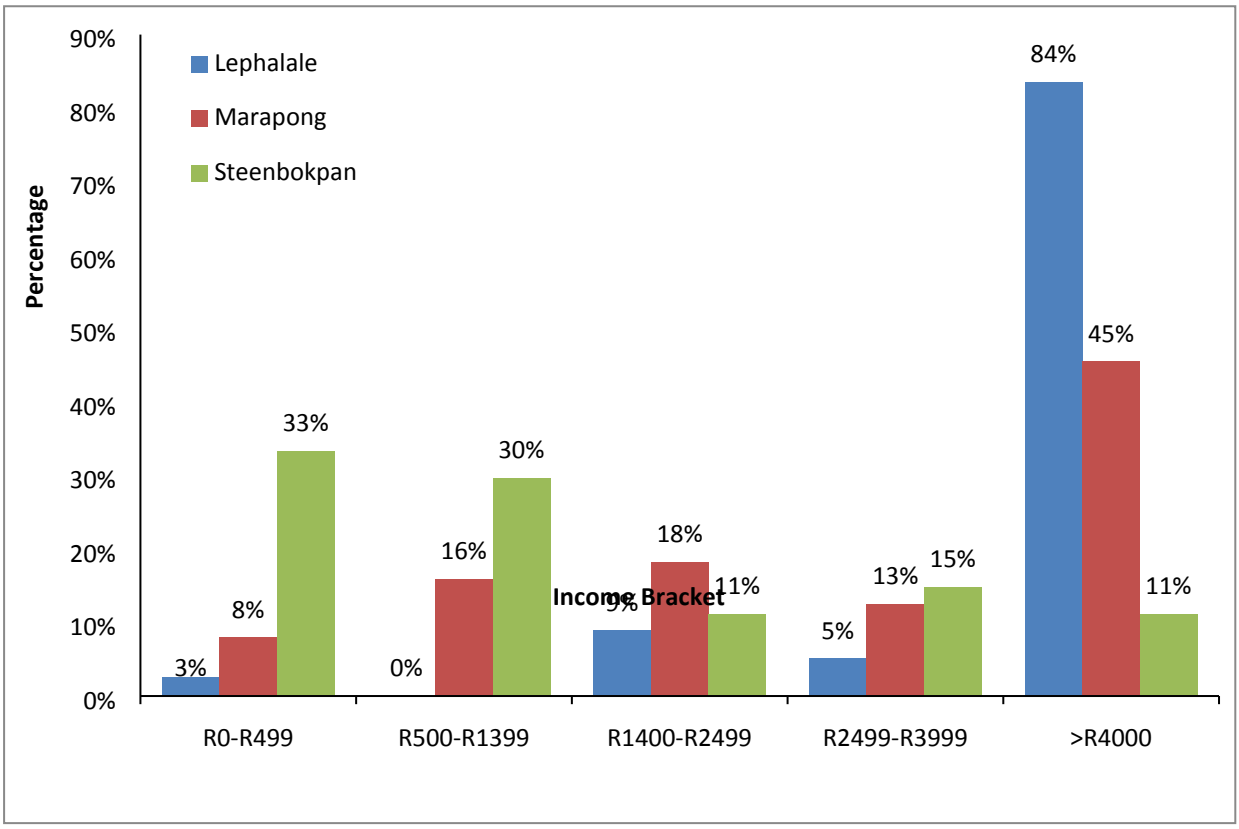


Figure 10. Percentage of households that fall within the designated combined monthly income brackets for Lephalale, Marapong and Steenbokpan.

Family Structure, Medical Aid and Home Ownership

Other socio-economic indicators also follow the same pattern with households in Lephalale having the highest proportion of household with two-parent families (χ^2 (2, N = 214) = 21.09, p < 0.001) and medical aid (χ^2 (2, N = 215) = 57.63, p < 0.001), followed by Marapong and lastly, Steenbokpan (Figure 11). Perhaps counter-intuitively, the percentage of households that rent their homes is also highest in Lephalale at 49%, followed by Marapong at 27%, with only three-percent of households surveyed in Steenbokpan renting , χ^2 (2, N = 222) = 24.65, p < 0.001 (Figure 11). This may be better understood by considering that while Lephalale town is largely made up of formal housing, with the only alternative to rental being home ownership by purchase; Marapong is a mix of formal and informal housing, and so those who do not rent could either own housing that they will have paid for, or live in informal housing. The community in Steenbokpan is, however, completely informal; with residents laying claim to plots through avenues that are not officially regulated.

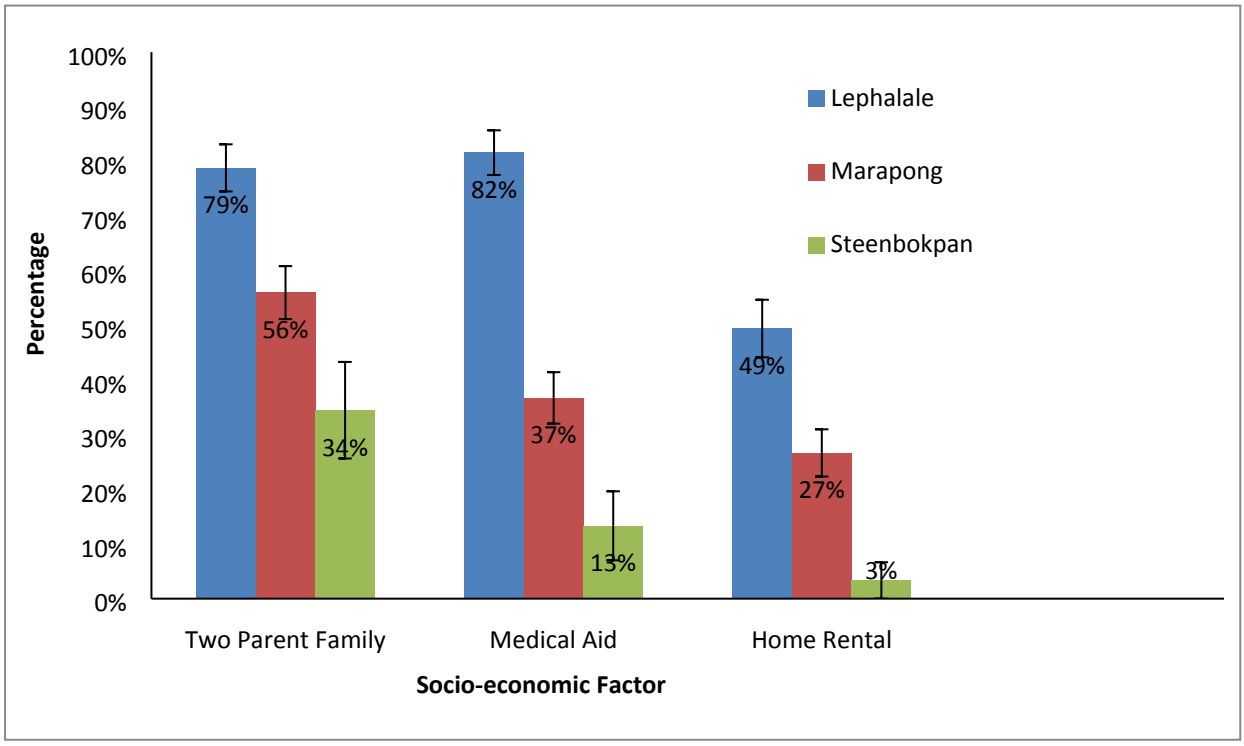


Figure 11. A comparison of the pattern of socio-economic indicators, namely two-parent family (where households with two parents present made up one category while those with a single parent or no parents made up the other), medical aid (which tested for presence versus absence of a medical aid scheme) and home rental (the alternatives of which could either be home ownership by purchase, or informal housing) between Lephalale, Marapong and Steenbokpan.

Poverty Index

The poverty index is a socio-economic indicator that is calculated by dividing the total household income by the number of people per household, in order to get a monthly income value per person. This value then corresponds to a particular poverty line. There are several national poverty lines used in South Africa such as the food poverty line, and the lower-bound and upper-bound poverty lines which include food and non-food items. The Rand values attached to each poverty line in 2011 are as follows: the food poverty line of R321 per person per month refers to the amount of money that an individual will need to consume the required energy intake, the lower-bound poverty line of R443 per person per month refers to the food poverty line plus the average amount derived from non-food items of households whose total expenditure is equal to the poverty line and the upper-bound poverty line of R620 per person per month refers to the food poverty line plus a higher amount derived from non-food items of households whose total food expenditure is equal to the food poverty line (Statistics South Africa 2014).

The poverty index for Lephalale, Marapong and Steenbokpan follow the same pattern as other socio-economic indicators, with Steenbokpan having the highest proportion of people below the food poverty line, and Lephalale having the highest proportion of those above the upper bound poverty line (Figure 11). Chi squared tests indicate that these differences in poverty levels between the three sites are significant, χ^2 (6, N = 190) = 55.40, $p < 0.001$.

Upon comparison with the 2011 national figures of about 20% of the population living below the food poverty line of R321 per person per month, the 40% of Marapong residents and 73.1% of Steenbokpan residents living below the food poverty line, gives a strong indication that these sites have elevated poverty levels (Statistics South Africa 2014). Lephalale, in contrast, has low levels of poverty with only 7.6% living below the food poverty line, and 78.5% living above the upper-bound poverty level (Figure 12).

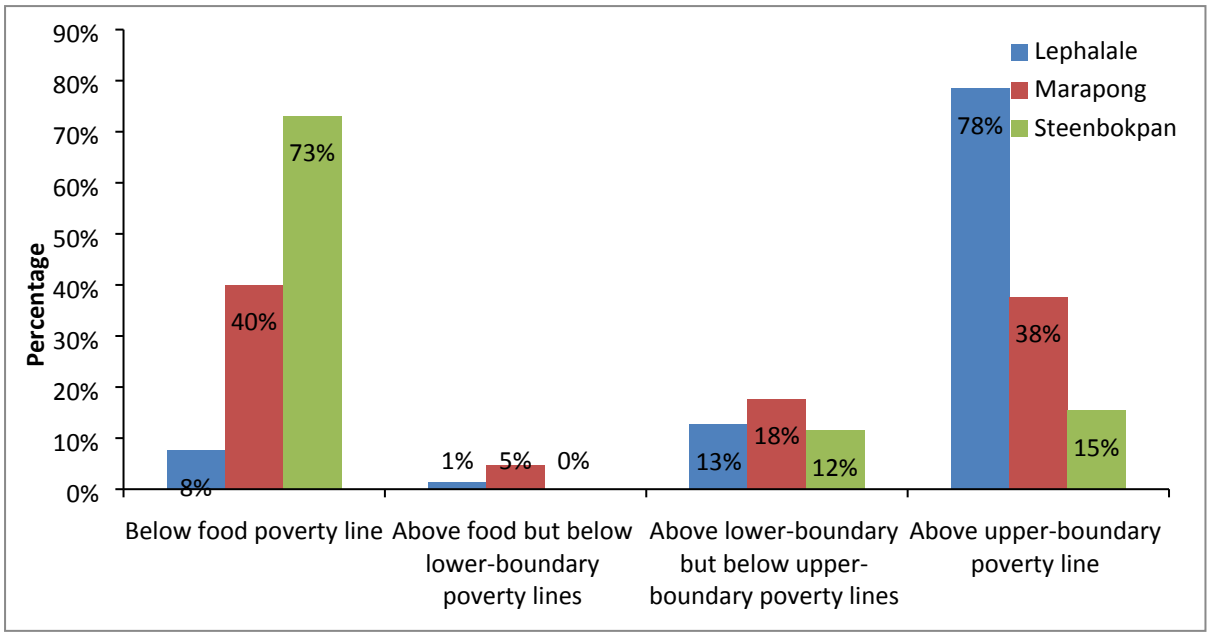


Figure 12. Proportion of households living at various poverty levels in Lephalale, Marapong and Steenbokpan. The poverty index is calculated by dividing household income by number of people.

Crowding

The number of bedrooms per person living in the house was used as a measure of crowding. Households in Lephalale have the lowest crowding at almost a whole room for each household member (0.89 of a room per person), Marapong is slightly more crowded with an average of 0.67 of a room per person, and Steenbokpan displayed the most crowing at 0.40 of a room per person (Figure 13)

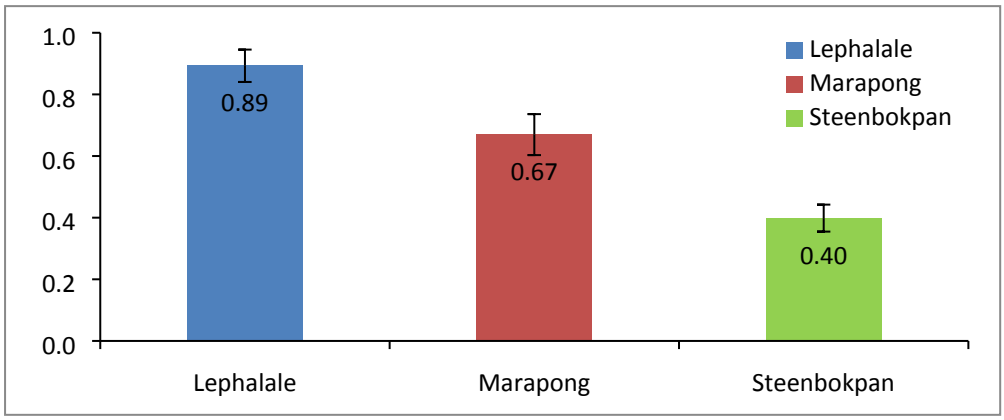


Figure 13. Average bedroom to people ratio for households in Lephalale, Marapong and Steenbokpan.

4.1.2. Energy Analysis

In this section, access to electricity, energy sources and the presence of a ceiling will be examined.

Access to Electricity

The percentages of households from Lephalale and Marapong who have access to electricity in their homes are 99% and 87% respectively, whereas the percentage from Steenbokpan who have electricity is only 17% (Figure 14). The differences in percentages between all three sites are significant, χ^2 (2, N = 225) = 115.73, p < 0.001. Access to electricity follows the same pattern as socio-economic indicators such as employment, two-parent families, medical aid and home rental examined in section 4.1.1.

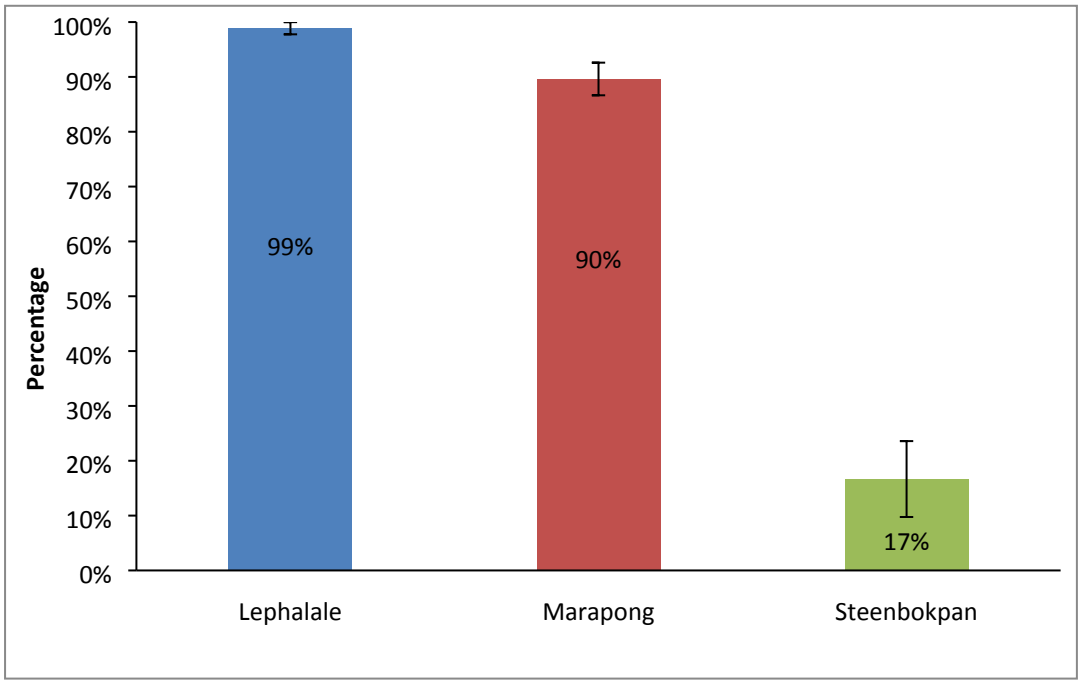


Figure 14. Percentage of households with electricity in Lephalale, Marapong and Steenbokpan.

Energy Sources:

Electricity provides the energy for lighting in 70% and cooking in 89% of household surveyed in Lephalale (Figure 15). The main alternative energy source for cooking in Lephalale is gas at 16%, with another 8% of households reporting using both electricity and gas. In Lephalale 1% of residents reported using gas for lighting, and 7% reported mixed electricity and gas usage. An electricity and gas combination thus accounts for lighting in 97% and cooking in 94% of Lephalale households surveyed. It can be concluded that electricity is the man energy source in Lephalale, compensated for by gas in some households.

Electricity is also the main energy source for lighting and cooking in Marapong, at 73% and 68% respectively. Residents in Marapong report a range of other combinations, many of which include electricity along with alternative energy sources (Figure 15).

Electricity is used for lighting by 10% and cooking by 13% of households in Steenbokpan. This represents a fairly large proportion of the 16.7% of households in Steenbokpan who have access to electricity (Figures 11 &12). In Steenbokpan 50% of households use candles for lighting, and 67% use wood for cooking. Alternative fuels used for lighting in Steenbokpan are wood (10%) “paraffin and candles” (10%), and “wood and candles” (10%).

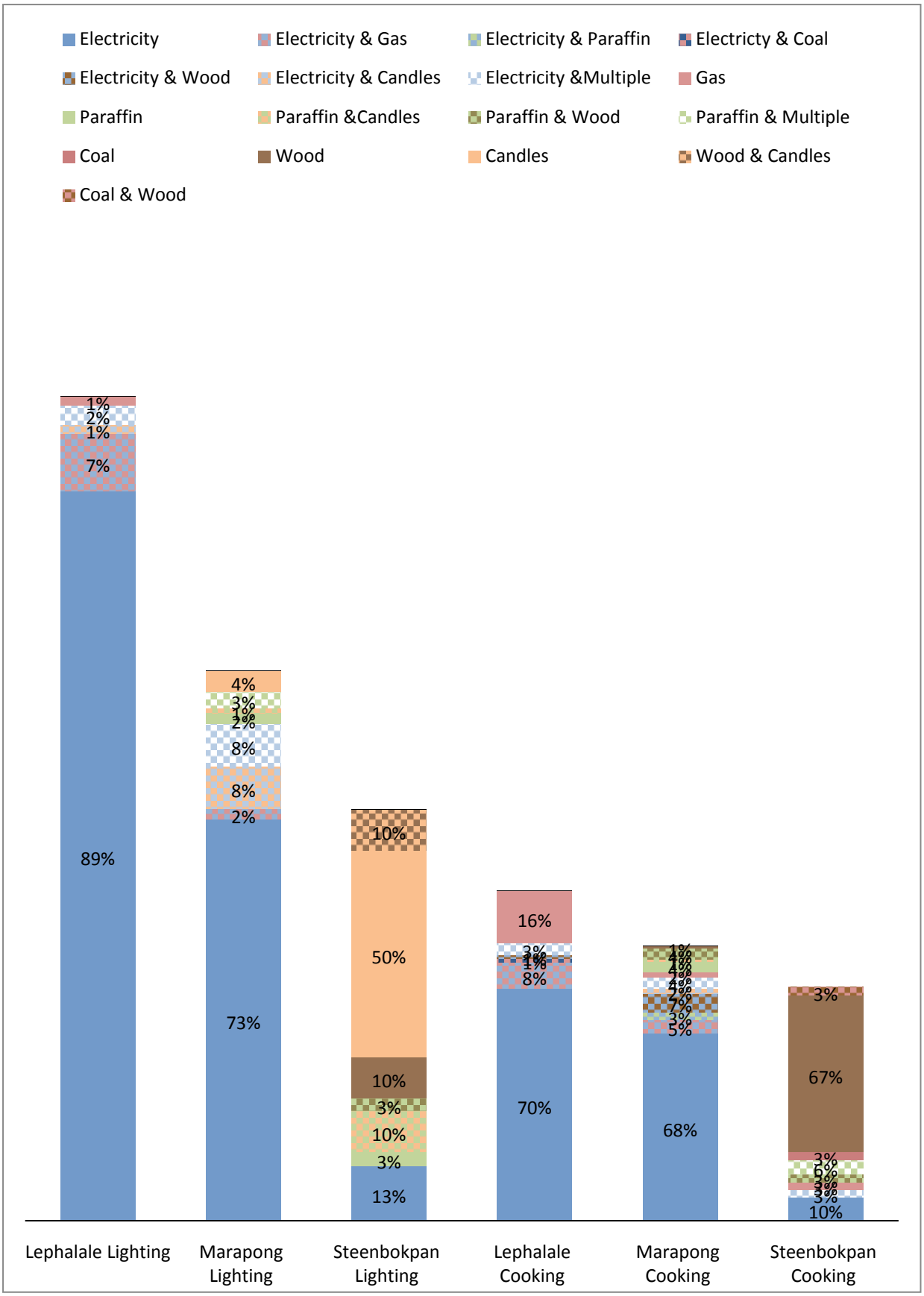


Figure 15. Percentage of households using various energy source combinations for lighting and cooking in Lephalale, Marapong and Steenbokpan.

Presence of a Ceiling

The presence or absence of ceilings in a home can be used to provide an indication of the level of insulation in houses, and consequently the indirect need for additional heating in the home. In this study 90% of respondents in Lephalale indicated that they do have a ceiling, compared with only 33% in Marapong and 14% in Steenbokpan (Figure 16). Chi-square tests indicate that these differences are significant χ^2 (2, N = 222) = 81.64, $p < 0.001$.

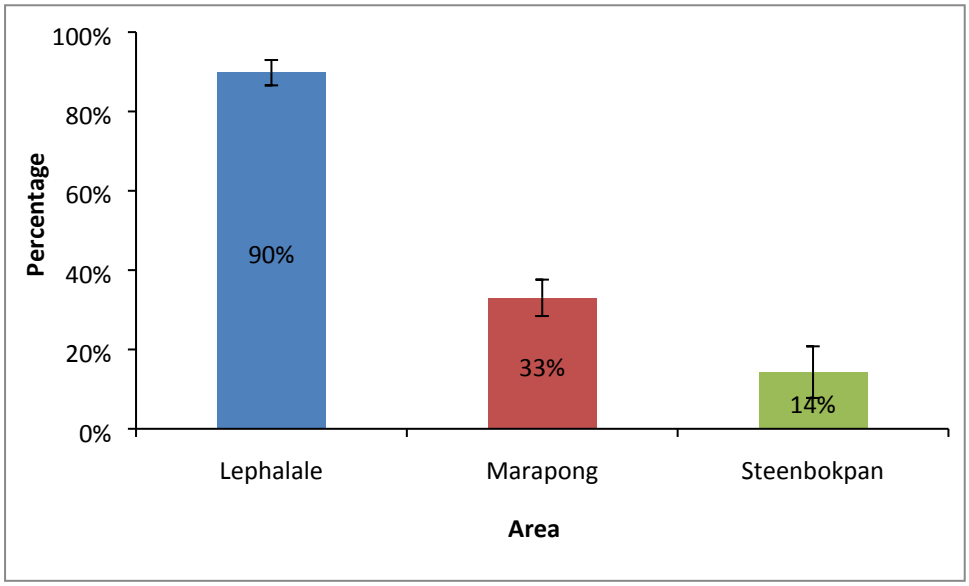


Figure 16. Percentage of households with a ceiling in their homes in Lephalale, Marapong and Steenbokpan.

4.1.3. Air pollution and Health Perceptions

Perceived Pollution Levels

In response to the question, "What is air pollution like in your area?" 42% of respondents from Lephalale rated air pollution as high, with 33% rating air pollution as fair. Most residents in Marapong also saw air pollution levels as high (33%), or fair (27%); but the pattern is less pronounced, with 19% rating air pollution as very high and 21% rating it as low (Figure 17). In Steenbokpan, air pollution was mostly rated as low (43%) to fair (30%). The overall view of air pollution showed significant differences between each of the three sites (χ^2 (6, N = 211) = 16.13, $p < 0.05$).

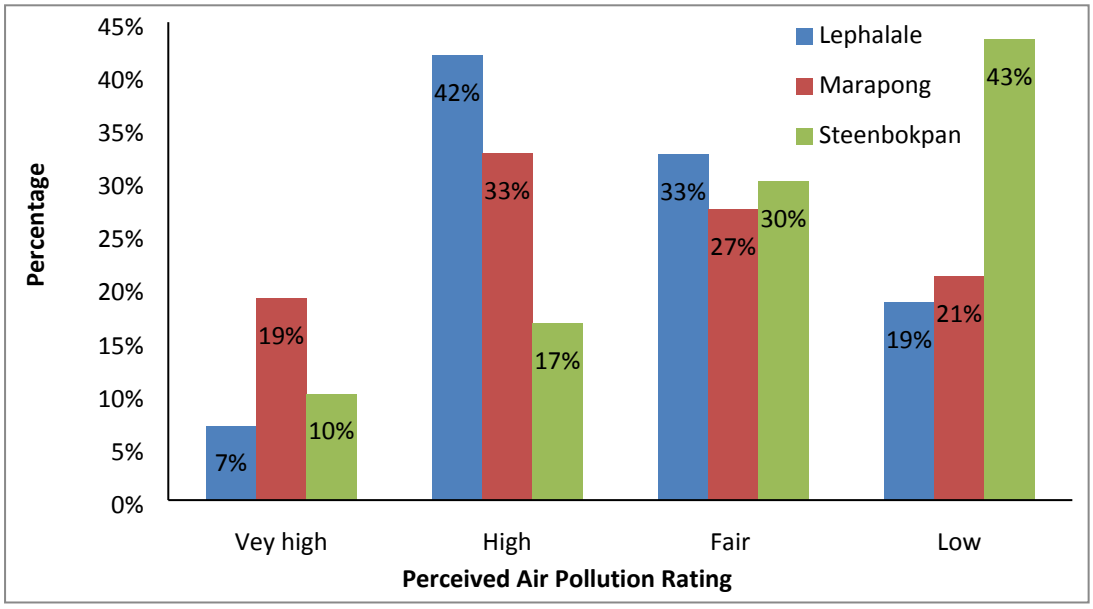


Figure 17. Perceived levels of air pollution in Lephalale, Marapong and Steenbokpan.

Air Pollution Understanding

Air pollution understanding was assessed based on responses to the question, "What is air pollution?" Responses that included neither a plausible cause nor effect of air pollution were

categorized as having no understanding; responses with either a plausible cause or effect of air pollution were categorized as having a partial understanding; and responses including either both causes and effects of air pollution, or multiple causes, or multiple effects were rated as having good understanding.

Chi squared tests revealed that air pollution understanding between the three sites also differed significantly (χ^2 (4, N = 159) = 13.88, $p < 0.01$). Interestingly, however, at 53% with a partial understanding and 41% with a good understanding of air pollution, Steenbokpan shows higher levels of air pollution understanding than might be expect based on the overall socio-economics of the three sites (Figure 18). Air pollution understanding was found to be associated with certain socio-economic indicators only, namely: qualification of respondent (χ^2 (4, N = 150) = 25.70, $p < 0.001$), family structure (χ^2 (2, N = 150) = 6.14, $p < 0.05$), subscription to medical aid (χ^2 (2, N = 153) = 6.65, $p < 0.05$) and the presence of a ceiling (χ^2 (2, N = 159) = 12.14, $p < 0.005$).

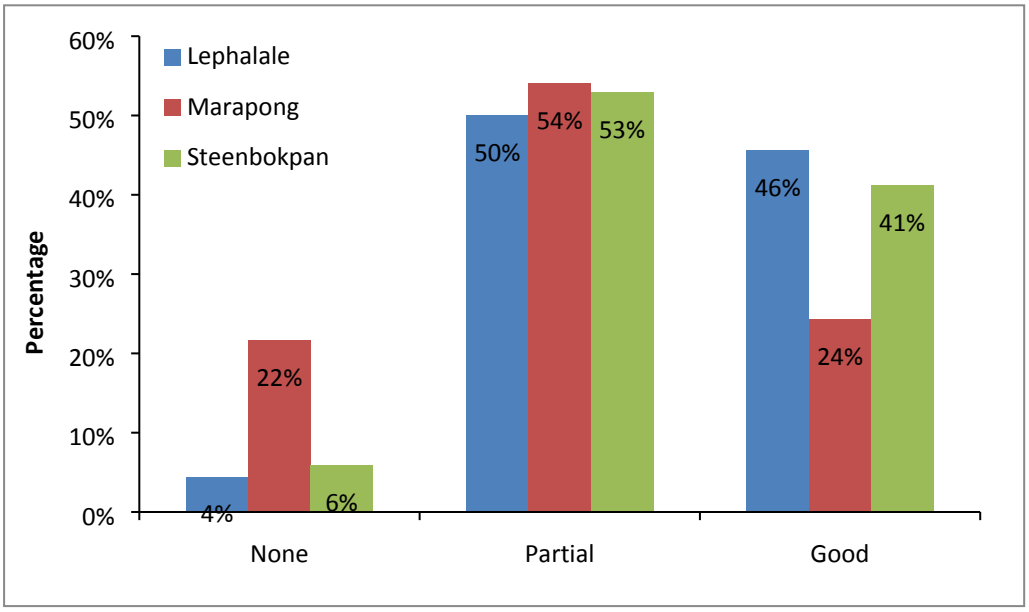


Figure 18. Air pollution understanding in Lephalale, Marapong and Steenbokpan. Understanding was rated according to responses to the question, "What is air pollution?" Responses that included neither a plausible cause nor effect of air pollution were categorized as no understanding; responses with either a plausible cause or effect of air pollution were categorized as partial understanding; and responses including either both causes and effects of air pollution, or multiple causes, or multiple effects were categorized under good understanding.

Perceived causes of bad air

Responses to the question "What causes bad air?" were listed and categorised as being domestic, industrial or mixed (Figure 19). A range of responses were received in all three sites but industrial causes featured prominently in Lephalale, with power stations being included in 77% of responses, compared to 70% of responses in Marapong and only 44% of responses in Steenbokpan. While no reference was made to domestic sources of air pollution in Lephalale; Steenbokpan had the largest number of people reporting air pollution from domestic causes at 22%, followed by Marapong at 17% (Figure 18). This corresponds with the lower socio-economic profiles and levels of electricity access, and thus the subsequent need for domestic burning of wood for cooking in these two areas.

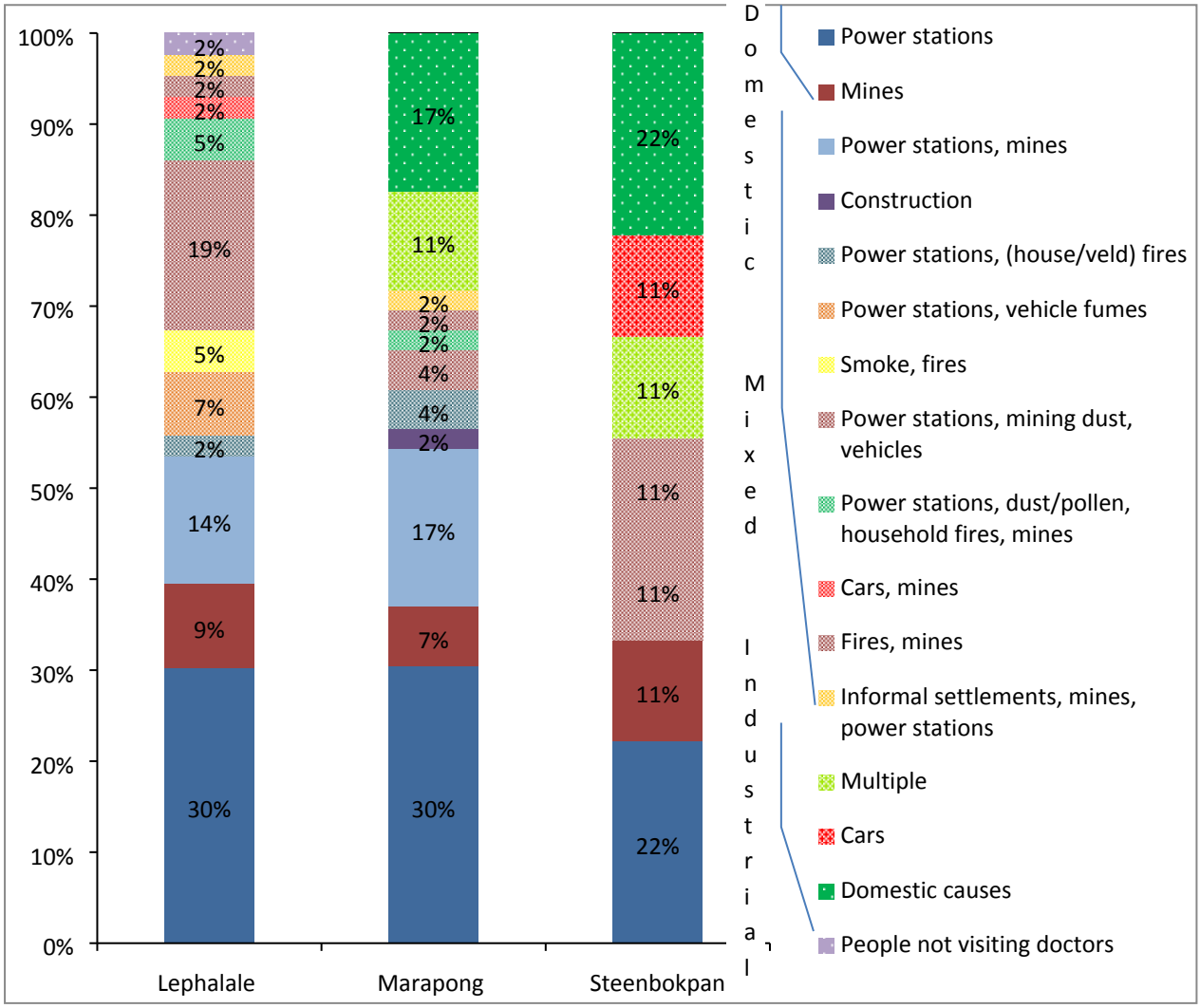


Figure 19. The perceived "main causes of air pollution" as listed by respondents in Lephalale, Marapong and Steenbokpan

Self-reported respiratory health problems

Households in Marapong reported 2.31 ± 0.83 (Mean ± SD), respiratory related problems in the last year, slightly higher when compared to Lephalale's 2.17 ± 0.95 (Figure 20). At 1.47 ± 1.18, Marapong also has a slightly higher number of people who visited a doctor or clinic regarding these problems in the last year than Lephalale at 1.35±1.22. Residents in Steenbokpan reported much lower incidence of respiratory related problems 1.38±1.02 as well as a much lower incidence of doctor or clinic visits with regard to these problems (0.83±1.05).

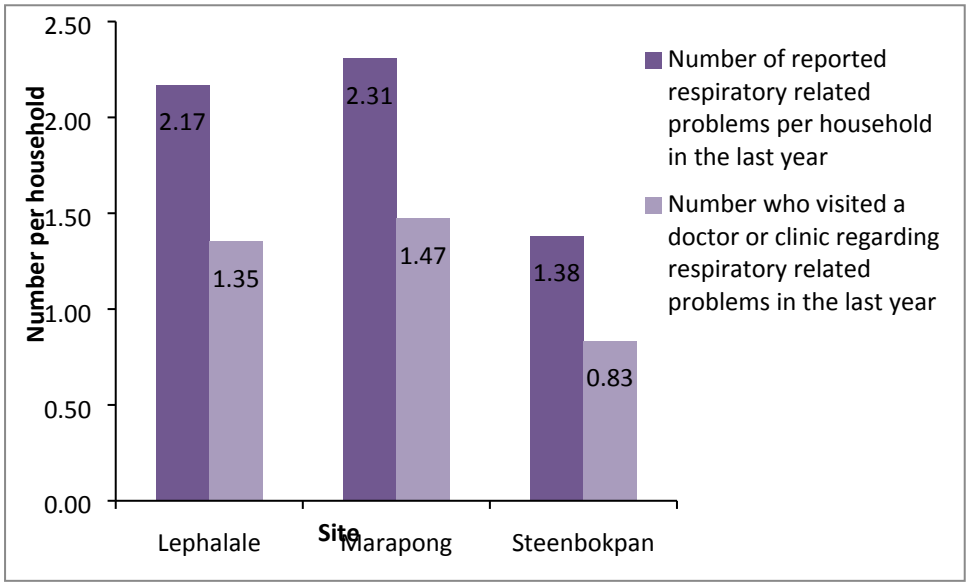


Figure 20. Number of respiratory related problems reported in Lephalale, Marapong and Steenbokpan for a one-year period between 2013 and 2014, as well as the number of people who visited a doctor or clinic regarding these problems.

Households in Lephalale reported higher numbers of people experiencing thirteen out of the fifteen possible symptoms of respiratory related illness (Figure 21). Lephalale also had the highest proportion of bronchitis and hay fever diagnoses (Figure 22). The peak for asthma however occurs in Marapong, with 36% of Marapong households having a case of asthma, compared to only 15% for Lephalale and 13% for Steenbokpan (Figure 22).

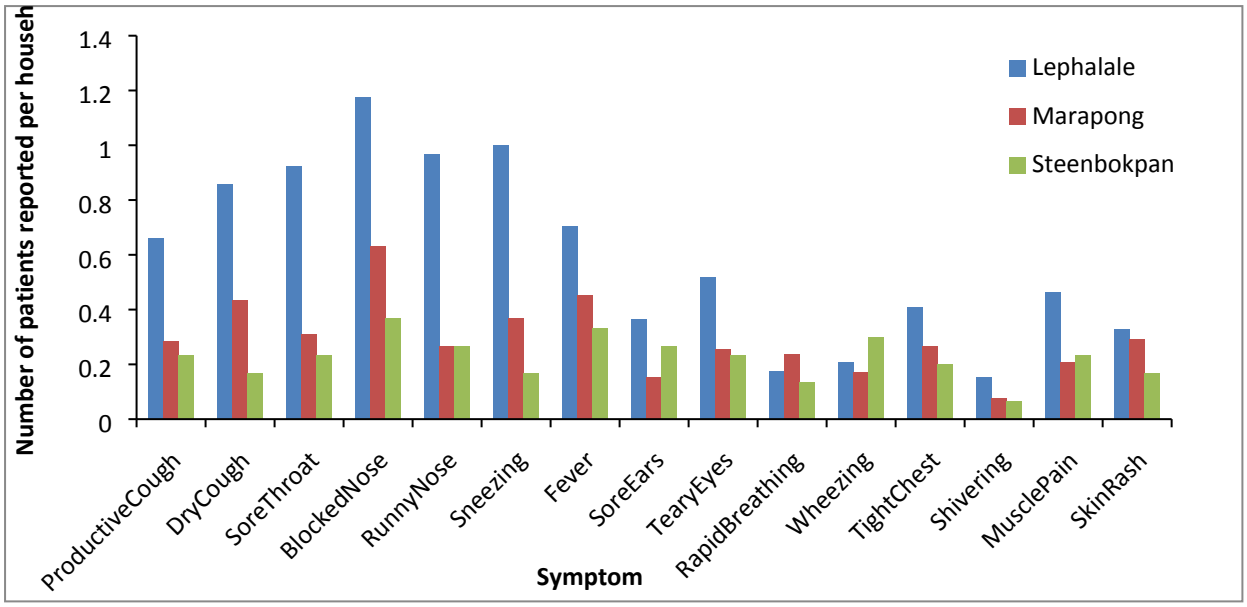


Figure 21: Number of people with respiratory problems who experienced each of the symptoms listed, measured as average per household for Lephalale, Marapong and Steenbokpan.

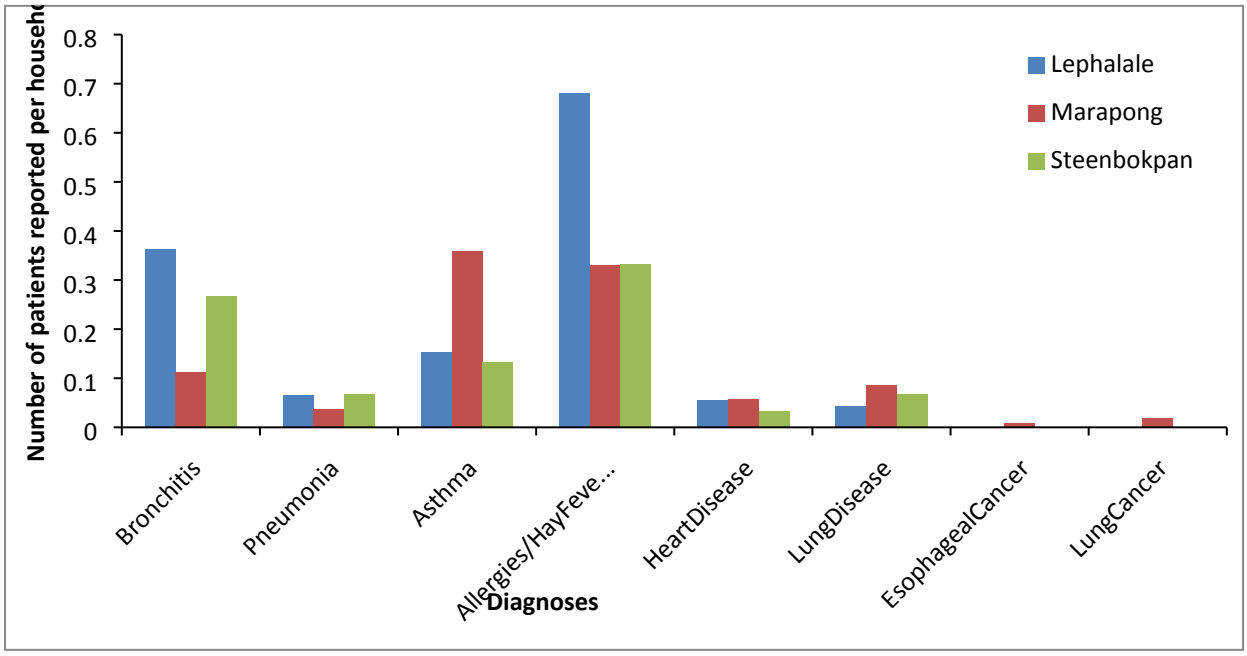


Figure 22: Diagnoses (represented as average number per household) of those who went to seek medical assistance, for Lephalale, Marapong and Steenbokpan.

Perception of Household Health over the last two years

Most respondents in Marapong (65%), and half of the respondents in Steenbokpan (50%) consider the health of their household over the last two years to be improving (Figure 23). Lephalale represents the site with the highest proportion of residents considering the health of their household over the last two years to be deteriorating (25%), compared with 11.4% and 11.5% in Marapong and Steenbokpan respectively (Figure 23). Chi-squared tests indicate that the difference in the perception of household health over the last two years between the three sites is significant, χ^2 (4, N = 173) = 18.86, $p < 0.005$.

The perception of household health over the last two years was also found to be positively associated with the qualification level of the respondent (χ^2 (4, N = 162) = 27.20, $p < 0.001$), household subscription to medical aid (χ^2 (2, N = 163) = 8.67, $p < 0.05$) and the presence of a ceiling in the home (χ^2 (2, N = 169) = 13.091, $p < 0.005$).

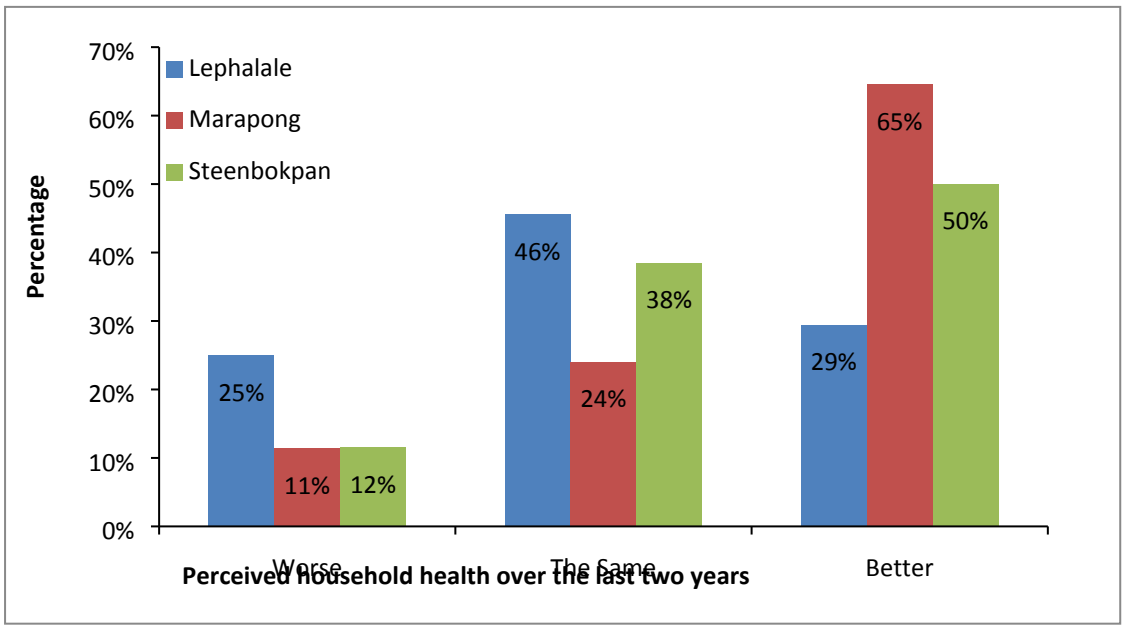


Figure 23. Comparison of the proportion of respondents in Lephalale, Marapong and Steenbokpan; that perceive the health of their household over the last two years is improving, deteriorating or staying the same.

Summary of Statistical Findings

"Sites" was used as the overarching independent variable against which air pollution and health perceptions were analysed. Fifteen other socio-economic indicators examined were gender, age, migration, household size, qualification, poverty levels, grants, two-parent families, medical aid, renting, bedrooms, electricity access, presence of a ceiling, smokers in the household, and whether smoking happens inside the home. Twelve of these fifteen were shown to be linked significantly to site, strongly reinforcing the hypothesis that the three sites represent three distinct socio-economic profiles (Table 6). The socio-economic profiles of the three sites can thus be classified in descending order as Lephalale, Marapong and Steenbokpan.

The only three factors that were found not to be associated with site are gender, presence of smokers in the household, and whether smoking happens inside the home (Table 6).

Table 6. Significance for site versus a range of socio-economic factors, using Chi-Squared tests.

Independent Variable	Dependent Variable	Significant	N	χ^2 Value	d.f.	Asymptotic. Significance (2-sided)
Sites	Gender	No	203	1.36	2	$p = 0.51$
	Age *	Yes	173	13.65	4	$p < 0.01$
	Migration	Yes	216	11.32	4	$p < 0.05$
	Household size	Yes	221	19.30	8	$p < 0.05$
	Qualification	Yes	206	56.80	4	$p < 0.001$
	Poverty levels	Yes	190	55.40	6	$p < 0.001$
	Grants	Yes	138	29.47	4	$P<0.001$
	Two-parent families	Yes	214	21.09	2	$p < 0.001$
	Medical aid	Yes	215	57.63	2	$p < 0.001$
	Renting	Yes	222	24.65	2	$p < 0.001$
	Bedrooms	Yes	223	83.20	8	$p < 0.001$
	Electricity access	Yes	225	115.73	2	$p < 0.001$
	Ceiling	Yes	222	81.64	2	$p < 0.001$
	Smokers vs non-smoker	No	214	0.50	2	$p = 0.78$
	Smoking inside	No	200	1.60	2	$p =0.449$

*There were more middle aged respondents in Lephalale (36-50 years), while Marapong and Steenbokpan had a higher proportion of younger respondents (18-35 years).

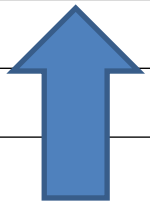
Six variables (namely: air pollution awareness, perceived air pollution levels, air pollution understanding, perceived household health, number with respiratory related symptoms and number that sought medical assistance) were used as measures of air pollution and health perceptions. All of these, with the exception of the number with respiratory symptoms that sought medical assistance, were found to be significantly associated with the variable site (a proxy for socio-economic profile), indicating that air pollution and health perceptions vary with socio-economic profile (Table 7). These associations sometimes follow the expected linear relationship, as is the case for factors such as air pollution awareness and perceived pollution levels; where awareness of air pollution and perceived pollution level are highest in Lephalale and lowest in Steenbokpan. This is, however, not always the case; Steenbokpan displays an understanding of air pollution that is much higher than might be expected based on the sites socio-economic profile (refer to Figure 16 page 15), and the largest proportion of respondents from Marapong perceive their household health over the last two years as having improved. While no difference was detected with regards to the number with respiratory symptoms that sought medical attention, the percentage of respondents from each site that were found at the various healthcare institutions (Table 8) suggests that the type of healthcare they seek (i.e. private or public) is linked to the socio-economics of their site of residence.

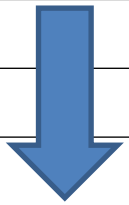
Table 7. Significance for sites versus a range of air pollution and health perceptions, using Chi-Squared tests.

Independent Variable	Dependent Variable	Significant	N	χ^2 Value	d.f.	Asymptotic. Significance (2-sided)
Sites	Aware of Air Pollution	Yes	215	24.45	2	P<0.001
	Perceived Air Pollution Levels	Yes	211	16.13	6	$p < 0.05$
	Air pollution understanding	Yes	159	13.88,	4	$p < 0.01$
	Household health	Yes	173	18.86	4	$p < 0.005$
	Number with respiratory related symptoms	Yes	182	10.36	4	p<0.05
	Number that sought medical assistance	No	227	8.39	6	P=0.21

Table 8. The percentage of respondents from each site that were found at private and public healthcare institutions.

Site	**Private**	**Public**
Lephalale	15.38	4.83
Marapong	9.43	16.04
Steenbokpan	3.33	33.33





Although air pollution understanding and perceived household health differ for the three sites, they were both found to be associated with only a few other socio-economic indicators namely qualification of respondent, subscription to medical aid and the presence of a celling (Tables 9 and 10). Air Pollution understanding was also found to be associated with family structure (Table 9) and household health was also found to be linked to poverty level (Table 10).

Table 9. Significance for air pollution understanding versus a range of socio-economic indicators for all three sites, using Chi-Squared tests

Dependent Variable	Independent Variable	Significant	N	χ^2 Value	d.f.	Asymptotic. Significance (2-sided)
Air Pollution Under-standing	Gender	No	143	3.40	2	$p = 0.18$
	Age	No	129	7.04	4	$p = 0.13$
	Migration	No	152	2.05	4	$p = 0.73$
	Household size	No	154	0.96	4	$p=0.92$
	Qualification	Yes	150	25.70	4	$p < 0.001$
	Poverty level	No	140	5.54	4	$P=0.236$
	Grants	No	104	4.36	4	$P=0.36$
	Family structure	Yes	150	6.14	2	$p < 0.05$
	Subscription to medical aid	Yes	153	6.65	2	$p < 0.05$
	Renting	No	158	1.36	2	$P=0.51$
	Bedrooms	No	158	9.92	6	$P=0.13$
	Electricity access	No	159	3.80	2	$P=0.15$
	Presence of a ceiling	Yes	159	12.14	2	$p < 0.005$
	Smokers vs non-smoker	No	152	2.25	2	$P=0.32$
	Smoking inside	No	142	2.00	2	$P=0.37$

Table 10. Significance of perceived overall household health versus a range of socio-economic indicators for all three sites, using Chi-Square tests.

Dependent Variable	Independent Variable	Significant	N	χ^2 Value	d.f.	Asymptotic. Significance (2-sided)
House-hold Health	Gender	No	157	3.31	2	p=0.19
	Age	No	139	4.95,	4	p=0.29
	Migration	No	165	7.76	4	p=0.10
	Household size	No	168	7.08	6	P=0.31
	Qualification	Yes	162	27.2	4	P<0.001
	Poverty level	Yes*	143	10.05	4	P<0.05
	Grants	No	104	4.91	4	P=0.30
	Family structure	No	163	5.07	2	P=0.08
	Subscription to medical aid	Yes	163	8.67	2	P<0.05
	Renting	No	169	1.77	2	P=0.41
	Bedrooms	No	170	7.11	8	P=0.53
	Electricity access	No	171	3.36	2	P=0.19
	Presence of a ceiling	Yes	169	13.09	2	P<0.005
	Smokers vs non-smoker	No	161	0.26	2	P=0.88
	Smoking inside	No	154	1.36	2	P=0.51

*More than 50% of the poor rate health as being better (56% below the food poverty line and 54% below the upper boundary poverty line) versus 34% of those above the upper boundary poverty line.

An analysis of the six air pollution and health perceptions against each other revealed significant associations between air pollution understanding with perceived household health, number that sought medical assistance with perceived household health, air pollution awareness with air pollution rating, air pollution awareness with air pollution understanding, number with respiratory related symptoms with air pollution understanding, and number that sought respiratory related medical assistance with number with respiratory related symptoms (Table 11).

Responses of people with a low or partial understanding of air pollution were skewed towards the perception that household health over the last two years is either better (60% and 50%) or the same (20% and 40%). Responses from people with a good understanding of air pollution were almost evenly split with 32% rating household health as being worse, 34% rating household health as being better and 34% rating household health as being the same.

Table 11. Associations between air pollution and health perceptions, using Chi-Square tests over all three sites.

		Significant	N	χ^2 Value	d.f.	Asymptotic. Significance (2-sided)
Air pollution awareness	Household health	No	167	5.60	2	P=0.17
Air Pollution Rating	Household Health	No	164	5.92	6	P=0.43
Air Pollution Understanding	Household Health	Yes	126	11.42	4	P=0.02 P<0.05
Number with respiratory related symptoms	Household Health	No	152	6.61	4	P=0.16
Number that sought medical assistance	Household health	Yes	173	13.61	6	$p < 0.05$
Air Pollution Understanding	Air Pollution Rating	No	155	9.84	6	P=0.13
Air Pollution Awareness	Air Pollution Rating	Yes	204	8.24	3	p<0.05
Number with respiratory related symptoms	Air Pollution Rating	No	173	12.00	6	P=0.62
Number that sought medical assistance	Air pollution Rating	No	211	10.62	9	P=0.30
Air pollution Awareness	Air Pollution Understanding	Yes	159	15.45	2	P<0.001
Number with respiratory related symptoms	Air Pollution Understanding	Yes	136	16.50	4	P<0.005
Number that sought medical assistance	Air Pollution Understanding	No	159	6.33	6	P=0.39
Air pollution Awareness	Number with respiratory related symptoms	No	175	0.75	2	P=0.69
Number respiratory related medical assistance	Number with respiratory related symptoms	Yes	182	141.36	6	P<0.001
Air pollution Awareness	Number respiratory related medical assistance	No	215	2.65	3	P=0.45

Thematic analysis of qualitative information:

A thematic analysis of qualitative information was conducted using information from the suggestions for addressing the issue of air pollution that were made at each of the three sites. The suggestions were categorised as being energy-related, domestic-related or nature-related.

There were major differences in suggestions with 26/41 (61%) of suggestions from Lephalale being energy-related, this was the predominant theme from site 1; while Marapong and Steenbokpan show similar numbers, with only 14/56 (25%) of suggestions from Marapong and 3/10 (30%) of suggestions from Steenbokpan relating to energy. A vast 39/56 (70%) of suggestions from both Marapong and Steenbokpan related to domestic issues. Most of the domestic-related suggestions from Steenbokpan (6/7 or 86%) related directly to electricity, with electrification as the suggested intervention. This qualitative information is telling of the diverging socio-economic statuses and priorities of the communities at the three sites.

4.2. Focus Group Meeting Findings

Three focus group meetings were arranged, one for each of the three sites. Although there were some positive responses on paper, there was zero attendance to the meeting held on 16 November 2013 at Bosveld Primary School in Lephalale. This meant that data could only be collected for the two remaining sites.

The Steenbokpan focus group meeting

The Steenbokpan focus group meeting conducted at the Leseding Community Hall on 15 November 2013 was attended by 13 people. The group resolved that the settlement (site 3) consists of approximately 400-500 houses which are not connected to the electricity grid, but which do have access to running water. The group collectively rated air pollution as low, and attributed air pollution listed to fuel from cooking, vehicle emissions and Eskom's Matimba Coal Power Station.

The Marapong focus group meeting

The Marapong focus group meeting conducted at the Nelsonskop Primary School in Marapong, was held on 11 November 2013 and was attended by 80 people. The group collectively rated air pollution as high. The group listed a number of air pollution sources: mining, Matimba power station, building construction, brick construction, littering, traffic, crowding, sewerage (in Extension 4) and bad infrastructure (informal settlements on the East). Another concern raised is that the clinic is "too small", with a minimum of a 4 hour wait, and is not open over weekends. The accompanying suggestion is to open a larger 24-hour clinic. People also brought up concerns over inconsistent water and electricity supply, a general "lack of space" and informal settlements area expansion.

4.3. Key Stakeholder Interviews

Meetings were held with various stakeholders from within the communities with the aim of compiling background information or further exploring the dynamics in the region.

Jeremiah: Steenbokpan 15 November 2015

Jeremiah, from the Leseding location of Steenbokpan reports that he, together with a group of others, has been trying to establish a community structure to address concerns of the Steenbokpan residents including sanitation, air pollution, and cultural and historic land claims. He says that they have heard of five new mines opening in the region, but that his community is ill-informed with regards to air pollution. According to Jeremiah, their biggest concerns are around issues that have a direct effect on their daily quality of life, such as sewerage. Jeremiah reports that the NGO "Earthlife Africa" have conducted a number of community information meetings to educate people in the region around issues of air pollution. This was confirmed with an employee at Earthlife (Makhoma, personal communication)

Astrid: Lephalale 15 November 2015

As there is not much official information available about the Leseding location of Steenbokpan, an interview with an elected councillor for the Waterberg District Municipality, Astrid Basson, was set up. Basson mentions that a number of self-generated and self-regulating human settlements have 'popped up in the region overnight'. She lists site 3, the 'Leseding Location' of Steenbokpan, as an example of such a settlement. She states that although there was talk in 2001 of plans to build an agri-village to provide housing for farmworkers in the site, it has not happened and this settlement of approximately 500 homes may have developed organically as a result .

Basson explains that grassroots developments of this nature, without official procedures or oversight, can have negative consequences. She refers to a settlement of shacks that has recently established along the R510 highway just outside Lephalale Central Business District, as particularly problematic because the site is below the flood line. This means that government cannot, in good conscience, provide these people with services or permanent housing at their current location, but it is governments responsibility to provide alternative accommodation should these people be removed. The settlement does not have services, and the survey results suggest a high rate of unemployment with an average of less than one working person (0.86) per household (refer to Table 5 page 4).

A number of other issues were also raised by Basson, including the following:

- The local municipality refuses to take responsibility for air quality management, as this is a district function.
- Environmental Impact Assessments may not be independent as they are conducted by organisations chosen and paid for by the developer.
- Information regarding all development plans is not easily accessible.
- Men's hostels contribute to social problems by breaking or preventing the traditional two parent family structure. Migrant labour is associated with raised levels of drug use and prostitution.

- Despite various advertisements regarding how Eskom's projects will empower the region's communities, Basson asserts that skilled work does not go to locals. She provides as an example the case of welding. The skills level of South African welders does not meet the standards required to do the welding at Medupi, so there are currently a large number of Taiwanese contractors hired for this purpose. This suggests that the assertion that locals often do not gain financially from these developments may have some credibility.

Andries Engelbrecht: Marapong 11 November 2013

Engelbrecht manages the private mediclinic hospital in the region. He states that the "Marapong Private Hospital" supports 34 beds, 36 staff members and does deal with a number of respiratory related illnesses. The clinic has been run in Marapong as a private mediclinic from 2007 to 2013, before which the premises were used by mines. The clinic was moved to Lephalale in November 2013, for reasons of access and safety. Engelbrecht says that the hospital premises will be donated, alluding to the possibility of the premises being taken over by government.

4.4 Findings on Ambient Air Quality

There are two ambient air quality monitoring stations in the study area, positioned in Lephalale and Marapong respectively. Not all the data are accessible due to data quality, calibration and formatting issues. The most recent data available, which have been validated by relevant professionals and included in the official Waterberg Bojanala Air Quality Management Plan are presented below.

Different air quality standards apply to different time periods. The annual, hourly and 24 hour average of SO_2, NO_2, PM_{10} and $PM_{2.5}$ ($\mu g/m^3$) measured were lower at Lephalale than at Marapong. The annual average of SO_2 at Marapong (9.87 $\mu g/m^3$) is almost ten times that of Lephalale (1 $\mu g/m^3$), but is still within the National Ambient Air Quality Standard (NAAQS) of an annual SO_2 average of 50 $\mu g/m^3$. The average PM_{10} concentration of 88.7$\mu g/m^3$ in Marapong is, however, shown to exceed the NAAQS value of 50µg/m3 (Table 12).

Table 12. Ambient air quality monitoring showing annual averages of various pollutants as measured at the Marapong and Lephalale continuous monitoring stations, as well as National Ambient Air Quality Standards (NAAQS) (Moodley *et al.* 2014).

Annual average ($\mu g/m^3$)	SO_2	NO_2	PM_{10}	$PM_{2.5}$
Lephalale	1.0	8.8	25.5	7.5
Marapong	9.8	12.5	88.7	37.7
NAAQS	50	40	50	65

The air quality data from these monitoring stations in its raw form is difficult to arrange and analyze due to its amount, as well as the presence of missing and unreliable values. Data assessed and summarized for the WBPA AQMP was therefore utilized in this study (Moodley *et al.* 2014). Hourly SO_2 concentrations ($\mu g/m^3$) show no hourly exceedances of the National Ambient Air Quality Standard (NAAQS) of 360 $\mu g/m^3$ SO_2 to have been recorded in Lephalale, but there were exceedances recorded during the winter months of June-August in Marapong (Figure 24). Although there is only 6

months worth of reliable data for Lephalale, a June-August period does fit into those 6 months, and shows substantially lower values SO_2 levels than the June to August periods in Marapong.

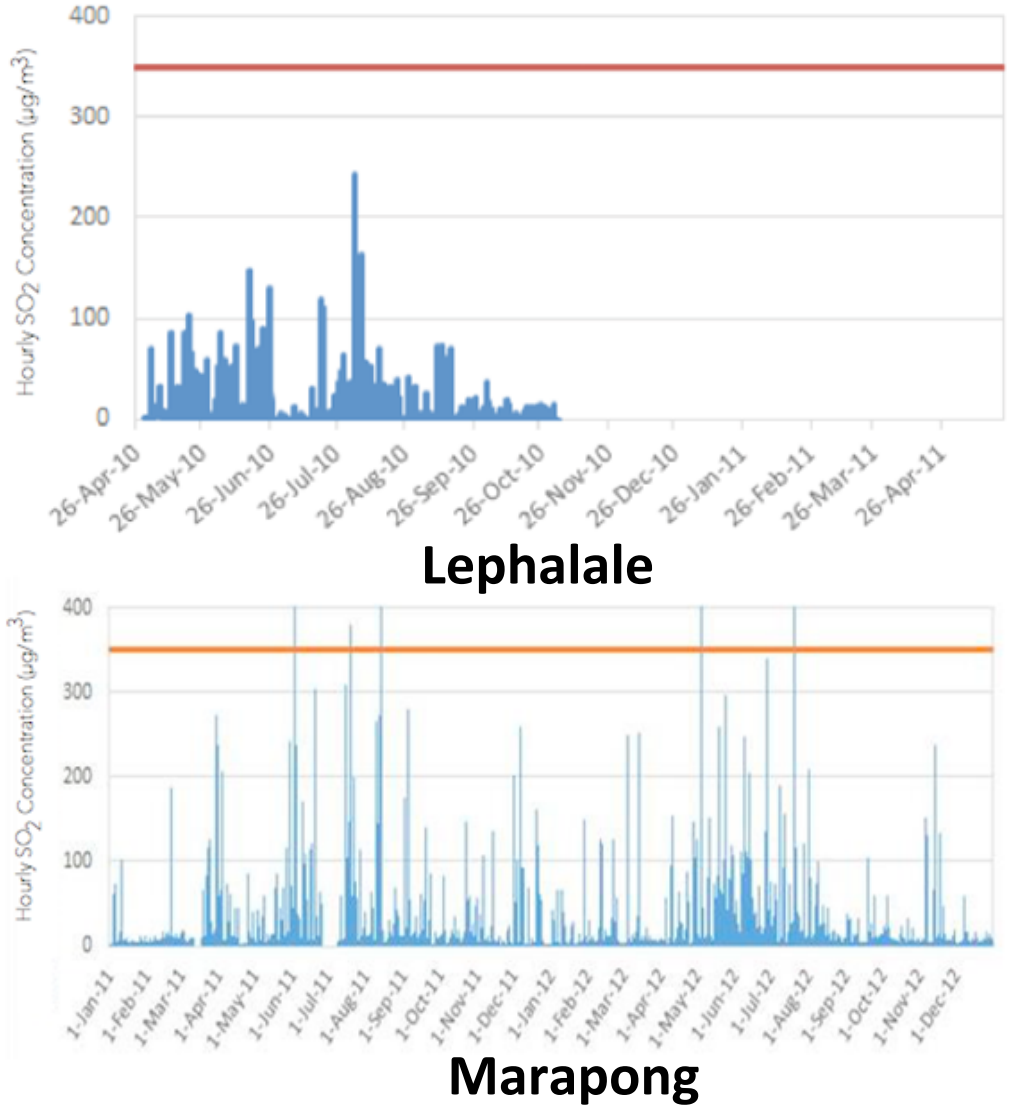


Figure 24. Hourly SO_2 concentrations (µg/m^3) collected at the Lephalale and Marapong ambient air quality monitoring stations for data between 2010 and 2012. While the Marapong station yielded reliable data from January 2011 to December 2012, the only reliable data collected in Lephalale were between April and October 2010 (Moodley *et al.* 2014). The National Ambient Air Quality Standard (NAAQS) of 360 µg /m^3 is indicated in red.

Hourly NO_2 concentrations show no exceedances of the national air quality standard of 200 µg/m^3 measured at either the Lephalale or the Marapong ambient air quality monitoring stations (Figure 25).

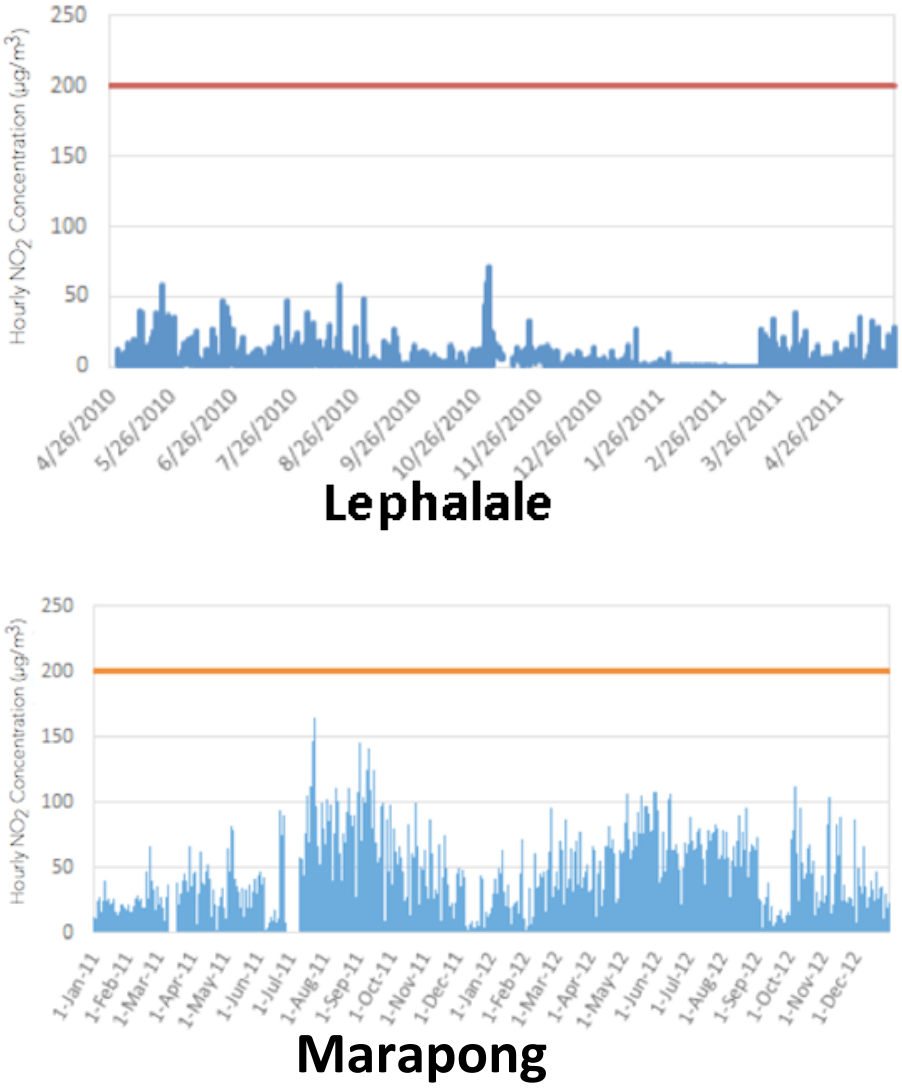


Figure 25. Hourly NO_2 concentrations (µg/m^3) collected at the Lephalale and Marapong ambient air quality monitoring stations for data between 2010 and 2012. While the Marapong station yielded reliable data from January 2011 to December 2012, reliable data were only collected in Lephalale from April 2010 to April 2011 (Moodley *et al.* 2014). The National Ambient Air Quality Standard (NAAQS) line of 200 µg /m^3 is indicated in red.

The 24-hour PM_{10} concentrations (µg/m^3) show no exceedances of the current NAAQS 24-hour PM_{10} limit of 120 µg/m^3 in Lephalale, but frequent exceedances in Marapong throughout the year (Figure 26). Based on scientific evidence of the dangers of PM to human health, a more stringent PM_{10} National Ambient Air Quality Standard of 75 µg/m^3 will come into effect this year, which can be expected to increase exceedances at both monitoring stations.

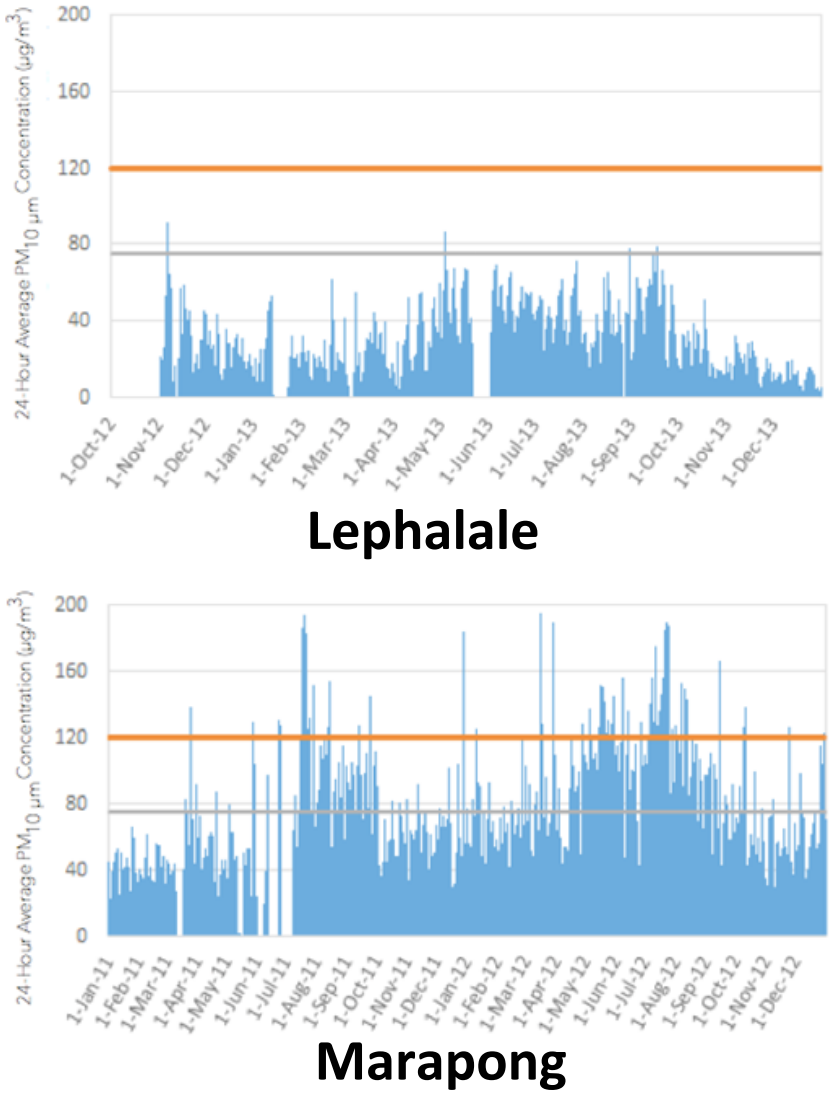


Figure 26. The 24-hour PM_{10} concentrations (µg/m^3) collected at the Lephalale and Marapong ambient air quality monitoring stations for data between 2011 and 2013. While the Marapong station yielded reliable data from January 2011 to December 2012, the Lephalale station only yielded reliable data for October 2012 to December 2013 (Moodley *et al.* 2014). The current National Ambient Air Quality Standard (NAAQS) of 120 µg /m^3 is indicated in red, and the 2015 standard of 75 µg /m^3 is indicated in grey.

The 24-hour $PM_{2.5}$ concentrations (µg/m^3) show no exceedances of the current NAAQS 24-hour $PM_{2.5}$ limit of 65 µg/m^3 in Lephalale, but frequent exceedances in Marapong throughout the year (Figure 27). Based on scientific evidence of the dangers of PM to human health, a more stringent $PM_{2.5}$ National Ambient Air Quality Standard of 40 µg/m^3 will come into effect this year, which can be expected to increase exceedances at both monitoring stations.

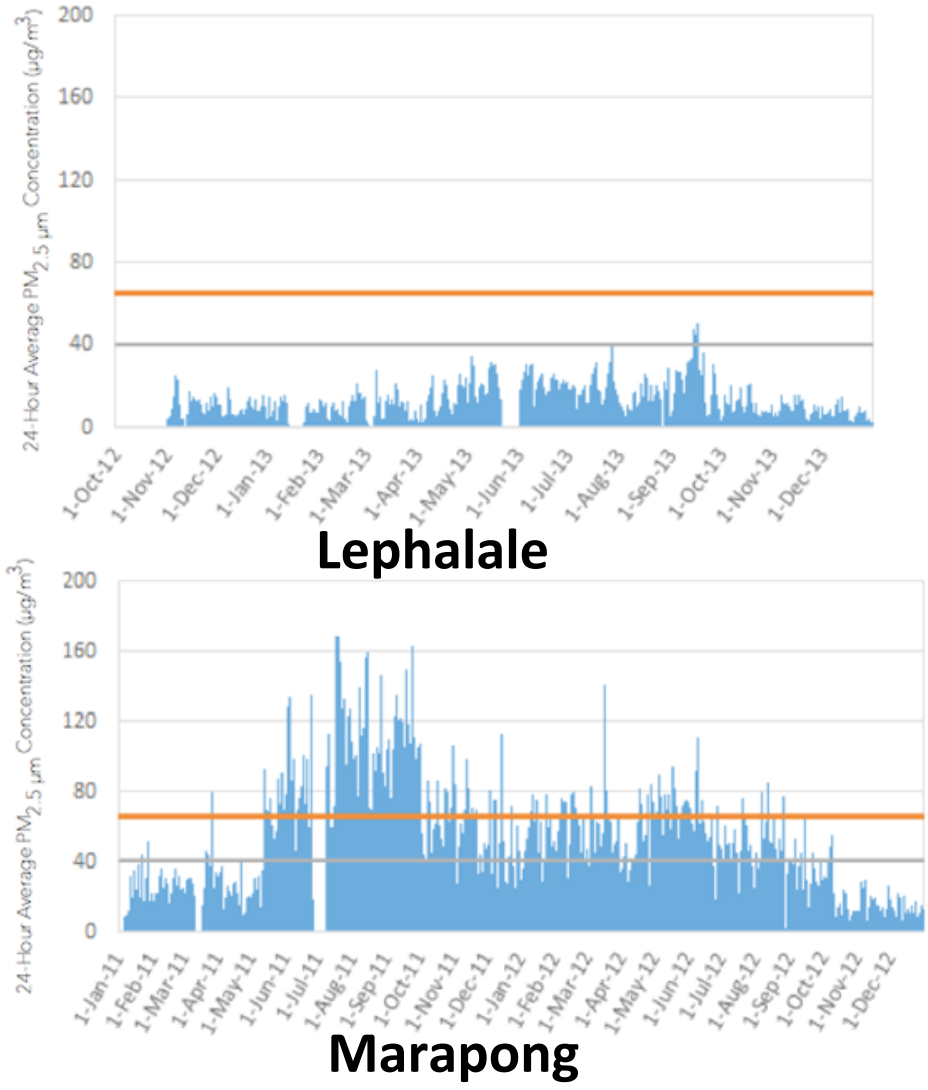


Figure 27. The 24-hour $PM_{2.5}$ concentrations (µg/m^3) collected at the Marapong and Lephalale ambient air quality monitoring stations for data between 2011 and 2013. While the Marapong station yielded reliable data from January 2011 to December 2012, the Lephalale station only yielded reliable data for October 2012 to December 2013 (Moodley *et al.* 2014). The current $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) of 65 µg /m^3 is indicated in red, and the 2015 standard of 40 µg /m^3 is indicated in grey.

4.5. Policy and Future Plans for the Region

Future scenarios can only be determined by taking into account the regulatory frameworks and associated policies, plans and programs which are applicable to the study area. This comprises international, national and regional level legislation and policies, which will be briefly described below. For a more detailed description of the most relevant legislation refer to the policy section of Chapter 2.

International Policies and Legislation from an Air Quality and Health Perspective

- International guidelines such as the World Health Organization's air quality standards are not legally binding, but are useful to take into consideration for best practice scenarios.

National Policies and Legislation relevant from an Air Quality and Health Perspective

- Section 24 of the current Constitution of South Africa, enshrined in 1996, stipulates that government is responsible for providing the socio-economic rights of citizens, including the right to a healthy environment.

- The Department of Environment Affairs and Tourism published "The White Paper of Environmental Management Policy" in 1997. This document identified, as a policy focus area, the "high levels of smoke and other pollutants in poorer urban and rural households without electricity and the impacts of the mining, energy, mineral and petro-chemical industries on air quality standards". This White Paper promoted the concept of sustainable development as being in the forefront of environmental management in South Africa.
- In May 2000, the White Paper on Integrated Pollution and Waste Management for South Africa was published. This policy document addressed pollution prevention, waste minimisation, impact management and remediation governance in South Africa, necessitating the introduction of a new approach to air quality management.

- The relevant national legally binding document with regards to air quality management in South Africa is currently the Air Quality Management Act (No 39 of 2004) (the AQA) which aims to control all major sources of pollution, and is managed by local government.
- Tools under the AQA include: regulation of emissions from point sources, ambient air quality standards for priority pollutants, and the development and implementation of air quality management plans at all spheres of government.
- The declaration and monitoring of National Priority Areas fits within this act. Priority area status moves policy control of the area from Provincial to National government (DEA 2012).

Provincial and district level policies and plans

- Following the 2012 declaration of the Waterberg-Bojanala Priority Area (WBPA), an Air Quality Management Plan (AQMP) is being developed as a proactive approach to managing air quality, while taking account of the level of development, including coal-based energy developments, known to be planned for the area over the coming years. The baseline characterisation report for the WBPA was published in July 2014. As a result of limitations in the data available, the information used to compile the AQMP uses a relatively coarse approach.
- The development of the AQMP is a six-step process, of which the baseline is the first step. Subsequent stages will involve:
  - Undertaking a gap and problem analysis;
  - Developing air quality vision and goals;
  - Developing an implementation plan, or intervention strategies and rules for implementation;
  - Implementing the intervention strategies; and
  - Monitoring, reporting and evaluating progress against the goals.

- Waterberg District Municipality produced its own air quality action plan in 2009. This plan contains several strategic goals for air quality; of key importance is the goal of maintaining "good air quality within the boundaries of the Waterberg District, with specific emphasis on PM_{10} and SO_2".

The World Bank recently commissioned a set of Regional Environmental and Social Assessment of Coal-based Energy Projects (RESA) specialist studies along the Waterberg coal belt expanding from the Waterberg District municipality across to the Botswana side of the border. Included therein are reports on air quality impacts on human health and/or biodiversity, surface water resource impacts, groundwater quality impacts, social impacts, economic impacts and climate change impacts. Once these studies have been completed, an Integrated RESA report is planned to bring together the findings (RESA Specialist Assessment Report: Air Quality (Task 2) 2014).

The area of influence (AOI) for air quality in the RESA report has been defined as a 300km wide (west to east) by 300km long (north to south) with a 50km area around current and proposed power plants. This area encompasses all three sites considered in this study.

Chapter Five: Scenario Description

Setting out scenarios for the Waterberg is a useful tool, because the region will be undergoing major changes in the near future, and scenarios can allow proactive decision making to occur based on the likely outcomes of these changes. Various sets of scenarios are being compiled in specialist reports for the Regional Environmental and Social Assessment of Coal-Based Energy Projects (RESA 2014), as well as for the Lephalale CBD Plan (2013). Outlined below are the scenarios set out by RESA for energy developments and air quality in the region, followed by scenarios of population growth as well as poverty and unemployment projections from the Lephalale CBD Plan. The findings of this study with regards to air quality perceptions and self-reported health outcomes will then be discussed in the context of the scenarios.

It is important to note that assessments such as these are undertaken at an early stage when limited information regarding the likely future development is available. Therefore, the scenarios have been based on reasonable working assumptions regarding the likely future developments (RESA 2014).

Energy Development Plans for the Region:

The RESA report outlines scenarios for thirteen current and proposed coal-based energy projects (four of which are existing or under construction and seven of which are proposed) near the Botswana and South Africa border which are expected to affect air quality and health outcomes in the region relevant to this study (Tables 13 and 14). A possible limitation of the report is that it states that mining impacts are more localized and does not set out scenarios for mines.

Table 13. Current and proposed coal based power stations on the South African side of the South Africa-Botswana border (RESA Air Quality report 2014).

	Plant /Phase	No. and size of units	Total gross output (MW)[a]	Developer	Location	Assumed commissioning year	Technology [b]	Coal source	Coal type	Coal burned (mtpa)[c]	Abatement technology[d]
	South Africa										
1	Matimba	6 x 665MW	3990	ESKOM	13km west of Lephalale, Lephalale municipality, Limpopo province	1988	Sub-critical, PF boiler	Grootegeluk	Washed	11.9	PM: electrostatic precipitators (ESP) and SO_3 plant
2	Medupi	6 x 800MW	4800	ESKOM	20km west of Lephalale, Lephalale municipality, Limpopo province	2016	Super-critical, PF boiler	Grootegeluk	Washed	13.9	PM: fabric filters NO_x: low NO_x burners SO_2: flue gas desulphurisation (FGD) introduced from 2024
3	Thabametsi	4 x 300MW	1200	Newshelf 1282 / Exxaro Resources	26km north west of Lephalale, Lephalale municipality, Limpopo province	2020	Circulating FBC (CFBC)	Thabametsi coal mine	Fieldstone Run of Mine	6.8	SO_2: direct limestone injection PM: ESP Water: dry cooling technology and dry ashing, zero liquid effluent discharge (ZLED) plant
4	Boikarabelo / Phase 1	3 x 15MW	45	Resgen	45 km west of Matimba Power Plant, Lephalale municipality, Limpopo province	2020	Circulating FBC (CFBC)	Boikarabelo mine	Discard coal, blended where necessary with beneficiated coal to ensure average coal quality of 15MJ/kg	0.3	SO_2: direct limestone injection NO_x: low combustion temp PM: fabric filters/ESP
	Boikarabelo / Phase 2	1 x 215MW	215			2024				1.1	
5	Remaining unknown IPP Phase 1	2 x 150MW	300	Unknown IPP	15km west of Medupi power station, Lephalale municipality, Limpopo province	2020	Circulating FBC (CFBC)	Thabametsi coal mine	Fieldstone Run of Mine	1.2	SO_2: direct limestone injection NO_x: low combustion temp PM: fabric filters/ESP
	Remaining unknown IPP Phase 2	4 x 150MW	600			2024				2.5	
6	Coal 3	5 sites, each 2 x 150MW	1500	ESKOM	Located at 5 different sites around the Waterberg District, relatively close to other energy projects in the region to represent a worst case	2034	Circulating FBC (CFBC)	Thabametsi coal mine	Discard coal	8.2	SO_2: direct limestone injection NO_x: low combustion temp PM: fabric filters/ESP
7	New PF plant	6 x 800MW	4800	ESKOM	Sited on one of the original Coal 3&4 preferred sites, approximately 40km west of Lephalale, Limpopo province	2034	Super-critical, PF boiler	Grootegeluk	Washed	13.9	PM: fabric filters NO_x: low NO_x burners

Table 14. Current and proposed coal based power stations on the Botswana side of the South Africa-Botswana border (RESA Air Quality report 2014).

	Botswana										
8	Morupule A	4 x 33MW	132	BPC	270km north of Gaborone and 5km west of Palapye, Serowe/ Palapye sub district, Central district	Currently de-commissioned, to be re-commissioned 2020.	Sub-critical, PF boiler	Morupule Coal Mine	Low grade (unwashed)	0.4	PM: fabric filters/ESP NO_x: low NO_x burners
9	Morupule B	4 x 150MW	600	BPC	Adjacent to the Morupule A plant	2014	Circulating FBC (CFBC)	Morupule Coal Mine	Low grade (unwashed)	1.7	SO_2: direct limestone injection NO_x: low combustion temp and SNCR if necessary to meet IFC emission limits PM: cyclones and fabric filters Water: recovery and re-use of water from ash ponds, wet ash handling system and recovery water system to be reused as slurry water.
10	Morupule B Units 5&6	2 x 150MW	300	Unknown IPP	Adjacent to the Morupule B plant	2020	Circulating FBC (CFBC)	Morupule Coal Mine	Low grade (unwashed)	0.1	SO_2: direct limestone injection NO_x: low combustion temp PM: fabric filters/ESP
11	Greenfield	2 x 150MW	300	Unknown IPP	60km west of Matimba power plant, Mahalapye sub district, Central district	2020	Circulating FBC (CFBC)	Mookane coal mine	Low grade (unwashed)	1.2	SO_2: direct limestone injection NO_x: low combustion temp PM: fabric filters/ESP
12	Mmamabula	Phase 1: 4 x 150MW Phase 2: 2 x 300MW	1200	JINDAL Africa	75km west of Matimba power plant, Mahalapye sub district, Central district	2024	Sub-critical, PF boiler	Mookane coal mine	Washed	4.3	SO_2: FGD NO_x: low NO_x burners PM: ESP
13	Mmamantswe	3 x 350MW	1050	African Energy	90km north east of Gaborone and 25km from SA border, Kgatleng district	2034	Super-critical, PF boiler	Mmamantswe mine	Washed	3.3	PM: ESP NO_x: low NO_x burners Water: air cooled condensers to reduce fresh water consumption, SO_2: option to retrofit FGD

RESA has grouped the power plants into the proposed scenarios to allow for assessment of the cumulative impacts and how these may change over time. Based on the information received from the governments of South Africa and Botswana and their respective national power utilities (ESKOM and BPC), the RESA team have identified the following power plant scenarios, which are defined by year, to take account of the phased introduction of the plants over the next twenty years. The current situation (with only Morupule B and Matimba power stations currently operational) is the baseline (2014) scenario. Moving towards the future, new scenarios are introduced after 2, 6, 10 and 20 years comprising of the baseline as well as all plants that will have been commissioned since the previous scenario. In this way, each scenario beyond the baseline builds on the previous ones so that the final scenario assessed includes all known existing and proposed plants (Table 15).

Table 15. Power Plant Scenarios set out in the RESA specialist Report on Air Quality (RESA Air Quality Report 2014).

Scenario	Year	Botswana energy projects included	South Africa energy projects included
1 (Baseline)	2014	Morupule B (Phase I) (4 units: total 600MW)[a]	Matimba (6 units: total 3990MW)
2 (Base + 2 years)	2016	Morupule B (Phase I) (4 units: total 600MW)[a] **Morupule A (recommissioned) (4 units: total 132MW)[a]**	Matimba (6 units: total 3990MW) **Medupi (6 units: total 4800MW, no FGD)[d]**
3 (Base + 6 years)	2020	Morupule B (Phase I) (4 units: total 600MW)[a] Morupule A (recommissioned) (4 units: total 132MW)[a] **Morupule B (Phase II) (2 units: total 300MW)[a]** **Greenfields IPP (2 units: total 300MW)[a]**	Matimba (6 units: total 3990MW) Medupi (6 units: total 4800MW, no FGD)[d] **IPP: Thabametsi (4 units: total 1200MW)** **IPP: Boikarabelo Phase 1 (3 units: total 45MW)** **IPP: Unknown IPP Phase 1 (2 units: total 300MW)[e]**
4 (Base + 10 years)	2024	Morupule B (Phase I) (4 units: total 600MW)[a] Morupule A (recommissioned) (4 units: total 132MW)[a] Morupule B (Phase II) (2 units: total 300MW)[a] Greenfields IPP (2 units: total 300MW)[a] **Mmamabula (Phase 1) (4 units: total 600MW)[b]** **Mmamabula (Phase 2) (2 units: total 600MW)**	Matimba (6 units: total 3990MW) **Medupi (6 units: total 4800MW, now with FGD)** IPP: Thabametsi (4 units: total 1200MW) IPP: Boikarabelo Phase 1 (3 units: total 45MW) IPP: Unknown IPP Phase 1 (2 units: total 300MW) **IPP: Boikarabelo Phase 2 (1 unit: total 215MW)** **IPP: Unknown IPP Phase 2 (4 units: total 600MW)[e]**
5 Base + 20 years	2034	Morupule B (Phase I) (4 units: total 600MW)[a] Morupule A (recommissioned) (4 units: total 132MW)[a] Morupule B (Phase II) (2 units: total 300MW)[a] Greenfields IPP (2 units: total 300MW)[a] Mmamabula (Phase 1) (4 units: total 600MW)[b] Mmamabula (Phase 2) (2 units: total 600MW) ***Mmamantswe (3 units: total 1050MW)[c]**	Matimba (6 units: total 3990MW) Medupi (6 units: total 4800MW, all with FGD) IPP: Thabametsi (4 units: total 1200MW) IPP: Boikarabelo Phase 1 (3 units: total 45MW) IPP: Unknown IPP Phase 1 (2 units: total 300MW) IPP: Boikarabelo Phase 2 (1 unit: total 215MW) IPP: Unknown IPP Phase 2 (4 units: total 600MW)[e] ***Coal 3 (10 units: total 1500MW)[f]** ***New pulverised fuel (PF) power station (6 units: total 4800MW)[g]**

Sources:

(a) List of power plant scenarios received from Botswana Department of Energy Affairs

(b) South Africa IRP (2013 update): Page 44: Preferred option for new coal generation is regional (i.e. Botswana) new coal development ("because it is expected that the [GHG] emissions from the generation will not count towards the South African total in a future global emission targeting regime"). Need to "…ensure the capacity is available in 2024 or 2025 as required". Page 32 of the updated IRP refers specifically to the inclusion of Mmamabula in the Base Case option.

(c) African Energy Resources presentation for investors (February 2014), available online at http://www.africanenergyresources.com/media/articles/Investor-Presentations/20140204-Investor-Presentation---February-2014-306/2014-02-04-AFR-Presentation.pdf

(d) Medupi Atmospheric Impact Report (AIR): Medupi is only expected to have FGD operational 6 years after commissioning of the generating units

(e) IRP (2013 update): Policy adjusted plan with ministerial determinations (Table 1)

(f) IRP (2013 update): Page 8: "Procurement for a new set of fluidised bed combustion (FBC) coal generation should be launched for a total of 1000-1500 MW capacity (as a preferable implementation of the "Coal 3" programme). It is recommended that these should be based on discard coal". Page 45: "…) the 'Coal 3' possibility should be limited to small-scale fluidised bed combustion".

(g) South African Coal Roadmap: Table 2, page 13. Size of plant assumed to be 4800MW.

Air Quality and Health:

The Air Quality Specialist Report (RESA 2014) presents air quality scenarios with 3 objectives in mind:

1. Avoid adverse impacts on human health by ensuring that ambient air quality concentrations of key pollutants are compliant with all applicable national air quality standards.

2. Where national ambient standards are met, increases in ambient concentrations due to the Project are kept to a minimum.

3. Avoid adverse impacts on ecology and agriculture, using the World Health Organization guidelines for critical levels of SO_2 and NO_2.

To date a preliminary assessment has been conducted, in which five scenarios have been set out, with current information (2014) being scenario 1 or the baseline and 2034 being scenario 5 or baseline+20years.

The 2014 prediction (scenario 1) includes exceedances of the annual mean and short term (24 hour, 1 hour and 10 minute) SO_2 standards at sensitive human health receptors. Increases in ambient concentrations due to energy projects are not kept to a minimum, as contributions to particulate matter concentrations are greater than 1% of the applicable standards. A relatively small area of exceedance of the WHO annual mean SO_2 guideline for agricultural crops and natural vegetation is predicted with a larger area exceeding the critical level for lichens. No exceedances of the annual mean NOx critical levels are predicted; however a small area downwind of Matimba was predicted to exceed the 24-hour NOx critical level.

The 2016 prediction (scenario 2) includes all the adverse impacts predicted in scenario 1, with the addition of exceedances of the short term (1 hour) NO_2 standard, and a relatively large area of

exceedance of the WHO annual mean SO_2 guideline as well as a larger area exceeding the critical level for lichens. A small area of exceedance of the annual mean NOx guideline is predicted immediately downwind of the Matimba and Medupi sites and the 24 hour NOx critical levels are expected to be exceeded over a relatively small area around the Matimba and Medupi sites.

This pattern in which the area and magnitude of exceedances increases with each new scenario continues for 2020 (scenario 3) 2024 (scenario 4) and 2034 (scenario 5).

None of the three objectives are met for any scenario, including the baseline, meaning that:

1. Human health will be adversely impacted from exceedances of national air quality standards for key pollutants;
2. Increases in ambient concentrations due to the energy-related project are not predicted to be kept to a minimum; and
3. Adverse impacts on ecology and agriculture measured against the World Health Organisation guidelines for critical levels of SO_2 and NO_2 are inevitable.

Growth Scenarios:

Lephalale town is set to become one of the largest cities in the province, due to booming mining and energy-related industries (Lephalale CBD Plan 2013). It therefore needs to be transformed from a small rural town to a city which plays a major role in South Africa. The challenge, and opportunity, in Lephalale is thus proactive planning for growth management. To this end, the Waterberg District Municipality commissioned the drafting of a CBD Development Plan for Lephalale (Lephalale CBD Plan 2013), which is based on the anticipated/projected future growth of the town as defined in the Lephalale Spatial Development Framework and Integrated Development Plan.

With regards to population growth, the Lephalale CBD Plan reported on two development scenarios, namely a Basic Growth Approach and an Exceptional Growth Approach. The exceptional growth scenario takes into account expected development related to the mining and energy sectors in the area, and attempts to extrapolate its expected impact on population figures. This scenario has been

formally adopted by provincial and local authorities for all planning purposes. According to the 2011 Census data, the estimated population of Lephalale Municipality is 115 768, of which 27 328 (23.6%) reside in the Lephalale Provincial Growth Point (PGP) comprising Lephalale Town (formerly Ellisras and Onverwacht) and Marapong Township. The population is almost equally divided between Lephalale Town and Marapong Township (Lephalale CBD Plan 2013). The Exceptional Growth approach estimated that a more than a doubling of the resident population will take place from 2011 to 2020. The growth is largely ascribed to the expected growth of the mining and energy sectors in the vicinity.

Other projections that consider the latest news on mining and energy-related developments in the Lephalale area estimate that the town will grow between four and five times its current size by 2030, if all foreseen developments take place within the projected timeframes (ibid 2013).

The CBD Plan includes sections on socio-economics, land use, transport, housing, environmental features and engineering services. A huge shortcoming of the plan is that neither air quality nor its health impacts in that area are considered. It is necessary to include air quality in any planning process for Lephalale especially in the context of the adverse impacts on human health predictions, which will be exacerbated by the poor socio-economic state of some communities. Another aspect that is missing from this planning document is the large disparity between Lephalale Town and Marapong Township and the surrounding areas. This disparity lends itself to a finer approach with interventions directed at the most vulnerable, in order to make the largest positive impact at the lowest cost.

Chapter Six: Discussion

There are three overarching areas for discussion that are necessary to bring this study together. Firstly the socio-economic drivers of impacts across sites, secondly the atmospheric impacts across sites and thirdly possible modes of intervention, linked to policy and other factors, that were identified in this study and elsewhere will be discussed. Each section will begin by discussing the results from this study and conclude by comparing and relating these to the wider knowledge base.

6.1 Socio-economic Drivers of Impacts across Sites

This study broadened the socio-economic knowledge collected in the Marapong study (Warnier et al. 2009), to include two other sites in the region. Upon comparison with Warnier and others, the results of this study from Marapong show some similarities and some differences. Respondents in the Marapong study, for instance, reported a much higher incidence of unemployment than in this study, but respondents in both studies show low levels of qualification with 54.5% of Warnier's respondents classifying themselves as un-skilled and 42% of Marapong residents in this study having a primary school level or no education. The fact that this study included part time and occasional work under the banner of employment may account for the discrepancy in unemployment responses, to some extent. A key similarity between the two studies was that both studies found residents of Marapong to have a very low understanding of air pollution, but that they rated their air quality as being good to excellent.

It was also found in the previous study as well as this one, that for residents with electricity, it is the energy source most used for both lighting and cooking. This is a very positive response to electrification when compared with other studies done on low-income households in other parts of South Africa (Annecke 1999; Mehlwana and Qase 1999), which are seen to reduce, but not eliminate, the consumption of other household fuels upon receiving electricity access. As Marapong is just one of the three sites surveyed in this study, the apparent buy-in of both the Marapong and Steenbokpan communities to electricity use will be discussed later in this section.

A first indication that the three sites have very different socio-economic characteristics is the fact that a much higher proportion of Lephalale residents are found to use private rather than public clinics, with the inverse pattern in Steenbokpan. This notion is supported by evidence with regard to most other socio-economic and energy related characteristics tested, in which socio-economic status can be set out in descending order as: Lephalale, Marapong, and Steenbokpan.

The gender of respondents from all three sites is skewed towards female respondents, which does not match the census data (2011) that indicated that at 54%, males are slightly more dominant than females in South Africa. The Lephalale CBD Plan (2013) attributes the high proportion of the male population within the Lephalale Municipality to the employment opportunities in the mining and industrial sectors, which are typically related to hard physical labour. The high proportion of female respondents in this study may, however, be linked to the fact that mothers are traditionally the primary caregivers responding to school requests, and attending medical visits with their offspring.

At 18-35 years old, most respondents from Marapong and Steenbokpan are young, which is often characteristic of communities with lower socio-economic statuses, as well as migrant labour settlements. This corresponds with the 2011 census data which indicate that the 15-34 age group constitutes the majority of the local municipality's population (Lephalale CBD Plan 2013). The fact that Lephalale displays a higher proportion of middle-aged residents could be expected when taking into consideration its higher socio-economic status.

Employment, social grants, poverty and crowding all showed Lephalale (a former white area) displaying characteristics associated with relative affluence when compared with Marapong and Steenbokpan (predominantly black African). These findings can be placed into the wider context that Limpopo, in which Lephalale is situated, was found (using the food poverty line) to be the poorest South African province, with a poverty headcount of almost 50% (Lephalale CBD Plan 2013). The CBD plan (*ibid* 2013) also indicated that the black African population to be the most severely affected by poverty, with 62% living under the upper-bound poverty line.

An anomaly to these observations is access to electricity, which displays the same trend of descending traits for Lephalale, Marapong and Steenbokpan, but in which the difference between Lephalale and Marapong is much less pronounced with 99% of households surveyed in Lephalale and 90% of those surveyed in Marapong being electrified (compared with a mere 17% in Steenbokpan). Marapong was thus found to have higher levels of electrification than might be expected based on the other socio-economic indicators tested. This may be a result of intensive electrification programs in the region as a very deliberate form of community outreach by Eskom (Spalding-Fecher and Matible 2003) which remain ongoing. Other manifestations of a deliberate Eskom presence in Marapong include signage indicating that upgrades to the Marapong school are funded by Eskom, and various Eskom marketing advertisements, such as that in Figure 28, which can be seen throughout the township. Community buy-in in Marapong may be so important because it is the site from which the power stations would be most visible.



Figure 28. Many walls around the township have been transformed into mediums for Eskom marketing.

Upon examination of the results regarding access to electricity (Figure 13) and energy sources used (Figure 14), it can be seen that a large proportion of those who have electricity are using it for lighting and cooking at all three sites. This implies that there is a high level of buy-in to use electricity, as opposed to some level of reluctance which is characteristic of traditional African villages. The 'buy-in' process is complex, involving many social and cultural as well as economic factors (Mehlwana and

Qase 1999), but a possible explanation for the enthusiasm to use electricity displayed by residents in Marapong and Steenbokpan may lie in the fact that these communities are transient rather than traditional, due to their history and nature as migrant worker settlements.

Although Marapong has a high level of electricity access in relation to its general socio-economic status, most dwellings do not have ceilings. This decreases the insulation potential of the dwellings, and makes Marapong similar to Steenbokpan, in that people at these sites require more energy to perform cooking or heating functions as a result of poor insulation. This is an example of how "the poor are benefiting less than the non-poor from free basic services such as free electricity, free water, free sanitation, etc. because of their disproportionate exclusion from access to the relevant services" (Statistics South Africa 2012).

The positioning of the three sites is also of interest with Marapong being placed in much closer proximity to emissions sources, Matimba and Medupi, than Lephalale. This is a typical result of the apartheid planning referred to by Wright Garland and Thambiran (2011), in which black labour communities were zoned closer to emissions sources. There are currently international calls being made for land-use planning to deliberately separate people from pollution (Wisham 2011).

The distinctly different socio-economic profiles of the three sites means that their degree of vulnerability and adaptability to changes in air quality differs. Those without electricity for example, would be expected to have increased exposure from domestic fuel burning. While Marapong has electricity, the lack of insulation in homes means that increased energy usage is required, thus increasing expense to a poor community, and possibly leading to the wide range of alternatives energy forms used, as seen in the energy usage section of the results chapter.

The differences in air quality perceptions and self-reported health outcomes between the three sites was found to not always be in accordance with the trend expected based on their socio-economic profiles, necessitating the consideration of other influencing factors. Steenbokpan for example, has the most domestic burning, but the responses from that site dominate in the air pollution rating "low". The assumption that this rating is a result of a low level of understanding of what air pollution is was

however refuted, as most respondents were found to either have a partial or good understanding of air pollution. This could be linked to the environmental education initiatives of Earthlife Africa and other NGOs which Jeremiah mentioned during his key stakeholder interview. The information given in these meetings could have improved the Steenbokpan community's air pollution understanding in theory, but although people understand what air pollution is, and despite their exposure from domestic and industrial sources, air pollution was still rated as being low. An explanation for this might lie in the priorities revealed by the thematic analysis of qualitative information, in which the intervention suggested by most residents of Steenbokpan to address the problem air pollution was electrification. This can be viewed through the lens of Maslow's hierarchy of needs, in which the priority of that community is their immediate need for electricity. The direct positive impact that electricity will have on their lives plays a more predominant role in their psyches than concerns about current or future air pollution.

An interesting finding was that high proportions of people from all three sites perceive the health of their households over the last two years as "the same" or "better" with 25% of residents from Lephalale perceiving the health of their households as worse, compared to only 11% from the other two sites. Previous studies in low-income communities in other parts of the country have also shown high percentages of respondents to perceive the health of their household as being good (John *et al.* 2008 and Wright *et al.* 2011).

Those living in Lephalale were found to report more respiratory symptoms. This corresponds with findings of previous studies which indicate that despite research repeatedly having identified an association between health and socio-economic status in which richer people are healthier than poorer people (Wilkinson 1986, Davidson, Kitzinger and Hunt 2006), people from poorer neighbourhoods are equally or less likely to perceive their health worse than their more socially advantaged counterparts (Macintyre, McKay and Ellaway 2005). The fact that the poor may be less likely to acknowledge the social gradient in health makes them even more at risk of ill health, and could, in part, be a consequence of poor understanding. Barnes'(2010) focus group discussions among an intervention and a control group in the rural North West Province showed a noticeable improvement in health understanding in the intervention group, influencing behavioural change to reduce exposure to indoor air pollution. This

points to behavioural intervention as a cost-effective option in increasing the adaptive capacity of poor communities.

Other factors that influence health perceptions are cultures, 'traditional' beliefs and local knowledge systems, and although this did not fall within the scope of this study, they must be acknowledged. Moreover, health is multi-dimensional, and is impacted on by poverty in various ways, some of which, such as diet, are not included in this study.

While it is important to understand the wider dynamics of the region, the differences in the socio-economic status and perceptions between the three sites surveyed in this study highlight the importance of scale at a community level. The socio-economics of people in Marapong and Steenbokpan mean that they face different risks and challenges, from those in Lephalale, making them more vulnerable to air pollution related illnesses. The community-scale interventions which will be discussed in section three are drawn from the survey results and thus focus on increasing the resilience of people in communities such as Marapong and Steenbokpan.

6.2 Atmospheric Impacts across Sites

When viewed through the World Health Organisation's 2005 framework of ecosystem services, it is clear that the ecosystem in the WBPA is disrupted. This is illustrated by the fact that the air quality monitoring stations are already showing pollution levels exceeding the thresholds which the atmosphere can regulate (Moodley *et al.* 2014). Monitoring station data also indicate that Marapong is predicted to be more negatively impacted by ambient air pollution than Lephalale. The RESA scenarios based on reasonable working assumptions regarding the likely future developments predict the air quality situation in the region as worsening progressively over the next twenty years (RESA 2014).

Data from the long term ambient air quality monitoring stations in Lephalale and Marapong does not correspond with air quality perceptions in any clear way. Monitoring stations in Lephalale indicated that levels of all four priority pollutants for human health were within compliance of national standards, yet

49% of respondents from Lephalale perceive pollution to be within the range of high to very high. Monitoring stations in Marapong showed higher levels of pollution with exceedances in SO_2, PM_{10} and $PM_{2.5}$. The frequent exceedances of the national 24 hour PM_{10} and $PM_{2.5}$ limits of 120µg/m^3 and 65 µg/m^3 (Air Quality Management Act No 39 of 2004) in Marapong are of particular concern because PM particles are said to affect the health of more people than any other pollutant (WHO 2014). The burning of biomass fuels is a likely cause of the higher levels of particulates in Marapong. Yet at 44%, a slightly lower percentage of respondents from Marapong report perceiving pollution to be within the range of high to very high, than their counterparts from Lephalale.

In contrast with the air quality reality, 25% of residents from Lephalale perceive the overall health of their households as worse, compared to only 11% from the other two areas. The largest proportion of respondents from Marapong-65%-perceive their household health over the last two years as having improved. As this is a baseline study, there are no data with which to confirm or compare this value. It is, however, comparable with other low income communities in South Africa, who despite high levels of air pollution, perceived their health to be good (John *et al.* 2008, Wright *et al.* 2011). Perceptions of improved household health may be linked to other factors such as electrification, which residents of Marapong perceive as improving their quality of life. Marapong also has the most people with little understanding of air quality. Therefore, not only is Marapong poorer and thus more vulnerable to the impacts of air pollution, it is also more severely impacted with the highest pollution levels as compared to neighbouring communities.

6.3 Possible Modes of Intervention Identified in this Study and Elsewhere:

The scenarios set out in chapter five confirm that national limits of air pollutants have been exceeded and that further exceedances are expected as a result of future developments in the region. This renders the ecosystem service of air quality regulation (WHO Millennium Assessment 2005) in the Waterberg disrupted to a point which will have negative impacts on human health and biodiversity, thus necessitating intervention.

The set of scenarios being compiled for the Regional Environmental and Social Assessment of Coal-Based Energy Projects is for all intents and purposes, one scenario over a twenty year time period which shows a pattern in which the area and magnitude of air pollution exceedances and adverse impacts increases over time (RESA 2014). There are no scenarios that can be likened to the Maximum Feasible Reductions (MFR) scenario in the international studies (Likhvar *et al.* 2015). This means that the only reasonable working assumption currently regarding the likely future developments guarantees that national legislation requirements in the area will not be met. These plans are, however, consistent with the South African government's climate response policy of increasing emissions until 2025 and stabilizing for ten years, prior to a possible decline, conditional on the provision of international funding and technology (Nteo *et al.* 2011).

Intervention can take various forms. In the first place, air quality limits should be adhered to, but as is evident from the ambient air quality data in Marapong, this is not always the case. Furthermore, the air quality itself is not the only factor influencing health. Addressing such secondary factors can mitigate the impacts. The factors that influence air pollution understanding and perceived household health thus point towards possible modes of intervention. Qualification of respondent, subscription to medical aid and presence of a ceiling on the dwelling came up as associated with air pollution understanding, as well as overall rating of household health over the last two years. This points to education, formal job creation and infrastructure improvements, such as the installation of ceilings on homes and electrification, as possible interventions.

A study on health behaviour change intervention on indoor air pollution indicators in the rural North West Province of South Africa indicated that the intervention group performed significantly better than the control group (Barnes, Mathee and Thomas 2011). The authors point out that effective educational and behavioural interventions are research intensive in order to target relevant issues, but an advantage of these interventions is that they are relatively inexpensive. The lack of basic understanding around air pollution and health in Marapong specifically, means that any educational intervention should begin by explaining air pollution in terms of its causes and effects. The improved understanding of these issues in the Steenbokpan area suggests that the non-governmental educational outreach by Earthlife Africa may be improving that communities' understanding and perceptions around air pollution and health.

Dwelling modifications are a common intervention in terms of air pollution and health in the developing world. There is evidence from India that suggests whether the kitchen is separate from the living area as well as the quality of ventilation to be the strongest predictors of indoor air pollution (Mehta and Shahpar 2004). Similarly, a study in Guatemala found that larger burning environments reduce concentrations of pollutants by every unit increase in volume (Albalak *et al.* 2001). A possible dwelling modification identified in this study is the installation of ceilings. Ceilings would increase insulation in the home, decreasing the amount of fuel needed to fulfil cooking and heating purposes. The disadvantage of dwelling modifications is that they are often expensive and require commitment from government to be rolled out at the necessary scale.

Electrification is an interesting intervention recommendation in that there are positive and negative aspects to it, depending on the scale considered. International studies of externalities in the electricity sector usually focus on the damages caused by air pollution and other negative environmental consequences. In developing countries, electrification creates significant health benefits by displacing ''dirtier'' fuels such as wood, coal and paraffin (Spalding-Fecher 2005). A study conducted in rural South African villages by Röllin and others (2004) found that concentrations of PM significantly higher in un-electrified homes compared to homes where electricity was used.

The lack of adequate healthcare services was strongly articulated in the Marapong focus group meeting. Residents complained of long waits due to the short hours and insufficient staffing of the public clinic located at their site. It is recommended that the Department of Health assess the situation, taking into consideration the massive population growth predicted.

Another recommendation linked to the Department of Health relates to health records of respiratory related admissions and treatments. These data are not currently collected for any clinics in the country, resulting in a huge gap in our knowledge of the current health status of the region. Incorporating this into the bureaucratic processes and making the data available for research would go a long way in improving our understanding of health impacts.

It must also be kept in mind that there is a major challenge in that we do not know what is contributing to levels at measuring stations. Certain results could be an anomaly affected by a single source close to the station, such as the closest homes. This brings the reliability of air quality data into question. It would be preferable if there were two or more sources of air quality information for each site, for the triangulation of data.

The World Bank commissioned studies are building a set of scenarios that concentrate on mining and energy developments. But both the World Bank studies and the Waterberg Bojanala Air Quality Management Plan do not consider the impacts domestic fuel burning in their scenarios. This is a real weakness, because there is evidence that strongly suggests that biomass fuel burning has a significant impact on air quality in Marapong (Moodley *et al.* 2014). The reason that this factor has largely been disregarded is the large information gap. Impact studies on transport, refuse burning and domestic contributions to air pollution are needed to improve our understanding of the region, and allow for better informed interventions to be identified.

The interventions and recommendations discussed thus far involve individual and collective actors, various spheres of government, business and research. There are also interventions that more directly involve industrial emitters. One such intervention is SO_x and NO_x abatement technology, which could be fitted on all Eskom power stations in the area. Short-term air quality limits were found to be exceeded in

SO_2, PM_{10} and $PM_{2.5}$ even before the operation of the Medupi Power Station (Ninham Shand (Pty) Ltd 2008), making it clear that SO_2 abatement technology is necessary to stay within legislated standards for SO_2. The abatement technology would however only decrease sulphur emissions.

A combination of interventions at different scales will be necessary to minimize negative impacts on human health across the region. The varied circumstances of the sites surveyed highlight the importance of community-based intervention, in order to protect the most vulnerable communities and build a more resilient regional picture in terms of respiratory health. Since human health is a multi-dimensional area, interventions aimed at improving health can arise from various sectors such as healthcare, infrastructure and legislative means. One approach towards identifying which interventions to implement would be to conduct a cost-benefit analysis of the modes of intervention identified in this study, in order to determine which would have the greatest positive impact at the lowest cost.

Conclusion

The surveys conducted at the sites confirmed three distinct socio-economic groups, demonstrating a large social and economic disparity between different communities. Some interesting findings of the study are, firstly, that the poor view themselves as less sick, and secondly that the poor have worse air quality, placing them in a very vulnerable position. Secondary interventions identified in this study are recommended to target the fields of education, formal job creation and infrastructure improvements (specifically installing ceilings and electrification). With the huge growth rates expected in Lephalale, there are opportunities for 'proactively planning' which takes into consideration interventions such as adequate insulation in the planning of government subsidized housing. In order for this study to inform decision-making at different levels key findings will be reported back to various organisations including the Waterberg Bojanala Priority Area Multi-stakeholder reference group, which includes a variety of stakeholders including government; uMoya-Nilu, the company commissioned with compiling the Waterberg Bojanala Priority Area Air Quality Management Plan (WBPA AQMP); and Earthlife Africa, an NGO involved with community educational programs in the region. Future studies in this area should focus on health records, cultural or traditionally driven perceptions and cost-benefit analyses.

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Appendix 1: Survey Documents

Project Title: Health in Waterberg, Up in Smoke? Participant Information Sheet

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Good day. You are being invited to take part in a research study that will be conducted by me, Ms Adela Itzkin, an MSc researcher from the University of the Witwatersrand.

The study will be focusing on the links between real and perceived air quality and health in your community. The reason for the study is to understand what people think of the air quality in their environment, as well as the impacts that this may have on their health. I am conducting this research as part of my university studies, but the information I gather may be interesting and useful to government and local communities interested in the research.

The study involves a ten minute questionnaire. You will be asked a number of questions about your household, your use of resources and your understanding of your air quality and health. While the questions will ask you to provide certain information about the people living in your house, **no** names will be used in any results, documents or reports with which this research project is concerned. Yours and your family's identities and information about your house will remain safe and anonymous at all times during and after the study.

Your participation in this study is voluntary and you may choose to stop being a part of the study at any time. You may also refuse to answer any questions with which you are not comfortable.

Many Thanks

Adela Itzkin

Cell Number: 082 801 2420

E-mail: adikind@gmail.com

Supervisor: Prof Mary Scholes

Office Number: 011 717 6407

Email: mary.scholes@wits.ac.za

Participant Consent Form (Questionnaire)

I was invited to participate in the research project conducted by Ms Adela Itzkin from the University of the Witwatersrand and I understand my role in the study.

I understand that the reason for the study is to understand what people think of the air quality in their environment, as well as the impacts that this may have on their health. I understand that this project is voluntary.

I am aware of time required to fill out the questionnaire.

I understand that the researcher will not identify me or my family by name in any reports using information obtained from this interview.

I volunteer to participate in the research project and I therefore agree to be one of the possible 100 people being interviewed.

_____ _____

Participants Signature Date

Interview Details:

Venue (School or clinic name): ……

Date: …….

Participant Gender: Male Female

Participant Age: 18-35 36-50 50+

Section A: Socio-Economic Livelihood Assessment							
Where do you live?	Ellisras	Marapong	Steenbokpan	Other (Please specify): …….			
How Long have you lived in your area?	Less than 6 months	1-2 years	3-5 years	6-9 years	10-12 years	13-15 years	Longer than 15 years
How many people (adults and children) are presently living in this house?	1-2	2-4	5-6	7-9	10-12	13-15	More than 15
Are you Employed?	Yes : Part time	Yes: Full time	No				
If you are employed what type of work do you do?							
D you have any of the following educational qualifications?	No formal education	Primary School	High School	Diploma	Trade	Tertiary Education	
Are other persons in the house employed?	Yes	No					
If you answered yes to the last question please explain how many people are employed and what type of work they do.							
What is this home's combined monthly income (by paid work and social or child grants)? o	R0-R500	R500-R1399	R1400-R2499	R2500-R3999	More than R4000		
How many people living in your home receive social grants?							
Is your family structure:	Married	Divorced	Single Parent	Other: ……..			
Do you have a medical aid scheme?	Yes	No					
What is the cost of transport to get to the Dr/Clinic?							
What are the medical charges for each visit?							

Section B: Lighting, Heating, Cooking and Resource Usage		
Do you pay rent for your home?	Yes	No
Do you have electricity in your home?	Yes	No

If yes to the last question how much does it cost you for electricity each month?	Less than R50	R51 to R100	R101 to R150	R151 to R200	R201 to R250	More than R250	
What fuel/s do you use for **lighting** in the home? (Please tick more than 1 if necessary)	Electricity	LPG (Gas)	Paraffin	Coal	Wood	Candles	Other
What fuel/s do you use for **cooking** in the home? (Please tick more than 1 if necessary)	Electricity	LPG (Gas)	Paraffin	Coal	Wood	Candles	Other
How many people living in the home smoke?	0	1	2	3	More than 3		
Does smoking happen <u>inside</u> the home?	Yes	No					
Does the house you live in have a ceiling?	Yes	No					
How many bedrooms are there in your home?	1	2	3	4	More than 4		

Section C: Air Quality Perceptions				
Have you ever heard of air pollution?	Yes	No		
If yes, from where?				
Please explain what air pollution (or bad air) is in your own words				
What is the air pollution like in your area?	Very high	High	Fair	Low
If you answered very high or high to the last question please indicate what the main cause of air pollution is in your area.				

Do you feel that the air pollution in the area where you live affects your health?	Yes			No		
Do you think the air pollution in the Waterberg is a problem?	Yes			No		
What do you think are the <u>most important</u> sources of air pollution in your area? (Rate 1 to 6, with 1 being the most important and 6 being the least important)	Motor vehicles	Power stations	Cigarette smoke	Open fires	Household fires	Mines
Does the making of electricity in your area affect the air pollution where you live?	Yes			No		
What can be done to make the air in your area better?						

Section D: Respiratory Health Perceptions			
Please think about whether you or anybody else in the home has suffered from any of these health problems in the last year:	Productive cough (with phlegm)	Dry cough	Sore throat
	Blocked nose	Runny nose	Sneezing
	Fever	Sore ears	Teary/watery eyes
	Rapid breathing	Wheezing	Tight Chest
	Shivering	Muscle pain	Skin rash
For each person who suffered any of the above health problems in the last year, please fill out:			

Person 1:	Unemployed		Employed		Scholar	Child
Age :	0-10 yrs	11-20 yrs	21-30 yrs	31-40 yrs	41-50 yrs	Older than 50 yrs
Which Problems did the person suffer from? (Please tick more than one if necessary)	Productive cough (with phlegm)		Dry cough		Sore throat	
	Blocked nose		Runny nose		Sneezing	
	Fever		Sore ears		Teary/watery eyes	
	Rapid breathing		Wheezing		Tight/sore Chest	
	Shivering		Muscle pain		Skin rash	
Comments:						
Did the person go to the clinic, hospital or doctor?	Yes			No		
Was the person diagnosed with any of the following?	Respiratory Tract infection	Tuberculosis (TB)		Bronchitis	Pneumonia	
	Asthma	Allergies/Hay Fever		Heart Disease	Lung Disease	
	Esophageal cancer	Lung Cancer		Other (Please state):		
The person is:	Not using any medication		Using medication bought from a chemist		Using medication prescribed by a doctor	
What time of the year are they the most sick?	Autumn	Winter	Spring	Summer	All the time	

Person 2:	Unemployed		Employed		Scholar	Child
Age :	0-10 yrs	11-20 yrs	21-30 yrs	31-40 yrs	41-50 yrs	Older than 50 yrs
Which Problems did the person suffer from? (Please tick more than one if necessary)	Productive cough (with phlegm)		Dry cough		Sore throat	
	Blocked nose		Runny nose		Sneezing	
	Fever		Sore ears		Teary/watery eyes	

	Rapid breathing		Wheezing		Tight/sore Chest
	Shivering		Muscle pain		Skin rash
Comments:					
Did the person go to the clinic, hospital or doctor?	Yes		No		
Was the person diagnosed with any of the following?	Respiratory Tract infection	Tuberculosis (TB)	Bronchitis	Pneumonia	
	Asthma	Allergies/Hay Fever	Heart Disease	Lung Disease	
	Esophageal cancer	Lung Cancer	Other (Please state):		
The person is:	Not using any medication	Using medication bought from a chemist	Using medication prescribed by a doctor		
What time of the year are they the most sick?	Autumn	Winter	Spring	Summer	All the time

Person 3:	Unemployed	Employed	Scholar	Child		
Age :	0-10 yrs	11-20 yrs	21-30 yrs	31-40 yrs	41-50 yrs	Older than 50 yrs
Which Problems did the person suffer from? (Please tick more than one if necessary)	Productive cough (with phlegm)	Dry cough	Sore throat			
	Blocked nose	Runny nose	Sneezing			
	Fever	Sore ears	Teary/watery eyes			
	Rapid breathing	Wheezing	Tight/sore Chest			
	Shivering	Muscle pain	Skin rash			
Comments:						
Did the person go to the clinic, hospital or doctor?	Yes		No			
Was the person diagnosed with any of the following?	Respiratory Tract infection	Tuberculosis (TB)	Bronchitis	Pneumonia		
	Asthma	Allergies/Hay Fever	Heart Disease	Lung Disease		
	Esophageal cancer	Lung Cancer	Other (Please state):			
The person is:	Not using any medication	Using medication bought from a chemist	Using medication prescribed by a doctor			
What time of the year are they the most sick?	Autumn	Winter	Spring	Summer	All the time	

Is the health of those living in the home better, worse or the same as it was 2 years ago?	Better	Worse	The same
If you have any other comments you would like to add please do so here:			

Request to attend focus group session

Because this study is about the views of your community, it would make the study more valuable if I could talk directly with you about the questions you answered in the questionnaire. I would therefore like to invite you to attend a short focus group discussion. The discussion will be held at your child's school, between on November, and will last approximately an hour. The identities of people attending the focus group session will remain anonymous. Refreshments will be served.

Please indicate below if you may be able to attend such a session, and if so, provide me with a contact number in order to make the arrangements.

I may be able to attend an hour long discussion at my child's school: Yes / No

Contact number: ……

Appendix 2: Ethics Clearance Certificate

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Itzkin

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER H13/05/11**
PROJECT TITLE	Health in the Waterberg; up in smoke?
INVESTIGATOR(S)	Ms A Itzkin
SCHOOL/DEPARTMENT	Animal Plant and Environmental Studies
DATE CONSIDERED	17/05/2013
DECISION OF THE COMMITTEE	Approved Unconditionally
EXPIRY DATE	11/08/2015

DATE 12/08/2013 **CHAIRPERSON** (Professor T Milani)

cc: Supervisor : Prof MC Scholes

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10003, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature

19 / 09 / 2013
Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES