Air Pollution in Nairobi Slums: Sources, Levels and Lay Perceptions

Kanyiva Muindi
Air Pollution in Nairobi Slums: Sources, Levels and Lay Perceptions

Kanyiva Muindi

Department of Public Health and Clinical Medicine
Epidemiology and Global Health
Umeå University, Sweden 2017
To my late parents Koki and Muindi
who instilled in me the desire to reach beyond…
“Clean air is a public good; indeed no other resource exhibits the same degree of ‘publicness’. Land can be parcelled and fenced; Water can be bottled; Scenery can be hidden; One can even isolate himself from noise; But man has no choice but to breathe the air around him – polluted or not.” -Anonymous
Table of Contents

Abstract .............................................................................................................................. vii
Contributing Papers ........................................................................................................ ix
Abbreviations and Acronyms ......................................................................................... x
Prologue .......................................................................................................................... xi
Background ...................................................................................................................... 1
  Slum health: an emerging public health issue in the 21st century ..................................... 1
  Air pollution: an under-researched environmental and health hazard in Africa ............... 3
  Air pollution and its impacts on health ............................................................................. 6
  Why PM2.5? ..................................................................................................................... 7
  Lay perceptions of air pollution exposure and its risk ....................................................... 7
  The social context of air pollution in the Nairobi setting ................................................ 8
  The winners and losers of social development ............................................................... 9
  The gendered exposure to air pollution ........................................................................... 11
Aims and objectives .......................................................................................................... 12
Specific objectives ........................................................................................................... 12
Conceptual framework ..................................................................................................... 13
Methods .......................................................................................................................... 17
  Study context .................................................................................................................. 17
  Study design .................................................................................................................... 19
  Quantitative studies ....................................................................................................... 19
  Qualitative study ............................................................................................................ 23
  Ethical considerations ................................................................................................... 26
Results ............................................................................................................................ 27
  Driving forces: perceived drivers of air pollution in slums ............................................. 27
  Pressure, state/exposure: sources and levels of indoor PM$_{2.5}$ ..................................... 28
  Pressure, state/exposure: perceptions about indoor and outdoor air pollution ............... 34
  Effects: Perceived health effects of air pollution .......................................................... 35
  Perceived actions to address air quality issues ............................................................... 36
Discussion .................................................................................................................................. 37
Pressure, state/exposure: sources and levels of PM$_{2.5}$ ......................................................... 37
Perceptions of and attitudes towards air pollution ...................................................................... 40
Effects: perceived health effects ............................................................................................... 42
Perceived actions to address air pollution ................................................................................ 43
Methodological considerations .................................................................................................. 44
Strengths ..................................................................................................................................... 44
Limitations ................................................................................................................................... 45
Conclusion ................................................................................................................................... 46
Implications for Policy ............................................................................................................... 47
Future Research .......................................................................................................................... 48
Acknowledgements .................................................................................................................... 49
References ................................................................................................................................... 51
Annexes ....................................................................................................................................... 65
Abstract

Background Air quality in Africa has remained a relatively under-researched field. Most of the African population is dependent on biomass for cooking and heating, with most of the combustion happening in low efficiency stoves in unvented kitchens. The resulting high emissions are compounded by ingress from poor outdoor air in a context of poor emissions controls. The situation is dire in slum households where homes are crowded and space is limited, pushing households to cook in the same room that is used for sleeping. This study assessed the levels of particulate matter with aerodynamic diameter $\leq 2.5$ microns ($PM_{2.5}$) in slum households and people’s perceptions of and attitudes towards air pollution and health risks of exposure in two slum areas, Viwandani and Korogocho, in the Nairobi city.

Methods The study employed both qualitative and quantitative methods. For the quantitative study, we used structured questionnaires to collect data about the source of air pollution among adults aged 18 years and above and pregnant women residing in the two study communities. We used the DustTrak™ air samplers to monitor the indoor $PM_{2.5}$ levels in selected households. We also collected data on community perceptions on air pollution, annoyance and associated health risks. We presented hotspot maps to portray the spatial distribution of perceptions on air pollution in the study areas. For the qualitative study, we conducted focus group discussions with adult community members. Groups were disaggregated by age to account for different languages used to communicate with the younger and older people. We analysed the qualitative data using thematic analysis.

Results Household levels of $PM_{2.5}$ varied widely across households and ranged from 1 to 12,369$\mu g/m^3$ (SD=287.11). The household levels of $PM_{2.5}$ levels were likely to exceed the WHO guidelines given the high levels observed in less than 24 hours of monitoring periods (on average 10.4 hours in Viwandani and 11.8 hours in Korogocho). Most of the respondents did not use ventilation use in the evening which coincided with the use of cookstove and lamp, mostly burning kerosene. The levels of $PM_{2.5}$ varied by the type of fuels, with the highest emissions in households using kerosene for cooking and lighting. The $PM_{2.5}$ levels spiked in the evenings and during periods of cooking using charcoal/wood. Despite these high levels, residents perceived indoor air to be less polluted compared with the outdoor air, possibly due to the presence of large sources of emissions near the communities such as dumpsites and industries. The community had mixed perceptions on the health impacts of air pollution, with respiratory illnesses perceived as the main consequence while vector or sanitation related diseases such as diarrhoea was also perceived to be related to air pollution.
**Conclusions** With poor housing and reliance on dirty fuels, households in slums face potentially high levels of exposure to PM$_{2.5}$ with dire implications on health. To address the poor perception on air pollution and knowledge gaps on the health effects of air pollution, education programs need to be developed and tailored. These programs should aim to provide residents with information on air quality and its impact on the health; what they can do as communities as well as empower them to reach out to government/stakeholders for action on outdoor sources of pollution such as emissions from dumpsites or industries. The government has a larger role in addressing some of the key pollution sources through policy formulation and strong implementation/enforcement.

**Keywords:** Air pollution, perceptions, slums, health impacts, Nairobi.
Contributing Papers

This thesis is based on the following four papers:


4. Muindi K, Kimani E and Ng N. Lay perceptions of the health impacts of air pollution: voices from Nairobi’s slums. In manuscript.

The original papers are published in Open-Access journal, and the authors retain the right of the manuscript.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>APHRC</td>
<td>African Population and Health Research Center</td>
</tr>
<tr>
<td>CO</td>
<td>Carbon Monoxide</td>
</tr>
<tr>
<td>COPD</td>
<td>Chronic Obstructive Pulmonary Disease</td>
</tr>
<tr>
<td>DPSEEA</td>
<td>Driving force-Pressure-State--Exposure-Effect-Action</td>
</tr>
<tr>
<td>DPSIR</td>
<td>Driving force-Pressure-State-Impact-Response</td>
</tr>
<tr>
<td>FGD</td>
<td>Focus Group Discussion</td>
</tr>
<tr>
<td>HIV</td>
<td>Human Immunodeficiency Virus</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome</td>
</tr>
<tr>
<td>LMICs</td>
<td>Low- and Middle- Income Countries</td>
</tr>
<tr>
<td>LPG</td>
<td>Liquefied Petroleum Gas</td>
</tr>
<tr>
<td>MEME</td>
<td>Multiple Exposures-Multiple Effects</td>
</tr>
<tr>
<td>MIYCN</td>
<td>Maternal, Infant and Young Child Nutrition</td>
</tr>
<tr>
<td>NIMBY</td>
<td>Not In My Backyard</td>
</tr>
<tr>
<td>NOx</td>
<td>Oxides of Nitrogen</td>
</tr>
<tr>
<td>NUHDSS</td>
<td>Nairobi Urban Health and Demographic Surveillance System</td>
</tr>
<tr>
<td>PM</td>
<td>Particulate Matter</td>
</tr>
<tr>
<td>SCALE-UP</td>
<td>Sustainable model for Cardiovascular health by Adjusting Lifestyle and treatment with Economic perspective in settings of Urban Poverty</td>
</tr>
<tr>
<td>SO2</td>
<td>Sulphur Dioxide</td>
</tr>
<tr>
<td>SSA</td>
<td>sub-Saharan Africa</td>
</tr>
<tr>
<td>VOCs</td>
<td>Volatile Organic Compounds</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>
Prologue

A journey of a thousand miles begins with one step, so the adage goes, and my first step into this journey started since I was old enough to cook, perhaps at the age of eight years. I grew up in a rural community where the norm was (and still is) for girls and women to cook for the family, mostly over an open fire. I disliked the smoke that was constantly emitted by firewood, which got worse in the rainy season when drying the fuel wood was almost impossible. As any young girl growing up in the village, I yearned for a better life; and throughout my high school years, I kept tabs on local solutions for stoves that were invented to save fuel wood and reduce the amount of smoke emitted and encouraged my mother to try some of these. My college years somehow led me down a different path and my concerns over indoor environments took a back seat until I got a job. I had not been prepared for the area of assignment and like many city residents, I had never ventured into what would become my ‘office’ for several years. My new job as a research assistant involved working in the slums and the first day hit me so hard I could not come to terms with the living conditions in these settlements. My concern over these settings continued long after that first assignment was over. As fate would have it, my working life would remain intertwined with slums for some years.

The defining moment came when I was visiting one respondent who was an older woman living alone in one of the study communities. I got into her little home, whose walls were made of mud and the roof was an array of tins, covered with plastic. As is customary in Kenya, a visitor is usually welcome with a cup of tea, and she offered to prepare one for me. I quickly noted that she was lighting her three-stone (more on this later in the thesis) using not wood or other forms of biomass but plastic waste. The smoke and smell were overpowering and thankfully she noticed my struggle to breathe and offered to sit outside for the interview. I did not get to drink the tea as the flames could not remain alight for long to boil two cups of water.

I could not comprehend how this lady managed to make any food on such a stove. I was so depressed by this experience I left for home early that day; not to run away from her situation, but to just go and think if there was something, anything that could be done to address this challenge. And so an obsession was born; I was observant of both indoor and outdoor environments, picking out sources of pollution; poring through data to see the trends in cooking and lighting fuels. I knew I would one day work on something touching on indoor environments, and hopefully open an opportunity for me to work with communities to identify local solutions to some of these challenges.

Fast forward to 2010; I met Prof Stig Wall in Nairobi and we got a chance to speak about possibilities of graduate training in Umeå. When the news came confirming that this was indeed possible, I was excited to finally get a chance to work on something I am passionate about. I am glad I was given an opportunity to follow my passion, while at the same time gaining skills that would be used in my home country and on the African continent to work with communities towards making the air within homes safe.
Background

This thesis addresses air pollution in two urban slum settlements in Nairobi, Kenya with specific focus on sources and levels of fine particulate matter across selected households in the study communities and people’s perceptions of and attitudes towards air pollution and its health risks. The thesis is organized as follows: the first part provides an overview of urban health problem specifically related to air pollution, factors that impact air quality, population perceptions of exposure to air pollution and its associated health risk. The first section ends with a presentation of the conceptual framework guiding this thesis, the overall and specific objectives of the thesis. The second section discusses the methods of studies included in this thesis, the study context, the study designs, data collection methods, instruments, and analytical approaches. The third section presents and integrates findings from the different studies in this thesis. The last section discusses the findings and situates this thesis in the local, national and global health context. This section also synthesizes the results in the broad perspective of existing literature and presents the recommendations for policy and programs and future research directions

Slum health: an emerging public health issue in the 21st century

Slightly over half of the world’s population currently lives in urban areas, with Asia and Africa urbanizing more rapidly than other regions. The annual rate of urbanization for these two regions are 1.5 and 1.1%, respectively, compared to the rate of less than 0.4% in more urbanized regions (United Nations Department of Economic and Social Affairs Population Division, 2014). While urbanization in the global north was accompanied by economic growth, the case is different in Africa where most of the urbanization is taking place during periods of inequitable resource distribution. This has led to the continued growth of slum settlements which are characterized by poor quality housing and a general lack of public services. The UN-Habitat defines a slum household as one that lacks one or more of the following: improved water, improved sanitation, sufficient living area, durable housing which considers the permanency of the structure as well as location away from hazardous areas and secure tenure that protects residents against forced evictions (UN-Habitat, 2010).

The World Health Organisation (WHO) that slums in cities in Low- and Middle-Income Countries (LMICs) are home to a large proportion of the urban population (WHO, 2015). In 2014, it was estimated that about 25% of Kenya’s population lived in urban areas, an increase from 17% in 1990 (United Nations Department of
Kenya’s urbanization mirrors that of other countries in sub-Saharan Africa with slums being a central feature of most urban areas across the country. The growth of slums in Nairobi can be traced to the pre-independence period when a restriction of movement for Africans was enforced by colonial masters. After the fall of the colonial powers, there was an influx of migrants into the city. This overwhelmed government efforts to settle landless citizens, leading to squatter settlements which continued to grow to present-day slums. It is estimated that 62% of Nairobi’s population resides in slums or slum-like neighbourhoods (Kenya National Bureau of Statistics, 2012).

The persistence of slums brings to the fore the face of ‘two urban systems’ within a single city. This is due to the stark differences in economic, social and health aspects of slum and non-slum areas of cities. Using Nairobi as a case, research has continued highlighting the differences in access to public goods including water, sanitation, health and education for city residents in slums and non-slum areas, leading to poorer health outcomes among the former compared to the latter and even when compared to the population in the rural areas. The advantages associated with urban living are therefore eroded or non-existent for slum residents. Health research in Nairobi slums has revealed a range of health issues that contribute to high morbidity and mortality. For example acute lower respiratory illness among children below the age of five years are a leading cause of mortality (Kyobutungi et al., 2008). Further, high rates of maternal mortality have been reported (Ziraba et al., 2009). In addition, there is a high prevalence of HIV (Madise et al., 2012). Further, urban areas have been found to have high levels of outdoor air pollution arising from transport-related and industrial emissions, with dire implications for residents’ health (Kinney et al., 2011; Gaita et al., 2014; Karagulian et al., 2015). Emerging health concerns for slum residents also include injuries, infectious diseases such as dengue (Ezeh et al., 2016), and cardiovascular disease (van de Vijver et al., 2013).

In Africa, urban areas are also known to concentrate poverty, especially within slum settlements where incomes are unstable owing to low employment rates and the informality of most sources of livelihood (The World Bank, 2006). While urban slums have been places of socio-economic advantages in the past, they also concentrate risks to both human and environmental health. These settlements face environmental challenges owing to their proximity to the industrial zones, city dumpsites, and major highways or along riparian land where they are more prone to flooding during rainy seasons, high level of pollutants, poor air quality and other environmental hazards.
Further owing to low household income, which has been identified as one of the determinants of household fuel choice (Mekonnen and Köhlin, 2008; Nlom and Karimov, 2015; Tembo et al., 2015), most households within slums face challenges in adopting cleaner cooking stoves and fuels therefore propagating the reliance on dirty fuels. Indeed, most recent estimates for Kenya indicate that about 46% of urban households rely on biomass and about 27% use kerosene for cooking (Kenya National Bureau of Statistics et al., 2015). These fuels, which are on the lowest levels on the fuel ladder, are classified as dirty fuels and have been associated with high emissions of air pollutants such as particulate matter (PM) and other health damaging compounds (Lam, Chen, et al., 2012; Lam, Smith, et al., 2012). The reliance on these fuels has implications for air quality and subsequent health outcomes of residents.

There is a growing push for slum health to be given priority as an area of research focus instead of subsuming it under urban health, due to the unique context of slums and the challenges they face both in terms of risk and health outcomes and the opportunities they offer for interventions aimed at improving health (Ezeh et al., 2016; Lilford et al., 2016).

**Air pollution: an under-researched environmental and health hazard in Africa**

Research on air pollution has been on-going in the USA for several decades (US Environmental Protection Agency, 2016). However, in LMICs especially in Africa, research on air pollution and its impacts to human health is quite scanty. Therefore, there is limited evidence on the extent and impacts of air pollution to inform policy and to guide health programs. Existing literature points to ‘scattered’ research in different countries on the continent and the need to strengthen this field of inquiry. For a long time, health research in Africa has overwhelmingly focused on infectious diseases such as malaria and HIV/AIDS. A PubMed search on these two areas of research yielded 26,268 published papers in contrast to only 324 published papers for a search on air pollution/quality research. The lack of focus on air pollution and its impact on health remains contrary to events taking place on the continent indicating the need for more focus on this neglected area. For example, there is increasing concern over the rising volumes of traffic in major urban centres in Africa (Guéniat et al., 2016; Amegah and Agyei-Mensah, 2017), with most of the motorized fleets being old and poorly maintained (Guéniat et al., 2016). In addition to an ageing fleet, fuel in most African countries is of poor quality (Guéniat et al., 2016), leading to higher emissions of particulates and other compounds that are harmful to human health. Most African governments have also laid down
elaborate plans to expand the manufacturing sector through industrialization. The focus on industrial expansion has not gone hand in hand with environmental protection. Most African cities also rely on open dumpsites for the disposal of municipal solid waste, and these remain important sources of air pollution in addition to affecting water and soil quality (Kimani, 2007). With limited legislation on environmental protection, the future of urban Africa will likely remain highly polluted.

Almost half of the global population relies on biomasses, which are main source of pollutants, to meet their cooking and heating needs (Bruce et al., 2015). The largest dependence is reported in rural communities in LMICs with rates of biomass use estimated to reach as high as 95% in some countries (WHO, 2015). Biomass use is not restricted to rural communities and there is a considerable proportion of urban households reliant on the same for cooking and heating. With urbanization taking place at a high rate in Asia and Africa (United Nations Department of Economic and Social Affairs Population Division, 2014), many cities are facing the challenge of slum settlements (UN-Habitat, 2003) characterised by poor housing and high levels of poverty. On the African continent, household air quality remains an issue of concern given about 79% of households still rely on biomass for cooking, lighting and heating (WHO, 2015). These fuels are usually used in low efficiency stoves and lamps, and in unvented spaces, leading to high indoor concentrations of emissions (Clark et al., 2013). Biomass burning is associated with emissions of several air toxics including particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), sulfur dioxide (SO2), volatile organic compounds (VOCs) among other hazardous air pollutants (Partnership for Policy Integrity, 2011).

Besides cooking and lighting fuels and outdoor sources, another factor that has an impact on air quality, especially within indoor environments is cigarette smoking. Although Kenya has enacted tobacco control policies with restrictions on smoking within public spaces such as offices, smoking within the home continues to be practised. Males are more likely to smoke than females, with studies indicating that the prevalence rate of cigarette smoking among adolescents was 13% and 7% among boys and girls respectively (Maina et al., 2013) while among adults, the rate was 11% (Tobacco Unfiltered, 2014). With regards to smoking indoors, estimates indicate that nationally, 14% of people are exposed to cigarette smoke at home (WHO Regional Office for Africa, 2015). This could be due to the family structure prevalent in the country in which patriarchy and the prevailing masculine norms that are associated with cigarette smoking (Peltzer, 2011) combine to propagate the habit of smoking indoors.
The situation in Kenya reflects that prevailing on the continent in general, with very few studies on air pollution and even fewer assessing the effects of air pollution on health. It was not until the late 1980s when the first (published) study on household air pollution was conducted in Kenya (Boleij et al., 1989). Since then, several studies have been conducted in different parts of the country, mostly in rural settings. Most of the studies focused on air pollution and the effects on health, especially on respiratory illnesses among children below the age of five years (Gachanja and Worsfold, 1993; Ezzati et al., 2000; Kituyi et al., 2001; Bruce et al., 2002; Majdan et al., 2015; Teather et al., 2015). Alongside these research efforts, there has been development and promotion of alternative cleaner cookstoves that considerably reduce kitchen emissions (Global Alliance of Clean Cookstoves, 2015). These efforts began with the introduction of the ceramic jiko (stove) in the 1980s which gained popularity in urban areas before spreading to rural areas. However, most of the stoves available during this initial period and into the mid-2000s were of poor quality. With the growth in innovation around reducing stove emissions, alternative and somewhat lower emission options such as the rocket stoves and biomass gasifiers became increasingly available in the last six years. Efforts of the Global Alliance of Clean Cookstoves and other partners have propelled Kenya into a leading position as a producer and consumer of alternative clean cooking options (Global Village Energy Partnerships International and Accenture Development Partnerships, 2012). These alternative cooking technologies have been the focus of several studies which assessed their efficacy in reducing emission levels and/or the associated health benefits (Foote et al., 2013; Ochieng et al., 2013). However, many of the researches has focused on rural communities where the reliance on biomass is almost 100% (WHO, 2015).

Various studies have revealed the urbanization of poverty in slums, with consequences on health, schooling and food security (African Population and Health Research Center, 2002; WHO and UN-Habitat, 2010; African Population and Health Research Center, 2014; Kimani-Murage, Schofield, et al., 2014); as well as the reliance on biomass and other less clean fuels (UN-Habitat, 2008). In Nairobi, most middle-income households combine the use of Liquefied Petroleum Gas (LPG) with charcoal stoves while low-income households rely on both charcoal and kerosene (Kenya National Bureau of Statistics et al., 2015). Given that slums in most countries of sub-Saharan Africa are home to majority of city residents, it is important that research on air pollution focuses on these areas, which have largely been left out of air quality studies. This study is one of the few in sub-Saharan Africa (SSA) to focus on slum households and will be an important addition to existing literature on air pollution research in the African context.
Air pollution and its impacts on health

Research has documented the health impacts arising from the combined effects of both household air pollution and outdoor air pollution. Outdoor air refers to the air in the surrounding environment while indoor air refers to air within various enclosed microenvironments such as homes and other types of buildings or enclosed spaces. In this study, we consider indoor air to be that within homes. The Global Burden of Disease study indicates that air pollution is the fourth leading risk factor for death globally. Further, the study indicates that 85% of global population lives in areas where the air pollutants exceed the WHO thresholds (Institute for Health Metrics, 2016), with implications for health and mortality. Estimates from the WHO indicate that seven million premature deaths in 2012 were due to air pollution. The largest burden is borne by countries in South Asia and in sub-Saharan Africa (WHO, 2014). In low-income economies, the leading cause of mortality was lower respiratory infections while stroke and ischemic heart disease were the third and fourth leading causes of death in these countries in 2015. In middle-income economies, the leading cause of mortality was ischemic heart disease (WHO, 2017). Air pollution is the fourth important risk factor of the burden of disease in Kenya in 2013 (Institute for Health Metrics and Evaluation, 2015).

Air pollution is associated with health outcomes including acute lower respiratory illness among children below the age of five years (Ezzati and Kammen, 2001; Duflo et al., 2008), chronic obstructive pulmonary disease (COPD), cancers and cardiovascular conditions (Zhiyong and Rao, 2009; Mu et al., 2013). The odds ratio for cancer reported by Mu and colleagues was 4.08 for solid fuel use while every 10µg/m³ in PM₁ was associated with 45% increase in lung cancer risk among non-smoking women (Mu et al., 2013). More recent research has also highlighted the impact of air pollutants on pregnancy outcomes, including pre-term delivery (Wilhelm et al., 2011; Fleischer et al., 2014; Olsson, 2014), low birth weight (Boy et al., 2002; Pogodina et al., 2009; Pope et al., 2010; Epstein et al., 2013) stillbirths (Pope et al., 2010) and small for gestational age (Vinikoor-Imler et al., 2014). In the study by Boy and colleagues, results showed that mothers using wood for cooking had babies whose birth weight was 63g lower than that for babies born to mothers using cleaner fuels (Boy et al., 2002). Epstein and colleagues found that use of coal led to 110g reduction in mean birth weight while kerosene and biomass were associated with 107g and 78g reduction in mean birth weight respectively (Epstein et al., 2013). Vinikoor-Imler and colleagues found that exposure to ozone was associated with risk ratios of 1.16 for small for gestational age and 2.03 for term low birth weight (Vinikoor-Imler et al., 2014).
Why PM2.5?

Fine particulate matter (PM$_{2.5}$) are particles with or below an aerodynamic diameter of two and half microns. These particles have been shown to have the ability to lodge deep into the lung tissue or get into the blood stream where they initiate an inflammatory process (Weichenthal et al., 2007; Grunig et al., 2014). PM$_{2.5}$ is a mixture of solid particles and liquid droplets, and includes both naturally occurring particles and man-made particles such as soot from the combustion of fuels and dust from the construction industry. Secondary sources of fine particles arise from the chemical reaction of gases such as NOx and SO$_2$ in the atmosphere. There is no safe threshold for fine particles below which no adverse health effects are noted. The governments/agencies set upper limits for both indoor and outdoor air as guidelines which should not be exceeded either in 24 hours or annually. For example, the WHO has set the PM$_{2.5}$ guideline to 25µg/m$^3$ for 24 hours while the annual guideline limits this to 10µg/m$^3$ (WHO, 2006).

Lay perceptions of air pollution exposure and its risk

Studies on people’s perceptions of air pollution have been conducted in the USA since the 1950s and in the United Kingdom in the 1970s (Bickerstaff and Walker, 2001). Extant literature on perceptions of exposure to pollution indicates the importance of this factor in people’s response to exposure (van Thriel et al., 2008; Claeson et al., 2013). Perceptions of exposure and risk have been said to act as community early warning systems (Claeson et al., 2013). Further, perceptions remain an important component of behaviour change theories (Janz and Becker, 1984; Ajzen, 1991) and have been explored in various studies (Strecher et al., 1986; Semenza et al., 2008; Rubin et al., 2009). Much of the literature on perceptions of exposure and risk has looked at odorous pollutants and suggest that sensory perceptions play an important role in people’s response (Bickerstaff and Walker, 2001; Bickerstaff, 2004; Claeson et al., 2013). Evidence has shown that the presence of known sources of pollution has shaped people’s perceptions of exposure and risk; for example proximity to industries or a busy highway would lead residents to perceive higher exposure to air pollutants (Bush et al., 2001; Bickerstaff, 2004) compared with those living farther from the source. Evidence has also shown that people living in polluted spaces tend to avoid stigma associated with such spaces by associating higher levels of pollution with the ‘other’ in what has been termed the ‘neighbourhood halo’ effect (Bickerstaff, 2004). Therefore, perceptions form a key component of behaviour change as they can propel people to act on the exposure or they can restrict action if people do not perceive themselves to be at risk.
Only very few studies in the African settings and in Kenya have been conducted to assess how exposure to air pollution and its risk are perceived by the population. Given the exclusion of slums in most of the city’s discourses, it was important to study how residents in the slum areas perceived their exposure and risk to air pollution. It is also important to study the attitude towards individual, community and government responsibilities in addressing the air quality issues facing slums as this information would guide the entry of interventions in the communities.

The social context of air pollution in the Nairobi setting

Nairobi is the capital city of Kenya, sitting at between 1660m and 1800m above sea level and occupying an area of about 689sq km (Omwenga, 2011). The population of Nairobi has drastically grown over the past few decades from just under half a million inhabitants in 1963 to 3.1 million in 2009 (Kenya National Bureau of Statistics, 2010). Much of the urban population growth is fuelled by rural to urban and urban to urban migration as well as natural population increase. The fast growth in the population has brought with it numerous key challenges including the lack of adequate and affordable housing for the mostly low-income migrants. The result has been a mushrooming of slum settlements. It is estimated that at least 62% of the city’s population resides in slums or slum-like neighbourhoods (Kenya National Bureau of Statistics, 2012) which occupy less than 5% of the city’s residential land area (Pamoja Trust, 2009). A considerable body of evidence has highlighted the plight of slum residents with poor housing, sanitation and near absence of the public sector being major concerns (African Population and Health Research Center, 2002; UN-Habitat, 2003; Dafe, 2009; African Population and Health Research Center, 2014). School enrolment, educational attainment and transitions, sexual and reproductive health and general health outcomes including mortality among population who live in the slum area remain worse than those of non-slum areas and even when compared to those living in the rural areas (Mugisha, 2006; Kyobutungi et al., 2008; Ziraba et al., 2009; Izugbara and Ngilangwa 2010; Kimani-Murage, Fotso J. C., et al., 2014)

Food insecurity is another challenge faced by slum populations (Faye et al., 2011; Kimani-Murage, Schofield, et al., 2014). This is driven by pervasive poverty due to the reliance on informal employment with unsteady and generally low incomes. A recent study reported that many households have one meal a day, placing these communities in a state of emergency as far as access to adequate food is concerned (Kimani-Murage, Schofield, et al., 2014). This has implications for the overall nutritional status of residents, more so for the young who need sufficient and
proper nutrition to meet their developmental needs. It is within these spaces of social deprivation that a further disadvantage in the form of air pollution is experienced.

Nairobi is a city of contrasts, from the lush high end residential areas to the sprawling shacks that exist close to these wealthy neighbourhoods. The contrast persists in indicators of social development such as income, with slum residents remaining at the bottom of the income ladder with poor access to adequate and quality food. Disparities also extend into the provision of public goods such as water and sanitation, with wealthier neighbourhoods are well provided with these services while slums remain under-served. Environmental issues also take the two-sided perspective with poorer areas bearing the brunt of pollution owing to their housing locations near the siting of pollutant sources such as roads, open dumpsites and factories. Further, slum areas lack solid waste collection services, leading to littering and open burning to rid the streets of the waste. In such a dichotomy, it is rational to find winners and losers, which is expounded further in the sections that follow.

**The winners and losers of social development**

Housing quality plays an important role in the health of occupants (Krieger and Higgins, 2002; Breysse et al., 2004; WHO, 2006). With most of an individual’s time spent indoors, housing quality becomes a critical factor for health. As far as household air quality is concerned, the quality of a house is critical in regulating emissions arising from various indoor sources. Presence of ventilation that allows adequate exchange of air is one of the most important aspects of a house. In Nairobi, most housing is reliant on in-built ventilation routes to aid air exchange. In wealthy neighbourhoods, construction of housing is regulated and this results in better quality homes with adequate ventilation. In the low socioeconomic status neighbourhoods, especially in slums, housing standards are not enforced, resulting in sub-standard homes. For example, most slum households only has a single room of 100sq feet, and some of these rooms lack windows. Most households living in slums can only afford to rent one room which functions as the bedroom and kitchen. This, coupled with the reliance on dirty fuels, has an impact on indoor concentrations of pollutants arising from stoves and kerosene lamps.
As cities in LMICs grow rapidly, there are attendant challenges such as solid waste management and the expansion and siting of industrial zones. Typically, open dumpsites are commonly used and are located in the fringes of the city. Nairobi’s only municipal dumpsite is located just seven kilometres from the city centre. Originally a piece of land was set aside for a planned housing scheme, indiscriminate and unchecked dumping rendered the land unusable for housing; therefore becoming a 30 acre open dumpsite (ETH Studio Basel Contermorary City Institute). The initial phases of the housing that had been constructed adjacent to this area still exist, in addition to later residential developments around the dumpsite. There are therefore, thousands of residents living near the dumpsite (Figure 1). Natural combustion of gases released on the dumpsite undoubtedly affects the quality of air in the immediate neighbourhoods and farther afield due to dispersion. The siting of dumpsites has remained a controversial issue pitting municipal authorities against unwilling communities, not only in Kenya but
globally too as the ‘not in my back yard’ movement takes root (Gerrar, 1993; Hager and Haddad, 2015). This has led to siting of potentially damaging developments such as industries and dumpsites in poorer neighbourhoods - a case of environmental injustice that has been observed in countries like the USA (Saha Robin and Paul, 2005; Mohai et al., 2009). In Nairobi, most of the land on which slums sit is either government-owned or private land (Amnesty International, 2009). These communities lack the agency to resist the siting of pollution sources such as dumpsites, industries or major highways in their neighbourhood as they do not have tenure on the land. Therefore, the poorest segment of the city population bears the highest burden of environmental degradation given the poor control of emissions in the country.

The gendered exposure to air pollution

African societies have for long been characterized by clear gender roles that strictly define what women and men can do. Women were and are still tasked with the collection of fuel wood for cooking and lighting (especially in rural areas) as well as getting, preparing and cooking food for the household (Ezzati et al., 2000; Rehfuess et al., 2006). Other chores within the house remain a woman’s responsibility including the provision of care to young children. On the other hand, men were traditionally tasked with roles that required physical strength such as tilling the land, building etc. In contemporary African society, some of the traditional gender roles have persisted and women continue to be the nurturers of their households even when they have jobs outside the home (Mokomane, 2014).

In the Nairobi slums setting, most of the women are unemployed. Some of the women are involved in petty trading such as selling street foods, groceries or scavenging at dumpsites, with implications for their exposure to health risks. Women spend most of the day inside their homes with a stove on, or next to a stove on the roadside as they cook and sell street food and other wares, exposing themselves to a higher cumulative level of air pollutants. Those working within more formal settings are additionally likely to face exposure to environmental tobacco smoke at the workplace. In addition, there is exposure at home where cigarette smoking indoors is a common occurrence (Peltzer, 2011; WHO Regional Office for Africa, 2015). Given all these sources of air pollutants and the proximity of women to these sources for longer durations, the total exposure a single individual woman (and the children under her care) faces in each day may be higher than that of men (Ezzati et al., 2000).
Aims and objectives

The aim of this study was to assess air pollution in two slums of Nairobi, as well as the population’s perceptions of and attitudes towards exposure and associated health risks.

Specific objectives

This thesis sets out to:

1. Assess the source and levels of indoor PM$_{2.5}$ across households in Nairobi slums (paper 1).
2. Explore the perceptions of and attitudes towards air pollution among residents of Nairobi slums (paper 2, 3)
3. Understand the perceived health risks associated with exposure to air pollution (paper 3, 4)
Conceptual framework

Several frameworks have been put forward that guide the understanding of environment-health linkages in environmental health studies. The Driving force-Pressure-State-Impact-Response (DPSIR) (Hambling et al., 2011) and the Multiple Exposures-Multiple Effects framework (MEME) (WHO, 2009) are some examples of these frameworks. The DPSIR framework does not have an exposure component while the MEME combines exposure, state and pressure, making both frameworks unsuitable to adapt for this work. Therefore, this study adapted the Driving force-Pressure-State-Exposure-Effect-Action (DPSEEA) framework (Kjellstrom and Corvalan, 1995; Corvalan et al., 1999) which shows linkages between driving forces that lead to pressure on the environment to alter the state (quality) of the environment. Exposure to the altered state of the environment (at certain doses) has effects on human health. Instead of having the State and Exposure components separately, this study combined the two since the state was used as a proxy for individual exposure. Associated with each component of the framework are actions that governments, individuals or institutions can take to influence outcomes at each step, for instance pollution monitoring and control would contribute towards changing the state and exposure and subsequently the effects of pollution. According to the adapted framework, social attitudes would act to propel driving forces into pressure on the environment while perceptions would influence exposure and actions taken at national, community or individual levels (see Fig 2). This thesis focuses on the pressure, state/exposure and effect components of the framework with additional focus on attitudes and perceptions as potential mediating factors. The driving force component of the framework is considered through a review of the literature while the action component is addressed mainly through recommendations for policy/action, targeting both the government and the communities where the research was conducted.
Figure 2: The DPSEEA framework (adapted from [Kjellstrom and Corvalan, 1995])

- Pressure (e.g. production, consumption, waste release)
- State/exposure (e.g. Pollution levels, natural hazards, resource availability; absorbed dose)
- Driving force (e.g. population growth, economic development)
- Effect (e.g. well-being, morbidity, mortality)
- Action
  - Economic & social policies; clean technologies
  - Hazard management
  - Environmental improvement; pollution monitoring & control
  - Education; awareness raising
  - Treatment; rehabilitation
The driving forces component in this thesis is largely based on literature review around the rapid urbanization process in SSA, and in Kenya which has led to the rise in slums. Further, the urbanization of poverty in slums, the poor housing and generally poor environmental quality in these areas have been discussed, based on literature and the data on which I base this thesis. The pressure component assesses the factors contributing to indoor levels of air pollution. It includes the characterization of the indoor environment in terms of types of cookstoves used, the availability and patterns of ventilation use as well as types of lighting fuels used. It also includes perceived sources of both indoor and outdoor air pollution.

The state/exposure component speaks to the levels of indoor air pollutants, specifically fine particulate matter (PM$_{2.5}$). This is achieved by assessing the variation in mean fine particle concentrations across households using different types of fuels for cooking and lighting. The levels of PM$_{2.5}$ are used as a proxy for individual exposure, therefore the state and exposure are treated as one component. Lastly, the effect component looks at the perceived health impacts of this exposure.

In this thesis, perceptions form a central part of the framework used to explain the pollution-health outcome linkages. Perceptions and attitudes act as overarching factors in the framework. For example, attitudes would be important in mediating between driving forces such as economic disadvantage of slums and the pressure applied to the environment e.g. through waste production and subsequent improper management. Similarly, perceptions mediate between state/exposure and the consequences of this exposure. How people perceive the state of the environment, their exposure and effect will have a bearing on whether and how the individuals respond to the exposure as well as the actions they take to mitigate these exposures and/or effects.
Methods

Study context

The study is set in two slum communities to the east of Nairobi City, Korogocho and Viwandani, both of which occupy less than 1sq km (see Fig. 3). The African Population and Health Research Centre (APHRC) has conducted a longitudinal study of the residents in both slum communities since 2002 under the Nairobi Urban Health and Demographic Surveillance System (NUHDSS) (Emina et al., 2011; Beguy et al., 2015). This surveillance involves visiting all households every four months to collect information on key demographic events such as pregnancies, births, deaths and mobility/migration. Basic socio-demographic data such as date of birth, education level, and marital status among others are collected. Data on household assets and characteristics and food security are collected on annual basis. The NUHDSS provides an ideal sampling platform that accords researchers the opportunity to carry out more specific or nested studies including the intervention study on which part of this study was nested.

Figure 3: Nairobi Demographic Surveillance Area in Korogocho and Viwandani slums (source: (Beguy et al., 2015))
Slums in Nairobi are characterized by sub-standard housing with rooms typically measuring 100sq feet in area, and made up mostly of zinc walls and roofs. This small space is all most households use as a kitchen, bedroom and living area. Korogocho lies near to the city’s municipal open dumpsite on which many residents rely for their livelihood through waste picking. Further, there are industries close to this community, most of which are a source of employment for residents in this slum. On the other hand, Viwandani is located at the heart of the industrial zone of Nairobi city, and just to the eastern boundary of this study site is an illegal open dumpsite. While regulations on industrial emissions exist, enforcement of the guidelines remains weak and there is substantial emission probably exceeding legislated thresholds. Therefore, the two communities share a common disadvantage in terms of location close to sources of environmental pollutants. Further, municipal services especially those concerned with the collection and transportation of solid waste are not provided in these communities. Residents must either pay private collectors or dump solid waste within the community, most of which ends up being burnt to get rid of it.

Table 1 highlights some of the differences existing between the two communities.

<table>
<thead>
<tr>
<th></th>
<th>Korogocho</th>
<th>Viwandani</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>0.97 km²</td>
<td>0.98 km²</td>
</tr>
<tr>
<td>Total households</td>
<td>10,491</td>
<td>18,873</td>
</tr>
<tr>
<td>Total population</td>
<td>30,718</td>
<td>45,917</td>
</tr>
<tr>
<td>Population density (people/km²)</td>
<td>31,668/km²</td>
<td>46,854/km²</td>
</tr>
<tr>
<td>Children under five (%)</td>
<td>12.8</td>
<td>12.6</td>
</tr>
<tr>
<td>Under-5 mortality rate (per 1000 live births)</td>
<td>57.7</td>
<td>36.0</td>
</tr>
<tr>
<td>Outdoor PM₂.₅ (µg/m³) in 2013</td>
<td>166</td>
<td>67</td>
</tr>
</tbody>
</table>
Study design

The thesis applies different study designs to answer the objectives. For the first objective, I use a cross-sectional design to assess the sources and levels of fine particles in the homes as well as other household member’s behaviours such as use of ventilation, cigarette smoking and types of fuels and stoves used for cooking. The second and third objectives are answered through studies using qualitative and quantitative approaches. I conducted a cross-sectional study and focus group discussions (FGDs) to understand people’s perceptions to and attitudes toward air pollution. The use of qualitative method allows me to get in-depth understanding of the issues being explored and look at convergence or contradiction of opinions (Johnson et al., 2007). I used simultaneous triangulation (Morse, 1991) as the quantitative study and qualitative study were conducted independently without using either study to inform the design of the other study.

Quantitative studies

Data sources

The quantitative data in this study originated from three different sources, i.e. the longitudinal data under the NUHDSS, the Maternal, Infant and Young Child Nutrition (MIYCN) study and the Sustainable model for Cardiovascular health by Adjusting Lifestyle and treatment with Economic perspective in settings of Urban Poverty (SCALE-UP project within the NUHDSS framework.

The longitudinal data available in the NUHDSS include basic socio-demographic information on all residents within the study areas, migration and mobility data, household wealth, pregnancies and births as well as mortality data collected through household visits at regular interval (Fig. 4). In this thesis, we extracted household wealth data from the NUHDSS to provide an indicator of household socio-economic status. The wealth data was estimated from the ownership of certain durable household goods such as cars, bicycles, furniture, phones etc., using the principal component analysis approach that is described elsewhere (Vyas and Kumaranayake, 2006).
The Maternal, Infant and Young Child Nutrition (MIYCN) study which was conducted from 2012 to 2014, was an intervention study that aimed to provide personalized counselling to pregnant mothers for better health outcomes for their infants and children. Pregnant women were recruited into either intervention or control group, and followed up until their children reached one year old. More details about the intervention have been published elsewhere (Kimani-Murage et al., 2013). The baseline data for each woman were collected at recruitment, and follow-up data were collected every two months during the follow-up period.

At the baseline of this intervention study, we introduced an air pollution module covering a range of issues including the types of stoves and fuels households use for cooking. In addition, it addressed the availability, nature and use of ventilation especially during cooking episodes; and the woman’s frequency of cooking and performing household chores. The study also collected information about the nature of income-generating activity the woman was involved in, her smoking status and exposure to environmental tobacco smoke at home and at the workplace for those reporting to be working. From the households recruited and followed up in the MIYCN study, a sample of households was selected from which data on PM$_{2.5}$ levels were collected. More details about the PM$_{2.5}$ measurement are presented in the next section. Data from this air pollution module and the PM$_{2.5}$ measurement were used to address the first objective of this thesis.
Data on community perceptions on air pollution, annoyance and associated health risks were collected from a study of adults on cardiovascular health (the SCALE-UP project) that was nested on the NUHDSS. This study was conducted from August to December 2012 with a total sample of 5,317 adults aged 18-55 years (3,887 in Korogocho and 1,430 in Viwandani). The SCALE-UP project was an intervention study that aimed to test a model for the management of cardiovascular disease in resource poor communities such as the slums (Oti et al., 2013). The baseline survey was the platform on which we nested a short module to assess quantitatively, the communities’ perceptions regarding indoor and outdoor air pollutions and their associated health risks as well as annoyance levels arising from air pollution (see annex 1 for the study instrument). Questions on perceived levels of air pollution were ranked on a scale of 1, representing very low pollution to 4 representing very high levels of pollution. To assess annoyance, we used a five-item ladder with 1 indicating no annoyance at all and 5 indicating extreme annoyance from air pollution. Respondents were asked to indicate on the ladder which corresponded to their level of annoyance due to indoor and outdoor air pollution. Data from this nested module was used to address the second objective of this thesis. Electronic data collection was the approach used for both the quantitative studies, (see Fig. 3) as it provides an opportunity to in-built data quality checks on the capture screen. It also reduces errors associated with data entry when paper based data collection is used.

**Measurement of particulate matter**

The PM$_{2.5}$ data were collected from a sub-sample of households in the MIYCN intervention study during April to October 2014. In each household, we monitored PM$_{2.5}$ levels using DustTrak ™ II Model 8532 (TSI Inc., Shoreview, MN, USA) monitors. Each day before placing monitors in houses, field staff checked the impaction plates to ensure they were properly oiled. The field staff had post-secondary level of education and were trained on how to operate the equipment. The training included a pilot exercise to ensure they were comfortable working with the equipment. The monitors were zeroed every day prior to the monitoring process. The data collection team checked for error messages on the screen regularly and changed the instrument filter when prompted by the device. Data were sent daily to the lead researcher who checked for possible errors such as negative readings or flow errors. This ensured constant communication with the data collection team to alert them of issues they could resolve on the ground. The equipment was shipped to the manufacturer at the beginning of 2014 for scheduled factory calibration.
Due to findings that the DustTrak monitors over-estimate the levels of PM (McNamara et al., 2011) a correction factor was calculated after simultaneously collecting data within the study area, using locally available gravimetric personal monitors (BGI model 400) alongside the DustTrak™. We worked with the Institute of Nuclear Science and Technology at the University of Nairobi who provided the gravimetric monitors and a micro-balance for weighing the filters before and after particle collection. The collection of samples was only possible during daytime hours and was done over three days, for a combined total of 24 hours. Collection was done in the outdoors and no calibration measurements were done inside homes, as it was felt that since the measurements were done within the same communities where the homes were located, there would be little variation in the source of fine particles, hence no need to collect calibration data for households. Fine particle data were corrected for over-estimation using a correction factor computed as follows:

\[
\text{Correction Factor} = \frac{\text{Gravimetric Concentration}}{\text{DustTrak Concentration}}
\]

The results of the simultaneous measurement of PM$_{2.5}$ levels with the two types of monitors are shown in Table 2.

<table>
<thead>
<tr>
<th>Date</th>
<th>Filter No.</th>
<th>DustTrak</th>
<th>BGI</th>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-15 Feb 2013</td>
<td>Feb 129</td>
<td>115</td>
<td>43</td>
<td>0.37</td>
</tr>
<tr>
<td>16-20 Feb 2013</td>
<td>Feb 130</td>
<td>125</td>
<td>31</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Average Correction Factor</td>
</tr>
</tbody>
</table>
Analysis of quantitative data

Data on the sources and levels of PM$_{2.5}$ was analysed using descriptive analysis; mainly cross tabulations with chi square or t-test where applicable to characterize the indoor environment, ventilation availability and usage patterns, types of cookstove and levels of PM$_{2.5}$, comparing these across some select background variables. We applied descriptive approach and hotspot analysis in ArcGIS to assess the perceived health risks and the spatial distribution of these perceptions based on village of residence and its proximity to known sources of air pollution. To generate a composite scale of annoyance, we used the *alpha* command in Stata, with the option to standardize each variable (to a mean of 0 and a standard deviation of 1) before generating a composite score. This allows for the combination of items even though they are not all measured on similar scales. Linear regression was used to assess factors associated with perceived air pollution and health risks.

Qualitative study

Data collection

Qualitative data were collected through focus group discussions (FGDs) among younger adults (18-29 years) and older adults (30+) separately. We did not conduct separate FGDs for men and women, since we discussed about environmental issues which were not expected to raise any sensitive issues for either sex. Even in a setting where gender roles are strong, we felt that the issue at hand for discussion would be better discussed when either sex brought their perspectives to the discussion table. The FGDs were conducted in the largely spoken Kiswahili language and the disaggregation by age took consideration of the use of Sheng–a mix of Kiswahili, English and native languages, which is mostly spoken by younger people. Recruitment of discussion participants was done by a community member who was asked to recruit participants from different villages and ethnic groups to ensure diversity of views from participants. During the discussions which were moderated by a colleague, I took notes and acted as an assistant moderator, asking some clarification questions whenever the need arose.
The FGDs focused on community perceptions and attitudes towards air pollution and health risks arising from exposure to this pollution. We discussed what the participants perceived as the sources of outdoor and indoor air pollution in their community, their views on individual and government responsibility in addressing air quality issues and a discussion on health impacts of air pollution.

We employed the emergent design when collecting the data in which we conducted some FGDs first then we analysed the data so that we could explore issues raised in the FGDs in the next FGDs. We therefore conducted the FGDs in two waves due to the need for time to analyse the discussions and revise the guide as necessary. The first round of FGDs was conducted in November 2012, while the second round was conducted in January 2013. In total, eight FGDs were conducted. The second and third objectives are partly based on these qualitative data.

**Analysis of qualitative data**

I transcribed all the FGDs verbatim in English. Data were coded in NVivo 9 and these codes were used to create broad categories of themes, then refining these into the final themes that emerged from the data. In the second objective, I used thematic analysis to bring out salient issues regarding people’s perceptions and attitudes towards air pollution. Initially *a priori* themes had been based on the broad questions in the interview guide. After data were coded, these themes were refined ending up with seven themes.

In the third objective, I used thematic analysis using *a priori* themes, comparing across the two communities to assess the convergence and divergence of perceptions of lay persons on the health conditions associated with air pollution. Convergence of perceptions indicates an overlap of perceived health effects in the two communities while divergence points to the differences in perceptions. Two sub-themes emerged under the theme on convergence of perceptions, namely: identification of plausible air pollution related health conditions and identification of health conditions unrelated to air pollution, based on current scientific evidence of the association between air pollution and health conditions. The use of *a priori* themes was preferred due to the limited data we had on perceived health effects, which lacked the depth to allow for the more traditional thematic analysis. In the collection and analysis of the data, the moderator and I remained as neutral as we possibly could, without allowing the knowledge we had regarding air quality influence the line of questions or the analytical path we took. This ensured little influence from the researchers on the data collection and analysis, and consequently, ensuring data validity and trustworthiness.
Table 3 illustrates the process of analysing the data to end up with themes.

<table>
<thead>
<tr>
<th>Meaning unit</th>
<th>Code</th>
<th>Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dumpsites near communities, industries, open burning of trash, smelly drainage channels, stoves and lamps, cigarette smoking.</td>
<td>Sources of air pollution</td>
<td>Mixed knowledge on air pollution sources</td>
</tr>
<tr>
<td>Seeing plumes of smoke, smelly industrial emissions, smelly trenches, visible dumpsites</td>
<td>Residents’ way of perceiving air pollution</td>
<td>Sensing air pollution</td>
</tr>
<tr>
<td>Responsible for air pollution, dumpsites, government inaction, residents burning trash</td>
<td>Taking responsibility for air pollution</td>
<td>Who is to blame?</td>
</tr>
<tr>
<td>Residents taking charge instead of waiting for outsiders to intervene, resistance towards dumpsite relocation, industries’ relocation pointless</td>
<td>Reducing indoor and outdoor air pollution</td>
<td>Resistance and ignorance</td>
</tr>
<tr>
<td>Threats of eviction, living space poor therefore no one pays attention to it, failure to raise issue of pollution rather keep quiet and continue living in slums, resort to faith in God for protection from polluted space</td>
<td>Lack of agency to address air pollution challenge</td>
<td>Fatalism and helplessness</td>
</tr>
</tbody>
</table>
Table 4 gives a summary of the research questions this thesis answers and the approaches used in data collection and analysis.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Research questions</th>
<th>Study design (and sample)</th>
<th>Analytical methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What are the household sources and levels of PM2.5?</td>
<td>Cross-sectional (1,308 households with air quality measured in 72 households)</td>
<td>Descriptive- cross-tabulations</td>
</tr>
<tr>
<td>2</td>
<td>What are the perceptions of and attitudes towards air pollution among residents of Nairobi slums?</td>
<td>Qualitative FGDs- (8 groups) – the same FGDs as in Objective 3</td>
<td>Thematic analysis</td>
</tr>
<tr>
<td>2 and 3</td>
<td>What are the community perceptions of air pollution and associated health risks in Nairobi slums?</td>
<td>Cross-sectional (5,317 adults)</td>
<td>Descriptive- cross-tabulations, linear regression and hotspot analysis</td>
</tr>
<tr>
<td>3</td>
<td>What are the perceived health risks associated with exposure to air pollution?</td>
<td>Qualitative FGDs (8 groups) – the same FGDs as in Objective 2</td>
<td>Thematic analysis</td>
</tr>
</tbody>
</table>

**Ethical considerations**

In line with guidelines on the ethical treatment of human study participants, all studies on which this thesis is based had received ethical approval by various Ethics and Scientific Review Committees mandated by the Kenyan government. The SCALE-UP study, NUHDSS and MIYCN studies were granted ethical clearance from the Ethical Review Committee of the Kenya Medical Research Institute (KEMRI) while the air pollution study which included both the qualitative and quantitative studies obtained ethical clearance from the Amref Health Africa’s Ethics and Scientific Review Committee. In all studies, individual informed consent was sought from participants and additional consent was sought from participants in the FGDs to have the discussions recorded. All participants were informed of their rights to decline to answer any questions they felt were uncomfortable as well as their rights to withdraw from the study at any time, for whatever reason without any reprisal. Analytical data were anonymized and no direct identifiers were used in any publication.
This thesis is anchored on the DPSEEA framework that has been applied in studies looking at environment and health issues and policy (Gentry-Shields and Bartram, 2014). Driving forces produce pressure on the environment to alter the state of the environment. Exposure to the altered state at certain doses leads to effects on the human health. Each of these components is associated with actions that are geared towards redressing the negative effect of exposure on health (see Fig. 4). The overarching issue of perceptions, which have a bearing on all components of the framework is discussed. The findings in this thesis are situated in different components of the framework. In the first part, the thesis presents findings on the driving forces, pressure and state/exposure components which addressed perceived drivers and sources of air pollution and the levels and sources of fine particulate matter in the indoor environment. In the next section, the results on the effect component, focusing on perceived health effects (third objective) will be presented. Lastly, the results shall touch on actions that can be undertaken to redress the situation; this will be drawn from qualitative data where it was addressed as well as in the policy implications and recommendations section.

**Driving forces: perceived drivers of air pollution in slums**

This section builds on the background section of this thesis where many of the driving forces have been addressed. I present findings from qualitative data on the perceived drivers of air pollution in the slums. The participants felt that there were several drivers of indoor air pollution, including poverty which prohibited household to use on cleaner cookstoves and lighting devices. Poverty also was said to push some households into using extremely dirty fuels such as plastic waste or foam mattresses, leading to higher emissions. Further, poorer people chose to live in houses without windows as the rent was cheaper; leaving them with only the door as the main ventilation. Besides poverty, lack of knowledge on what air pollution meant to the health of slum residents was mentioned as a driver of pollution. For example, some participants felt that ignorance led people to block and close all ventilations during cooking which led to high exposure of pollutants inside the house. Additionally, ignorance was said to be behind some of the practices noted in the two communities such as putting out stoves using water, which led to high emissions; lighting charcoal stoves with waste plastic or foam as well as bringing the stove inside the house when the charcoal was still smoky. Similar arguments were brought forth regarding smoking inside the home. Most men were faulted for smoking indoors and not being aware of or not caring much
about the harm they caused for non-smoking family members. Poor housing with the lack of proper kitchens and poor building materials as well as congestion of houses in a small space was also seen as a driver for poor indoor air.

With regards to outdoor air, the perceived drivers include lack of government interventions in the slum space due to its perceived poor status and the establishment of dumpsites within the neighbourhoods. Like indoor air, ignorance was said to lead to polluting practices such as burning of trash. This was further complicated by a careless attitude among community members who were said to litter the streets instead of recycling and paying for waste collection.

**Pressure, state/exposure: sources and levels of indoor PM$_{2.5}$**

In addition to the external sources of pollution, the reliance on polluting fuels for cooking and lighting such as charcoal and kerosene was faulted for polluting indoor air. In these two communities, the main source of energy for cooking was kerosene while charcoal/wood was the second most used cooking fuel (Table 5). Analyses on types of fuel and stoves used for cooking and heating revealed that 69.7% and 22.8% of households used kerosene and charcoal, respectively, as the main cooking fuel; while there was also substantial fuel mixing within homes (i.e. the simultaneous or subsequent use of different fuels/stoves on the same day).

<table>
<thead>
<tr>
<th></th>
<th>Korogocho</th>
<th>Viwandani</th>
<th>Total</th>
<th>$\chi^2$ (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Commonly used fuels</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerosene</td>
<td>71.7</td>
<td>67.8</td>
<td>69.7</td>
<td>40.88 (P&lt;0.001)</td>
</tr>
<tr>
<td>Charcoal/wood</td>
<td>26.1</td>
<td>19.9</td>
<td>22.8</td>
<td></td>
</tr>
<tr>
<td>Gas/electricity</td>
<td>2.2</td>
<td>12.3</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td><strong>Types of stoves used</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerosene stove</td>
<td>94.0</td>
<td>93.9</td>
<td>94.0</td>
<td>0.38 (P=0.828)</td>
</tr>
<tr>
<td>Charcoal stove</td>
<td>76.2</td>
<td>73.2</td>
<td>74.6</td>
<td>2.48 (P=0.290)</td>
</tr>
<tr>
<td>Gas/electric stove</td>
<td>3.6</td>
<td>18.4</td>
<td>11.4</td>
<td>57.25 (p&lt;0.001)</td>
</tr>
<tr>
<td>Traditional 3-stone</td>
<td>1.0</td>
<td>0.2</td>
<td>0.6</td>
<td>3.17 (p=0.075)</td>
</tr>
<tr>
<td><strong>Space heating fuels used</strong></td>
<td></td>
<td></td>
<td></td>
<td>28.10 (p&lt;0.001)</td>
</tr>
<tr>
<td>Charcoal/sawdust</td>
<td>26.9</td>
<td>14.3</td>
<td>20.2</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>0.2</td>
<td>1.1</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>No space heating</td>
<td>73.0</td>
<td>84.6</td>
<td>79.1</td>
<td></td>
</tr>
</tbody>
</table>
A small proportion of households reported using wood or other forms of biomass such as saw dust or crop residues, while very few households reported using LPG or electricity as the main cooking fuel. Only a negligible proportion relied on the three-stone stove (see Fig. 5), traditionally used in Africa for cooking. The three stone is the most rudimentary cookstove, consisting of three stones erected either indoors or outdoors in which fuel wood or crop residues are burnt.

Figure 5: Traditional three stone stove (Source: (Onyango, 2016))

The three stone stoves are traditionally not vented and have high emissions due to their low combustion efficiency (Figure 5). There was simultaneous use of other stoves and fuels even though the main fuels were reported differently. For instance, households reported using charcoal even when they mainly relied on kerosene and vice versa; indicating that the sources of indoor emissions were mixed in the same household even in a single day. During the cold season that runs from June through early August, some people reported heating their homes mostly using charcoal stoves. Where households were not connected to a source of electricity, the main source of lighting was a kerosene lamp with an exposed wick (locally known as ‘koroboi’ as shown in Fig. 6).

Figure 6: Open wick lamp (Koroboi) (Source: Africagoodgovernancenow.org)
Further pressure arose in the availability and use of ventilation especially during episodes of cooking. The quantitative data revealed that a substantial proportion of houses did not have a window (37.6%) and relied only on the door for ventilation. The qualitative data revealed that there were deterrents to the use of ventilation, especially in the evening. There were concerns about insecurity in these communities and therefore residents chose to close doors and windows and bear the indoor emissions.

“I don’t know how the kerosene of today is- you find that when you put off the stove, perhaps you will open the door because it emits a bad smell that lingers for the next 15 minutes. Also the lamps (koroboi) we use emit smoke, you find such things in a house made of corrugated sheet and at night maybe you can’t open the door for fear of thieves so you just bear with the smoke until it finds a way out of the house” [FGD, Younger adults, Korogocho].

Other than security concerns, the qualitative study also raised the issue of privacy, unavailability of windows as well as their perceived non-functional state due to their small size. Our findings show that most households opened their doors and windows during morning and mid-day meal preparation, but the number felt drastically during the evening (see Fig. 7). Further, it emerged that residents had modified the eaves by blocking them to keep out the polluted outdoor air and vectors. This contributes to extreme concentrations of pollutants in the home.

Figure 7: Patterns of ventilation use in the study communities (source: Muindi et al 2016)
Besides the use of high-emission cooking and lighting fuel sources and ventilation using behaviour, human behaviour such as indoor cigarette smoking was also cited as a source of pressure. The data showed that 14.7% of households had one or more members of their household, who smoked, and 6.7% households had members who smoked inside the house. Smoking was also mentioned in qualitative discussions as being one of the causes of poor indoor air quality.

“Smoking in the house. Smoking. The man of the house smokes in the house, he does not go outside [to smoke], he comes to the house and he does not care; he will smoke inside the house. You will find that the house is crowded and when he lights the cigarette, the air does not circulate” (FGD, Older adults, Korogocho).

Cigarette smoking indoors not only affected the air quality in the smoker’s house, but also in neighbouring houses due to poor housing structure and crowding in the two communities.

“Also smoking cigarettes, you know instead of smokers going outside to smoke and come back to the house…, you find that they will light a cigarette in the presence of family- the wife and children. Besides affecting the people in his house because you know cigarettes, the smell [smoke] is carried far, the neighbours too are affected” (FGD, Younger Adults, Viwandani).

There were divided opinions on who was responsible for the poor state of air quality in the communities. On the one hand, there were those who acknowledged that the blame lay on them while others felt that it was the government, apparently from its failures to address the visible sources of emissions. In addition, there was little acknowledgement of the possible poor state of indoor air quality considering people’s reliance on poor quality stoves and polluting fuels. For example, when asked to compare both the indoor and outdoor air quality, there was almost unanimous consensus that the outdoor air was more polluted. This was also reflected in the quantitative results on perceived annoyance arising from air pollution which showed that a high proportion (37%) had a very high annoyance rating from outdoor air compared with indoor air quality (6%). The respondents felt that poverty was to blame for the state of indoor air quality, as it constrained people from using cleaner fuels instead relying on dirty and sometimes unconventional fuels such as cloth rags and foam (from old mattresses) or waste plastics. Further, lack of knowledge on the consequences of using dirty fuels or the emissions from conventional fuels was cited as a factor in the state of indoor air quality. The crowding of many houses within small land areas, typical of slum
settlements in Nairobi was also said to bring about a ‘neighbourhood’ effect on air quality by having homes using dirty fuels polluting indoor air of their neighbours, even though the neighbours could have adopted clean cooking technologies.

“You cannot command someone when they are in their house, because you are in your house and they are in their house. You see someone has a charcoal stove but they don’t use charcoal and they buy firewood and you can’t command them to use such and such a thing…they can only afford firewood to cook with, so that smoke is still there, and if you complain, they will say you are looking down on them or you are proud…” (several women agree) (FGD Older adults, Korogocho)

Results from monitoring of PM2.5 levels indicated that the state of indoor air quality was poor in the majority of the households. Indoor levels varied widely across households and ranged from 1 to 12,369 µg/m³ (SD=287.11). The mean PM2.5 levels were equal to or below the WHO 24-hour limit of 25 µg/m³ only in 14% of the households, while the rest of the households exceeded this limit. The guideline level of PM2.5 was exceeded by a factor of 4 or more in about 19% of households. Figure 8 presents the raw PM2.5 levels in households over the monitoring duration, displaying some extreme levels in some of the households.

Figure 8: PM2.5 concentrations across the monitoring duration (source: Muindi et al 2016)
The mean PM$_{2.5}$ levels varied by main cooking fuel. Households reliant on wood/charcoal and kerosene had the highest levels of PM$_{2.5}$. Those reliant on cooking gas or electricity had the lowest. Household lighting also contributed to high levels of fine particles, especially when the use of lamps was needed in the evenings (see Fig. 9). The observed indoor levels, however, need to be interpreted carefully as outdoor pollutants could also influence the indoor environment.

![Figure 9: Mean household PM2.5 concentrations by cooking and lighting fuel](Source: Muindi et al. 2016)

When disaggregated by cooking times- i.e. time periods when meal preparation was likely to take place (see Fig. 10), we noted spikes in the evening across both study communities and this could have been propelled by a combined effect of poor ventilation use and simultaneous use of stove and kerosene lamps.

![Figure 10: Mean household PM2.5 concentrations at different cooking times](81.3 38.3 79.5 30.3 94.0 80.3)

Pressure, state/exposure: perceptions about indoor and outdoor air pollution

The results revealed that people residing in the two slum communities, Korogocho and Viwandani, were aware of the sources of air pollution. Industries and open dumpsites near the two communities were said to contribute to the poor state of air. Viwandani is home to Nairobi’s main industrial zone where diverse manufacturing activities such as production of plastic products, agro-chemicals, flour and resins used in the production of tear gas take place. The factories operate all day and into early evening and were said to release emissions especially in the evenings. In addition to manufacturing, there is a constant flow of heavy trucks bringing raw materials or carrying finished products to the market, with implications for emissions. In addition to the industries, Viwandani neighbours an illegal dumpsite that receives waste from households and industries. The dumpsite is always smoky due to combustion of waste. Korogocho, on the other hand, is located adjacent to the city’s only dumpsite – the Dandora dumpsite- an open site which was an old disused stone quarry. This site was established in the 1970’s to fill up the quarry, after which the plan was to find a suitable location for the city’s dumpsite. However, the dumpsite grew and spread into neighbouring residential areas and currently occupies about 30 acres. Efforts to relocate the dumpsite have failed and it remains in use today even though it was to be closed in 2001 when it reached its maximum holding capacity. Several light industries which manufacture various products including paints are located near Korogocho, and their operations could have an impact on air quality in the surrounding areas. With regards to annoyance arising from air pollution, study participants expressed more annoyance from outdoor air pollution than they were with indoor air pollution. This was perhaps motivated by the perception that indoor air was cleaner than outdoor air.
**Effects: Perceived health effects of air pollution**

Results from the thematic analysis of perceptions of the health consequences of exposure to air pollution indicate that residents in the two communities have mixed perceptions on the health effects of air pollution. There were perceptions that pointed to either lack of knowledge on specific conditions arising from exposure to air pollution or the view of the environment as a single entity and not in its different components, so that if one of the components is polluted, then the entire environment is. For example, there were opinions of diarrheal and vector borne diseases being related to air pollution, which does not have any scientific ground. On the other hand, there were those who mentioned specific health conditions related to air pollution with respiratory illnesses being the most common conditions mentioned. This finding reflected what was found from the quantitative study in which majority of respondents – 61.5% in Viwandani and 74.4% in Korogocho mentioned respiratory conditions (cough and colds). Other health conditions mentioned in the quantitative study include cancer (6.4% and 6.5% in Viwandani and Korogocho, respectively), heart problems (15.1% and 13.3% in Viwandani and Korogocho, respectively), and headache and eye problems. Further, the respondents also mentioned difficult breathing and asthma as being related to air pollution. The results from the qualitative study also point to incorrect information available to residents in the two communities regarding the health effects of air pollution. The quantitative study revealed that air quality issues are given little coverage both in media and community forums. Differences in the perceptions of health risks between the two communities were noted, with Korogocho residents raising more concerns on the pollution-related health effects compared to their Viwandani counterparts. For instance, only Korogocho residents mentioned effects on pregnant mothers and the foetus/neonate as well as psychological effects while Viwandani residents mostly mentioned respiratory issues.
Perceived actions to address air quality issues

Through the focus group discussions, we sought to find out what could be done, both by the communities and the government to address the current situation. On the one hand, there were opinions that the residents needed to act to improve both indoor and outdoor air quality. For example, there were suggestions on better solid waste management to discourage people from burning waste, which was mentioned as a cause of air pollution. Participants felt that ignorance among residents regarding recycling of waste, led them to burn it, consequently affecting their health. Participants were aware that government had a responsibility to reduce outdoor emissions through legislation/policies. The participants had a strong opinion that the government did not have any role in reducing indoor air pollution.

On the other hand, the participants expressed that there was lack of agency to address the issues especially those from external sources such as dumpsites and industries. This was compounded by threats of eviction from people in authority whenever the community voiced their concern about emissions from these sources. The lack of agency led to resignation to fate and to living in the current polluted space even though they acknowledged the dirty air they breathed.

“…the problem is where we can get help because we live in a poor area, what can we do and this is where we can live?” (FGD, Older adults, Viwandani).

Lastly, there were opinions that creation of awareness on air pollution including its effects on health, was needed so that people could understand how their actions contributed to poor air quality; and what it is they could do to bring change in their communities.

If the community could be educated about the effects of these things- you see there are things people do out of ignorance e.g. as you said charcoal stove, (kerosene) stoves are lit, the man is smoking cigarettes and the windows and doors are closed. If the community can be educated on the effects of these things so that they have that knowledge; that will really help…”(FGD, Older adults, Viwandani).
Discussion

This study assessed the sources and levels of indoor fine particulate matter (PM$_{2.5}$) as well as perceptions and attitudes towards air pollution and health risks among residents in two slum communities in Nairobi city. The study utilized data to answer the research questions, generated from both qualitative and quantitative approaches. The discussion is structured along the components of the DPSEEA framework with a separate discussion on people’s perceptions of and attitudes towards air pollution. I conclude the discussion with a reflection on policy and practical implications of the findings and provide suggestions for future research directions.

Pressure, state/exposure: sources and levels of PM$_{2.5}$

Household air pollution can arise from various sources including cooking and lighting fuels, ingress of outdoor air and cigarette smoking indoors. In the context where this study was conducted, households use a range of cooking fuels such as kerosene, charcoal, wood and cloth rags as well as plastic waste. The kind of stoves on which these fuels are combusted are not very efficient, leading to emissions into the living space. Based on the household energy ladder (Hiemstra-van-der-Horst and Hovorka, 2008), households reliant on wood and charcoal remain on the lower rungs of the ladder, and the results indicate that wood/charcoal using households had some of the highest levels of particulate pollutants. Further, there was substantial stove stacking in most of the households included in the study, with kerosene and charcoal being common combinations of fuels used either simultaneously or at different times in a single day. This stacking leads to higher emissions especially where households use cleaner fuels like LPG or electricity alongside charcoal or kerosene, negating the positive impacts of cleaner fuels on indoor levels of PM$_{2.5}$. Similar findings have been reported especially in poor households where this stacking phenomenon is common (Mdluli, 2007).

There are disparities in the exposure of household members to cookstove emissions in the study community, largely due to differences in economic status of households among other factors. Qualitative accounts indicate that fuel choice in these settings is driven by a household’s financial ability, meaning that the poorest households would rely on wood and non-conventional fuels like plastic waste, leading to higher levels of indoor pollutants from resultant emissions. On the other hand, kerosene is higher up on the energy ladder and though it is thought to be a cleaner option, the results indicate kerosene using households were also exposed
to high levels of PM$_{2.5}$ more so if kerosene was used as both the lighting and cooking fuel. The use of old/worn-out stoves, compounded by practices around putting off the stove using water, and other household behaviour on ventilation use, could lead to the observed levels of pollution. Given concerns around the safety of kerosene as a household fuel (Lam, Smith, et al., 2012; WHO, 2014), the results support the need to discourage its use.

Current developments in the clean cookstoves sector in the country are hoped to lead to wider availability and lower product prices. The government provides subsidies to local manufacturers of clean stoves and alternative fuels in the form of lower import tax of materials needed to assemble stoves (Stockholm Environment Institute, 2016). However, there remain challenges in affordability of the stoves especially among the poor since these tax cuts are not strong enough to push the cost of products down. In addition to government efforts, several non-governmental organizations and bilateral partners are working with local communities to ensure access to cleaner cookstoves and lighting. Various financing options have been implemented that take into consideration the population with low incomes for instance mobile money solutions that enable buyers to pay in small instalments, but uptake remains minimal especially in slums.

In the study communities, most houses are not supplied with electricity for lighting and where they have access, interruption in the supply leads to use of other light sources. The most common source of lighting in these settings is a simple kerosene lamp which is made of simple materials, mostly tin, and an exposed wick which burns with a lot of smoke emissions. Other sources of light include candles that also contribute substantially to emissions. Kerosene for household use has been indicated as a source of harmful emissions both to human health and the environment (Lam, Chen, et al., 2012; Lam, Smith, et al., 2012) and the discontinuation of its use has been encouraged (WHO, 2014).

The prevalence of dirty fuels in urban settings in Kenya is high (Kenya National Bureau of Statistics et al., 2015) and this has implications for indoor and outdoor air quality. The results indicate use of unconventional fuels such as plastic waste which undoubtedly has a range of pollutants with implications for the health of users and their family. Given existing research that has shown high levels of poverty within urban slums (African Population and Health Research Center, 2002; UN-Habitat, 2003), it is conceivable that some families would rely on the dirtiest of fuels including cloth rags and plastic waste. Other cooking fuels used in the study communities such as charcoal and wood are also associated with high
emissions of health harming compounds (Naeher et al., 2007; Department of Ecology State of Washington, 2012), with similar poly aromatic hydrocarbons (PAHs) also found in tobacco smoke. Some studies have shown that wood smoke has more PAHs and their levels are higher than in tobacco smoke, posing a greater health risk to the billions of biomass users globally (Australian National Environment Protection Measure).

There were reported structural limitations in the form of absence of windows or their perceived small size and therefore seen as non-functional. These were strong deterents to the use of ventilation, leading to poor indoor air quality. Further, concerns over insecurity, especially in the evening, limited household’s use of ventilation, contributing to poor indoor air quality. The small windows and a total absence of the same reflect an unregulated ‘real estate’ within slums, resulting in sub-standard housing with serious implications for health (Krieger and Higgins, 2002). The effect of these structural issues is amplified by the blocking of ventilation eaves in a bid to keep away disease vectors such as mosquitoes as well as poor outdoor air. This may reflect poor knowledge among residents on the impact such actions have on indoor emissions on one hand while on the other it may reflect the limited choices they have in dealing with poor outdoor air.

In addition, crowding of houses that is typical in slums in the city is also a potential factor in cross-household contamination of air. Government efforts to upgrade slum housing is a step in the right direction. These efforts should go hand in hand with addressing security of tenure to allow community ownership of land and houses, and therefore encourage local commitment in addressing environmental issues.

In addition to cooking and lighting fuels and the structural limitations cited above, cigarette smoking in the house was reported as a factor contributing to indoor air pollution. In Kenya, as in many African communities, masculinity is associated with cigarette smoking (Peltzer K., 2011). Given that patriarchy is the dominant form of household structure in most African societies, it is not uncommon to find male household members smoking in the home (Nichter et al., 2010), thereby contributing to poor indoor air. The findings that 14.7% of respondents had one or more members of the household who was a cigarette smoker, is similar to what was reported in a previous study (Ayah et al., 2013). Further, the proportion of slum residents reporting being exposed to tobacco smoke in their homes was considerable being about half of the national proportion exposed to cigarette smoke at home (WHO Regional Office for Africa, 2015). Various studies have
shown the contribution of cigarette smoking to poor indoor air quality (Saade et al., 2010; WHO, 2014; Gerber et al., 2015), while exposure to secondary cigarette smoke has been shown to have adverse effects on the health of non-smoking household members (US Department of Health and Human Services, 2006; WHO, 2017).

Another source of indoor air pollution is the interaction between indoor and outdoor air (Leung, 2015). A previous study on levels of PM$_{2.5}$ in the outdoors in the same study communities revealed spatial and temporal variations in the concentrations of outdoor PM$_{2.5}$, with extremely high level in some areas close to the farmers’ market, the municipal dumpsite and other visible sources of emissions. Mornings and evenings were also found to have higher levels of emissions compared to the rest of the day (Egondi et al., 2016). These observed outdoor levels are bound to influence indoor levels of pollutants (Leung, 2015).

When asked to compare outdoor and indoor levels of pollution, indoor air was thought to be less polluted compared to outdoor air in both the qualitative and quantitative assessments of people’s perceptions. However, measured levels of indoor fine particles revealed spikes in levels of pollutants especially during episodes of stove use, which at times exceeded outdoor levels. Indoor pollutants were highest in the evenings, which could arise from concomitant use of stoves and kerosene lamps as well as poor use of ventilation and ingress from outdoors.

**Perceptions of and attitudes towards air pollution**

People’s perceptions of and their attitudes towards air pollution is motivated by several factors key among them being the presence of visible sources of pollution as well as knowledge or availability of information on pollution (Elliott et al., 1999; Bush et al., 2001; Bickerstaff, 2004). The study revealed that residents relied a lot on sensory perceptions such as sight and smell to make associations of visible sources with the state of air in the community. The presence of dumpsites, industries, and other visible sources of emissions led to the perception that the air around these sources was highly polluted. Outdoor measurements of levels of pollutants support the perceptions on poor outdoor air quality in both communities (Egondi et al., 2016). The reliance on sensory perception for odorous pollution or visible pollution such as smoke can act to spur people to respond either by moving away from the source or addressing the source. It however raises concern over indoor concentrations of the mostly odourless and invisible carbon monoxide that might be ‘undetected’, with dire consequences. Results indicate that residents only became aware of monoxide poisoning when fatalities occurred.
People’s attitudes towards air pollution especially indoors reveal a resigned attitude. Participants in the qualitative study felt that indoor air was within the mandate of private citizens and not at all in the hands of government. This attitude exposes a lack of knowledge regarding the responsibility of governments in improving indoor air quality through policies that make households access cleaner cookstoves and fuels at affordable prices. This lack of knowledge may also indicate a failure in the policy making process in which lay persons are not involved yet this has been encouraged and is increasingly being embraced in some countries (Brulle, 2010; Wesselink et al., 2011; Mauerhofer, 2016). The lay public remains a key partner in the implementation of environmental policies and their participation in the policy making process is therefore important to ensure ownership of the actions arising from these policies.

The results of annoyance due to indoor and outdoor air pollution indicate that higher proportions of residents were annoyed by outdoor air pollution which was reported in terms of odour from stagnant waste water in drainages and industries with odorous emissions, as well as the visible emissions such as smoke from dumpsites and industries. Few studies have looked at annoyance due to air pollution and they point to odorous and chemical pollutants as sources of annoyance (van Thriel et al., 2008; Claeson et al., 2013). Our study shows low levels of annoyance with indoor air pollution as opposed to outdoor pollution perhaps due to people’s tendency to look less critically at conditions within their residential space while laying more weights on those issues perceived to be other people’s responsibility, a situation that has been termed the ‘halo’ effect (Bickerstaff, 2004).

It is possible that residents in the two communities do not think emissions from cookstoves cause much air pollution due to the belief that charcoal/wood being natural products are harmless (Department of Ecology State of Washington, 2012). Although perceived quality of air does not overlap measured levels, the opinion that indoor air is less polluted could be a way of individuals making their personal living spaces ‘clean’ in a context of poor environmental quality (Bickerstaff, 2004).

The finding points to reliance on visual and olfactory senses to assess exposure to air pollution, given the absence of monitoring in Kenya. Considering that both communities are located near visible sources of air pollution (smoke from dumpsites, emissions from factories), then it is plausible that they might think the visible pollution leads to worse air quality outdoors than indoors. It might also be due to failure to acknowledge the contribution of outdoor levels of pollutants to indoor levels, given the context in which there is no or limited public education on air quality and associated effects.
Lay perceptions on health impacts of air pollution indicated mixed knowledge. While some study participants mentioned conditions known to be caused or aggravated by exposure to air pollution such as respiratory illnesses, others mentioned conditions not biologically related to air pollution. The concern about respiratory health aligns with other studies that indicate respiratory illnesses as the health risk mostly mentioned by lay persons (Bush et al., 2001; Lan et al., 2016). The findings are also in agreement with an earlier assessment of the burden of disease in these communities that showed respiratory illness as a leading cause of morbidity and mortality in children (Kyobutungi et al., 2008). The results reflect findings in other studies on the association of air pollution and respiratory health in various settings (Duflo et al., 2008; Guan et al., 2016; Nguyen et al., 2017). To explain how air pollution might bring about some of the health conditions, some mechanisms were put forward. However, the some of the suggested mechanisms were not aligned with science, for example getting tuberculosis from consuming soot covered food cooked with unconventional fuels like rags. These opinions, however, indicate an appreciation of biological processes that take place when one is exposed to air pollution to bring ill health. Perceived consequences of air pollution differed by community with people from Korogocho displaying varied perceived health effects compared to their Viwandani counterparts. This can be attributed to existing environmental activism in the former community pushing for the relocation of the Dandora dumpsite which neighbours Korogocho This has created awareness regarding the impact of having the municipal dumpsite in the neighbourhood (Ogola and Moschetti, 2009; Conrad, 2012). The same efforts have however not been registered in Viwandani, despite the existence of an illegal dumpsite and industries in the neighbourhood. The Dandora dump is associated with enormous human and environmental health impacts it has on the thousands of residents and areas around it (Kimani, 2007). The site is a source of air pollutants owing to the combustion of mixed waste streams (household, health, agricultural and industrial waste) disposed here.

The participants mentioning unrelated conditions might display a lack of information on specific health conditions related to air pollution. This is supported by findings from a previous study that revealed that environmental matters were not given enough airtime in media or other forums such as community meetings and considerable proportions reported never having heard any messages on air pollution (Egondi T et al., 2013). On the other hand, these opinions might point to a view on the environment as a single entity. With this view, it is possible that
pollution of a component of the environment and the effects arising are generalized to all components. Further participants may have been airing opinions regarding what they felt was a more pressing issue given the deprived spaces they live in, where poor sanitation remains an overwhelming concern (African Population and Health Research Center, 2014), and was overwhelmingly mentioned as a source of air pollution, ostensibly from the odour arising from blocked drainage channels (Egondi T et al., 2013).

Perceived actions to address air pollution

The acknowledgement of government responsibility alongside residents’ actions to reduce outdoor pollution indicates an appreciation of the need for partnership in facing the air quality challenges in the communities. The outdoor air pollution challenge is perceived to be more of a public issue which requires government intervention in dealing with known source of pollutants such as industries and dumpsites through legislation on emissions control or relocation of the dumpsite to sites far from human settlements. However, the prevailing perception that the government has no role in mitigating air pollution in people’s homes indicates a view of indoor air as being a private issue with no opportunity for government intervention. This is contrary to the reality in which government policies and interventions such as subsidies targeting cleaner cookstoves and lighting, aim at ensuring the indoor space has lower levels of air pollutants. However, these efforts appear to remain unknown to residents in the two communities, perhaps owing to low penetration of the products of such subsidies.

Lack of agency by the communities to voice their concerns about environmental issues meant they had to live in the polluted space if they could not afford to move to better off neighbourhoods. On the one hand, residents in the two communities were conflicted because of their reliance on these two main pollution sources (dumpsites and industries) for their livelihoods. Dumpsites have been a source of income for waste pickers for decades while the industrial zone is a main employer for hundreds of residents in the two communities. On the other hand, they felt there was an urgent need to address the emissions from these sources. Their diminished agency and counter threats of eviction if they voiced concern over the contamination of their physical space led them to keep silent and just live in these communities. Their agency was further curtailed by the general view of slums in the country- for a long time they have been perceived as illegal and therefore left out of policies and service provision, which perpetuates the disregard of environmental issues in these communities. This has contributed to the
communities’ general resignation to fate and to living in the current situation even though it is clear to residents the poor environment in which they live. This finding resonates with other results, where residents perceived themselves to have poor control over industrial, odorous and air pollution (Omanga et al., 2014). The outlook of slum areas is slowly changing as the government together with partners have been undertaking slum upgrading projects (Candiracci and Syrjänen, 2007) which are expected to improve housing and access to basic services.

Calls to have more awareness created in the communities reflect a need for relevant information on sources, effects and ways to reduce pollution. This was identified as one of the most important steps that would do away with ignorant practices that cause/worsen air pollution. In addition, it was felt that the government needed to implement emission controls in industries and vehicles to ensure better air quality. This is one of the areas the government has been lacking in, however in 2014 the national air quality regulations came into force (NEMA, 2014), and it is now their implementation and enforcement that need to be given priority moving forward.

Methodological considerations

Strengths

One of the key strengths of this thesis is the triangulation of qualitative and quantitative data to study a common topic. This offered an opportunity for the validation of findings, which increased the trustworthiness of the study.

Another strength is the combination of both scientific and lay perspectives to answer the research questions. The scientific perspective included the measurements of indoor PM levels, which puts into perspective the state of air within the homes, while also highlighting the drivers of poor indoor air in the study settings. The lay perspective was achieved through qualitative data in which community experiences of air pollution and perceptions on several issues including the health effects of air pollution were assessed. The measured levels of PM in these settings gave empirical evidence where very little had existed before while lay perspectives gave in-depth understanding of community perceptions of the state of air in their communities and homes, their exposure and effect on their health.
A further strength lay in the research team which had in-depth engagement with the two study communities. The author of this thesis and the moderator of the FGDs both have years of interaction with the two communities and this ensured willingness of the communities to take part in the study, while also ensuring cultural sensitivity during discussions.

Finally, nesting the study on an existing platform— the NUHDSS was a strength of this study. The NUHDSS provides key data such as household wealth and socio-demographic data, which removes the need to collect these data. Further, the NUHDSS platform has already established important relationships with the communities that are key in ensuring participation in nested studies.

Limitations

There are some limitations that must be taken into consideration in interpreting the findings reported in this study. Firstly, we conducted the PM measurements only in conveniently sampled households due to considerations for staff and equipment safety. We however do not think these households differ significantly from the other households in the respective study communities regarding indoor sources of air pollutants, and therefore the results remain a representation of the air quality in homes within each study site.

Secondly, we did not have an opportunity to collect 24-hour indoor concentrations due to the aforementioned reasons; we however believe these results shed light into the levels of pollutants within these homes.

Third, the limited number of equipment did not allow for simultaneous collection of outdoor data which would have been controlled for; neither did we have equipment to collect data on humidity and temperature for which to adjust observed levels. This might have led to imprecise levels of indoor PM.

A fourth limitation arose from conducting the FGDs in groups with mixed sexes which might have had an impact on some participants’ freedom to express personal views on the topic. Given strong gender roles in the communities, it is not unlikely that some of the participants, especially women, could have been tempered in their contribution to the discussions due to the presence of men.

These gaps are some of the areas future research should fill.
Conclusion

This study has adopted the DPSEEA framework to assess the challenge of air pollution in the two slum communities in Nairobi city in Kenya. Based on the findings, we conclude that the two communities face potentially high levels of PM$_{2.5}$ mainly arising from poor quality cooking fuels and stoves, as well as from the outdoor environment. These high levels are cause for concern and there is need for action to address the air pollution challenge. Further, residents are aware of air pollution sources and perceive air pollution as an issue. They also have knowledge regarding possible health effects, however this information is imperfect in both communities and there is need to provide accurate and targeted information on air pollution and its impact on people’s health. This would empower individuals to embrace actions aimed at reducing pollution and/or exposure while also equipping them with skills to push for government action to improve their environment.
Implications for Policy

The findings presented in this thesis have the following implications for policy involving different public sectors in Kenya.

1. Solid waste management which has been cited as a main source of air pollutants needs urgent attention. Policies on proper solid waste management need to address ideal siting of dumpsite/landfills, recycling and the position that waste pickers would hold in the system to discontinue their reliance on dumpsites for their livelihood. On the other hand, individuals and communities at large need to appreciate their role in ensuring proper waste management by collecting and properly disposing of solid waste; and avoiding open burning of waste.

2. Policies on industrial emissions need to be enforced to reduce their contribution to poor air quality in the communities and beyond. The enforcement must involve the industries who would be key partners in the implementation of any requisite changes in emissions control systems.

3. Housing construction standards should be enforced in slums to ensure better quality housing, given the poor housing e.g. some lacking windows- that is prevalent in these communities. The enforcement of standards and upgrading efforts would also require the issue of land tenure to be addressed to ensure that communities are invested in improving the housing and general environment in which they live. Acceleration of ongoing slum upgrading projects would be timely.

4. Switching to cleaner household cooking and lighting systems is encouraged; government policies on pricing of clean cooking and lighting options should consider those living in the lower end of the income bracket to ensure affordability.

5. There is need for the public reporting system on environmental issues to be strengthened and publicised so that residents can make use of it to report cases of environmental pollution; while being assured of proper action against offenders and the protection of those reporting such cases.

6. Education/awareness creation regarding air quality and its effects on health would be important and this can be implemented through community-based organizations that have wide acceptance in the study communities.
Future Research

1. This study focused only on two slum communities, however to gain insights into potential socio-economic differentials in pollutant levels, it would be important to conduct a city-wide study covering different residential areas.

2. It would offer more insights if a well designed prospective study simultaneously measuring indoor and outdoor concentrations, and personal exposure could be carried out to assess the impact of air pollution on health.

3. It would be important to conduct operational research on switching to cleaner cookstoves, and incorporate a qualitative assessment of enablers and barriers to the adoption of this clean cooking and lighting technologies, both at the household and community levels.

4. An assessment of the best approaches to educate communities on such a technical field like air pollution is warranted. This assessment should focus on what the content of such an initiative would be, who should offer this education and how to ensure program continuity.

5. Lastly, efforts to engage multi-sectoral actors are needed to push for their collaboration in working towards addressing the important issue of air quality, not only in slums but in the entire city. A systems assessment would shed light on how to engage these actors, their roles and what would work best.
Acknowledgements

This journey has been long and sometimes trying... but as the African adage goes: ‘wisdom is like fire; people take it from others’, I have been blessed to have wonderful people from whom I have taken some warmth of their fire along the way.

First to God who has been a pillar of strength for me throughout this journey; your steadfastness has been witnessed in this journey and I give thanks and Glory to your Holy name. You have made all possible even when it seemed impossible.

To my wonderful supervisors Prof Nawi Ng; Prof Joacim Rocklöv and Dr. Elizabeth Kimani-Murage. You listened to the ideas of a prospective student armed with little knowledge and a great passion for air quality and you were willing to hold my hand and sometimes carry me through some of the toughest stretches of this journey. I will forever be indebted to you for shaping me into the researcher that I have become. God richly bless you for what you have invested in me.

My gratitude goes to Birgitta, Lena, Ulrika, Karin and colleagues I may not have named, your organizational skills for my stay have been great. During my visits, I knew I would find everything in place, you made my stays away from home so comfortable, I felt at home.

This journey would not have been possible without the efforts of Dr. Alex Ezeh and Dr. Catherine Kyobutungi, who ensured the agreement between Umeå and APHRC was signed, setting me off on this journey. My colleagues at APHRC, you have been a support system like no other- providing intellectual stimulation and support and being there when I needed to bounce ideas off other people. Thank you all for your support.

Lucy, my dearest sister from another mother, you have taught me to always see the positive in the midst of tough times. Your support during this journey has been God-send! Thank you for late-night chats that gave me the push I needed to press on with this journey. I will always treasure this friendship!

Marilyn, our various discussions at coffee break and over the net have kept me inspired- you truly challenge me to be better both physically and intellectually. You particularly have taught me to be meticulous even in the little things to do with data- I have been extremely lucky to have you for a friend!
Benta, you truly have been a friend and a source of inspiration; you encouraged me when I was at the lowest and thinking of packing up and leaving the entire pursuit behind me. You helped me understand grounded theory and other qualitative techniques that were not my cup of tea and in the end I am sold over to qualitative methods. Thank you.

Maria Forsman and Staffan, you always ensured that I did not get too entangled in academic pursuits at the expense of communion with my brothers and sisters in the Lord. Thank you for the many times you have come to visit for stimulating Bible studies and for your generous spirit in picking me up and dropping me off from church. God bless you.

The friends I have met at Umeå - Gladys, Mikkel, Sirili, Sewe, Sulis, Tetui, Zulu, Jing, Iraxte, Kateryna, Trang and the many others I cannot name, you have been a source of ‘kinship’ while far from our own families. May the bonds we created go beyond the Umeå setting and be indeed mighty networks bringing change wherever we find ourselves.

My family especially my sister Nthenya and my brother-in-law Nicholas- you truly have been wonderful- accepting to look after my daughter- even when you were not parents to your own child- while I took time to travel to Umeå each year. My sister Wanza, you too have been a great aunt to my daughter in my absence. I will forever be indebted to you all. And to the entire Muindi family- thank you for your encouragement and prayers for me while I undertook this tough task. You have all stood by me and I am blessed to come from such a wonderful family.

Last but not the least my beloved daughter Kokugonza Koki, you have been an inspiration, bearing my absence from home each year without complaints. You didn’t fuss about my ‘absence’ while at home as I took time to work on this thesis, instead you became my in-house ‘supervisor’, always reminding me to get up early and push the papers! The sacrifice on your part has been awesome, and I am immensely blessed to have you for a daughter. I love you.
References


Australian National Environment Protection Measure Comparison of toxic chemicals in wood and cigarette smoke.


ETH Studio Basel Contermporary City Institute *The Waste Network*, Basel, Switzerland.


Olsson D. 2014. *Adverse effects of exposure to air pollutants during fetal development and early life with focus on pre-eclampsia, preterm delivery, and childhood asthma*. PhD, Umea.


Wilhelm, Michelle, Jo Kay Ghosh, Jason Su, Myles Cockburn, Michael Jerrett and Beate Ritz 2011. Traffic-related air toxics and preterm birth: a population-based case-control study in Los Angeles county, California. Environmental Health, 10(89).

Zhiyong H and Rao KR. 2009. Particulate air pollution and chronic ischemic heart disease in the eastern United States: a county level ecological study using satellite aerosol data. Environmental Health, 8(26).

Annex 1: Questionnaire for community perceptions of air pollution and associated annoyance and health risk

<table>
<thead>
<tr>
<th>SECTION 1: BACKGROUND</th>
</tr>
</thead>
<tbody>
<tr>
<td>101 FW CODE</td>
</tr>
<tr>
<td>102 START TIME (HH:MM)</td>
</tr>
<tr>
<td>103 NAME OF HOUSEHOLD-HEAD</td>
</tr>
<tr>
<td>104 LOCATION ID</td>
</tr>
<tr>
<td>105 HOUSEHOLD ID</td>
</tr>
<tr>
<td>106 RESULT OF INTERVIEW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SECTION 2: PERCEPTIONS, BELIEFS AND ATTITUDES</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO. QUESTION AND FILTERS</td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td>201 How long have you lived in Kongopoh/Kwembo?</td>
</tr>
<tr>
<td>202 Have you been involved in any income generating activity in the last 12 months?</td>
</tr>
<tr>
<td>203 What would you say (has been) your most regular source of livelihood that you have been involved in during the last 12 months?</td>
</tr>
<tr>
<td>204 For how long have you been involved in this work?</td>
</tr>
<tr>
<td>205 How would you describe the place where you work/have been working in the last 12 months: Would you say it is:</td>
</tr>
<tr>
<td>206 How would you rate the quality of air in the community where you live (Kwembo/Kongopoh)? Would you say it is:</td>
</tr>
<tr>
<td>207 How would you rate the quality of air in your house? Would you say it is:</td>
</tr>
</tbody>
</table>
Assume that people’s level of annoyance due to indoor and outdoor air pollution from any source can be stacked on a ladder like the one shown here, with level 01 representing NO ANNOYANCE and level 05 representing EXTREME ANNOYANCE.

Where would you place yourself on this ladder with regards to annoyance due to?

a) Outdoor air pollution?

b) Indoor air pollution?

(RECORD THE LEVEL IN THE BOXES)

The following questions will touch on sources of air pollution inside and outside our homes. We will then discuss the degree of health risks posed by the various sources of pollution.

Which of the following would you say are the sources of outdoor and indoor air pollution within your house?

<table>
<thead>
<tr>
<th>Source of Air Pollution</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 DUST</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>02 VISION EMERGIES</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>03 INDUSTRIAL EMISIONS</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>04 COOKING FUELS</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>05 BURNING TRASH</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>06 SMELLY SEWAGE</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>07 CIGARETTE SMOKING</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>08 OTHER</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

If any of these sources are present, which level of pollution do you consider it to be?

<table>
<thead>
<tr>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
</tr>
<tr>
<td>MODERATE</td>
</tr>
<tr>
<td>HIGH</td>
</tr>
<tr>
<td>V. HIGH</td>
</tr>
</tbody>
</table>

How aware would you say you are of air pollution in your home?

Which of the following would you say are the sources of indoor air pollution within your home?

<table>
<thead>
<tr>
<th>Source of Air Pollution</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>09 RADIO</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10 TELEVISION</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>11 NEWSPAPER/MAGAZINES</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>12 BARAZAS</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>13 HEALTH WORKERS/FACILITIES</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>14 OTHER</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

If any of these sources are present, which level of pollution do you consider it to be?

<table>
<thead>
<tr>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
</tr>
<tr>
<td>MODERATE</td>
</tr>
<tr>
<td>HIGH</td>
</tr>
<tr>
<td>V. HIGH</td>
</tr>
</tbody>
</table>

How much health risk do you think it is to you and your family?

In the past 12 months, have you received any information regarding air pollution or the health effects associated with air pollution from any of the following sources?

<table>
<thead>
<tr>
<th>Source of Information</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 RADIO</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>16 TELEVISION</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>17 NEWSPAPER/MAGAZINES</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>18 BARAZAS</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>19 HEALTH WORKERS/FACILITIES</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>20 OTHER</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

If any of these sources are present, which level of information do you consider it to be?

<table>
<thead>
<tr>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
</tr>
<tr>
<td>MODERATE</td>
</tr>
<tr>
<td>HQ. MODERATE</td>
</tr>
<tr>
<td>HIGH</td>
</tr>
<tr>
<td>V. HIGH</td>
</tr>
</tbody>
</table>

END TIME (HH/MM)
Annex 2: Qualitative guide

**Qualitative guide: people's perceptions and attitudes towards air pollution**

There will be focus group discussions, separately for young adult males and females (mixed) and older adult males and females. Young adults are defined as those aged between 18 and 29 while older adults will be 30 and above. Each focus group will have 6-12 participants and two facilitators.

**Objectives:**
The study's objectives are to:

1. Understand the perceptions, attitudes and beliefs of individuals regarding air pollution in the community as well as in the houses.
2. Assess the communities' understanding of the health risks associated with air pollution.

**Discussions**

**General understanding of environment**

1. Let us discuss the broad issue of our environment
   a. What does ‘environment’ mean to you? (Explore what the word environment means and let the participants discuss briefly on this).
   b. What comes into our minds when we hear the term pollution of the environment? Let the group discuss on any issue regarding the overall environment (air, water, land).

**Outdoor air pollution**

2. Let us discuss about the different types of air pollution we face in our day to day lives. Let us start with a discussion about the air outside our homes for example on our way to work, to the market and other places outside.
   a. What do we think are the sources of pollution of the air outside our homes?
   b. What do we feel should be done by individuals, communities and government to address any identified issues?

**Indoor air pollution**

3. Now let us talk about the air within our homes.
   a. What would we say are the sources of pollution of the air within our homes?
   b. In addition discuss ventilation and how it is viewed e.g. windows or door open/closed when stove is on?
   c. What are the possible steps that can be taken by individuals, communities and government to address any identified issues? This question was not asked to all previous groups

**Concern over air pollution**

3a. Do we think people in this community are concerned about air pollution? Why or why not?

**Comparing outdoor and indoor pollution**

3b. When we compare the state of outdoor air and that of indoor air in our community, which would we say is worse? Why?

**Health risk related to air pollution**

4. What comes into our minds when we hear the term ‘risk’?

5. We will discuss the health risks arising from exposure to air pollution both in our homes, work place and in the outdoor environment.
   a. In your opinion, what are the health problems associated with air pollution?
b. Which of these are the most common problems experienced by people living in our communities?

Ending the discussion

Thank the participants for answering all these questions and explain once more that their answers will help us understand their thoughts on exposures to and risks arising from air pollution. Also explain that there will be a report back to the community later on when all information has been gathered and analyzed.