ASAP
EAST AFRICA

Vulnerability Scoping Study: **Air Pollution Exposure in Low Income Households in Kampala**

Kampala (Uganda)

EARF EAST AFRICA RESEARCH FUND

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About this report:

The ASAP-East Africa vulnerability scoping studies explore the experiences of those particularly vulnerable populations, occupations and locations in the East African cities of Addis Ababa, Kampala and Nairobi, exposed to high levels of both indoor and outdoor air pollutants. By undertaking vulnerability scoping studies, the research team seeks to generate a more textured understanding of specific characteristics and factors associated with vulnerability to air pollution. This will allow the exploration of these vulnerabilities across cities and facilitate the development of targeted recommendations that respond to the needs of specific populations, occupations or locations.

Author and contributions:

This report was written by William Avis (Research Fellow, University of Birmingham United Kingdom), Shelton Mariga (Makerere Lung Institute) and Ajit Singh (University of Birmingham). The authors would like to thank the participants in this study, without their willing participation this study would not have been possible. The author also appreciates the contributions of Jessie Pinchoff (Population Council) and Suzanne Bartington (University of Birmingham) who made valuable comments on earlier versions of the Report.

About the A Systems Approach to Air Pollution – East Africa (ASAP-East Africa) project

ASAP-East Africa brings together leading UK and East African researchers in air pollution, urban planning, economic geography, public health, social sciences and development studies to provide a framework for improved air quality management in three East African cities: Addis Ababa (Ethiopia), Kampala (Uganda) and Nairobi (Kenya).

This timely and responsive programme of activity will enhance local decision-making abilities to improve urban air quality, reduce the effects of air pollution upon human health, and allow for sustainable development to proceed without further deterioration in air quality.

Central to the project's aims are strengthening research capabilities and technological expertise in East Africa, with local stakeholders and experts involved in the conception, implementation, and uptake of the programme and its outcomes.

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Acronyms

APHRC:	African Population and Health Research Centre
AQ:	Air Quality
ARI:	Acute Respiratory Infection
ASAP-East Africa:	A Systems Approach to Air Pollution – East Africa
COPD:	Chronic Obstructive Pulmonary Disease
CSO:	Civil Society Organisations
DALY:	Disability Adjusted Life Year
DFID:	Department for International Development
EARH:	East African Research Hub
GACC:	Global Alliance of Clean Cookstoves
HAP:	Household Air Pollution
HEI:	Health Effects Institute
IHD:	Ischemic Heart Disease
IHME:	Institute for Health Metrics and Evaluation
IPCC:	Intergovernmental Panel on Climate Change
KCCA:	Kampala Capital City Authority
LAC:	Local Adaptive Capacity
LIC:	Low Income Country
LPG:	Liquid Petroleum Gas
MIC:	Middle Income Country
MLI:	Makerere University Lung Institute
NCD:	Non-communicable Disease
NEMA:	National Environment Management Authority
NGO:	Non-Governmental Organisation
OPC:	Optical Particle Counter
PM:	Particulate Matter
US EPA:	United States Environmental Protection Agency
UBOS:	Uganda Bureau of Statistics
UoB:	University of Birmingham
WHO:	World Health Organisation
WP:	Work Package

Executive Summary

Air pollution is a global environmental health threat, contributing to an estimated 3-7 million deaths per year globally. Whilst various types of air pollution exist, particulate matter (PM) air pollution contributes the most to global burden of disease. The effects of air pollution on human health are well documented in a range of epidemiological studies; exposure increases the risk of lung cancer, heart disease, bronchitis and other cardiorespiratory conditions. Whilst air pollution is considered to impact on all groups, particularly when exposed over prolonged periods of time, some groups are considered to be more susceptible than others. Low income groups are often considered more vulnerable given dependency on polluting fuels and increased susceptibility. The sixth of the ASAP-East Africa vulnerability scoping studies explores the vulnerability of low income households in Kampala. Vulnerability scoping studies provide readers with a synthesis of existing evidence and theoretical approaches to the study of air pollution exposure. This synthesis in turn contextualises the empirical data gathered during the study and allows the reader to relate findings to existing literature.

This study has explored the exposure of low income groups in Kampala via the deployment of low cost PM sensors in indoor settings. The study also probed perceptions of low income groups regarding air pollution. Findings underscore the vulnerability of low income groups to air pollution and suggests that people from low socioeconomic backgrounds are likely to face a dual burden of exposure in both indoor and outdoor environments. Data gathered during this study indicates that air pollution levels in indoor (household) and outdoor (AIR QO monitoring sites) settings regularly exceed WHO guideline amounts. Average PM concentrations, in the $PM_{2.5}$ size range, were measured to be 72.61 ± 64.42 μg/m^3 in households that used charcoal and firewood compared to 43.46 ± 33.44 μg/m^3 for households that reported using LPG and electricity. Further to this, air pollution levels tend to peak during cooking periods, consistently recording levels beyond air quality indices. Data gathered from the AIR QO monitoring sites showed that ambient levels of air pollution are also of concern, averaging 41.64 μg/m^3 and peaking at 73.47 μg/m^3 (moderate to unhealthy levels).

Survey findings suggest that low income groups are relatively cognisant of their inherent vulnerability to air pollution, perceiving their vulnerability on a scale of 1-5 at an average of 3.08/5 (five indicating extreme levels of vulnerability). Low income groups also demonstrated a mixed understanding of the potential sources of air pollution, though this is to be expected given the relative lack of knowledge regarding air pollution in many societies. This study underscores that good air quality in household environments is central to the provision of a safe, healthy, productive, and comfortable living environments. Given the inherent vulnerability of low income groups to air pollution exposure, coupled with the significant proportion of time certain household members spend indoors, it is clear that there is a need to develop policies that protect low income groups from exposure to unhealthy levels of air pollution in such settings. This is a particularly pressing concern given the extent of energy poverty and informality across the global south.

Introduction

Air pollution is a global environmental health threat contributing to an estimated three million deaths per year worldwide (Lelieveld et al., 2015). The Global Burden of Disease project (World Bank & IHME, 2016) estimates a figure for premature deaths closer to 5.5 million (one in every ten and the fourth highest factor for causing early death). The most extreme estimates are presented by the World Health Organisation (WHO, 2014), reporting that in 2012 over seven million people died - one in eight of total global deaths - as a result of air pollution exposure.

The effects of air pollution on human health are well documented in a range of epidemiological studies; exposure increases the risk of lung cancer, heart disease, bronchitis and other cardiorespiratory conditions (Kelly & Fussell, 2015). The economic cost of this health loss is also significant, the World Bank estimates that globally in 2013 air pollution led to an estimated $5.11 trillion in welfare losses, and $225 billion in lost labour income (World Bank & IHME, 2016). The World Bank concludes that air pollution “is not just a health risk but also a drag on development…By causing illness and premature death, air pollution reduces the quality of life. By causing a loss of productive labour, it also reduces incomes” (ibid: 2).

Whilst these headline figures are alarming, they tend to gloss over the disproportionate impact of poor air quality on certain populations, locations and occupations. Common approaches to assessing the impact of air pollution have tended to assume an equal vulnerability, sensitivity or susceptibility to air pollution (Stilianakis, 2015). This assumption masks differences in exposure and risk across populations, locations and occupations with air quality in cities varying both spatially and temporally (Kathuria & Khan, 2007). Although average changes in risk associated with exposure to air pollution are considered small, some individuals or groups can be considered more vulnerable or susceptible than others, for example low income groups (Avis & Khaemba, 2018).

Vulnerability scoping studies

The ASAP-East Africa vulnerability scoping studies explore the experiences of those particularly vulnerable populations, occupations and locations in the East African cities of Addis Ababa (Ethiopia), Kampala (Uganda) and Nairobi (Kenya), exposed to high levels of indoor or outdoor air pollutants. By undertaking vulnerability scoping studies, the research team seeks to generate a more textured understanding of specific characteristics and factors associated with vulnerability to air pollution. This will allow the exploration of these vulnerabilities across cities and facilitate the development of targeted recommendations that respond to the needs of specific populations, occupations or locations.

Whilst air pollution is considered to impact on all groups, particularly when exposed over prolonged periods of time, some groups are considered to be more susceptible than others. The WHO considers as vulnerable groups; young children, the elderly, persons with certain underlying diseases, foetuses, groups exposed to other toxicants that interact with air pollutants and those with low socioeconomic status (WHO, 2004). The sixth of the ASAP-East Africa vulnerability scoping studies explores the vulnerability of low income groups living in the Namuwongo informal settlement in Kampala.

Vulnerability scoping studies provide readers with a synthesis of existing evidence and theoretical approaches to the study of air pollution exposure. This synthesis in turn contextualises the empirical data gathered during the study and allows the reader to relate findings to existing literature.

Low income groups and air pollution

Rapid urbanisation, inequality and environmental risk[1] are global trends exerting an impact on society. It is broadly accepted that for the first time, the majority of the world's population lives in what can loosely be classified as 'urban areas'[2]. In 2014, an estimated 54% (around 3.8 billion people) lived in towns or cities (UNDESA, 2014: 1). By 2050, 66% of people are projected to be living in urban areas, with the highest rates of urban growth expected in low- and middle-income countries (LICs and MICs) (ibid.).

More specifically, it is in poor informal or slum settlements on the peri-urban periphery that growth is expected to be greatest, indeed poverty in LICs and MICs is becoming increasingly urban. The growth of informal settlements, slums or poor residential neighbourhoods is a global phenomenon accompanying the expansion of urban populations. An estimated 25% of the world's urban population live in informal settlements, with 213 million informal settlement residents added to the global population since 1990 (UN-Habitat, 2013: 126–8). Informal settlements are residential areas where (UN-Habitat, 2015; Brown, 2015):

- inhabitants often have no security of tenure for the land or dwellings they inhabit;
- they may squat or rent informally;
- neighbourhoods usually lack basic services and city infrastructure;
- housing may not comply with planning and building regulations and is often situated in geographically and environmentally sensitive areas.

A number of interrelated factors have driven the emergence of informal settlements: population growth; rural-urban migration; lack of affordable housing; weak governance (particularly in policy, planning and urban management); economic vulnerability and low-paid work; marginalisation; and displacement caused by conflict, natural disasters and climate change (UN-Habitat, 2015b).

Many governments refuse to acknowledge the existence of informal settlements, which undermines citywide sustainable development and prosperity. These settlements are often geographically, economically, socially and politically disengaged from wider urban systems and excluded from urban opportunities and decision-making (UN-Habitat, 2015). According to the World Bank[3] the percent of the urban population living in informal settlements in Uganda was 54%, Kenya 56% and Ethiopia 74%.

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[1] Environmental Risk can be defined as the "actual or potential threat of adverse effects on living organisms and the environment by effluents, emissions, wastes, resource depletion, etc.

[2] National differences mean the distinction between urban and rural populations is not amenable to a single definition for all countries or even to the countries within a particular region: 6% of countries have no official urban definition and 11% report that their population is either entirely urban or entirely rural (Buettner, 2014).

[3] https://data.worldbank.org/indicator/EN.POP.SLUM.UR.ZS

A recurrent issue in informal settlements is the quality of housing. Homes in East African informal settlements are typically constructed of tin/corrugated iron roofing and mud or tin/corrugated iron sheet walls. According to the African Population and Health Research Centre (APHRC, n.d.), most households rent one room measuring circa 10 x 10 feet with rooms often serving multiple functions i.e. as a kitchen, bedroom and living room (APHRC, n.d.). The rooms usually have one door and one window, although in some cases there are no windows. Poor quality housing has been shown to impact negatively on health and wellbeing, increasing the risk of ill-health or disability.

Living in informal settlements may also increase exposure to environmental risk. Exposure to environmental risks are determined by a number of technological, environmental, and behavioural factors and key environmental health issues in the global south include poor water and sanitation, flooding, indoor air pollution from solid fuels and urban ambient air pollution. In the context of this report, air pollution is the focus, both household and ambient. Whilst various estimates of mortality associated with air pollution exist, the WHO asserts that there are 4.2 million deaths every year as a result of exposure to ambient (outdoor) air pollution and 3.8 million annually as a result of household (indoor) exposure primarily related to smoke from cooking and heating[4]. It is important to note that the estimated mortality rate associated with air pollution based on general population studies may not be representative of the effects on certain subgroups (Cakmak et al., 2007).

Low income groups are often disproportionately exposed to higher levels of air pollution related to poor housing structures, close proximity to air pollution sources and dependency on certain fuel sources for cooking, heating and lighting. The location of low income areas and informal settlements may exert a significant impact on air quality and exposure. Global evidence suggests that low income areas are often located in close proximity to busy highways, within industrial zones or near open dumpsites. This is a product of individuals seeking livelihood opportunities and of market forces as locations with higher environmental risks are perceived to be less valuable. The Namuwongo informal settlement is located in close proximity to an industrial area with numerous respondents in our survey identifying emissions from factories as a source of pollution. The European Environment Agency (2009: 14) has commented that “poorer people, immigrants, and other disadvantaged groups typically inhabit the worst parts of the city, for example near contaminated sites, and are more affected by the lack of green space and public transport services, by noise and dirty roads and by industrial pollution”. It is also suggested that populations living in such areas are more vulnerable as they have fewer coping mechanisms to deal with risk (e.g. lower levels of awareness or social capital) (Environment Agency 2009).

Outdoor measurements of $PM_{2.5}$ concentrations in informal settlements in Nairobi found that there were spatial and temporal variations with areas close to major outdoor sources such as dumpsites having higher concentrations, while mornings and evenings were also noted to have elevated levels (Avis et al., 2019; Egondi et al., 2016). In a context of weak or non-existent policies to minimise emissions from various sources, certain informal settlements may experience high exposure to air pollution compared to other areas of the city.

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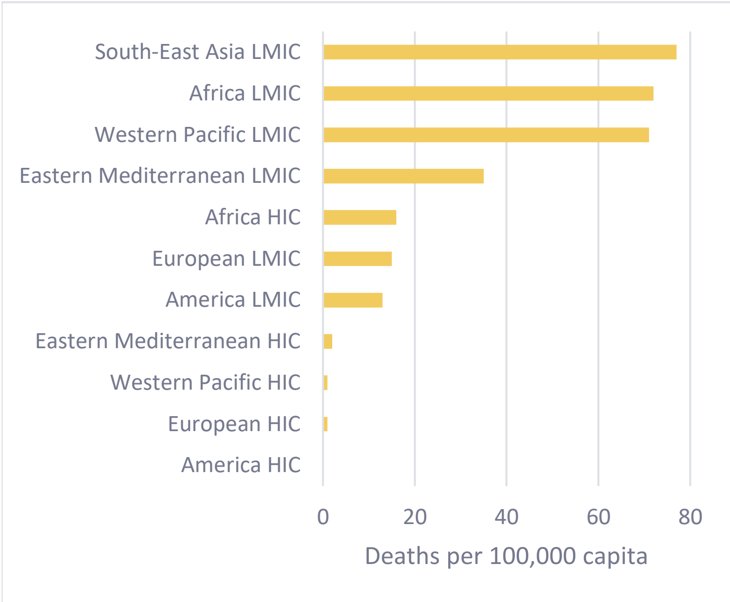
[4] https://www.who.int/airpollution/en/

Conversely, given the density of informal settlements and the limited road network in some areas, outdoor air quality might be better in informal settlements.

Figure 1: ***Deaths per capita attributable to HAP in 2016, by region (WHO, 2018: 2)***



Alongside ambient (outdoor) air pollution, indoor air quality is a concern in informal settlements. Household Air Pollution (HAP), largely generated by domestic fuel combustion using biomass fuels (such as wood, dung and coal burned in simple stoves) leads to high pollutant exposures in and around the home and contributes to ambient air pollution. Exposure to domestic cooking smoke is currently the world's single largest environmental health risk, responsible for circa 4 million early deaths each year, predominantly in LIC and MIC settings. Globally, whilst the number of people cooking with solid fuels has declined, disparities persist, and populations in the global south continue to suffer the highest exposure to HAP (Health Effects Institute (HEI), 2019: 8). In 2017, 3.6 billion people (47% of the global population) were exposed to HAP from the use of solid fuels for cooking predominantly in sub-Saharan Africa, South Asia, and East Asia. In East Africa, many households rely on kerosene (paraffin) for cooking and lighting as well as charcoal or wood for cooking. In the poorest of households, the use of plastic waste, cloth rags and other unconventional fuels has been reported (Muindi et al., 2014).

This scoping study explores the intersection of these issues (urbanisation, inequality and environmental risk) in Kampala. When considering the impact of poor air quality on the health of low income groups there is an established body of evidence that highlights that the poorest are particularly vulnerable to the adverse effects of air pollution. Impacts may result in rising medical costs and demand for health services, as low income groups are more likely to suffer from chronic diseases, including respiratory diseases, such as chronic obstructive pulmonary disease (COPD), asthma and pneumonia (Bentayeb et al. 2012). Those with lower incomes may also be less able to reduce or minimise their exposure due to a number of factors primarily related to limited assets.

Available studies, drawn from a range of geographic settings, suggest that low income groups people are often exposed to poor air quality in the locations where they spend significant proportions of time. In such environments a number of factors affect air quality including emissions from indoor sources, household ventilation and the penetration of air pollutants from surrounding areas. Studies exploring this issue in East Africa are, however, limited. The present study seeks to address this paucity of evidence and was initiated to fulfil four objectives:

1) to measure the levels of $PM_{2.5}$ in households in Kampala and assess low income groups exposure to air pollution;
2) to study the relationship between indoor (i.e. household) $PM_{2.5}$ concentrations and socioeconomic status;
3) to investigate perceptions of air pollution amongst low income groups;
4) to develop recommendations to improve air quality or reduce exposure to air pollution amongst Kampala's low income groups.

Methodology

Based on initial findings from urban profiling and stakeholder mapping alongside data collected in Work Packages 1-5 (WP), six case studies (two per city) are being undertaken that explore the spatial and demographic impact of air pollution, focusing on areas exposed to high levels of air pollution, or particularly vulnerable populations. Case studies focus on the following subset of vulnerability issues: vulnerable locations (e.g. informal settlements or areas close to sources of pollution such as roads or factories); vulnerable populations (e.g. the urban poor, women, children or the elderly who may be more susceptible to air pollution) and vulnerable occupations (e.g. street vendors, motorcycle taxi drivers that may be exposed to higher levels of PM over sustained periods of time). A mixed methods approach is used, combining quantitative and qualitative data collection and drawing on other WPs. This approach includes:

A desk review to identify and incorporate existing and available information, including previously conducted research, surveys and assessments. Our desk review was undertaken using a Boolean methodology searching a range of databases and including both academic and grey literature.

Standardised surveys will be conducted in vulnerable areas and amongst vulnerable groups. Surveys will be co-designed with research partners and tailored in relation to findings from WP1-5, urban profiles and stakeholder mapping. A total of 20-30 surveys will be conducted per case study. Survey modules will be tailored for specific occupations, locations and populations[5].

Semi-structured key informant interviews will be undertaken with a minimum of five stakeholders including relevant representatives of; Local Government, Private Sector, Civil Society Organisations and Informal Community based organisations.

Synthesis of data collection and analysis (WP1-5), information gathered from other WPs will also inform the development of vulnerability scoping studies.

Study site

The ASAP-East Africa research team partnered with Makerere University Lung Institute (MLI) and residents of Namuwongo to undertake this study. Kampala is the capital and largest city of Uganda. It occupies a series of

[5] This scoping study includes 38 completed surveys.

hills at an elevation of circa 1,190 metres and is situated in the southern part of Uganda. Kampala lies north of Mengo, the former capital of the 19th century kingdom of Buganda. It was selected in 1890 by Frederick Lugard as the headquarters of the British East Africa Company. In 1962 Kampala (a municipality since 1949) became the capital of independent Uganda. The city proper had an estimated population of 2,577,000 people in 2015, by 2035 the population is forecast to grow to over 7,000,000 (UN DESA – World Urbanisation Prospects[6]). This is considered an underestimate of the population given that the Kampala metropolitan area consists of the city proper and neighbouring districts (Wakiso, Mukono, Mpigi, Buikwe and Luweero) which are rapidly growing, forming a large urban conurbation.

Kampala has experienced significant urban growth in recent decades and is considered to be one of the fastest growing cities in East Africa with an annual urban population growth rate of circa 5.2% (ACTogether, 2014). The city has expanded in all directions with growth primarily concentrated along the city's main roads. The Urban Extent of Kampala in 1988 was 16,492 hectares growing to 30,698 hectares in 2003 and 51,321 hectares in 2015[7].

According to UN Habitats (2007: 10) situation analysis, informal settlements make up at least a quarter of the total city area, housing roughly 60% of the city population. Kampala has 57 informal settlements dispersed across the city's five divisions: Central, Kawempe, Nakawa, Rubaga and Makindye. This study is focused on the Makindye division where approximately 409,500 people live in fifteen informal settlements: Bukasa, Ggaba, Kabalagala-Kataba, Kabalagala-Kikubamutwe, Kansanga, Katwe I, Katwe II, Kibuye I, Kibuye II, Kisugu, Lukuli Kilombe, Nsambya, Gogonya, Nsambya, Kevina, Salaama and Wabigalo.

More specifically Namuwongo (the focus area of this study) is located in the Wabigalo informal settlement which was founded in 1970. Wabigalo encompasses an area of approximately 41.9 acres, the majority of which is owned by private individuals (60%) with the remainder owned by the Church (40%). There are 9,000 households in Wabigalo, with an average household size of four and a total population of 36,000 (ACTogether, 2014: 44). The most common type of house occupied by people in Makindye division is the tenement (locally known as mizigo) (ACTogether, 2014). This is a multi-unit structure with three or more housing units that are either one or two roomed. Housing structures serve a wide range of purposes and meet a variety of needs e.g. as homes and businesses. As a result of their location, residents of Namuwongo must cope with natural location hazards including floods, exposure to garbage dumps, busy roads, power lines, open drains, and industrial hazards. These areas are also subject to evictions, crime, community violence and riots (ACTogether, 2014). Interestingly, neither ACTogether (2014) nor UN Habitat (2007) identify air pollution as an issue of concern despite widespread reliance on polluting fuels.

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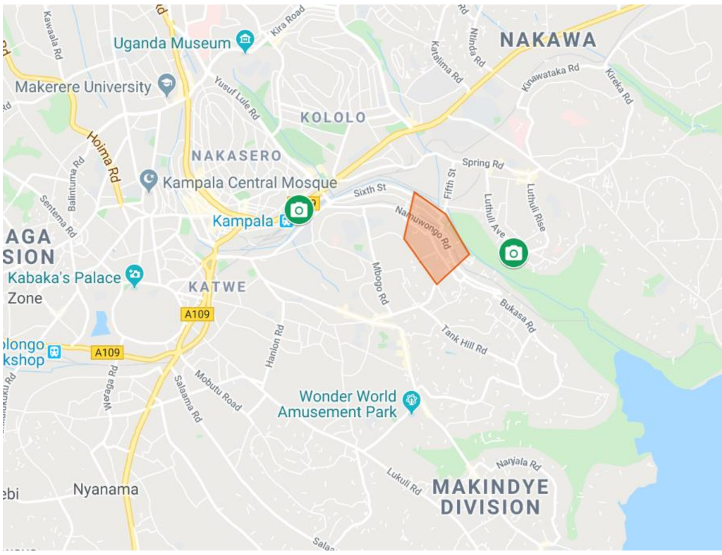
[6] https://population.un.org/wup/Download/
[7] http://www.atlasofurbanexpansion.org/cities/view/Kampala

To gather data on low income group's exposure to indoor air pollution, the ASAP-East Africa research team monitored indoor air pollution in 20 households throughout September to November. Air pollution was monitored via the deployment of air pollution monitors installed within the household (e.g. Bartington et al., 2017). Measurements were collected using calibrated Alphasense optical particle counters (OPC-N2) which recorded $PM_{2.5}$ and PM_{10} at ten second intervals, aggregated to one-hour time steps. The calibration approach, and the use of the OPC-N2, is discussed in Crilley et al. (2017) and Pope et al. (2018). Sensors were located in the primary cooking area at a distance and height of 1.5 meters from the stove. Whilst low income groups are considered more exposed to indoor air pollution than other groups, it is important to note that they do not spend their entire day at a single location, but move between home and other environments (work, recreation or community areas). It is therefore important to complement household monitoring with data from outdoor locations. In this instance we gathered data from air quality monitors operated by AIR QO located at Central Kampala and Bugolobi.

A survey was also undertaken with residents of Namuwongo. Thirty eight volunteers were recruited by MLI spread across Namuwongo. Exploring perceptions of air pollution provides an opportunity to investigate attitudes towards this issue and draw associations between perceived and actual exposure. A number of studies have identified correlations between perceptions of air quality and monitoring data (Hunter et al., 2004), others challenge this association (Semenza et al., 2008). Given the small number of participants involved, the survey is used for illumination purposes to identify areas of future research and to identify broad trends and differences across participants responses. Surveys were conducted in English and Bantu.

Image 1: ***Location of Namuwongo (red bordered area) and AIR QO Monitoring Sites (Green Icons)***



Vulnerability and air pollution

Understanding vulnerability to air pollution presents a unique challenge for researchers. Authors commonly refer to vulnerability as the level of exposure of human life, property and resources to the impact from hazards (in this case air pollution) (Fussell, 2007; O'Brien et al., 2009). Factors, such as sex, age, education, and occupational exposure can modify the relationship between hazards and mortality (Kan et al., 2008). Further to this, the effects of air pollution exposure on health are considered greater in people from lower socioeconomic backgrounds (O'Neil, 2003). According to Stilianakis (2015: 10-11) exposure to air pollution may have different effects on individuals and population groups due to differences in innate and acquired characteristics. Innate characteristics are mainly biological and physiological and reflect the capacity of the human body to respond to exposure. Acquired factors, such as socioeconomic status, are those that affect social coping or adaptive capacity and do not allow the individual or the population group to minimise exposure. Vulnerability is thus considered to involve two components:

- External risks, shocks and stresses to which an individual or household is subject.
- Internal abilities which offer a means for coping without causing damage or loss (i.e. adaptive capacity).

The ASAP-East Africa programme adopts the WHO's (2004) definition of vulnerability i.e. "the likelihood of being unusually severely affected by air pollutants either as a result of susceptibility to the effects of these substances or as a result of a greater than average exposure". Three dimensions of vulnerability are commonly identified in the literature and are explored in the ASAP-East Africa Vulnerability Scoping Studies (Howe et al., 2013):

- **Exposure** i.e. the degree to which the subjects or areas could be effected by air pollution.
- **Susceptibility** i.e. the likelihood or being harmed by air pollution.
- **Adaptive capacity** i.e. the ability to take actions to either reduce or avoid risk.

Vulnerability may thus be compounded by factors including location; adaptive capacity (i.e. the ability to protect oneself from harm including access to materials, technology, knowledge, information and social protection) the extent of assistance and support, including services, resources and technical expertise, that society can provide. For an overview of relationships between population, location and occupation characteristics and associated factors that contribute to vulnerability see Avis and Khaemba (2018: 20).

An individual's vulnerability to air pollution is thus complex, the product of interactions between environmental stressors, innate and acquired susceptibility, differential exposure and adaptation mechanisms (US EPA, 2003). Further to this, vulnerability to air pollution consists of a number compounding factors inherent in the individual and influenced by broader social or environmental contexts e.g. smoking and co-exposures. It is also important to note that concerns regarding air pollution compete for space alongside a number of other issues and may be mediated by these (see table 1).

Table 1: ***Survey respondents ranking of issues of concern (1 = most pressing concern, 10 = least pressing concern)***

Concerns	
1. Lack of access to clean toilets	6. Government corruption
2. Lack of employment opportunities	7. Poor quality schools
3. Crime	8. Energy shortages
4. Poor health care	9. Food shortages
5. Lack of clean drinking water	10. Too few citizens participating in politics

Vulnerability Dimensions

In the context of ASAP-East Africa research, exposure to high levels of particulate matter (PM) is a focus. PM or atmospheric aerosols is the term used to indicate any solid or liquid particles suspended in the atmosphere. Atmospheric particles vary widely in their physical parameters such as size and chemical composition. PM is generated from a variety of natural and anthropogenic processes. Natural sources of PM include dust storms, ocean/sea spray (sea salt), dust erosion due to wind, forest fires, volcanic eruptions, and the release of biogenic PM (e.g. pollen and spores). Man-made sources include traffic, non-combustion and combustion industrial processes, power plants, construction activities, agricultural activities (including waste burning) (Haq & Schwela, 2008: 6). A key contributor to heightened levels of PM in urban settings is the combustion of solid and liquid fuels for power generation, domestic heating, cooking or lighting and in vehicle engines. PM of small size fractions are considered to be particularly detrimental to public health as they can enter the respiratory system and lead to respiratory disease, asthma, strokes, cancer and heart disease (Thurston et al., 2016). Other health-effects of exposure to air pollution include dermal absorption and ocular exposure which may result in eye or skin irritation. The smaller the size of PM particle, the more impact they are considered to have on health. $PM_{2.5}$ and PM_{10} are particulate matter with aerodynamic diameters less than 2.5 and 10 µm, respectively (Seinfeld & Pandis, 2016). The $PM_{2.5}$ size fraction is the focus of this study, having greater association with determinental health outcomes.

To guide discussions of vulnerability to air pollution, the ASAP-East Africa research team have adapted the US Environmental Protection Agencies (US EPA) Air Quality Index Scale to illustrate how different levels of air pollution contribute to different health impacts amongst different groups. An air quality index identifies limits on the amount of a given pollutant in the air. The standards are designed to protect people's health and have been calculated to allow a margin for people most at risk e.g. the young and old and people with pre-existing health conditions. The ambient air quality standards most often utilised include those developed by the European Union, the United States and the WHO. The WHO air quality standards (25 µg/m^3 24 hour mean) are not legally binding, rather they represent a guideline for countries and are significantly tougher than those suggested by others. Table 2 provides a guide to different levels of exposure to $PM_{2.5}$ over a 24 hour period, health implications associated with that level of exposure and provides a cautionary statement identifying those groups likely to be affected.

Table 2: ***Air Quality Index scale as defined by the US EPA (2016)***

$PM_{2.5}$ µg/m^3 (24 hour average)	***Air Pollution Level***	***Health Implications***	***Cautionary Statement for $PM_{2.5}$***
0.0-12.0	Good	Air quality is considered satisfactory, and air pollution poses little or no risk.	None
12.1-35.4	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, and people with respiratory disease such as asthma should limit prolonged outdoor exertion
35.5-55.4	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Active children and adults, and people with respiratory disease such as asthma should limit prolonged outdoor exertion
55.5-150.4	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may begin to feel more serious health effects.	Active children and adults, and people with respiratory disease such as asthma should limit prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion.

150.5-250.4	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease such as asthma should limit prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion.
250.4-500.4	Hazardous	Health alert; everyone may experience more serious health issues.	Everyone should limit outdoor exertion.

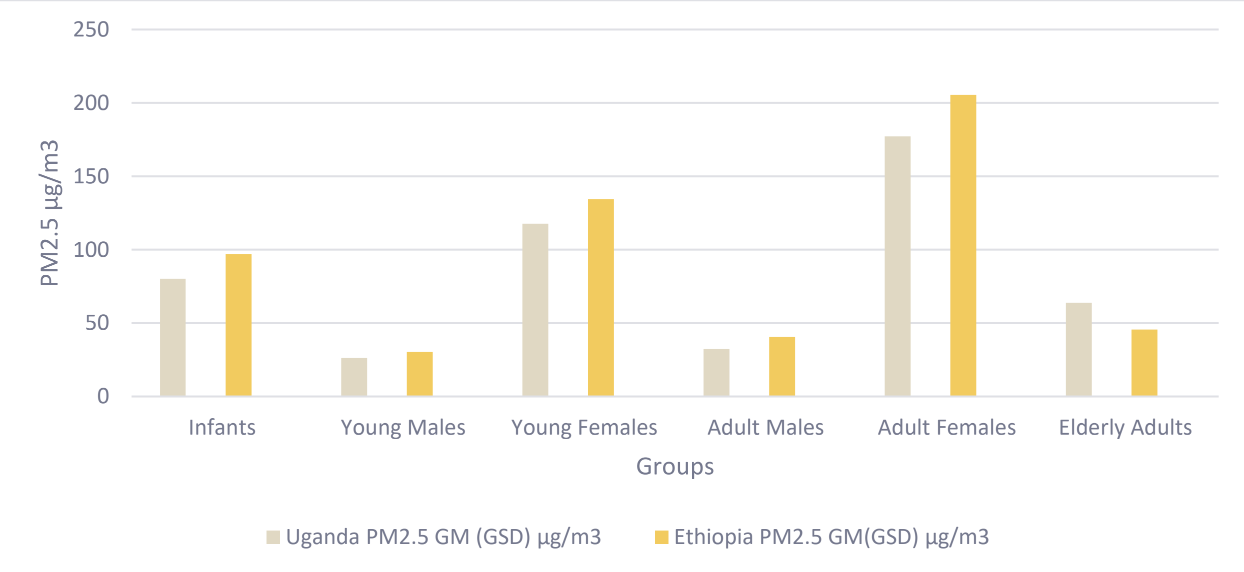
Exposure

Exposure denotes the degree to which subjects or areas could be affected by air pollution. The level of exposure is generally defined by several components and measures, including: the frequency and intensity of exposure and the location relative to sources of air pollution. Exposure to air pollution is thus largely determined by the concentration of air pollutants in the environments where people spend time, and the duration spent within them. To understand exposure of vulnerable populations to air pollution it is therefore important to identify the micro-environments in which they spend significant amounts of time.

In the context of this report, exposure to HAP is the primary focus. Indoor air quality refers to the quality of the air in a home, school, office, or other building environment. The potential impact of indoor air quality on people's health is considered important for a number of reasons. People who are often most susceptible to the adverse effects of pollution (e.g., the very young, older adults, people with cardiovascular or respiratory disease) tend to spend more time indoors. Indoor concentrations of some pollutants may also reach particularly harmful levels, particularly in those households dependent on polluting fuels for cooking, heating or lighting.

Interest in low income group's exposure to environmental risk factors such as air pollution has increased in recent years given. A number of studies have focused on $PM_{2.5}$ in terms of mass and source contribution in both indoor (Okello et al., 2018; Simoni et al., 2015; Bentayeb et al., 2015; Mendes et al., 2015) and outdoor settings (Simoni et al., 2015; Rajagopalan et al., 2018). Of particular interest is the work of Okello et al. (2018) who gathered data on 24-hour personal exposure to HAP across six groups defined by age and gender (young children, young males, young females, adult males, adult females, and elderly) in rural households in Ethiopia and Uganda. Findings highlighted in figure 2 suggested that adult females are most exposed to HAP followed by young females and infants. This likely relates to household activities – namely cooking – undertaken by these groups or dependency on mothers. These findings also suggest that women and girls will likely be most susceptible to the long-term health effects of HAP exposure, particularly in households that are dependent on more polluting fuels.

Figure 2: ***Comparison of mean 24 hour $PM_{2.5}$ μg/m^3 among the six age groups in Ethiopia and Uganda (Okello et al., 2018: 433)***



Air pollution exposure of low socioeconomic groups in Kampala

Ugandan environmental policy mandates that all should enjoy the fundamental right to an environment adequate for their health and wellbeing while conserving the environment and natural resources equitably and for the benefit of present and future generations. Environment Law is enforced by the National Environment Management Authority (NEMA) under the National Environment Act CAP 153 of the Laws of Uganda.

Despite this commitment, air quality is considered to be declining and an issue of increasing concern in Kampala. This decline is associated with population growth, increasing numbers of vehicles, construction and the widespread use of biomass as a source of fuel for cooking and heating. Population growth in Kampala is estimated to be 5.2% annually and Kampala had an estimated 465,000 motor vehicles in use in 2012. Between 2002 and 2012, vehicle use has increased significantly: light transport is up 5.7%, automobiles 7.4%, mini buses 12.6%, buses 5.4%, trucks 9.2%, and motorcycles 15.8% (UBOS, 2012). Finally, according to the Global Alliance for Clean Cookstoves (GACC, 2017: 64), a large portion of the population uses unprocessed biomass to cook.

Table 3: ***Percent distribution of household cooking fuel use (Uganda Demographic and Health Survey, 2016: 23)***

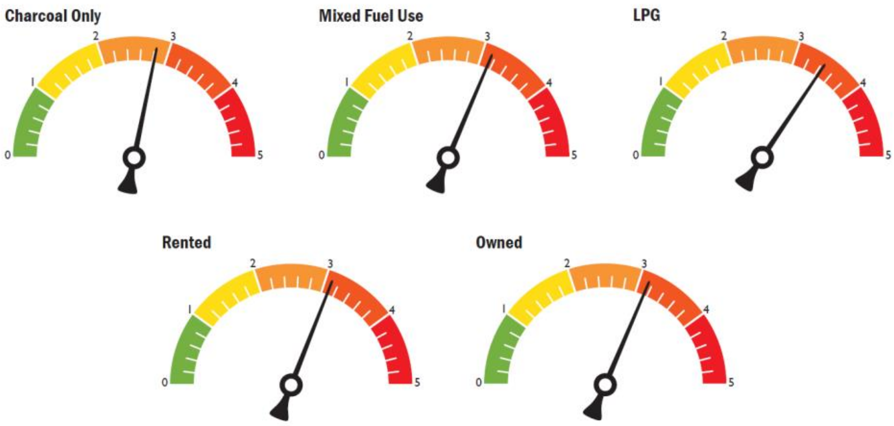
	Urban	Rural
Electricity	1.10%	0.10%
LPG/Cylinder gas/Biogas	1.80%	0.20%
Kerosene	2%	0.30%
Charcoal	59.90%	13.50%
Wood	29.90%	83%
Straw/Shrubs/Grass	0.20%	0.30%
Agricultural crop	0%	0%
Other	0%	0%
No food cooked in the household	5%	2.60%

The proportion of the Ugandan population living below the National Poverty Line in 2016/17 was 21.4% (UBOS, 2018: 5). Whilst estimates of the total number of Kampala residents living in informal settlements are subject to much debate, organisations such as UN Habitat suggest that over 60% of the city's population live in slums. In such settings a number of issues impact on the health and wellbeing of residents, primarily related to housing and living conditions. The WHO model of healthy housing identifies four housing dimensions: the "home" which – if safe and intimate – provides psychological benefits and a refuge from the outside world; the "dwelling" which is the physical infrastructure of the house; the "community" which is linked to the surrounding population living there and comprises area characteristics such as education, socioeconomic status and ethnicity and finally the "immediate housing environment" such as access to green space, noise sources, accessibility and neighbourhood design. In the context of informal settlements, housing may fall short of providing a healthy environment.

As noted, a primary driver of HAP exposure is cooking practices, in particular fuel use. GACC (2017: 64) estimate that unprocessed biomass is used as cooking fuel by the majority (85%) of the Ugandan population; charcoal by 13% of the population, mainly in urban and peri-urban areas and that liquid petroleum gas (LPG) and kerosene are used by limited numbers, less than 0.5% each; the remaining 0.8% is a mix of fuels produced by small enterprises and some electricity.

To gauge perceptions of exposure to air pollution, residents of Namuwongo were asked, “do you feel that the air in your home is polluted?” Of the sample 81% (31/38) indicated that they felt they were exposed to air pollution in their home. Survey respondents were also asked “how would you rate your vulnerability to air pollution on a scale of 1-5 (one being not vulnerable at all, five being extremely vulnerable)?” Responses were grouped according to fuel used for cooking as well as whether respondents owned or rented their home. For fuel, respondents included those who reported using charcoal only (16), those who used a mixture of fuels[8] (13) and those who had access to LPG (9). To further contextualise survey findings, responses were also grouped according to whether individuals rented (23) or owned (15) their homes. This disaggregation is important, having a determining factor on whether households reported having a separate kitchen for cooking or cooked in a room also used for sleeping and living. The average vulnerability score of the surveyed people was 3.08/5, suggesting a relatively high perception of vulnerability. There was, however, an interesting variance according to fuel used and home ownership status with those using LPG or owning their homes reporting highest levels of vulnerability. Perceptions of vulnerability were as follows: Charcoal only (2.81/5), mixed fuel (3.15/5), LPG (3.44/5), rented (3.09/5) and owned (3.14/5).

Figure 3: ***Survey respondent’s perceptions of vulnerability according to cooking fuel type and household ownership status***

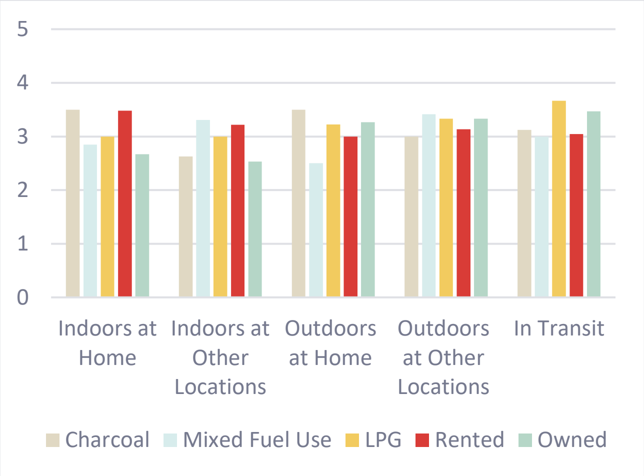


To explore this issue further, survey respondents were asked to provide an assessment of air pollution levels at different locations (indoors at home, indoors at other locations, outdoors at home, outdoors at other locations, and in transit – figure 4). Interestingly, those who reported using charcoal only for cooking or rented their homes reported higher levels of air pollution in their home than others (a contrast to the lower perceptions of vulnerability noted above). This poses an interesting question as to how perceptions of vulnerability are mediated by contemporaneous concerns (i.e. access to income, limited alternative choices and concerns regarding flooding

[8] Mixed fuel use was reported by a number of households, fuels included: kerosene, charcoal, piped natural gas, electricity, firewood or sawdust, briquettes or paraffin.

etc.) and why, whilst individuals may acknowledge that they are exposed to higher levels of pollution than others, this may be considered inevitable, unavoidable or of relatively little importance compared to other concerns.

Figure 4: ***Survey respondents perceptions of air pollution levels (1 being not polluted at all, 5 being extremely polluted)***



Household Air Quality Monitoring

The home environment is a complex setting in which to undertake an assessment of air quality. Thermal comfort, air pollution sources, building characteristics and household tasks are factors influencing exposure (see image 2). These are in turn affected by other aspects inside and outside the home environment. Increased PM concentrations are often correlated with household activities, small room sizes, high occupation rates, fuel usage etc. (Bartington et al., 2017). Locations in close proximity to industrial areas, busy roads or sources of dust are likely to experience higher levels of air pollution (Kim et al., 2016). Measuring household pollutant exposure is thus beset by complexity, it requires indoor assessment techniques, including efforts to estimate personal exposure. Most pollutants affecting indoor air quality come from sources inside buildings, although some may originate outdoors. Indoor sources include[9]:

- ***Combustion sources*** in indoor settings, including tobacco, heating and cooking appliances, and fireplaces can release harmful combustion by products such as carbon monoxide and PM.
- ***Cleaning supplies, paints, insecticides, and other commonly used products*** introduce many different chemicals, including volatile organic compounds, directly into the indoor air.
- ***Building materials*** are also potential sources, whether through degrading materials (e.g., asbestos fibres released from building insulation) or from new materials (e.g., chemical off-gassing from pressed wood products). Other substances in indoor air are of natural origin, such as radon, mould and animal dander.

Outdoor pollutants can enter buildings through doors, windows, ventilation systems, and cracks in structures:

- ***Harmful smoke from chimneys or vehicular emissions*** can enter homes to pollute the air. In areas with contaminated ground water or soils, volatile chemicals can enter buildings through the same process.
- ***Volatile chemicals in water supplies*** can also enter indoor air when building occupants use water (e.g., during washing, cooking).

[9] https://www.epa.gov/report-environment/indoor-air-quality

- ***People entering buildings*** can inadvertently bring in soils and dusts on their shoes and clothing from outdoors, along with pollutants that adhere to those particles.

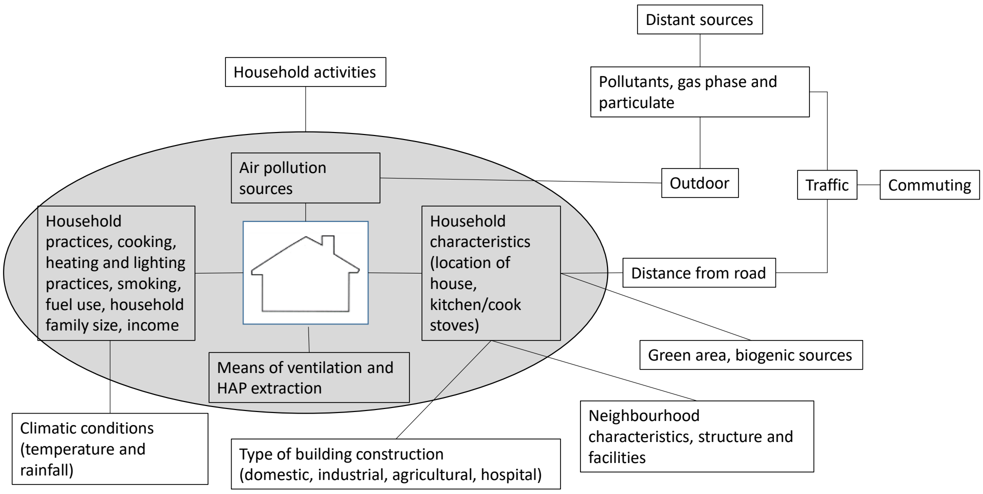
The combustion of biomass for cooking purposes is a matter of particular concern, and the primary source of HAP in many households. Significant numbers rely on biomass fuels (wood, charcoal, crop residue, dung) for cooking or heating purposes. HAP resulting from the use of these fuels is of particular concern, given the overall prevalence as well as the intensity of exposure and the range of potential adverse health outcomes (see table 4 for emission estimates from a range of cooking appliances).

Table 4: ***Emission parameter assumptions (Jeuland & Tan Soo, 2016: 19)***

Description	Unit	Low	Medium	High
$PM_{2.5}$ (traditional wood burning stove)	24-hr µg/m3		695 (549)	
$PM_{2.5}$ (wood burning ICS)			303 (224)	
$PM_{2.5}$ (improved charcoal stove)		50	185	320
$PM_{2.5}$ (LPG)		20	70	120
$PM_{2.5}$ (electric)			0	
CO2 (traditional wood burning stove)	g CO2/MJ	450	510	570
CO2 (wood burning ICS)		300	345	390
CO2 (improved charcoal stove)		300	525	750
CO2 (LPG)		125	140	155
CO2 (electric)	g CO2/kW-hr	10	650	1300

Understanding the relative contribution of HAP exposure to population disease burden will also enable investigation of how intervention measures may be introduced, which are appropriate, accessible and acceptable to the local context and meet the needs of end users. Identifying feasibility and acceptability of such measures requires mixed-methods research to identify barriers and facilitators for intervention uptake; which is essential to inform development and implementation.

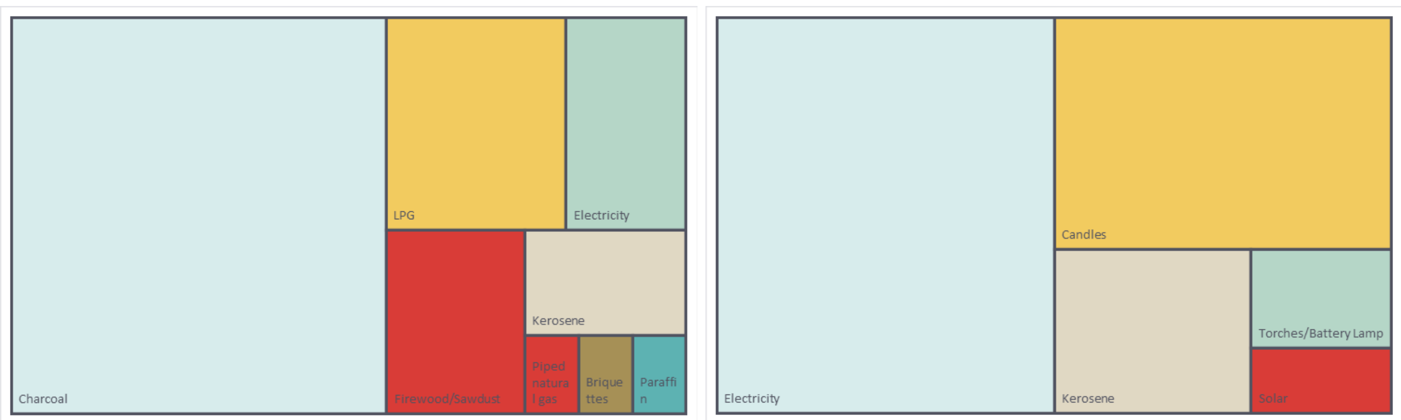
Image 2: ***Representation of factors and linkages with possible impact on the indoor air quality in classrooms - primary factors highlighted in the grey area (adapted from Salthammer et al., 2016: 197)***



Quantifying the contribution of household exposure with observed health symptoms, however, poses a number of challenges. In addition to ascertaining the impact of non-household-based exposures, air pollutant exposure is influenced by daily patterns of activity during and outside periods spent at home hours which make it difficult to compare the contribution of household-based and non-household-based exposures (WHO, 2000).

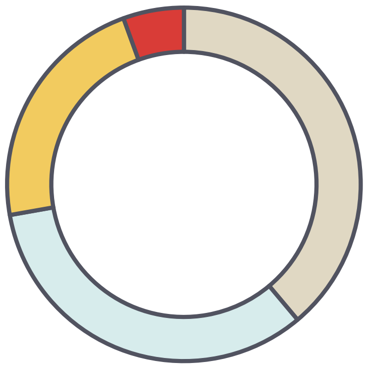
To ascertain potential sources of air pollution in homes, survey participants were asked to list what type(s) of fuel households usually used for cooking and lighting. Findings highlight that, despite increasing access to LPG and electricity, charcoal continues to be widely used. Of the responses, sixteen households reported using charcoal only, thirteen reported using a mixture of fuels and nine reported having access to LPG (see figure 5).

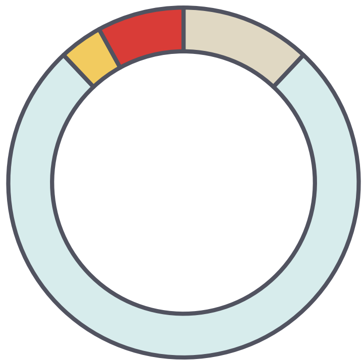
Figure 5: ***Survey respondent's identification of fuel(s) used for cooking (left) and lighting (right)***



A further determinant of HAP exposure is the extent to which cooking is carried out in a room used for living or sleeping or whether the household has access to a separate kitchen. As noted above, the most common type of house occupied by people living in Namuwongo is the tenement, a multi-unit structure with three or more housing units that are either one or two roomed. The survey highlighted that cooking location was determined by household ownership status. Whilst this will not reduce exposure to the individual(s) preparing meals (principally women and girls), it may serve to reduce levels of HAP as a whole. In owned homes only 33% reported cooking in a room also used for living and sleeping, in rented homes this figure was 76%.

Figure 6: ***Ownership status and location of cooking (left = owned and right = rented)***





Existing data shows that low income groups are a group particularly vulnerable to air pollution, both short- and long-term. Overall, few studies have explored this issue in detail with a lack of direct comparisons between this group and the rest of the population, or investigations of the interactions according to location and pollution (Bentayeb et al., 2012).

Household air pollution (Namuwongo)

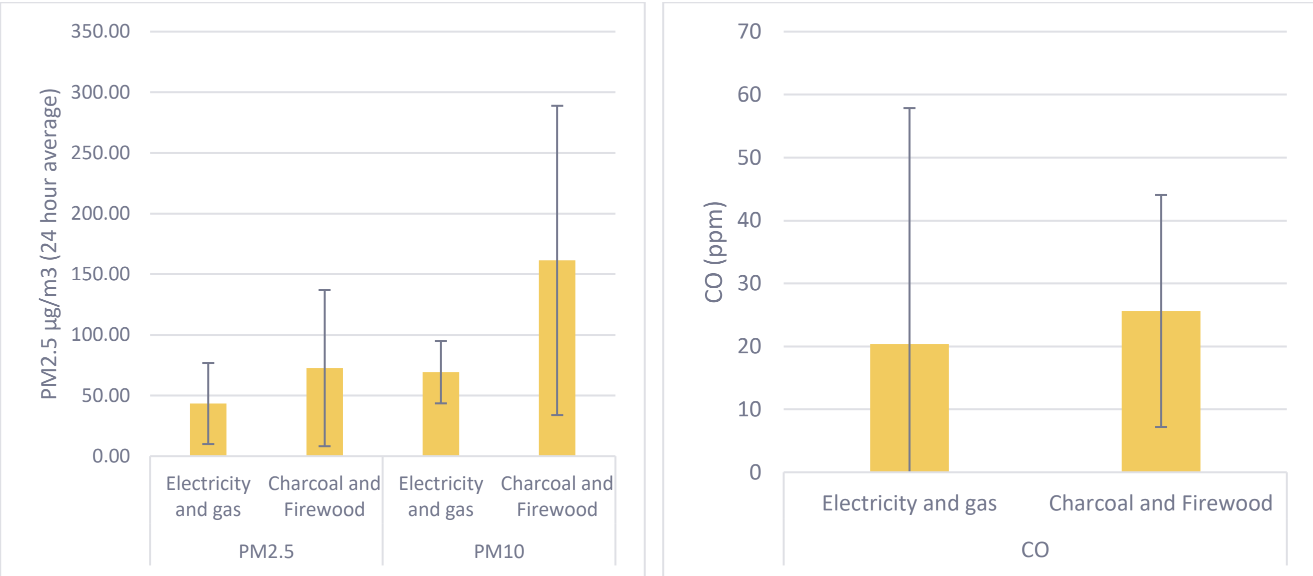
Whilst the majority of studies exploring air pollution monitor outdoor levels, indoor air quality is also a concern, particularly in households where vulnerable groups may be present. Results that focus on outdoor readings alone may fail to provide an accurate estimation of personal exposure given length of time spent indoors. Globally, a range of studies have highlighted that many households have health problems linked to poor indoor air quality, with recorded indoor air pollutant levels often exceeding outdoor levels. This has been found to be the case across East Africa when cooking with biomass occurs in small or space constrained homes (Tarekegn & Gulilat, 2018, Okello et al., 2018).

Table 5: ***Average indoor $PM_{2.5}$ ($\mu g/m^3$) daily concentrations (LPG and Electricity versus Charcoal and Firewood)***

Average $PM_{2.5}$ ($\mu g/m^3$) daily concentration (LPG and Electricity)	Average $PM_{2.5}$ ($\mu g/m^3$) daily concentration (Charcoal and Firewood)
43.46 ± 33.44	72.61 ± 64.22

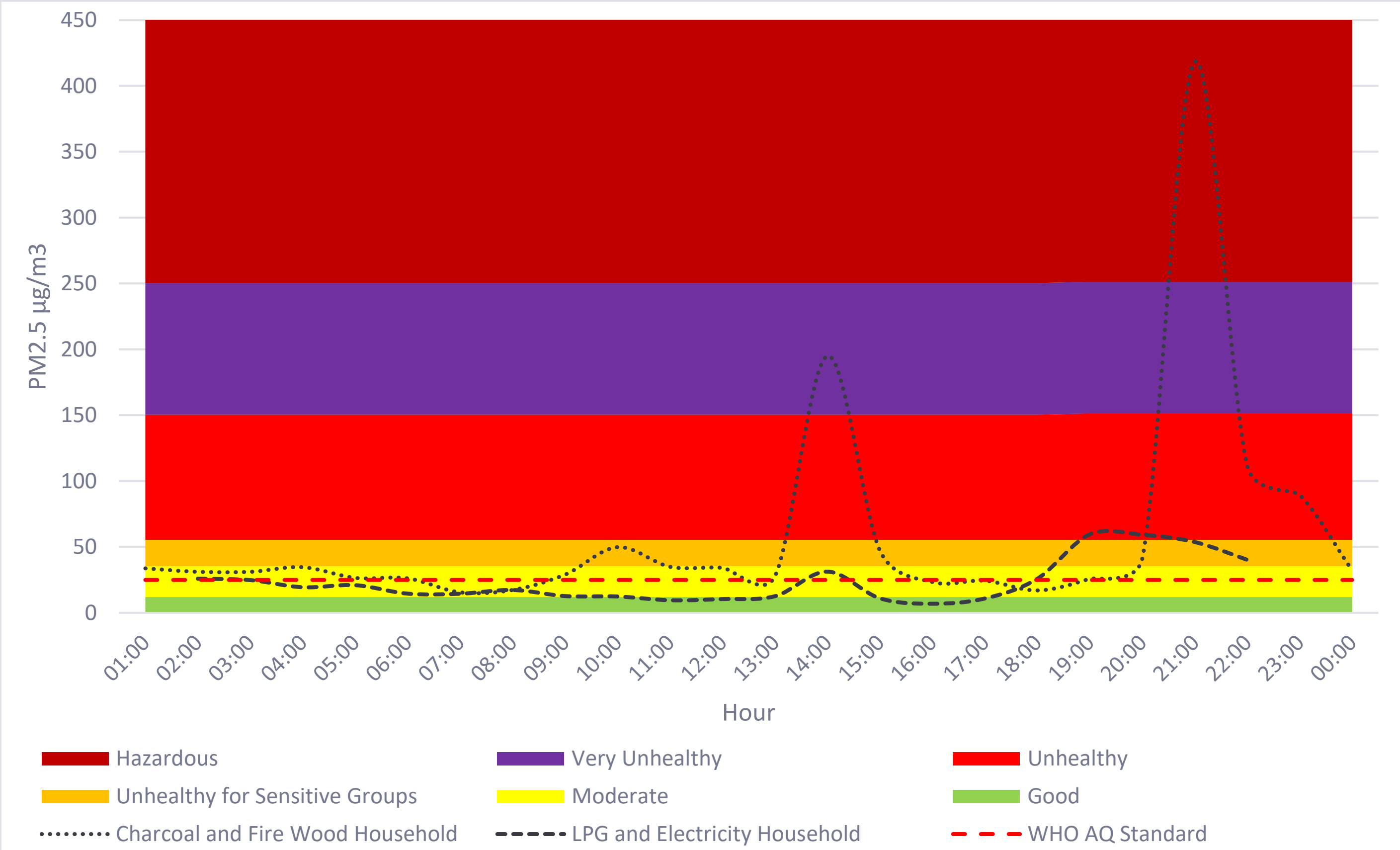
The ASAP-East Africa monitored air pollution in twenty households to ascertain exposure to air pollutants. Whilst, we focus on $PM_{2.5}$, it is important to note that household practices may also lead to elevated levels of other pollutants (namely PM_{10} and Carbon Monoxide CO). Figure 7 provides a comparison of households that reported using charcoal or firewood for cooking versus LPG or electricity. Figure 7 demonstrates the extent to which energy poverty exposes households to significant risk with levels of exposure higher across all pollutants monitored for those households who used charcoal and firewood.

Figure 7: ***Mean and standard deviation for selected pollutants monitored in households in Namuwongo***



Alongside this comparison, figure 8 contrasts two households (one charcoal and firewood and one LPG and electricity) over the 24 hour periods monitored. Across the monitored period, the charcoal and firewood household recorded an average level of $PM_{2.5}$ of 59.1 µg/m^3 and the LPG and electricity household 23.54 to µg/m^3. Whilst these figures are significant, it is when one considers peak levels of air pollution that we get a true sense of the impact charcoal and firewood has on HAP. In the charcoal and firewood house, peak (maximum) concentration recorded during the monitoring period was 418.38 µg/m^{3,} In contrast, the LPG and electricity household recorded a peak level of 59.61 µg/m^3.Over the 24 hours air quality was monitored, pollution levels in the first household were on average considered unhealthy and peaked at hazardous levels according to the US EPA AQI and were significantly above the WHO guidelines for $PM_{2.5.}$ In contrast, readings in the LPG or electricity household levels of air quality were considered to be moderate peaking at unhealthy levels. Indoor air quality in those households that use charcoal or firewood is thus considered to be an issue of particular concern. To contextualise these readings, figure 8 maps both outdoor and indoor air pollution on the US EPA air quality index during the day monitored.

Figure 8: ***HAP $PM_{2.5}$ Monitored in Namuwongo – Households that use Charcoal and Firewood versus LPG and Electricity***



Outdoor air pollution (Kampala)

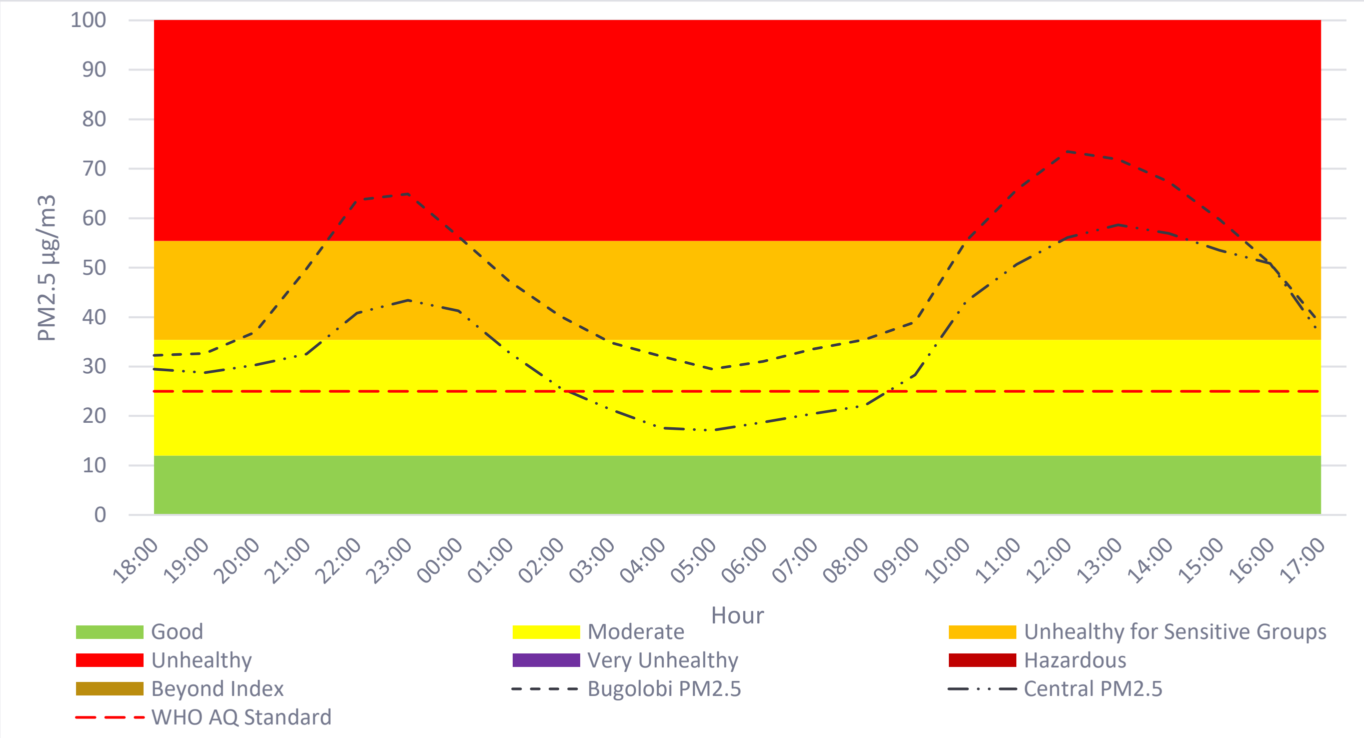
Whilst HAP is a pressing concern in many countries of the global south, in rapidly urbanising areas outdoor air pollution is also an issue. Indeed, vulnerability to air pollution's negative impacts is mediated by exposure in the environments in which people spend significant periods of time. In addition to poor indoor air quality, low income groups may also be exposed to poor air quality in outdoor areas. Recent initiatives in Kampala, principally led by AIR QO, have increased the number of monitoring stations and air quality data available. The ASAP-East Africa collected data from two AIR QO monitoring sites (Central Kampala and Bugolobi) located in close proximity to Namuwongo. This will allow readers to ascertain the potential double burden of exposure indoors and outdoors.

Table 6: ***Average and peak outdoor $PM_{2.5}$ ($\mu g/m^3$) daily concentrations (Central Kampala and Bugolobi)***

Average $PM_{2.5}$ ($\mu g/m^3$) daily concentration (Central Kampala)	Average $PM_{2.5}$ ($\mu g/m^3$) daily concentration (Bugolobi)
35.702	47.95

Data gleaned from the AIR QO monitoring stations highlights that air quality levels ($PM_{2.5}$) in outdoor locations exceeded WHO guidelines (on average) at all times monitored. Data was gathered over one month (October 2019) during which indoor air quality was monitored. At the monitoring sites, the average $PM_{2.5}$ daily concentration was 41.64 $\mu g/m^3$ and peak concentration was 73.47 $\mu g/m^3$ (see figure 9 for hourly time series data of outdoor air pollution). Over the period air quality was monitored, pollution levels on average, exceeded WHO guidelines for $PM_{2.5}$. During the study period, outdoor air quality at monitoring sites located close to Namuwongo is thus considered to be at a moderate to unhealthy level.

Figure 9: ***Average outdoor concentration of $PM_{2.5}$ Central Kampala and Bugolobi Air QO Monitoring stations (16th October 2019)***



Susceptibility

Susceptibility to air pollution is more difficult to assess than exposure and one needs to consider both the components and measures of susceptibility. Demographic factors such as age, gender, and socioeconomic status play an important role in assessing susceptibility to air pollution. However, these factors are highly context-specific, and can also interact with one another. Poverty and the socioeconomic conditions that produce it are considered to contribute to increased susceptibility to air pollution linked to either absence of or substandard medical care, substandard nutrition, substandard housing and reliance on inefficient and excessively polluting vehicles, heating and cooking methods.

The WHO (2018) estimates that in 2016 HAP accounted for 7.7% of global mortality (3.8 million) with nearly all of these deaths reported in LICs and MICs. Of these deaths, estimates suggest that 27% are due to pneumonia, 18% from stroke, 27% from ischaemic heart disease (IHD), 20% from COPD and 8% from lung cancer[10]. In Uganda, IHME ranks air pollution fourth (2007 and 2017) in the list of risk factors that drive most death and disability. This impact is not distributed evenly, women and children bear a large share of the associated health burden, and the adverse impacts from HAP are largely caused by energy poverty.

Historically there has been a dearth of epidemiological information concerning the health impacts of air pollution exposure, particularly HAP in East Africa and especially with regards to vulnerable groups (Bruce et al., 2000). The evidence base is however growing (Bartington et al. 2017; Okello et al. 2018). That data which is available shows that outdoor and indoor air pollution contribute significantly to annual mortality in Uganda with HAP linked to 16,630 deaths per year in 2013.

Table 7: ***Global Burden of Disease Study – 2015: http://www.healthdata.org/infographic/global-burden-air-pollution***

Country	Outdoor air pollution	Household air pollution	Unsafe water	Unsafe sanitation	Childhood underweight	Air pollution combined
Uganda	5,933	16,630	14,861	11,168	8,786	22,563

Evidence gleaned from available epidemiological studies has highlighted links between air pollution and premature mortality particularly from cancer, cardio-respiratory diseases and stroke (Shah et al., 2015). More recent evidence also suggests that exposure to air pollution can impact on cognition, cognitive decline (Shebab and Pope, 2019) and influence the onset of dementia (Moulton & Yan, 2012). In general, both long-term and short-term exposures have been shown to be associated with adverse health effects.

Globally, a number of studies have examined health inequalities associated with air pollution at a regional level. A study of six districts in Sao Paulo, Brazil, demonstrated that PM_{10} had less effect on respiratory mortality among adults in areas with a higher proportion of college educated individuals and high-income families, and it had greater effect in areas where the proportion of the poor population was high (Martins et al., 2004). Another study in Hamilton (Canada) highlighted that air pollution exposure had a relatively large effect on acute mortality in areas with a higher proportion of low educational attainment and high manufacturing employment (Jerrett et al., 2004). A study of Hong Kong, China, found that air pollution had a greater effect on the mortality of people living in public rental than those living in private homes, and a greater effect on blue-collar workers than those who had never worked and white-collar workers (Wong et al., 2008).

A determinant of the health impacts of HAP is the type of fuel used which varies within and across countries depending on resources available or cost of fuel (Rehfuess et al., 2014). Biomass solid fuel, such as cow dung, is preferred in many Indian rural villages for cooking in indoor kitchens (Sidhu et al., 2017). In China on the Tibetan

[10] https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

Plateau, wood stoves are a source of heat and contribute greatly to fine PM exposure, especially for women, in rural kitchens (Ni et al., 2016). In the context of this report, charcoal is used by the majority of households. Depending on the source, size and chemical composition of the PM, as well as the duration of the exposure to the suspended particles, different respiratory and cardiovascular health impacts are triggered.

Biomass smoke exposure has been associated with an increased risk of chronic bronchitis and COPD, circa 15% of those experiencing long-term exposure to wood smoke suffer from COPD (Ezzati, 2005). Women exposed to smoke from coal fires are reported to have an elevated risk of lung cancer (Ezzati, 2005). Similarly, though considered a cleaner fuel than coal or wood, exposure to fumes created by burning paraffin have been shown to impair lung function and increase asthma (WHO, 2014). The effects of exposure to HAP may also be exacerbated by other confounding factors including, for example, poor ventilation in the dwelling, inefficient stoves, smoking and burning of incense and mosquito repellent, indoor temperature and relative humidity levels.

Non-Communicable Diseases and Air Pollution

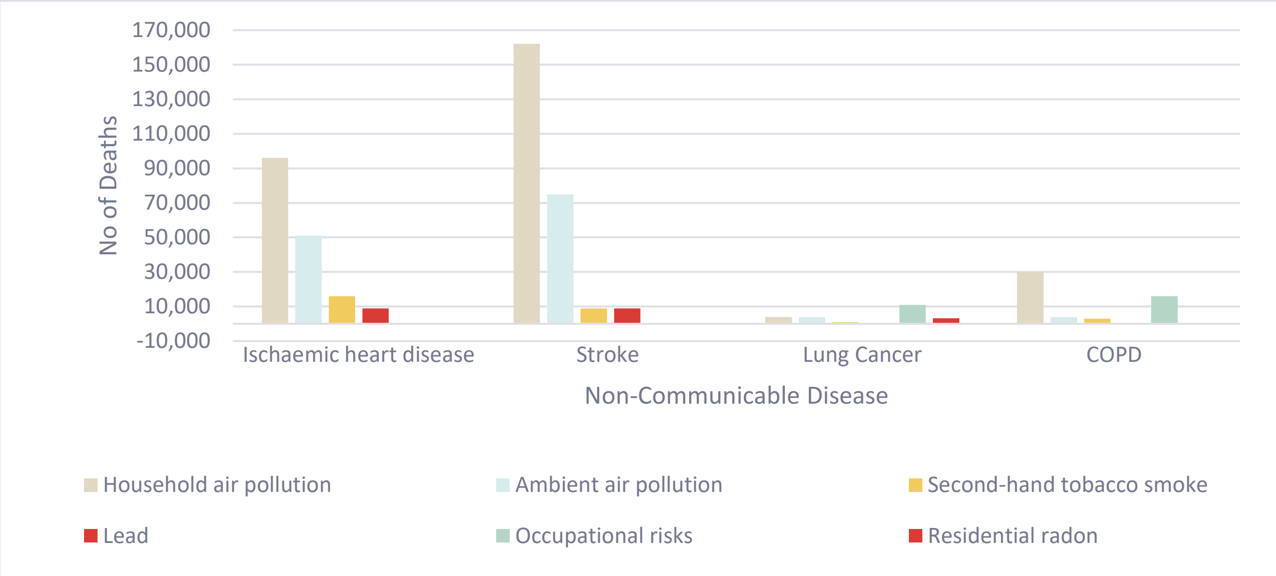
The United Nations have highlighted that urbanisation, environmental risk alongside population ageing has been accompanied by an increase in Non-Communicable Diseases (NCDs). These are commonly known as chronic or lifestyle-related diseases, the main NCDs are cardiovascular diseases, diabetes, cancers and chronic respiratory diseases (UN, 2011). The WHO (2019) highlights the links between air pollution and NCDs commenting that heart disease, stroke, lung disease and cancers, are among the top five causes of death, and one-quarter to one-third of deaths from these diseases are attributable to air pollution.

Air pollution is the second leading cause of deaths from NCDs after tobacco smoking (WHO, 2019). Household and outdoor air pollution have been recognised as one of the risk factors for NCDs, alongside unhealthy diets, tobacco-smoking, harmful use of alcohol, and physical inactivity. Worldwide, 24% of cases of stroke, 25% of IHD, 28% of lung cancer and 43% of COPD were attributable to ambient and household air pollution in 2016, and evidence on additional NCDs is emerging (WHO, 2018; 2018a).

In Uganda, NCDs were estimated to account for 33% of all deaths in the country. It is suggested that an epidemiological transition is happening in Uganda as the disease burden transitions from predominantly infectious diseases to NCDs (WHO, 2018: 1). Cardiovascular diseases account for 10% of all national deaths, cancers 9%, respiratory diseases 2% and diabetes 2% (other NCDs account for 11% of all national deaths) (WHO, 2018: 1).

It is important to note that mortality many NCDs such as IHD and stroke are also affected by risk factors such as high blood pressure, unhealthy diets, lack of physical activity and smoking. Some other risks for childhood pneumonia include suboptimal breastfeeding, underweight and second-hand smoke. For lung cancer and COPD, active smoking and second-hand tobacco smoke are also main risk factors.

Figure 10: ***Deaths from main NCDs in Africa attributable to environmental risks in 2012 (WHO, 2019)***



Pneumonia

Exposure to HAP is considered by the WHO (2018) to almost double the risk for childhood pneumonia and is responsible for 45% of all pneumonia deaths in children under 5 years old. HAP exposure also increases risk for acute lower respiratory infections (pneumonia) in adults, and contributes to 28% of all adult deaths to pneumonia.

Chronic obstructive pulmonary disease (COPD)

COPD is an umbrella term used to describe progressive lung diseases including emphysema, chronic bronchitis, and refractory (non-reversible) asthma. This disease is characterised by increasing breathlessness. Subjects with chronic respiratory diseases such as COPD and asthma are especially vulnerable to the detrimental effects of air pollutants. Air pollution can induce the acute exacerbation of COPD and onset of asthma and increase the respiratory morbidity and mortality.

One in four (25%) of deaths from COPD in adults in LICS and MICS are due to exposure to HAP. Women exposed to high levels of indoor smoke are more than two times as likely to suffer from COPD as women who use cleaner fuels and technologies. Among men (who already have a heightened risk of COPD due to their higher rates of smoking), exposure to household air pollution nearly doubles that risk (WHO, 2016). COPD is characterised by an enhanced chronic inflammatory response in the airways and the lung to noxious particles or gases[11]. Systematic reviews and meta-analyses have suggested that short-term exposure to air pollutants increases the burden of risk of COPD acute exacerbations significantly (Li et al., 2016).

In a review of evidence on the role of air pollution in the development of COPD, Schikowski et al, (2014) comment that the overall, evidence of chronic effects of air pollution on the prevalence and incidence of COPD among adults was suggestive but not conclusive, despite plausible biological mechanisms and good evidence that air pollution affects lung development in childhood and triggers exacerbations in COPD patients. They suggest that to fully integrate this evidence in the assessment, the life-time course of COPD should be better defined. Larger studies with longer follow-up periods, specific definitions of COPD phenotypes, and more refined and source-specific exposure assessments are needed.

In relation to asthma, the literature highlights issues with reporting and identification of cases across the global south and thus a corresponding paucity of data. Studies that have explored asthma cases in Africa from 1990-2010 suggest an increasing prevalence of asthma in over the past two decades (Adeloye et al., 2013). The authors, however, caution that given the paucity of data, the true prevalence of asthma may be significantly under-estimated. They assert that there is a need for national governments in Africa to consider the implications of this increasing disease burden and to investigate the relative importance of underlying risk factors such as rising urbanisation and population aging in their policy and health planning responses to this challenge.

*Box 1: **Metrics: Disability-Adjusted Life Year (DALY)***

Whilst much attention has focused on the mortality linked to air pollution exposure, the impact of ill health is equally concerning. Exposure to PM2·5 cost an estimated 103·1 million (90·8 million 115·1 million) disability-adjusted life-years (DALYs) in 2015, representing 4·2% of global DALYs (Cohen et al., 2017)

One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.

DALYs for a disease or health condition are calculated as the sum of the Years of Life Lost (YLL) due to premature mortality in the population and the Years Lost due to Disability (YLD) for people living with the health condition or its consequences.

According to the WHO (2019a: 8) 629,603,271,704 DALYs were accrued in 2015 in the Africa region and could have led to a loss in productivity amounting to Int$ 2,429,764,432,048 in the African Region’s GDP.

Country	Int$ (PPP)
Ethiopia	88,425,883,890
Kenya	69,219,515,912
Uganda	39,881,834,432

Stroke

Stroke remains the second most common cause of death and third most important cause of disability worldwide accounting for over 118.6 million DALYs and 6.3 million deaths in 2015 (Lee et al., 2018). An increasingly robust

[11] Global Initiative for Chronic Obstructive Lung Disease **https://goldcopd.org/**

evidence base has identified a link between air pollution exposure and risk of stroke. The Global Burden of Diseases study estimated that in 2015, air pollution accounted for 21% of deaths due to stroke (Lancet, 2016) with the WHO (2019) placing the figure at closer to 25%. More specifically, an estimated 12% of all deaths due to stroke can be attributed to the daily exposure to HAP (WHO, 2016).

Both short- and long-term exposure to air pollution are considered to increase the risk of stroke. In a systematic review and meta-analysis of the evidence for the short term association between air pollution and stroke Shah et al., (2015: 1) comment that, in over 6.2 million stroke events across 28 countries globally, their pooled analysis showed robust and clear associations between both gaseous and particulate air pollution and stroke admission or mortality. They reported that the strongest associations between air pollution and admission or mortality were observed from studies originating in LICS and MICS. Shah et al., (2015) conclude that gaseous and particulate air pollutants have a robust and close temporal association with admission to hospital for stroke or stroke death.

In a similar vein, Alessandrini et al., (2016) explored associations between short term exposure and mortality in 12 Italian cities comment that $PM_{2.5}$ and PM_{10} are positively associated with admission to hospital or mortality from stroke, with a stronger association identified for $PM_{2.5}$. The increase in relative risk was 1.011 per 10 µg/m^3 increase in $PM_{2.5}$ concentration. The association between $PM_{2.5}$ and stroke was evident on the day of the event and was present for up to two days before the event. Long term exposure studies have also shown strong associations between air pollution and stroke.

Ischaemic heart disease (IHD)

IHD is one of the most common health threats afflicting the adult population, with prevalence of IHD closely associated with ageing. IHD is related to the gradual build-up of fatty material within arterial walls. Known risk factors include high blood pressure, smoking, diabetes, lack of exercise, obesity, high blood cholesterol, poor diet, depression, and excessive alcohol (WHO, 2011).

Increasing evidence highlights an association between air pollution and IHD, however, the relationship remains unclear. Gold et al., (2000) have demonstrated a significant increase in cardiovascular disease, from 0.5% to 1.5%, for every 5-6 µg/m^3 increase in $PM_{2.5}$. Further, they showed a 69% increase in cardiovascular deaths after acute exposure to particulate air pollution. Approximately 11% of all deaths due to IHD, accounting for over a million premature deaths annually, can be attributed to exposure to HAP (WHO, 2016).

Studying data from the Beijing Monitoring System for Cardiovascular Diseases Xie et al., (2014) noted that a 10 µg/m^3 increase in $PM_{2.5}$ was associated with a 0.27% increase in IHD morbidity and a 0.25% increase in mortality on the same day. This study suggested that fine particulate matter i.e. smaller size fractions than $PM_{2.5}$ air pollution are the most important environmental risk factor contributing to global cardiovascular mortality and disability. It is thought that the mechanisms by which air pollution (particularly PM) causes cardiovascular disease include directly toxicity to the cardiovascular system or indirectly by inducing systemic inflammation and oxidative stress in peripheral circulation (Du et al., 2016).

Lung cancer

Air pollution and its chemical components are known to be carcinogenic to humans (IARC, 2013) and air pollution is known to be a contributory factor to lung cancer burden. Studies originating from China have identified a significant positive correlation between $PM_{2.5}$ concentration and lung cancer mortality (Cao et al., 2018). Additionally, Cao et al. (2018) suggest that the longer the period of exposure to $PM_{2.5}$ is, the higher morbidity is.

Approximately 17% of lung cancer deaths in adults are attributable to exposure to carcinogens from HAP caused by cooking with kerosene or solid fuels like wood, charcoal or coal (Raspatani et al., 2016). The risk for women is higher, due to their role in food preparation. However, few studies have comprehensively investigated the risk of lung cancer associated with HAP in contexts where biomass usage is the norm. Studies undertaken in Nepal have highlighted a statistically significant association between HAP exposure and lung cancer risk (Raspatani et al., 2016). The authors noted increased risk among tobacco users, those with older age and females. Participants who had previously been diagnosed as having tuberculosis were found to have a considerably higher lung cancer risk compared to those who did not. Importantly, the authors identified a significantly decreased lung cancer risk among those with higher socio-economic status (Raspatani et al., 2016).

Whilst evidence suggests a strong association between exposure to air pollutants and increased lung cancer incidence and mortality, the evidence base is less clear on the impacts of air pollution exposures on survival. A study by Eckel et al., (2015) explored the link between individual-level estimates of air pollution exposures after lung cancer diagnosis to survival. Findings supported the hypothesis that air pollution exposures after lung cancer diagnosis shorten survival with patients with lung cancer, with higher average ambient NO2, $PM_{2.5}$ and PM_{10} exposures since diagnosis, having shorter survival,

Other health impacts and risks

More broadly, PM and other pollutants in indoor smoke have been shown to inflame airways and lungs, impair immune responses and the oxygen-carrying capacity of blood. There is also evidence of links between HAP and low birth weight, tuberculosis, cataract, nasopharyngeal and laryngeal cancers.

Perceptions of susceptibility to air pollution amongst residents of Namuwongo

To explore perceptions of susceptibility to air pollution, survey respondents were asked to identify in what ways they thought air pollution adversely affects them or their city (findings are presented in figure 11). Survey respondents acknowledged that air pollution was an issue and had an impact on daily life, responses suggest that individuals were aware of a link between air pollution and long term health impacts with 24/38 highlighting that air pollution contributed to respiratory issues. Of the sample, 27/38 also associated exposure with the triggering of allergies or respiratory problems. Only two of the sample indicated that air pollution did not have an impact on them. Indeed, of the respondents, 27/38 reported that air quality affected their health with almost all (37/38) reporting that they had experienced some form of illness during the last year with seven noting that their illness had lasted for 21 days or more. Whilst this illness cannot be solely attributed to air pollution it is of interest that coughs and flu featured prominently alongside malaria and stomach pains as main causes of illness.

Figure 11: ***Survey respondent's perceptions of air pollutions adverse impacts on individuals and Namuwongo***

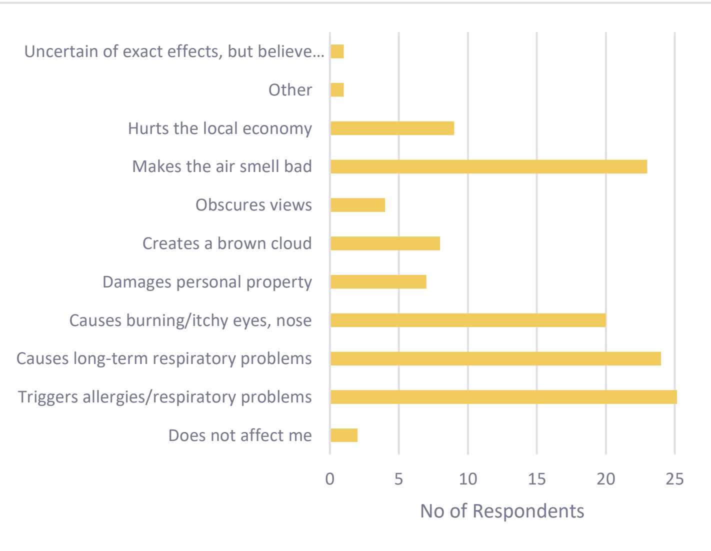
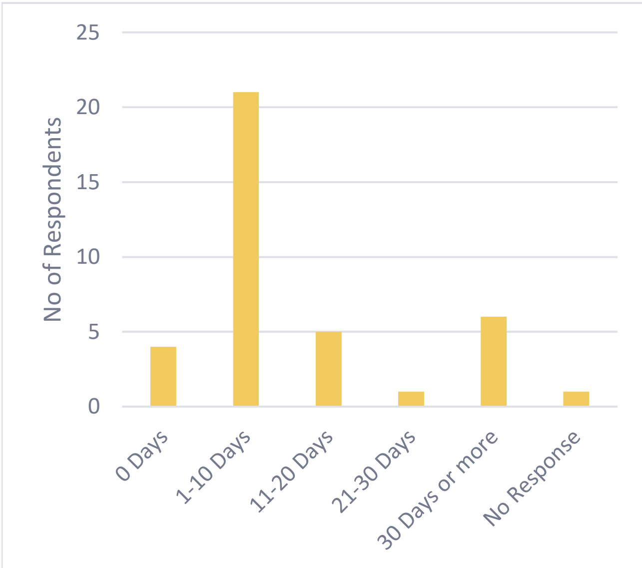


Figure 12: ***Survey respondent's identification of length of sickness in the past twelve months***



Whilst a range of factors inhibit efforts to address the causes and consequences of household air pollution, knowledge and sensitisation are often cited as pivotal factors. Tamire et al. (2018) explored socio-cultural reasons and community perceptions regarding indoor cooking using biomass fuel and traditional stoves in rural Ethiopia noted that study participants repeatedly identified effects of smoke mainly on the eyes of the women who are cooking. Participants also frequently mentioned respiratory health problems, particularly a cough, nose irritation, shortness of breath and the effects on the lungs.

Adaptive capacity

The concept of adaptive capacity remains contested, but can broadly be defined as the ability of individuals, communities, organisations, nations or other actors to take actions to either reduce or avoid risk. While greater exposure and higher susceptibility to air pollution increase vulnerability, adaptive capacity refers to the means by which people can reduce their vulnerability. The concept of adaptive capacity is important because while exposure and susceptibility, characterise vulnerability in a negative way, adaptive capacity recognises the ability of actors to learn and change behaviour.

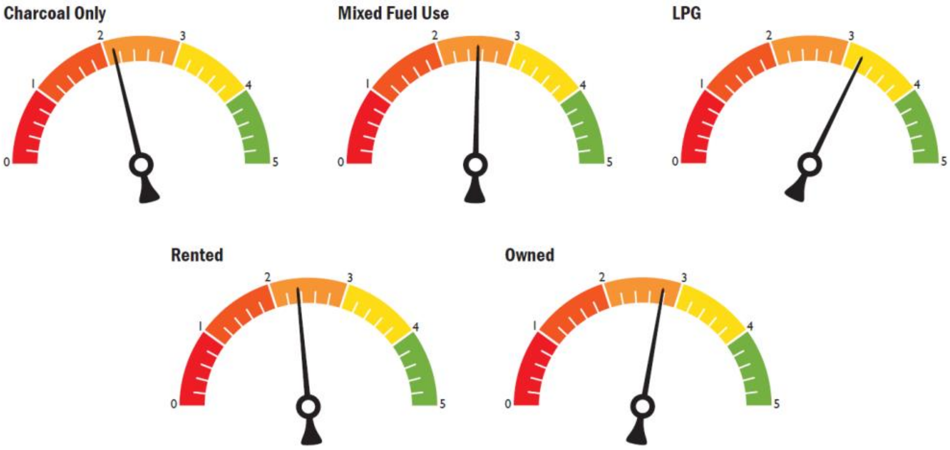
Whilst many studies of air pollution focus on efforts to reduce air pollution levels and improve air quality (i.e. mitigation), some recent literature has explored how various actors can protect themselves against the impacts of pollution by developing adaptive capacity. This focus on adaptation stems from an awareness that due to a lack of air quality regulations, enforcement institutions or effective agreements on air quality management, improvements may be difficult to achieve (Ebert & Welsch, 2011; Lankao & Tribbia, 2009). Indeed, mitigation requires consensus and cooperation across a number of stakeholder groups (public and private sector and civil society) and levels (local, regional, national and global). In contrast to mitigation, adaptation requires less consensus and some actions may be taken at an individual, organisational or city level.

Factors that may impact upon the adaptive capacity of lower income groups include livelihoods, underlying health issues (such as respiratory illness, heart disease etc.), social, economic and political exclusion and reduced access to resources. In addition, lower income groups may be more dependent on services, such as health and social protection services. In many contexts these may be limited, poorly functioning or badly designed. Lower income group's adaptive capacity will vary significantly – with some having higher levels than others, gender and age for example will likely exert an impact on adaptive capacity.

In the context of rapid urbanisation, low income groups are likely to be most affected by continued exposure to high levels of HAP and increases in ambient air pollution levels. Consequently, a key focus of 'soft' actions for adaptation should be directed at developing the adaptive capacity of low income groups in the environments in which they spend significant periods of time. Finding reliable ways to measure adaptive capacity and promote behaviours, particularly of low income groups, is challenging and remains a priority for researchers and policymakers. Numerous indicators have been developed, including 'education, income, and health' as well as access to financial, technological and institutional resources. More broadly, recent literature has attempted to identify determinants of adaptive capacity and specify the processes through which those determinants interact. Eakin et al. (2014), for example, explore the relationship between socioeconomic development and in the context of their research climate risk reduction, as an interaction between 'generic' and 'specific' capacities and explore how those capacities might complement or undermine each other. In a similar vein, the Local Adaptive Capacity (LAC) framework, seeks to understand how different determinants of adaptive capacity influence each other at household and community levels.

To ascertain individuals perceived adaptive capacity, participants in the survey where asked to assess "how they rated their ability (as an individual) to take actions to improve air pollution or minimise exposure (1 being no ability at all, 5 being very able)?" Those who used LPG for cooking or owned their homes considered themselves most able, recording an average score of 3.22/5 and 2.79/5. Those who cooked with charcoal (2.13/5), mixed fuel (2.56/5) or rented homes (2.35/5) where less confident of their ability to improve air pollution or minimise exposure.

Figure 13: ***Survey respondent's perceptions of vulnerability according to cooking fuel type and household ownership status***

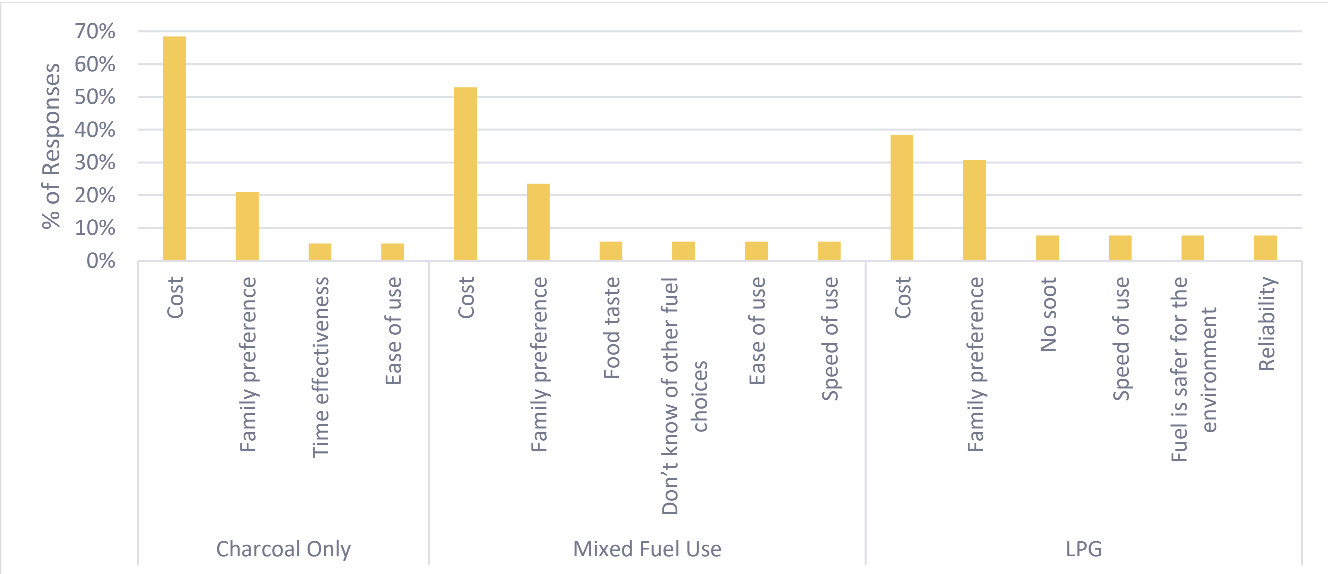


There exists a relationship between socioeconomic status and adaptive capacity. According to the IPCC, socioeconomic factors that determine adaptive capacity include access to technology and infrastructure, information, knowledge and skills, institutions, equity, social capital, and economic development (IPCC 2014). There, however, is a dearth of evidence that explores the impact of socioeconomic status and location on air pollution exposure and adaptive capacity. Some studies have found that house location and exposure to pollution sources is higher for people from poor neighbourhoods (Sanbata et al., 2014). There is also some evidence of differences in exposure between age groups and genders (Bartington et al., 2017; Okello et al., 2016).

In addition, the nature of informal settlements, principally their density, renders the adoption of measures to reduce pollution at individual household level challenging due to a 'neighbourhood effect' in which adopting households may continue to suffer due to exposure from non-compliant households (Muindi et al., 2014). Political, social and economic exclusion of informal settlements further puts these areas in a vulnerable position as they lack systems to manage such things as waste collection or find a collective voice to bargain for services and protection against external polluters such as industries (Arimah, 2001).

In the context of this report, disposable income exerts an influence on exposure to air pollution, dictating which fuels are used, access to kitchen areas away from living and sleeping areas and access to technologies that may affect changes in exposure both indoors and outdoors. For example, whilst clean cook stoves have been heralded as a potential means of addressing HAP, a common critique is that the cost of purchase is often perceived as prohibitive by those households most at risk. Tamire et al. (2018) identified economic factors as a major barrier in uptake of improved household cooking practices, hindering the ability to afford a separate kitchen, improved cook stove or improved household construction. Respondents in their study reported that small living areas were not appropriate for the adoption of improved cook stoves as the space was not enough to accommodate them. In the survey undertaken for this report cost was identified as the main determinant of fuel choice. According to the UBOS (2018), the average Ugandan monthly wage was 168,000 Shillings. There is, however, significant differences between men and women (220,000 versus 110,000), between rural and urban settings (120,000 versus 220,000) and public versus private employment (450,000 versus 150,000). Survey respondents in Namuwongo reported an average monthly household Income of 150,167 Shillings.

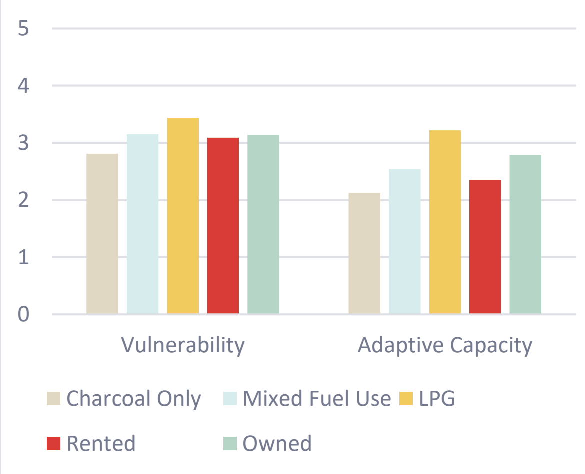
Figure 14: ***Survey respondent's clarification or reason for fuel use***



Whilst the survey sample (both in size and composition of respondents) limits the ability to make any assertions regarding this issue, some interesting findings do emerge. Survey respondents were asked what fuel they used for cooking and whether they owned or rented their homes. Past studies have highlighted that income determines both fuel use as well as home ownership. In terms of adaptive capacity it is of interest to note that those who are used LPG or owned there house considered themselves to have higher levels of adaptive capacity than other groups.

Alongside economic resource, knowledge is also as an important determinant of adaptive capacity (Williams et al., 2015). The LAC framework identifies knowledge as both a dimension of adaptive capacity, but also an element within other dimensions. Similarly, the IPCC considers a 'lack of knowledge' to be a possible constraint on adaptation.

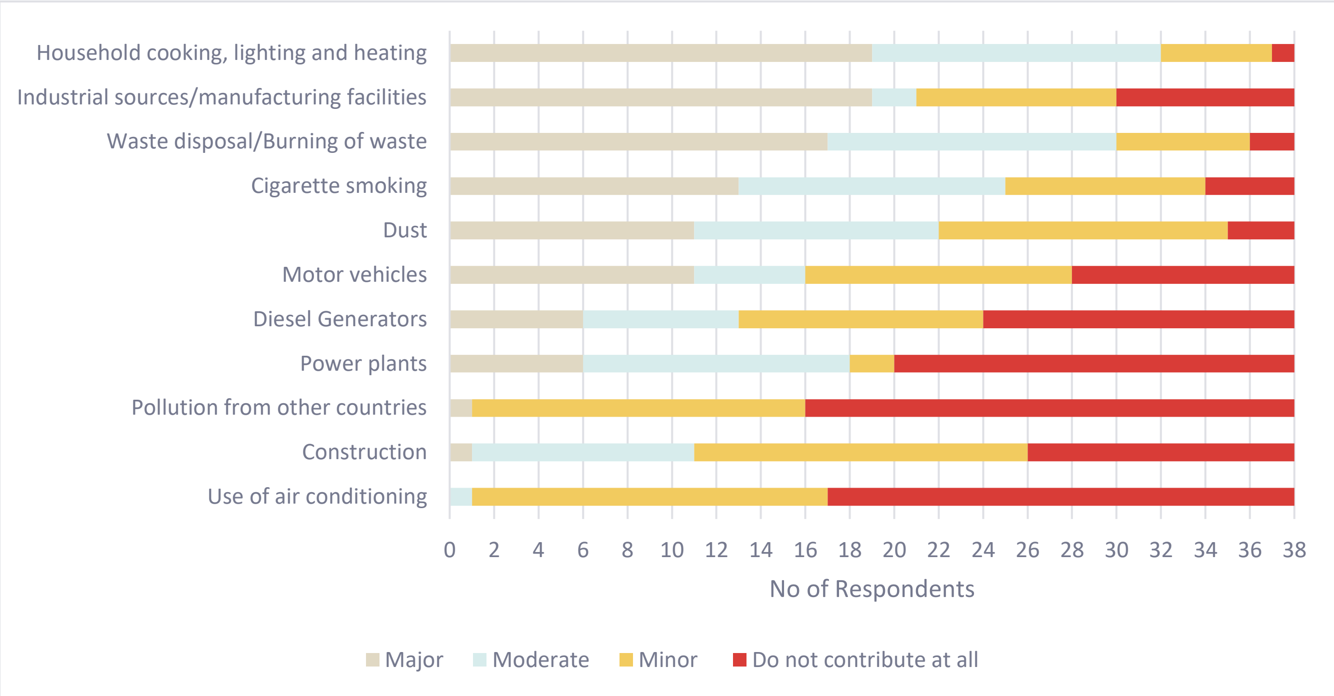
Figure 15: ***Survey respondent's identification of fuel use and home ownership status perception of vulnerability and adaptive capacity***



Whilst studies have suggested that East Africans possess a degree of awareness regarding air pollution and its potential impacts, they highlight that such knowledge is limited (Tamire et al., 2018; Muindi et al., 2014). Such studies are more limited in Uganda. A report produced by the BBC world Service Trust (2010) notes that the issue of congestion and pollution – visible air pollution from cars and factories as well as rubbish – is a prevalent theme within urban groups, and closely tied to sanitation concerns. They continue that slums, poor sanitation, and pollution from industry and traffic are identified as a problem for Ugandans, especially in Kampala. Ugandans tend to view these problems under the umbrella term of "pollution" and often talk about them interchangeably, stressing their combined health impacts. Many Ugandans, especially those in urban areas, think pollution comes about as a result of poor garbage disposal, others attribute it to emissions from old vehicles and smoke from industry. Similar findings have been reported by Muindi et al. (2014) who noted that residents of informal settlements in Nairobi viewed drainage channels and toilets as a source of air pollution.

To ascertain knowledge, survey respondents were asked to specify sources of air pollution and to rank their relative contribution (major, moderate, minor or whether they did not contribute at all). Respondents identified a broad range of sources (see figure 16). Findings can be contrasted with EU research that identified population-weighted averages for relative source contributions to total $PM_{2.5}$ in urban sites in Africa. These included domestic fuel burning (34%), natural sources including soil dust and sea salt (22%), traffic (17%), unspecified sources of human origin (17%) and industry (10%) (Karagulian et al., 2015).

Figure 16: ***Survey's respondent's perceptions of sources of air pollution (major, minor, moderate does not contribute at all)***



Survey respondents were also asked to identify steps taken by them, household members or the broader community to address air pollution. Six broad areas of action were identified across surveys:

- **Household ventilation** was mentioned by twenty respondents, this involved opening windows and doors during cooking, taking charcoal stoves outside after cooking or operating fans to disperse smoke.
- **Cleaning households and neighbouring areas** was mentioned by nineteen respondents, this include dusting and maintaining households as well as managing waste in the community.
- **Minimising charcoal use time and using better quality charcoal as well as avoiding the burning of solid waste** was cited by four respondents.
- **Spraying insecticide** was mentioned by one respondent.
- **Use of air conditioners** was mentioned by one respondent

- **Not knowing of any steps** was mentioned by two respondents

Studies in Nairobi (Kenya) have highlighted a feeling of helplessness amongst residents of low income settlements attributed to a lack of 'voice' and a perceived inability to approach authorities to demand action. Linked to this was the issue of poor social capital among residents, thought to inhibit collective action to address the causes and consequences pollution. Given their informal residential status, poverty and lack of available alternatives, Muindi et al. (2014) report that low income groups often felt trapped in polluted spaces.

Muindi et al. (2014) highlighted a lack of agency to address air quality in the two communities, a finding confirmed in this report. Indeed, feelings that there was nothing that could be done to reduce the levels of pollution in their home or communities. In response to the question, "do you think you could do more to improve air quality and reduce air pollution?" 28/38 (73%) reported no. This perceived lack of agency is important as it could potentially derail efforts the government puts in place to address air pollution in these and similar communities.

More broadly, in terms of disposable income, the poor may bear disproportionate shares of the economic burdens of any cost ineffective environmental regulations that unduly increase prices of housing, fuels, vehicles, or appliances. Environmental justice requires the costs imposed by environmental regulations to match their benefits for everyone, not just for society as a whole (Lipfert, 2004).

Facilitating adaptation

Whilst understanding the adaptive capacity of low income groups is fraught with issues, it is clear that the most effective pathways for adaptation are likely to arise out of an informed evolution of existing institutions and the participation of civil society groups, public and private sector actors. A number of studies emphasise the importance of the support and political will of local public officials in developing successful solutions to environmental issues such as air pollution (Slovic et al., 2016). Others emphasise the need for communities to build from and integrate modern techniques into air quality management practices and for local networks to effectively collect and disseminate data needed for assessing impacts.

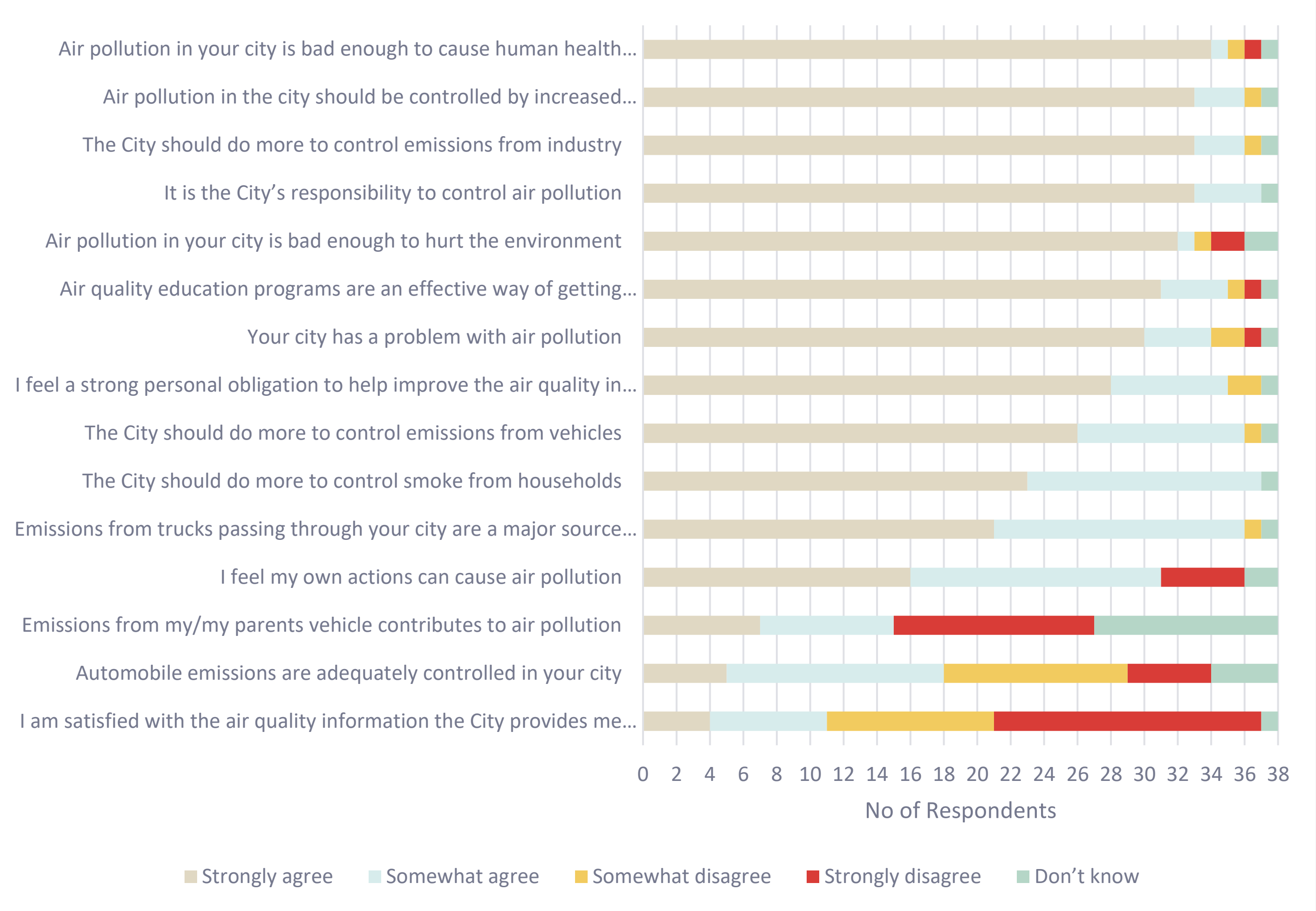
Several research and knowledge gaps exist. More work is needed to understand if there is an unequal distribution of air pollution and whether the gap between richer and poorer areas is widening or narrowing. Specifically, as air pollution policies and regulations (both related and unrelated to inequality) are put into place, it is important to understand if these policies impact inequality. Another policy relevant issue is that of which sources or components are most unequally distributed. Although a few studies have begun to examine this question, inequalities may be driven by local sources of pollution, thus necessitating more research (Hajat et al., 2015).

More work could also focus on how to enhance individual's knowledge of actions that they take that may exacerbate or minimise HAP. For example Muindi et al (2014) comment that daily practices such as blocking eaves to prevent cold, dust and mosquitoes are an example of how residents balance either letting in the cold, polluted outdoor air and mosquitoes or living with indoor air pollution. Few countries have specific environmental health protection policies that focus on low income groups and there are also limited examples of air quality campaigns centred on informal settlements. Further to this, air pollution exposure is associated with a range of social, economic and political factors – cultural norms, past occupation exposure and economic factors will all play a role. Despite these challenges, the case for taking action is increasingly compelling.

A European study assessing the health impacts of urban air pollution in 25 cities found that the monetary gain of complying with WHO guidance for PM concentration would be 31 billion Euros (Pascal et al., 2013). The life course health benefits are also clear. Gauderman et al., (2015) identified gains in respiratory outcomes in 11–15 year olds in California as a result of improvements in air quality over a 4 year period – these benefits will often accrue in older age. Similarly, as risk of morbidity and mortality increase amongst older people when exposed to high levels of pollution – improvements in air quality will disproportionately benefit those who are most at risk. Indeed, underlining how certain population groups are more vulnerable than others is an important input into policy decisions about setting ‘acceptably safe’ levels (Cakmak & Vidal, 2011). With the excess risk of death associated with air pollution being particularly high amongst those with low educational attainment or low income, it is particularly important to understand how their risk may differ from others and the extent to which policies can address this.

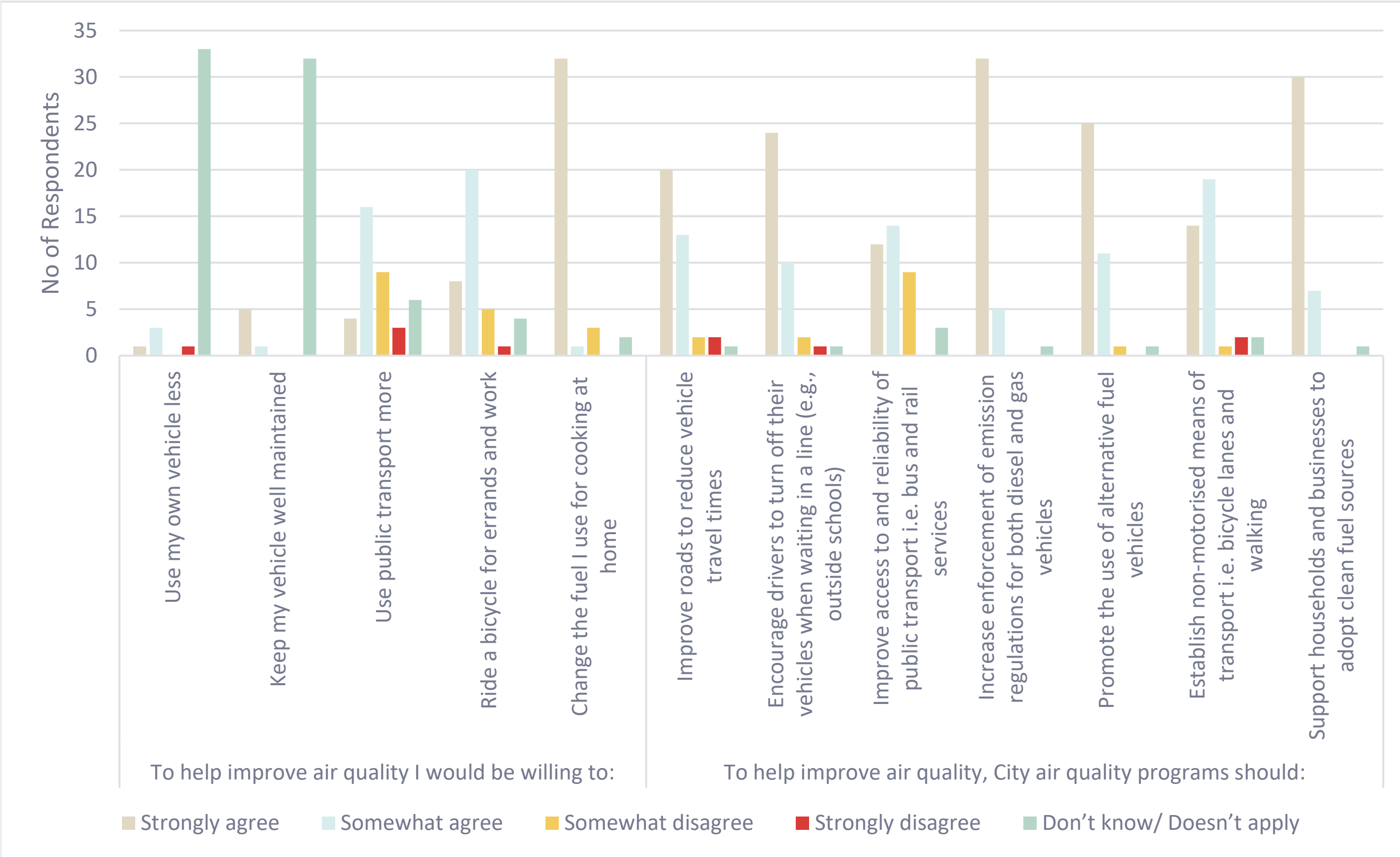
Given the need for policy interventions to be publicly acceptable it is important to identify how receptive groups would be to interventions. This can be accomplished through participatory consultative processes. The rationale for consultation is clear, it aides government in garnering views and preferences, understanding possible unintended consequences and getting views on implementation. Increasing levels of transparency and engagement with stakeholders also improves the quality of policy making. Figure 17 below provides an overview of how strongly individuals agreed or disagreed with a series of statements about actions to curb air pollution. This provides an insight into areas policy makers may wish to explore when addressing air pollution.

Figure 17: ***Survey respondent's perceptions of actions to curb air pollution***



Survey respondents were also asked to identify how acceptable a number of potential policy interventions would be. Responses pertaining to individual actions whilst supportive, were mixed. Responses pertaining to government supporting air quality interventions were broadly unanimously in favour.

Figure 18: ***Survey respondent's perceptions of policy interventions***



Adaptable, affordable and acceptable initiatives to improve the quality of air should be prioritised when considering how best to address air pollution in both indoor and outdoor environments through both preventive and remedial actions. Relevant national, state, and local stakeholders, including health officials, family members, community and industry leaders, public health professionals, environmental scientists, and representative organisations need to work together to develop policies that ensure improved environment in informal settlements. This can often be challenging given competing agendas and priorities. To achieve the goal of improving air pollution in households, this report identifies a number of options targeted at the individual, organisational (i.e. representative organisation for older people) and governmental (local, regional and national) levels.

Conclusions and recommendations

This study has explored the exposure of low income groups to air pollution in Kampala via the deployment of low cost sensors in indoor settings. These findings are complimented by the collection of data pertaining to air quality from the AIR QO air quality monitoring network stations located at Central Kampala and Bugolobi. The study also probed perceptions of low income groups regarding air pollution. Findings underscore the vulnerability of low income groups to air pollution and suggest that those living in informal settlements are likely to face a higher burden of exposure at home and in outdoor environments. Data gathered during this study indicates that air pollution levels in indoor (household) and outdoor settings regularly exceed WHO guideline amounts. Household air pollution exposure averaged 72.61 ± 64.42 $\mu g/m^3$ in households that used charcoal and firewood compared to 43.46 ± 33.44 $\mu g/m^3$ for households that reported using electricity and gas. Further to this, air pollution levels tend to peak during cooking periods, consistently recording levels, at times well above those measured by air quality indices. Data gathered from the AIR QO monitoring sites showed that ambient levels of air pollution are also of concern, averaging 41.64 $\mu g/m^3$ and peaking at 73.47 $\mu g/m^3$ (moderate to unhealthy levels).

Survey findings suggest that low income groups are relatively cognisant of their inherent vulnerability to air pollution, perceiving their vulnerability on a scale of 1-5 at an average of 3.08/5 (five indicating extreme levels of vulnerability). Resident of Namuwongo people demonstrated a mixed understanding of the potential sources of air pollution, though this is to be expected given the lack of sensitisation around air quality issues in Uganda and corroborates findings from other studies that have explored this issue and the relative lack of knowledge in many societies regarding air pollution. This study underscores that good air quality in household environments is central to the provision of a safe, healthy, productive, and comfortable living environments. Given the inherent vulnerability of low income groups to air pollution exposure, coupled with the significant proportion of time spent in household environments, it is clear that there is a need to develop proactive policies and interventions that protect low income groups from exposure to unhealthy levels of air pollution in such settings. To achieve the goal of improving air pollution levels in household environments, this report identifies a number of recommendations, targeted at the individuals, organisations (i.e. informal settlement representative organisations) and governments (local, regional and national) levels.

Individual and household (low income groups)

While effective policies to reduce emissions at their source are clearly preferable, some evidence supports the effectiveness of individual action to reduce exposure and minimise health risks. As noted, low income groups often have little or no choice in where they live or work, drawn to areas where housing is accessible or livelihoods are available. It is also important to note that informal settlements are often the product of historic factors, established over decades in locations where others chose not to live. These factors makes it imperative to support low income groups in the locations where they live, enabling them to take actions to eradicate or minimise exposure to air pollution in both indoor and outdoor settings.

Personal exposure to air pollution can be reduced by avoiding sources of emissions. An assessment of potential levels of air pollution is required to ensure that risk is minimised. In order to most effectively adjust behaviour, individuals must be able to anticipate when and where air pollution is likely to be elevated above levels thought to increase risk. This requires providing individuals, in this instance low income groups, with the information they need to make informed decisions. Such information would allow individuals to better understand when and where exposure is likely to be highest and whether they are more likely than the general population to be susceptible to the harmful effects of air pollutants. This would require publicly available air quality data in near real time and sensitisation regarding the impacts higher levels of air pollution may have – particularly related to

HAP. For ambient air quality in Kampala this information is available via the AIR QO monitoring network which has established sensors across Kampala. Whilst Kampala and AIR QO are leaders in terms of ambient air quality monitoring in East Africa, more effort is needed to put this information in the hands of those who are able to advocate for change. The ASAP-East Africa research team have acted as an interlocutor between ACTogether and AIR QO and discussions are ongoing about locating a sensor in Namuwongo.

Personal exposure to HAP can be reduced by transitioning to cleaner fuel sources and methods of cooking, heating and lighting. It has been established that significant benefits can be gained from reducing air pollution, e.g. through switching to improved cook stoves or cleaner fuel sources such as LPG and electricity (Jeuland & Tan Soo, 2016: 19). Despite the benefits of such as transition, issues associated with affordability, accessibility and familiarity persist. Whilst KCCA is supporting the provision of LPG across the city, the majority of informal settlements continue to be reliant on charcoal. An area explored by the ASAP research team (Okello et al., forthcoming) highlights the potential of briquettes (made in part from household waste) as a possible transitional fuel source that can reduce HAP, manage some household waste and provide a livelihood opportunity for low income households. Initial results suggest that briquettes can reduce the level of HAP up to 147.65 $\mu g/m^3$ compared with charcoal only cooking, more research is, however, needed. Whilst extension of cleaner fuel provision is a must, households may want to consider alternative fuel sources as an interim measure.

Households should prioritise interventions that address sources or minimise emissions in the home. There are changes that can be made to homes, as well as changes in people's use of their homes, that can help minimise some negative effects on health. These measures would also reduce exposure to other sources of indoor air pollutants. Encouraging people to change their habits e.g. using improved ventilation when cooking. These changes will require support from civil society and government and may explore the development of a toolkit of options for households to draw from.

Organisational (civil society groups)

Whilst the ability of organisations to address air pollution is limited and often dependent on government willingness to tackle the issue, there are a number of steps they can take to sensitise individuals to air quality concerns, to advocate for policies that acknowledge the specific vulnerability of low income groups and to support groups develop and implement contextually appropriate solutions.

Organisations can play a significant role in sensitising the wider community to the causes and consequences of air pollution. Education is considered a key factor in developing public knowledge and awareness about issues such as air pollution. Studies show that many lack sufficient environmental knowledge despite possessing positive attitudes towards taking actions to improve air quality. By encouraging organisations to include air quality issues as part of their advocacy activities, they, and the individuals they represent, may become more knowledgeable about air quality issues, play a role sensitising others and ultimately become agents of change. In contexts where knowledge is limited, organisations could become a significant community resource. In some contexts, such organisations can play a public information role regarding air pollution levels.

Organisations can highlight the increasing evidence of the links between poor air quality, exposure to air pollution and public health issues, most importantly links with NCDs. Indeed whilst respondents in this study acknowledged links between health issues and air pollution – knowledge remains limited. Advocacy organisations can play a key role in promoting healthy living and tackling the key risk factors linked to air pollution from all sources. In particular, groups such as ACTogether can support the collection of health data to provide a fuller picture of the impact of HAP in informal settlements. Given the paucity of data currently available, it is important to expedite such initiatives.

Organisations such as ACTogether should commission further research that assesses sources of air pollution that originate within household environments and identify interventions that can reduced or eliminate these. Steps may include supporting households to address pollution sources (improving cooking stoves, supporting the adoption of alternative fuels, reducing the need for fire); improving the living environment (through structural ventilation, kitchen design and stove placement) or advocating for changes in behaviour (this may include use behaviour, smoke avoidance or encouraging ventilation of cooking sources). Studies originating in the global north have demonstrated that HAP tends to be worse in low income households but also that energy efficiency retrofitting measures can have a marked impact on air quality (Shrubsole et al., 2016). More work is required to understand and test which interventions will have most impact in low income households.

It is important that these interventions are tested in specific contexts to ensure that these are acceptable to local communities, affordable and most importantly accessible. Such an approach could be supported by the development of a HAP tool kit that allows individuals, communities and organisations to assess sources of pollution and potential interventions. Criteria of assessment should include: Potential Air Quality Improvement, Cost, Deliverability and Stakeholder Support. Civil society groups such as ACTogether are uniquely well placed to advise households on quick win interventions that may reduce HAP over the short term but also to advocate for governmental support to address this issue.

Organisations can also advocate for the creation of inclusive and enjoyable shared urban spaces that encourage social activity and provide easier access to services and opportunities, and supporting those engaged in street-based livelihood activities. This also includes providing green and public spaces that encourage physical activity and social interaction, and increasing public transport provision that is adequate, accessible, safe and accountable. The work of Kounkuey Design Initiative in Kibera (Nairobi) provides an example of a model that could be replicated. They work with local residents to transform unsafe and under-used sites into "Productive Public Spaces". From permanent parks to temporary vacant lot activations, each space integrates key amenities such as community buildings, water and sanitation facilities, green infrastructure, and open spaces for recreation and exercise. All of these steps could serve to minimise the exposure of low income groups to ambient air pollution. Such steps will require collaborative efforts between civil society groups, public bodies and government agencies to strategically identify where interventions will have most impact and what polices will support these.

Organisations should harness and build on existing community responses to issues such as solid waste management and flooding response and explore how these could inform efforts to address air pollution. Throughout the engagement in Namuwongo, community residents highlighted responses to flooding and the mobilisation of collective action to clean water ways and respond to floods. Further to this, the provision of support to community based organisations who are producing briquettes from household waste could improve briquette production, scale up activities and help households transition to cleaner fuel. Fuels produced from locally available waste materials will have lower environmental impacts.

Governmental

Given the multi-scalar and interdependent nature of urban air pollution it is clear that government must play a key role in supporting efforts to address this issue. Recommendations for government include:

Governments should analyse current living conditions and cooking practices across the income spectrum to ascertain where HAP is worst and what initiatives will have most impact. Household construction guidelines and support to improved cooking behaviours should seek to protect families from exposure to air pollution. However, many countries lack adequate regulations or enforcement powers related to household construction. Governments at local and national levels should draw on existing best practice to develop such policies where they are absent and consider how they could be applied retrospectively for existing households. More research is also required to explore how the future provision of housing for low income groups could play a role in minimising exposure to HAP. Such research would investigate how the design and performance of buildings themselves (both before and after energy retrofitting) – as well as the behaviour of occupants – may drive health inequalities between different socioeconomic and age groups.

The Ugandan government can learn from international experience of efforts to support household transitions to cleaner fuels and develop contextually appropriate interventions for rural and urban areas. This will include learning lessons on what worked and why, governments in some countries have implemented largescale programs to proactively replace solid fuel with cleaner energy sources for household cooking which can provide a starting point:

- In China, the government banned the use of coal for household cooking and heating in municipalities around Beijing in favour of a switch to natural gas. The effort stemmed from the emissions benchmarks established in China's Air Pollution Prevention and Control Action Plan, issued in 2013.
- In India, government efforts seek to shift more households to LPG. While many families can afford subsidised LPG fuel, the fee for installing a household LPG can be prohibitive. A government initiative, (Pradhan Mantri Ujjwala Yojana), provided LPG connections to 35 million poor families free of charge between 2016 and 2018 and aims to provide 80 million connections by 2020. A unique facet of the program is its focus on women as the drivers of change. Recognising the role of women in household cooking, as well as the disproportionate burden of household air pollution on India's women and children, the program requires that each LPG connection be registered in the name of a woman.

- In Ghana, the government has worked to promote adoption of LPG for three decades. While the proportion of people cooking with solid fuels has declined since 1990, when 95% of the population relied on such fuels, it still remains high (73% in 2017). As part of its Sustainable Energy for All Action Plan, Ghana's government aims to provide 50% of the country's population with LPG access by 2020. In a related effort, the government launched the Rural LPG promotion program in 2013 to focus on increasing LPG use in rural areas where solid fuels are the most common source of energy.

Governments can intervene strategically to guide fuel use in a number of way. It is broadly acknowledged that fuel use patterns evolve in relation to available resources; cultural preferences; geographic dispersion of the population; poverty and awareness; existing subsidies, taxes, and trade policy and other contextual factors. Government interventions to influence fuel use may include (GACC, 2017: 19):

- Agricultural and Forest Management: Biomass will continue to be a dominant fuel in the household energy mix and should be incorporated into policy planning. Zoning land for sustainable woodlots and growing renewable biomass fuels should be incorporated into forest management plans. Governments should also increase regulatory involvement in markets for purchased firewood and charcoal.
- Financing Programs: Government financing programs should look across the fuel value chain to identify who should receive the support (consumers, producers, or both), which part(s) of the value chain should financial support target (collection, storage, transportation, manufacturing, distribution/sales), and if financial support should be based on outcomes. In countries where waste residues can and are being used productively and where higher efficiency combustion technologies exist, national governments should provide policies and financial support for fuel production.

Government at all levels should play a more active role in increasing public awareness regarding the causes and consequences of air pollution. In the Ugandan context, NEMA has a mandate to promote public awareness through formal, non-formal and informal education about environmental issues, to undertake research and disseminate information about the environment for both public and private users. Research programmes must actively engage NEMA to support these activities, providing access to research to support the development of evidence based policies. This can also involve supporting NEMA and their local partners, namely District Environment and Local Environment Committees which are required to promote the dissemination of information about the environment through education and outreach programmes. Dianati et al. (2019) suggest that supporting household air quality monitoring and health impact assessment studies may serve to bring the issue of household air quality higher up on the list of public/government priorities.

Government at all levels should support participatory informal settlement upgrading initiatives to address broader issues afflicting low income groups in cities. It is apparent that whilst air pollution exposure is the focus of this report, inequities in environmental risk are inextricably tied to insecurity of tenure. Efforts to address the challenges faced by residents of informal settlements can concomitantly alleviate some of the drivers of exposure. Drawing on the evidence from informal settlement upgrading programmes, Lucci et al. (2015) identify a series of insights on what works in slum upgrading.

- Community participation and working in partnership: An important feature of successful programmes is their recognition of the key role of informal settlement communities in improving their own circumstances. Programmes are more likely to be effective if tailored to addressing informal settlement top concerns. More fundamentally, participatory processes trigger deeper changes in community development, as marginalised communities become active participants in the policy-making process.
- Incorporating the needs of the poorest and most vulnerable Reaching the poorest within informal settlements is often hard. Indeed, some within these communities will be more vulnerable than others. This includes the old and the young, women and those with disabilities. Efforts must be made to address specific vulnerabilities within communities.
- Recognising the importance of tenure to access utility services, including pragmatic solutions: The recognition of the importance of tenure as a way of accessing utility services has also contributed to the success of programmes. Tenure security is also critical to the quality of housing; fear of eviction means households cannot invest in better quality structures.
- Flexibility in programme design and implementation: The provision of a range of upgrading options through flexibility in programme design allows communities to tailor interventions according to need.
- Scaling up the interventions: Interventions should be conceived at least at city scale and seek to trigger relevant spin-off programmes with a wider reach as appropriate.
- Effective implementation agencies: The success of the programmes also depends on having a nodal agency with a clear mandate.
- Wider enabling factors: Programmes are more likely to be successful when there is strong commitment from the municipality. This can be driven, in part, by pressure from below. The availability of finance is another enabling factor – this can be made available through loans from donors or multilateral banks or a mixture of the latter and own resources.

Addressing the causes and consequences of air pollution can be factored into informal settlements upgrading process. In existing settlements, the quality of the environment could be evaluated, and steps taken to address ambient sources of pollution.

Governments should support efforts to improve ambient air quality particularly in areas where vulnerable groups may spend significant periods of time. Policy interventions have been identified by a variety of organisation. These include:

- adopt policy measures, economic incentives and strengthened enforcement to reduce car use and traffic speeds;
- invest in street infrastructure such as wide and well maintained pavements and cycling facilities to support healthy alternatives to driving;
- support the development of dense, walkable and mixed-use communities through effective local government planning capacity and decision making;

- support those engaged in street-based livelihoods activities by improving street safety through reduced traffic flow and speeds and consulting with those impacted by planning and development decisions;
- provide well-designed and well-maintained green and public spaces that encourage physical activity, social interaction and counteract social isolation;
- increase public transport provision that is adequate, accessible, affordable, safe and accountable, particularly for older people and women.

Government should encourage greater cooperation among agencies. Oversight and enforcement at the national, regional, and local levels is needed to ensure better indoor and outdoor environments. Regional and local actors interested in creating healthier societies can benefit from the application of scientific knowledge, technical expertise and environmental data. Government environmental agencies should cooperate closely with other departments in contexts of rapid urbanisation and population growth to better manage city development. Institutional fragmentation – overlapping mandates, weak integration and coordination. The World Bank (2015) asserts that at both national and city level agencies are directly involved in different aspects of land and urban environment management and their regulatory scope and responsibilities overlap. As it stands, these overlapping mandates, unclear lines of reporting create ambiguity in terms of accountability and complicate the processes for planning, implementation, monitoring and enforcement of the urban environment. While it may not be necessary to eliminate overlapping functions, there needs to be clear understanding of the roles and responsibilities of each, whether there is or needs to have a reporting structure or relationship between agencies/departments. In addition, better coordination and streamlining of the processes and reinforcing the complementarity of roles would lead to better ultimate results.

Governments at local and national levels should also provide support to households who are often at the forefront of initiatives to address air pollution. Households in this study, for example, highlighted a range of efforts they already support to improve living environment. These include improved waste disposal and community cleaning initiatives. Government could incentivise such community based responses to air quality and support those that demonstrate most impact.

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