Air Quality Briefing Note:

CONTEXT

- Uganda is urbanising rapidly, the population of Kampala is estimated to have grown by 167% between 2000 and 2020. The population of Kampala was 1,233,000 in 2000, and will reach 3,298,000 by 2020 according to UNDESA.
- Urbanisation is occurring at the expense of outdoor air quality.
- It is difficult to ascertain whether indoor air quality is changing, but for households using biomass burning, air pollution exposure is very high.
- Kampala has an extensive and expanding 'low-cost' air quality monitoring network which provides spatial data, but lacks regulatory grade equipment necessary to record long term data.
- That data which is available highlights that air pollution in the city consistently exceeds World Health Organisation guideline limits for Particulate Matter ($PM_{2.5}$) $\mu g/m^3$ 24-hour mean.
- Monitored $PM_{2.5}$ data indicates that current air quality in Kampala is typically at levels considered *'unhealthy for sensitive groups'* to *'unhealthy'* according to the United States Environment Protection Agencies Air Quality Index (AQI).
- Analysis of the health effects of air pollution in Kampala is hindered by the lack of available and appropriate medical data.
- Analysis of visibility data suggests that air quality has been declining since the 1970s, with average air quality now approximately 2.7x worse than in the 1970s.
- Anthropogenic emission sources in Kampala include those from vehicles, open burning of waste, indoor sources and industrial emissions.
- Government at both national and city levels are taking actions to develop Air Quality Regulations, reflective of an awareness of poor air quality in the country's cities.
- At the national level, drives to address air quality issues are limited and rhetorical. No cohesive or cross-sectoral plan to develop Air Quality Regulation for the country have been developed.
- At the city level, the Kampala Capital City Authority are developing an Air Quality Information Management System to inform the development of an Air Quality Management plan. The efforts of city government are commendable, developing an air quality monitoring and management framework as well as enhancing the technical capacity of the authority in air quality monitoring.
- Air pollution is a growing concern for city officials and the public alike, there are good prospects for education programs to encourage action against air pollution.

Kampala (Uganda)

November 2019

Air quality monitoring

Efforts to assess air quality in Kampala are facilitated by the cities extensive air quality monitoring network, however, the city lacks long-term data required to ascertain changes in air pollution both temporally and spatially. The Greater Kampala Area has over fifteen active monitoring sites (**http://aqicn.org/**) with plans to establish a wider network of 25 outdoor sensors (operated by KCCA) currently in development. That data which is available suggests that air pollution in the city consistently exceeds World Health Organisation guideline limits for Particulate Matter ($PM_{2.5}$) µg/m^3 24-hour mean[1]. Archived $PM_{2.5}$ data collected from the US Embassy indicates that air quality in Kampala is typically at levels considered *'unhealthy for sensitive groups'* to *'unhealthy'* (Figure 1) according to the United States Environment Protection Agencies AQI. (***Figure 1***). The ASAP-East Africa team have supplemented available long term air quality monitoring with spot measurement campaigns at selected outdoor (Uganda National Road Authority Headquarters) and indoor (household) locations and mobile monitoring on motorcycle taxis (Boda Boda). Alongside this, analysis of visibility data has been undertaken to fill historical data gaps and suggests that air quality levels are poor and declining (***Figures 2a and b***).

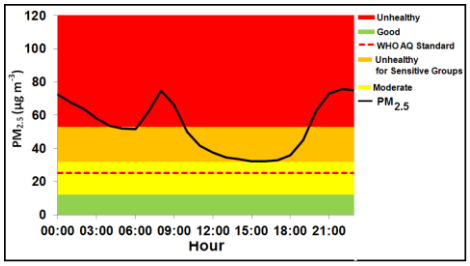

Figure 1 *Hourly $PM_{2.5}$ concentration at WHO air quality standard, where different colour backgrounds show the EPA air*

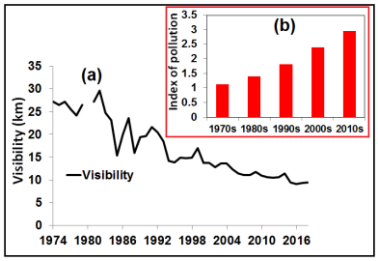

Figure 2 a) *Annual visibility trends and* ***b)*** *index of pollution level at Kampala derived from 45 years of hourly visibility data (1974-2018). The air pollution index is referenced to the levels observed in the 1970s.*

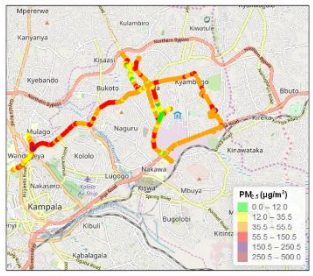

Figure 3 *Boda air quality monitoring study linking pollution data with GPS*

Low cost particle sensors: ASAP are simultaneously monitoring $PM_{2.5}$ and PM_{10} at multiple sites in Kampala; urban background (Business Studies building, Kampala campus of Ndejje University), urban roadside (Uganda National Road Authority Headquarters) and rural background (Engineering Building at Ndejje University, Luweero campus). Comparison of sites has facilitated an understanding of PM variation between urban background, urban roadside and rural areas.

Visibility and satellite data: Visibility has been routinely recorded at airports worldwide and allows for analysis of past patterns of PM air pollution. ASAP researchers have collated hourly visibility data for the period 1974-2018

[1] $PM_{2.5}$ and PM_{10} are particulate matter with diameters less than 2.5 and 10 microns, respectively. The World Health Organization (WHO) recommends that $PM_{2.5}$ and PM_{10} daily mass concentrations do not exceed 25 and 50 µg/m^3, respectively.

alongside meteorological factors (relative humidity, temperature and wind) at Kampala Entebbe International Airport to investigate long term historical air quality trends. A significant loss (0.45km year^{-1}) in visibility was observed in Kampala between 1974 and 2018 (***Figure 2a***). Findings suggest that air pollution levels have increased by 162% between the 1970s and 2010 (***Figure 2b***).

Household and other additional studies: Household studies and spot measurement campaigns have been implemented across Kampala to explore spatial and temporal variation of air quality in the micro-environments where people spend significant periods of time. Household monitoring highlights that indoor air pollution is an issue of concern with a large proportion of households reliant on a fuel mix that includes charcoal and firewood. Measurements highlight that air quality during cooking in many households reaches at an alarming level. Average levels of air quality monitored across households was 205 µg/m^3 24-hour mean (*very unhealthy levels*). Mobile air quality monitoring on-board Boda indicates that certain occupations, particularly transport providers, spend significant periods of time (up to 25% of journey times) in locations where air quality is at a level considered '*unhealthy*' (***Figure 3***).

Air quality modelling

The project team have also investigated air pollution using a numerical modelling approach able to reproduce the main meteorological patterns, anthropogenic emissions related to road transport and the chemical and transport processes acting in the low troposphere (***Figure 4***). Efforts have focused on the following objectives:

- Analysis of the impact of anthropogenic road transport emissions on Kampala air quality.
- Simulation of the main regional and local meteorological processes and air pollutants dispersion patterns for Uganda and Kampala.
- Creation of scenarios with reduced emissions centred on the improvement of the urban road network. Scenarios will be tested in terms of emission reduction and increase of Kampala air quality.

Two modelling systems have been adopted for this purpose. The Highway Development and Management version 4 (HDM-4) reproduces the ground state conditions of a road network. The Meteorological and chemical dispersion patterns are simulated by a modelling system that comprises the Weather and Research for Forecast model coupled with the chemistry-transport model CHIMERE.

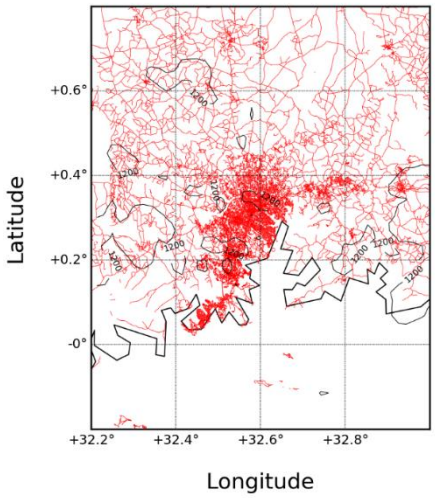

Figure 4 *Geographical domain of the City of Kampala obtained from the WRF's pre-processor WPS at a spatial resolution of 2x2 km. In red the representation of the local road network provided by OpenStreetMap open source data.*

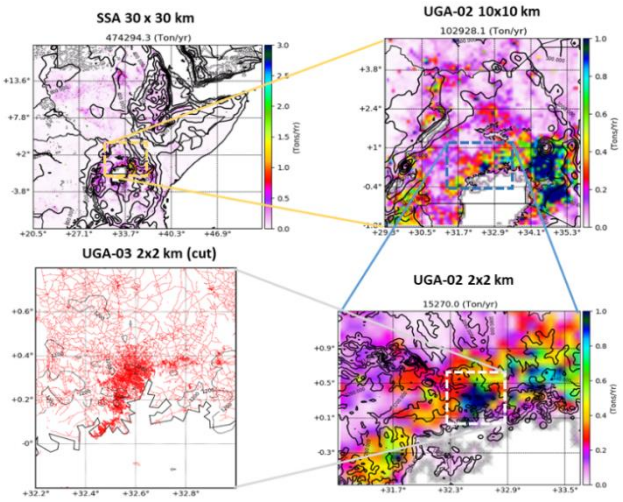

Figure 5 *Geographical domains at different resolutions obtained from WRF's pre-processor WPS and used for meteorological and chemistry simulations. Spatial distribution of PM_{10} emissions from road transport sector from the merged emission inventory HTAP-DICE: On top left the coarse domain for East Africa at 30x30km (SSA), on top right the first nested domain at 10x10km (UGA-02), on bottom right the second nested domain at 2x2km UGA-03), finally, on bottom left a portion of the UGA-03 domain at 2x2km centred on the city of Kampala with the relative road network (in red).*

In year one, ASAP focused on identification, recovery and treatment of input data necessary to run models. The quantitative analysis of the individual emission inventories has highlighted that the source apportionment of the emissions is dominated by the wood burning emissions for aerosols and by traffic emissions for gases. However, the lack of quantitative and qualitative data regarding vehicle abundance, traffic distribution highlights the need for a more systematic study of air pollution in Uganda.

The final stage of analysis will focus on the creation of a new input data set usable by both modelling platforms to reproduce the current levels of anthropogenic emissions. A new emission inventory has been created for project purposes. Emissions rates obtained will be updated by an interpolation of the emission rates over the population density for the years 2015, 2017 and 2020 from the Socioeconomic Data and Application Centre (SEDAC) of the Columbia University and NASA (**http://sedac.ciesin.columbia.edu/**). The final product will allow the creation of different scenarios according to HDM-4 projections for road transport emissions.

The road network of Kampala will be extrapolated from the road sections identified in this first phase and the model will be calibrated to reproduce the relative annual emission quantities. Regional and local simulations will be carried out and validated against observations derived from field measures. Finally, different scenarios for improvement of the urban road network and policies aimed at reducing emissions will be simulated and assessed in terms of improving urban air quality.

Air quality management

Government in Uganda at both national and city levels are taking actions to develop Air Quality Regulations, reflective of an awareness of poor air quality in the country's cities. However, actions taken at national level, to date, will fail to address air quality issues sufficiently. At the National level, drives to address air quality issues are limited and rhetorical. No cohesive or cross-sectoral plan to develop Air Quality Regulations for the country exists. It is evident that the recognition accorded to poor air quality management in the country is more of a political discussion

than any indicative of any concerted political action. This is not to say that government does not have plans to address air quality in the country, but rather that air quality management is not a priority. The efforts of technical officers to ensure the development of evidence based air quality management have been undermined by a lack of political will. Similarly, international development partners' support lacks sustainability or continuity. An example of this is the inability to pass the National Environmental Act Bill, 2017 into law. The stalling of environmental policy is common in Uganda, despite claims that the country has good policies.

At the city level, the Kampala Capital City Authority (KCCA) is developing an Air Quality Information Management System to inform the development of an Air Quality Management plan for the city. The efforts of the city government are commendable as they are currently taking holistic actions to develop an air quality monitoring and management framework as well as enhancing the technical capacity of the authority to monitor air quality. The Kampala Air Quality Management Project is one component of Kampala Climate Change Action Plan supported by the European Union. Through this international assistance, the authority has developed an action plan, which should soon become operational. The efforts of the city authority highlights the significance of local government in taking local action to address urban air pollution. Among current actions to improve air quality in Kampala, the authority are installing 25 air quality monitoring stations with 5 stations in each Division of Kampala. This will provide real time air quality information. The city government are also promoting the development of alternative sustainable transport systems.

Both national and city governments are taking actions, driven by city growth and deteriorating transport infrastructure. However, more needs to be done to improve the state of urban infrastructure in the city to complement significant ongoing investment in technical skills and capacity building for air quality management. Proactive interventions such as improved and cleaner public transport could make a significant difference in a city that currently lacks sustainable alternatives to polluting vehicles. In addition, the recognition by the national government of the poor state of air quality needs political action rather than politicising issues that affect citizens. Whist the actions of city government may develop an effective air quality action plan, the national government exerts a significant influence over the implementation of control measures that are also central to the promotion of good air quality in the city. In Uganda, significant efforts are needed to address policy silos and institutional disconnects that political disputes exacerbate.

Disclaimer Statement

This material has been funded by UK aid from the UK government; however the views expressed do not necessarily reflect the UK government's official policies.

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