Air Quality Briefing Note: Nairobi (Kenya)

November 2019

CONTEXT

- Kenya is urbanising rapidly, the population of Nairobi is estimated to have grown by 114% between 2000 and 2020. The population of Nairobi was 2,214,000 in 2000, and will reach 4,735,000 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.
- Nairobi has a limited air quality monitoring network and lacks long-term data required to ascertain variations of air quality temporally and spatially.
- 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 air quality in Nairobi 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 visibility data suggests that air quality has been declining since the 1970s, with average air quality now approximately 2.5x worse than in the 1970s.
- Anthropogenic emission sources in Nairobi include those from vehicles, open burning of waste, indoor sources and industrial emissions.
- The national government of Kenya developed Air Quality Regulations for the country in 2014, however, policy implementation has been limited and currently fails to address air pollution issues.
- Currently, the focus of action for air quality management has been driven by demands for information provision and capacity building with little to no attention paid to the socio-economic factors that can motivate people to change environmental behaviours.
- The role of national government in infrastructure provision poses questions as to how county and national government will work together to achieve the goal of developing clean and affordable urban infrastructure.

Air quality monitoring

Efforts to assess air quality in Nairobi are challenged by the cities limited air quality monitoring network and lack of long-term data required to ascertain variations in air pollution both temporally and spatially. The city has one active monitoring site (**http://aqicn.org/**) located at Nairobi Alliance Girls High School with plans to establish a wider network 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]. $PM_{2.5}$ data collected by ASAP-East Africa indicates that air quality in Nairobi is typically at levels considered *'unhealthy for sensitive groups'* to '*unhealthy'* (***Figure 1***) according to the United States Environment Protection Agencies Air Quality Index. The ASAP-East Africa team have supplemented available long term air quality monitoring with spot measurement campaigns at selected sites including outdoor (Moi Avenue and Dandora) and indoor (school and household) locations. Alongside this, analysis of visibility data has been undertaken to fill historical existing data gaps and suggests that air quality levels are poor and declining within the city (***Figures 2a and b***).

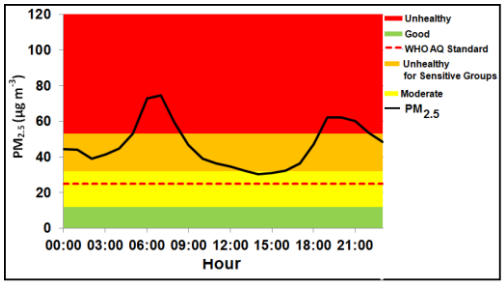

Figure 1 *Hourly averaged $PM_{2.5}$ concentrations in Nairobi at WHO air quality standard, derived from two month (Jan-Feb 2017) data. Here, different colour backgrounds show the EPA air quality index for health.*

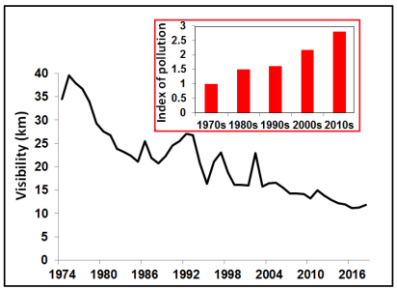

Figure 2 a) *Annual visibility trends and* ***b)*** *index of pollution level at Nairobi derived from 45 years of hourly visibility data (1974-2018). The air pollution index is referenced to the levels observed in the 1970s.*

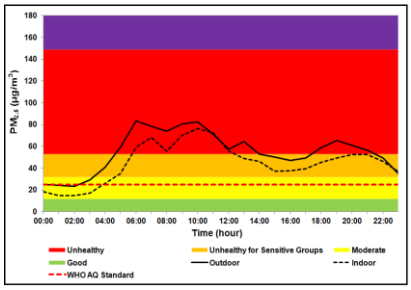

Figure 3 *Hourly averaged $PM_{2.5}$ concentrations Moi avenue primary school (July / August 2018) Indoor and Outdoor*

Low cost particle sensors: ASAP are simultaneously monitoring $PM_{2.5}$ and PM_{10} at multiple sites in Nairobi; urban background (American Wing building, University of Nairobi), urban roadside (Nairobi's Central Business District) and rural background (outskirts of Nanyuki town). 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-East Africa researchers have collated hourly visibility data for the period 1974-2018 alongside meteorological factors (relative humidity, temperature and wind) at Jomo Kenyatta International Airport to investigate long term historical air quality trends. A clear trend of decreasing annual visibility

[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.**

(0.52 km year^{-1}) was observed in Nairobi between 1974 and 2018 (***Figure 2a***). Findings suggest that air pollution levels have increased by 182% between the 1970s and 2010 (***Figure 2b***).

Household and other additional studies: Household studies and spot measurement campaigns have been implemented across Nairobi to explore spatial and temporal variation of air quality in the micro-environments where people spend significant periods of time. A study of Moi Avenue Primary School, located in Nairobi's Central Business District, highlighted that school air quality was an issue of concern (***Figure 3***). Classroom PM concentrations, in the $PM_{2.5}$ size range, were measured to be on average 43 ± 19 µg m^3 and peaked at 47 ± 14 µg m^3 during school days. Outdoor levels of $PM_{2.5}$ recorded larger concentrations, averaging 54 ± 22 and peaking at 61 ± 21, which is consistently at an unhealthy level. Studies in the vicinity of Dandora dump site recorded average levels of $PM_{2.5}$ to be 47.4 ± 9.5 µg/m^3 and peak concentration was 94.5 ± 32.6 µg/m^3 during the monitoring period highlighting the potential impact of solid waste management (or the lack of) on air pollution.

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 Nairobi air quality.
- Simulation of the main regional and local meteorological processes and air pollutants dispersion patterns for Kenya and Nairobi.
- 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 Nairobi 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.

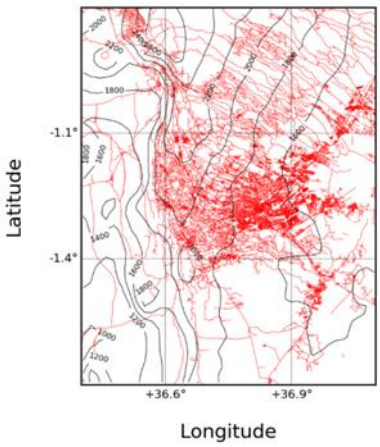

Figure 4 *Geographical domain of the City of Nairobi obtained from the WRF's pre-processor WPS at a spatial resolution of 2x2 km. In red the representation of the local road network provided by OpenStreetMap open source data.*

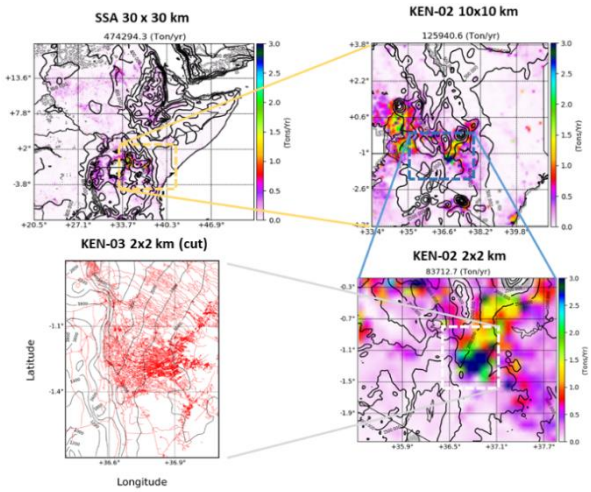

Figure 5 *Geographical domains at different resolutions obtained from WRF's pre-processor WPS and used for meteorological and chemistry simulations. Spatial distribution of PM_{10} emissions from road transport sector from the merged emission inventory HTAP-DICE: On top left the coarse domain for East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

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 Nairobi 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

The government of Kenya developed Air Quality Regulations for the country in 2014, however, policy implementation has been limited and currently fails to address air pollution issues. Urban air pollution remains concerning despite high levels of institutional awareness and action. The City County Government in partnership with UN Environment and other stakeholders have developed Nairobi City's first Air Quality Action Plan (2019-2023). The action plan identifies four broad overlapping actions to build the scientific evidence base for policy

interventions for air quality management; raising public awareness on the health and environmental impacts of air pollution; developing effective approaches for air quality management and building an effective implementation and enforcement programme for air quality legislation. Alongside this, a number of NGOs e.g. the Kenya Air Quality Network, and professionals have collectively taken actions to push government to tackle air pollution in Kenya holistically.

Despite these efforts, successful interventions will only emerge with the development of a holistic approach cognisant of the socio-economic and cultural context of the country. Currently, the focus of action for air quality management has been driven by demands for information provision and capacity building with little to no attention to the socio-economic factors that can motivate people to change environmental behaviours. The development of an action plan shows the importance of bringing governance to the people but challenges are posed by the nature of political power in Kenya and the dominant role played by national government in the provision of urban infrastructure.

The state of air quality management in Nairobi is indicative of the inconsistencies in policy and practice. The development of air quality regulations took a number of years before being approved, yet after its emergence it became a political document for referencing purposes; this may set a negative precedence because actions may be driven by political expediency, rather than addressing the underlying societal issues. The above highlights the likely challenge the city government may face in implementing the action plan. The role of national government in infrastructure provision also raises a questions as to how county and national governments will work together to achieve the goal of developing clean and affordable urban infrastructure for the people.

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.