Air Quality Briefing Note: Addis Ababa (Ethiopia)

November 2019

CONTEXT

- Ethiopia is urbanising rapidly, the population of Addis Ababa is estimated to have grown by 102% between 2000 and 2020. The population of Addis was 2,377,000 in 2000, and will reach 4,794,000 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.
- Addis Ababa 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 ($PM_{2.5}$) μg/m^3 24-hour mean.
- Monitored $PM_{2.5}$ data indicates that air quality in Addis is typically at levels considered *'moderate'* to '*unhealthy for sensitive groups'* according to the United States Environment Protection Agencies Air Quality Index.
- Analysis of visibility data suggests that air quality has been declining since the 1970s, with average air quality now approximately 1.6x worse than in the 1970s.
- Anthropogenic emission sources in Addis Ababa include those from vehicles, open burning of waste, indoor sources and industrial emissions.
- Despite government commitment to develop air quality management plans for all major cities, these are insufficient to address urban air quality issues considering existing city infrastructure and broader policy implementation issues.
- Emissions control of the increasing number of vehicles in Addis is required. Presently, no significant policy actions to control importation of vehicles have been developed.
- Further to this, the national government exerts control over most policies related to transport and energy infrastructure in the city, undermining city based initiatives.

Air quality monitoring

Efforts to assess air quality in Addis Ababa 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 (**airnow.gov**) established in 2017 at the US Embassy 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]. Archived $PM_{2.5}$ data indicates that air quality in Addis is typically at levels considered *'moderate'* to '*unhealthy for sensitive groups'* (***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 (Addis Ababa National Bus Station) and indoor (household) locations and mobile monitoring (buses). Alongside this, analysis of visibility data has been undertaken to fill historical data gaps and suggests that air pollution levels are plateauing within the city see (***Figures 2a and b***).

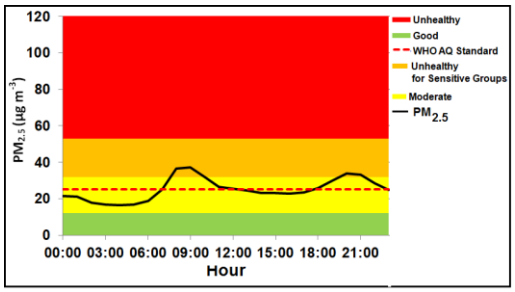

Figure 1 *Hourly $PM_{2.5}$ concentrations in Addis and WHO air quality standards, where different colour backgrounds show the EPA air quality index for health.*

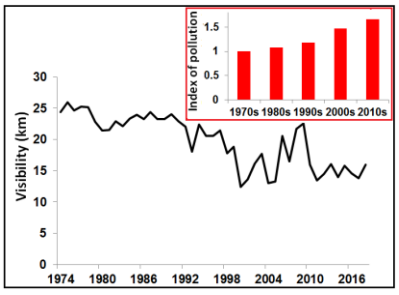

Figure 2 a) *Annual visibility trends and* ***b)*** *index of pollution level at Addis derived from 45 years of hourly visibility data (1974-2018). The air pollution index is referenced to the levels observed in the 1970s.*

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

Low cost particle sensors: ASAP simultaneously monitored $PM_{2.5}$ and PM_{10} at multiple sites in Addis Ababa; urban background (The Ethiopian Public Health Institute), urban roadside (Commercial Bank of Ethiopia, Teklehaimanot square) and rural background (Geferssa Mental Health Rehabilitation Centre in Geferssa). 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 alongside meteorological factors at Addis Bole International Airport to investigate long term air quality trends. A clear trend of decreasing annual visibility (0.26km year^{-1}) was observed in Addis between 1974 and 2018 (***Figure 2a***). Findings suggest that air pollution levels have increased by 76% between the 1970s and 2010 (***Figure 2b***).

[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.

Household and other additional studies: Household studies and spot measurement campaigns have been implemented across Addis Ababa to explore spatial and temporal variation of air quality in the micro-environments where people spend significant periods of time. Findings obtained from these studies have highlighted that air quality at bus stations and on buses is a matter of concern. At Addis Ababa Stadium bus station air quality ($PM_{2.5}$) was on average at a level considered *'unhealthy'* (113 ± 99 µg/m^3). Across buses studied, air quality levels for $PM_{2.5}$ ranged between $PM_{2.5}$ 49 ± 19 µg/m^3 and 105 ± 45 µg/m^3. According to the US EPA air quality index, this range entails air quality that is consistently '*unhealthy for sensitive groups'* or '*unhealthy'*. Household monitoring highlight that indoor air pollution is also an issue if concern with a large proportion of households reliant on a fuel mix that involves charcoal and firewood. Measurements illustrate that air quality during cooking in many households is at an alarming level.

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 Addis Ababa air quality.
- Simulation of the main regional and local meteorological processes and air pollutants dispersion patterns for Ethiopia and Addis Ababa.
- 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 Addis Ababa air quality.

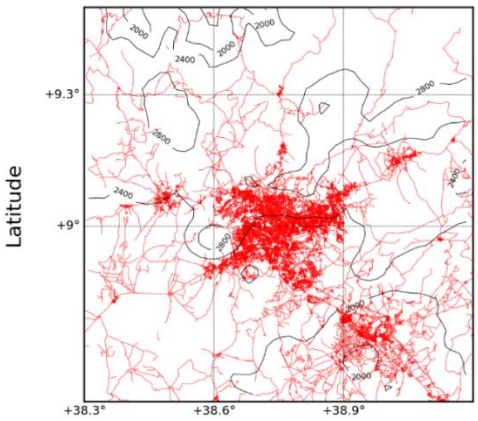

Figure 4 *Geographical domain of the City of Addis Ababa obtained from the WRF's pre-processor WPS at a spatial resolution of 2x2 km. In red the representation of the local road network provided by OpenStreetMap open source data.*

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.

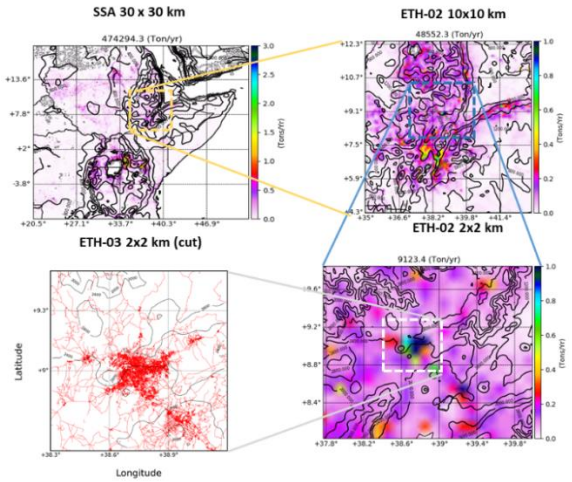

Figure 5 *Geographical domains at different resolutions obtained from WRF's pre-processor WPS and used for meteorological and chemistry simulations. Spatial distribution of PM_{10} emissions from road transport sector from the merged emission inventory HTAP-DICE: On top left the coarse domain for East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

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 will be 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 Addis Ababa 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

Whilst Addis Ababa city government currently lacks an Air Quality Management Plan, the government of Ethiopia has recognised the need for one. The Ministry of Environment, Forest and Climate Change (MEFCC) developed an Urban Air Quality Management guidance framework in 2016 with the support of the Centre for Society and Environment in India and is currently developing evidence based Air Quality Management Plans (AQMP) for all major cities. The MEFCC is also currently implementing a roadmap to develop an evidence based countrywide AQMP. The Addis Ababa city administration, with the support of US EPA, have developed a draft Air Quality

Management Plan for the city. Whilst this effort is commendable, it is doubtful the plan will be sufficient to address urban air quality issues considering existing city infrastructure and broader policy implementation issues.

Initiatives to improve air quality include the development of a light rail corridor for mass transit and an ongoing US$ 300 million Transport Systems Improvement Project (TRANSIP) funded through international development assistance which aims to design and implement an Intelligent Transport System Master Plan (2016-2023), an integrated program for traffic management and pedestrian safety. The plan calls for the development of bus rapid transport and extension of light rail transport in the city.

However, other initiatives essential for the improvement of air quality are currently missing. Emissions control of the increasing number of vehicles in the city is required. Presently, no significant policy actions to control importation of vehicles have been developed. Further to this, the national government exerts control over most policies related to transport and energy infrastructure in the city. Whilst the city administration are entitled to formulate city based environmental laws and AQMPs, the inability of regional government to manage transport and energy related issues responsible for air pollution may hinder the implementation of citywide regulations.

Whilst the first nation environmental policy emerged in the 1990s, progressive integration of the policy into all development practices has been limited and ineffective. Contradictions are evident in the prioritisation of investment in transport infrastructure versus management of urban air pollution. While the adoption of a light rail system is a welcome clean air development, inaction on vehicle emissions monitoring and control undermines potential gains. Summarily, whilst local action towards air quality management is commendable, maintaining momentum is required.

In terms of household air quality improvement, the national government is implementing a National Improved Cookstoves Program (2013-2030). The program is aligned with the Growth and Transformation Plan. Whilst, reports show that government has distributed 11 million improved cookstoves (2017), many are still dependent on biomass and unable to afford stoves.

Attempts to improve air quality in Addis Ababa are commendable, but there are grey areas that might make the process unsustainable. Political factors often make investment in air quality monitoring systems impossible. Further to this, the localisation of control measures to improve air quality in the city are also an issue.

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.