Highlights

CLEAN AIR CATALYST

Sources of Air Pollution: Addis Ababa

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EXECUTIVE SUMMARY

The city of Addis Ababa, Ethiopia's capital, is experiencing an accelerated rate of growth both economically and in population, as are many other African cities. Currently the city is estimated to have a population of slightly more than 5 million and a population density of 5,165 individuals/km^2. According to the United Nations Department of Economic and Social Affairs, the city's population has been growing at a steady annual rate of more than 4% in the last decade and this trend is projected to continue beyond 2030. This growth is accompanied by an increased demand for various services and amenities, such as housing, transport, water, waste management and energy, among others, which the city cannot provide without exacerbating its environmental challenges. This trend has been commonplace for most developing countries across the globe.

One environmental challenge that the city faces is deteriorating air quality, which the city authorities have identified as an issue of concern that requires agent action and have developed an air quality management plant. Reducing air pollution is challenging because it has varied sources and its very real impacts on human health and economy are difficult to quantify. Various opportunities exist for the city of Addis Ababa to learn from and also choose among many air pollution control policy choices that can alter the city's development trajectory. However, the choice of these policy choices requires a deeper understanding of the current and projected air pollution challenges, including awareness of sources, impacts, and current policy and regulatory
actions to control emissions.

Air Quality Data and Trends

The city has a limited number of air quality monitors, and it is hard to ascertain the temporal and spatial variation of air quality. However, using visibility data from the Addis Bole international airport as a proxy for air pollution, the general trend has been a constant decline of air quality since 1970. Currently the city has three functional reference-grade air quality monitoring stations for fine particulate matter ($PM_{2.5}$), two established by the U.S. embassy in 2016, and a third monitoring station that was established by the Eastern Africa GEOHealth Hub in 2015. Data from these stations indicate that air pollution in the city

consistently exceeds the guideline limits of the World Health Organization (WHO) for fine particulate matter of 25 μg/m^3 24-hour mean.

Lack of monitoring data for gas-phase pollutants limits source identification as the gases can serve as indicators of different pollution sources. For instance, various ratios of nitrogen oxides (NOx) to carbon monoxide (CO) represent different combustion sources, which can also help identify the contribution of vehicular emission for different fuel types. Lack of this data limits the ability of city air quality managers to develop targeted policy and regulatory actions that would improve air quality for the city. To the best of the authors' knowledge, no studies have been conducted to understand the general atmospheric chemistry of the city, which is critical in controlling secondary pollutants such as ground-level ozone (O_3) and secondary particulates.

Emissions Data and Air Quality Modeling

Locally explicit emission inventories at grid scales < 10 km are not available for Addis Ababa; consequently, global anthropogenic and biomass burning emission inventories must be employed for air quality modeling. Air quality modeling exercises in the city are limited and most have coarse spatial resolution and limited ground-level-based data to validate results. The recently published World Bank vehicular emissions reports are a valuable contribution. There is an urgent need for more ground-based air pollution data and the application of emission inventory downscaling techniques to better specify the distribution of local sources in Addis Ababa for improved model-based analyses.

Source Identification

Existing analyses indicate that the most important sources of air pollution in Addis Ababa are transport, use of biomass-based fuels for cooking and space heating, open burning of waste, and, to a lesser extent, industrial activities. However, there is uncertainty about the relative contribution of each of these sources, which limits the prioritization of policy and regulatory actions.

Health Impacts

Most air pollution monitoring efforts in the city have focused on $PM_{2.5}$, using both reference and low-cost monitors. It is widely recognized that $PM_{2.5}$ is the most important air pollutant: it drives more than 70% of the health impacts associated with air pollution. The $PM_{2.5}$ pollution in Addis Ababa is constantly above the WHO's annual mean guideline of 10 $\mu g/m^3$ and is estimated to cause 10,000 to 20,000 premature deaths per year, in the city. Although $PM_{2.5}$ exposure is estimated to cause approximately 70% of all the health impacts associated with air pollution, gas-phase pollutants such as O_3 and NO_2 also have considerable impacts on health and the ecosystem.

Gender and Equity Analysis

In Addis Ababa, air pollution affects women and children disproportionately because of cultural norms and occupational hazards. Most low-income households are in the city's informal settlements and use solid fuels to meet their household energy demands. These solid fuels are burned in inefficient cookstoves, translating to increased emissions and aggravated indoor air quality, especially in the many homes with poor ventilation. Some studies show pollution levels multiple times higher than the WHO standards. Because of the cultural norms that mean that women and children spend a lot of time around these cooking areas (as well as traditional coffee ceremonies), their exposure to these emissions is considerably higher compared with that of other groups. In addition, women make up a bigger proportion of food vendors in the city and most of the food vendors are located close to major transport hubs, where emissions from both the cooking and from the transport sector exacerbate the women's exposure. Even though women have a greater probability of exposure to unsafe air, gender-segregated air pollution impacts data are not available. Therefore, more work is needed on gendered and sex-differentiated impacts of exposure from known and suspected sources of air pollution, including open burning (including during Hidar Sitaten, a ceremony held each year to commemorate the Spanish Flu; the ceremony is usually accompanied with increased open burning), waste separation in landfills, wastewater discharges, transport, and industrial sites.

Intersection with Climate and Ecosystems

Air pollution and climate change are closely interrelated, because some air pollutants, such as black carbon (BC) and O_3, are also short-lived climate pollutants (SLCPs) and most air pollutants are emitted by the same sources as other greenhouse gases. Because of their short atmospheric lifetimes, reducing SLCPs can provide an opportunity for quick successes in addressing climate change. In addition, air pollution exacerbates climate change impacts and complicates adaptation efforts, as some air pollutants, such as O_3, are known to reduce agricultural productivity for crops such as soy, wheat, and maize. Major emission sources of greenhouse gases (GHGs), such as transport and energy generation from fossil fuels, are also major sources of air pollutants. Technologies that air pollution managers advocate using to reduce emissions in these sectors, which include increasing energy efficiency and increased use of renewable energy sources, could also bear major benefits in reducing greenhouse gases. Ethiopia's GHG emissions reduction commitments, as stipulated in the Nationally Determined Contribution, are anchored on the country's Climate-Resilient Green Economy strategy. Under this strategy the country aims at minimizing GHG emissions by focusing on four pillars: reducing agricultural emissions, protecting and expanding forests, expanding renewable electricity generation, and adopting energy-efficient technologies in transport, industry, and the built environment. These focus areas are expected to yield substantial benefits in improving the country's air quality.

Regulatory Landscape

Ethiopia adopted ambient air quality standards in 2003 for sulfur dioxide (SO_2), NO_2, CO, O_3, PM_{10}, $PM_{2.5}$ and lead, with the WHO guidelines as the reference point. Even though the national ambient air quality standards are in place, there is little evidence of their implementation and enforcement, and the need to establish an enforcement framework is urgent. Cognizant of this, the City of Addis Ababa authorities, with support from the U.S. Environmental Protection Agency and the United Nations Environment Programme (UNEP), developed the Addis Ababa Air Quality Management Plan (AQMP). The plan was launched in May 2021 and provides a roadmap for compliance with the national and city-

level ambient air quality standards by 2025. The plan will be implemented under the guidance of the Addis Ababa Environmental Protection and Green Development Commission. A steering committee chaired by the mayor of the city will oversee and support its implementation. Five priorities have been identified to achieve the objectives of the plan: air quality monitoring, emission inventory development, establishment of laboratory facilities, cooperation between national and city governments, and knowledge and skills.

The government has invested in the establishment of light rail and bus rapid transport systems that will improve mobility in the city. Despite these investments, the public transport sector is still underfunded, as pedestrian trips make up more than 54% of all journeys in the city. In addition, the potential contribution of public transport toward improved air quality will be superseded by increased emissions from private vehicles—a growing problem because of limited emissions control requirements and poor fuel quality. The government has also made major investments in supporting households to improve indoor air quality through access to cleaner fuels and improved cookstoves. However, despite these efforts, more than 90% of the country's population still have no access to clean cooking solutions.

Conclusions and Next Steps

Air pollution in Addis Ababa is a major challenge and its importance will only grow as the city continues to expand in population and economic output. As such, there is a need to increase efforts aimed at addressing this challenge. This is part of the CAC consortium objective, which aims to build on previous efforts and support the city authorities toward improving air quality in the city. The CAC consortium brings together a strong team composed of local scientific partners with expertise in atmospheric sciences, policy–science interactions, health effects, and urban development to work alongside a team of leading global partners who are experienced in supporting cities to become more livable and sustainable. With this partnership, the coalition aims to close major gaps toward improved air quality in the city. Some of these gaps include the generation of evidence for action, the development of a menu of priority actions, and gender, equity, and climate interactions with the aim of supporting the implementation of the recently launched AQMP.