Highlights

CLEAN AIR CATALYST

Sources of Air Pollution: Jakarta

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EXECUTIVE SUMMARY

Nine out of 10 people globally breathe air with levels of pollutants that exceed World Health Organization (WHO) air pollution guidelines, according to WHO data (WHO updated those guidelines in September 2021, and the statistics may change with those updates). Low- and middle-income nations bear the brunt of the burden, with the greatest toll on populations living in the WHO's Western Pacific and South-East Asia regions.

The capital city of Indonesia, Jakarta, has experienced rapid development. Its economy has doubled in size in the past decade and accounted for 16% of Indonesia's economy in 2020. In 2020, the city's population was estimated at 10.56 million with a population density of 14,464 people per km^2 and a growth rate of approximately 0.92%; that rate has held steady in the past 10 years. Air pollution management is a major challenge faced by city authorities. Air pollution is expected to worsen in the coming decades because of increasing economic activity and rapid urbanization.

Air Quality Monitoring

Air quality monitoring in Jakarta can be traced as back as 1998 for PM10 in six monitoring sites. Today, there are nine air quality reference monitoring stations in Jakarta, including five managed by the Environmental Agency of the Special Capital Region of (Daerah Khusus Ibukota; DKI) Jakarta, monitoring CO, O3, SO2,NO2, PM10, and PM2.5; two stations managed by the U.S. Embassy in Jakarta measuring PM2.5 and one managed by the Ministry of Environment and Forestry measures PM2.5, PM10, CO, O3, SO2 and NO2. The Meteorology, Climatology, and Geophysical Agency (BMKG) monitors PM2.5, PM10, SPM, O3, SO2 and NO2. In addition to the reference monitoring stations, several low-cost monitors have been deployed in the city to better understand air pollution and its main drivers.

The levels of air pollutants recorded over the past decade have exceeded Indonesia's air quality standards for nitrogen dioxide (NO2) and ozone (O3). Levels of PM2.5, which have been monitored since 2019, have exceeded Indonesia's daily and annual limits on that pollutant. Further, Jakarta's air pollution levels have consistently exceeded WHO limits for PM2.5, O3, NO2, and sulfur dioxide (SO2).

In general, air quality is worse during the dry season (December to May) compared with the rainy season (June to November), due to meteorological conditions such as high temperature, low humidity, and low wind speeds in the dry season. On the other hand, during rainfall season, wet deposition contributes to slightly lower some air pollutants concentration.

Although air quality monitoring infrastructure has been rapidly improving in the past two years, particularly for PM2.5, there are some areas of opportunity for existing and upcoming air quality monitoring resources are unevenly distributed within the city; the southern and central regions house more stations than the northern and eastern regions. Therefore, for a holistic understanding of the scope and extent of air quality pollutants in Jakarta, two key priorities emerge.

Emissions Inventories

Several emission inventories have been developed for the city, with varying methodology and activity data. From these emission inventories, the transport sector was identified as the greatest source of NOx, CO, and PM2.5. Energy generation and the manufacturing sectors are both the greatest emitters of SO2 and NOx, and the second most important sources of secondary PM2.5. However, this result might not represent the entire picture of the major sources of air pollutants in the city because other critical emission sources, such as residential and agricultural areas, were not included in the inventories. Though the current emissions inventories offer a great starting point, their quality and accuracy could be enhanced by filling three notable gaps: the lack of a consistent methodology, limited local activity data, and localized emission factors.

Source Identification

Previous source apportionment studies suggest that the major sources of air pollution in Jakarta include vehicular emissions, power generation from coal-fired power plants operated in areas surrounding Jakarta (power plants in Jakarta use only combined gas and heavy oil fuel). From the emissions inventories developed using data from 2015, transport and industrial combustion were found to contribute 46% and 43% of PM2.5 emissions, respectively. Industries also contributed more than two thirds of SO2 emissions; vehicular emissions contributed more than 90% and 57% of the CO and NOx emissions, respectively. Although these studies paint a good picture of Jakarta's emissions sources, more comprehensive studies that account for emissions from secondary processes are required to strengthen air quality managers' goals and outcomes.

Air Quality Modeling

Several air pollution models developed by research organizations corroborate the monitoring data that point to transportation and energy generation as the most important sources of air pollutants. However, these modeling exercises are short-lived and are not available to policymakers for use as tools in developing emissions mitigation actions. In addition, these exercises tend to focus mostly on pollution from transportation and rarely focus on the sources of air pollution that can alter emissions and significantly contribute to worsening air quality.

DLH developed an air quality forecasting system, the Air Pollution Management Information System or (Sistem Informasi Pengelolaan Pencemaran Udara; SIPPU), to aid in making decisions that could improve the city's air quality. This tool incorporated several aspects that drive emissions, including topography, atmospheric processing, local meteorological variables, and exposure risks. The system is not yet fully operational because of technical challenges and lack of local data. Additional support to develop and such tools and put them into operation will be required for robust air quality management in Jakarta.

Regulatory Landscape

The DLH, which has the mandate to control air pollution in Jakarta, has outlined key actions toward improving the city's air quality. These actions are outlined in the Grand Design for Jakarta Clean Air, which identifies seven key strategic actions for long-term air pollution control. These actions include banning vehicles used for public transport that are more than 10 years old or not in compliance with emissions standards; expanding the odd-even license plate policy for private cars wherein vehicles are restricted to circulate based on their license plate number, and increasing parking rates; tightening emissions test requirements for private vehicles and banning private vehicles more than 10 years old; encouraging the use of public transport and improving pedestrian facilities; tightening control of stationary sources of pollutants; reforestation of public facilities and infrastructure, and adoption of green building principles; and shifting to renewable energy sources and reducing dependence on fossil fuels.

Though these actions are commendable, they target only local emissions and fail to address sources located outside the city. A regional approach that emphasizes collaboration with neighboring local authorities is required to develop comprehensive emissions mitigation strategies. Future air pollution analyses should also include the interconnection with adjacent cities, such as Bogor, Depok, Tangerang, and Bekasi. Ozone and methane are the only short-lived climate pollutants (SLCPs) currently being monitored, resulting in a less comprehensive mapping of the pollution sources in the city. The DLH is estimating methane in the agricultural sector, livestock sector, and landfill activities as part of its inventory of greenhouse gases (GHGs) in Jakarta. Some studies on black carbon have been conducted; the transportation sector was identified as one of the largest contributors. Opportunities to include black carbon in the climate action plan and/or emissions inventories reported by DLH should be considered.

Gender, Equity, and Health

As there is a lack of local research on the health impacts of air pollution, Clean Air Catalyst will prioritize research on characterizing exposures of vulnerable populations to air pollution, particularly children, women, pregnant women, the elderly, low-income communities, and those who are malnourished or with pre-existing conditions. These data will make possible local health impact assessments disaggregated by age, sex, and potentially other vulnerable subpopulations. CAC expects to include this investigation to fill in data and analysis gaps in its work plan for the second year.

Potentially vulnerable locations and populations include residential neighborhoods situated in industrial areas and motorcycle taxi pit stops that are exposed to air pollution from land transportation. Commercial activities such as street food stalls and small-scale industries that involve vulnerable populations such as women laborers should be considered for further analysis. The burning of biomass (firewood) and kerosene for cooking should be considered; the use of these fuels tends to impact women and children disproportionately.

Analysis of Existing Data

The air quality measurements from the five DLH monitoring stations showed a decreasing trend for the five major pollutants (PM_{10}, O_3, NO_2, CO, and $PM_{2.5}$) in 2020 compared with 2019. This could be attributable to changes in commuting patterns and other restrictions put in place by the Government of Indonesia to curb the spread of COVID-19. Surprisingly, this was not observed for SO_2 concentration, which has continued to increase during this period. Coal-powered power plants and the use of fuel with a high sulfur content (500 ppm) are suspected sources of SO_2 emission. However, since there was limited vehicular traffic during this period, a substantial reduction in SO_2 should have been observed. This raises very interesting questions for air quality managers in the city and it also points to how little is known about air pollution sources in Jakarta.

The current limited understanding of air pollution drivers and critical control points in Jakarta is a major hindrance for policymakers and city air quality managers in their efforts to devise policy and regulatory actions to improve air quality. There is a need to fill these knowledge gaps, especially the gaps in source awareness. Filling these gaps would include (a) identifying and quantifying major sources of pollutants (especially $PM_{2.5}$); (b) determining the temporal and spatial variations of these pollutants, (c) developing and rolling out policy-relevant tools to help policymakers devise appropriate actions and interventions for pollution control, and (d) tracking and quantifying the impacts of interventions.

Toward this end, CAC aims to support Jakarta's air quality managers by undertaking additional air quality monitoring in the city with the aim of increasing source awareness. This will entail an in-depth understanding of transboundary contributions to local air pollution, major local emissions sources, and the background contribution to local air pollution, including setting a baseline for black carbon. To achieve this, multiple methods will be used, including stationary monitoring and mobile monitoring using Google Street View cars equipped with air quality monitors as part of Google's Project Air View efforts.

Preliminary analyses have been performed in the first year of CAC to identify high-risk areas where additional monitoring is required. These priority sites were identified by taking into consideration existing studies and factors such as population density, income levels with a focus on low-income households, proximity to major emission sources, proximity to public facilities such as schools and hospitals, existing air quality, and meteorological information. In these locations, CAC will focus on monitoring black carbon, which is a good indicator of combustion sources, and PM2.5, which is the main driver of air pollution-related health impacts.

In Jakarta, CAC will also support the implementation of DLH's SIPPU as an interactive dispersion model system. The SIPPU aims to identify sources of air pollution and conduct forecasting in Jakarta for greater public awareness of the city's air quality. Future plans for SIPPU include complementing this system with the most updated data from emissions inventories, particularly for the industrial and transportation sector, and adding specific knowledge from source attribution modeling.

Conclusions and Next Steps

Several studies in Jakarta have conducted air quality monitoring across a number of points in the city. However, the current state of research, data, and other information related to air quality in Jakarta is not adequate considering the scale and impact of emissions produced by the transportation and industrial sectors.

To support the availability of up-to-date data and the development of research on air quality, CAC plans to conduct additional air quality monitoring in Jakarta to establish transboundary pollution patterns, a black carbon baseline, and potential high-risk areas. In addition, considering the gendered impacts and burdens of air pollution, CAC will also focus its research on vulnerable populations, namely children, pregnant women, the elderly, low-income communities, and those who are malnourished or with pre-existing conditions.