Using the source awareness approach to support local solutions: Jakarta, Nairobi and Indore Case studies

UNECE Air Convention (LRTAP)
6th Expert Panel on Clean Air in Cities (EPCAC)

World Resources Institute | Ross Center

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Clean Air Catalyst

WORLD RESOURCES INSTITUTE

Environmental Defense Fund

COLUMBIA CLIMATE SCHOOL Clean Air Toolbox for Cities

CLIMATE & CLEAN AIR COALITION TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

Internews

openaq

MAP-AQ

Vital Strategies

From August 2020 to January 2025,the US Agency for International Development funded this work through the Clean Air Catalyst global partnership. The contents of this presentation do not necessarily reflect the views of the United States Government.

Clean Air Catalyst Focus Cities

INDORE,
INDIA

JAKARTA,
INDONESIA

NAIROBI,
KENYA

Clean Air Catalyst Program Strategy

Improve Source Awareness

Build a clear, commonly-held understanding of local contributors to air pollution among stakeholders and impacted communities

Co-Design Solutions

Identify data-driven strategies to address priority sources and the root causes of pollution

Build Strategic Coalitions

Form partnerships to advance actions that maximize health, climate and gender equity benefits

Clean Air Catalyst Improve Source Awareness

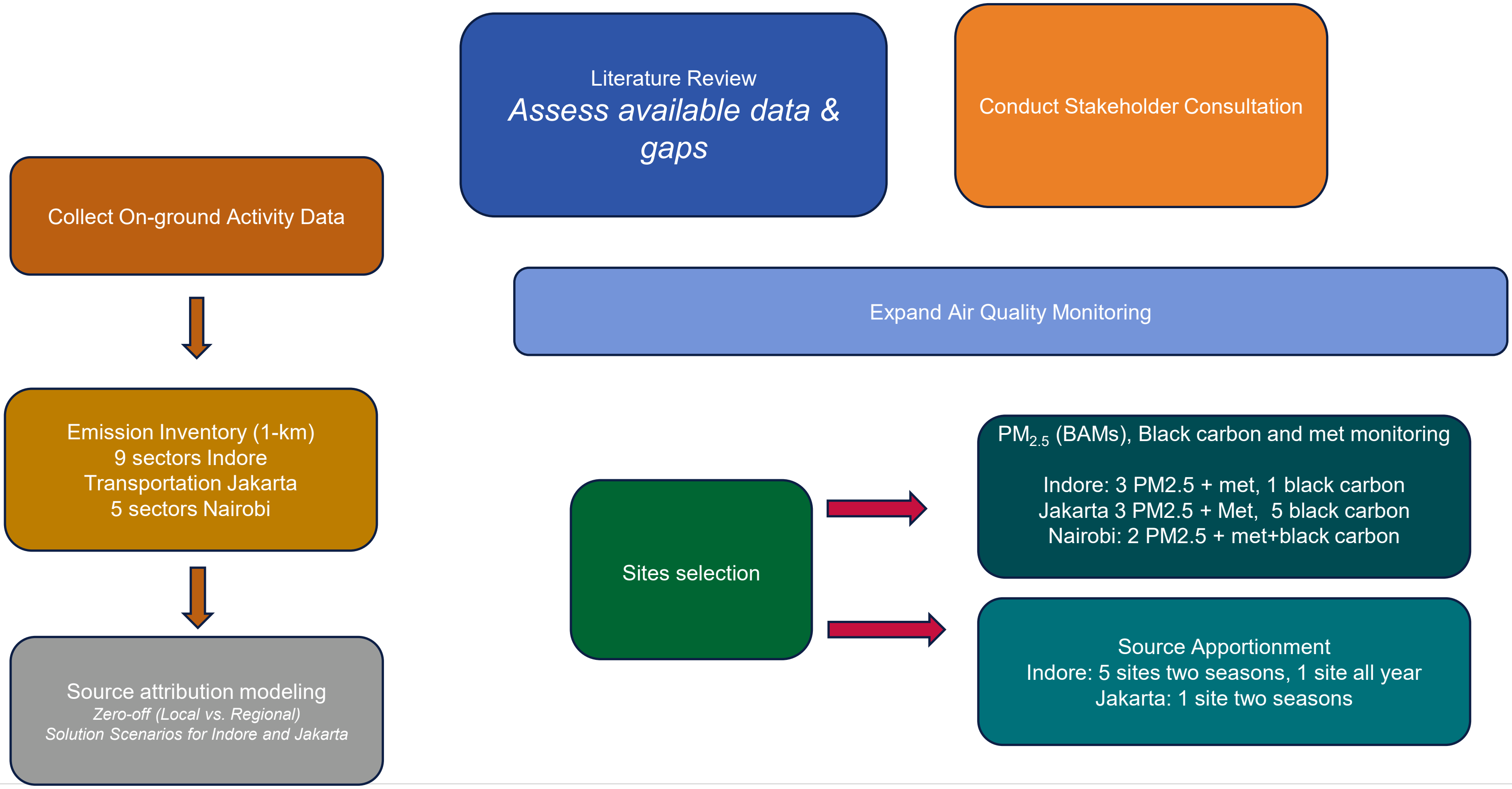
Build a shared understanding of the pollution sources that affect communities in each city

Strengthen scientific understanding –strategic monitoring and research reveal the sources of pollution that damage health and climate

Deepen community understanding – key stakeholders are able to identify major sources affecting their air pollution

Focus on targeted solutions – data and analysis are the basis for action on the right emission sources in the right places

CAC´s comprehensive approach for source awareness



Slide 6

1 Missing in the proceedings.
Beatriz Cardenas, 2025-09-19T13:19:12.795

Source awareness in Indore India

Air Pollution in Indore: Challenges

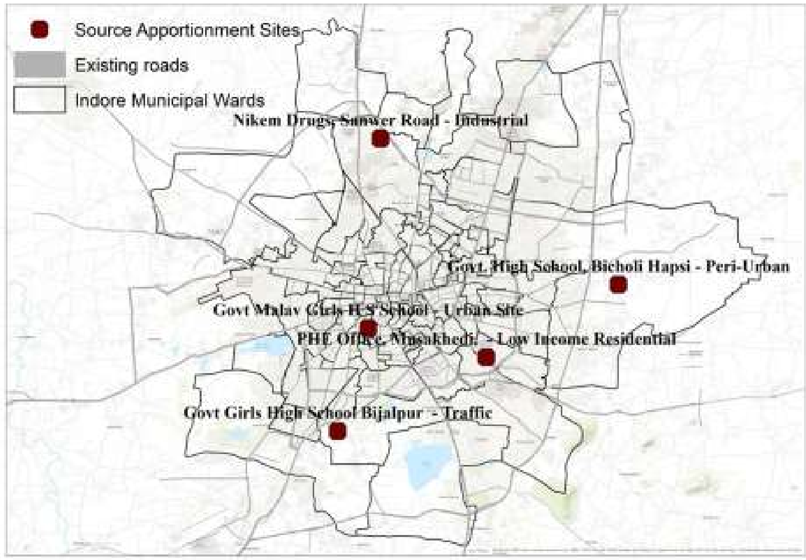
- **Indore is recognized as one of India's cleanest cities in terms of solid waste management. However**, Indore continued to face persistent air pollution challenges that were complex and inadequately understood
- **Prior to the Clean Air Catalyst (CAC) intervention**, the city lacked comprehensive, localized and source-specific data on emissions and exposures to guide evidence-based policy action
- **Limited insights were available into the dominant local emission sources**, their spatial variability, and the uneven burden borne by different population groups
- **Institutional responses were largely siloed and sectoral**, with minimal integration across air quality, public health, and gender and equity issues

Google map

Indore population is 3.2 million (Distric Indore, 2025)

Indore Clean Air Catalyst Monitoring

Urban Supersite

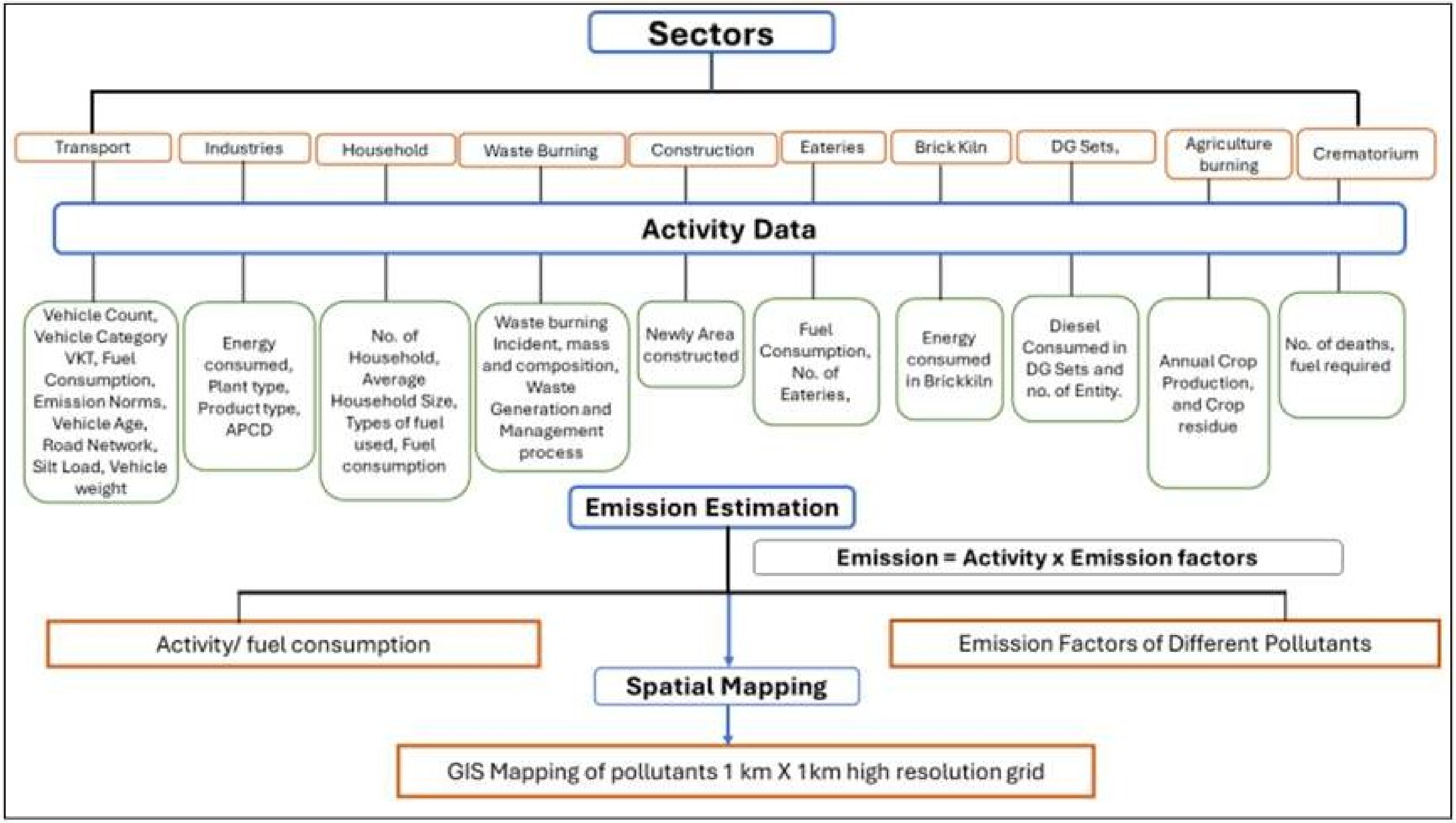


- PM2.5 (BAMs) and meteorological instruments at 3 sites
- CO and BC (5-wavelength) at supersite (urban)
- Exploratory low-cost sensor measurements
- Source apportionment sampling at 5 sites in two seasons and one year long at the supersite

Low-income Residential site

- 2.5 years of data PM2.5, 1.5 years of data available on OpenAQ

Indore´s Emission Inventory Approach



Source: https://www.cleanaircatalyst.org/where-we-work/indore-india

Indore´s Activity Survey of Various Sectors

S. No.	Sectors covered	Area covered	Samples Collected	Primary Survey	Secondary Data
1	Transport	Indore Municipal Corporation (IMC) Area and Surroundings	3456	TVC and OD & Questionnaire-based	RTO, Online secondhand cars sellers
2	Waste burning	IMC and Rural Area	207	Transect walk	
3	Eateries	IMC and Rural Area	469	Commercial establishment	Economic Survey of India
4	Brick Kilns	IMC and Rural Areas	86	Questionnaire-based	Google Earth
5	Industries	IMC area	44	Questionnaire-based	MPPCB, Annual Survey of Industries
6	Household Cooking, Agriculture Burning, and Construction Activities	Indore Rural Areas	526	Household Survey	NSSO, Census of India, Time Use Survey, Ministry of Agriculture, Development Plan, MoSPI

54 representative wards surveyed out of 85 wards, selected based on parameters such as population, land use, socio-economic status, etc.

Waste Burning

Transportation

Eateries

Industries

Brick Kilns

Source: https://www.cleanaircatalyst.org/where-we-work/indore-india

Source attribution modeling in Nairobi

WRF-Chem model was used to model baseline concentrations in Indore and surrounding regions at 3 km resolution (Domain d02) nested within a larger domain at 15 km resolution (d01)

Emissions from Indore were zeroed out to see impact of local emissions

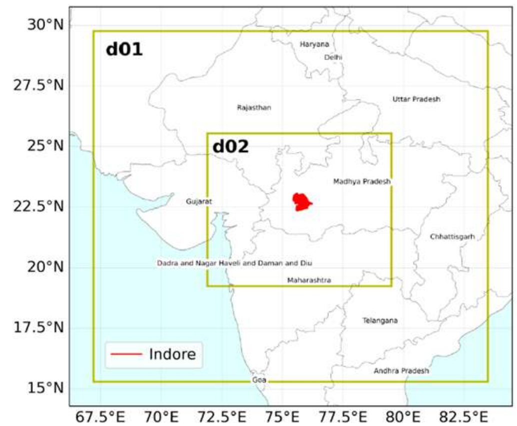
Zero-out run indicated that local PM2.5 emissions contributed about 37% in January (winter) to 45% in April (summer). For PM10, this varied from 46% (winter) to 52% (summer).

- About 54% to 63% of PM in Winter is influenced by emissions from outside the Indore city, while in summer, about 48 to 55% is from outside

For CO, about 33 to 36% of CO was contributed by local emissions.

For NOx, nearly 79 to 94% was contributed by local emissions

Scenarios were also modeled to estimate exposure changes if a set of solutions were implemented. Health impact assessments were done.



Source: MAPAQ report, 2024

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Indore key source awareness findings

Uncovering the Sources and Patterns of Pollution

Transport emissions, including resuspended dust, turns out to be the **largest contributing source sector** to both emissions and observed concentrations.

Following transport sector, industries and biomass combustion are found to be key contributors.

PM2.5 measurements indicate a **regional influence** which was also confirmed by modeling that pointed nearly half of the PM originating from outside the city.

Clear **seasonal trend** with post-monsoon and winter seasons showing the highest concentrations with distinct diurnal pattern, while the monsoon season showing the lowest concentration with relatively less pronounced diurnal variation

Learnings

Ensure Regulatory Relevance for Air Quality Monitoring Support: Cities monitoring efforts are primarily in adherence to the regulatory requirements and the generation of air quality index. Any effort aimed to building monitoring capacity of the cities will need to address this.

Capacity building through trainings strengthened local understanding: Extensive trainings conducted for government officials, civil society, health professionals, media, and academic institutions played a pivotal role in demystifying air pollution science and making it actionable.

Locally-generated Data Increased Understanding and Buy-in: The air monitoring infrastructure, source apportionment studies, and bottom-up emissions inventories enabled stakeholders to identify and act on key pollution sources such as transport and road dust. Locally generated data increased confidence and helped prioritize solutions.

Slide 13

1 Keytake aways on uncovering the sources of pollution should be added. We need to bring a summary of data gathered and knowledge generated in the summary

Beatriz Cardenas, 2025-09-19T13:30:55.202

Source Awareness in Jakarta, Indonesia

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Air Pollution in Jakarta: Challenges

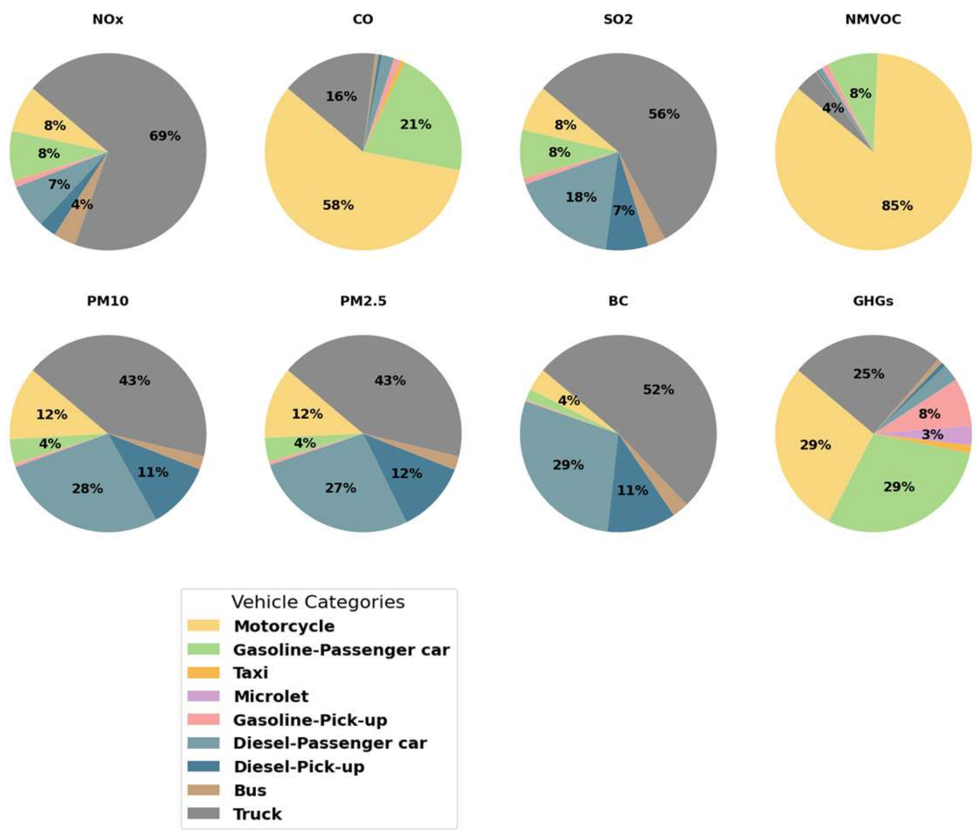
- **Jakarta ranked among the most polluted cities globally**. Exposure to PM2.5 contributes to thousands of premature deaths each year and economic losses equivalent to around 2.2% of the city's gross regional domestic product.

- Based on data from 2015, **transport and industrial activities were major emission sources**.

- **Pollution sources vary across locations and seasons**. Source contributions vary by time and location: transport emissions predominate on weekdays, while open burning and regional pollution become more significant during the dry season.

- **Jakarta lacked sufficient air quality monitoring coverage**. A Jakarta Environment Agency (DLH) study recommended at least 25 reference-grade monitors and 44 LCS for better spatial and temporal resolution in Jakarta. At the start of the CAC project, DLH operated 6 monitoring stations.

Emission Inventory for Jakarta's Transportation Sector



Transport EI in Jakarta

- Previous top down EI have identified the transport sector as one of the largest contributors to emissions in Jakarta
- CAC inventory covered nine vehicle categories.

Key Findings

- HDVs and diesel light-duty vehicles are the major contributors to NOx, PM10, PM2.5, SO2, and BC, with emissions steadily increasing due to rising fuel use and vehicle numbers.
- Motorcycles and gasoline light-duty vehicles are the main sources of CO and NMVOCs, with emissions consistently high due to low combustion efficiency.
- GHG emissions are significant across all vehicle types, especially from motorcycles and gasoline vehicles.

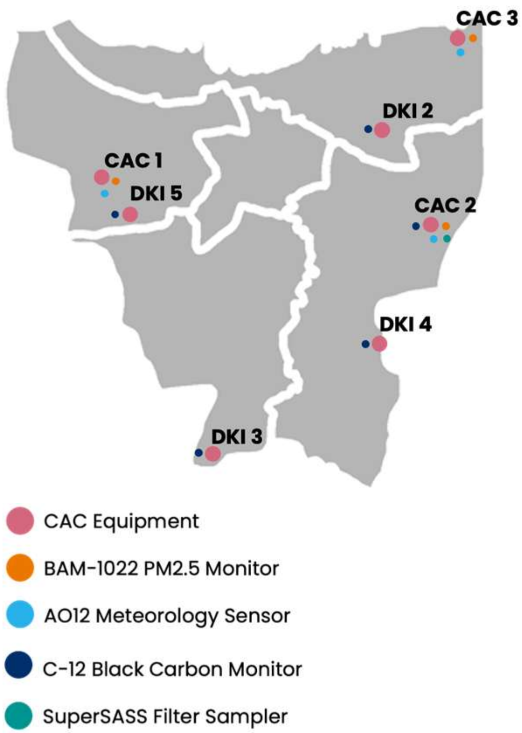
Why This Matters

- Helps identify priority vehicle groups for emission control.
- Informs targeted and effective transport policies.
- Highlights the urgency to shift toward cleaner fuels and technologies.

Sources: CAC Jakarta & ITB Emission Inventory in Jakarta Transport Sector (2025)

Expanding Jakarta's Air Quality Monitoring Network

Monitoring Sites and Instruments



Jakarta's size and population demand more comprehensive coverage and real-time data access.

To help address this, CAC installed three new continuous monitoring sites in 2023, bringing the total to 12 reference grade stations operating in Jakarta:

- **CAC1** (West Jakarta): residential area
- **CAC2** (East Jakarta): **near an industrial area** on the Bekasi border, **source apportionment site**
- **CAC3** (North Jakarta): coastal industrial zone previously unmonitored; **observes port emissions and sea salt influence**.

BC monitors were also added at four existing DLH stations to strengthen the monitoring.

Slide 17

BE1 Can we add text on how many total stations now? (nine) [@Satya Utama]
Beth Elliott, 2025-08-07T01:11:50.517

DD1 0 As of 2024 there are 12 reference grade monitoring stations including 3 from CAC
Danny Djarum, 2025-08-07T02:22:17.731

Jakartaa summary of source awareness findings

Uncovering the Sources of Pollution

- Heavy-duty vehicles (HDVs) and diesel-powered transport are the dominant source of on-road pollution, contributing disproportionately to key pollutants despite their relatively low numbers in the overall vehicle fleet.
- Our emission inventory shows that **trucks alone are responsible for 69% of NOx and 43% of PM2.5** emissions from the transport sector, making them a critical target for mitigation.
- Beyond transportation, source apportionment at our East Jakarta site identified **open waste burning** as a surprisingly large local pollution source (**14.5% of PM2.5**), highlighting a critical gap that may not be fully captured in broader, city-wide emission inventories.

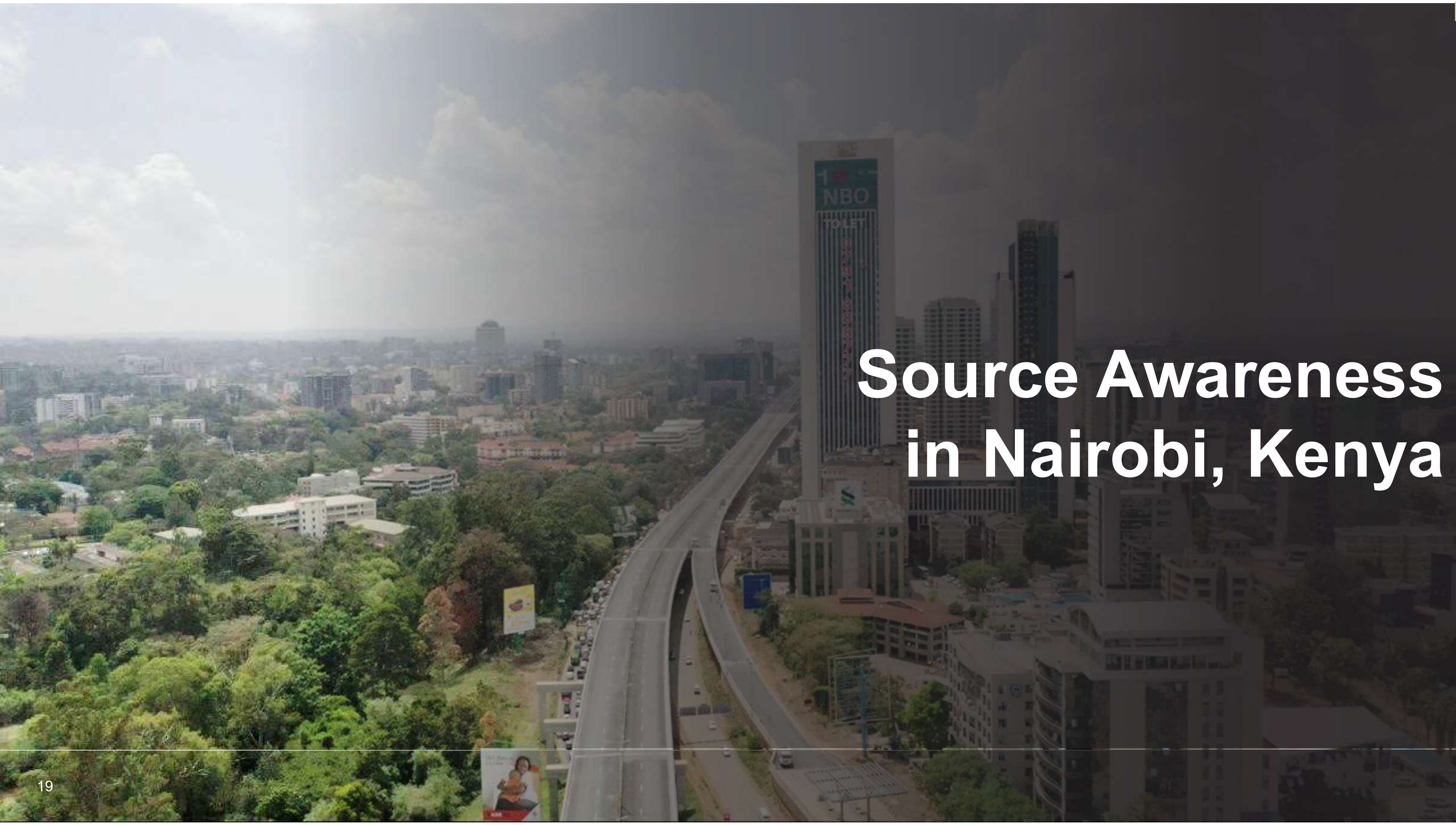
Characterizing Pollution Patterns Across the City

- Air pollution exhibits strong seasonal trends, with PM2.5 concentrations consistently higher during the dry season and **frequently exceeding 50 µg/m^3,** significantly higher than annual NAAQS standard of 15 µg/m^3.
- Our expanded monitoring network reveals distinct daily pollution peaks, often linked to morning and evening traffic, but also influenced by nighttime atmospheric conditions that trap pollutants.
- Pollution events have been traced to specific source regions, such as industrial zones to the east, port activities to the north, and major traffic corridors.

The Scientific Case for Targeted Action

- The strong scientific link between Black Carbon and NOx emissions provides a clear mandate for prioritizing the control of diesel vehicle emissions to achieve multiple air quality benefits simultaneously.
- Source apportionment: secondary **aerosols accounted for 16.6%** of PM2.5, underscoring the need to control precursor gases like SO2 and NOx.
- Source attribution modeling: Scenario with city-wide **implementation of Euro 4 standards alone could slash PM2.5 emissions by 75%** and SO2 by 79% by 2030.

Source Awareness in Nairobi, Kenya



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BE1 [@Ivy Murgor] is this the photo you wanted?
Beth Elliott, 2025-08-05T21:38:49.473

IM1 0 This one is fine
Ivy Murgor, 2025-08-06T11:49:16.799

Air Pollution in Nairobi: Challenges

- Prior to the launch of CAC in Nairobi, **city authorities had no continuous air quality monitoring networks.** Existing monitoring sites were run by third parties, **minimal access to the data.**
- **Limited research,** mostly derived from short-term studies, insufficiently captured air pollution impacts
- Important emission sources were identified as **vehicular emissions, industries, and open burning of waste,** but little was known about other sources.
- The City's Health Department found upper respiratory tract infections—strongly associated with air pollution—are the leading cause of morbidity and **consume nearly 30% of the county's health budget**

Monitoring Air Quality in Nairobi

Monitoring Sites

- Nairobi City's first-ever reference-grade monitors installed to enhance the city's air quality monitoring capacity and complement the existing low-cost sensor (LCS) network
- PM2.5, black carbon and weather station installed at each monitoring site.
- AirQo co-located LCS in each monitoring site
- Handover of equipment to NCCG in 2 years.
- NCCG has allocated a maintenance budget.
- Conducted training of county staff (10) on data and equipment maintenance

Reference Grade station set up in Mama Lucy Kibaki Hospital, Nairobi

Reference Grade station set up at Fire station - Tom Mboya Street

Sectors considered for emissions estimations in Nairobi

Transport Sector
On-road fuel combustion

Commercial Eateries
Energy use from fuel burning during food preparation and other associated activities

Waste Burning
Open burning of waste

Industries
Combustion of fuel, process and fugitive emissions

Households
Energy use from fuel burning during food preparation, heating and lighting as well as other associated sources

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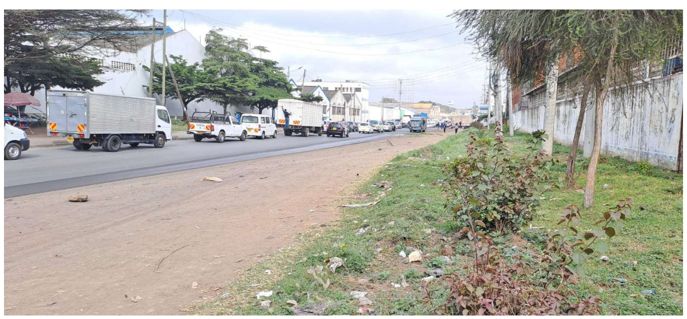
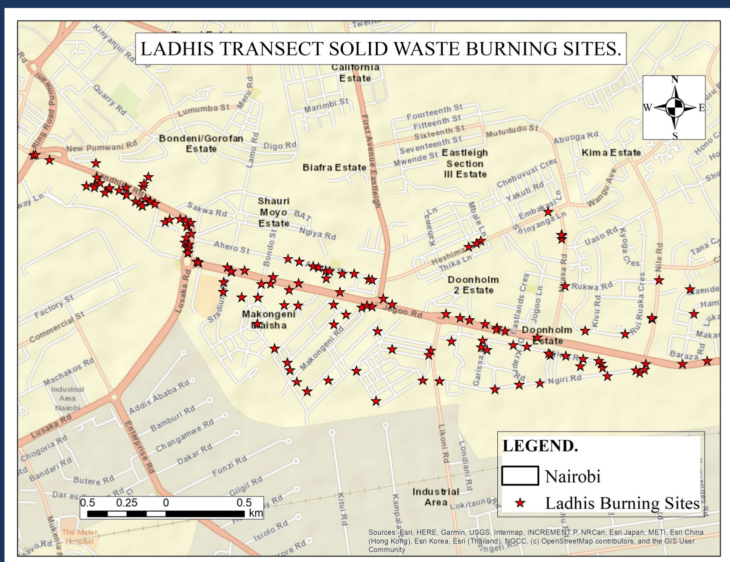
Transport Sector activity data collection in Nairobi



TVC exercise along Lunga Lunga road - Outbound

TVC along Mombasa road - Outbound

Transect walks in Nairobi to estimate activity data for Waste Burning



Nairobi Summary of source awareness findings

Policy / Government impacts

- First ever budget was allocated for AQ in the County
- Air quality policy, Law already developed, and draft regulations under development.
- Keen interest from health department on air quality.
- Hospital waste management a key focus on the county with draft policy under development (UNEP)
- More robust air quality data available to city managers and residents (CAF).
- Vehicular emission standards implementation framework under development.

The Scientific Case for Targeted Action

- Vehicular emissions influence on Nairobi AQ is significant, with waste and household energy use potentially being the other major contributors, more research is required to differentiate their relative contribution.
- Historically Nairobi AQ is potentially underestimated (18-24ug/m3), the CAC equipment will help validate this in a years time.
- The capacity of AQ managers at both city and national level is limited and a targeted /hands-on training is required.

Summary

- Source awareness approach was used in the three cities contributing to a better understanding and identification of the sources contributing to air pollution
  - While transport was confirmed as one of the major source of air pollutants, other sources were identified and their contribution recognized
- Based on the data and knowledge generated, several solutions were identified for different sectors
- Data and knowledge generated should help future plans as well as data to build indicators.

About CAC:

- CAC finalized in August 2025
- Local WRI teams continue engaging and supporting Indore, Jakarta and Nairobi as part of other projects
- Publications will be coming in the following months

CAC Science teams

Indore Science Team: Prakash , Vandana Tyagi, Ritesh Kumar, Sanjar Ali, Bhavay Sharma, Azra Khan, Nivedita Barman, Sreekanth Vakacherla,Shafa Sajjad, Shailendra Yadav, Ajay Nagpure
Other Indore Pilot Team Members: Kaushik Raj Hazarika, (Former CAC Project Manager), Megha Namdeo, Sudhir Gore, Saurabh Porwal, Dilip Wagela
Indore Science Partners: Prof. Harsha Kota, IIT Delhi; Prof. Ramya Sunder Raman, IISER Bhopal

Jakarta Science Team: Satya Budi Utama, Danny Djarum, Khalisha Qatrunnada , Hafidz Abdillah, Azka Ghaida, Fadhil Firdaus, Muhammad Shidiq, Fadhli Zakiy, Bellathea Hutauruk
Jakarta Science Partners: Prof. Dr. Puji Lestari (Professor at Bandung Institute of Technology-ITB)

Nairobi Science Team: George Mwaniki, Ivy Murgor, William Apondo Amos Mwangi, Christine Muthee
Nairobi Science Partner: Dr. M.J Gatari, Co-Principal Investigator

Global science team: Beatriz Cardenas, Ramon Alvarez, Dan Peters, Tammy Thompson, Ananya Roy, Alexandra Koek, Melanie Scruggs

Columbia team: Faye MacNeil, Beizhan Yan, Steven Chillrud, Dan Westervelt and Jackie Klopp

MAPAQ team: Rajesh Kumar, Suvarna Tikle, Andrea Orfanoz-Cheuquelaf, Idir Bouarar, Guy Brasseur

OpenAQ team: Chris Hager Baumer

New clean air standards for Europe: implications for cities

Project Objectives

- Better understand the potential implications of the new EU Air Quality Directive on attainment of clean air standards in urban areas
- Assess the existing haps and opportunity areas for the implementation of air quality measures in urban areas and the potential of multi-level governance measures to support implementation
- Country profiles on Spain, Italy, France, Bulgaria and Poland.

Map highlighting the 5 focus Member states

Initial draft findings

- Cities and regions have a big opportunity to improve living standards, quality of life, health of citizens – using the new standards of the AAQD to drive forward locally beneficial urban development policies
- Effective policy design with health and equity at the forefront is key for successful implementation.
- Wider EU policy framework need to coherently support national and local implementation of measures.

Project Partners

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For more information, please reach out to Steven Bland (Steven.bland@wri.org) and Chaandi Malhotra (Chaandi.Malhotra@wri.org)

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