Project report

Enhanced capabilities to adopt innovative technologies for city air pollution control in select countries of the Asia-Pacific

January 2022 to December 2023

Project funded by Korea ESCAP cooperation fund (KECF)

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APCTT
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A. BACKGROUND AND RELEVANCE OF THE PROJECT

Globally, air pollution is acknowledged as a prominent environmental health hazard. According to the latest data from the Global Burden of Disease (GBD) study, 6.7 million deaths in 2019 were attributed to air pollution, with the Asia-Pacific region contributing about 70% of these fatalities. Notably, lower, and middle-income countries accounted for 90% of air pollution-related deaths (Dey, 2023).

Airborne pollutants encompass particulate matter and gaseous elements, originating either directly from various sources (referred to as primary pollutants) or emerging in the atmosphere through chemical reactions (referred to as secondary pollutants). Predominant air pollutants in the Asia-Pacific regions include particulate matter with an aerodynamic diameter smaller than 10 μm (PM10) and 2.5 μm (PM2.5), sulphur dioxide (SO2), nitrogen oxides, ozone, carbon monoxide (CO), lead, and non-methane volatile organic compounds (NMVOCs).

Recent studies have established links between air pollution and various health outcomes, including child mortality, adverse birth outcomes, acute respiratory infection, child and women anaemia, child physical and cognitive developmental failure, diabetes-mellitus, cancer, and more (Dey, 2023).

Beyond its health impacts, air pollution also poses a significant transboundary environmental challenge. In efforts to safeguard human health by improving air quality, ESCAP member States are working to reduce air pollution through diverse measures, including technological interventions, policy initiatives, regulations, and incentives. Despite these efforts, challenges persist, such as limited capacity, resource constraints, insufficient public awareness, and access to effective and affordable technologies.

In response to the escalating challenge of air pollution in the Asia-Pacific region, the Asian and Pacific Centre for Transfer of Technology (APCTT), a Regional Institute of the United Nations Economic and Social Commission for the Asia and Pacific (UNESCAP) initiated a project titled: *Enhanced capabilities to adopt innovative technologies for city air pollution control in select countries of the Asia-Pacific*, supported by the Korea ESCAP Cooperation Fund. The project targeted policymakers, pollution control authorities/departments, city municipal authorities, and the private sector.

The project supported three ESCAP member States (Bangladesh, India, and Thailand) in strengthening policies and city-level action plans (in Dhaka, Gurugram, and Bangkok respectively) to facilitate the adoption of innovative technologies for air pollution control.

The project was executed from January 2022 to December 2023 in collaboration with key partners, including national focal points, academic institutions such as IIT-Delhi, Asian Institute of Technology, and Bangladesh University of Engineering and Technology, as well as environmental organizations like the North-East Asia Clean Air Partnership (NEACAP) and the South Asia Cooperative Environment Programme (SACEP).

B. KEY RESULTS, MAIN LEARNINGS AND CRITICAL ACTION POINTS EMERGING FROM THE PROJECT

This section summarizes the key results, key learnings and action points emerging from the project.

a. Results of the Project

The key results of the project were as follows:

Project Outcome: City officials and stakeholders in target countries strengthen city action plans for adoption of innovative technologies for air pollution control.

Output 1: Improved availability of technical knowledge regarding technologies, innovations and good practices, and better understanding of technology needs and gaps for air pollution control in the selected cities.

Output 2: Increased awareness and capacity of city officials and stakeholders to strengthen action plans for adoption of innovative technologies to control air pollution.

b. Main Learnings

1. **Need for Tailored City-Specific Action Plans:** Effective control necessitates city-specific plans encompassing local policies, airshed dynamics, and cost-benefit analysis.
2. **Importance of Data-Driven Insights:** Hybrid monitoring frameworks utilizing real-time data, satellite information, and AI are critical for comprehensive air pollution management and forecasting. Collaboration between research institutions and industry is key to driving innovation in data-driven air pollution technologies.
3. **Inclusive and Prioritised Adoption of Technology:** Promoting technologies with high PM2.5 reduction potential like Diesel Particulate Filters, Electric Vehicles, satellite detection, and remote sensing of vehicle emissions, alongside inclusive interventions, could ensure equitable access to cleaner air.
4. **Criticality of Regional Collaboration:** Knowledge sharing, technology transfer, and cross-border cooperation among member States are vital for collective progress. Follow-up activities with target cities, potential project expansion and scale-up, and robust knowledge-sharing platforms are crucial elements.
5. **Use a Multi-faceted, Multistakeholder approach:** Strong inter-agency collaboration, active community involvement, and robust regulation enforcement are key to successful action plan implementation. Integrating feedback mechanisms, economic instruments, and circular economy principles can further strengthen air pollution control strategies.
6. **Need to promote Green Infrastructure and Public Engagement:** Promoting green infrastructure, sustainable urban development practices, and cleaner technologies, especially in construction, plays a significant role in mitigation. Public awareness campaigns and community participation through real-time air quality monitoring and stakeholder engagement can ensure informed and engaged communities, vital for long-term success.

c. Potential Future Action Points Air Pollution Control in Asia Pacific

1. **Pilot Project Acceleration:** Prioritize and support targeted pilot projects for promising new technologies like satellite air quality monitoring and electric vehicle integration, ensuring seamless scaling up and optimization within city plans.
2. **Develop Actionable Roadmaps:** Develop "roadmaps to action" for individual cities, translating overarching plans into actionable steps with defined milestones and responsible agencies. Facilitate the establishment of dedicated task forces at the city level to champion air pollution control efforts and foster cross-departmental collaboration.
3. **Strengthen Open-Source Data Platforms for Air Quality:** Promote the development and maintenance of an open-source data platform for air quality data in the region, allowing researchers and policymakers to leverage shared knowledge and identify regional trends.
4. **Build technologies and capacities in AI-powered forecasting:** Support the development and deployment of AI-powered air pollution forecasting models tailored to specific cityscapes and weather patterns for proactive mitigation strategies.
5. **Support Regional Innovation Hubs:** Establish regional innovation hubs focused on air pollution technology, connecting academia, industry, and government to accelerate research and development.
6. **Support Inclusive Technology Adoption:** Develop financial and policy incentives to encourage the adoption of clean technologies for low-income communities and small businesses. Invest in capacity-building programs and skills training for local communities to ensure equitable participation in the maintenance and operation of clean technologies.

7. **Build a Regional Knowledge-Sharing Platform:** Establish a robust regional knowledge-sharing platform for best practices and lessons learned in air pollution control, facilitating peer-to-peer learning and cross-border collaboration. Organize regular capacity-building workshops and training programs for government officials, technicians, and community leaders to build regional expertise.
8. **Sustainable Financing Models:** Support cities in developing and implementing sustainable financing models for long-term air quality management, ensuring financial viability beyond project timelines. Explore innovative financing mechanisms like green bonds and public-private partnerships to attract investment for air pollution control projects.
9. **Advocate for Green Infrastructure and Urban Transformation:** Advocate for the integration of green spaces, urban forests, and sustainable public transport networks into city planning strategies to promote natural air filtration and reduce reliance on private vehicles. Support the development and implementation of green building technologies and energy-efficient construction practices.
10. **Strengthen Public Awareness and Community Engagement:** Develop targeted public awareness campaigns tailored to different demographics and communication channels, utilizing real-time air quality data and storytelling techniques. Empower communities through citizen science initiatives and air quality monitoring networks, enabling active participation in data collection and environmental decision-making. Integrate air quality education into school curricula and community outreach programs, fostering environmental awareness and promoting responsible actions among future generations.

By prioritizing these critical action points and leveraging the valuable lessons learned from the project, APCTT can play a transformative role in advancing air pollution control initiatives across the Asia-Pacific region, paving the way for cleaner air, healthier communities, and a more sustainable future.

C. SUMMARY OF PROJECT ACTIVITIES

Following were the key activities taken up under the project:

Output 1: Technical Knowledge Enhancement

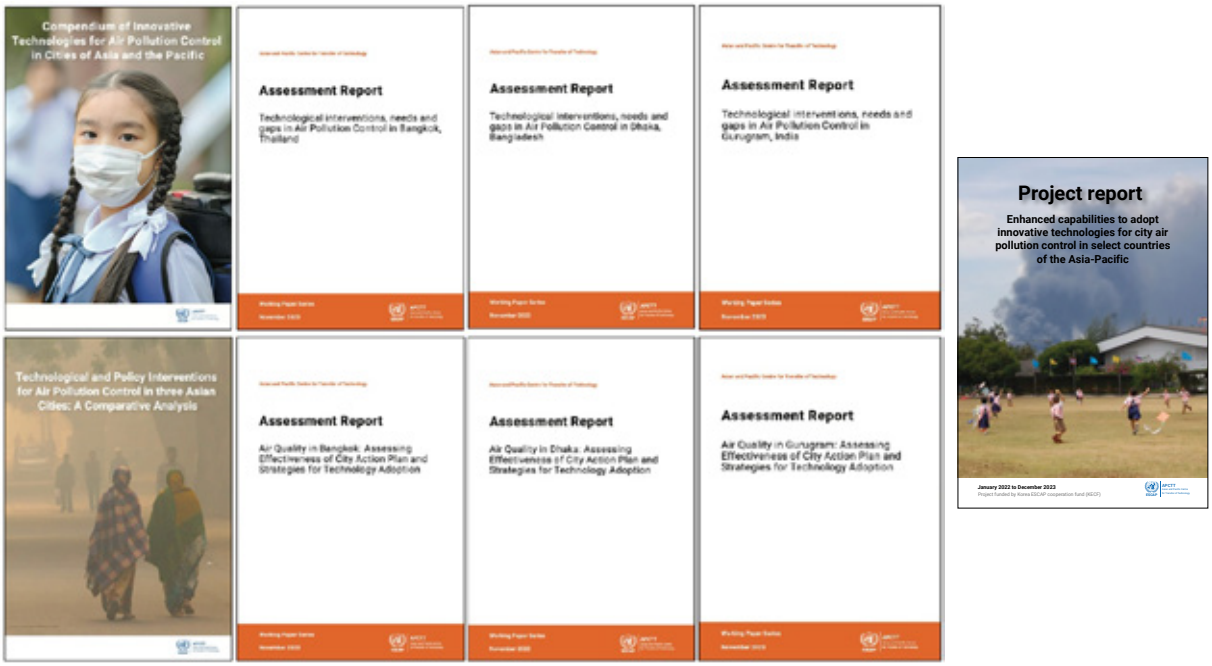

Figure 1: Knowledge Products developed under the project

Under this output, the project achieved significant milestones in improving technical knowledge for air pollution control. A "Compendium of Innovative technologies to control air pollution" was created, showcasing successful technology adoptions across the Asia-Pacific region. This valuable resource, drawing from literature surveys and expert group meetings, has the potential to guide policymakers and stakeholders in adopting effective measures (section C.1 below).

Moreover, technology assessments were conducted in three cities - Bangkok, Dhaka, and Gurugram - to identify technological gaps and needs for air pollution control. The ensuing assessment reports provided nuanced insights, outlining specific areas requiring urgent policy action. Additionally the examination of City Level Action Plans, policies, and strategies in the three cities also resulted in detailed reports, outlining areas for city authorities and policymakers to fortify their action plans for more effective air pollution control (section C.2 below).

A comparative study between the selected cities formulated a common framework for analysing air pollution technologies and policies. The methodology and lessons learned from this comparative study are expected to benefit the entire Asia-Pacific region, providing a scalable model for effective air pollution control strategies (Section C.3 below).

Output 2: Awareness and Capacity Building

The second output focused on increasing awareness and capacity among city officials and stakeholders. The project facilitated knowledge exchange events, city-level consultations, and training workshops in India, Bangladesh, and Thailand. Over 280 stakeholders participated, gaining insights into cutting-edge technologies and best practices in air pollution control. (Section C.4. below).

City Level Consultations involving approximately 300 key stakeholders generated recommendations for enhancing city action plans, fostering the adoption of enabling and innovative technologies. Training workshops for over 220 city officials and stakeholders in the three cities equipped participants with practical knowledge of sources and technological options for air pollution control. Notably, an app was developed in Gurugram on the initiative of the Metropolitan Authority for monitoring and reporting on key pollution sources, showcasing a tangible outcome of the project.

A study tour to the Republic of Korea further enriched the understanding of policymakers and municipal officials of all three cities on effective implementation (Section C.5 below).

The project concluded with a Regional Knowledge Sharing Workshop on December 21, 2023, where experiences and outcomes from the select cities were shared with participants from several member states. This workshop not only provided valuable learnings from the three cities but also offered recommendations for upscaling learnings across the Asia-Pacific region (Section C.6 below).

D. DETAILS OF ACTIVITIES TAKEN UP UNDER THE PROJECT

D.1: Compendium of Innovative Technologies for Air Pollution Control

Beginning with an introductory section on the relevance of technologies in addressing air pollution globally, the compendium listed technologies for various end-uses.

a. Technologies for air pollution monitoring: In this section, various innovative approaches are explored. This includes the utilization of Sensors and the Internet of Things (IoT) for real-time air pollution data collection; Remote Sensing techniques for estimating PM2.5, PM10, and gaseous pollutant concentrations using satellite data; use of Unmanned Aerial Vehicles (UAVs) to gather photographic and

sensor-based data, especially from hard-to-reach areas. Real-time source apportionment methods are also discussed, providing insights into the origins of pollutants. The section concludes by delving into the advancements of New Generation Reduced Complexity Models, offering sophisticated yet more accessible tools for pollution analysis.

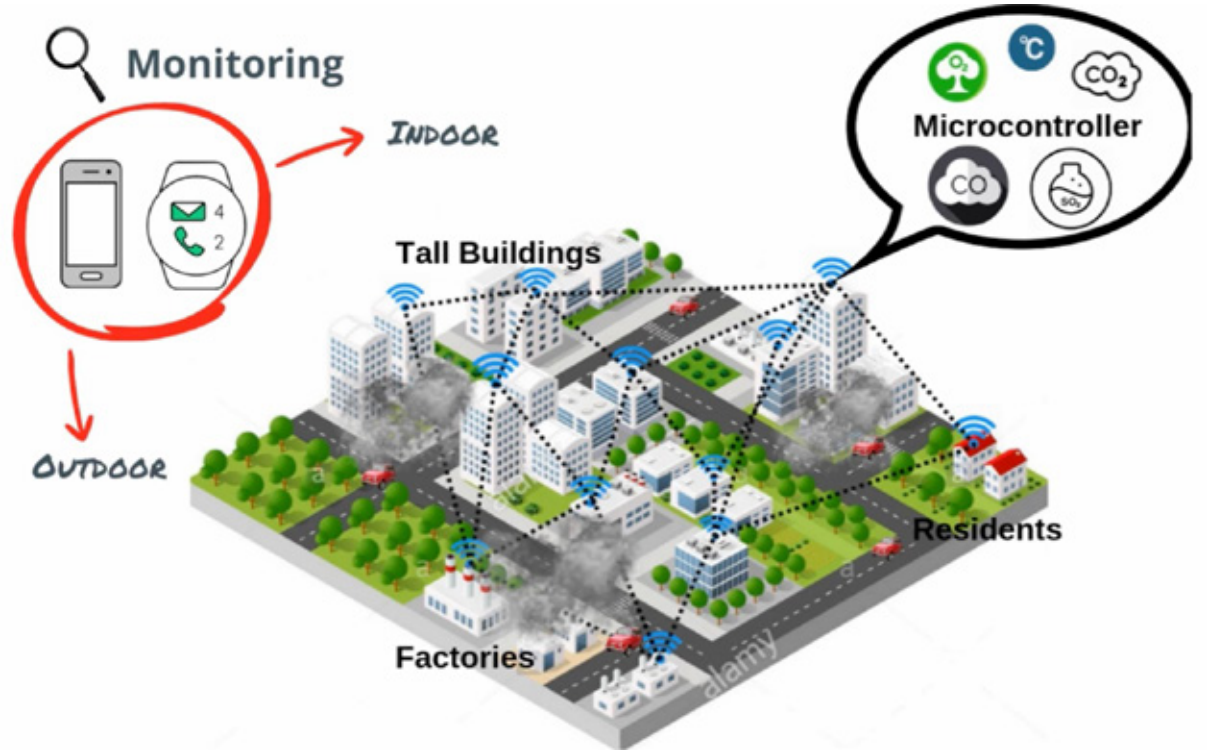

Figure 2: IoT based AQM systems *(Source:* www.iotchallengekeysight.com*)*

b. Technologies for emission control: This section provides a comprehensive overview, beginning with strategies tailored for the residential sector such as improved cookstoves, fuel-efficient stoves, and electricity-based and alcohol-based cooking devices. Technologies to reduce emissions from diesel generator sets such as Retrofit emission control devices are also presented. For the transport sector, technologies for spark ignition, compression ignition, and dual fuel engines are presented. Additionally, technologies for transition to Electric Vehicles are discussed. For the industry and power sector, emission control technologies such as Electrostatic Precipitators, Baghouses, Cyclones, catalytic reduction and desulphurisation technologies, gravity settling chambers, scrubbers, and centrifugal separators are presented. Additionally, thermal processors are discussed including sorptive processes and distillation. The section also presents various options available for reducing emissions from brick kilns, Municipal solid wastes, and in-situ and ex-situ agricultural waste processing technologies.

Finally, the section concludes by discussing dust control technologies and air pollutant removal technologies.

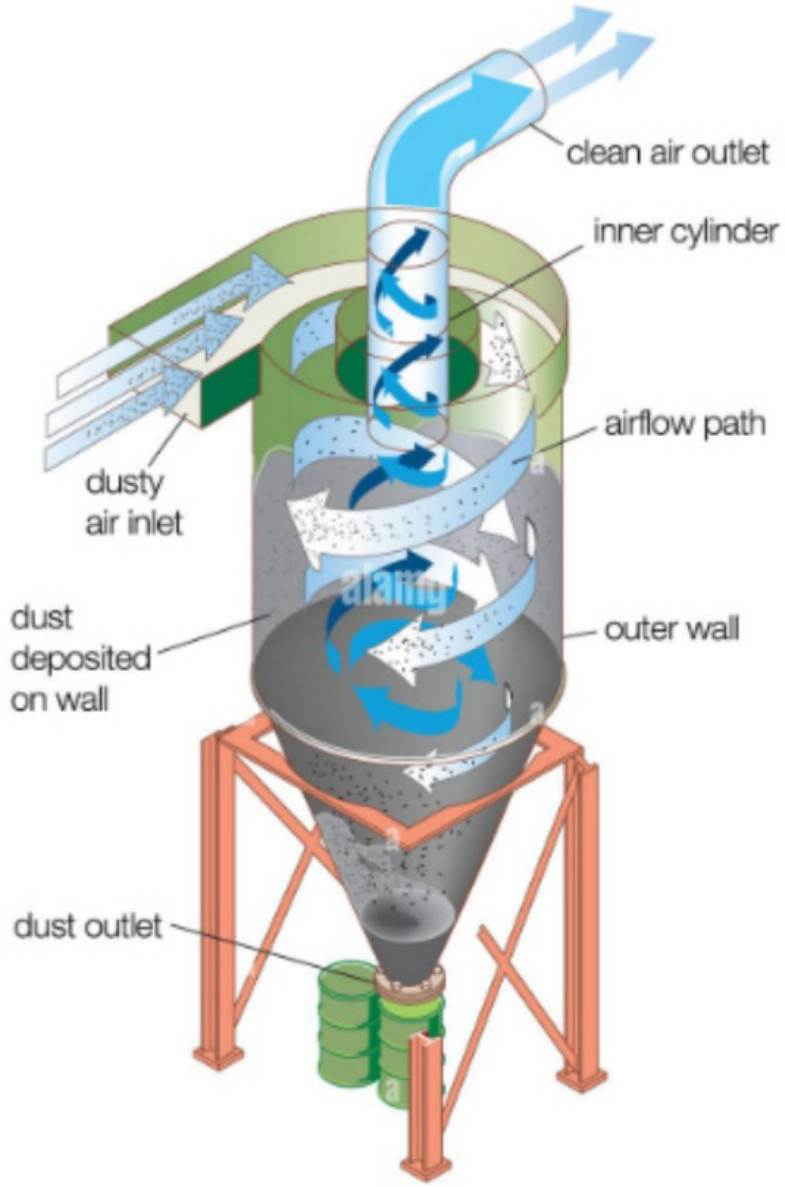

Figure 3: Cyclones for Emission Control *(Source: Dey, 2023)*

c. New and emerging technological opportunities for air pollution: This section explores the potential of IoT-based hyperlocal monitoring and local source characterization for precise data collection. Satellite applications are investigated as valuable tools for air quality management at airshed levels. Real-time source apportionment techniques in cities are discussed, offering insights into the origins of pollutants. Further, intervention studies are highlighted, examining the effectiveness of specific measures such as applying dust suppressants and deploying smog towers in Delhi, along with the impact of urban greening initiatives.

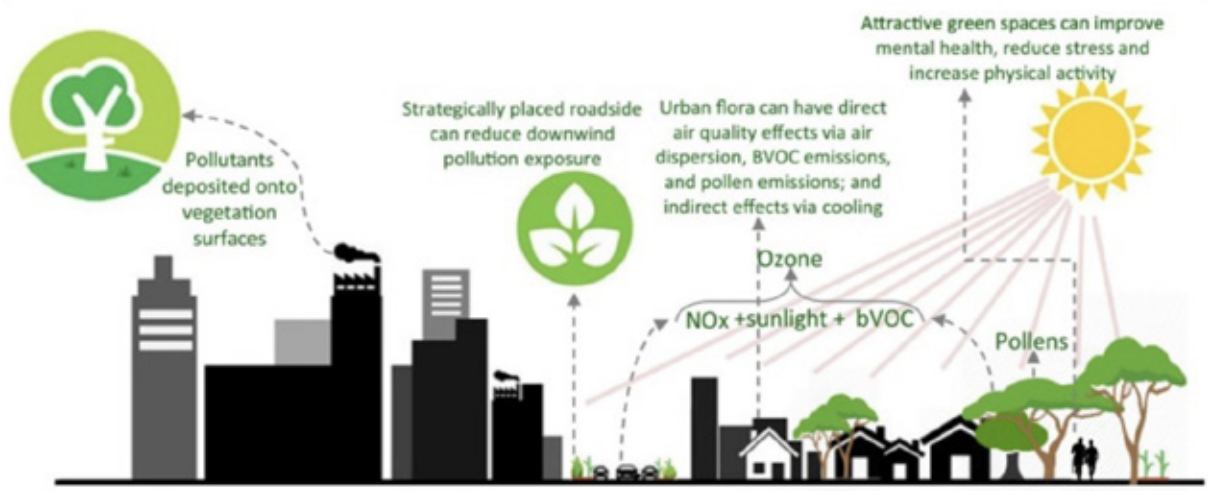

Figure 4: Role of Urban Greening in controlling air pollution *(Source: Dey, 2023)*

Recommendations: The compendium identifies recommendations and a strategic roadmap for advancing air pollution technologies. These include the systematization of a hybrid monitoring and data analytics framework within the city airshed to enhance comprehensive data management. Encouraging engagement with academia and industry partners is emphasised, fostering collaborative research and innovation. Stakeholder involvement is highlighted, emphasizing the importance of consulting with relevant parties to ensure a holistic approach. The section also advocates for piloting new technologies to assess their efficacy, reinforcing the need for sector-specific interim targets with clear timelines. Additionally, a technology adoption strategy is proposed to streamline the integration of innovative solutions, and the importance of inclusive technological interventions, embedded within a decision support system, is underscored. Finally, the compendium urges a concerted effort to accelerate progress toward carbon neutrality, aligning with sustainable goals in air quality management.

D.2 City Level Assessments

The city-level assessments under this project centred on three cities: Bangkok in Thailand, Dhaka in Bangladesh, and Gurugram in India. The primary focus was on studying the current technologies employed for air pollution control and related aspects. The assessments aimed to identify existing gaps and needs for technological interventions in these urban areas. Simultaneously, the project reviewed the action plans or strategies of the selected cities, seeking to comprehend the strengths and challenges of the current strategies for adopting innovative technologies in air pollution control.

Additionally, the alignment of these strategies with national-level plans in India, Bangladesh, and Thailand for air pollution control underwent a thorough review. These assessments were conducted through a combination of direct interactions with relevant stakeholders and extensive secondary research. Based on these comprehensive assessments, a comparative study among the selected cities was undertaken to draw valuable lessons, identify opportunities, and highlight best practices for the adoption of innovative air pollution control technologies.

D.2.1. Assessments of Technological interventions, needs and gaps for Air Pollution Control

D.2.1.1. Bangkok, Thailand

The Bangkok assessment found that the city faces a severe PM2.5 pollution issue, attributed to meteorological factors like air stagnation and high pressure during the dry season, causing pollution accumulation. Primary air pollution sources include transportation (50% from road transport with fossil fuel reliance and old vehicles), industrial activities (12% from 5,639 factories), and agriculture (20% from burning residuals and waste during the "burning season"). While electric vehicles show a gradual increase, their impact is limited. The report underlined the urgent need to address these major contributors to improve air quality in Bangkok. The key Air pollution control technologies identified for Bangkok were as follows:

a. Low-cost Sensor for ambient air quality monitoring

Advantages of low-cost sensors include their affordability, portability, and easy installation, providing real-time data for raising public awareness of air pollution. However, they have disadvantages such as low accuracy, variations in quality, lack of calibration, susceptibility to humidity, and the potential for misleading readings based on placement, impacting their reliability for health-related interpretations. Typical purchase cost of a low-cost sensor ranges from $100 to $5,000 while that of a full monitoring station is $15,000 to $40,000. Models such as "Sensor for All" and "Dust boy" are available in Thailand, as per the report.

b. Diesel Particulate Filter (DPF)

The DPF is a device that reduces diesel particulate matter, and is available for both new and retrofitted vehicles. It effectively filters exhaust emissions, trapping particulate matter, with 'full' DPFs reducing PM emissions between 85% and 99%, especially effective against small particles. 'Partial' filters, with a reduction range of 30% to 50%, are suitable for in-use vehicles with moderate emission levels.

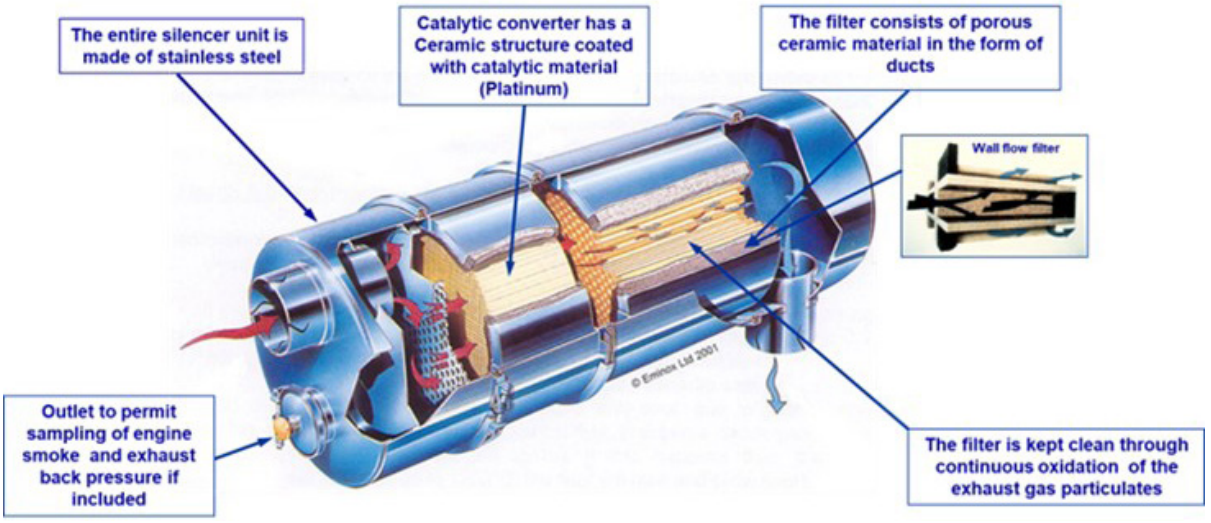

Figure 5: Schematic of a Diesel Particulate Filter *(Source: Winijkul et al, 2023)*

c. Low Emission Zones

Low Emission Zones (LEZs) are areas where only vehicles meeting the minimum emission standards are allowed to enter freely. Advantages of a Low-Emission Zone include controlling PM2.5 at the source, encouraging emission-standard compliant vehicle choices, reducing air and noise pollution,

and enhancing overall city life quality. Disadvantages involve potential limitations to public transport, enforcement complexities, costs associated with vehicle upgrades, inconvenient rerouting to avoid zones, and financial impacts on businesses relying on non-compliant delivery vehicles.

d. Electric Vehicles (EV)

EVs are increasingly seen as a strong technology to reduce vehicular emissions. The advantages include the utilization of 100% electrical energy, resulting in cost savings for maintenance and electricity, zero exhaust emissions, environmental friendliness, and the potential for reducing reliance on fossil fuels, contributing to sustainable transportation. On the flip side, disadvantages involve challenges such as the limited impact on older emission-generated vehicles, insufficient charging infrastructure and financial incentives in emerging markets like Thailand, unrealistically ambitious recommendations, high initial costs and battery replacement expenses, and performance concerns including range estimation and charging time.

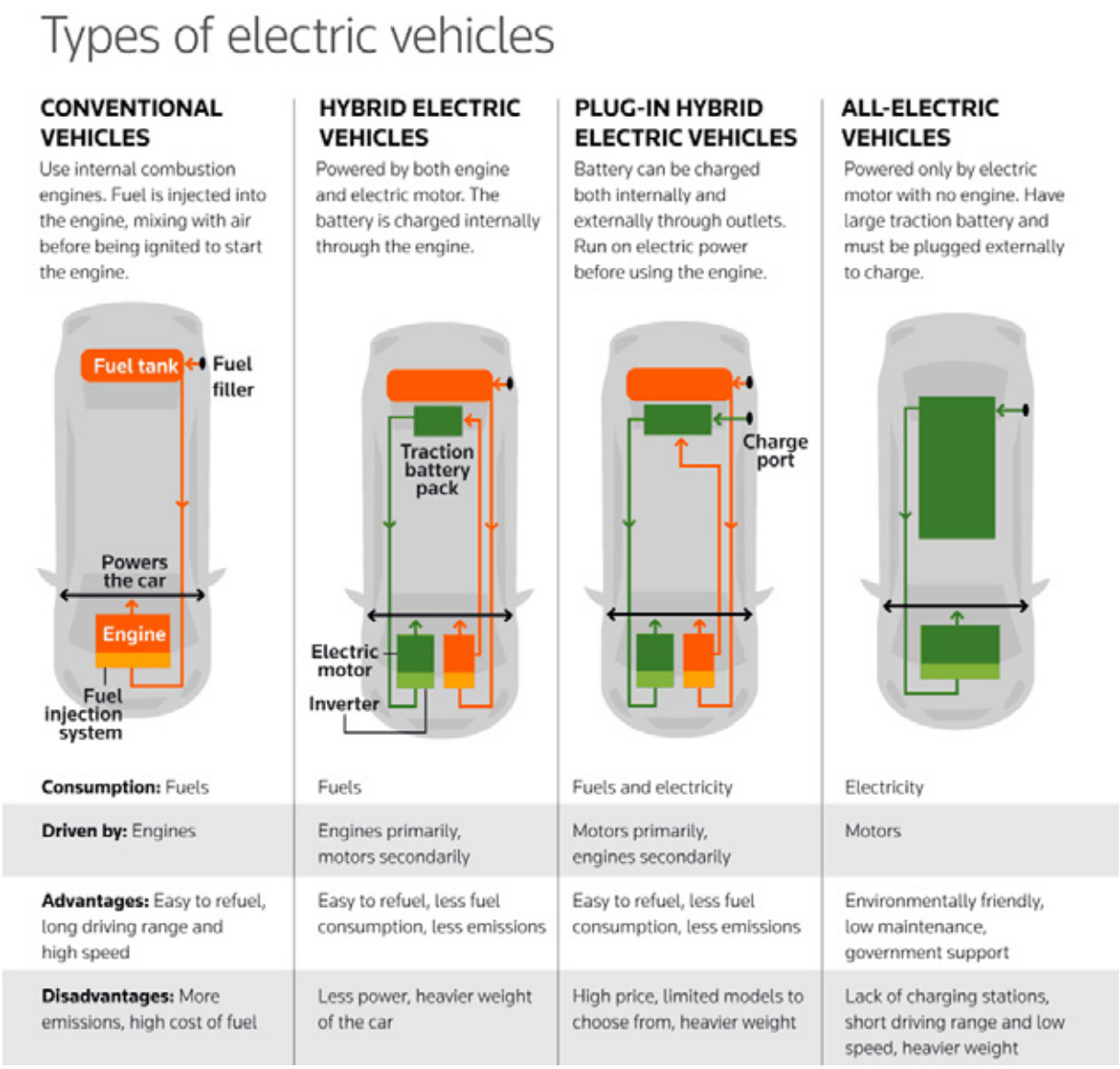

Figure 6: Types of Electric Vehicles *(Source: Winijkul et al, 2023)*

e. Continuous Emission Monitoring Systems (CEMS)

CEMS offers advantages such as real-time 24-hour reporting, high potential for successful implementation with supportive laws, environmental impact assessments, and widespread global usage. They enable self-monitoring for process optimization, ensure better compliance with emission standards, and reduce community pressure through information disclosure, fostering trust and effective communication. However, CEMs have limitations, applying only to large-scale factories in specific industrial sectors, and not mandating PM measurement for certain fuel types, posing challenges in addressing diverse emission sources and specifying particulate matter characteristics.

f. Cleaner cooking and heating fuels

In Bangkok, reliance on solid fuels for cooking and heating leads to the release of harmful pollutants (15% of total PM 2.5). The report identifies solutions for clean cooking and heating - using fuels like electricity, natural gas, and Liquefied Petroleum Gas (LPG).

Additionally, the report encourages energy efficiency through rooftop solar panels to reduce the environmental impact of traditional combustion methods.

Advantages of cleaner cooking include significant fuel use reduction (30%-60%) with modern stoves, a substantial decrease in black carbon emissions (50%-90%), and overall transformative benefits for health, climate, environment, and cost savings. However, the report finds that the challenge lies in the adoption of these technologies, influenced by cultural, socioeconomic, and contextual factors, leading to complexities in achieving widespread acceptance and implementation.

g. Applications to track and manage the burning of agricultural wastes

The report emphasises the utilization of applications designed to manage agricultural wastes as an alternative to burning. These applications play a crucial role in the registration and permitting processes for the controlled disposal of agricultural waste, along with facilitating the reporting of fire incidents. Some applications identified for Bangkok are Burn Check and Fire D.

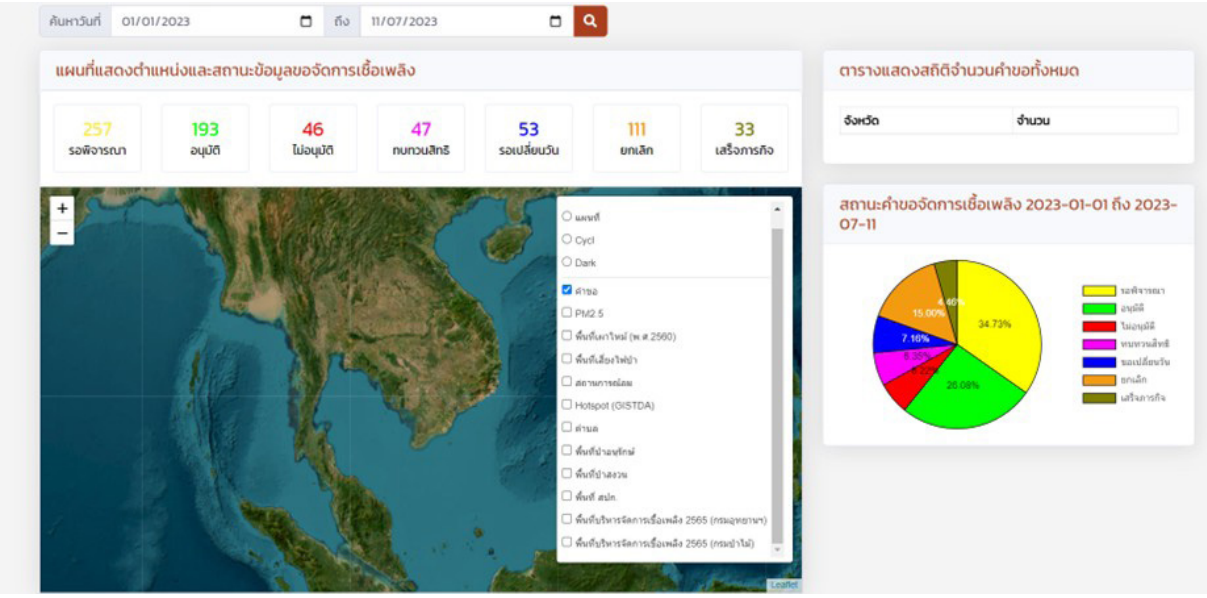

Figure 7: Burn Check Application to track biomass burning *(Source: Winijkul et al, 2023)*

h. Satellite detection for agricultural open-burning control

The report identifies Remote sensing techniques, specifically satellite-based observations, as crucial for monitoring various aspects of fires, encompassing pre, during, and post-fire conditions. These techniques enable the assessment of weather conditions, pollutant concentrations, fuel characteristics, fire risks, smoke detection, fire behaviour, and post-fire landscape conditions. Satellite models such as MODIS and VIIRS, along with instruments like GEMS on the KOMPSAT-2B satellite, contribute valuable data for global fire mapping and continuous monitoring of gases and particulate matter, aiding air pollution management efforts, particularly in Thailand, states the report.

i. Remote sensing for vehicle exhaust emissions

A Remote Sensing Device (RSD) inspects and monitors exhaust emissions from vehicles on streets and highways, measuring pollutants like hydrocarbons, carbon monoxide, carbon dioxide, nitrogen oxides (NOx), ammonia, and particulate matter. Vehicle remote sensing offers advantages, including rapid measurements under real-world driving conditions at a reduced cost, high accuracy compared to other technologies, and the collecting statistically representative samples for fleet emission analysis. It is an economical technology with minimal cost per test, less than 0.5 USD, and has been utilised for three decades in various studies. Despite its advantages, vehicle remote sensing faces challenges such as uncertainties, limitations in measuring individual vehicle emissions, and susceptibility to misjudgements, particularly in detecting diesel vehicle tailpipe emissions.

j. Weather Research and Forecasting Chemistry (WRF) Model

The WRF model is a versatile and collaboratively developed numerical weather prediction and atmospheric simulation system for research and operational purposes. Applications span real-time numerical weather prediction, data assimilation, parameterised physics research, regional climate studies, and air quality modelling. It currently contains over 6,000 registered users and is actively employed in operational and research capacities worldwide.

It has advantages such as the ability to forecast PM2.5 concentrations for three days in advance for planning for haze-free conditions and public notifications for outdoor activity. However, the model presents challenges, including the need for a high-performance computing system for air pollution forecasting and the necessity of regularly updated input data to ensure evaluation accuracy.

Recommendations

The report also scored these technologies based on criteria such as innovativeness, affordability, availability, and PM2.5 reduction potential. It found that the technologies with the most potential to reduce PM 2.5 in Bangkok were Diesel Particulate Filter and Electric vehicles, Burn check applications and satellite detection for open burning; with medium potential were cleaner cooking fuels, Low Emission Zones and Remote Sensing for vehicles and CEMs while those with low potential to reduce PM 2.5 were Low-cost sensors, WRF-Chem model.

D.2.1.2. Dhaka, Bangladesh

The main sources of air pollution in Dhaka city in 2015 were brick kilns (58%), vehicles (10.4%), and dust from construction activities (15%). Transboundary sources and agri-waste burning also contributed to the city's air pollution levels. However, recent source apportionment data were not available. Particulate Matter were found to be the key pollutants of concern. The key technologies identified by the assessment for control of air pollution in Dhaka were as follows:

a. Low-cost sensor (LCS) for ambient air quality monitoring

Department of Environment operates 16 Continuous Air quality Monitoring Systems (CAMS) and 15 compact CAMS devices for monitoring PM2.5 and PM10. However, due to the high expense of these, LCS is reported to be a more accessible technology.

b. Filters and Dust Collectors

Filters and dust collectors, such as baghouses, strategically installed at major intersections, utilise bag filters to capture dust from ambient air, achieving a high removal efficiency of 99.9% for both high and low particle concentrations. However, these fabric filters are most effective for dry and free-flowing particles and require periodic removal of collected dust or particulates.

c. Diesel Particulate Filter (DPF)

The DPF, described in the Bangkok report earlier, decreases diesel particulate matter (PM) or soot in the exhaust gas of diesel engines and can be installed in both new and existing vehicles through retrofitting. A 'full' DPF, provides substantial PM reduction (85-99%) and effectively addresses emissions of small particles, while a 'partial' filter, offers a moderate PM reduction (30-50%) and is suitable for in-use vehicles with a moderate emission level.

d. Electric Vehicles

Described above in the Bangkok study also, EVs were also found to be relevant technologies for Dhaka.

e. Dust Control Measures

The report identified various measures to control dust in Dhaka city such as mechanical road sweeping trucks and anti-smog guns to help the dust to settle down.

Figure 8: Mechanical Road Sweeping Trucks *(Source: Choudhary, 2023)*

f. Control over biomass burning: The report advocates for a shift to cleaner cooking fuels such as natural gas, electrical and waste-to-energy plants.

g. Remote sensing Devices for vehicle exhaust emission

Also described in the Bangkok report above, the technology was found to be economical and effective for Dhaka conditions.

h. Continuous Emission Monitoring Systems (CEMS) for industrial air pollution control

In addition to the information presented in the Bangkok study above, the report also emphasised the need for data centres to collate and track polluting industries for pollution control.

Recommendations

The report recommends implementing a series of measures to address the severe air pollution in Dhaka. These include enforcing stringent regulations on old vehicles, establishing automated modern vehicle emission testing centres, and upgrading refining capacity to produce high-quality fuels compatible with Euro 5/6 engines. Additionally, the report suggests introducing energy-efficient clean fuel transportation systems, promoting the use of metro rail services and electric vehicles, and improving solid waste management through better waste collection, segregation, and landfill practices. The construction sector is urged to adopt environmentally friendly practices, and the installation of Continuous Emission Monitoring Systems in industries is emphasised. Finally, the report calls for enhanced public awareness through real-time air quality monitoring systems and dissemination through electronic media.

D.2.1.3. Gurugram, India

The assessment study of air pollution in Gurugram reveals a critical need for technological interventions to address existing gaps in pollution management. Although specific source identification and inventory studies are currently underway by HSPCB, the city, as part of Delhi NCR, faces notable air quality challenges. According to several studies quoted in the assessment, emissions from vehicles, industries, thermal power plants, DG sets, residential sources, and various other contributors significantly impact air quality. The limited public transport options, coupled with high rates of vehicle ownership (esp. two-wheelers and cars), pose serious challenges. Construction activities, road dust, waste combustion, seasonal stubble burning, and increasing dust from the Thar desert further compound the issue. This underscores the urgency for targeted technological solutions to mitigate pollution from these diverse sources and improve the overall air quality scenario in Gurugram.

After an initial introduction to the basic mechanisms used to separate pollutants from air such as sedimentation, migration of charged particles in an electric field, inertial deposition, and Brownian diffusion, the assessment identifies the key technologies for control of air pollution in Gurugram:

i. Dust Control Technologies

Figure 9: Back pack dust blowers *(Source: Deshpande, 2023)*

The report presents the following promising technologies for dust control:

a. Air Filters with a small Low-Powered Fan giving 12 air changes per hour for a 4000 ft room.
b. Backpack street sweeping equipment
c. Wayu - a filtration-based air cleaning technology developed by NEERI and IIT-Bombay
d. Water fogging and water jet mist spray machines

ii. Industrial pollution control technologies

a. Continuous Emission Monitoring System linked to online Realtime data collection and reporting
b. Phasing out brick kilns and controlling industrial DG set emission

iii. Technologies for Solid Waste Management

The technologies mentioned in this section include landfilling with biogas recovery, composting, anaerobic digestion, and thermal processes like incineration, gasification, and pyrolysis. Traditional methods like landfilling and composting, are gradually being replaced. Incineration, while advantageous for heat recovery, has drawbacks such as large flue gas volumes, fly ash waste, and poor public image. A recent trend is combining incineration with energy recovery in Waste-to-Energy (WtE) plants, addressing both energy recovery and environmental concerns. Bio methanation or anaerobic digestion also emerges as a potential alternative, providing renewable energy and recycling degradable organic waste. Solid Waste pyrolysis and gasification offer options with lower pollution emissions, presenting the potential for higher energy production efficiency. The report advocates for the inclusion of startups for rapid uptake of technologies. Some of the startups mentioned are Circulate Capital (a venture capital), Phool, Thaily, Swachha Pune, and Saahas Zero Waste, Bengaluru.

iv. Technologies for controlling vehicular pollution

Approaches

The assessment discusses various approaches to control air pollution from vehicles. These include:

- Improving fuel economy and vehicle technology to minimise tailpipe emissions
- A greater share of trips using sustainable modes of transport
- Intelligent traffic management systems, e.g. signalling mechanisms, traffic diversions, and segregating heavy and light traffic
- Strengthening the public transport network, optimizing services for affordability, and promoting electric vehicles and e-public transport
- Enhancing street networks to prioritise pedestrian and non-motorised transport activities
- Effective parking management strategies like pricing and vehicle restraint to rationalise urban space and discourage excessive private vehicle dependency
- Retrofitting (Deisel particulate filters and Diesel Oxidation catalysts), rebuilding engines for low emissions, repowering engines with cleaner options, and refuelling, that is shifting engines to cleaner fuels.

Remote sensing instruments for on-road vehicles

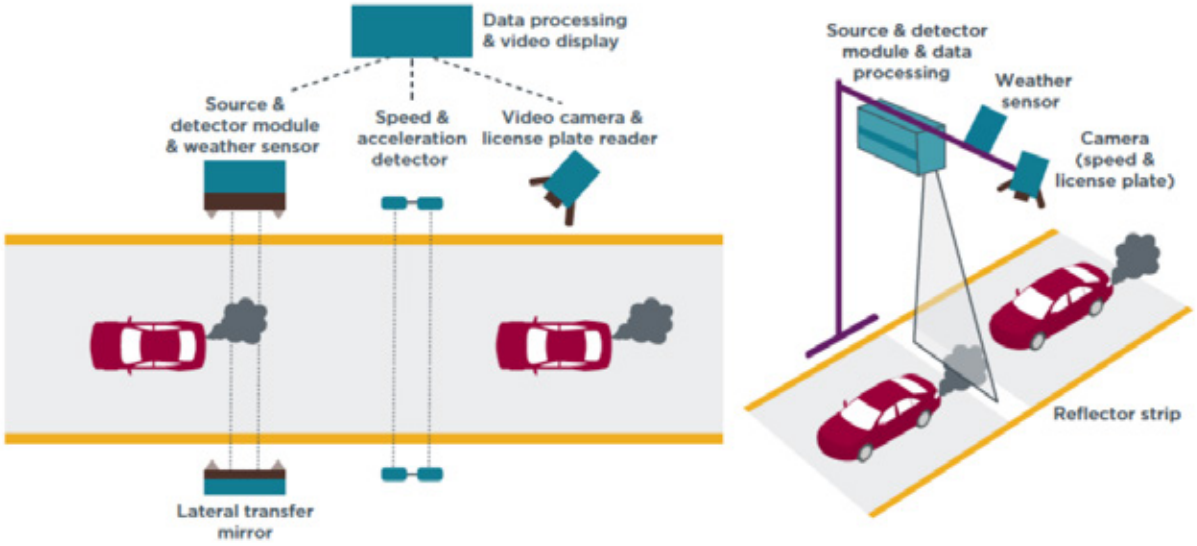

Figure 10: Remote sensing for assessing vehicular pollution *(Source: Winijkul et al, 2023)*

The report explains the Remote sensing technology and underlines that it offers a significant advantage by allowing non-intrusive emissions testing without the need for vehicles to physically report to centralised test centres or PUC stations. This setup can efficiently measure emissions from various vehicle types, evaluating hundreds to thousands of vehicles daily using the same remote sensing equipment.

Plantation

The report also emphasises the role of plantations and lists specific indigenous varieties that have been identified by NEERI as important dust collectors. Another technology called UBreathe that produces clean air through passing polluted air to plant roots is also discussed.

Reduction of residential emission reduction

Technologies detailed in this category are Electro-static precipitation carbon cutter and catalytic oxidation.

Other technologies covered in the assessment are Pulse radio wave, Smog Towers, Smog Free Towers, Vehicle Mounted mist sprays, Stationery filter-based air filtration, Road sweeping and filtration machines

Figure 11: Vehicle mounted mist sprays *(Source: Deshpande, 2023)*

Recommendations

The assessment recommended prioritizing advanced monitoring tools like LCS and remote sensing as crucial for pinpointing pollution hotspots in Gurugram. To ensure effective adoption, it suggested evaluating the performance of air pollution control technologies before integration into the city action plan. Developing robust infrastructure and enhancing the technical capacity of urban local bodies and the State Pollution Control Board (SPCB) was another suggestion. The study advocated embracing a dynamic, technology-centric city-specific action plan grounded in comprehensive source inventory studies to achieve targeted air quality improvements.

D.2.2. Assessments of Effectiveness of City Action Plan and Current Strategies for Technology Adoption

The project also supported the assessment of the effectiveness of city action plans and current strategies for technology adoption in the context of air pollution control in the three cities of Dhaka, Bangkok, and Gurugram. This included reviewing city action plans to discern their strengths and challenges in adopting innovative technologies. Additionally, the alignment of these strategies with national-level plans in India, Bangladesh, and Thailand for air pollution control was explored. The assessments employed a combination of literature review and direct interactions with relevant stakeholders. The analysis of technological interventions and a gap-versus-need evaluation in the three cities described in the section above also provided the need to identify enabling policy interventions for effective air pollution control. The three reports from these assessments offer nuanced insights for informed policy actions and fortification of city-level action plans and policies in the three target cities as well as for other cities in the Asia Pacific.

D.2.2.1. Bangkok, Thailand

The key policy bottlenecks identified by the study encompass various sectors in Bangkok's air pollution control strategies. In the transportation sector, the key issues revolve around slow progress in adopting cleaner and electric vehicles, the absence of regulations for removing old vehicles, and unclear policies regarding the Low Emission Zone. Notably, the taxation system in Thailand promotes older, higher-emission vehicles. In the agricultural sector, inadequate waste management policies coupled with the lack of incentives for alternative farming practices contribute to widespread agri-waste burning. On the other hand, the industrial sector shows insufficient measures to control unregulated factories, a scarcity of emissions data, and a lack of public participation in monitoring. Additionally, controlling pollution from residential areas and street food presents difficulties due to privacy concerns and cultural-economic factors. The study identifies the absence of regulations for low-cost sensors which raises concerns about their quality and community impact.

In response to the challenges described above, the study presents a set of recommendations to address specific sectors contributing to air pollution in the city. In the Transportation Sector, the Ministry of Environment should propose incentives for cleaner vehicles and enforce policies like vehicular age limits and automatic roadside inspections. Clear regulations for a Low Emission Zone (LEZ) are essential, emphasizing public transport accessibility. For the Agricultural Sector, the study recommends enhancing local awareness, introducing mobile apps for burn checks, and creating a comprehensive PM2.5 database managed by the Bangkok Metropolitan Authority (BMA). In the Industrial Sector, regular updates on air quality by the Ministry of Industry through a website and collaboration between BMA and communities to control emissions from small industries are crucial. Regarding Air Quality Monitoring, the Ministry of Environment should create a website, establish reporting formats, and develop guidelines for low-cost sensor usage to improve monitoring accuracy.

D.2.2.2. Dhaka, Bangladesh

The Dhaka study highlights strengths, including enacted regulations, CNG and LPG facilities, transit developments, and government commitments to EVs and waste management. Challenges involve phasing out old vehicles, modernizing emission testing, manpower shortages, compliance enforcement, refinery upgrades, MRT completion, resource availability, waste management, coordination issues, and transitioning to cleaner technologies. Overcoming these hurdles is essential for effective air quality control and pollution reduction.

The recommendations include the urgent preparation and approval of both National and City-level Clean Air Plans. Encouraging public practices, introducing improved cookstoves, and promoting clean fuels are essential for reducing biomass use in cooking. Coordination among departments for road-related activities is crucial, advocating for a common utility window. Timely repair of infrastructure, a complete ban on open waste burning, and strict control of roadside waste production are imperative. Monitoring and enforcing emissions standards for brick kilns and industries, enhancing monitoring activities, and fostering awareness among stakeholders and the public are underlined as vital measures for effective air pollution control.

D.2.2.3. Gurugram, India

Gurugram is situated in the National Capital Territory region of Delhi and faces distinct air quality challenges. It is not part of the 132 cities that are targeted under the National Clean Air Plan (NCAP) which aims to reduce Particulate Matter (PM10) levels by 40% in 132 cities by 2025-26. The city still operates under the Graded Response Action Plan (GRAP), which is set into motion to address severe winter air pollution in Delhi.

The study recommends a comprehensive, long-term, and multi-sectoral approach that goes beyond seasonal interventions. Key approaches suggested including evaluating actions through cost-benefit analysis, adopting an airshed approach, and enhancing public participation.

The study also identifies policy recommendations specific to Gurugram. These include conducting source inventory studies, improved monitoring, promotion of innovations, prioritization of air pollution control in sectors contributing to pollution, and evaluating the performance of pollution control technologies. Urgent infrastructural and capacity development, adoption of economic instruments, and integration of circular economy principles are also emphasised. The study advocates for a city-specific action plan, increased public participation, and alignment with city-specific policies for a holistic approach to air quality improvement in Gurugram. This holistic strategy seeks to address not only immediate concerns but also pave the way for sustained and long-term air quality enhancement.

D.3. Comparative Analysis of Air Pollution Technologies and Policies in three Asian Cities

The comparative analysis of air pollution mitigation strategies in Bangkok, Dhaka, and Gurugram is based on an assessment of all three cities on diverse parameters, encompassing geographical features, urbanization metrics, population density, economic development indices, air quality status, pollution challenges, climatic conditions, cultural and social determinants, data availability, environmental complexities, governance structures, urban mobility patterns, waste management methodologies, rapid development scenarios, industrial activities, cultural diversity nuances, and governmental policies.

Delving into the crux of these strategies unveils distinct focal points for each city. Bangkok prominently centres its efforts on the transportation sector, followed by targeted interventions in agriculture, industry, and residential domains. Dhaka strategically aligns its initiatives towards industries, vehicular emissions,

residential and commercial sectors, construction activities, road dust, transboundary air pollution, and open waste burning. Gurugram strategically concentrates its approach on transportation, industry, construction, waste management, and residential sectors.

Significantly, Bangkok has taken substantial strides in implementing devised strategies, primarily attributed to the adoption of comprehensive policies. Gurugram actively partakes in ongoing implementation endeavours, while Dhaka, albeit a late entrant, exhibits growth potential and is progressively converging with its counterparts.

Analysing outcomes reveals a positive trajectory in air quality improvement across all three cities. This positive trend is attributed to a multifaceted approach, encompassing the enforcement of stringent emission standards, bolstering public transportation, executing awareness campaigns, and integrating cutting-edge technology solutions. Bangkok, equipped with a robust transit system, is advancing towards WHO-recommended air quality standards. Dhaka faces challenges arising from seasonal variations, necessitating reinforced policies and technological interventions. Gurugram, grappling with rapid urbanization and intense transport loads, is charting a gradual trajectory, slightly constrained by its non-attainment city status under the National Clean Air Programme (NCAP).

A nuanced examination of technological interventions emphasises the uniqueness of challenges faced by each city, demanding tailored solutions. A unanimous demand is observed in all three cities for comprehensive air quality monitoring systems, underscoring the crucial role of accurate data in forecasting and planning. Smart technologies, including air quality sensors and data analytics, emerge as crucial for the efficacy of interventions. Recognizing transportation as a primary contributor, all three cities underscore the imperative need for stringent emission standards, cleaner fuel adoption, and strategic investments in public transport infrastructure.

Collaboration across sectors also emerges as indispensable, illustrated by Gurugram's initial collaborative ventures with the private sector. The foundation of strategic urban development, grounded in sustainability principles, is perceptible, particularly in Bangkok's eco-friendly planning initiatives.

The study also underscores the significance of long-term vision and adaptability in the strategies. The success of technological interventions necessitates a continuous feedback loop for real-time dynamic adjustments. The alignment of localised city action plans with national strategies and enabling policy instruments is also identified as critical.

Technological and policy recommendations from the comparative analysis span various sectors. Technological interventions target emission mitigation, vehicle testing upgrades, energy-efficient transportation, and improved waste management. Policy recommendations encompass developing a national-level clean air plan, advocating public practices for waste segregation, and enforcing regulations on industries.

Additionally, strategies the study advocates involve conducting source inventory studies, promoting innovation, and prioritizing sectors like transport, industry, and waste management. Economic instruments such as green credits and the adoption of circular economy principles are also suggested. City-specific policies, public engagement, and information dissemination are identified as crucial elements for effective air quality management.

In their collective endeavour to combat air pollution, Bangkok, Dhaka, and Gurugram converge upon shared strategies, each nevertheless tailored to their unique characteristics. These commonalities underscore the imperative for context-specific solutions in the ongoing battle against air pollution.

D.4. City-Level Consultations and Trainings on Air Pollution Control

APCTT supported several capacity building events to enhance the knowledge and awareness of city officials on innovative technologies and city action plans and strategies for air pollution control.

a. Technical Consultation Meeting on Air Pollution Control Studies in Dhaka City, 27 March 2023

This consultation meeting was jointly organised with the Ministry of Science and Technology of Bangladesh, the Local Government Division of the Ministry of Local Government, Rural Development and Cooperatives, Bangladesh, Dhaka North City Corporation, and Dhaka South City Corporation, Bangladesh. The meeting was organised to seek suggestions from relevant stakeholders for city-level assessment studies in Dhaka on technological interventions and gaps/needs for air pollution control, city-level action plan and its alignment with the national plan of Bangladesh, and strengths and challenges related to the strategies for adopting air pollution control technologies. The meeting was attended by 12 experts and government officials from Bangladesh who provided valuable suggestions for the assessment studies.

Key recommendations include focusing on air pollution from brick kilns, road transport, and municipal waste, conducting source apportionment study to develop appropriate policies and actions, and setting up air purifier technology to reduce air pollution in Dhaka city.

b. Project Inception Meeting Sharing Session: perspectives towards the air pollution control for the good quality of life, 25 April 2023, Bangkok, Thailand

The inception meeting was jointly organised with the Ministry of Higher Education, Science, Research and Innovation, Thailand, and Thailand Institute of Scientific and Technological Research which is implementing the project activities in Bangkok city. The meeting was attended by 38 experts and participants from Thailand and internationally. The experts shared perspectives on air pollution control in Bangkok and assessment of the gap between policies and practice and the need of technologies to be developed for sustainable pollution control and management. Key recommendations are developing innovative technologies to control air pollution, achieving efficient and effective technologies for air pollution control, adopting supportive and preventive measures to minimise air pollution, and raising the participation of communities and stockholders to achieve positive results.

c. Consultation meeting with stakeholders (Gurugram), 7 June 2023, New Delhi

The meeting was jointly organised with the Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India to seek suggestions from experts and stakeholders for conducting the city-level assessment studies in Gurugram on technological interventions and gaps/needs for air pollution control, city-level action plan and its alignment with the national plan of India, and strengths and challenges related to the strategies for adopting air pollution control technologies. The meeting was attended by 16 participants including experts and government officials from city authorities, pollution control boards, the Ministry of Environment, Forest & Climate Change, and Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India. The experts brainstormed and provided key suggestions for consideration in the assessment studies. Key recommendations include identifying technology-based solutions to mitigate air pollution, introducing stringent air quality standards, and district-level mapping of hot spots of air pollution.

Figure 12: Stakeholder Consultation workshop in Bangkok

d. Consultation Workshop with stakeholders in Bangkok

On October 26, 2023, from 09:00 to 12:00 hrs., TISTR organised "The KECF Air Pollution Control: A Multi-stakeholder Consultation Workshop" at Ballroom B Meeting Room, Maruay Garden Hotel, Bangkok, Thailand. The workshop aimed to engage city officials, stakeholders, and the National Consultant in discussions regarding the outcomes of assessment studies. The 34 on-site participants, representing government, industries, academia, and relevant agencies/institutions, focused on developing recommendations to strengthen the city-level action plan for the adoption of innovative technologies.

During the workshop, the Thai national consultant, Assoc. Prof. Dr. Ekbordin Winijkul presented a summary of two assessment reports titled "Strengths and challenges of city-level action plan for adopting technologies for air pollution control in Bangkok." The presentation covered a study of technological interventions and gaps/needs for air pollution control in Bangkok, an examination of the city-level action plan, and an assessment of strengths and challenges related to strategies for adopting air pollution control technologies. Recommendations were also provided for enhancing the city-level action plan through the adoption of enabling mechanisms for innovative technologies.

Participants actively shared their perspectives on policies, strategy options, technologies, and good practices, offering recommendations on the assessment. Many organizations stressed the importance of including data analysis on the cost-effectiveness of technologies, including investment costs and operating costs. Additionally, participants highlighted the need for a life cycle assessment (LCA) of each technology.

The workshop provided a valuable platform for the Thai national consultant, relevant organizations, and stakeholders to exchange views on air pollution management and control. The suggestions and recommendations gathered during the workshop will be processed into a summary of Bangkok's air quality, aiming to bridge the gap between existing policies and the imperative for sustainable technological advancements in pollution control.

e. Training Workshop on Air Pollution in Bangkok

Figure 13: Training on Air Pollution Control Technologies, Bangkok

On November 27, 2023, from 09:00 to 16:30 hrs., TISTR organised "The KECF Air Pollution Control: A Training Workshop" at Ballroom AB Meeting Room, Maruay Garden Hotel, Bangkok, Thailand. The workshop aimed to provide training for Bangkok city officials and relevant organizations responsible for overseeing and managing air pollution control. The primary objectives were to enhance knowledge and understanding among participants regarding the adoption and implementation of enabling mechanisms for innovative technologies in air pollution control and to strengthen cooperation among organizations involved in air pollution management.

The workshop saw the participation of 150 individuals, including representatives from 50 district offices (Environment and Sanitation Section) of the Bangkok Metropolitan Administration (BMA), the Department of Environment, and various government, industry, academia, and relevant agencies and institutions engaged in air pollution control/management.

Expert speakers from institutions such as Kanazawa University (Japan), the Hub of Talents on Air Pollution and Climate (HTAPC) in Thailand, the Asian Institute of Technology (AIT), and Chulalongkorn University (Thailand) covered topics related to atmospheric ultrafine particles, a review of air pollution problems, air quality forecasting, air pollution reduction technology assessment, and frequently asked questions during the high PM2.5 season.

The training workshop proved beneficial in enhancing capabilities in the field of air pollution control, contributing to the preservation of a sustainable environment for the community. The content covered during the workshop serves as a valuable platform for BMA officials and relevant stakeholders to acquire knowledge in air pollution control/management, encompassing both policies and technologies. This knowledge contributes to an increased understanding and the necessary abilities to effectively address the issue of air pollution in the region.

f. Training on Air Pollution in Gurugram

Figure 14: Training on Air Pollution Control Technologies, in Gurugram

A training was organised for officials of the State Pollution Control Board, Gurugram Municipal Corporation, and Gurugram Metropolitan Development Authority on Oct 19th. The key topics covered in the training were:

1. Introduction to Air Pollution:
   - Overview of air pollution and its environmental and health impacts.
   - Identification of common air pollutants (particulate matter, NOx, SOx, VOCs, etc.).
   - Understanding air quality standards and regulations.
2. Air Quality Monitoring:
   - Techniques and methods for air quality monitoring.
   - Selection and operation of monitoring equipment.
   - Data interpretation and analysis.
3. Emission Sources and Inventory:
   - Identification of major pollution sources in various industries and sources in Gurugram.
   - Emission estimation and inventory development.
4. Air Pollution Control Technologies:
   - Overview of different control technologies for various pollutants.
   - Best Available Techniques (BAT) for specific industries.
   - Integration of pollution control measures.
5. Regulatory Compliance:
   - Understanding and compliance with air quality regulations.
   - Permitting processes and compliance reporting using the App developed by GMDA.
6. Technological Innovations:
   - Emerging technologies for air pollution control.
   - Advances in monitoring equipment and data analysis.
   - Case studies of successful technology implementations.

7. Health and Environmental Impacts:
    - Health effects of air pollution on humans.
    - Impact on ecosystems and biodiversity.
    - Risk assessment and management.
8. Public Awareness and Community Engagement:
    - Importance of public involvement in air quality improvement.
    - Communication strategies for raising awareness.
    - Building partnerships with communities and NGOs.
9. Case Studies and Best Practices:
    - Real-life examples of successful pollution control programs from South Korea.

The training program equipped pollution control officers with the knowledge and skills necessary to address air pollution challenges effectively.

g. Stakeholder Consultation Workshop in Gurugram

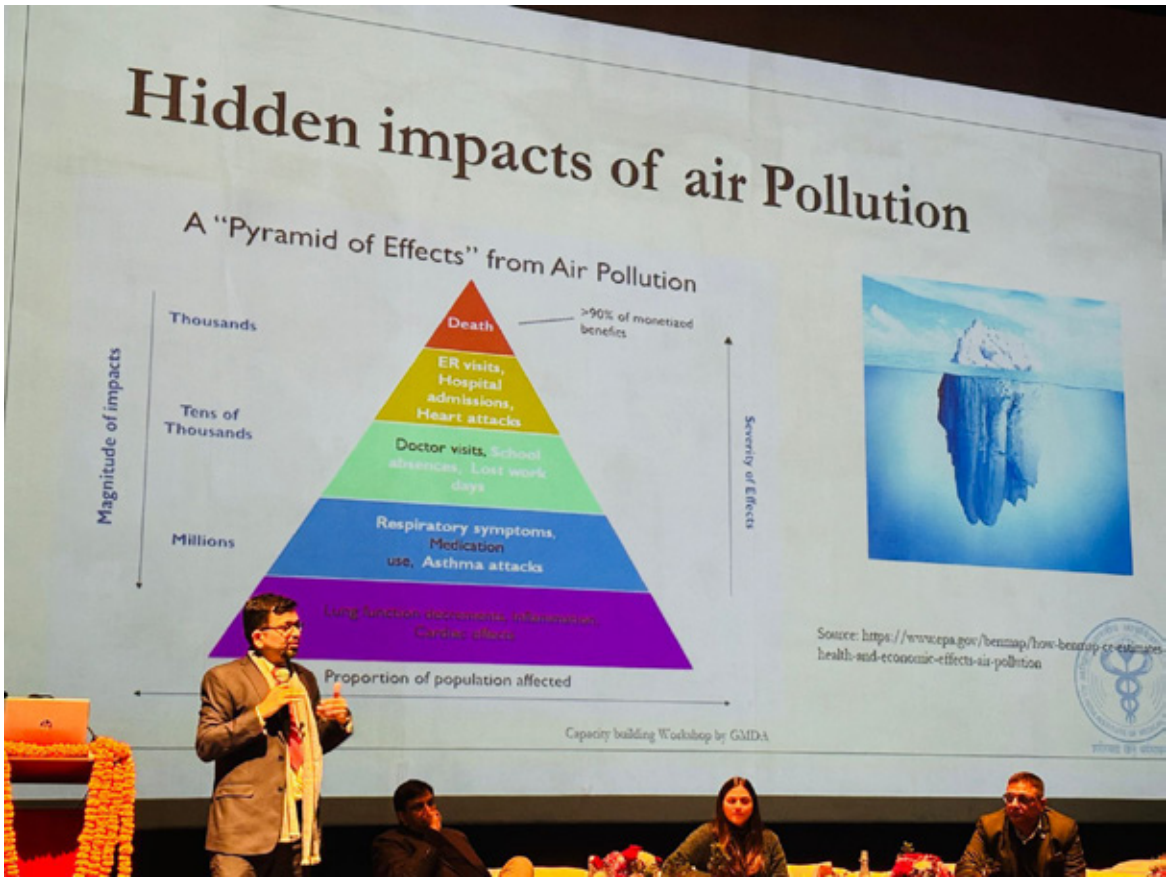

Figure 15: Stakeholder Consultation on Air Pollution Control, Gurugram

A stakeholder consultation held by GMDA in Gurugram on December 30 2023 highlighted key considerations on air pollution. More than 125 participants attended the workshop. Stakeholders emphasised the need for a holistic, long-term regional approach with a multi-sectoral strategy for the National Capital Region (NCR) and adjoining areas. Recognizing the complexity of air pollution, stakeholders stressed the importance of multi-pronged measures across various sectors rather than relying on a single solution.

The participants felt that action plan should extend beyond a response to seasonal air quality issues, aiming for year-round improvement. Continuous efforts to reduce emissions from sources throughout the year were emphasised, discouraging heavy reliance on emergency measures like the Graded Response Action Plan. Stakeholders called for verifiable and quantifiable data on source-wise emissions.

Active public participation was deemed essential in the entire air quality improvement process, from designing the action plan to its implementation and evaluation. The proposed action plan, while not limited to city boundaries, is expected to adopt an air-shed approach, specifically addressing rural and peri-urban areas.

Stakeholders stressed the importance of evaluating the efficacy and sufficiency of various actions through modelling-based cost-benefit analysis to drive interventions. Additionally, they recommended publishing periodic reports on progress against interim targets, accompanied by assessments of why regulatory and enforcement measures either succeeded or failed. The development of sectoral action plans and the solicitation of expert and public comments were also proposed to enhance the overall effectiveness of the action plan.

h. Stakeholder Consultation in Dhaka

Figure 16: Multi-Stakeholder Consultation on Air Pollution Control, Dhaka

On the 31st of December 2024, the Crystal Ball Room at Hotel InterContinental, Dhaka, served as the distinguished backdrop for a crucial event—the Multi-stakeholder Consultation on Air Pollution Control of Dhaka City. This gathering, convened with a collective vision for a cleaner and healthier Dhaka, brought together prominent figures and stakeholders committed to tackling the pervasive issue of air pollution.

Participants

The Consultation was graced by the presence of esteemed Chief Guest Mr. Md. Tazul Islam, Honourable Minister of Local Government, Rural Development, and Cooperatives. Also, present were Special Guests such as Dr. Farhina Ahmed, Secretary of the Ministry of Environment, Forest and Climate Change, and Mr. Md. Ali Hossain, Secretary of the Ministry of Science and Technology. The proceedings were led by Mr. Muhammad Ibrahim, Secretary of the Local Government Division under the Ministry of Local Government, Rural Development, and Cooperatives.

This high-profile assembly served as a platform for robust discussions, strategic planning, and collaborative efforts towards effective air pollution control in Dhaka City. The consultation brought together a diverse group of participants representing key stakeholders in air quality management, including government officials, environmental experts, community leaders, NGOs, industry representatives, and concerned citisens. In total, more than 100 stakeholders actively contributed to the discussion. APCTT's consultant.

After opening remarks by the chair stressing the importance of this multi-stakeholder collaboration, Dr. Shoukat Choudhary gave a presentation on the current Air Quality Status in Dhaka and highlighted the key pollutants and their sources. He made a comparison with national and international air quality standards and identified key industrial, vehicular, and other sources of pollution. He also touched upon the policy and regulatory landscape of the city and emphasised the need for regulatory effectiveness required for Dhaka. Dr. Choudhary talked about the critical role of the community in addressing air pollution. He also presented the main innovative technologies available for air pollution control.

Following Dr. Choudhary's presentation, several speakers, including the Honourable Minister stressed the need for addressing the menace of air pollution in Dhaka. The key insights and recommendations that emerged were as follows:

- Multi-Sectoral Approach: Stakeholders emphasised the need for a holistic, multi-sectoral approach to address air pollution, involving government bodies, industries, communities, and civil society.
- Community Involvement: There was consensus on the importance of actively engaging the community in air quality improvement initiatives, including awareness campaigns and citisen science projects.
- Technology Adoption: Stakeholders stressed the adoption of innovative technologies for pollution control and real-time monitoring to enhance data accuracy.
- Policy Enhancement: Participants recommended reviewing and strengthening existing policies, introducing new regulations, and ensuring strict enforcement to curb pollution.
- Inter-Agency Collaboration: The need for improved coordination and collaboration among different government agencies and departments was highlighted.

Conclusion:

The stakeholder consultation provided a platform for open dialogue and collaboration among diverse stakeholders committed to addressing air pollution in Dhaka. The insights gathered will contribute to the development of a comprehensive action plan for sustained air quality improvement in the city.

D.5. Study tour to the Republic of Korea

Study tour on Innovative Technologies and Good Practices for Air Pollution Control for City Officials of Bangladesh, India, and Thailand (18th to 21st September 2023)

Introduction

Figure 17: Participants of Study Tour on Air Pollution Technologies in Republic of Korea

A Study Tour on Innovative Technologies and Good Practices for Air Pollution Control for City Officials from Bangladesh, India, and Thailand to the Republic of Korea was organised from 18 to 21 September 2023. The study tour was jointly organied with the Subregional Office for East and North-East Asia (SRO-ENEA) of ESCAP. The participants belonged to the three target cities covered under the project titled "*Enhanced capabilities to adopt innovative technologies for city air pollution control in select countries of the Asia-Pacific*" funded by the Korea-ESCAP Cooperation Fund (KECF). These three cities are Dhaka (Bangladesh), Gurugram (India) and Bangkok (Thailand). The objective of the trip was to gain insights into the innovative technologies and good practices for air pollution control management as well as the strategies and city-level action plans and measures for the adoption of innovative technologies for air pollution control implemented by the Republic of Korean authorities and institutions. The visiting team consisted of Government officials working at the policy level and implementation of air pollution control and management, project focal points, and technology experts from the three countries.

Day 1: 18th September 2023

1. Opening session

The participants were welcomed by Mr. Ganbold Basanjaav, Head of the SRO-ENEA, and Ms. Preeti Soni, Head of APCTT. Both Mr. Basanjaav and Ms. Soni expressed the need for fast-tracking solutions to air pollution in target cities and underlined the many learnings that the Republic of Korea could offer and the importance of collaboration for the same. The ten participants from the three countries also outlined their expectations for this visit.

Figure 18: Welcome address by Mr. Ganbold Baasanjav, Head of SRO-ENEA, Korea

2. Incheon Metropolitan City Council

After the opening session, the participants visited the Incheon City Hall and interacted with relevant officials of the Incheon Metropolitan City Council. They were presented with a comprehensive lecture on Incheon's government policies and regulations concerning air quality management. Key aspects discussed included the air quality management system, and the roles of various stakeholders such as research institutions, citizens, industry, and national and local governments. The Council outlined the regulations, policies, and incentives put in place for air quality improvement in power generation, industry, transportation, measurement, and analysis and in the seasonal management of Particulate Matter (PM). The Council also presented their various efforts to involve citizens in anti-pollution efforts.

Figure 19: Presentation by Incheon Metropolitan Council

3. Shinincheon Combined Cycle Power Plant of Korea Electric Power Corporation (KEPCO)

The power plant operated by the Korea Electric Power Corporation (KEPCO) is at the forefront of air pollution control research and innovation, with a focus on measures developed by the KEPCO Research Institute (KEPRI). The Centre works on the development of emission-pollutant removal systems for gas turbines using catalysts, production of catalyst modules, experimental plant for the reduction of pollutants using temperature-based catalysts, selective catalytic reduction, and ammonia oxidation catalysts.

Figure 20: Methods of emission removal in Shinincheon Plant

Day 2: 19th September 2023

4. Seoul Metropolitan City Council

On the second day, the participants visited the Seoul City Hall and attended a lecture and video session on Seoul's ambitious policies to mitigate air pollution. The "Clearer Seoul 2030" initiative, which aims to reduce air pollutants by half by 2030, was highlighted. Strategies discussed encompassed the incentives and methods for conversion of diesel vehicles to electric vehicles (EVs), restricted operation of polluting vehicles, and the establishment of a regular management system for air pollutants. Participants also visited the city-level real-time automobile management system dashboard powered by Artificial Intelligence for tracking and predicting air pollution trends and entry of polluting vehicles into Seoul City (figure below).

Figure 21: Real Time monitoring of traffic and pollution by Seoul Metropolitan Authority

5. Resource recovery facility of Seoul Metropolitan Government in Gangnam

The participants visited the Resource Recovery Facility of the Seoul Metropolitan Government in Gangnam. The facility included an incinerator plant that transforms waste into energy. The facility's impressive capacity (900 tons per day), automated waste segregation methods, and positive impact on reducing landfill and neighbourhood heating were noteworthy.

Figure 22: Waste Incineration Plant-Gangnam

Day 3: 20th September 2023

6. Environmental Satellite Monitoring Centre at the National Institute of Environmental Research (NIER)

On the third day, the participants visited the Environmental Satellite Monitoring Centre at the National Institute of Environmental Research (NIER) to learn about the use and applications of the GEMS (GK-2B) satellite, the world's first geostationary satellite. This satellite, equipped with the Geostationary Environment Monitoring Spectrometer (GEMS), monitors air pollutants and climate change-causing pollutants in the Republic of Korea and neighbouring countries in Asia, providing real-time data and forecasts. Opportunities for joint research and development of remote sensing instruments, air quality mapping and forecast support, and joint monitoring for air quality were discussed. The Centre offered to share data with visiting countries on demand. (See pictures below)

Figure 23: Environmental Satellite Monitoring Centre

7. Transportation Pollution Research Centre at NIER

At the Transportation Pollution Research Centre of NIER, the participants learned about air pollution testing equipment, methods, and technologies for vehicles, with a focus on supporting national environmental policies related to zero-emission vehicles. Management of transport emissions and international standardization of vehicle emission measurement methods were key areas of interest.

Figure 24: Transportation Pollution Research Centre

8. Korea Environmental Corporation (KECO)

The participants visited the Korea Environmental Corporation (KECO) and were introduced to the Air Korea (Real-time Ambient Air Quality Disclosure System) and NAMIS (National Ambient Air Quality Monitoring Information System). These systems collect, select, and statistically process data measured from the national air pollution measurement network, providing essential data for air quality assessment.

Figure 25: Presentation by Korea Environmental Corporation

9. Sudokwon Landfill site

During a visit to the Sudokwon Landfill site, the participants were presented with a comprehensive view of the sustainable waste management practices. This facility not only efficiently produces electricity, gas, and solid refuse fuels from diverse sources such as household waste, sewage sludge, and food waste but also showcases innovative landfill site designs and methods, including the conversion of landfills into golf courses for community use. Furthermore, the presence of a leachate treatment facility and a 50 MW waste gas power plant underscored the commitment to environmental stewardship and resource optimization at the landfill site.

Figure 26: Sudokwon Landfill site overview

Day 4: 21st September 2023

10. Wrap-up meeting

The final day of the Study Tour began with a wrap-up presentation summarizing the insights gained throughout our visit. The session allowed for a thorough discussion and reflection on the knowledge gained during the visit and opportunities for potential collaborations.

Figure 27: Wrap up Meeting of Study Tour

11. Incheon Free Economic Zone Control Room

The participants' last visit was to the Incheon Free Economic Zone Control Room, an integrated centre for monitoring various aspects, including air pollution, traffic congestion, emergency response for health, fire and other emergencies, automatic crime detection and action and other functions. The advanced technology and real-time giant dashboard and coordination with all relevant departments underscored the commitment of the Incheon Metropolitan Agency to enhancing the quality of life for its citizens.

Conclusions

The study tour to the Republic of Korea was an enlightening and fruitful experience for the visiting participants. All participants were exposed to innovative and cutting-edge technologies, innovative policies, and successful initiatives aimed at improving air quality and addressing the challenges of air pollution in cities. The trip facilitated sharing of knowledge and exploring international collaboration, which will undoubtedly contribute to more sustainable and cleaner environments in the participating countries.

D.6. Regional Knowledge Sharing Workshop

Summary of discussions

1. The **Regional Knowledge Sharing Workshop on Innovative Technologies and City Action Plans**, organised by APCTT, brought together 52 participants from several member States, namely Bangladesh, India, Indonesia, Philippines, Russia, Thailand, Viet Nam, and others. The participants included APCTT's national focal points, policymakers, project focal points and representatives from target cities and countries such as Dhaka (Bangladesh), Gurugram (India) and Bangkok (Thailand), technical experts and relevant stakeholders involved in city air pollution control in the Asia Pacific region.

2. The workshop was organised under the project titled "*Enhanced capabilities to adopt innovative technologies for city air pollution control in select countries of the Asia-Pacific*" for sharing of project findings, experiences, and learnings from the target cities with policymakers and stakeholders from ESCAP member States for wider dissemination and adoption.
3. The workshop deliberated on the key learnings from various project activities and outcomes such as the Compendium of good cases of innovative technologies for air pollution control, city-level assessment in Dhaka (Bangladesh), Gurugram (India), and Bangkok (Thailand), comparative assessment between the selected cities, technical and stakeholder consultations, study tour and capacity building workshops. The project focal points from the three countries also shared their respective experiences during the project implementation.
4. It was noted that city air pollution control needs sustainable technology solutions and enabling strategies for adoption by cities. In addition to capacity building, there is a need to enhance and adopt improved technologies for air quality management. For example, monitoring stations could be improved with advanced technologies for collecting reliable data.
5. Innovative technologies analysed in the technology compendium were shared with regional stakeholders. Air quality monitoring technologies and applications include the deployment of IoT sensors, the use of satellite data, and real-time source characterization for Decision Support Systems (DSS) among others. Promising technologies for air pollution control and removal technologies include dust control technologies (dust suppressants, chemical agents), artificial rain technology, diesel generator sets, *In-situ* and *Ex-situ* management of stubble burning, EVs/retrofits/filtration technologies for the transport sector, zig-zag technology for brick kilns, incineration for municipal waste management, and improved cookstoves.
6. The city-level assessments have recommended promising technologies and strategies and management practices for suitable adoption as per the specific needs.
    a. **Dhaka (Bangladesh):** Improved CAMS with a better algorithm, low-cost sensors (LCS) for air monitoring, automated vehicle testing centres, portable emissions testing equipment, diesel particulate filters (DPF), EVs, clean fuels (CNG, LPG), metro rail services and expressways, non-adulterated and low sulphur fuels, mechanical and vacuum based street cleaning, high power wet sweeping, multifunction water trucks, dust collectors, zigzag/hybrid Hoffman/trunk technologies for brick kilns, introducing Euro 5 and 6 level diesel engines for vehicles, and apportionment studies.
    b. **Gurugram (India):** Anti-smog guns, vehicle and DG-set retrofitting, ionization technologies, sensor-based monitoring, road cleaning equipment, remote sensing for vehicle emission, low-cost emission zones, evaluation of technologies, choice of technologies, identifying hotspots, air shade approach, capacity building of local institutes, air quality prediction modelling, the greening of fleets, and viable financial model for practical and sustainable air quality action plans.
    c. **Bangkok (Thailand):** Diesel particulate filter (DPF) for vehicles, EVs, Burn Check Mobile Application to manage the agricultural waste on the field, Satellite detection of open burning (hotspot identification), CEMS, Low emission zones, cleaner cooking, Remote sensing for vehicles, and Low-cost sensors.
7. The comparative assessment highlighted the scope for improvement in various sectors/aspects of the three cities: Infrastructure and inter-agency collaboration (Bangkok); industry, construction, agriculture, and waste management (Bangkok); infrastructure and agriculture sectors; develop city-level action plan.
8. Key recommendations of the comparative study for city action plans are context-specific strategies, enforcing of stricter emission standards, policy flexibility, strengthening multi-stakeholder collaboration, fiscal policies to support AQM work, policy to make green infrastructure and ensure industrial compliance, clean energy transition, and regional collaboration.

9. As the way forward, it was suggested to countries and their cities to identify shared challenges, develop new approaches for strengthening collaboration, establish a platform for knowledge-sharing, develop customised and need-based urban strategies, implementing pilot projects, integrating sustainable practices, and ramping-up capacity building initiatives.
10. The project focal points shared their country experiences during the implementation of activities.
    a. **Thailand** appreciated the capacity building, cross-learning of knowledge and experience, and collaboration between stakeholders (city, national, and institutions). They noted that it is important to implement the findings and recommendations of the studies, ensure harmonization of policies to facilitate technology transfer across countries, and develop a long-term collaboration framework, and ensure the adoption of localised solutions, adaptability, awareness, and sharing of new technologies between countries.
    b. **Bangladesh** highlighted key elements for air pollution control in Dhaka as identified by this project which will be helpful in preparing the city action plan. These include expanding the sensor-based monitoring network in Dhaka; developing city action plans and strategies; and establishing a database for data management and utilization as a decision-making tool.
    c. **India** appreciated various project outcomes such as capacity building, knowledge enhancement, and recommendations for innovative technologies and strategies for adoption. As a follow-up of this project, Gurugram City will develop a Clean Air Action Plan by 1st March 2023. The study tour and knowledge-sharing on available innovative technologies and city action plans of Seoul, Incheon, and Bangkok would be beneficial for the target cities.

Recommendations for APCTT

1. APCTT could follow up with the target cities on the implementation of project findings and recommendations.
2. The Centre could explore opportunities to develop a second phase of the KECF project to provide additional support to the target cities for developing/improving their city-level action plans for air pollution control.
3. APCTT could strengthen cross-border technology cooperation and transfer between stakeholders across member States for achieving existing regional and global commitments.

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