Integrated Programme for Better Air Quality in Asia (IBAQ Programme)

CITY SOLUTIONS TOOLKIT:
EMISSIONS INVENTORY: DATA AVAILABILTY ASSESSMENT & DATA COLLECTION METHODS

BACKGROUND INFORMATION

An emissions inventory (EI) is a complete listing of estimated amounts of key air pollutants emitted by various sources. Compiling an EI is a complex process which requires mapping of available data and adoption of sound data collection methods before the actual EI analysis (i.e., calculation of final mass of emissions per year). The information gathered from EIs identifies key emission sources, the magnitude of its contribution to the total emissions, as well as the trends/distribution of the pollutants across time and space.

Emissions inventories are integral to air quality management (AQM) since the data generated can be used to design air quality monitoring systems, perform air quality modelling, and develop control strategies such as permitting, emission fees, among others. The data and modeling output can also be used to meet reporting requirements and to provide information to all stakeholders to raise awareness (refer to modules on Data visualization of emissions inventory results and Air quality modeling application to policymaking). In summary, EIs guide the AQM framework by identifying the sources of pollution that must be controlled, helping in identifying priorities for action, and providing data essential for other AQM components.

The availability of data, time, human, and financial resources will determine the type of EI methodology that can be adopted (NCCEH, 2011). Emissions inventory development can be challenging and tedious, hence it is important to adequately prepare especially in the assessment of data availability and planning for and executing the data collection process.

This toolkit aims to guide air quality management (AQM) practitioners on specific data considerations in starting an EI, to ensure a more efficient process and robust outputs. Using the Guidance Framework module on Emissions Inventory and Modelling (Clean Air Asia and UN Environment, 2019) as main reference, the following information is provided:

1. Concepts relevant to EI,
2. Considerations in assessing data availability and kinds of data collection approaches,
3. Concerns and limitations common in Asia in compiling an EI, and
4. Recommended steps to progress through an EI

The approach to EI development (including the method, timeframe, and resources needed) is mainly dependent on the set objectives. The objectives of EI development must be clear to the AQM practitioners, including technical officers and decisionmakers. These will define the scope and limitation/s of what needs to be done, which should match with the available resources.

THE METHODOLOGY

There are two approaches in conducting EIs, and the decision to choose one over the other impacts what kind of data assessment and collection is needed and is possible. The characteristics of each approach are described below.

1. **Top-down approach**: **Estimation of emissions using available general data** (e.g., use of national statistics data)
    - National or regional emission estimates are used
    - Used when specific local data is not available
    - Generally done in a shorter period if there is access to national statistics data
    - General demographics data is obtained from the Statistics Office (e.g., projected population, age, sex, employment, income, etc.)
    - For area sources, data is obtained from the Statistics Office (e.g. estimated household fuel use, other activity data related to households) or the Trade and Industry Office (e.g. types, number and locations of establishments, estimated fuel use, etc.)
    - For mobile sources, data can be obtained from the Transport Office (e.g. number and classification of registered vehicles) or Energy Office (e.g. vehicle fuel sales)
    - For stationary sources, data can be obtained from the Environment Office (e.g. types, number and locations of facilities, estimated fuel use, pollution control devices, etc.)

2. **Bottom-up approach: Estimation of emissions using specific data** (use of specific data obtained through surveys)
    - Uses individual sources, processes, and activities with specific data
    - Results in more comprehensive emission estimates
    - Requires more financial resources and takes more time to accomplish
    - General demographics data is obtained through representative house-to-house surveys based on census data done by Statistics Office (e.g. population, age, sex, employment, income, etc.)
    - For area sources, data is obtained from specific interviews from households and establishments in the area as guided by data from the Statistics and the Trade and Industry Office (e.g. types, number and locations of establishments, actual fuel use, etc.)
    - For mobile sources, data can be obtained from household and establishment surveys (e.g. specific fuel use, kilometers traveled by the vehicle, engine type, vehicle age, etc.) or

through actual counting and classification of vehicles in specific road sections/locations, which can be done real-time in the streets or through CCTV records

- For stationary sources, data can be officially requested from the facilities through the Ministry of Environment (if possible). This should provide actual emissions data coming from continuous emissions monitoring systems (CEMS), third party testing results or other self-monitoring test reports.

Starting an emissions inventory

Data mapping and collection processes are the basic steps to start EI development. These are also the most crucial ones because the results of the analysis will only be as good as the input data. It is thus important that AQM practitioners are aware of what they should prepare for these steps and start with a basic understanding of the classifications of pollutants as described below.

Air pollution sources can be generally classified according to the following:

Basis	Type	Examples
Origin	Biogenic	natural sources such as biological and geological processes (e.g. volcanic eruptions, sandstorms, natural forest fires)
	Anthropogenic	man-made (i.e. all emissions from human activities)
Mobility	Mobile	mainly from the transport sector (e.g. road and non-road sources)
	Stationary	from factories and permanent establishments
	Area sources	temporary activities and processes that emit air pollutants (e.g. waste burning, construction activities)
Location	Indoor	emissions sources from activities inside the household/establishment (e.g. cooking)
	Outdoor	all external pollution sources

It must be noted that some sources can be classified in more than one category. For instance, household cooking can be classified as an indoor, anthropogenic and area source, while forest and bush fires if naturally occurring, are classified under biogenic, outdoor and area source.

Other details about organizing air pollution through sources, examples are provided:

Man-Made Sources (types)

Stationary Sources or Point Sources

- Industries
- Power Plants

- Generator sets
- Incinerators

Mobile Sources or Line Sources

- Automobiles – cars, buses, trucks, motorcycles
- Trains
- Ships and Marine Vessels
- Airplanes/Helicopters

Fugitive Sources or Area Sources

- Gas Service Stations
- Open Burning
- Construction
- Mining
- Household cooking

Stakeholder engagement

Prior to performing an EI, a workshop with a core group or technical working group of stakeholders is prescribed to facilitate the development of the work plan which will identify how the EI process will be implemented. The stakeholders primarily come from local government/s (e.g., representatives of planning, transport, health offices), academe, and non-governmental or civil society organizations. Ideally, the EI planning process should align with the overall framework of establishing an AQM system in the form of a Clean Air Action Plan (CAAP) (refer to module on Step-by-step guide for cities to develop clean air action plans).

Through various meetings, the working group will assess and organize necessary technical, financial and human capacities to conduct an EI. The support of policymakers and heads of agencies is also key in order to facilitate access to data and deployment of necessary resources for the EI process.

Presented below are the suggested steps to assess data availability to determine the approach for data collection that can be conducted.

STEP 1: Data scoping (general) – Check to see if the working group has access to or is familiar with these kinds of data/knowledge:

1. Sources and magnitude of local, regional or national emissions;
2. Pollutants of concern; and
3. Distribution and trends (tracking emissions over time)

Pre-existing general information from previous AQM efforts (city profile, monitoring, and modeling data) or academic research can help in already identifying what should and can be prioritized for the EI, in the case that not all sources can be covered due to limitation in time and resources.

Step 2: Data mapping (specific) - For Step 1 to be concretized, the analysis would require a compilation of emissions data and activity data. A master list or checklist of all available data must be mapped through desktop research, technical workshops, or consultations with concerned agencies. If a top-down approach is more feasible where national statistics data is needed, the requested scope of data must be specified (e.g. time frame needed, areas covered). It would also help to request in a specific format and file type. If this is not achieved, time for data cleaning and formatting process should be allocated. If a bottom-up approach is preferred, the following pointers are prescribed in developing an EI survey:

- Ensure that all necessary information is asked (refer to discussion on Bottom-up approach above)
- Specify the units of measurements needed to avoid having to convert later on (e.g. when asking for amount of waste produced, ask for the specific mass in kilograms (not in grams or pounds); for fuel, ask for specific volume in Liters (not in gallons))
- Consider the resource that it would take to accomplish the survey. There must be a balance between being comprehensive yet also considerate of the time it would take for the respondent to provide accurate data and the finances that the detailed survey would entail. In some cases, a very long survey also may discourage participants from answering truthfully.

Below is a sample data template that can be useful in the collection of activity data for each pollution source, as well as the suggested corresponding data gathering method. For each dataset collected, the period covered of the most recent available data collected must be tabulated as well.

Pollution source	Existing or relevant pollution sources	Activity data required (minimum)	Data gathering method
Point Source	Heavy industry and manufacturing facilities	Fuel use (type, amount); Equipment (type, fuel); Pollution control devices; Actual emissions data	Utilize activity data extracted from Self-Monitoring Reports (SMRs), 3rd party tests, and Continuous Emissions Monitoring System (CEMS) submitted by the industries/ facilities/ establishments to Environment Ministry
	Establishments located within the study zone		

Area Source	Residential activities	Household fuel use (type, amount); waste production and burning; solvent use	Perform household survey or collect census data from Statistics Office
	Commercial activities	Equipment/ cooking fuel use (type, amount); waste production and burning; solvent use	Perform household survey or collect data from Environment or Trade Ministry
	Crop residue open burning	Amount of biomass burned	Utilize data from City Agricultural Office.
	Agricultural sector activities such as fertilizer use and animal manure management	Fertilizer use (type and amount); Manure production (can be estimated through number of livestock)	Utilize data from City Veterinary/Agricultural Office
Mobile Source	On-road vehicles	Vehicle data (count and classification) passing through streets	Perform classified vehicle volume count in collaboration with City Traffic Management and Enforcement Office
		Travel time and delay data; Time and speed profile	Perform travel time and delay studies with City Engineering Office/ Traffic Management and Enforcement Office
		Database of registered public utility vehicles in the city	Utilize data from the Transport Ministry or the City Traffic Management and Enforcement Office

Step 3: Data collection - To come up with the actual emissions information, *emission factors (EF)* of a known source (refer to module on Compendium of emission factors), *activity data*, or direct emission measurements must be compiled. These are described briefly in the following paragraphs.

Emission factors are average rates of emissions of a pollutant per unit of activity for a given sector. They are based from literature and are compiled by regulatory agencies such as the United States Environmental Protection Agency (US EPA)'s AP-42 and the European Environment Agency's CORINAIR/EMEP.

Activity data gives the scale or magnitude of the activity that cause emissions. Since EFs are constant, emissions are directly proportional to activity data. The list of activity data per emission source types have been identified in the beginning of the Methodology section, depending on the approach.

Direct emission measurement provides the most accurate emissions estimate but requires large resources. In case direct measurements cannot be done, appropriate emission factors are selected from existing compilations.

Summary of data collection requirements:

EF – from literature, actual measurements/local studies

Activity data – statistics of previous data, of national and international sources and local surveys

Direct emission measurement – actual direct measurement from source, no need for EFs

The working group should anticipate the following challenges on data availability as they go through the process of developing an EI, and consider these in work planning and engaging partners to facilitate the data collection process:

- Difficulty in acquiring reliable local data, especially for source activities and Emissions Factors (EF),
- Lack of quality assured data for developing and updating EI,
- Unavailability of accessible and user-friendly EI programs for government staff for policy making,
- Lack of site-specific meteorological data,
- Lack of local source profiles, and
- Lack of procedure to gather the data for EI across the different ministries/organizations.

Similar to any data collection and analysis process, a proper quality assurance/control (QA/QC) method should be performed. A robust and reliable EI needs a comprehensive QA plan and a thorough QA/QC system to ensure confidence in the inventory (US EPA, 2017c; 2011).

Components of QA/QC include:

- Technical reviews;
- Accuracy checks;
- Use of approved standardized procedures for emissions calculations;
- External review and audit procedures conducted by personnel not involved in the inventory development process to assess the effectiveness of the QC plan and the quality, completeness, accuracy, precision, and representativeness of the inventory;
- Devotion of adequate resources to QA/QC activities;

- Implementation of data quality objectives (DQO) to ensure that the data in the EI will be sufficient for the intended use;
- Balancing DQO with available resources including time constraints, resource (staff and funding) limitations, and lack of data;
- Describing data quality indicators such as accuracy (precision, systematic error), comparability of methods and data, completeness (amount of valid data obtained compared to the planned amount), and representativeness with respect to sources and the area to be covered;
- A standardized checklist that assesses the adequacy of the data and procedures at various intervals in the inventory development process and includes questions concerning completeness, use of approved procedures, and reasonableness; and
- Application of techniques such as reality check, computerized data checks, peer review, statistical checks, replication of calculations, and QA audits.

A key part of QC is recognizing where errors can occur and devising a plan to avoid them in the planning stage. One of the common errors is double counting. Since a source can be classified in various ways, the classification must be clearly defined at the onset of inventory development to avoid double-counting, which occurs when emissions are accounted for two (or more) sources due to overlapping classifications. Other typical errors found in inventories include the following (All4, 2010):

- Missing facilities;
- Improper facility location data;
- Missing operating or technical data;
- Erroneous technical data including misinterpretation of data or transcription errors;
- Inconsistent classification of sources;
- Size designation or failure to designate inventory size;
- Errors in calculations such as transposition of digits, decimal errors, entering wrong numbers, and misinterpreting emission factor applications; and
- Data entry, transposition and coding errors.

Data gaps in the inventory may be a result of any or a combination of the following:

- Pollutants unaccounted for due to a lack of credible EFs,
- Sources that are missing or unaccounted for due to incomplete source lists,
- Source categories that have not been considered due to a lack of credible EFs or activity data,
- Oversight of a facility or source category during inventory compilation, and
- Data entry errors.

All QA/QC activities and results should be well documented and reported, either as part of the inventory report, or as a separate document. Another approach to verify EI is to process and use EI results as input to air simulation models. Output concentrations from simulation can then be used to compare with monitoring data on-the-ground. This process not only validates EI in terms of

magnitude but also on other characteristics (e.g., spatial variation, temporal variation).

After understanding that the above steps can be done through review and additional research, the working group can finalize the workplan for conducting an EI with various stakeholders with specific roles. Presented in the next section is a case study to show mobile emissions EI output and other consideration in doing an EI.

Emissions inventories can be conducted from six months to one year from the inception stage with the working group. The length of time needed can be extended depending on the specific approach to be used, as well as the desired level of detail and geographical scope of analysis. In some cases, AQM managers opt to look into the period of time where the results are needed, and work backwards. This means if the results are needed within six months, the chosen approach would be one which will require less detail and will only focus on a specific source category, or on a smaller area, instead of covering all details.

CASE STUDY: DEVELOPING AND EMISSIONS INVENTORY FOR MOBILE SOURCES

It is possible that EI would focus on mobile emissions, since this is most dominant source of emissions especially in urban centers in Asia. Completing a mobile EI involves gathering the following information (Clean Air Asia and UN Environment, 2019):

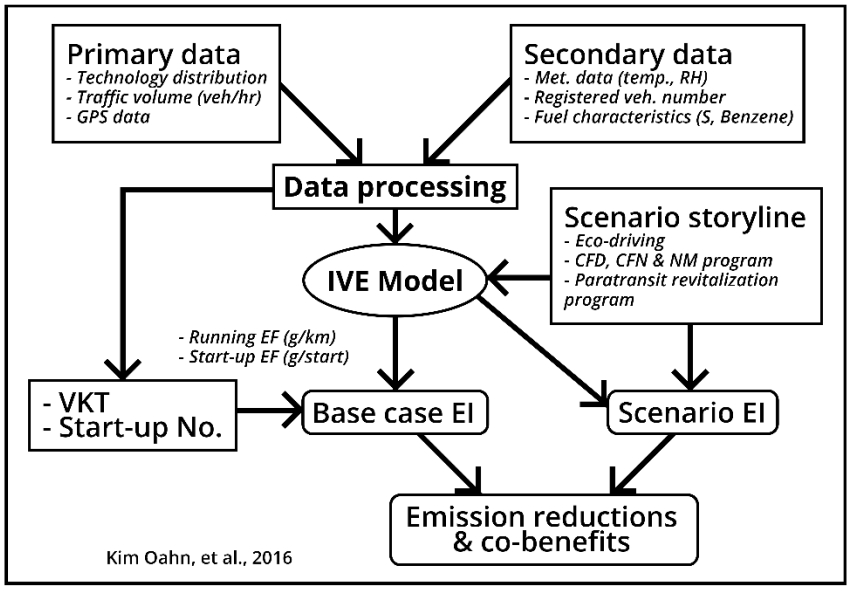
- Number of vehicles
- Vehicle fleet composition (e.g., light/heavy duty, petrol/diesel etc.)
- Vehicle age distribution
- Number of vehicles meeting different emission standards
- Information on inspection and maintenance level
- Annual mileage for different vehicle categories
- Vehicle speed information based on road category (e.g. urban/rural/highway)
- Fuel characterization
- Total fuel consumption

Developing a vehicle emissions inventory in Asian Cities (Kim Oanh et al., 2015)

Objective and scope of the inventory	**Passenger fleets of vehicles**
Area covered	Urban areas of Bangkok, Kathmandu, Hanoi and Ho Chi Minh City
Method	International vehicle emission model (IVE) http://www.issrc.org/ive/
Data collection	Following IVE methods: design for survey (e.g. 1500 MC in Hanoi), GPS survey, vehicle counting ➔ representative data for each city • Running emissions: exhaust and evaporative emissions

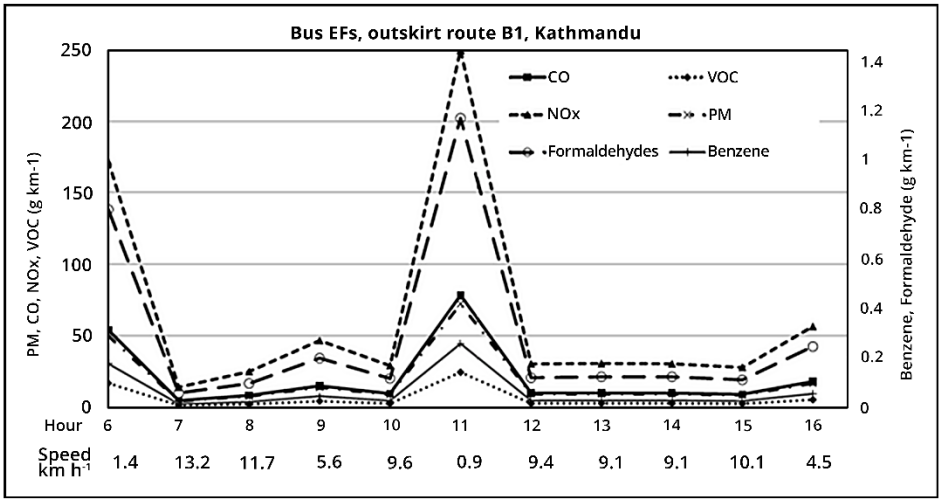
	• Start-up emissions: cold start (high emission), hot start • EF factors: IVE modeling with local data • Activity data: VKT by survey + number of starts by GPS survey
Important outcomes	<table><tr><th>Annual emissions (kt)</th><th>Bangkok</th><th>Kathmandu</th><th>Hanoi</th><th>Ho Chi Minh City</th></tr><tr><td>Toxic air pollutants</td><td>3544</td><td>60</td><td>319</td><td>1605</td></tr><tr><td>GHGs and SLCPs in CO2 equivalent</td><td>487,328</td><td>8540</td><td>5920</td><td>26,315</td></tr></table> If all on-road vehicles in each city would at least compile with Euro 3: annual emission would be reduced by 44-85% for toxic air pollutants and 28-42% for climate forcing as CO2 equivalent.

Traffic EI: Study design & method



Shown in this figure is the overall design of an EI with modeling included. Focus on the aspect of data availability the collection. Under Primary and Secondary data that are collected, emissions will be calculated to arrive at a 'Base case EI'.

EI results: EF [g/km] vs. speed [km/h] for Kathmandu



Shrestha, et al., (2013)

For Kathmandu, the fleet of buses emit the highest in the middle of the day with low speeds which pertain to longer presence in the area while engines are running (emitting).

WAY FORWARD

With the leadership of the working group, institutions and stakeholders should aim for the following to produce the best EIs for the city:

- Set up an institutional framework for continuous improvement of capacity and infrastructure including state-of-the-art laboratory facilities, techniques, documentation and database management systems for EI (and SA).
- Establish a mechanism for use of EI in policy decisions and feedback for improving EI as scientific inputs.
- Allocate adequate and sustainable technical and financial resources.

Additional information on EIs are found in the other modules in this Toolkit: Development of source and emissions database, Integration of criteria pollutants and GHG/SLCP emissions inventory, Data visualization of emissions inventory results, and Compendium of emission factors.

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