Integrated Programme for Better Air Quality (IBAQ Programme)

CITY SOLUTIONS TOOLKIT:

TECHNOLOGY OPTIONS

CONVENTIONAL VS NEXT-GENERATION

BACKGROUND INFORMATION

The key to air quality management (AQM) is knowing what must be addressed. One of the first steps in improving air quality is thus having a clear picture of pollutants in the air through measurement. Identifying the most appropriate air quality monitoring technology to perform this is crucial, as it must match the city's needs and available resources.

There are several air quality monitoring technologies available in the market, and they can be grouped either as 'conventional' or 'next-generation' technology. Conventional technologies for air quality monitoring mainly refer to *reference* or *reference-equivalent* instruments which are the most accurate equipment for quantifying air pollutants and regarded as the 'gold standard' in monitoring. Underlying technology for each device varies depending on the type of pollutant measured. Given the intricacy of such instruments, conventional technologies are mostly expensive and require more space, extensive power supply, and highly-technical personnel for its operation and maintenance.

On the other hand, *non-conventional or 'next-generation'* air quality monitoring instruments and methods have become more popular in the last decade due to its availability and rapid technology innovations. It also promises features that aims to address concerns involved in the use of the conventional types of air quality monitoring instruments such as cost, accessibility, and portability. Most popular are *low-cost sensors,* which can be as inexpensive as less than 100 USD and have increased data access to the general public, with a caveat on data accuracy.

This document provides guidance for air quality managers to consider on the use of either conventional or non-conventional technologies. This is essential especially in line with other issues covered in other modules in this Toolkit, such as data reliability and appropriate analysis to be used. Since there are multiple aspects to consider, a decision maker refer to this document as a guide to look into all factors that must be considered in the decision making process. What worked based on other institutions' or governments' experiences can also inform the reader how best to navigate the discussion on what technologies to use.

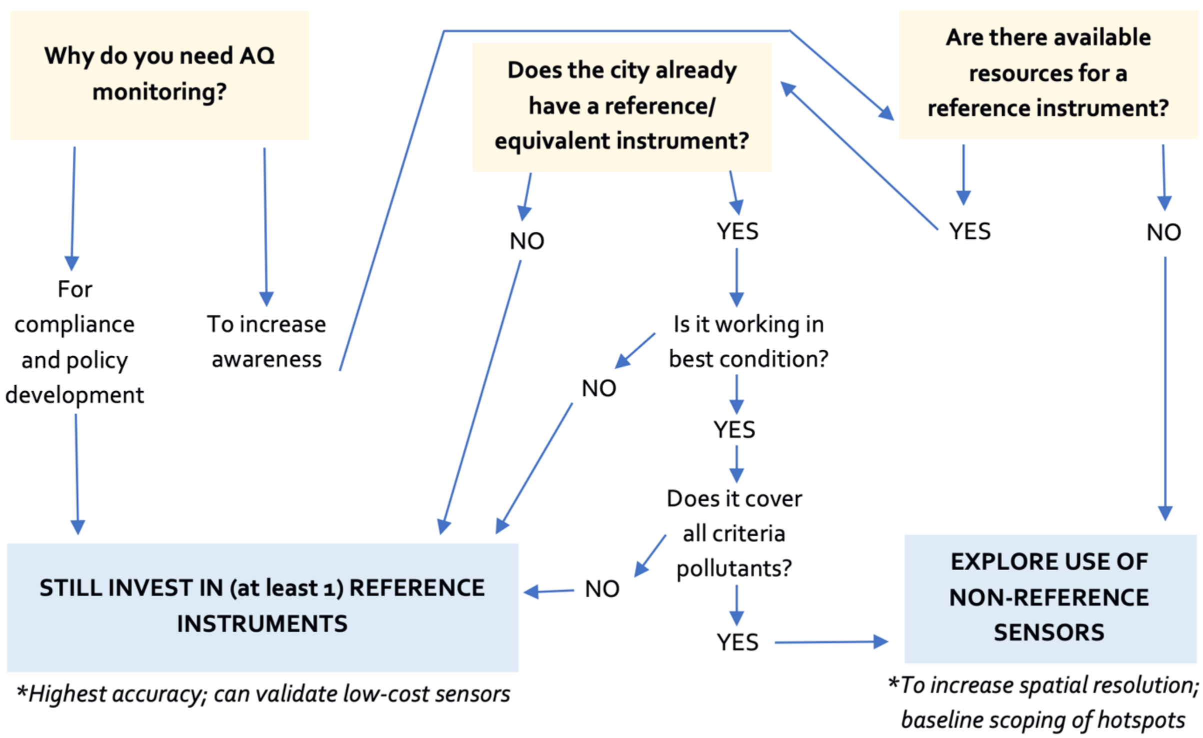
This module will specifically discuss the following:

- A quick guide on the various types of air quality monitoring instruments and how it can match the need of the city;

- A summary of considerations to be discussed in deciding which technology to adopt;
- A decision guide on how to implement an inclusive approach in the decision-making process; and,
- Case-study on the use of various AQ monitoring instruments

AIR QUALITY MONITORING APPROACHES

The decision tree below can be used as guide when deciding when to invest in conventional or non-conventional air quality monitoring technologies. The decision process is not straightforward and there are several factors to be considered, as shown as decision points in the diagram. These considerations include the objective of establishing or improving the air quality monitoring network, the availability of technical and financial resources for operating AQ monitoring instruments, and the pollutants of concern.



The following sections discuss essential steps and considerations that must be addressed to come up with well-informed decisions in addition to using the quick scoping diagram above. It is recommended to have a grasp and understanding of the available technologies on air quality monitoring. Afterwards, a screening method through weighing significant considerations must be made.

1. **Understanding air quality monitoring technologies**

In deciding whether to use conventional or non-conventional monitoring systems, the most time-consuming would be the research phase on which technology is available and fits the needs of the city.

While this document provides a brief introduction on air monitoring and more detailed information can be found in the Guidance Framework Guidance Area 1, it is a preliminary step to study the technological specifications of instruments that are locally available. This includes soliciting information from partners and suppliers, the process of which can run for one to two months minimum. The study and decision making process depend on the number of people focused on the activity, and urgency of the process as imposed by high-level decisionmakers.

The table below summarizes the different types of AQ monitoring technologies and the most common type of pollutants/parameters monitored.

Monitoring Parameters		**Non-conventional Methods**			**Conventional Method**
		Low cost sensors	**Remote Sensing/ Satellite-based**	**Non-equivalent/ Non-reference monitors**	**Reference/ Equivalent point monitors**
Criteria Pollutants	$PM_{2.5}$	✓	✓	✓	✓
	PM_{10}	✓	✓	✓	✓
	SO_2	✓	✓	✓	✓
	NO_2	✓	✓	✓	✓
	CO	✓	✓	✓	✓
	O_3	✓	✓	✓	✓
	Pb	-	-	-	-
Meteorological parameters		✓	✓	✓	✓
SLCPs	Methane	✓	✓	-	✓
	Black Carbon	✓	✓	NA	✓
	HFCs	-	✓	NA	✓
GHGs		✓	✓	NA	✓
Others (HAPs, PAHs, POPs, etc.)		-	NA	NA	✓

Commonly used conventional methods for Particulate Matter (PM) include Manual, Semi-Automatic High-Volume Samplers, a low-volume sampler MiniVol, Beta Attenuation Monitor (BAM), or a Tapered Element Oscillating Microbalance (TEOM). Various real-time monitors are also based on optics or laser-based detection and counting of particles.

Data from reference instruments may not be easily accessible unless connected to an online dashboard. Since complex reference instruments require higher capital and operating costs, as well as technically-trained personnel, most cities in Asia may not have adequate number of monitoring stations that can provide a high-resolution 'picture' or spatial map of air quality in the whole city. These concerns have led to the use of near-reference and low-cost sensors.

Low-cost sensors are more inexpensive options for monitoring changes in pollution levels and providing spatial distribution of air pollutants, but not used for regulation purposes because these sensors provide data with less accuracy compared to reference instruments. The low-cost sensors, however, can complement existing conventional methods to achieve specific objectives for air quality monitoring. Issues on data accuracy can also be addressed through thorough field validation and collocation (side-by-side placement of the instruments and correction of data to match that of reference instruments).

An advantage of these easily accessible sensors is that it can raise awareness and engagement of the public. Low-cost sensors have aided in involving the general public in air quality monitoring through citizen science. It must be noted, however, that proper evaluation of the capacity and limitations of the sensors, along with the quality of the generated data is necessary to avoid confusion and misinterpretation.

2. Considerations in decision making

Governments are mandated to perform air quality monitoring and are responsible for the purchase, siting, set-up, maintenance of air quality monitoring instruments and processing of data generated. However, the responsibility of AQM does not fall on the government alone. A more progressive approach of cities for AQM involves the engagement of the academe, local government offices (or sub-offices) other than the environment office, and private and civil society groups. Academic researchers can provide insights and technical advice on which air quality monitoring technology to adopt, while local government offices can give information that can confirm suitability of the equipment with the proposed sites. Private groups, on the other hand, can also be a source of resource (manpower and financial) needs that will augment the initiative to help invest on the desired air quality monitoring technology.

The following factors must be researched on, understood, and discussed with stakeholders, to decide on what type of technology can be adopted:

Objectives of the monitoring:

1. Will it be for timely-public reporting?
2. Will it be used for compliance?
3. Will it be for an impact assessment of an initiative or ordinance?
4. Will it be for long-term monitoring?

Available manpower and financial resources:

1. How much personnel time (workdays) can be dedicated for research, consolidation of information, and other related tasks?
2. What is the available technical capacity of personnel? Does it match operational requirements of the chosen technology? Is capacity building needed?

3. How much budget can be allocated for the purchase, operation, and maintenance of the monitoring activity?
4. What are other possible sources of financial, technical and manpower resources?

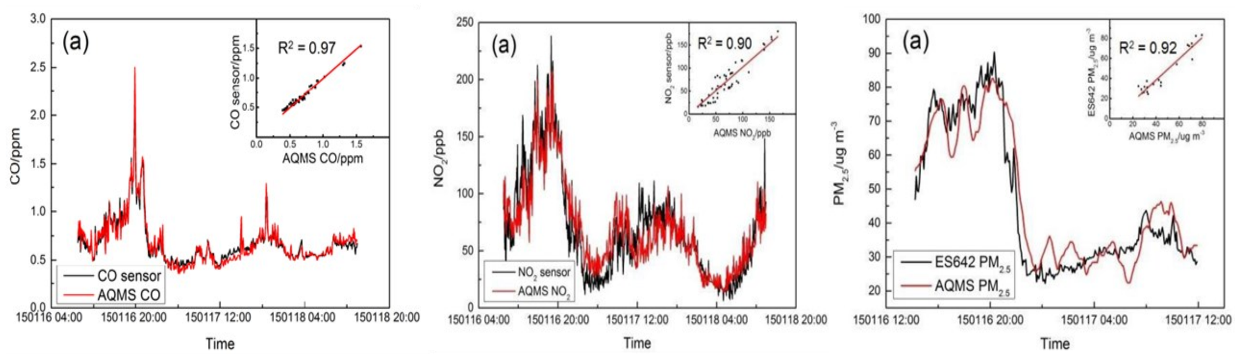
Objectives, costs, and key strengths for both methods are summarized in the tables below. Regardless of specific kind of technology, data accuracy and precision is the priority – requiring proper siting and quality control/quality assurance (QA/QC) of instrument and data.

METHODS	**Objectives Satisfied**	**Cost**
Low-cost sensors	timely-public reporting, impact assessment, long-term monitoring	$
Reference/Equivalent	timely-public reporting, impact assessment, long-term monitoring, compliance and planning	$$$$$$
Remote Sensing	impact assessment, long-term monitoring	$-$$$$$$
Non-equivalent	compliance and planning, impact assessment, long-term monitoring	$$$$$

Instrument category	**Key strengths**	**Key considerations**
Reference/Reference-equivalent	✓ Accuracy and reliability ✓ Recognition of governments as technology most apt for compliance checking	✓ Expensive price point for the unit, its housing, maintenance (obsolete units are more expensive to maintain) ✓ Requires ample space for installation, requiring additional safety and logistics ✓ Requires higher electric consumption (and costs) ✓ Requires more technical handling
Non-reference sensors	✓ Affordability (compared to reference instruments) ✓ Ease of installation and use	✓ Must be locally calibrated with a reference instrument ✓ Performance may decline after 2 years
Both	✓ Provides air quality data that can be used to achieve monitoring goals	✓ Requires proper siting, QA/QC of instrument and data

CASE STUDIES

Case Study: Air Sensor Network for Monitoring Air Quality during the 2015 Hong Kong, China Marathon



Next generation (low-cost) sensor-based air monitoring system deployed along the route of the 2015 Green Marathon in Hong Kong, China was able to detect immediate impacts of temporary traffic control on roadside air quality.

This study demonstrated the potential of low-cost sensors in supplementing existing air quality monitoring stations with high spatial and temporal resolution air pollution measurements. However, the study emphasized the need to: i) characterize performance of sensors in response to ambient environmental conditions, ii) understand sensor limitations, and iii) undergo quality control and assurance protocols to ensure reliability of results (*Sun, et al. 2016)*.

Case Study: Smart Personal Air Quality Monitoring System (SPAMS) for monitoring pollutant concentrations in urban microenvironments

In Chennai, India, a study was conducted to test the applicability of low-cost sensors for real time urban air quality monitoring and personal exposure assessment. A SPAMS consists of commercially available low-cost sensors that can measure CO, NO_2, O_3, and PM, relative humidity and temperature was developed. The sensors used showed good laboratory calibration and field validation results. Field measurements to obtain varying pedestrian exposure were obtained by walking on footpaths in three different locations (an urban background site, a busy traffic road, and a beach side road) and while travelling on three major bus routes. Results show that $PM_{2.5}$ concentration is highest in busy traffic site and lowest in urban background while CO concentration is lowest along beach road. Also, CO and NO_2 concentrations are higher in the morning and evening while travelling in buses due to the rush hours. This study was able to show that calibrated sensors can effectively capture spatial and temporal variations of pollutant concentrations at different urban microenvironments. However, it was also recognized that the low-cost sensors used are sensitive to temperature and humidity. Selection of low-cost monitors thus remains to be a challenge as their performance under varied environmental conditions is varied and not well documented (*Nagendra, et al., 2019*).

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