Integrated Programme for Better Air Quality (IBAQ Programme)

CITY SOLUTIONS TOOLKIT

PROPER SITING AND REQUIRED NUMBER OF MONITORING STATIONS

CONTEXT

There are several considerations in designing and developing a monitoring network for air quality management (AQM). The two factors that this document will focus on include: (1) guiding the user on the specific aspects of proper siting to answer the question 'where to measure', and (2) the minimum number of stations to be operated based on existing guidelines and best practice.

This document summarizes technical information on site selection and basic concepts on the types of monitoring systems to be established. This document informs the policy- and decision maker as well as practitioners to be guided on the number of monitoring stations, types of appropriate locations for these.

In this toolkit you will find:

1) A brief discussion on monitoring and the preliminary factors to consider in setting up monitoring stations or network. This will help in understanding further the approach to proper siting and choosing the number of monitoring stations to be setup based on the objectives of the monitoring plan or project.
2) A guide on siting and the prescribed number of stations.
3) Case studies on various monitoring schemes implemented in other cities.

In this toolkit, practitioners would be able to determine key factors involved in developing an air quality monitoring system. Preliminary knowledge will help in developing a monitoring plan based on monitoring objectives and techniques to match available resources. Understanding the scientific basis for proper siting of air quality monitors would avoid wasting resources and can ensure optimum data quality that to achieve the monitoring objectives.

In general, the optimal configuration of an air quality monitoring network must be able to capture temporal and spatial variability of pollutant concentrations, with the least number of monitoring stations, and at the lowest possible cost. This document aims to give the opportunity for stakeholders to look into these factors closely.

DEVELOPING AN AIR QUALITY MONITORING PLAN

Air quality monitoring requires extensive resources in terms of finances (for purchase of instruments and other consumables), manpower, and time. The total resources that will be utilized will depend on the monitoring objectives and the characteristics of the planned and established air quality monitoring system.

Below are a first key considerations to inform the development of an air quality monitoring plan:

Characteristics of Ambient Air Pollutant Concentrations

The following are characteristics of ambient air pollutant concentrations necessary to interpret monitoring reports properly (Illustration 1).

Pollutants present in ambient air is already a mixture of different local, area, and regional sources.

Concentrations vary spatially on different scales: local or neighborhood, urban, regional, hemispheric, or global scale.

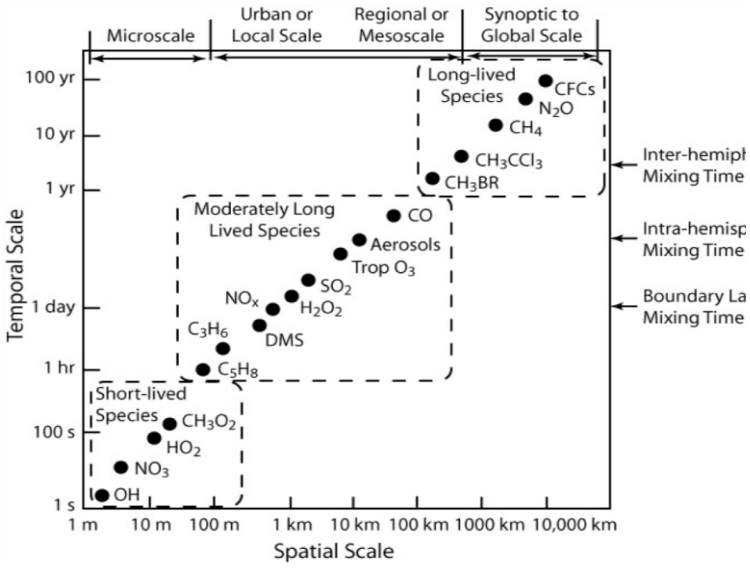

Illustration 1: Temporal and spatial scale of air pollutants (Source: Seifeld and Pandis, 2002)

Concentrations also vary with time, due to meteorological factors like temperature, pressure, relative humidity, wind speed, and wind direction.

Monitoring Objectives

It is important to determine the monitoring objectives before deciding on how many monitoring stations to establish and where to site them. Depending on your city's capacity for air quality monitoring, your monitoring objectives may fall under or can be a combination of these four categories: **timely public reporting, compliance or planning, impact assessment, or long-term monitoring**.

Summarized below are the specific objectives under the four categories mentioned (Table 1).

Basic Objectives	**Specific Objectives**
Timely public reporting	Assess short-term pollution levels
	Develop an air quality index (or other tools for data communication)
	Forecasting
	Activate emergency control procedures for episodic conditions
Compliance/Planning	Determine compliance levels with standards
	Observe pollution trends

	Formulate pollution control strategies
	Evaluate the effectiveness of pollution control strategies
	Support national and international agreements and initiatives
Impact Assessment	Assess impacts to different groups of populations
	Assess impacts of land use, transport plans and other control strategies and regulations to ecosystems and assets
	Develop and validate management tools (e.g. models)
	Discover new contaminants
	Develop and test analytical instruments
	Assess the impact of significant sources or source categories on ecosystems and assets
	To establish exposure-response and/or cause-effect relationships regarding the risk of human health, animals, crops and ecosystems
Long-term Monitoring	Observe long-term pollution trends
	Establish general background concentration levels

STAKEHOLDER ENGAGEMENT

The local government usually leads the process of air quality monitoring considering policies and ordinances, and in compliance with national laws and standards, such as national ambient air quality standards. This is often achieved through extensive collaboration with and review by technical experts either from the private sector or the academe. Other stakeholder groups may be involved such as the civil society and private sector to support infrastructure and roll-out of the air quality monitoring system. Other groups may include foreign collaborators for financing and expert review; people's organizations also form part of public engagement and could be a source of manpower for the collection of ancillary data to support monitoring activities.

THE METHODOLOGY

SITING

The locations of the monitoring sites depend on the monitoring objectives. The following are types of sampling sites that can be adopted based on monitoring objectives:

- **Population-oriented sites**: these sites focus on representing community exposure rather than monitoring at the expected maximum impact point for specific source emissions
- **Compliance sites**: these are selected to determine when air quality standards are attained or exceeded
- **Special Purpose Monitors (SPM)**: the sites aim to determine excessive concentrations from natural or man-made sources
- **Transport sites**: these monitor concentrations transported into and out of an area (e.g., coastal, intermountain, or transboundary)

- **Background sites**: regional or upwind locations where local man-made concentrations are not superimposed

Siting Considerations

Key considerations when choosing the locations of monitoring stations:

- **Provides adequate exposure** – The observations must provide adequate exposure levels, so the station should be set up at a location where nearby barriers and particle deposition surfaces are avoided.

  Minimize nearby barriers and particle deposition surfaces

- **Minimizes influence of nearby emitters** – The station should be outside the zone of influence of specific emitters, at a location with minimum number of nearby emitters.

  Monitor should be outside zone of influence of specific emitters

- **Maximizes collocated measurements** – The location maximizes other air quality and meteorological measurements, which can aid in the interpretation of high or variable particulate matter levels.

  Consider air quality and meteorological measurements to aid in the interpretation of high or variable PM levels

- **Ensures long-term site commitment** – The station can be maintained in the long term, so there should be sufficient operating space, accessibility, security, safety, power, and environmental control (mostly air conditioning).

  Maintain sufficient operating space, accessibility, security, safety, power, and environmental control

Zones of representation and pollutants

The location of the monitors is set to capture pollutants at the range of distances that they are expected to have travelled. Some general relationships are noted below:

- Collocated samplers are set up from one to ten meters from each other to reflect sampling precision. Multiple units of the same sampler are placed side-by-side to demonstrate similar performance (precision) and can also be compared to a reference instrument for accuracy.
- Odors, traffic emissions, hazardous air pollutants, and dust fall are monitored at the micro- and middle-scale, from 10 to 500 meters from their source.
- Vehicle exhaust, residential heating and burning, and primary industrial emissions are measured at 500 meters to 4 kilometers from their source, which represents neighborhood scale.
- Photochemical ozone, secondary sulfates, nitrates, organic aerosols, forest fires, and regional haze may be monitored at a distance of 4 to 1,000 kilometers, in the urban to regional scales.

- Large scale fires, Asian and Saharan dust are monitored at distances as far as 1,000 to 10,000 kilometers, considered as continental or hemispheric scale.
- Greenhouse gases, halocarbons, and black carbon may be measured at distances greater than 10,000 kilometers from their source, at the global scale.

Summarized in the table is the scale to which the monitoring system can be designed and deployed, based on the range and pollutants:

Zone	Range	Pollutants
Collocated	1-10m	For sampling precision
Microscale	10-100m	Odors, traffic, HAPs, dustfall
Middle-scale	100-500m	Odors, traffic, HAPs, dustfall
Neighborhood-scale	500m-4km	Vehicle exhaust, residential heating and burning, primary industrial emissions
Urban scale	4-100km	Secondary sulfates and nitrates
Regional scale	100-1,000km	O_3, secondary sulfates, nitrates, organic aerosol, forest fires, regional haze
Continental scale	1,000-10,000km	Large scale fires, Asian & Saharan dust
Global scale	>10,000km	GHGs, halocarbons, BC

Understanding monitoring station classification in relation with zones of representation

Monitoring stations serve various purposes. Thus, it is important to identify the monitoring objective that a station addresses to correctly interpret observations and data from the station. The various station types and their description are described below. Further guidance on types of monitoring instruments are provided in the module **Technology Options for Air Quality Monitoring: Conventional vs Next Generation**.

- A *general station* located in a sub-urban area may be set-up to capture neighborhood-scale to regional scale pollution, representing an area with radial distance of four to 100 kilometers. Such a station is set up for the determination of population exposure to air pollutants.

- *Roadside stations*, often set up in urban areas, are for hotspot monitoring. They represent an area within a radial distance of 100 to 500 meters from the source.

- A *general station in a rural area* with radial distance above 100 km is set up to monitor regional scale of pollution mainly from the transport sector.

- *Background sites* are set up to represent elevated regional zones, for an area with radial distance of 100 to 1000 kilometers from the source. They are used to determine transport of pollutants occurring at higher elevation.

Site Code	Zone of Representation	Scale of Representation (km)	Monitoring Purposes
General station (sub-urban)	Neighborhood/Urban	4-50	Exposure
General station (sub-urban)	Urban-Regional	50-100	Exposure/ Photochemical
Roadside station (urban)	Middle	0.1-0.5	Hot Spot
General station (rural)	Regional	>100	Transport
General station (background site)	Elevated Regional	100-1000	Elevated Transport (958m)

Other important points to consider after understanding the site codes:

- Regional background stations must be at least three kilometers away but no more than 50 kilometers away from built up areas.
- Urban background stations, whose zone of representation is at 1-km scale, should be away from local sources such as streets and industries.
- Stations that determine traffic impacts must be located at the curbside and along streets.
- Industrial pollution is captured downwind from industries.

Siting: Air Intake Design Location

Once the location of the station is determined, the following are additional considerations in setting up the station, particularly the air intake. In samplers, air intakes are an integral part where maintenance and location of the sampler would impact accuracy of measurements:

- Air intake for various pollutants should be at the same height above ground, ideally not below three meters from the ground (higher if resuspension of dust in the area is very likely).
- It should be placed away from buildings and local sources.
- There should be no obstruction of the inlet airflow from all directions.
- Vegetation canopies must also be avoided as they are sites for deposition of particulate matter, which causes inaccurate measurements

According to a baseline survey of air quality monitoring systems in 69 Asian cities (from 17 countries), several monitoring stations in developing Asian cities do not collect meteorological information (ADB and

Clean Air Asia, 2014). The absence of meteorological data reflects the limited modeling and forecasting capacity of most monitoring systems and must therefore always be collected in parallel with air quality data.

The city and agencies in charge of air quality monitoring must look into these elements in a holistic manner, to achieve the monitoring objectives and in the long-term, establishing a sustainable monitoring system with the best data quality.

Capacity building of the core air quality monitoring team would also be helpful prior to the design of the air quality monitoring plan. This would ensure a resource- and time-efficient approach in the determination of the number and location of air quality monitoring stations.

The following section provides case studies and examples for further guidance.

ILLUSTRATIONS

Air Quality Monitoring and Siting in China

The table shows the required minimum number of stations based on area and population (Source: Technical Regulation for Selection of Ambient Air Quality Monitoring Stations in China, 2013). T:

Population (million)	Area (km^2)	Minimum station points
<2.5	<20	1
2.5-5	20-50	2
5-10	50-100	4
10-20	100-200	6
20-30	200-400	8
>30	>400	Every 50-60 km^2 has one point, minimum of 10

Although the minimum number of stations are determined based on the population and area occupied by the population, different conditions may require a different criterion. For instance, areas with complex terrain or mixed emissions distribution most likely would require a higher number of monitoring sites to better represent local air quality (EC-JRC, 2012).

Air quality monitoring based on population exposure (EU and US EPA)

If the objective of the air quality monitoring is to determine exposure of the population to a specific pollutant, the following factors must be considered: time-activity data (time spent near/within areas of high pollution concentration) and actual areas of residence. Population of agglomeration zones must be mapped. Considerations considered by the European Union and US Environmental Protection Agency are summarized in the table below.

EU					US EPA (for PM_{10} sampling points)		
Population of agglomeration or zone (thousands)	If maximum concentrations exceed the upper assessment threshold		If maximum concentrations are between the upper and lower assessment thresholds		Population of agglomeration or zone (thousands)	Low pollution level	High pollution level
	Pollutants except PM	PM (sum of PM_{10} and $PM_{2.5}$)	Pollutants except PM	PM (sum of PM_{10} and $PM_{2.5}$)			
0-249	1	2	1	1	100-250	0	1-2
250-499	2	3	1	2	250-500	0-1	3-4
500-749	2	3	1	2	500-1,000	1-2	4-8
750-999	3	4	1	2	> 1,000	2-4	6-10
1 000-1 499	4	6	2	3			
1 500-1 999	5	7	2	3			
2 000-2 749	6	8	3	4			
2 750-3 749	7	10	3	4			
3 750-4 749	8	11	3	6			
4 750-5 999	9	13	4	6			
≥ 6 000	10	15	4	7			

Source: EC (2008), Asian Development Bank and Clean Air Asia (2014)

The minimum number of stations that must be set up depends on the population as well as the attainment status of the airshed. If the air pollutant levels exceed the standards or guideline values, more stations are needed, proportional to the population. The table shows the prescribed number of stations based on particulate matter levels and population size. Less stations are needed if the maximum concentration is between the upper and lower assessment thresholds.

REFERENCES:

Asian Development Bank (ADB) and Clean Air Asia (2014). Improving Air Quality Monitoring in Asia: A Good Practice Guidance. Mandaluyong City, Philippines.

Clean Air Asia (2019). Guidance Framework for Better Air Quality in Asian Cities: Guidance Area 1 - Ambient Air Quality Standards and Monitoring. Unpublished