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Location Of Low-cost Sensor-based Air Quality Monitoring Devices

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August 2020

Introduction

Monitoring the pollutant concentration is fundamentally important to develop and evaluate pollution control strategies. It enables us to understand the trend and extent of pollution by identifying pollution sources, and thereby indicating where more efforts are needed. It is important to ensure that the measured air quality provides adequate and accurate information. One of the key factors affecting the accuracy of monitoring data is the location and placement of the air quality monitor.

Inappropriately placed monitors lead to inaccurate measurement of pollutant concentration, which may not meet the data quality required for the given objective. Site selection is carried out by assessing various factors like scope of monitoring, meteorological conditions, the topography of the region, availability of space, distance from the source, presence of various obstructions, etc. This paper represents general and objective specific factors that affect air quality monitoring and how to choose the best location to place air quality monitors.

Representation and Comparability

Principal factors governing the selection of monitoring locations are the objective of the study, representativeness, and comparability of the data. To avoid influence by the sources that are not being investigated, it is important to select a site that is representative of the sources of interest. To be able to do that, it is very much important to clearly identify the objectives of the study. A representative site's data is capable of accurately reflecting concentrations and its fluctuations within the given area. Also, in order to carry out trend analysis, the selected site should remain representative for a long time. Moreover, sites, where land-use change and rebuilding are anticipated, should be avoided. Further, a standardized procedure of location selection should be followed to enable a comparison of monitoring data with past monitoring data and data from other monitoring sites

Preliminary Survey

A preliminary survey is carried out in the area of interest to understand local sources of emissions, population distribution in the region, land-use pattern, topography, meteorological factors, etc. Such details about the potential monitoring site guide in choosing the right spot for the monitoring. If emission data of potential sources are available, it can be used to model pollutant transport and dispersion. If such data are not available, then simply developing pollution-rose based on wind speed and wind direction can also give a fair idea about potential monitoring sites.

Effect Of Topography On Local Meteorology

Topographical features are capable of causing a particular meteorological change, which significantly affects the pollution dispersion in the region. Important topographical features to be

considered are mountains, valleys, hills, rivers, lakes, and oceans. Mountainous and sloped terrain may produce upslope and downslope winds generating canyon/valley structures. As a result, winds are channeled into a preferred direction, which may also increase local wind speed. The presence of large water bodies such as lakes, sea/ocean, etc. dominates local wind patterns by land-sea breeze circulation. Such circulations that determine the transport and dispersion of pollutants are highly variable in its extent and strength. Urban sites are also prone to local microclimatic conditions such as urban heat island (UHI), which changes urban wind patterns, and resultantly affects pollution distribution. As the unique topography of the region develops unique meteorological conditions, guidelines based on a general case cannot be developed and thorough analysis for local topography and meteorology must be carried out.

Apart from these general considerations, there are some of the considerations which are specific to the study objectives and nature of the site.

Urban Monitoring And Campus Monitoring

The common objective of urban air quality monitoring is to understand background concentration levels, pollution trends, and pollution exposure to people. Spatial scales associated with these studies are usually micro to middle-scale which range from about 0.5 km to 4 km. A preliminary study should be carried out to understand local emission sources such as diesel-generator (DG) sets, nearby roads, etc.

If the objective is to understand human exposure to pollution, the monitoring station should be placed in the human breathing zone at the height of 2-4 m. If the objective is to understand the background pollution or pollution trends of the region, the monitoring stations should be outside the influence zone of any direct emission sources at the height of 10-14 m. Usually, in the case of campus, housing society, etc. the monitor is placed in the periphery. To avoid pollution spikes from the traffic it must be placed a minimum of 50 m away from the nearby roadway. It should also be at least 100 m away from any other source of emission. If the objective is to assess the impact of a particular source, the monitoring station is located in the downwind direction of the emission, which is then compared with another station placed in the upwind direction. Such monitors also should be placed at the height of 10-14 m.

Roadside Monitoring

Emissions from the vehicular activity and pollution exposure on the roads require intensive monitoring owing to the sharp concentration gradients that are likely to be encountered. Maximum pollutant concentration from vehicular traffic is expected to be found in busy streets. Moreover, the presence of buildings across roads increases pollutant concentration by restricting natural ventilation. In general, the study location should be selected to provide an easy interpretation of roadway source contributions. The spatial scale associated with such monitoring is micro to the middle, which is suitable to assess vehicular pollution, and it can also accurately capture periodic pollution spikes. A monitor placed within 5-10 m from the roadway is expected to record a repre-

sentative concentration of traffic. The height of the monitor should not exceed 10 m. Air quality at intersections is generally unrepresentative and may be better or worse than the rest of the road, depending on congestion and air flows. Unless the road intersection is the specific objective of monitoring, it is advisable to not conduct monitoring at intersections, and instead should be carried-out mid-way along the block.

Also, the physical layout of the study location, including arrangement of roads, ramps, the intersection should be considered. Greater geometric complexity (locations that include two or more roadways and multiple ramps or interchanges) should be avoided. Locations with relatively flat terrain (gradient not greater than 5%) around the roadway should be considered, to ensure that the mobile source emission plume impacts the monitoring site in an unperturbed manner. Further, locations with other local emission sources within 1 km should not be selected.

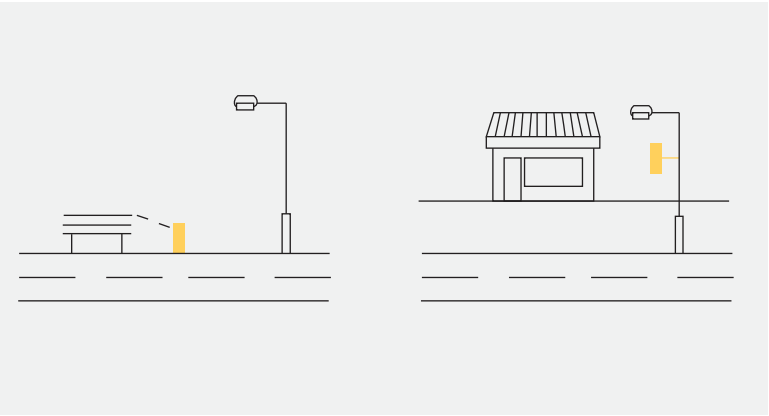

Fig 1: Kerbside and Roadside Monitoring Locations

Odour and Gas monitoring from Landfill

Gas emission monitoring and odor monitoring is of profound importance for dump yards, landfill sites, and incineration facilities. Usual gaseous emissions from dump yard/landfill include gases such as methane (CH_4), carbon dioxide (CO_2), hydrogen sulfide (H_2S), methyl mercaptan (CH_3SH), sulfur dioxide (SO_2), etc. Landfill fires pose a great public health risk. While surface fires are comparatively easy to manage and can be identified visually, subsurface fires are difficult to detect. Studies suggest that landfills with subsurface fires have carbon monoxide (CO) concentration of more than 1000 ppm. Monitoring CO concentrations acts as an indicator to take countermeasures to avoid subsurface fires. The landfill monitoring carried out must be representative of each section of the landfill. While gas monitoring is usually carried out within the waste-body and on the periphery of the landfill site, odor monitoring is usually carried out only on the periphery to avoid odor diffusion from the dump yard/landfill. Also, odor monitors should be placed in the vicinity, if sensitive receptors such as residential areas, schools, etc are present. The location of the monitoring site should be downwind, and should not be close to any other emission sources such as waste-to-energy plants, generator units, nearby roads, etc.

Odour Monitoring From WWTP and Industries

Odour is a parameter of concern for water and wastewater treatment plants and also for various industries. Gases such as methane (CH_4), hydrogen sulfide (H_2S), methyl mercaptan (CH_3SH), ammonia (NH_3), formaldehyde, total volatile organic carbon (TVOC), chlorine gas, etc. are the common cause of odour pollution.

Common sources of odor at the water and wastewater treatment plants are equalization tanks, digesters, aeration tanks, skimming tanks, drying beds, etc. In the case of industries, odor sources depend upon the type of industry. Such sources should be identified during the preliminary survey and the odor monitor should be installed in the downwind direction to the source.

Care must be taken while selecting an offsite monitoring location. It should be away from major sources of emission, such as roads, generators, or any other industrial unit.

Industrial Plant / Thermal Power Plant

Stack emissions from thermal power plants and industries are major contributors to ambient air pollution. The usual height of stacks is 30 m, which makes them elevated stationary emission sources. Due to such a height, the point of maximum impact is away from the source and may affect residential areas, ecological and archeological sites, etc. The maximum impact distance in terms of effective stack height is used as a guideline. Maximum concentration distance is usually found downwind between 10 times effective stack height to 25 effective stack height.

However, the distance of maximum concentration can be more accurately measured with the use of various air pollution dispersion models. The monitor is placed at the height of 20 m above the ground to effectively avoid the influence of fugitive and ground emissions like vehicular traffic.

Ventilation of Tunnel And Underground Parking

The air quality in the tunnel is relatively poor as compared to a surface road or ambient environment. The main objective of air quality monitoring in tunnels or underground parking lots is to understand whether the ventilation systems are working as planned or not, to assess the visibility level in order to avoid accidents, and to carry out exposure studies. The aim is to develop the link between ventilation and pollutant dispersion to determine the most effective protocol for the activation of ventilation systems based on real-time air quality levels.

Parameters of interest for tunnel monitoring are, visibility, NO, NO_2, CO, and particulate matter. The environment inside the tunnel is very different from the ambient environment and that makes the choice of monitoring location crucial to get representative data. Various factors affecting the air quality concentration discrepancies are turbulence in the tunnel, piston effect generated due to vehicular movement, type of ventilation system, road design in the tunnel, etc. Air pollutant concentration in the tunnel can vary significantly with depth and across the cross-section. In order to get representative concentration, air quality monitoring is carried out in the ventilation stacks, as well as at the ground locations. It should be placed both, on the roof and roadside locations to get representative concentration. The sites selected should have minimum interference from turbulence. Curved sections should be avoided for monitoring sites. Tunnels may face communications issues.

In such cases, monitors are given wired connection instead of wireless communication protocols.

In the case of underground parking facilities, at least one monitoring device should be provided at each entrance and exit point. The Inlet port must be placed at a minimum distance of 1.8 m above the floor surface. Its placement should be closer to the ventilation exhaust inlet than the supply air outlet. Interference from unwanted emission sources must be avoided. Monitors can be placed on the roof or light pole. Air quality monitoring for underpasses should be carried out similarly.

Airport Monitoring

The aviation industry emits high concentrations of NO_2, SO_2, Volatile Organic Compounds (VOC), and unburnt hydrocarbons. As a result, ground-level pollution due to landing and takeoff (LTO) is of particular concern for airports along with the background concentrations due to vehicular and domestic emissions.

The location of the monitoring device depends on the scope of studies like the evaluation of background concentrations, infrastructural changes, operation optimization (taxi in and out timing, runway utilization, etc), and development of emission inventory. General guidelines are issued by the International Civil Aviation Organization (ICAO) in Ambient Air Quality Manual. The figure depicts the location of the devices and the table justifies each location based on the purpose of monitoring.

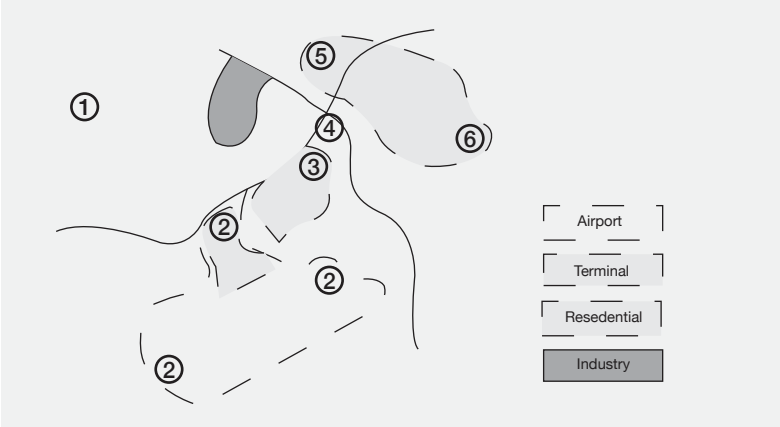

Fig 2: Generic Site Selection Plan for an Airport (Circled Arrow: Prevailing Wind Direction)
Source: Airport Air Quality Manual, International Civil Aviation Organization.

Site 1: A background concentration site for background and baseline data where the airport is located.
Site 2: (Both 2a & 2b) Location within the airport area for reflecting intense airport activities like aircraft handling, infrastructure, take-off, and landings, etc.
Site 3: Residential area downwind to the airport which reflects the average situation of residential sites.
Site 4: Next to a major traffic road to study road traffic impacts on local air near the airport vicinity.
Site 5: Another residential area downwind of an industrial area to discriminate between the airport and industrial emissions.
Site 6: Station is located further downwind from the airport for general monitoring purposes.

Mining and Construction

Dust, sand, ashes, and saw-dust are the majo pollutants at mining and construction sites. Due

to larger site areas, both fixed and optional mobile monitoring stations can be provided over the site and on the site perimeter. The preliminary survey includes identifying the sources of dust generation, meteorological survey for determining predominant wind speed and wind direction, background emission study, etc. Monitoring devices like Oizom's Dustroid can be placed at sites where the workers are exposed to dust, near the source of generation, site perimeter, etc.

General conditions from a report of National Mineral Development Corporation, India states that four ambient air quality monitoring stations should be established in the core zones and buffer zones of mining. Monitoring should be carried out for respirable particulate matter, suspended particulate matter, sulfur dioxide (SO_2), and oxides of nitrogen (NOx). The location of stations should be selected based on the meteorological data(downwind and upwind conditions), topographical features, environmentally and ecologically sensitive targets. Respective regulatory authorities are consulted for further instruction (SPSB in case of India). For larger mining areas, satellite imagery/data is used as auxiliary data to identify the potential sites for dust generation and exposure to establish appropriate monitoring stations.

In the case of construction sites, the monitoring stations are placed on the periphery of the site. Dust dispersion analysis is carried out through the perimeter air monitoring (PAM). Off-site monitors are placed in the downwind location as receptors. Fixed/Mobile monitors are placed inside the site for exposure monitoring. The sampling height should be more than 2 meters from the ground.

A clear angle of minimum 270 degrees is favorable to cause minimum obstruction to the wind. Monitors can be integrated with automatic sprayers to optimize dust suppression.

Site Selection- Local Factors

After finalizing the site for the monitoring, there are few local factors that should be considered in order to measure representative pollutant concentration.

Obstruction

Obstruction due to buildings, walls, trees causes a change in wind speed and direction and blocks the air, which generates erroneous data. A pole having the 270° clear angle is suggested for air monitoring as compared to the wall installation (clear angle is 180°). However, in any case, a minimum of 120 degrees of a clear angle must be provided. USEPA and Indian Standards (IS-5182:14) recommends a clear spacing of 2-5 m from building and infrastructure. The orientation of the device should be North facing without any obstruction. Clearance of a 1-meter radius from the device is provided for auxiliary devices such as routers, weather stations, CCTV cameras, etc, and for effective sampling.

Moreover, in the absence of a pre-existing pole or wall, tripods can be used, as Oizom devices are lightweight and can easily be installed on a tripod. Wind speed and direction data are required for setting up the tripod as it is more likely to get damaged in high wind speed conditions and also poses a threat of theft and vandalism.

The top of the monitoring devices measures light intensity, UV radiation, and rainfall that help to understand the reaction chemistry of ozone with other pollutants. Shadows must be avoided from; overhanging foliage, roofs, sheds, buildings, walls, etc. Air pollutants like particulates and

gases (SO_2, O_3, NO_2) get adsorbed on building surfaces and trees, which under-estimates the actual results. To avoid that, monitoring stations should be placed at a minimum distance of 2 m from building walls and 10 m from the drip line of the trees.

Theft And Vandalism

The Oizom devices are strong and sturdy to face the direct impact of birds and animals. Users can provide a cage for additional safety against birds and monkeys. However, care must be taken to avoid flow obstruction due to such an arrangement. Oizom devices are equipped with the anti-theft feature. When any individual forcefully tries to tamper the device it will alert the occupier and the company through the smart alert system. Moreover, CCTV cameras can be placed just above the device to detect any unusual activities.

Mobile/ EMF Towers

The electrochemical sensors have different electrodes which detect and measure air pollutants like Carbon Monoxide (CO), Sulphur dioxide (SO_2), etc.. These sensors get affected due to the electromagnetic forces (EMF) and installation near the sources of EMF should be avoided. Common sources of EMF are mobile network towers, transformers, and generators. The siting guidelines of New Zealand and Australia also recommend avoiding high voltage lines and other electrical sources mentioned above to prevent any electrical interference.

Power Source

The electricity source should be present near the monitoring device for power supply. However, in the absence of a power source Oizom devices can also operate on solar energy. Solar panels can be installed at the pole itself. A preliminary study should be carried out to calculate the solar insolation and angle of the incidence for maximum solar energy generation. In case of power failure, the device is also equipped with 3 days of battery backup that keeps the device in working condition.

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