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Spatiotemporal Variation of Air Pollution in Public Transport Facilities using an Integrated IoT-GIS-based Sensor Monitoring Network in Hong Kong

Objectives

(i) Objective #1: Development and application of IoT-based sensors for a monitoring network of multiple air pollutants at representative semi-enclosed public transport interchanges (PTIs);
(ii) Objective#2: Elucidation of spatial variability of multiple air pollutant concentrations in PTIs using a geographic information system (GIS) to determine of pollution hotspots at PTIs and best fitted interpolation models in air pollution studies.

Methods

Integrated air quality sensor (IAQS)
Several important design criteria have been identified for a system to ensure it is capable of continuous monitoring of indoor air quality inside public transportation interchanges (PTIs): the system must be compact and lightweight to allow easy transport within multiple locations in a PTI; have high sensor integration to allow air pollutants, temperature, and humidity to be measured in real time; have wireless data communication for real-time air quality transmission; and have sufficient battery power to allow at least 8 hours of remote field operation.
Considering the above-mentioned criteria, we develop an integrated IoT air quality sensor (IAQS). The data are transmitted by the IAQS to the server in the IoT laboratory. The IAQS is capable of measuring PM2.5, CO, and CO2. It has been reported that many air quality sensor devices for industrial/ commercial uses are not well. In this study, we aim to develop low-cost IAQSs which are reliable for research purposes and industrial/ commercial applications with improved precision and accuracy, high sensitivity and rapidity.

Sampling
A systematic sampling will be adopted where the sampling field is divided into regularized grid squares (about 25m x 25m) and 1–2 samples will be collected in a grid unit individually. Air pollutants are to be automatically monitored at multiple locations (i.e., 5 locations) within each PTI for 40 minutes at 5 semi-enclosed representative PTIs. For monitoring multiple PTIs, the air quality data from IAQS are stored in the cloud, where it can be accessed using a computer, mobile phone or tablet. A web-based system will be deployed for air quality data visualization and management.
Air pollutants inside public transport modes (i.e., buses) have been measured using the IoT air quality sensors. Long-haul bus routes (3 Nos.) were selected in this study and the measurement for each bus route was conducted 3 times during the measurement campaigns.

Spatial analysis using GIS technique
Spatial analyses will be performed using ArcGIS Pro 3.0 (ESRI). The spatial distributions of air pollutants (i.e., PM2.5, CO and CO2 concentrations) are depicted in a spatial map in which kriging was used for interpolation. This will enable the generation of instantaneous snapshots of pollution maps to identify pollution hotspots and to clarify the spatiotemporal changes of these pollutants within PTI microenvironments. A theoretical model will be fitted for the kriging interpolation; the experimental semivariogram is calculated using the gstat and sp library in GStat-R. A given experimental variogram is then approximated by the theoretical models (i.e., Gaussian, Exponential and Spherical semivariogram models). The best fitted models will be recommended for interpolating the air pollutants.

Results

An IoT-based air sensor measurement network will be established in representative PTIs in Hong Kong. The current air pollutant concentrations inside PTIs and public vehicles in Hong Kong were measured using an air quality sensor monitoring network, and the results will provide critical information on pollutant concentrations and driving factors affecting these. Additionally, the spatial variability of pollutant concentrations inside the PTIs will be analyzed using the GIS. Various kriging interpolation methods coupled with semi-variogram models will be deployed and the best-fitted models will be recommended for interpolating the air pollutants. Recommendations will be formulated to rectify pollution hotspots inside the PTIs, and through the continuous monitoring of air pollutants, practical measures will be developed to reduce the concentrations of air pollutants to below the stipulated maxima. The results of the proposed project will be used to formulate long-term strategies to manage air quality in PTIs in Hong Kong. These strategies will also be applicable in other semi-enclosed environments with similar settings.

Conclusions

An improved understanding of spatiotemporal variations of toxic pollutants will contribute to the efforts to mitigate the sources and address public health challenges from air pollution inside the semi-enclosed PTIs and provide scientific evidence for relevant departments to formulate more targeted air quality improvement measures.

Keywords: public transport, health risks, particulate matter, gaseous pollutants, IoT technology, sensor, GIS analysis, Spatial interpolation technique

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