Science of the Total Environment 619–620 (2018) 1308–1318

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Urban local air quality management framework for non-attainment areas in Indian cities

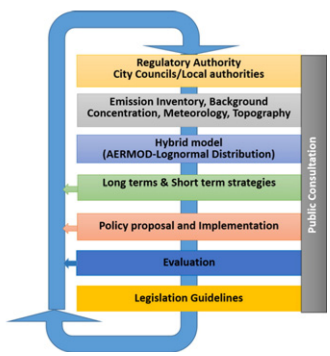
Sunil Gulia [a], S.M. Shiva Nagendra [b], Jo Barnes [c], Mukesh Khare [a,*]

[a] Civil Engineering Department, Indian Institute of Technology Delhi, Hauz Khas, New Delhi, India
[b] Civil Engineering Department, Indian Institute of Technology Madras, Chennai, India
[c] AQMRC, University of West of England, UK

HIGHLIGHTS

- Local scale air quality management is an important tool for better urban air quality.
- ULAQM framework is based in prediction of hybrid model.
- ULAQM framework tested for NO_x and $PM_{2.5}$ concentrations at Delhi and Chennai locations in India.
- ULAQM significantly reduce the NO_x and $PM_{2.5}$ concentrations.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 20 August 2017
Received in revised form 20 October 2017
Accepted 10 November 2017
Available online 23 November 2017

Editor: P. Kassomenos

Keywords:
Urban local air quality management framework
Non-attainment area
Vehicular pollution
Episodic condition
Hybrid model

ABSTRACT

Increasing urban air pollution level in Indian cities is one of the major concerns for policy makers due to its impact on public health. The growth in population and increase in associated motorised road transport demand is one of the major causes of increasing air pollution in most urban areas along with other sources e.g., road dust, construction dust, biomass burning etc. The present study documents the development of an urban local air quality management (ULAQM) framework at *urban hotspots* (non-attainment area) and a pathway for the flow of information from goal setting to policy making. The ULAQM also includes assessment and management of air pollution *episodic* conditions at these hotspots, which currently available city/regional-scale air quality management plans do not address. The prediction of *extreme* pollutant concentrations using a hybrid model differentiates the ULAQM from other existing air quality management plans. The developed ULAQM framework has been applied and validated at one of the busiest traffic intersections in Delhi and Chennai cities. Various scenarios have been tested targeting the effective reductions in elevated levels of NO_x and $PM_{2.5}$ concentrations. The results indicate that a developed ULAQM framework is capable of providing an evidence-based graded action to reduce ambient pollution levels within the specified standard level at pre-identified locations. The ULAQM framework methodology is generalised and therefore can be applied to other non-attainment areas of the country.

* Corresponding author: Room No. 220, Civil Engineering Department, Block –IV, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India.
E-mail addresses: sunilevs@gmail.com (S. Gulia), shivanagendra@yahoo.com (S.M.S. Nagendra), Jo.Barnes@uwe.ac.uk (J. Barnes), mukeshk@civil.iitd.ac.in (M. Khare).

http://dx.doi.org/10.1016/j.scitotenv.2017.11.123

1. Introduction

Urban air pollution (UAP) is a major concern in most megacities (with population > 10 million) around the world. The pollution level exceeds the national and international ambient as well as health- based air quality standards (Gurjar et al., 2008; Marlier et al., 2016). The growth in urban population and associated increased volume of motorised traffic in cities are majorly responsible for severe air pollution (MoPNG, 2003; Badami, 2005; Molina et al., 2007; Singh et al., 2007; Wang et al., 2010; Kumar et al., 2017). The sudden rise in vehicle exhaust emissions during *peak* traffic period results into extreme air pollution events (episodes) at *urban hotspots* (Chelani, 2013; Pant et al., 2015; Cakmak et al., 2014). Urban hotspot is the location in the city where air pollution level are already fails or likely to fails to meet national ambient air quality standards (NAAQS) due to high source activities or adverse meteorological condition or both. Mostly, the central business districts, busy traffic intersections and heavy trafficked congested roadways convert in to urban hotspot (Gokhale and Khare, 2007; Kanlindkar, 2007; Tiwari et al., 2012). Due to the heterogeneous and unplanned growth of cities in developing countries, the movement of vehicles is non-uniform throughout the city, which results in high spatial variations in pollutant emissions leading to formation of urban *hotspots*. In addition, topographical and meteorological variations in urban areas lead to complex spatial and temporal variations in pollutant concentrations (Gokhale and Khare, 2007).

Over the last few years, increasing air pollution in mega and growing cities in India has become one of the major problems affecting the environment (Gurjar et al., 2016; Amann et al., 2017). Air pollution concentrations frequently exceed NAAQS especially during the winter season when atmospheric dispersion potential is very low (Guttikunda et al., 2014; Gulia et al., 2017a). In particular for Delhi city, increasing concentrations of particulate matter (PM) result in tens of thousands of premature deaths and six million asthma attacks each year (Guttikunda and Goel, 2013; Lelieveld et al., 2015). Kesavachandran et al. (2015) have reported that those undertaking physical exercise outdoors at locations with higher $PM_{2.5}$ (≤2.5 μm in aerodynamic diameter) concentrations in Delhi are at a risk of lung function impairment. Further, Maji et al. (2017) have estimated that mortality attributable to PM_{10} in Mumbai and Delhi has increased by ~1.6 and ~2.5 times, respectively in year 2015 compared to year 1995. However, annual average mortality due to $PM_{2.5}$ in Mumbai and Delhi was reported 10,880 and 10,900, respectively in the year 2015. They also estimated that total economic cost increased from US$ 2680.87 million to US$ 4269.60 million for Mumbai city and US$ 2714.10 million to US$ 6394.74 million for Delhi city from year 1995 to year 2015 due to increased PM_{10} concentrations. Therefore, there is a need to reduce air pollution exposure related health impacts which can be accomplished by controlling/managing the increasing urban air pollution loads through an efficient and effective integrated management plan.

Current air quality management practices/action plans (AQMP) (CPCB, 2009; NILU, 2007; Sivertson, 2008; Moussiopoulos et al., 2010) are useful at the city level but inadequate to address sudden rises in pollution at an urban hotspot or non-attainment area (NAA). Each NAA is unique in terms of spatial and temporal patterns of emission sources. Therefore, one of the essential requirements is the site specificity of an AQMP, which make it capable of effectively dealing with the complexity of atmospheric changes, topographical constraints and pollution sources at local scale. The concept of air quality management at a local level, as required by the Environment Act 1995 in the United Kingdom (UK), is described by Longhurst et al. (1996) for notified air quality management areas. The researchers emphasise the importance of the role of relevant local government departments, for air quality management at a local scale. Later, Beattie et al. (2002) have reviewed the working pattern of various local authorities in England and found gaps in joint working between departments within the authorities and with non- local government agencies impacted on the successful implementation of the local air quality management process. They also observed a lack of political will and funding for implementation of mitigation measures for air quality improvement. As a result, they suggested that effectiveness of particular measures should be evaluated not only based on scientific and economic parameters but also on public and political acceptability. In the UK, local air quality is still managed through an improved version of the Local Air Quality Management (LAQM) framework (DEFRA, 2016). Following the UK LAQM approach, Gokhale and Khare (2007) have also introduced the concept of an episodic urban air quality management framework to control CO pollution for Delhi city. However, this is currently a theoretical framework and not tested to evaluate the impacts of interventions. Recently, Li et al., 2017 suggested that air quality management strategies, including regional environmental coordination and collaboration, restrictive vehicle emission standards and promotion of public transport should strictly implement for improvement of urban air quality. They also reported that source apportionment based on high time resolution of trace element can be a powerful tool for local air quality management.

The present study aims to formulate an urban local air quality management (ULAQM) framework to manage the *exceedences* of air pollution thresholds at specified locations in urban areas in Indian cities. Further, the developed framework has been tested theoretically to investigate its effectiveness in reducing NO_x and $PM_{2.5}$ concentrations in Delhi and Chennai cities, respectively.

2. Status of vehicular air pollution in India

Motorised vehicles have emerged as one of the major contributors to increased levels of urban air pollution in India (Sharma and Dikshit, 2015; Kumar et al., 2017; Dhyani et al., 2017). The population of registered vehicles in India has increased from 67 million in 2003 to 210 million in 2015 (MoRTH, 2017). Similar growth has been observed in fuel consumption. Based on 2012–13 data, India's total diesel and petrol consumptions were 69.74 and 15.7 million tons, respectively with the transport sector accounting for about 70% of diesel and 99.6% of petrol consumption (MoPNG, 2013). In Indian metropolitan cities (Delhi, Mumbai, Kolkata, and Chennai), ambient PM concentrations frequently violate the NAAQS as well as WHO guideline thresholds (Gupta and Kumar, 2006; Singh et al., 2007; CPCB, 2010a, 2010b; Gupta et al., 2010). Ramachandra and Shwetmala (2009) have reported that India's transport sector emits 258.10 Tg of CO_2, of which 94.5% is due to motorised road transport. The Central Pollution Control Board (CPCB) Delhi has reported that vehicular emission contribution to the total urban air pollution in Delhi and Mumbai is about 76–90% for CO, 66–74% for NO_x, 5–12% for SO_2 and 3–12% for PM (CPCB, 2010a). In the recent past, Sharma and Dikshit (2015) have estimated that approximately 12.9 Ton/day, 11.6 Ton/day, 113.4 Ton/day, 1.2 Ton/day and 322.4 Ton/day of PM_{10}, $PM_{2.5}$, NO_x, SO_2 and CO, respectively are emitted from in use road vehicles in Delhi city. This indicates that urban air quality in developing countries is deteriorating due to high vehicular activities and related inadequate management practices. The following sub-sections discuss the sources and other related air pollution issues in two Indian megacities, Delhi and Chennai cities (Sections 2.1 & 2.2) which have also been considered as case study examples in the application of the developed ULAQM.

2.1. Delhi city

Delhi city has a population of 16.8 million, which has grown at a decadal growth rate of 47% (Census, 2011) spread over an area of 1483 km^2 at average altitude of ~215 m above mean sea level. The city faces heavy seasonal climatic variability. For example, temperature varies from minimum of 4–5 °C during the winter (months of December–February) to maximum of 45–48 °C during the summer (months of March–May) (Perrino et al., 2011). The winter season faces frequent ground based inversion conditions which restrict the dispersion of pollutants. Further, the monsoon season experiences >80% of the annual rainfall. Studies consistently show high PM_{10} and $PM_{2.5}$ concentrations