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Evaluation of control strategies for industrial air pollution sources using American Meteorological Society/Environmental Protection Agency Regulatory Model with simulated meteorology by Weather Research and Forecasting Model

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ABSTRACT

Industrial air pollution creates severe problems and evaluation of control scenarios rationally which can be carried out using air quality models. In this study, an industrial region Chembur in Mumbai city was selected to estimate air quality change for various control scenarios. Weather Research and Forecasting (WRF) and AMS/EPA Regulatory Model (AERMOD) were used for this study. Since, the industries of Chembur region were already existing and residential and commercial zones were pre-set in the domain, so scenarios like increment of stack height and fuel change of industries can help to make better and healthier air quality. Scenarios selected were the 10% (SH1), 25% (SH2) and 50% (SH3) increment of height of stacks of industry and use of low emission fuel (F1 and F2) in the industries. Industrial air pollution modelling was done for current scenario as well as proposed control scenarios. The reduction of air quality level for each control scenario was calculated. Overall scenario SH3 as expected had more or less maximum reduction at ground level concentration for various temporal cases for all pollutants. However, it would cause more residence time of pollutants in atmosphere. Also this scenario was not based on source emission reduction strategy. Scenario F1 considers fuel with lowest emission and source emission reduction strategy. Therefore, scenario F1 seems to be the most preferred option for all pollutants among all scenarios. This study can help in taking objective and rational decisions for control scenarios for industrial sources.

1. Introduction

Concentration of air pollutants is high in urban areas and is largely derived from vehicular and industrial sources as well as population congestion. This causes climate change and a spectrum of health effects ranging from eye irritation to death (Bamniya et al., 2012a; Ilyas et al., 2007, 2010; Panepinto et al., 2014; Sharma, 2010). The control strategies are easy to implement for industries as they are within regulatory requirements. Therefore, the study of control scenarios is needed for air quality management framework of industrial regions.

Many air quality monitoring stations have been installed to control and regulate environmental pollution. Also, monitoring data can help to identify the source type and location with the help of meteorology (Clarke et al., 2014). But monitoring technique does not help to evaluate the efficiency of control strategies of air pollution sources. Few case studies have been analysed to control air pollution for industries using control devices and specific road-side trees in industrial region of India (Bamniya et al., 2012b; Bandyopadhyay, 2011; Furlan et al., 2007). Various air quality studies and some control options have been carried out to mitigate air pollution based on emission control strategies (Moraes et al., 2002; Sivacoumar et al., 2001; Vafa-arani et al., 2014; Vieira de Melo et al., 2012; Wei et al., 2015). The achievements of the co-benefits of climate change and air pollution reduction have been carried out in different sectors through policy measures (Jiang et al., 2013; Kanada et al., 2013). Five factors such as coal pollution

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intensity, end-of-pipe treatment, energy mix, productive efficiency change, and production scale changes were considered to control emission from industrial sectors and this reduced 65% dust emission over 10 years (Fujii et al., 2013). Policies and regulations were focused on prevention and control $PM_{2.5}$ pollution level and current status of $PM_{2.5}$ were illustrated (Zhang et al., 2015). Many other studies have been carried out for air pollution control for various perspectives like energy system and management (Liu et al., 2003; Zhu et al., 2013; Zhou et al., 2014). In these studies, evaluations of control strategies and modelling approach have been attempted. All these studies have been performed on estimated emission but dispersion modelling has not been carried out to include atmospheric dynamic. Modelling techniques can help to evaluate the efficiency of control strategies and provide concentration profile of air pollutants in spatial and temporal scale. Various control scenarios and their efficiency can be studied using modelling to improve ambient air quality before applying management plans (Bandyopadhyay, 2009; Mukherjee, 2011; Sappurd and Al-damkhi, 2011). This methodology is useful to make environmental policy for rational air quality management by regulatory authorities (Jiménez-guerrero et al., 2007; Mumovic et al., 2006; Sax and Isakov, 2003; Thunis et al., 2012a, 2012b).

Modelling requires emission inventory, geographical characteristics and meteorological parameters. In emission data, emission from sources such as vehicles, industries, bakeries, open eat burning and domestic sector are needed. Geographical data such as terrain data and base map are needed. In meteorological data, nine parameters such as wind speed, wind direction, rainfall, temperature, humidity, pressure, ceiling height, global horizontal radiation and cloud cover are needed. Data availability of the region for the study is a crucial issue in modelling. The estimation of emission of industrial sources can be done for each stack as point source. Generally meteorological data are taken from nearby recognized meteorological station and it is interpolated with time and space to the study site. This leads to major inaccuracy. Number of meteorological stations in India is comparatively less, thereby getting accurate meteorological data valid for the site under study for air quality modelling is a severe problem. Hourly onsite meteorological data can be provided by WRF model and this can increase the accuracy with saving time and resources. A recognized air quality model AERMOD has been applied in study because it has been used in many case studies for air quality modelling for various perspectives (Khare and Sharma, 1999; Kumar et al., 2015; Mohan, 2011; Mokhtar et al., 2014; O'Shaughnessy and Altmaier, 2011; Rood, 2014; Seangkiatiyuth et al., 2011; Tartakovsky et al., 2013; Zou et al., 2010). Coupling of AERMOD with WRF has been reported for existing air quality but control scenarios have not been considered by Kesarkar et al. (2007).

The aim of this study is to formulate an air quality management framework for industrial air pollution based on impact of different control scenarios using air quality models. Many studies have been done for air pollution reduction. Since, the industries of Chembur region are already existing and residential and commercial zones are pre-set in the domain, thus, in the present study, not all control strategies can be applied. Moreover the data needed to apply these control strategies cannot be obtained. Hence, two control strategies could be tested. These are based on increment of stack height and fuel change. Some control strategies for industrial sources based on abatement of emissions which included cleaner fuel substitution, change in basic production processes, and pollution abatement through flue gas treatment modifications of exit gas characteristics besides shifting of industries outside the city premises have been evaluated (NEERI, 2010).

In the present study, air quality modelling has been done for industrial sources of Chembur region of Mumbai city using simulated meteorology by WRF model. Various control scenarios have been applied for industrial sources and impacts have been quantified for each control scenario. Further, ranking has been made for the control scenarios. This would be useful for making decisions and policy for air quality management of an urban region.

2. Study area

The industrial area of Chembur in Mumbai was one of the most polluted areas about 20 years back (Gupta and Kumar, 2006). However, sustained efforts and public pressure led to series of control measures by authorities and industries. But even now, Chembur is one of the most densely populated and highly industrialized areas of Mumbai city. In the last two decades, the region has changed in terms of closure of many industries, high-density residential development and increased vehicular density. Four major industries such as two refineries, one fertilizers and one power plant still exist in this region. The Chembur region has a score 69.19 in the Comprehensive Environmental Pollution Index (CEPI) score published by Central Pollution Control Board, Government of India, for various industrial regions in the country, which indicates that this region should be rated as severely polluted area (CEPI, 2010). Hence, this region should be kept under surveillance and pollution control measures should be efficiently planned and implemented for this region. The latitude and longitude of Chembur are 19.05° N and 72.89° E respectively. The study area is 6.5 km east-to-west and 8.45 km north-to-south as shown in Fig. 1. Major industries in this area are Bharat Petrochemical Corporation Limited (BPCL), Hindustan Petroleum Corporation Limited (HPCL), Tata Power Corporation Limited (TPCL) and Rashtriya Chemical Fertilizers Limited (RCFL). The residential block mainly covers Anushakti Nagar Colony, Tata Colony, BPCL, RCF Colony, Mhada Colony; and Chembur Colony area. North boundary of study area is Sindhu Society and Shivnery nagar. South boundary is TPCL, west boundary is RCFL and Mahul and east boundary is Shahyadri Nagar and Prayag Nagar. Emission data were collected for four major industries namely BPCL, HPCL, RCFL and TPCL for air quality modelling. The annual average of stack emission data (g/sec) was used for each stack in air quality modelling. Terrain data and base map are needed for modelling. Hourly nine meteorological parameters were generated using WRF model at 25 km resolution.

3. Methodology

The methodology of the study has been given in Fig. 2. The emissions for NO_x, SO_2 and PM were estimated for each stack of four major industries of Chembur region for the year 2011 for existing scenario. These emission inventories were fed based on actual spatial locations of stacks in the base map. Onsite hourly meteorological data were generated by WRF model version 3.2. The model domain extends between 71°E to 81°E zone and 11°N to 21°N meridian consisting of 100 by 100 grid points with 25 km grid spacing. NCEP FNL (Final) Operational Global Analysis data with $1.0 \times 1.0°$ grid and six hours temporal resolution were been used as an input of WRF. This product was from the Global Data Assimilation System (GDAS), which continuously collects observational data from the Global Telecommunications System (GTS) and other sources. The model run was performed from 1st January to 31st December of the year 2011. The details of WRF model description are given in NCAR (2011). The output of WRF model was fed as input of AERMOD in pre-processor AERMET of the model. The observed meteorological data were collected from RCFL and compared with WRF results. These meteorological parameters from WRF model (wind speed, wind direction, rain fall, temperature, humidity, pressure, ceiling height, global horizontal radiation and