Evaluation and future predictions of air pollutants level in Karachi city

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Abstract. The purpose of this study was to determine the present air pollutant concentrations and predicted levels for next 30 years in urban environment of Karachi city. For that, a total of fifty measurements were made for each twenty selected locations of the city. The locations were selected on the basis of land use pattern such as residential, commercial, industrial settlements, open areas, congested traffic and low traffic areas for investigation of air pollutants variability and intensity. The measurements were taken continuously for six months period using PM Meter, Model AEROCET 531 and Ambient Air Quality Meter, Model AAQ 7545. The concentration of air pollutants were found higher at Al Asif Square and Maripur Road due to higher intensity of traffic and at Korangi Crossing because of industrial areas. The level of pollutants was lower at Sea View owing to lower traffic congestion and transportation of pollutants by sea breezes.

Keywords: air pollutants; carbon compounds; vehicle emissions; particulates matter; urban areas

1. Introduction

Air pollution and its consequences on the society in the urban areas have been known since long times. However, the approach towards solution of these problems was ambiguous. Even, air pollution was considered as a sign of progress and prosperity, and the endeavors to fight them were discrete and ineffective. In recent years, the public feels that pollution is detrimental to health and prosperity, especially in urban agglomerations. Major probable causes for air-quality deterioration in cities are urban population growth combined with change in land use pattern in urban areas because of migration of people from rural areas towards cities (Vera and Langlois 2007, Zhang *et al*. 2010). This population growth raised the rate of air pollutant emissions. Although, the emission rate per inhabitant of major air pollutants is presently higher in industrialized countries yet the tendency is obvious that this rate will be higher in developing countries in future.

The emission of air pollutants in cities are mainly caused by different source groups such as motor traffic, industry, power plants, trade, domestic fuel etc. It is reported that motor traffic contributes more than half of the air pollution in megacities (Mayer 1999, Baumbach 2012, Molina

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and Molina 2004). However, rate of air pollutant emissions by motor traffic depend on different factors such as traffic density, driving behavior and/ or ratio of automobiles to trucks. Since 1950, the worldwide vehicle fleet has grown tenfold, and is estimated to double again within the next 20 to 30 years. Much of the expected growth in vehicle numbers is likely to occur in developing countries and in Eastern Europe. As cities grow, more people will drive more vehicles over greater distances and for longer periods of time.

The intensity of air pollutant dispersion and dilution is influenced by topography, elevation from sea level, wavelength of solar radiation, ambient temperature, and relative humidity of the location concerned (Seinfeld and Pandis 2012). The concentrations of different substances varied with respect to time and space along with chemical reactions, dispersion and dilution processes. Quantification, extent of probable impacts and time requires for dispersion of air pollutants can be predicted either with the help of measurements or use of models. Measurements provide essential quantitative information about ambient concentrations and deposition, but just describe air quality at particular location and time, without providing obvious causes of air quality deterioration (Zannetti 2013, Weber 2013). Models are the only feasible techniques to quantify the deterministic link between emissions, concentrations and deposition rates, including past and future scenarios and help to determine an effective abatement strategy for future reduction and control of air pollutant emissions (Shah *et al.* 1997).

This makes air pollution models crucial decisive tool for governing, monitoring, research, and scientific applications. Modeling of air pollutants enable to sketch the spatial dispersion on different urban scales. These also help to forecast the changes in air-quality conditions due to construction of new structures such as skyscrapers, or industrial plants.

The spatial variability of air pollutants are mostly visible if they are emitted close the ground level, i.e., especially for emissions from motor traffic. The temporal variability of air pollutants can be characterized by different time intervals such as daily, weekly, annual, and by trends (Morawska 2006, Chang and Lee 2007). Indeed, model requires long term ambient air quality data and baseline concentration of leading air pollutants to predict the future scenarios of the cities. Since, the long term time series data in developing countries is rare and therefore predictions cannot be made without that. This study aims at measurements of major air pollutants namely particulate matter (PM), and carbon monoxide and carbon dioxide concentration level in Karachi city, which is the 7th largest urban agglomeration in the world (Asafu-Adjaye 2000, Forstall *et al.* 2009, Mukwana *et al.* 2015). It is a mega city having population of 13 million with 0.274 million automobiles. The city has shown trends of rapid growth in population, automobiles and industrial setup during the past few decades (Mukwana *et al.* 2015, Qureshi and Lu 2007). The findings of this research will help the regulatory authorities to make policies for controlling, monitoring and reducing the concentration level of air pollutants in the major cities of Sindh province especially in Karachi.

2. Materials and methods

This research study focuses on current air pollutants concentration level and future prediction of important air pollutants in Karachi city. The equipment used in this research work included PM Meter, Model AEROCET 531, and Ambient Air Quality Meter, Model AAQ 7545. A total of twenty different sites were selected for this study. From each selected sampling location and air pollutant parameter, 50 measurements were made. The measurement of air pollutants were carried
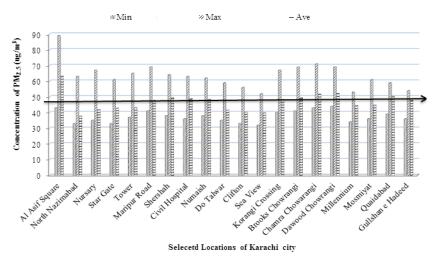
Fig. 1 Concentration of particulate matter, $PM_{2.5}$ at various locations of Karachi

out in different timings of the day like morning, afternoon, evening andnightto explore the variations during different periods of time. The readings were taken on the three different days of the week, like Monday, Friday and Sunday to evaluate the pollutants difference between working days and weekends continuously for six months. The sites were selected on the basis of land use purpose such as residential, commercial and industrial settlements and open areas for investigation of air pollutants intensity. US EPA's standard method "Ambient Air Quality Surveillance Siting Criteria" was adopted using spectrometric direct equipment for the air pollutants measurement (Mukwana 2015, Ott 1977).

3. Results and discussions

The measured results of twenty different locations are presented first and then predictions were made based on the measured results for future fate of air pollutants in the city. Figs. 1 to 4 illustrates the current concentration level during study period and Figs. 5 to 8 predicted results of $PM_{2.5}$, PM_{10}, CO_2 and CO respectively. The horizontal arrow over the figures indicates the maximum permissible value of Ambient Air Quality Standards. The standards for particulate matter and carbon monoxide is set by Pakistan Environmental Protection Agency (PEPA), whereas, for the level of carbon dioxide the guideline value is given by World Health Organization (WHO), (Parekh *et al.* 2001, Gurjar *et al.* 2008).

3.1 Measurement of air pollutants

The recorded minimum, maximum and average values of Particulate Matter ($PM_{2.5}$) of various locations of Karachi city are shown in Fig. 1. It was found that maximum, minimum and average value of $PM_{2.5}$ was higher at most of the locations except Star gate, Clifton and Sea View. The maximum concentration of $PM_{2.5}$ was observed at Al Asif Square with 90 $\mu g/m^3$, Maripur Road 68 $\mu g/m^3$, Korangi Crossing 66 $\mu g/m^3$, Brooks Chowrangi 68 $\mu g/m^3$, Chamra Chowrangi 68 $\mu g/m^3$ and Dawood Chowrangi 70 $\mu g/m^3$, against the maximum permissible level of 35 $\mu g/m^3$.
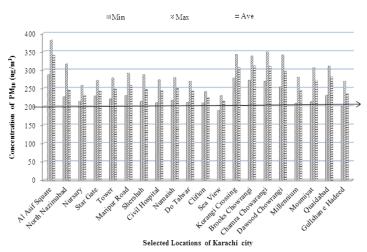
Fig. 2 Concentration of particulate matter, PM_{10} at various locations of Karachi

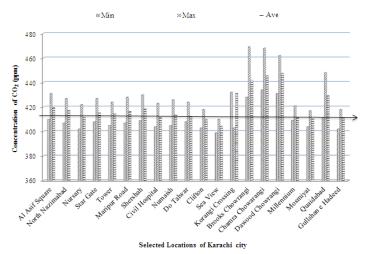Fig. 3 Concentration of carbon dioxide at various locations of Karachi

The recorded minimum, maximum and average values of Particulate Matter (PM_{10}) at various locations of Karachi city are shown in Fig. 2. The maximum, minimum and average value of $PM_{10}$was found higher at most of the locations except Star gate, Clifton and Sea View. The maximum concentration of PM_{10} was observed at Al Asif Square with 380 $\mu g/m^3$, Korangi Crossing 340 $\mu g/m^3$, Brooks Chowrangi 335 $\mu g/m^3$, Chamra Chowrangi 350 $\mu g/m^3$ and Dawood Chowrangi 340 $\mu g/m^3$ against the maximum permissible level of 150 $\mu g/m^3$.

Fig. 3 shows the recorded minimum, maximum and average values of Carbon Dioxide (CO_2) at various locations of Karachi city. The maximum, minimum and average value of $CO_2$was found higher at most locations. The maximum average concentration of CO_2 was observed at Brooks Chowrangi with 470 ppm, Chamra Chowrangi 465 ppm, and Dawood Chowrangi 460 ppm against the maximum permissible level of 397 ppm set by WHO.

Similarly, the recorded minimum, maximum and average value of Carbon Monoxide (CO) at various locations of Karachi city is shown in Fig. 4. It was observed that the maximum, minimum
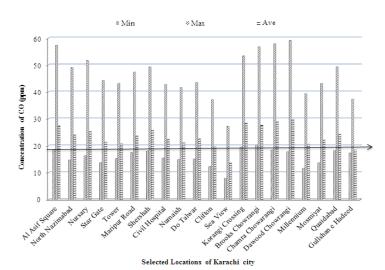
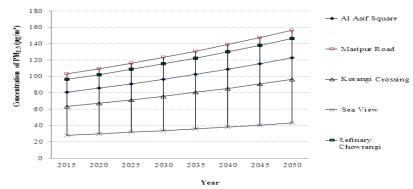Fig. 4 Concentration of carbon monoxide at various locations of Karachi

Fig. 5 Predicted concentration of particulate matter, $PM_{2.5}$ at various locations of Karachi

and average values of CO are higher at most of the locations. The maximum concentration of CO was observed at Al Asif Square with 57 ppm, Korangi Crossing 52 ppm, Brooks Chowrangi 56 ppm, Chamra Chowrangi 58 ppm, and Dawood Chowrangi 59 ppm against the maximum permissible level of 10 ppm.

3.2 Future predictions of air pollutants

Future predictions of air pollutants were made using measured data of air pollutants through OpenAir software. The OpenAir software is based on Artificial Neural Network (ANN) and is used by researchers for predicting the ambient air quality. It gives the status of ambient air quality, ranging from good to hazardous. The working of OpenAir Model which offers wide range of data analysis and statistical abilities has excellent graphics output. There are over 4000 packages that offer suitable analysis techniques (Mukwana 2015). In this research work the predicted results of $PM_{2.5}$ from year 2015 to year 2050 of various locations of the city are illustrated in Fig. 5. It was found that the growth rate of $PM_{2.5}$ varies from 1% to 4% in the city. The current average level of $PM_{2.5}$ at Al Asif Square, Maripur Road, Korangi Crossing and Sea View in year 2015 was 80.50
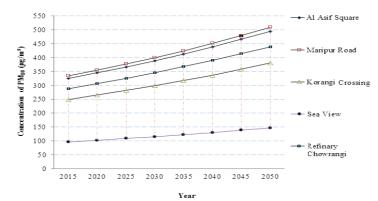
Fig. 6 Predicted concentration of particulate matter, PM_{10} at various locations of Karachi

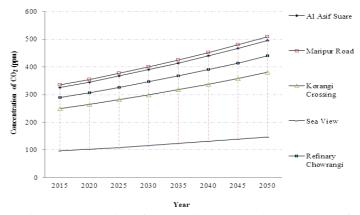Fig. 7 Predicted concentration of carbon dioxide at various locations of Karachi

$\mu g/m^3$, 102.90 $\mu g/m^3$, 63.30 $\mu g/m^3$, and, 28.16 $\mu g/m^3$, and the predicted values in the year 2050 would be 122.5 $\mu g/m^3$, 156.60 $\mu g/m^3$, 96.34 $\mu g/m^3$, and 42.85 $\mu g/m^3$, respectively.

Similarly, Fig. 6 shows the predicted growth rate of PM_{10} at the selected four locations of Karachi city. The prediction rates were considered from 0.5% to 1.5% using OpenAir software. The current average level on 2015 for PM_{10} at Al Asif Square, Maripur Road, Korangi Crossing, and Sea View were 325.56 $\mu g/m^3$, 334.46 $\mu g/m^3$, 250.06 $\mu g/m^3$, and 96.73 $\mu g/m^3$, and the predicted results for the year 2050 would be 495.48 $\mu g/m^3$, 509.03 $\mu g/m^3$, 380.58 $\mu g/m^3$, and 147.21 $\mu g/m^3$ respectively.

Fig. 7 shows the predicted growth rate of CO_2 at the selected four important locations of Karachi city. The prediction rates were considered from 1.0% to 6.0% using OpenAir software. The current average level on 2015 for CO_2 at Al Asif Square, Maripur Road, Korangi Crossing, and Sea View were 423.13 ppm, 425.05 ppm, 418.26 ppm, and 378.30 ppm, and the predicted results for the year 2050 would be 794.47 ppm, 798.07 ppm, 785.32 ppm, and 710.30 ppm respectively.

Likewise, the predicted growth rate of CO_2 at the selected four locations of Karachi city is shown in Fig. 8. The prediction rates were considered from 1.0% to 4.0% using OpenAir software. The current average level on 2015 for CO_2 at Al Asif Square, Maripur Road, Korangi Crossing, and Sea View were, 10.91 ppm, 12.05 ppm, 10.97 ppm, and 3.30 ppm, and the predicted results for
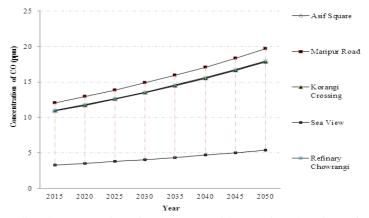
Fig. 8 Predicted concentration of carbon monoxide at various locations of Karachi

the year 2050 would be 17.80 ppm, 19.66 ppm, 17.90 ppm, and 5.38 ppm respectively. Since, it was assumed that the factors and sources contributing to the addition of particulates in the air are unchanged. Results revealed that the current level of $PM_{2.5}$ is higher at the Al Asif Square and Maripur Road locations due to higher intensity of road traffic, therefore the predicted values are also showing heavy concentration in year 2050. However, in case of Sea View, the current and predicted values of $PM_{2.5}$ are low as the location is quite free from traffic congestion as compared to that of other locations of Karachi.

4. Conclusions

The level of pollutants in ambient air was found higher at Al Asif Square and lower at Sea View as compared to other selected locations of Karachi city. At Al Asif Square location, the measured $PM_{2.5}$, PM_{10}, CO_2 and CO concentration was found 80.50 $\mu g/m^3$, 325.56 $\mu g/m^3$, 423.13 ppm and 10.91 ppm, whereas, the predicted values for the year 2050 were 122.51 $\mu g/m^3$ and 495.48 $\mu g/m^3$, 794.47 ppm and 17.80 ppm respectively. Similarly, at Maripur Road and Korangi Crossing, the level of air pollutants was found higher like at Al-Asif Square than other locations of the city. The level of air pollutants at Sea View were found lower with 28.16 $\mu g/m^3$, 96.73 $\mu g/m^3$, 378.30 ppm and 3.3 ppm and the predicted value for the year 2050 were 42.85 $\mu g/m^3$, 147.21 $\mu g/m^3$, 710.30 ppm and 5.38 ppm for $PM_{2.5}$, PM_{10}, CO_2 and CO respectively as compared to other examined locations, may be due to lower intensity of traffic.

It was concluded from the study that the concentrations of air pollutants were found higher at Al Asif Square and Maripur Road due to higher intensity of traffic and at Korangi Crossing owing to industrial settlements, whereas, the level of pollutants were found lower at Sea View due to lower intensity of traffic and movement of pollutants towards land area due to sea breezes.

Acknowledgments

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