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Assessment of spatio-temporal variations in air quality of Jaipur city, Rajasthan, India ☆

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ABSTRACT

This paper presents the evaluation of air quality in different wards of Jaipur city. Geo-spatial and geo-statistical techniques were utilized to estimate the seasonal and temporal variations (2004–2015) of gaseous and particulate pollutants. Data of six fixed monitoring stations was collected from Central Pollution Control Board (CPCB) and Rajasthan Pollution Control Board (RPCB) and the relationship between air quality and local weather parameters were also analyzed for the Jaipur city. It was found that SPM and PM_{10} is the major contributor to the deterioration of air quality in Jaipur city, while NO_X and SO_2 concentrations were below the CPCB standards. Results show that the concentrations of the air pollutants are high in winter and summer in comparison to the monsoon. The spatio-temporal distribution of Air Quality Index (AQI) clearly depicts the severe air pollution in Vidhyadhar nagar, Civil lines, Hawa Mahal, Kishanpole and Aadarsh Nagar area of Jaipur city. Ordinary least square (OLS) regression reveals good correlation between AQI and weather conditions (temperature, relative humidity and wind speed) for summer and winter seasons. The spatial analysis was also conducted to ascertain the degree of spatial association between AQI and weather conditions in different wards of Jaipur city using bivariate Moran's I and LISA (Local Indicator of Spatial Association). Moran's I results imply strong positive autocorrelation between AQI and relative humidity followed by temperature and wind speed. The combination of GIS and statistical analyses contributes to characterize the spatial influences of weather conditions on air pollutants and provide a quick view of the relatively critical areas that need more attention from decision makers to initiate the policies geared towards developing appropriate strategies for reducing air pollution.

1. Introduction

Urban air quality is one of the most serious issues, receiving attention by developing as well as developed countries. Studies also show poor air quality, not only in the megacities of Asia, but also in smaller cities with populations of 150,000 to 1.5 million (IAQP, 2010). Consequential population and economic growth surrounding industrial nuclei have often serious concern for the environmental deterioration on surrounding areas (Reddy et al., 2004; Khandelwal et al., 2017). In densely populated urban centers, the pollution level tends to increase towards the city center (Marsh and Grossa, 2002) due to high transportation activities (Dadhich and Hanaoka, 2012) and improper maintenance of vehicles (Ravindra et al., 2003). The high concentration of air pollutants has worsened the human health (Tandon et al., 2008) and quality of life. This increased level of air pollutants in urban area is responsible for deficits in pulmonary functions, cardiovascular disease, neurobehavioral effects, and mortality (Gupta, 1999; WHO, 2005). The impact of gaseous and particulate pollutants on health varies with season, hence; seasonality has always been a factor for determining the concentration of pollution in the lower atmosphere (Balogun and Orimoogunje, 2015). Although a number of studies have reported seasonal variations in urban air quality (Karar and Gupta, 2006; Kulshrestha et al., 2009; George et al., 2013; Chen et al., 2015), the influence of local weather conditions are still poorly understood, and considerable effort needs to be devoted to this issue.

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Jaipur city, as many other fastest growing cities of India, faces expanding urbanization, with traffic congestion, poor road conditions, poor control of industrial emission and increase in air pollution (Dhamaniya and Goyal, 2004; Kala et al., 2014). Thus, a bigger pressure is placed on the local authorities, decision makers and stakeholders. This has highlighted the need to evaluate the level of gaseous and particulate pollutants spatially and temporally for policy and management action to reduce the air pollution levels in Jaipur. In this sense, the data sets created and organized under a Geographical Information System (GIS) generate a comprehensive and accurate solution (Puliafito et al., 2003; Dadras et al., 2015). GIS provides a flexible environment for entering digital data from various sources, and is a powerful tool (Jenson, 1998; Dadhich and Hanaoka, 2010; Kushwaha and Goyal, 2016; AbdelRahman et al., 2016) in analyzing statistical relationships within and among the map layers. Therefore, in this research an attempt has been made to study the ward wise spatial distribution of air quality in Jaipur city for the period of 2004–2015 using latest geospatial tools. The main objective of this study is to evaluate the temporal and seasonal variation in concentration of air pollutants using six fixed monitoring stations of Jaipur city and to analyze the relationship between air quality and local weather parameters.

2. Materials and methods

2.1. Site description

Jaipur district, covering geographical area of 11,061.44 sq. km and extending between north latitudes 26° 25′ and 27° 51′ and east longitudes 74° 55′ and 76°15′ forms east-central part of the Rajasthan State. It is situated in the foot hills of Aravali range, surrounded by hillock in northern and eastern sides and vast stretch of plains in western and southern sides. Jaipur district has an average population density of 470 people per sq. km. as per the 2011 census and decennial growth of 26.91% (period 2001–2011). Jaipur, the capital city is popularly known as Pink city, is the largest city of Rajasthan with fascinating forts, magnificent palaces and is situated towards central part of the district. Jaipur district has a semi-arid climate. The winter season is mild and pleasant, with average temperatures in the 15–18 °C range and relative humidity ranges between 35 and 63%. December and January are the coldest months when temperature varies between 5 and 10 °C. March is a pleasant transition month to summer. The summer months of April to June record average daily temperature of around 35 °C. May and June are the hottest months in Jaipur district. Temperature reaches up to 48 °C in these months and relative humidity in the summer ranges between 16 and 52%. The lowest humidity is observed in the month of April and highest in the month of August. Jaipur receives over 650 mm of rainfall each year. Most of the annual rainfall is received in the monsoon months between July and September. In monsoon season the temperature varies 25–34 °C with relative humidity ranging from 50 to 90%. Generally, the average monthly wind speed varies in between 2.5 and 10.0 km/h with maximum during summer (6–10 km/h) and monsoons (7–8 km/h) and minimum in winters. In winter generally wind blows from East to North. In summer, the dust storms are frequently observed during the period from March to June (IMD, 2011). In summer season the wind direction is east to south-easterly during morning hours and northwesterly during evening hours. During monsoon season northwesterly to west north westerly component of wind direction remain prominent. The weather data was collected for five different locations within and around the Jaipur city for the period of 2004–2015 from Global weather data (SWAT, 2016) and WU website (WU, 2016).

2.2. Data collection and analysis

2.2.1. Spatial data

For the study area, the spatial data was first created within a GIS. The district boundary map of Jaipur and Jaipur municipal wards boundary is created in GIS environment. The data of five weather locations were used for the interpretation of local weather conditions within Jaipur city (Fig. 1a). On the basis of these five weather locations, the interpolated maps were generated for temperature, relative humidity and wind speed for the period 2004–2015. Interpolation predicts the values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data (Watson and Philip, 1985). The Inverse distance weighted (IDW) interpolation is used to determine the cell values using a linearly weighted combination of a set of sample points. Compared with other methods, the IDW method is simpler to programme and does not require pre-modeling or subjective assumptions in selecting a semi-variogram model (Henley, 1981). It provides a measure of uncertainty of the estimates that is directly related to the values being estimated, in contrast to kriging standard deviation which is based on the modeled semi-variogram (Adisoma and Hester, 1996).

2.2.2. Ambient air quality

In Jaipur city, the daily data of air pollutants concentration was collected for six air quality monitoring stations for a period of 12 years (2004–2015) to give a comprehensive analysis of the air

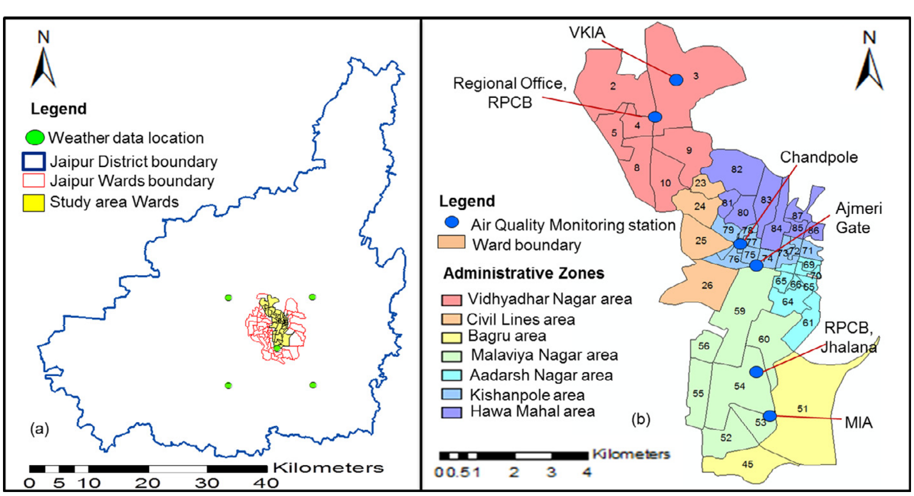

Fig. 1. a. Study area location with ward map of Jaipur city. b. Different administrative zones with air quality monitoring stations.

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