Atmósfera 27(1), 35-46 (2014)

Chemical composition of wet precipitation of air pollutants: A case study in Karachi, Pakistan

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Received January 31, 2013; accepted October 14, 2013

RESUMEN

La contaminación atmosférica se ha considerado como uno de los desafíos ambientales más importantes a causa de su impacto directo en los ecosistemas y la salud humana. Se monitorearon los cambios temporales en la composición de 20 muestras de agua de lluvia en la región árida de Karachi, Pakistán, durante el monzón del suroeste de 2009, para evaluar de forma indirecta la calidad del aire. El objetivo del estudio fue identificar los niveles de la contaminación atmosférica y su posible componente antropogénico. Se analizaron los iones de metales con el fin de predecir riesgos para la salud. Se encontró que las muestras de lluvia fueron alcalinas (pH 5.55-7.55) debido a la presencia de partículas ricas en calcio y magnesio. Las lluvias continuas en días consecutivos mostraron un descenso notable en los niveles de contaminación, en tanto que la estación seca los potenció. Se observaron correlaciones importantes del total de sólidos disueltos con K^+, Na^+, Ca^{2+}, Mg^{2+} y Cl^-, así como una correlación relativamente débil del total de partículas suspendidas con los metales, lo que sugiere la presencia de otras partículas suspendidas en el aire. Se utilizaron análisis de componentes principales y de medias para predecir fuentes antropogénicas de contaminación. Este estudio será útil para definir la planeación estratégica y formular políticas orientadas a controlar los niveles de contaminación atmosférica en la ciudad.

ABSTRACT

Air pollution has been considered one of the most important environmental challenges because of its direct effect on ecosystems and human health. Temporal changes in the composition of 20 samples of rainwater in the arid region of Karachi, Pakistan during the southwest monsoon of 2009 have been monitored to carry out the indirect assessment of air quality. The study has been fulfilled with the aim of identifying the level of air pollution, and the relative contribution of possible anthropogenic activities. Metal ions were analyzed to predict health risks. Rain samples were found to be alkaline (pH 5.55-7.55) due to the influence of calcium and magnesium rich particles. Continuous rains in consecutive days showed a remarkable decline in air pollution while the dry season boosted up the level of pollution. Strong correlations of total dissolved solids with K^+, Na^+, Ca^{2+}, Mg^{2+}, and Cl^- were observed. A relatively weak correlation of total suspended particles with metals showed the possibility of some other particulate matters being suspended in the air. Principal component analysis and analysis of means were used to predict the anthropogenic source of pollution. This study will be helpful to formulate strategic planning and policies for controlling the level of air pollution in the city.

Keywords: Karachi, air pollution, rainwater, chemical composition, multivariate analysis.

1. Introduction

Pollution monitoring through the estimation of air pollutants in wet deposition has increased during the last decades (Zapletal *et al*., 2007; Holder, 2004). Fog in the metropolitan area of Karachi occurs during the winter season (November to March). The southwest monsoon arises during the summer from June to September throughout Pakistan, excluding the regions of western Balochistan, Chitral, Gilgit-Baltistan, and the Federally Administered Tribal Areas. Monsoon rains bring a much-awaited relief from the scorching summer heat. These monsoon rains are quite heavy by nature and can cause significant flooding.

The monsoon regime dominates the climate of Pakistan. Karachi is the biggest and largest industrial city of the country, heavily populated with 18 million inhabitants in an area of 3527 km^2 and an elevation of 8 m. It has an arid climate with a low average precipitation level (approximately 250 mm per annum), most of which occurs during July-August or in September as a late monsoon season. Located on the coast, pollutants are pushed towards the shore during the north-east (NE) monsoon and inland during the south-west (SW) monsoon (Ghauri and Mirza, 1994). Depending upon the nature of air pollutants, rainwater may be acid or alkaline. Industries and vehicles emit a large amount of NO_x and SO_2, which are responsible for acid rain. Acid rain reflects the emission of acidic gases as the result of anthropogenic activities (Ham *et al*., 2010). NO_x and SO_2 are transformed to HNO_3 and H_2SO_4 when they interact with water in the atmosphere. The acids combine with moisture in the air and fall to the earth as acid rain or snow. Conversely, dust particles may contain a significant amount of basic cations which neutralize the acidity of rainwater. The composition of rainwater plays an important role in attracting pollutants from the atmosphere. Particulate matter plays an important role in attracting metal pollutants (Mohiuddin et *al*., 2010). The scavenged metals can deposit to the air up to a distance of 100 km from their source. Therefore, the estimation of anions in acidic rain and cations in alkaline rain is of great importance for source identification of air pollution in rainwater.

Considering the importance of rainwater chemistry, the present study has been carried out with the aim of identifying the variations in the amount of ionic species during one monsoon season (comprising 13 events) and the contribution of possible anthropogenic activities in the studied areas. The data obtained in this study significantly contribute to the limited knowledge of temporal variations of rainwater quality in Karachi, in order to understand its use as an alternative to drinking water, especially in areas of short domestic water supply. The study can also increase the awareness of common people towards an important environmental issue. Data are compared by means of statistical analysis with similar works carried out at various regions of the world.

2. Materials and methods

2.1 Sampling sites

Karachi is located in southern Pakistan (24º 48' N, 66º 59' E) at the coast of the Arabian Sea (Indian Ocean); as a result, it has a relatively mild arid climate. Being the industrial hub of the country, most industries (including textiles, chemicals and fertilizers, food processing, building materials, petroleum refining, and ship repairing) are located in this region. According to a report of air quality management in Karachi, NO_x and SO_2 levels range from 10 to 43.70 and 7.90 to 21.90 $\mu g/m^3$, respectively (Institutional Analysis of Air Quality Management in Urban Pakistan, 2009). Moreover, the city is rapidly affected by the increase in industrialization, energy consumption, dust emitted from vast construction activities and dry sand storms. For these reasons, significant deterioration on air quality has occurred, causing accumulation of pollutants on trees, land, and air. These pollutants reach ground through precipitation (Wahid *et al*., 2001) and were subjected to analysis for the assessment.

The Pakistan Meteorological Department recorded pre-monsoon activity in Karachi on June 23 and 25, 2009 due to the formation of a weak tropical depression in the Arabian Sea. As a result of this depression, the storm caused monsoon rainfall on June 26. It was a light shower with gusty winds (11 km/h) in the coastal area. The next heavy shower was witnessed from July 18 in Karachi. It was the second highest precipitation in the history of Karachi (245 mm in four hours), and caused severe flooding in the city. This record-breaking rainfall in Karachi developed first as a tropical depression in the Bay of Bengal and moved in a west-north-west direction; it hit Karachi after crossing Madhya Pradesh and Rajasthan, in India. The second monsoon system