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Evaluation of the relationship between PM_{10} concentrations and heavy metals during normal and dusty days in Ahvaz, Iran

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ABSTRACT

This study aimed to survey the concentration of PM_{10} and heavy metals (cadmium, chromium, cobalt, nickel, lead, and zinc) on normal and dusty days in Ahvaz, Iran. Concentrations of PM_{10} in a high-traffic area of the city were measured from October 2012 to September 2013 using a high-volume sampler (HVS). Extracted heavy metals were speciated and quantified using Inductivity Coupled Plasma Optical Emission Spectrometry (ICP-OES). The results of this study showed that the average concentration of PM_{10} in the autumn (October, November, and December), winter (January, February, and March), spring (April, May, and June), and summer (July, August, and September) was 131, 189, 145, and 127 $\mu g/m^3$ on normal days, respectively. The corresponding values on dusty days were 410, 742, 300, and 278 $\mu g/m^3$, respectively. The concentrations of the heavy metals during dusty days were higher than those on normal days. The ratio of the overall mean concentration of the heavy metals on dust storm days relative to normal days (D/N ratio) ranged from 1.21 to 2.53. Due to the importance and impacts of PM_{10} and associated heavy metals on human health, further studies should be conducted to evaluate the concentrations, impacts, and the associated diseases during pollution periods to establish and implement strategies to minimize harmful effects of PM inhalation.

1. Introduction

The Asia continent is a major source of particulate matter on a large scale due, in part, to the presence of growing economies of developing countries such as India and China in addition to the presence of large deserts (Kulshrestha et al., 2009; Oanh et al., 2005; Simoneit et al., 2004; Xu et al., 2015). The World Health Organization (WHO) reported that 4–8 percent of the deaths occurring annually in the world are related to anthropogenic air pollution (López et al., 2005). In recent years, air pollutants in urban areas are of growing concern because human exposure leads to an increase in the rate of chronic respiratory and pulmonary diseases, outbreak of cancer, other adverse health effects, and mortality (Kulshrestha et al., 2009; Neisi et al., 2017b; Dehghan et al., 2018; Yari et al., 2016; Geravandi et al., 2015). It has been demonstrated in previous research that PM_{10} and gaseous pollutants increase hospital admissions and death rate due to respiratory and cardiovascular diseases in Iran's megacities (Marzouni et al., 2016; Marzouni et al., 2017). The extent of adverse health effects associated with exposure to airborne PM is greatly affected by particles' size, concentration, composition, toxicity, and capacity to carry potentially toxic substances and elements (Behrooz et al., 2017; Lee and Hieu, 2011; López et al., 2005). The comparison of the impact of air pollution

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between dusty and non-dusty days on fractional exhaled nitric oxide and pulmonary function in healthy children has also been reported (Neisi et al., 2017a).

Airborne particulate matter (PM) originates from both anthropogenic sources (e.g., motor vehicles, industrial facilities, residential fireplaces) and natural sources (e.g., biogenic emissions, dust, and sea spray). The composition of airborne PM can be organic, inorganic or a mixture of both. Among different inorganic elements and substances constituting chemical composition of PM, heavy metals associated with respirable PM are of major concern, and therefore, their concentrations in ambient air should be considered and evaluated (de Kok et al., 2006; López et al., 2005; Melaku et al., 2008). The exposure to heavy metals generally occurs through ingestion (drinking or eating) or inhalation (breathing). Heavy metals can accumulate in the environment as well as in the body of animals and human beings for many years once emitted from their sources (Simeonov et al., 2010). Long-term exposure to toxic heavy metals can induce cardiopulmonary, neurological, and carcinogenic impacts (López et al., 2005; Simeonov et al., 2010). For instance, a wide range of neurobehavioral problems such as learning disabilities, memory and attention deficits, impaired problem solving, reduced intelligence test (IQ) performance, increased behavior problems such as aggression, conduct disorder, and criminality, and psychiatric problems such as depression and anxiety were observed in children exposed to even small concentrations of some heavy metals (Simeonov et al., 2010). Although the neurotoxic effects of environmental exposure to heavy metals are not well identified, it remains as a topic of important concern as it could be considered as an early endpoint for health impacts induced by exposure to heavy metals. It can be concluded that heavy metals in the atmosphere not only can threaten human health but also can have socioeconomic implications, and adversely affect the quality of life (Simeonov et al., 2010).

In recent years, researchers have carried out studies to identify the concentration of heavy metals attached to respirable particles and their emission sources. Lee and Hieu (2011) surveyed the seasonal changes of the heavy metals in the atmospheric aerosols in Korea. The results showed that the concentrations of most of the heavy metals in spring were higher compared with winter. Norouzi and Khademi (2015) reported that traffic and industrial activities were the major sources of zinc and copper emission. Furthermore, Thakur et al. (2004) found a strong relationship between the concentration of the heavy metals, meteorological parameters, and human activity related to each region. In the southwestern United States, higher levels of metals and metalloids coincided with higher fine soil levels, especially near urban areas (Prabhakar et al., 2014). Dust emissions near mining and smelting operations have also been shown to be enriched with toxic contaminants such as lead, cadmium, and arsenic in areas such as southwestern United States (Sorooshian et al., 2012; Youn et al., 2016) and southern Iran (Soltani et al., 2017a; Soltani et al., 2017b).

The Middle East region (especially Iraq, Kuwait, Saudi Arabia, and parts of Iran) is considered as a major source of desert dust storms, which contributes significantly to the total transport of dust particles worldwide. However, our knowledge about this dust source is limited (Goudarzi et al., 2014; Naimabadi et al., 2016; Shahsavani et al., 2012a), especially with regard to relationships with heavy metals concentrations. Our study area is in Khuzestan Province, specifically the city of Ahvaz, Iran. Epidemiological survey in Ahvaz showed acute effects of air pollution on spontaneous abortion, premature delivery, and stillbirth (Dastoorpoor et al., 2018). In the field of animal studies, findings revealed effects of PM_{10} on eNOS mRNA expression level, blood pressure, and electrocardiogram parameters (Dianat et al., 2016a; Dianat et al., 2016b). Ahvaz is located in vicinity of Iraq, Kuwait, and Saudi Arabia (Fig. 1) which are the primary sources of dust storms in the Middle East region (Dianat et al., 2016b; Goudarzi et al., 2014; Naimabadi et al., 2016; Rezaei et al., 2014; Shahsavani et al., 2012b; Soleimani et al., 2013; Soleimani et al., 2016; Soleimani et al., 2015). The city has experienced many dust storms each year during recent decades (Shahsavani et al., 2012a). An annual average of 60 dust storm days was recorded in different cities of Khuzestan Province (Naimabadi et al., 2016). The frequent occurrence of dust storms in this city has caused the closure of industrial and educational centers and led to thousands of hospital admissions due to cardiovascular and respiratory diseases (Goudarzi et al., 2014; Soleimani et al., 2013; Soleimani et al., 2016). In addition, these dust storms have interfered significantly with many aspects of normal life and resulted in many environmental and economic problems (Goudarzi et al., 2014; Naimabadi et al., 2016; Shahsavani et al., 2012a). Therefore, due to the importance of the Middle Eastern dust storms and the lack of enough and documented studies related to the levels of heavy metals in the ambient air during dust storms, this study aimed to survey the concentration of PM_{10} and associated heavy metals (cadmium, chromium, cobalt, nickel, lead, and zinc) on days with and without significant dust influence.

2. Materials and methods

2.1. Description of the study area

Ahvaz is the capital of the Khuzestan Province and a major megacity in Iran (Fig. 1). Ahvaz has geographical coordinates of 31°20′ north latitude and 48°40′ east longitude and has an elevation of 18 m above sea level. This study was conducted to measure the PM_{10} concentrations and the associated heavy metals between 2012 and 2013 in a high traffic area in the city (Fig. 1). This city with the population of 1,112,000 people and surface area of 530 km^2 is characterized with long and sweltering summers and mild and short winters (Naimabadi et al., 2016; Maleki et al., 2016). Ahvaz is consistently one of the hottest cities on the planet during summer, typically ranging between 38 and 45 °C, but sometimes exceeding 50 °C. There is no snow during winter, and the temperature falls to 5 °C (typically is in the range of 5–20) (Iran Meteorological Organization, 2017). In 2011, the WHO ranked Ahvaz as the worst city regarding air quality in the world based on PM_{10} concentration (TIME, 2011). The existence of important industries, official and industrial buildings, National Iranian South Oil Company, and National Iranian Drilling Company have made Ahvaz one of the main industrial centers in Iran. Consequently, there has been population growth in this megacity. However, it should be noted that during the last decade, due to the frequent occurrence of dust storms as well as air pollution and its associated problems, many people have migrated to neighboring provinces or other cities of the country.

2.2. Sampling procedure

During the entire study period, PM_{10} sampling was carried out according to the United States Environmental Protection Agency (U.S EPA) method (U.S. EPA, 1999), and 24 h PM_{10} samples were collected at six-day intervals (at least 5 samples in each month for normal days). Additional samples were collected in the case of dust storms occurrence. The classification system developed by Hoffmann et al. (2008) was used in combination with visibility and wind speed to define the catergory of dust storms in our study according to Table 1.

A relatively high traffic area in the city was selected to sample PM_{10} using a high volume air sampler equipped with a glass fiber filter (Whatman® glass microfiber filters, Grade GF/A) and a PM_{10} cutoff inlet. The high volume air sampler was placed on the top roof of the Health Research Center at the height of 4 m above the ground level and far away from any obstruction such as trees, buildings, and other anthropogenic air pollution sources to minimize biasing effects on measurements of particulate matter concentrations and heavy metal contents. The shortest distance of the sampler from the road and other nearest obstacles was > 20 m. The sampler equipped with a fiberglass filter was operated with a flow rate in the range of 1.1–1.7 m^3/min (the average flow rate was calculated) for 24 h to collect particulate matter.