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Characteristics of mineral dust impacting the Persian Gulf

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ABSTRACT

It is generally assumed that severe dust events in western Iran could be responsible for elevated levels of toxic and radioactive elements in the region. Over a period of 5 months, from January 2013 to May 2013, dust particles in the size range PM_{10} (i.e. < 10 μm) were collected at Abadan, a site beside the Persian Gulf. The research aim was to compare chemical compositions of dust and aerosol samples collected during the non-dusty periods and during two severe dust events. Results of ICP-MS analysis of components indicate that during dust events the concentrations of major elements such as Ca, Mg, Al and K increase relative to ambient conditions when Fe and trace elements such as Cu, Cr, Ni, Pb and Zn are in higher proportions. Toxic trace elements that are generally ascribed to human activities including industrial and urban pollution are thus proportionately more abundant in the dust under calm conditions than during dust events, when their concentration is diluted by more abundant mineral particles of quartz, calcite and clay. The variability of chemical species during two dust events, noted by tracking the dust plumes in satellite images, was also assessed and the results relate to two different source areas, namely northern Iraq and northwestern Syria.

1. Introduction

Airborne mineral dust is typically composed of 0.001 to 50 μm sized mineral and organic particles, as well as similar size particulates of liquid phases. The surfaces of dust particles provide suitable interfaces for reactions with gases, liquids and other solids in the environment. Dentener et al. (1996) found that oxidation of gases such as SOx and NOx occurs on the surfaces of mineral dust particles. Also dust particles can mix with sulphate and anthropogenic contaminants by coagulating with aerosols (Roth and Okada, 1998; Wurzler et al., 2000).

Dust events are a natural phenomenon occurring around the globe, but recently (from 1996 to present), according to the World Meteorological Organization,[1] dust events are occurring more frequently (for example, the dust event frequency in the current decade over Iran is 50% greater than last decade). In some seasons in certain Middle East regions, such as Iran, north-eastern Iraq and Syria, the Persian Gulf, Sea of Makran and the southern Arabian Peninsula, dust events are immense and occur about 30% of the time, on average being more frequent in summer (Kutiel and Furman, 2003). In recent years, statistics demonstrate that some cities in Iran rank first to third in the world in terms of dust pollution, measured as the annual average of PM_{10} particle size (e.g. Ahvaz city beside the Abadan, Zabol city the northern Sea of Makran, Bushehr city the northern the Persian Gulf) (WHO Report, 2016). These data suggest the need for more research on this dust.

Some of the increase in dust activity has been ascribed to climate change, but major factors are desertification (both human induced and climate related), wind erosion (Rashki et al., 2013), dam construction on rivers, civil wars, wetland desiccation and excessive ground water withdrawal (Ahmady-Birgani et al., 2017, 2015). Much dust is derived from near-surface Quaternary regolith and soil, which can be easily contaminated by pollutants from agricultural, industrial and military activities in the source regions.

Mineral dust can severely impact human health (Merrifield et al., 2013; Bu-Olayan and Thomas, 2011; Engelbrecht et al., 2009a,b; Erel et al., 2006; Kellogg and Griffin, 2006). Small particulates penetrate deeply into the bronchi and bronchioles and exacerbate chronic respiratory and pulmonary diseases (Pope et al., 2002; Berico et al., 2007), reduce lung capacity and can be added to the blood directly to cause various diseases. Although the effect of dust particulates from increased dust events on the incidence of diseases has not been extensively recognized, a sharp decline in the health status of the human population and the appearance of strange diseases around the Aral Sea (Small et al., 2001; O'Hara et al., 2000; Abrahamson and Beer, 1998),

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Khuzestan province on the northwestern the Persian Gulf (Rezaei et al., 2014) and the Sistan region of the northern Sea of Makran (Rashki et al., 2013) have been reported and ascribed to an increase in dust events in these areas. However, the effects of dust particles depend on particle size and composition. In order to limit these adverse impacts and to develop appropriate strategies for air quality control, knowledge of the chemical composition of the dust is necessary (Salameh et al., 2015), particularly the more soluble components that are more likely to be bioavailable.

As well as the health issues related to particle size, morphology, abundance and the presence of toxic components, it should be noted that the chemical compositions of the particulates are important for identifying their sources (Zhai et al., 2012; Sharifi et al., 2011; Okada and Kai, 2004). These chemical characteristics are likely to be different under ambient atmospheric conditions and major dust events, in response to different combinations of source.

The aim of this study is to investigate the characteristics of mineral dust and anthropogenic air pollution at Abadan near the Persian Gulf in southwestern Iran where there is significant dust deposition related to dust events in the area adjacent the Arab States of the Persian Gulf.

2. Materials and methods

2.1. Sample collection

Samples of atmospheric particulates were collected at the Abadan synoptic meteorological station during periods of both ambient and dust event conditions over a five-month period from January 2012 to May 2012 using a Medium Volume (MVS) Microcomputer Controlled Air Sampler (Fig. 1). A total of 20 PM_{10} samples were collected over weekly intervals for the five-month period, except for the dust event samples. Following collection, each sample including the filter was weighed using a precision weighing balance and the weight of the filter subtracted to obtain an estimate of the mass and concentration of the particulates. Care was taken during handling, but some small sample loss was inevitable and estimated at less than 5% from visual inspection. The particle size collected for this study was the PM_{10} size (i.e. particulates less than 10 μm) (Fig. 1). This size was selected because particles less than 10 μm commonly have the greatest potential to affect human health. These particles can penetrate the deepest parts of the lungs and access the gas exchange regions via diffusion, as well as prepare special surfaces for chemical interactions (Jordanova et al., 2012). Particulate matter with a size greater than 2.5 μm is commonly associated with road dust and construction activities or produced by mechanical and physical processes such as re-suspension of dusts, smashing and eroding of materials (Cesari et al., 2012). These dust particles contain minerals as a major component and certain adsorbed endotoxins (Ghio et al., 2012).

The Abadan synoptic meteorological station is located at the northwestern end of the Persian Gulf (37°27′ latitude, 48°17′ longitude, 3 m AMSL) and has a mean annual precipitation of 146 mm, mean annual temperature of 26 °C and an arid and desert climatic type. The station is outside the city of Abadan and far from industrial zones and high-traffic roads on a flat plain (Fig. 1).

Each ambient sample was collected over 168 h (one week) at a 38 l/min suction volume (2.3 cubic meters per hour). Dust event samples were collected over one week intervals covering the duration of dust occurrence, which varied from 15 h to three days. Over the sampling periods, no sample filters were overloaded even in the severe dust events, and the volume concentrations represent the complete sample (Table 1). The sample intakes on each instrument were 2 meters high to prevent suctioning of suspended particles near to the ground surface during strong winds. Particulates were collected on quartz fibre filters 47 mm in diameter. The PM_{10} particulate filled filters were removed from the sampler head and packed into zipper plastic bags to prevent contamination. The date, time, site and related information were

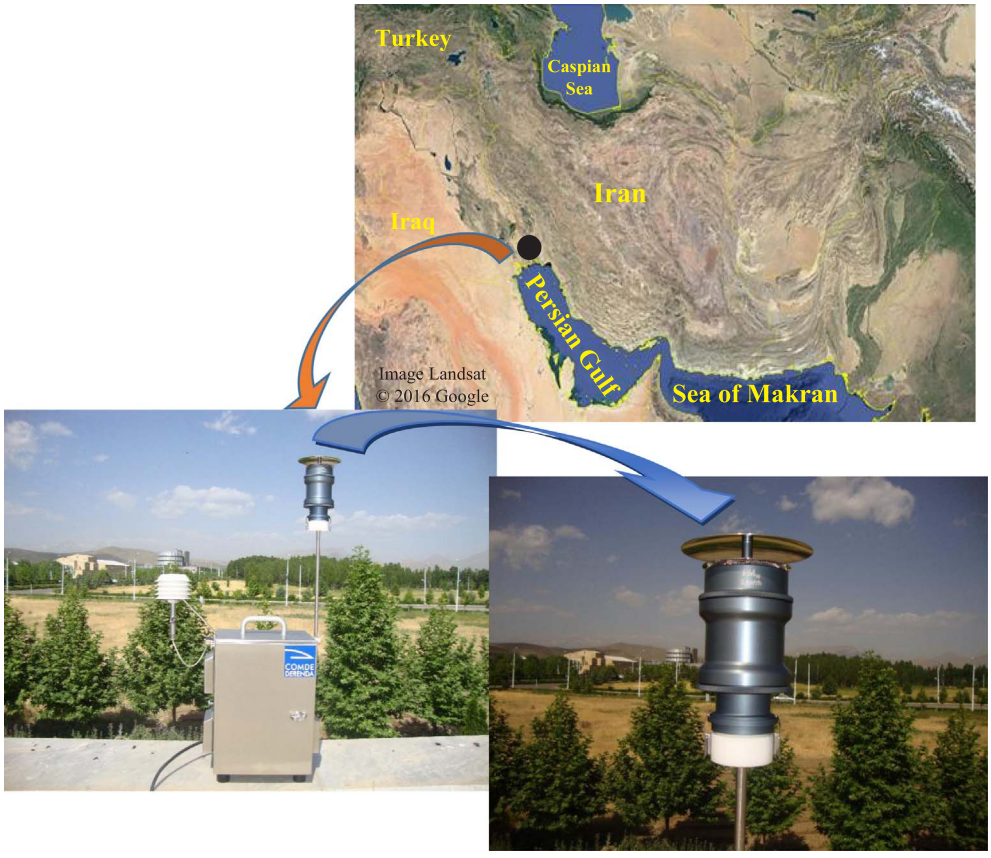

Fig. 1. Location of sampling site near Abadan in Iran (black circle), northwestern the Persian Gulf and the surrounding countries. The Medium Volume (MVS) Microcomputer Controlled Air Sampler and its PM_{10} sampling head is seen.