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Assessments of dust fallout within Kuwait

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Abstract

Kuwait has one of the highest dust precipitation rates in the World. The annual average number of dusty days due to dust storms or rising dust or suspended dust in Kuwait is 255.4 (70% of the year). Sixty seven dust collectors were installed in forty-seven sites all over Kuwait. Six of these sites contain four collectors for radionuclide collection. The monitoring of dust fallout and associated pollen was conducted for 2 years from September 2009 to August 2011. The sites were morphologically described and the locations were identified by the Global Positioning System (GPS). Also, minerals, trace elements, grain size and statistical parameters, surface area, pollen and radionuclide maps were produced. The highest dust depositional rates were detected within the Huwaimiliyah-Wafra Wind Corridor, Sabiya and Bubiyan Island. The annual amount of dust in Kuwait varies from 10 to 1065 unit with an average of 278 t/km^2. The year 2010-2011 was found more dusty compared to 2009-2010 by 43%. The socioeconomic effect of dust storms (visibility less than 1000 m) shows an increase in car accidents and allergic diseases by 8.8% and 33.1% respectively.

The analysis lead to a conclusion that the northwestern, western, and northern winds play a key role in producing dust within Kuwait. Regional areas represent the dominant sources of dust fallout, while local sources contribute appreciable amounts. The very fine and fine sand particles originate from local sources as they move in the form of saltation for a short distance and represent 37% of the average dust fallout percentages in Kuwait. There is a trend of fining in mean size of dust particles towards the east and the northeast. Mineralogically, carbonates and quartz are the major components of dust in Kuwait, feldspars are found in considerable amounts. Other minerals in the dust are gypsum, anhydrite, bassanite and heavy minerals. Carbonates are more and quartz is less towards the coastal areas compared to desert areas. Natural ^{210}Pb, man-made (anthropogenic) ^{137}Cs, and cosmogenic ^{7}Be radionuclides were determined. The assessment gave low values compared to standards; but large values were observed in Um Umara area, west of Kuwait. Pollen originate predominantly from regional sources. However, the presence of a large amount of pollen from Haloxylon *sp. Cyperus sp.* indicates that close-by regional and local areas are also a source of fallen dust.

Keywords: Dust fallout; saltation; suspension; radionuclide ; pollen.

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1. Introduction

Wind is the most active agent in the desert ecosystem. It can remove sand, silt and clay sized particles from the surface and blows them as dust and sandstorms to great distances (Al-Dousari, 2009). Al-Dousari (2009) listed Kuwait as one of the highest in dust precipitation rates among other parts in the world. Safar (1980) stated that the annual average number of dusty days of dust storms or rising dust or suspended dust in Kuwait is 255.4 d (Al-Dousari, 2009). Data on the frequency and the rates of dust deposition suggested that the rates of aeolian accumulation may be of similar order of magnitude to rates of fluvial erosion (Goudie, 1978). Although dust is a result of soil erosion from some areas, it is also a major contributor to the soil in other areas, with the dust deposition noted in Oman (Badawy et al., 1992), Riyadh (Al-Tayeb and Jarrar, 1993) Australia and New Zeeland (Marx et al., 2005), Canary Islands (Moreno et al., 2006); Florida and Bahamas and Barbados (Muhs et al., 2007), and Spain (Querol et al., 2007). Desert areas are important sources of mineral dust to the atmosphere, which upon deposition can influence oceanic and terrestrial biochemical cycles and affect forest productivity (Avila & Penuelas, 1999). Dust, travelling long distances, is commonly very fine with the predominant sizes between 0.068 and 0.02 mm (Walker & Costin, 1971). Significant quantities of dust may be blown thousands of kilometres from their source (Meng & Lu, 2007), and it was estimated that windblown dust derived from soil erosion contributes approximately 500x106 tons of particulate matter to the atmosphere each year (Peterson & Junge, 1971). Therefore, this study was aimed to:

- assess the physical (morphometry of the grains) and chemical (trace elements percentages) characteristics of dust fallout in order to identify its origin;
- identify the new local potential sources and distribution pattern of the dust fallout in Kuwait.

2. Methodology

The selection of the site for dust collectors were based on reconnaissance field survey, analysis of satellite images (2003), 47 sites for dust collectors were selected. The BET-surface area and grain-size parameters were determined using standard sieve analysis and Centrifugal Particle Analyzer (Shumadzu, SA-CP3) for dust fallout in all samples. The grain-size percentages and statistical parameters using different methods were done for all samples within 4 months in 2010 (January, May, August and November); it was also done for two sites for 10 month in order to observe the variation with time. The main textural components (very fine sand, silt and clay) of the dust samples were subjected to mineralogical analysis using X-ray diffraction (XRD). Also, geochemical analysis for dust sample using ICP-OES (Inductively Couples Plasma – Optical Emission Spectrometer) was performed to measure main trace elements. Thirty sand traps were used for trapping pollens from the air. A sample for each month in a two year period was collected. Each sample was analysed for pollen grain and spore content.

3. Dust regional sources

The area suffered from three war activities (the Iraq-Iran war (1980 - 1988), the first Iraq war (August 1990 - February 1991) and the second Iraq war (March -April 2003). There are five major sources of dust are: 1) South-western desert of Iraq, 2) The Mesopotamian Flood Plain in Iraq, 3) North eastern desert of Saudi Arabia, 4) Drained marshes (Ahwar) area in southern Iraq, and 5) Sabkhas, dry marshes and abandoned farms in Iran at northern coastal area of Arabian Gulf. (Fig. 1).

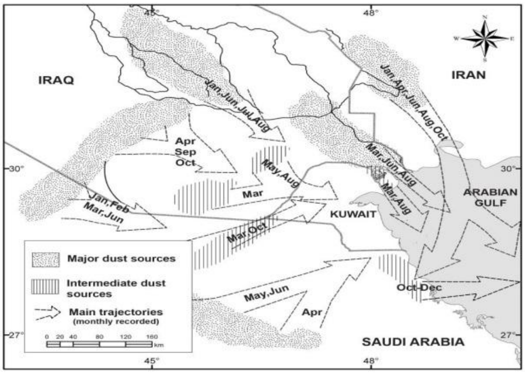

Fig. 1. Dust storms major and intermediate source areas and trajectories for the northwestern areas of Arabian Gulf including.

4. Dust fallout in Kuwait

Fig. 2 illustrates the average fallen dust for all months. The western areas of Kuwait show higher amounts of average deposited dust compared to coastal areas as shown in the deposition of fallen dust in Fig.3 and Fig.4 for the duration 2009-2011.

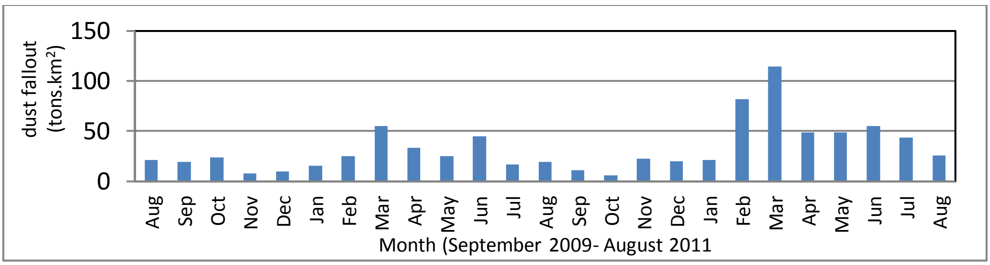

Fig. 2. Monthly dust fallout for 2011.

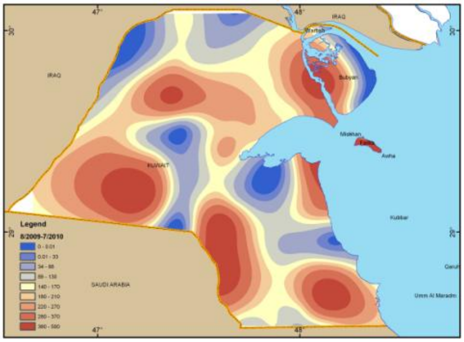

Fig. 3. Annual dust fallout for 2009-2010.

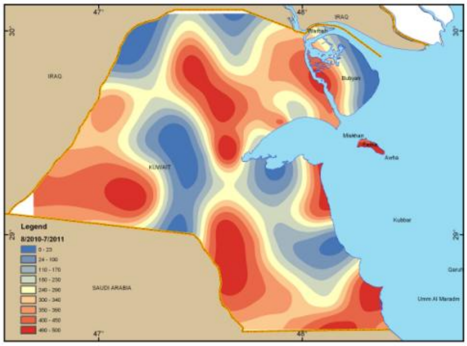

Fig. 4. Annual dust fallout for 2010-2011.

5. Grain size characteristics

The long distance suspended dust consists of mud particles that dominantly originated from regional sources such as the Western Desert of Iraq and Mesopotamian Flood Plain. In addition to local dust deposition that produces relatively coarse saltated dust material larger than 63 µm grain size fractions. The former type represents 63%, while the later is 37%. Generally, the distribution of particle size is trimodal and slight variation with time (Fig. 5).

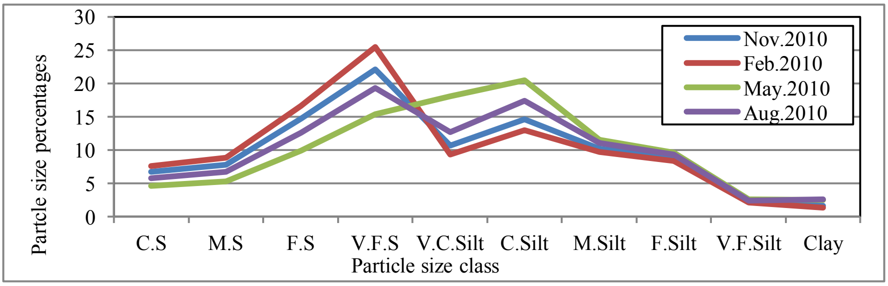

Fig. 5. Average of mean grain size percentages of dust fallout in Kuwait.

6. Mineralogical analysis

The XRD semi-quantitative analysis shows that quartz carbonates (mainly calcite) are the major minerals in the dust fallout samples. Feldspars are found with appreciable amounts (13% in average), while other minerals with small percentages (3%). Quartz percentage varies from 35% to 52% with average of 44%. Generally, quartz percentages increase with decrease of carbonates during summer time due to the increase in 4 eolian activities. The average percentages for clay, very fine silt , very coarse silt and very fine sand show the dominancy of clay at the sides of the dunes corridor (Huwaimiliyah-Wafra), Um Umara, north and east Bubiyan and Bahrat Hushan.The later areas also show smaller mean particle size, lower sorting, but higher skewness and kurtosis.

7. Trace elements analysis

The crushed powders from defined grain size fractions were analysed using ICP-OES for major and trace elements. The reason for using ICP to analyse major elements was because some size fractions had less weight than that needed (7 g) for analysis by X-ray fluorescence. Only 2 g (+/- 0.05) of powder is used in the ICP method. The method used to dissolve sediment samples for ICP was open evaporation of the sample with hydrofluoric acid, together with nitric acid (HNO_3), in a platinum crucible.

The ICP was used for determination of trace elements and the ten major elements: (Na, K, Ca, Mg, Al, Fe, V, Cr, Pb, Ba, Ti, and Tl) quoted as weight percent oxides (Table 1). Iron is an important element for the marine environment phytoplankton's and ciano-bacteria as nutrient. This element ranges from 1,851 to 191,413 with average 27,309 ppm.

Table 1. Average ICP measurements for dust samples.

ICP Elements	Na	K	Ca	Mg	Al	Fe	V	Cr	Pb	Ba	Ti	Tl
Average	9091	18035	48318	10822	41246	27309	70	251	2169	511	2328	4
Stdev	7674	26458	26916	2572	13649	25713	23	343	1685	879	1040	3
Max	62771	178613	115515	14774	80108	191413	153	2128	8543	4979	8873	14
Min	941	848	1247	1192	2999	1851	11	28	6	47	4	3

8. Depositional fluxes of radionuclides in dust fallout

The depositional fluxes of the natural radionuclides (^{40}K, ^{21}0Pb and ^{7}Be) and the man-made radionuclide (^{137}Cs) have been measured in 9 sampling sites covering Kuwait. Temporal variations of the radionuclides depositional rates have been observed in spring months (February, March, April); the time where the precipitation rates is maximum and hence more dust washed out. However, a strong correlation of depositional fallout and the terrestrial origin ^{40}K radionuclide has been observed; where it was less for the other radionuclides in the order of $^{40}K<^{137}Cs<^{210}Pb<^{7}Be$ as shown in table 2. This is probably due to several factors such as wind speed and direction, grain size of the dust fallout and frequency of dust storms. However, the spatial distributions of radionuclide depositional fluxes showed site-dependant relationship: highest in the interior areas and gradually decreased on the costal line. It is worth to mention that the calculation of the radiation hazards due to man-made radionuclide (^{137}Cs) inhalation was negligible.

Table 2. The correlations between the dust fallout and the radionuclide depositional fluxes.

	Dust Deposition	*Be-7*	*Cs-137*	*Pb-210*	*K-40*
Dust Deposition	1				
Be-7	0.33	1			
Cs-137	0.82	0.47	1		
Pb-210	0.69	0.83	0.78	1	
K-40	0.98	0.34	0.84	0.71	1

9. Total pollen count

The local flora is the main source of the pollen load and the concentration depends on the amount of vegetation around each station. Except for very low percentage (2-3%) of

Pinaceae pollen recorded in the north and northwest of Kuwait, it could be interpreted as being transported by the north-westerly wind (Fig. 6).

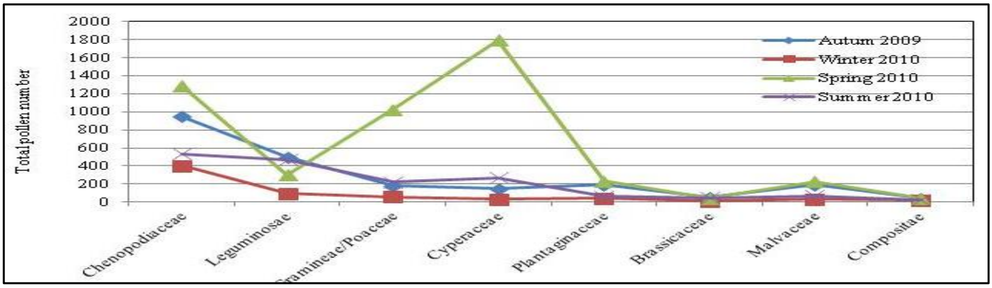

Fig. 6. Seasonal pollen counts of the most dominant families during 2009-2010.

10. Summary and conclusions of distribution and lab analysis

The northwestern, western and northern winds play a major role in producing dust in the study area within Kuwait. Regional areas represent the dominant sources of dust fallout, while local sources contribute with appreciable amounts. The very fine and fine sand particles originated from local sources as they moves in the form of saltation for a short distance and represent 37% of the average dust fallout percentages in Kuwait. There is a trend of fining in mean size for dust particles towards the east and the northeast. Carbonates and quartz are the major components of dust in Kuwait, feldspars are found in appreciable amounts. Other minerals in the dust are gypsum, anhydrite, bassanite and heavy minerals. The muddy playas, depressions, sabkhas and intertidal zone (Bubiyan and Warba islands) are the major sources of local dust. Natural vegetation plays a major role in minimizing and reducing fallen dust. Open desert areas show an increase in the quantities of dust fallout by at least two thirds more than in the National Park within Kuwait.

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