Abstract

A dust storm is meteorologically defined whenever visibility is less than 1,000 meters (Al-Kulaib 1990). Al-Dousari (2009) lists Kuwait as having one of the highest dust precipitation rates in the world. Safar (1980) states that the annual average number of dusty days due to dust storms or rising dust or suspended dust in Kuwait is 255.4. Forty-seven sampling sites representing all the geomorphological and sedimentological provinces in Kuwait were selected for the installation of dust traps to measure the average annual amount of deposited dust during 2009–2010 and 2010–2011 in tons.km⁻².

Sample Location

Forty-seven sampling sites representing all the geomorphological and sedimentological provinces in Kuwait were selected for the installation of dust traps (Fig. 2.1). The sites included the largest island in Kuwait, coastal areas, desert ecosystems, and the Kuwaiti boundaries with Saudi Arabia and Iraq. The dust fallout in Kuwait was monitored continuously to attain the following objectives:

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

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- To test and environmentally evaluate many varieties of effective control measures.
- To identify the pollen distribution in dust samples.
- To establish a GIS database on dust and pollen in Kuwait.

Deposited Dust

Introduction

Wind is the most active agent in the desert ecosystem. It can remove sand, silt, and clay-sized particles from the surface and blow them, as dust and sandstorms, over great distances (Al-Dousari 2009). Al-Dousari (2009) lists Kuwait as having one of the highest dust precipitation rates in the world. Safar (1980) states that the annual average number of dusty days due to dust storms or rising dust or suspended dust in Kuwait is 255.4 (Al-Dousari 2009). Data on the frequency and rates of dust deposition suggest that the rates of aeolian accumulation may be of a similar order of magnitude as rates of fluvial erosion (Goudie 1978; Wells et al. 2007). Although dust is a result of soil erosion from some areas, it is also a major contributor to soil in other areas, as noted in the dust deposition in Oman (Badawy et al. 1992); Riyadh (Al-Tayeb and Jarrar 1993); Australia, New Zealand (Marx et al. 2005); Canary Islands (Moreno et al. 2006); Florida, Bahamas, 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 and Penuelas 1999). Dust traveling long distances is commonly very fine, with sizes predominantly between 0.068 and 0.02 mm (Walker and Costin 1971). Significant quantities of dust may be blown thousands of kilometers from their source (Meng and Lu 2007), and it has been estimated that windblown dust derived from soil erosion contributes approximately 500×10^6 t of the PM to the atmosphere each year (Peterson and Junge 1971).

Fig. 2.1 Dust traps sampling locations among Kuwait

Methodology

A dust storm is meteorologically defined whenever visibility is less than 1000 m (Al-Kulaib 1990). In the first decade of this century (July 2000–March 2010), dust storm days were counted in Kuwait using airport meteorological data. Low-resolution images such as METEOSAT (visible and infrared images), MODIS (bands 3, 4, and 7), TOMS, AVHRR, and SeaWiFS were collected within the same period to locate the dust storm primary, intermediate, regional, and local sources and trajectories. Dust storm images were obtained from the satellites' free websites. A map was produced by locating the significant trajectories showing the trajectory direction and duration. The trajectories were classified into two types according to surface area covered by the dust storm that was detected using meteorological data and satellite images: major (greater than or equal to 3000 km²) and intermediate (less than 3000 km²) trajectories.

Modified dust traps were manufactured following the design of Al-Awadhi (2005). Modifications included thermal insulation on the sides and the bottom of the dust containers. The dust traps were installed at 47 sites, at 240 cm above the ground surface, and were chosen to represent the prevailing environmental conditions of Kuwait (Fig. 2.2). The traps were

fixed in fields at least 50 m away from any infrastructure. The fallen dust rates were monitored monthly, from September 1, 2009, to August 31, 2011. The collected data and samples were compared with those from the Kuwait Environment Public Authority (KEPA) and regional and global literature.

Initially, the characteristics of the dust were examined and interpreted using a series of analytical tools. Grain-size parameters were determined using standard sieve analysis and the Centrifugal Particle Analyzer (Shimadzu, SA-CP3) for all dust fallout samples in January and October 2010. The Brunauer, Emmett, and Teller (BET) surface area is expressed as the value of a specific weight of loose sand in terms of m²/g measured by using isotherm plot diagrams of volume against pressure and the BET equation. The whole components of the dust samples were gently powdered and analyzed using Philips PW-1830 X-ray Diffraction (XRD). Semi-quantitative analysis was carried out for the Bubiyan (D07), Warba (D09), Sabiya (S-3), and National Park (RD4) samples, and the results were compared with regional and global dust collection by the authors or others from the literature. Furthermore, a scanning electron microscope (SEM) was used to analyze the Bubiyan and Al-Liyah dust samples (L18 and D-08) with a magnification ranging from 600 to 2700X.

Fig. 2.2 Dust trap in Al-Liyah newly preserved area (2009)

Annual Deposited Dust

The average annual amount of deposited dust during 2009–2010 was 220 tons km^{-2} . The northern coastal areas and the western areas of Kuwait had the highest amount of deposited dust. The preserved areas and southern coastal areas had the lowest amount. The preserved areas around Jahra, with dense vegetation cover compared with the open desert areas, had less deposited dust, which is attributed to the capability of native vegetation preventing the movement (re-suspension) of dust particles after the initial deposition (Fig. 2.3).

Areas of high deposited dust concentration	Areas of low deposited dust concentration
Bubiyan Island	Um Eish
Abdulli	Doha
Salmi	Um Qudayr
Shuwaikh	Khur Fawaris
Kabd	Shuaiba

The annual dust deposited rate in Kuwait during 2010–2011 was 373 tons km^{-2} , which is higher than in 2009/2010 by 33.2% (220 tons km^{-2}). The areas of lower and higher concentrations of dust were nearly the same as in 2009–2010. It is evident from the slight variation in the distribution of dust fallout over the two years that there is an appreciable amount of dust fallout contribution from local sources. This knowledge guides us for planning future urban areas such as the Sabiyah and Bubiyan Island, which suffer from a high concentration of dust fallout as they are rich in mud size particles. Spatial and temporal variations in dust fallout

Fig. 2.3 Annual deposited dust for 2009–2010

fluxes within Kuwait are shown in the attached Figs. 2.4, 2.5, 2.6, 2.7, 2.8, 2.9 and 2.10.

Areas of high deposited dust concentration	Areas of low deposited dust concentration
Ratqah	Ras Ezur
Bubiyan Island	Qurain
Abdulli	Gudhi
Kabd	Jal Al-Liyah
Salmi	Rwdatayn

Fig. 2.4 Annual deposited dust for 2010–2011

Fig. 2.5 Deposited dust

Fig. 2.6 Deposited dust for August 2009–December 2009

Fig. 2.7 Deposited dust for January 2010–May 2010

Fig. 2.8 Deposited dust for June 2010–October 2010

Fig. 2.9 Deposited dust for November 2010–March 2011

Fig. 2.10 Deposited dust for April 2011–August 2011

References

- Al-Dousari. (2009). Section III: Recent studies on dust fallout within preserved and open areas in Kuwait. In N. R. Bhat, A. Y. Al-Nasser, & S. Omar (Eds.), *desertification in arid lands: Causes, consequences and mitigation* (pp. 137–148). Kuwait: Kuwait Institute for Scientific Research.
- Al-Awadhi, J. (2005). Dust fallout characteristics in Kuwait: a case study. *Kuwait Journal of Science and Engineering*, 32(2), 135–152. ISSN: 1024–8684.
- Al-Kulaib, A.A. (1990). *Climate of Arabian Gulf*. Kuwait: That Alsalasil Press.
- Al-Tayeb, N. T., & Jarrar, B. M. (1993). Dust fall in the city of Riyadh. In *Proceedings of the Industrial Air Pollution Symposium*, Riyadh, 15–17 November 1993, Saudi Arabia, pp. 66–74.
- Avila, A., & Peñuelas, J. (1999). Increasing frequency of Saharan rains over northeastern Spain and its ecological consequences. *the Science of the Total Environment*, 228, 153–156. [https://doi.org/10.1016/S0048-9697\(99\)00041-8](https://doi.org/10.1016/S0048-9697(99)00041-8).
- Badawy, M. I., Hernandez, M. D., & Al-Harthi, F. (1992). Sources of pollution at Mina al Fahal coastal area. *Bulletin of Environmental Contamination and Toxicology*, 49, 813–820. <https://doi.org/10.1007/BF00203152>.
- Goudie A. (1978). Arid geomorphology. *Progress in Physical Geography: Earth and Environment*, 2(2):333–338. <https://doi.org/10.1177/030913337800200207>
- Marx, S. K., Kamber, S. B., & McGowan Hamish, A. (2005). Estimates of Australian dust flux into New Zealand: Quantifying the eastern Australian dust plume pathway using trace element calibrated 210Pb as a monitor. *Earth and Planetary Science Letters*, 239(3–4), 336–351. <https://doi.org/10.1016/j.epsl.2005.09.002>.
- Meng and Lu. (2007). Dust events as a risk factor for daily hospitalization for respiratory and cardiovascular diseases in Minqin, China. *Atmospheric Environment*, 41, 7048–7058. <https://doi.org/10.1016/j.atmosenv.2007.05.006>.
- Moreno, T., Querol, X., Castillo, S., Alastuey, A., Cuevas, E., Herrmann, L., Mounkaila, M., Ivira, J., & Gibbons, W. (2006). Geochemical variations in Aeolian mineral particles from the Sahara-Saheldust corridor. *Chemosphere*, 65, 261–270. <https://doi.org/10.1016/j.chemosphere.2006.02.052>.
- Muhs, D. R., Budahn, J., Reheis, M., Bean, J., Skipp, G., & Fisher, E. (2007). Airborne dust transport to the eastern Pacific Ocean off southern California: Evidence from San Clemente Island. *Journal of Geophysical Research*, 112. <https://doi.org/10.1029/2006JD007577>.
- Peterson, S. T., & Junge, C. E. (1971). Sources of particulate matter in the atmosphere. In W. W. Kellogg & G. D. Robinson (Eds.), *Man's impact on the climate* (pp. 310–320). MIT Press.
- Querol, X., Viana, M., Alastuey, A., Amato, F., Moreno, T., Castillo, S., Pey, J., De La Rosa, J., Sanchez De La Campa, A., Artinano, B., Salvador, P., García, Dos Santos, S., Fernández-Patier, R., Moreno-Grau, S., Negral, L., Minguillón, M. C., Monfort, E., Gil, J. I., Inza, A., Ortega, L. A., Santamaria, J. M., & Zabalza, J. (2007). Source origin of trace elements in PM from regional background, urban and industrial sites of Spain, Atmos. Environ., 41, 7219–7231. <https://doi.org/10.1016/j.atmosenv.2007.05.006>.
- Safar, M. I. (1980). *Frequency of dust in day-time summer in Kuwait*. Kuwait: Directorate General of Civil Aviation.
- Walker, P. H., & Costin, A. B. (1971). Atmospheric dust accession in South-Eastern Australia. *Australian Journal of Soil Research*, 9, 1–5. <https://doi.org/10.1071/SR9710001>.
- Wells, K. C., Witek, M., Flatau, P., Kreidenweis, S. M., & Westphal, D. L. (2007). An analysis of seasonal surface dust aerosol concentrations in the western US (2001–2004): Observations and model predictions. *Atmospheric Environment*, 41(31), 6585–6597. <https://doi.org/10.1016/j.atmosenv.2007.04.034>.

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