Environ Earth Sci (2012) 66:2247–2256
DOI 10.1007/s12665-011-1445-6

ORIGINAL ARTICLE

Geochemistry and mineralogical composition of the airborne particles of sand dunes and dust storms settled in Iraq and their environmental impacts

Salih Muhammad Awadh

Received: 2 March 2011 / Accepted: 5 November 2011 / Published online: 17 November 2011

Abstract Five dust storms that occurred in 2008 (15 March, 11 April, 28 April, 25, May and 26 June) in addition to the many sand dunes disseminated in the Western Desert of Iraq are sampled. The worse dust storm that occurred in Iraq in 11 April, 2008 covered 75% of the Iraq area and deposited 6.9 million tons approximately as a total weight of fallout during just 8 h, declining temperature 6°C. During the episodes of dust storms, visibility decreased enormously, no more than 30 m. Many people were taken to hospitals after sustaining breathing problems. Some of them died. Clay fraction is the dominant part in the dust storms forming 70% besides a little silt (20.6%) and sand (9.4%), then classified as mature arkose of clay to sandy clay, whereas sand dunes are formed from 72.7% sand, 25.1% silt and 2.19% clay, then classified as mature arkose of silty sand. Sand dunes have much maturity. Mineralogical composition of dust storms and sand dunes are Quartz (49.2%, 67.1%), feldspar (4.9%, 20.9%), calcite (38%, 5%), gypsum (4.8%, 0.4%), dolomite (0.8%, 1%) and heavy minerals (3.2%, 6.6%), respectively. Heavy mineral suites in the dust storms are represented by zircon, pyroxene, hornblende, chlorite and magnetite; whereas the sand dunes are represented by zircon, tourmaline, garnet and pyroxene, concentrated within sand fraction. Heavy minerals according to satellite images revealed the dry land of Sahara Desert in North Africa and the Arabian Peninsula as well as Syria and Jordan were a major source of the dust storms that have occurred in Asia, including Iraq.

S. M. Awadh (✉)
Earth Sciences Department, College of Science,
University of Baghdad, Baghdad, Iraq
e-mail: salihauad2000@yahoo.com

Keywords Geochemistry · Mineralogy · Dust storms · Sand dune · Iraq

Introduction

Dust storms are meteorological phenomena common in arid and semi-arid regions that have occurred throughout the recent history and ancient geological time. Dust can remain in the atmosphere for weeks and influence regional weather and climate (Shi et al. 2005). It is estimated that nearly 50% of troposphere atmospheric aerosol particles are minerals, mainly sourced from the deserts and their boundaries (Andreae 1995), and can carry heavy metals, bacteria for long distance. Aerosols, especially those carried by dust storms, can be transported globally, and have significant impacts on the global environments and climate (Prospero 1999; Clarke et al. 2001; Bishop et al. 2002). Aerosols also play an important role in removal, deposition and transport of atmospheric pollutants (Sievering et al. 1989; Dentener et al. 1996; Carmichael et al. 1996).

Annually, massive dust storms occurring off the African Desert and Asia have blanketed hundreds of thousands of square kilometers of Asian area. Two main types of winds blow on Iraq, these are Al-shamal and Sahara. Al-shamal is a northwesterly wind blowing over Iraq and the Arabian Gulf states (including Saudi Arabia and Kuwait) creating large sandstorms that impact Iraq, most sand having been picked up from Jordan as well as Syria (Farouk and Makharita 2009). Sahara is a western wind that comes off the Sahara Desert in North Africa (Fig. 1), and is locally known as a simoom, occasionally reaching large areas of Asia, including Iraq. Dust storms strongly influence the global environment, because it is capable of transferring and redistributing the fine-grained sediments. Asian dust

Fig. 1 Map shows Iraq location in the way of the dust storm blowing from the west

storms can transport mineral grains thousands of kilometers to Japan, Korea, North Pacific Ocean, Hawaii and even North America (Clarke et al. 2001; Yang et al. 2001; Moore et al. 2003). African dust storms have been studied by Bergametti et al. (1989); Avila et al. (1997); Falkovich et al. (2001).

Iraq is situated in the northeast of the Arab world in western Asia, between latitudes 29.5°N and 22°N and longitudes 38.45°E and 48.8°E, bordering Turkey to the north, Iran to the east, Syria to the west and Saudi Arabia to the south, comprising an area 438,446 km^2. Iraq has hot dry continental weather in summer and cold, wet weather in winter. Dust storms in Iraq occur more frequently during spring and summer, with an average of 20 days per year (Al-Farrajii 1998). Northerly and northwesterly winds sweep the country during the dry months, where wind velocity may exceed 100 km/h, which raises dust storms. Wind speeds may reach their maximum by midday in July (average 3.3 m/s). The measured threshold velocity for the movement of soil and sediment particles was 3.0 m/s (Dougramedji 1999). Sand particles and dust particles will be blown away from the dry land surface and transported for several hundred kilometres to the Atlantic Ocean (Thompson 1984). When a low-pressure system occurs in the north of the Sahara Desert or above the Mediterranean, the turbulence takes place from west to the east. Strong winds will transport “hot sand particles and dust particles” from the Sahara Desert to the Mediterranean coasts and the delta of the Nile. This wind can blow for 50 days without stopping and reduce visibility to a few meters. It is locally termed “Wind Hilleck” in Algeria or “Sirocco” in southern Europe (Thompson 1984).

In Sudan, the strong wind is locally called Haboob (Thompson 1984). It was reported that the wet–warm strong winds in the Northern Sudano, at the southern fringe of the Sahara Desert, normally associated with sand-dust storm and thunder can last, on average, 3 h and can flatten sand dunes and accumulate new barchan dunes. Haboob windstorms sometimes originated from the Northern Sahara Desert and are related to the lower atmospheric pressure in the Mediterranean (Thompson 1984). It blows with dense contents of sands and dusts.

Three major categories of particles have been differentiated in dust storms of China during 20 March 2002: mineral particles, coal fly, and soot aggregates. Soot aggregates were characterized by chain-like and “fluffy” appearance, coal fly ash by a smooth spherical shape and mineral particles by irregular shape. Mineralogy and geochemistry of dust storm particles may be more diagnostic of their sources (Shi et al. 2005).

Dust storms and sand storms are the most natural hazard in Iraq due to extreme heat, low humidity and little precipitation. The deposited dust influences vegetation productivity, atmospheric transparency, heat balance, decrease of photo-radiation received by vegetation, vegetation cover, increasing particles on the plant leaves, which prevents the arrival light to the chlorophyll, and damages the small crops.

This work aims to describe the mineralogical composition, mineral maturity and classify the sediments of sand dune and the African–Asian dust storms that occur in Iraq in their way toward the east, and giving a preliminary estimation on the amount of transported and deposited dust.

Materials and methods

Many dust storms occurred in Iraq in 2008. Five samples were collected from occurrences on 15 March, 11 April, 28 April, 25 May and 26 June at Baghdad city. A total number of 20 sand dune samples were also collected randomly at the surface of four locations (between Al-Ramadi and Rutba) emplaced in the shadow of the south side of the highway which crosses the Western Desert of Iraq and connects Iraq with Jordan and Syria (Fig. 2).

In attempt to calculate the mass of transferred fallout dust, a clean glass plate of 1 × 1 m was designed and installed horizontally on the building roof of 3 m high at Baghdad city. Accordingly, the fallout dust was collected from the glass slab and carefully and weighted. The amount of deposited dust in Iraq during only 8 h was calculated by multiplying the area which was covered by dust (75% of total area of Iraq approximately) by weight of dust deposited in an area of 1 m^2.

Mechanical sieve analyses for both types of samples (dust storms and sand dunes) were performed (Table 1). In this procedure 50 gm from each sample was taken; from then, the sand fraction was separated by dry sieving; thereafter, the mud fraction was split into silt and clay by the pipette method following Folk (1974). Heavy minerals were separated from dust storms and sand dunes samples

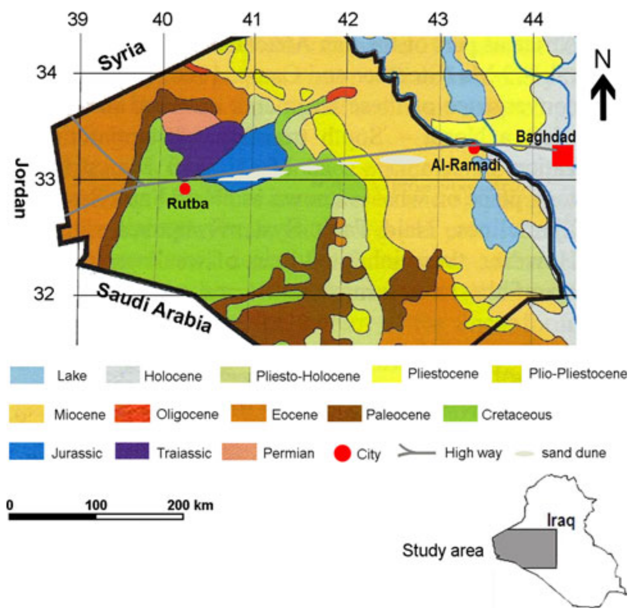


Fig. 2 Geological map shows the studied area

using bromoform. The mineralogical identification for heavy and light minerals was carried out petrographically on the prepared thin sections and tested under polarized microscope in the Department of Earth Sciences, College of Science, University of Baghdad. Then, at least 100 grains were identified and counted manually based on their optical properties, then calculated as percent (Table 2). The methods of heavy mineral grain identification are described in Grosz et al. (1990) and Mange and Maurer (1992). One whole sample of both of the dust storm and the light mineral fraction of sand dune were prepared as powdered (less than 4 μ), then identified mineralogically using the X- ray diffraction technique (XRD) (Fig. 5), where the XRD Philips PW1729 was used. Chemical analyses were done by different methods; Fe_2O_3 and Al_2O_3 were determined using the Atomic Absorption Spectrophotometer (AAS); which is a computerized-type GBC 933 at the Department of Chemistry in the University of Baghdad. Na_2O_3 and K_2O were determined by Flame photometry; CaO and MgO were determined according to the ASTM (1989) by titration with ethylenediaminetetraacetic acid (EDTA) (0.01 N).

Results and discussion

Grain size analyses

Dust storm and sand dune samples were sieved mechanically. On the basis of the interpretation of the average grain

Table 1 Results of grain size analyses of sand dune and dust storm samples

Sand dune	Sand (%)	Silt (%)	Clay (%)	Dust storm 2008	Sand		Silt		Clay	
					(%)	Diameter (μ)	(%)	Diameter (μ)	(%)	Diameter (μ)
1SD	70	29	1.0	15 March	9	210–62.5	21	53–7.8	70	3.9–0.006
2SD	75	32	2.0	11 April	12		20		68	
3SD	66	23	1.0	28 April	13		17		70	
4SD	72	25.5	2.5	25 May	6		22		72	
5SD	69	28.4	2.6	26 June	7		23		70	
6SD	72	26.5	1.5	Average	9.4		20.6		70	
7SD	73	23.3	3.7							
8SD	77	21.4	1.6							
9SD	78	19.8	2.2							
10SD	75	21	4.0							
11SD	69	28.9	2.1							
12SD	74	23	3.0							
13SD	73	25.3	1.7							
14SD	68	31.1	0.9							
15SD	70	28.4	1.6							
16SD	69	28	3.0							
17SD	77	21.6	1.4							
18SD	76	22	2.0							
19SD	72	25.6	2.4							
20SD	79	18.3	2.7							
Average	72.7	25.1	2.19							

Table 2 Average mineralogical composition in the dust storms and sand dunes, dash lines represent 0%

Sample type	Quartz (%)	Feldspar (%)	Calcite (%)	Gypsum (%)	Dolomite (%)	Heavy minerals (%)	Total (%)
Dust storm samples 2008							
15 March	51.2	7.9	33.0	2.2	1.2	4.5	100
11 April	52.5	3.3	32.3	8.1	0.9	2.9	100
28 April	55.0	4.2	25.1	3.2	0.9	3.5	100
25 May	52.6	6.8	30.7	6.4	0.5	3.0	100
26 June	33.5	2.7	56.7	4.5	0.5	2.1	100
Average	48.96	4.98	35.56	4.88	*2.42*	3.2	*100*
Sand dune samples							
1SD	60.1	25.2	7.9	0.3	–	6.5	100
2SD	69.5	9.9	12.3	0.2	0.5	7.6	100
3SD	51.5	24.3	6.5	–	1.2	6.5	100
4SD	63.2	23.2	3.9	0.3	1.2	8.2	100
5SD	68.9	19.2	2.2	0.5	1.6	7.6	100
6SD	59.7	28.0	2.0	1.0	2.0	7.3	100
7SD	72.4	10.7	6.8	–	1.8	8.3	100
8SD	62.8	28.3	3.3	0.7	–	5.0	100
9SD	64.0	23.3	2.1	0.5	0.9	9.2	100
10SD	67.7	18.1	5.4	0.3	1.6	6.9	100
11SD	61.8	20.7	10.0	0.8	2.1	4.6	100
12SD	67.8	17.9	7.2	0.8	0.4	5.9	100
13SD	68.2	17.8	5.4	0.4	2.0	6.2	100
14SD	66.6	22.7	3.4	1.1	0.5	5.7	100
15SD	70.2	21.5	1.8	0.3	0.5	5.7	100
16SD	55.0	29.6	7.1	–	1.7	6.6	100
17SD	64.0	27.7	4.0	–	0.3	4.0	100
18SD	66.5	21.4	3.7	0.2	–	8.2	100
19SD	60.9	30.1	1.9	0.3	0.4	7.4	100
20SD	60.2	30.4	3.2	0.3	1.3	4.6	100
Average	*64.35*	*22.5*	5.0	0.4	1.0	6.6	*100*

size of the dust storm samples; clay particles are dominant (70%), while the remnant ratio is shared between silt fraction (20.6%) and fine sand fraction (9.4%) (Table 1; Fig. 3a). The grain size of clay is less than 0.0039 mm, whereas the grain size of silt ranges from 0.062 to 0.0039 mm and fine sand ranges from 0.125 to 0.062 mm. The average grain size of sand dunes was distributed as 72.7% sand (0.062–1 mm), 25.1% silt and 2.19% clay (Table 1; Fig. 3b). Dust storm samples appear to be clay to sandy clay sediments, whereas the sand dune samples are silty sand (Fig. 4).

Sand storm is basically a wind storm that carries sand through the air, forming a relatively low cloud near the ground. Accordingly and based on grain size, the current studied storms are dust storms, but not sand storms. Fine particles may also be swept upwards hundreds of meters into the air. The average height of a dust storm was 900–1,800 m (Al-Farajii 2000).

Mineralogical composition

Mineralogical composition in dust storm and sand dune samples are presented by X-ray diffractograph (Fig. 5) and polarized microscope (Fig. 6). The identification of mineral assemblages of aerosols participates in diagnostics of their sources (Davis and Guo 2000). The particles of the dust storms were mainly formed from light minerals like quartz (49.2%), calcite (38%), and feldspar (4.9%) which were represented by orthoclase and plagioclase, gypsum (4.8%) and dolomite (0.8%) (Table 2), besides little quantity of the heavy minerals (3.2%) which are represented by hornblende, pyroxene, chlorite, magnetite and zircon (Fig. 5a). Heavy minerals provide valuable evidence about the origin of sediment and interpretation of their provenance and can give insights into the types of geology that formed the target rocks (Walkden et al. 2008). Zircon and hornblende basically reflect the granitic igneous rock

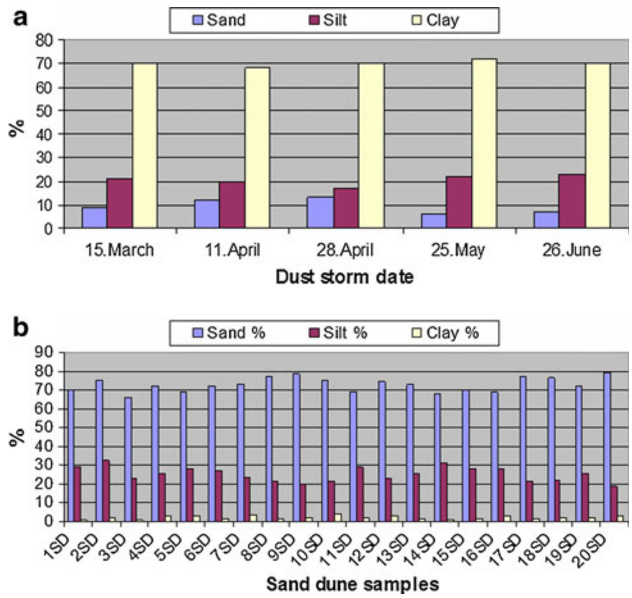


Fig. 3 Average distribution of grain size in dust storm samples (**a**); in sand dune samples (**b**)

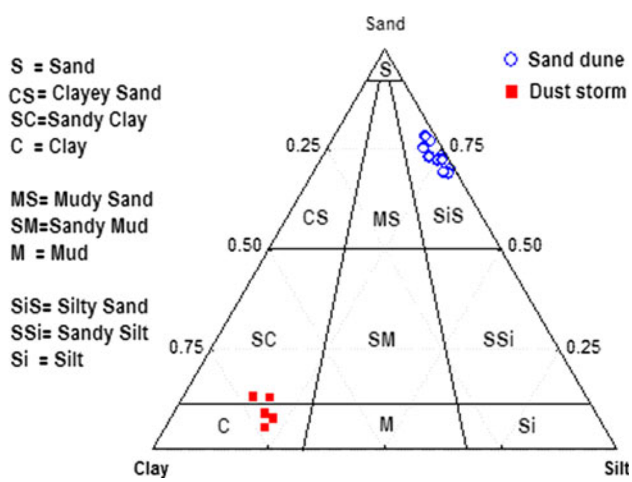


Fig. 4 Grain size analyses of the average of dust storm and sand dune samples

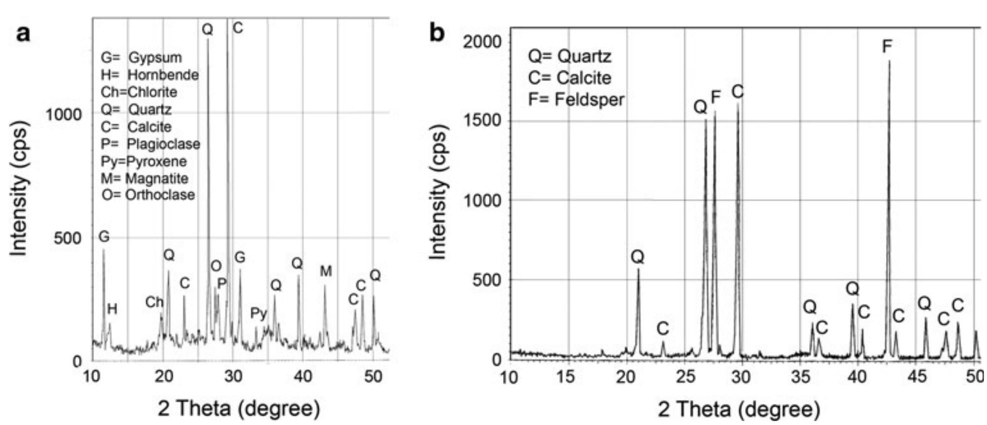
origin. Pyroxene and magnetite originated from basic igneous rocks. Chlorite was probably derived from metamorphic rocks. Mineralogical composition indicates that the dust sources are eroded igneous, sedimentary and metamorphic. Since the wind has been blown from the west of Iraq, therefore the probable supplying sources are the dried land in the Saudia Arabia, Jordan, Syria and North Africa. Egypt, Saudia Arabia, Jordan, Syria and even some parts of Iraq are source points of dust (Fig. 7a; MOIRI 2009). The satellite images support that the Sahara Desert in North Africa was a source of the dust storms in case of east direction wind. Arabian shield contains granitic and metamorphic rocks (Glennie 2010). Sahara and dry lands around the Arabian Peninsula are the main sources of airborne dust, with some contributions from Iran (Victor 2007), Basaltic flow exposed on surface in eastern Jordan and ordinary extends to the southeast of Syria (Abed 2000).

Sahara Desert is the largest desert providing a different type of loss sediments. Satellite images present that the Sahara Desert participated in supplying particles (Fig. 7b). Accordingly, Sahara Desert, Arabian shield, weathered igneous rock in Syria and Jordan as well as the dried land and loss soil are considered as a parent material source.

With regard to the sand dunes, the major constituents are quartz, feldspar and calcite (Fig. 5b). The average mineralogical composition is comprised mainly from quartz (67.1%), feldspar (20.9%) and calcite (5%), whereas gypsum (0.4%) and dolomite (1%) formed a little quantity (Table 2). Heavy minerals contributed 6.6% from the average of mineralogical composition of sand dunes (Table 2).

Heavy mineral suites are represented by zircon, tourmaline, muscovite, garnet and pyroxene. Heavy minerals are concentrated within the sand fraction; therefore, they existed much more in sand dune samples than in dust storm samples. The metamorphic source is indicated by existence of epidote, garnet, kyanite, staurolite, chlorite, andalusite, and blue-green hornblende (Milner et al. 1962). In the dust

Fig. 5 X-ray diffractograph of: **a** dust storm sample collected during 11 April, 2008 in Iraq; **b** light fraction of sand dune sample collected from the Western Desert of Iraq



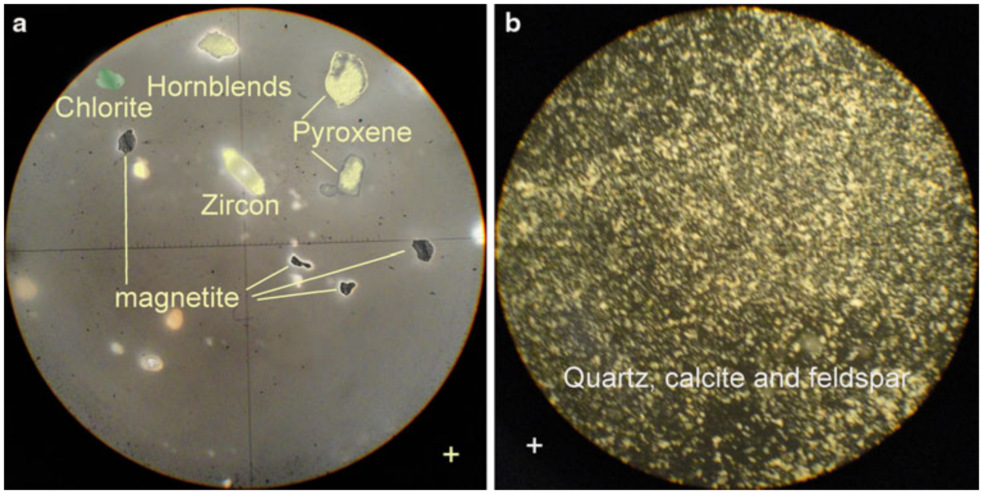


Fig. 6 Microscopic photos of storm dust samples. **a** Displays the separated heavy minerals from the fine sand fraction (20×); **b** displays light minerals (5×); (+) represents cross-polarized light

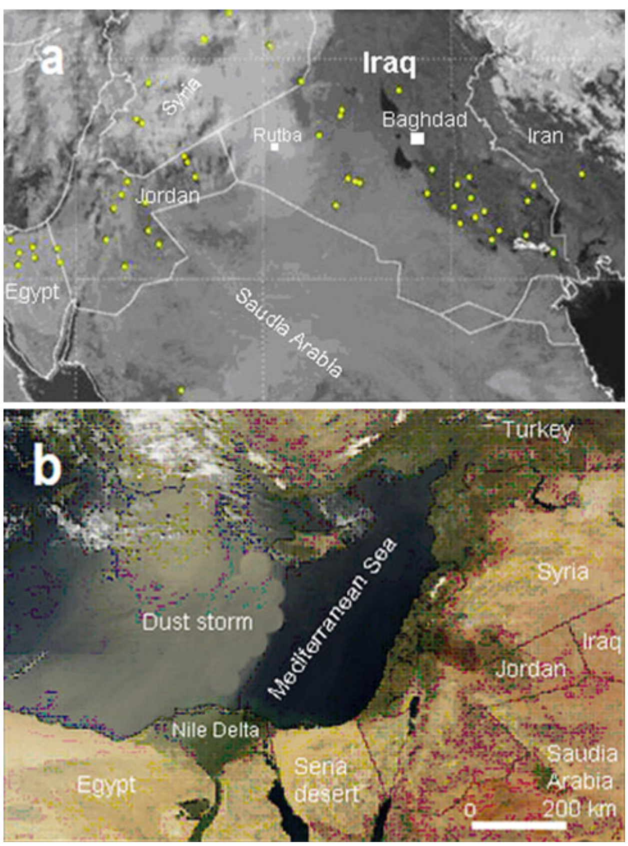


Fig. 7 Satellite images. **a** Middle East with point sources of dust (after MOIRI 2009); **b** dust storm coming from Sahara Desert in the Africa toward Asia (after UCAR 2008)

storm samples, chlorite reflects the metamorphic origin. Magnetite, chromite, chromian-spinels, pyroxene and rutile commonly refer to basic igneous sources (Zimmerle 1984). Magnetite and pyroxene reflect the basic igneous rocks. Large bodies and occurrences of acidic igneous rocks (granite) and basic igneous rocks (gabbro and diabase) are well exposed in the western side of the Arabian shield in Saudia Arabia (Hussein and Omer 2011). The occurrence of Lower Paleozoic rocks in Saudi Arabia crop out in three regions, in the northwestern, central and southern portions of Saudi Arabia (Wanas and Abdel-Maguid 2006). In the northwestern region, outcrops of the Lower Paleozoic rocks extend from Great Nafud to Jordan (Helal 1968). In the central area, exposures of Lower Paleozoic rocks were recorded by AL-Laboun (1986) in the Hail and Qasim regions. In the southern region, exposed Lower Paleozoic rocks extend from Gabal Wajid to North Yemen (Kellogg et al. 1986). The sandstone in southern Saudi Arabia that occurred directly above the Precambrian Arabian Shield has been described as 'Nubian type' (Hardley and Schmidt 1975) because of its similarity to other similar sandstones exposed in North Africa, northern Saudi Arabia and Jordan (Beydoun 1988). Zircon, muscovite and hornblende reflect the acidic source.

Wind speeds may reach their maximum by midday in July (Al-Farajii 2000). The measured threshold velocity for the movement of soil and sediment particles was 3.0 m/s (Dougramedji 1999). Wind speed, in addition to the mineral hardness, is control factor of the shape of the mineral surface. The resistant minerals such as quartz possessed smooth surface during weathering and transportation processes, whereas the surface of non-resistant minerals (calcite and feldspar) are rough and uneven.

Geochemistry

The results of geochemical analyses for dust storm and sand dune samples are listed in Table 3. The concentration

Table 3 Chemical composition of the dust storm and sand dune in Iraq

Oxides	SiO_2	Al_2O_3	CaO	K_2O	Na_2O	Fe_2O_3	MgO	LOI	Total
Dust storms									
15 Mach	60.0	3.3	17.1	1.9	2.0	2.5	0.5	13.0	100.3
11 April	59.8	4.7	14.5	2.6	1.2	2.1	2.0	12.8	99.7
28 April	60.3	4.2	11.7	2.3	2.8	1.5	2.1	15.0	99.9
25 may	58.2	4.9	14.3	3.2	2.0	1.6	0.7	15.0	99.9
26 June	57.7	2.4	21.9	2.5	2.0	1.3	0.2	137	101.7
Average	59.2	3.9	15.9	2.5	1.8	1.8	0.3	14.0	100.5
Sand dunes									
1SD	70.1	12.2	3.0	2.6	1.9	0.9	1.2	7.7	99.6
2SD	72.3	9.9	2.7	1.2	2.2	2.1	1.6	7.6	99.6
3SD	77.1	12.3	1.2	2.4	2.4	1.9	0.9	1.7	99.9
4SD	72.6	11.1	2.9	2.5	2.4	1.2	1.7	5.0	99.4
5SD	70.0	10.0	4.4	2.9	3.1	1.3	1.8	6.2	99.7
6SD	69.5	9.8	5.7	2.7	2.2	2.2	1.9	6.1	100.1
7SD	70.2	11.2	5.3	3.3	1.7	0.8	1.4	5.9	99.8
8SD	73.9	11.3	3.3	3.2	0.9	1.1	1.3	4.9	99.9
9SD	74.7	12.9	3.3	3.5	2.5	0.9	1.4	0.5	99.7
10SD	75.8	13.0	2.1	3.6	2.7	1.6	1.0	0.4	100.2
11SD	75.0	10.9	2.2	3.0	3.0	1.9	0.3	2.9	99.2
12SD	74.8	11.5	1.9	3.3	0.6	0.7	1.1	5.7	99.6
13SD	73.2	10.8	2.9	3.2	2.1	2.2	0.4	4.5	99.3
14SD	69.0	10.1	6.6	3.4	2.6	2.1	0.2	5.7	99.7
15SD	67.5	9.8	8.3	2.8	1.9	1.3	2.5	5.4	99.5
16SD	77.7	12.7	1.0	2.9	1.1	1.1	0.1	3.6	100.2
17SD	80.2	10.4	1.1	3.7	2.0	1.7	0.1	0.9	100.1
18SD	75.0	11.4	3.3	3.0	2.7	1.6	0.2	2.6	99.8
19SD	73.8	12.0	4.0	3.6	1.8	1.8	0.6	2.1	99.7
20SD	73.6	6.7	6.8	4.7	1.9	3.6	2.3	2.6	102.2
Average	73.3	11.0	3.6	3.1	2.1	1.6	1.1	4.1	99.9

of three major oxide groups such as silica and alumina, alkali oxides and iron oxides plus magnesia were used to classify sandstones. The enrichment of SiO_2/Al_2O_3 by mechanical and chemical processes produces quartz arenites (Orthoquartzites; Obiefuna and Orazulike 2010). Sand dunes appear to be more mature than dust storm because they have more quartz, where quartz is a function of the intensity of weathering. Abundance of alkalis (Na_2O and K_2O) characterizes immature sandstones such as Arkoses and greywackes, whereas the ratio of Na_2O/K_2O determines both the provenance and diagenesis of the sandstone (Akinmosin and Osinowo 2008; Ibe and Akaolisa 2010). Most of the Alkalis (K_2O and Na_2O) reflect high quantity of feldspar relatively indicating immature sediments.

According to Pettijohn et al. (1972), sandstone classification is presented in Table 4; as arenite, greywacke, arkose and lithic arenite. In dependence on the comparison between the results in Table 5 with the results in Table 4, dust storms and sand dunes are classified as arkosic sediments.

Table 4 General classification of sandstone according to logarithmic oxide ratio (after Pettijohn et al. 1972)

Log of ratio for oxides	Types of sandstone
Log $(SiO_2/Al_2O_3) > 1.5$	Arenites
Log $(SiO_2/Al_2O_3) <$ and log $(K_2O/Na_2O) < 0$ 3	Greywacke
Log $(SiO_2/Al_2O_3) < 1.5$, log $(K_2O/Na_2O) > 0$	
Log $(Fe_2O_3 + MgO)/(Na_2O + K_2O)$, log $(SiO_2/Al_2O_3) < 1.5$ and either log $(K_2O/Na_2O) < 0$	Arkose
Log $(Fe_2O_3 + MgO/K_2O) > 0$	Lithic arenite (including subs greywacke and protoquartzites

Table 5 Classification of dust storm and sand dune

Sample type	Log (SiO_2/Al_2O_2)	Log (K_2O/Na_2O)	Log ($Fe_2O_3 + MgO/K_2O + Na_2O$)	Classification
Dust storm	1.18	0.14	−0.31	Arkose
Sand dune	0.82	0.17	−0.28	Arkose

The environmental impacts

Dust storms in Iraq are most prevalent in the spring and summer when a prevailing northwesterly wind known locally as the Shamal kicks up the fine desert sand and the silt along the Tigris and Euphrates river basins (Al-Farajii 2000). A dust storm which occurred in 11 April, 2008 continued to blow on Iraq for 8 h, covering 75% of the total area of Iraq. This storm deposited 20.987 g per square meter, where it was collected on a glass sheet of 1 × 1 m^2; and therefore, the total weight of deposited dust equaled 6.9 million tons, which is calculated through the following equation:

$$D_w = 75\% A \times W$$

where, D_w is the weight of dust, A is the total area of Iraq; and W is the weight of the deposited dust on 1 m^2 during 8 h.

The 75% of the Iraq area equaled 328,834.5 km^2; 20.987 g of dust was deposited on each square meter approximately. Accordingly, the total weight of fallout dust is calculated to be 6.90125 million tons (rounded to 6.9 million tons). It was deposited as a thin layer during just 8 h. This phenomenon displays how wind power can rapidly influence the weather, climate and environment. The atmospheric temperature declined in Baghdad (the capital of Iraq) from 36 to 30°C during 8 h. During the episodes of dust storms, visibility decreased enormously and became no more than 30 m. Dust components play a certain role in the decay of solar radiation by decreasing the transparency of the atmosphere (Muminov and Mnagamova 1995; Chube 1998. High levels of airborne dust reduce the amount of sunlight that reaches the land; if it occurs over the ocean, there is a lowering of sea surface temperatures and, generally, hurricane probability. Depositing dust on traffic road highway and railway sections confused traffic flow, causing road accidents, and increasing maintenance costs.

Air quality standards for suspended particulate matter generally are designated as PM10 standards for inhalable particulate matter and PM2.5 standards for fine particulate matter (Alonso et al. 2002). Public health concerns focus on the particle size ranges likely to reach the lower respiratory tract or the lungs. Inhalable particulate matter (PM10, 10-μ component) represents particle size categories that are likely to reach either the lower respiratory tract or the lungs after being inhaled. Fine particulate matter (PM2.5) represents particle size categories likely to penetrate to the lungs after being inhaled. Size, shape, and density are important physical characteristics of suspended particulate matter. Because of the large relative size of sand (210–62.5 μ; Table 1). It does not affect the respiratory system, while clay affects the respiratory system because of its fine size (3.9–0.006 μ; Table 1). With regard to the silt fraction (53–7.8 μ; Table 1), the soft and very soft parts affect the respiratory system. Accordingly, clay fraction is considered the worst part within the dust storm which forms 70% (Table 1). Air quality considerations focus on the smaller component of particle suspension (Buchdahl 1999; Alonso et al. 2002). Coarse dust particles generally only reach as far as the inside of the nose, mouth or throat. Smaller or fine particles can, however, get much deeper into the sensitive regions of the respiratory tract and lungs. These smaller dust particles have a greater potential to cause serious harm to human health. However, some people with pre-existing breathing-related problems, such as asthma and emphysema, may experience difficulties. Many people were taken to hospitals after sustaining breathing problems. Some of them died.

Wind cannot erode moist soil, but the dry soil can easily be eroded. Wind erosion physically removes the lighter, less dense soil constituents such as organic matter, friable and loss constituents like clays, silts and sometimes fine sand. Thus, it removes the most fertile part of the soil and lowers soil productivity (Al-Farrajii 1998). Therefore, dust can also have beneficial effects where it deposits. Central and South American rain forests get most of their mineral nutrients from the Sahara; iron-poor ocean regions get iron (Ilan 2006) when dust blows in a westward direction; the transported dust added fertile matters may dilute salinity, and redistribute the pollen participating in plant pollination.

Conclusions and recommendations

In terms of grain size, dust storms were classified as clay to clayey sand sediments, whereas sand dunes are classified as silty sand. Due to differences in the grain size, the mineral components in dust storms and sand dunes have varied. Geochemistry and mineralogy revealed that the sand dune samples tend to have much more maturity than the dust storm, but both are classified as arkose.

Heavy minerals as well as the satellite image refer that the Sahara of North Africa, dry lands in Saudi Arabia, Syria and Jordan are sources of the dust. Sand and dust storms are a visible natural process on the African Continent; the vast areas and distribution and extent of the desert landscape, including the Sahara Desert, indicate that this region is the very source of material for sand and dust storms in historical time (Yang et al. 2001). Dust storms from the Sahara are a source of minerals to the Mediterranean and Black Seas (UCAR 2008).

Sahara, North Africa and the Arabian Peninsula and west Asia are going to be desertification, while new useful material is added to the lands in some parts of Asia, including Iraq, and redistributed to refreshing the soil. From the dust storm that occurred in Iraq on 11 April, 2008 settled 6.9 million tons of clay and clayey sand during 8 h as a thin sheet layer covering 75% of the total area of Iraq.

Dust storms affected a direct impact on the climate where the temperature dropped 6°C during 8 h and also especially affected the respiratory system in humans, causing an increase in the numbers of people who died or were admitted to hospitals. Many components of suspended particulate matter are respiratory irritants (Alonso et al. 2002), 70% of dust storm samples are clay (Table 2) and have a size less than 0.0039 mm. Dust storm samples are not carcinogenic because they do not prove the existence of fibrous minerals. Suspended particulate matter or compounds adsorbed on the surface of particles can also be carcinogenic or mutagenic chemicals (Alonso et al. 2002). Fine particulate matter (PM2.5) represents particle size categories likely to penetrate to the lungs after being inhaled (Alonso et al. 2002). Accordingly, the clay fraction is the harmful factor on human health due to penetration to the lungs.

Dust storm-affected plants, causing a pulling from their places or breaking some of their parts, and deposition of a thin layer of dust on the leaves, which partially prevents sunlight, reducing the efficiency of photosynthesis. As plant roots and wet lands reduce erosion (Gerasimov 1986), and for the purpose of combating desertification and land reclamation, this study recommends that the desert land should be planted and irrigated to become resistant to desertification.

References

Abed A (2000) Geology of Jordan, its environment and water. Jordanian Geologists Association, Aman

Akinmosin A, Osinowo O (2008) Geochemical and mineralogical composition of Ishara sandstone deposit. SW Nigeria Cont J Earth Sci 3:33–39

Al-Farajii FA (2000) Compating desertification and sand storms in Iraq. In: Part IV—case studies of-DUS sand-dust storms in Asia, part IV, Chapter 8

Al-Farrajii FA (1998) Combating desertification in Iraq. Desertification Control Bull 33, 2–10

AL-Laboun AA (1986) Stratigraphy and hydrocarbon potential of the Paleozoic succession of both the Widyan and Tabuk basins, Arabia. In: Halbouty M (ed) Future petroleum provinces of the world American association of petroleum geologists memoir, vol 40, pp 373–394

Alonso R, Biland L, Chavis P, Gellete D (2002) The potential for fugitive dust problems at the Salton Sea if water levels are lowered significantly from current conditions. Summary of the Salton Sea science office workshop, April 3–4, La Quinta, California

Andreae MO (1995) Climate effects of changing atmospheric aerosol levels. In: Henderson-Sellers A (ed) Future climates of the world: a modeling perspective. Elsevier, New York, pp 341–392

ASTM (1989) Annual book of ASTM standards.American Society for Testing materials, Philadelphia, pp 1110

Avila A, Queralt-Mitjans I, Alarcon M (1997) Mineralogical composition of African dust delivered by red rains over northeastern Spain. J Geophys Res 102(21):977–996

Bergametti G, Gomes L, Coude Gaussen, Rognon P, Le Costumer M (1989) African dust over Canary Islands: source regions, identification and transport pattern for some summer situations. J Geophys Res 94:14,855–14864

Beydoun ZR (1988) The Middle East: regional geology and petroleum resources. Scientific Press, UK, p 291

Bishop JK, Davis RE, Sherman JT (2002) Robotic observations of dust storm enhancement of carbon biomass in the North Pacific. Science 298:817–821

Buchdahl J (1999) Global climate change, student guide. A review of contemporary and prehistoric global climate change. Manchester Metropolitan University, UK, p 99

Carmichael GR, Zhang Y, Chen LL, Hong MS, Ueda H (1996) Seasonal variation of aerosol composition at Cheju Island, Korea. Atmos Environ 30:2407–2416

Chube VE (1998) Estimation of aerosol influence on climatic characteristics of the Aral Sea basin. Probl Desert Dev 3–4:50–55

Clarke AD, Collins WG, Rasch PJ, Kapustin VN, Moore K, Howell S, Fuelberg HE (2001) Dust and pollution transport on global scales: aerosol measurements and model predictions. J Geophys Res 106:32555–32569

Davis BL, Guo J (2000) Airborne particulate study in five cities of China. Atmos Environ 34:2703–2711

Dentener FJ, Carmichael GR, Zhang Y, Lelieveld J, Crutzen PJ (1996) Role of mineral aerosol as a reactive surface in the global troposphere. J Geophys Res 101:22:869–22:889

Dougramedji JS (1999) Aeolian sediment movements in the lower alluvial plain, Iraq. Desertification Control Bull 35:45–49

Falkovich AH, Ganor E, Levin Z, Formenti P, Rudich Y (2001) Chemical and mineralogical analysis of individual mineral dust particles. J Geophys Res 106:8:029–18:036

Farouk E, Makharita RM, Gordon and Breach Publishers (2009) (ed) The gulf war and the environment, pp 31–54

Folk RL (1974) Petrology of sedimentary rocks. Hemphill Publishing Company, Austria 182

Gerasimov IP (1986) Arid land development and the combat against desertification: an integrated approach. UNEP and USSR Commission for UNEP, Moscow

Glennie KW (2010) Structural and stratigraphic evolution of Abu Dhabi in the context of Arabia. Arab J Geosci 3:331–349

Grosz AE, Berquist CR, Fischler CT (1990) A procedure for assessing heavy-mineral resources potential of the continental shelf sediments. In: Berquist CR Jr (ed) Heavy mineral studies—Virginia inner continental shelf, vol 103. Virginia Division of Mineral Resources Publication, Virginia, pp 50–76

Hardley DG, Schmidt DL (1975) Non-glacial origin for conglomerate beds in the wajid sandstone of Saudi Arabia. Directorate General of Mineral Resources, United States of America, Geological Survey, Saudi Arabia Report

Helal AH (1968) Stratigraphy of the outcropping Paleozoic rocks around the northern edge of the Arabian Shield. Zeitschrift Deutschengeologischen Gesellschaft 117:509–543

Hussein MT, Omer AL (2011) Major ionic composition of Jizan thermal springs, Saudi Arabia. J Emerg Trends Eng Appl Sci (JETEAS) 2(1):190–196

Ibe KK, Akaolisa CC (2010) Sandclass classification scheme for Ajalli sandstone units in Ohafia area. SE Nigeria J Geol Min Res 2(1):16–22

Ilan K (2006) The Bodélé depression: a single spot in the Sahara that provides most of the mineral dust to the Amazon forest. Environ Res Lett 1:014005. doi:10.1088/1748-9326/1/1/014005

Kellogg KS, Fourniguet J, Janjou J, Minoux L (1986) Geologic map of the Wadi Tathlith quadrangle, Sheet-20G, Saudi Arabian Deputy Ministry for Mineral Resources, Map GM-103 A, Scale 1:250000

Mange MA, Maurer HF (1992) Heavy minerals in color. Chapman and Hall, New York

Milner HB, Ward AM, Highan F (1962) Sedimentary petrography, v.11, principle and application, 4th edn. The Macmillan, New York

MOIRI Meteorological Organization of the Islamic Republic of Iran (2009) Dust haze in Iran, causes and consequences. A scientific and meteorological investigation into the dust storm in Western Iran, March, 2009

Moore KG, Clarke AD, Kapustin VN, Howell SG (2003) Long-range transport of continental plumes over the Pacific Basin: Aerosol physiochemistry and optical properties during PEM-Tropics A and B. J Geophys Res 108(D2):8236. doi:10.1029/2001JD001451

Muminov FA, Mnagamova SI (1995) Variability of the climate of Central Asia, Tashkent (in Russian)

Obiefuna GI, Orazulike DM (2010) Geochemical and mineralogical composition of Bima sandstone deposit, Yola area, NE Nigeria. Res J Environ Earth Sci 3(2):95–102

Pettijohn FJ, Pootter PE, Siever R (1972) Sand and sandstone. Springer, New York, p 618

Prospero JM (1999) Long-range transport of mineral dust in the global atmosphere: impact of African dust on the environment of the southeastern United States. Proc Natl Acad Sci USA 96: 3396–3403

Shi Z, Shao L, Jones T, Lu S (2005) Microscopy and mineralogy of airborne particles collected during severe dust storm episodes in Beijing, China. J Geophys Res 110:D01303. doi:10.1029/2004JD005073

Sievering H, Boatman J, Luria M, van Valin C (1989) Sulfur dry deposition over the western North Atlantic: the role of coarse aerosol particles. Tellus Ser B 41:338–343

Thompson C (1984) Sahara desert. Pergamon Press, Oxford

UCAR University Corporation for Atmospheric Research (2008) Forecasting dust storms. (Accessed April 1)

Victor RS (2007) Physics, mechanics and processes of dust and sandstorms. Adelaide University, Australia. http://www.unccd.int/publicinfo/duststorms/part1-eng.pdf. (Retrieved 2007-07-29)

Walkden S, Kelley R, Parrish M, Horstwood A, Indares J, Still J (2008) Determining source of Ejecta using heavy mineral provenance techniques; A manicouagan distal Ejecta case study. Lunar and Planetary Science 1254

Wanas HA, Abdel-Maguid NM (2006) Petrography and geochemistry of the Cambro-Ordovician Wajid Sandstone, southwest Saudi Arabia: implications for provenance and tectonic setting. J Asian Earth Sci 27:416–429

Yang Y, Victor S, Lu Q (2001) Global alarm: dust and Sandstorms from the world's drylands. UNSCO, United Nation, p 343

Zimmerle W (1984) The geotectonic significance of detrital brown spinel in sediments. Mitt Geol Palaontol Instit Hamburg 56: 337–360