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Research Article

Determining the Origin of Aeolian Sediments of Chah Nimeh4 Located at the Sistan Plain, Iran

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Abstract: In order to combat and control wind erosion of Sistan Plain, with an area of 8117 km^2 and with a poor and dry climate, understanding the origin or areas of its wind deposits is of particular importance. To determine the origin of the sediments existing in reservoir of the Chah Nimeh 4, studying and comparing aerial photographs and satellite images from different periods, studying the winds in the area and its positioning include geomorphological study of the concerned area, sediment sampling of the sediments and performing required mineralogical tests. This study includes collecting local information about erosion, studying the general geomorphology and winds in the area. Therefore, an important purpose of this study was to identify the critical wind erosion Association (origins) and identification of the deleterious effects of wind. According to the obtained results, occurring drought in the area of Sistan and consequently reducing vegetation and making Hamoun Lake drought as well as 120-day winds have provided favorable conditions for wind erosion and occurring dust storms. It was estimated that the origin of existing sediments in the reservoir of Chah Nimeh is the erosive winds in the area from north to north-west and with 330 to 360°. The most important areas of deposits are abandoned land, sandy land-fields and puffy salt lake basin plain of Hamoun Lake and northern plains (in Afghanistan) in that sand storms and moving sandy plains are considered as threatening factors in the area.

Keywords: 120-day winds, chah nimeh 4, determining the origins, sand dunes, zabol

INTRODUCTION

Two thirds of Iran, is located in arid and semi-arid zone, around 450,000 km^2 of which constitute deserts (Farahi and Mohammadi, 2012). Drought is a normal recurrent feature of climate and causes a serious hydrological imbalance. Virtually, it occurs in all climatic zones, but its characteristics vary significantly from one region to another. Drought is a temporary aberration, which is restricted to low rainfall (Sharifikia, 2013). Basically, various geomorphological environments are also suitable for substantial dust generation. It is important, that water plays substantial role in formation of mineral dust particles, even in arid zones (Varga, 2012).

The study area is located in the southeast of Iran, in the northeast of great plain of Sistan and in the southwest is abutted with Afghanistan (Fig. 1). Considering the geographical position, it has been located in the 30° and 45 min to 30° and 50 min of northern latitude and 61° and 38 min to 61° and 45 min in the eastern longitude. Chah Nimeh 4, with volume of 820 million m^3 and 12 m depth and 96 km^2 areas, is located near the Chah Nimeh 1, 2 and 3. Chah Nimeh 4's dam, with 15 km length, has been built in the direction of east-west perpendicular to prevailing winds of the region. In the northern part of Chah Nimeh, there are abandoned lands, agriculture, poor and sandy areas miles away, which are the origin of windy erosion in the area. In other words, Chah Nimeh 4 is located along the sand deposit in the area. Windy erosion ranges from 1000 to 10000 tons per km^2 per year. According to the performed studies, 33 cm sand is annually deposited at the northern part of dam crest which may create some problems for the dam. Occurring drought in Sistan area, and consequently reducing vegetation and making Hamoun Lake drought as well as 120-day winds provided favorable conditions for windy deposits and occurring dust storms. The severity of winds in such an amount that every activity in the public will be removed and create disruptions by increasing concentrations of dust in the air and raiding flowing sands at the ground level. Sometimes these winds create holes in the depth of 2-3 m and s width of 6-9 m. In the Sistan area, maximum wind speeds increases in January of each year and this increase will be continued to the next year of July and then will be declined. Since 1997, from the beginning of the drought, 120-day wind speeds will be increased in that this increase stems from the lack of humidity, temperature rise, increasing the slope of the pressure and finally accelerating 120 day winds, which by itself causes dry and hot weather and unfortunately more transportation of deposits to the water reservoir of Chah Nimeh. Identifying

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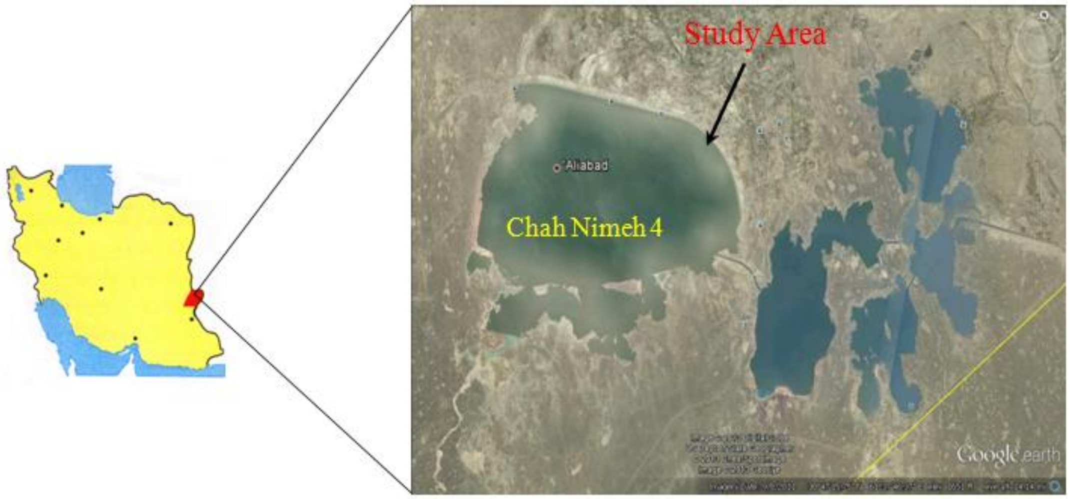


Fig. 1: Geographical location of the study area based on satellite images from Google Earth

the origin or areas for deposits of windy sediments is considered as the basic principles of controlling and fighting against windy erosion in each area, because safeguard strategies not to scattering the sediments can be thought by identifying this area. Numerous studies have been done on a variety of environmental problems in this area and acceptable results are obtained. Sistan area is one of the storm creating centers in the world where more than 70 days dust storms are annually occurred in this area (Washington *et al*., 2003). An important part of the dynamic identification of flowing sands is to identify their origin (Muhs *et al*., 2003; Pease *et al*., 1999). By studying the sand dunes and identifying their pathways using Landsat data (Thematic Mapper, TM) in Amman, they concluded that these satellite data are extremely useful and effective in the geomorphologic interpretation and identification of deserts, sedimentary environments and isolation of these sedimentary environments in terms of the mineralogy of sediments as well as the expansion and development of sands mineralogy in different positions (sampling points) in surface mode. Giresse *et al.* (2008) also conducted some studies on sedimentary processes and the origin of sediments in the western Algerian margin in the late Holocene and Pleistocene and the effects of winds on the shape of quartz grains were studied by Mazzullo *et al.* (1992).

Therefore, this study will try to determine the Origin of Aeolian Sediments of Chah Nimeh 4 Located at the Sistan Plain by field operations and laboratory studies.

RESEARCH METHOD

To perform this study, library studies and providing scientific and international research papers was first done. Then the sediments existing in the reservoir of Chah Nimeh, shipment areas and potential despite area's sampling was done using Google's satellite image interpretation and field operations. The position of existing images was determined by GPS (Global Positioning System) and then was specified on the maps with a scale of 1:50000. The shape and type of sediments, which mostly was of quartz and often semi-rounded and semi-angular type, was identified in sedimentology laboratory of University through polarizing microscope and lens 4.

RESULTS AND DISCUSSION

Geology of the area: Desertification as a serious challenge affects most of the countries and occurs in different climatic conditions. Wind erosion especially in arid regions has greater intensity and it can lead to land degradation with more power (Hosseini *et al*., 2012), and desertification is defined as land degradation in arid, semi-arid and dry sub humid areas (generally called dry lands which cover 41% of global land surface) due to climate variations and human activities. More than 900 million people in hundred countries in all continents except South Pole, suffer from desertification (Shafie *et al*., 2012).

Sistan basin has been created as a result of leading Hirmand River to large lakes in the region and consequently delta processes. For this reason, it is about tens of meters in terms of smooth regional topography attitude with a difference of height. According to the geological conditions prevail in the Sistan area, i.e., the condition of existing a steady platform in continual subsidence, no trace of rock units and deposits of the past periods (other than quartz) can be seen in this area. Sistan Plain and its eastern parts in Afghanistan named Hirmand Delta was filled with in the last geological periods due to Alpine orogeny movements and the accumulation of sediments and the alluvial resulted from flowing water and takes the current shape. The eastern region is formed by alluvial and flood plains and the lowlands round Hamoun Lake. Sistan region has a morphologically simple construction which includes west highlands and the valleys drawn towards the west.

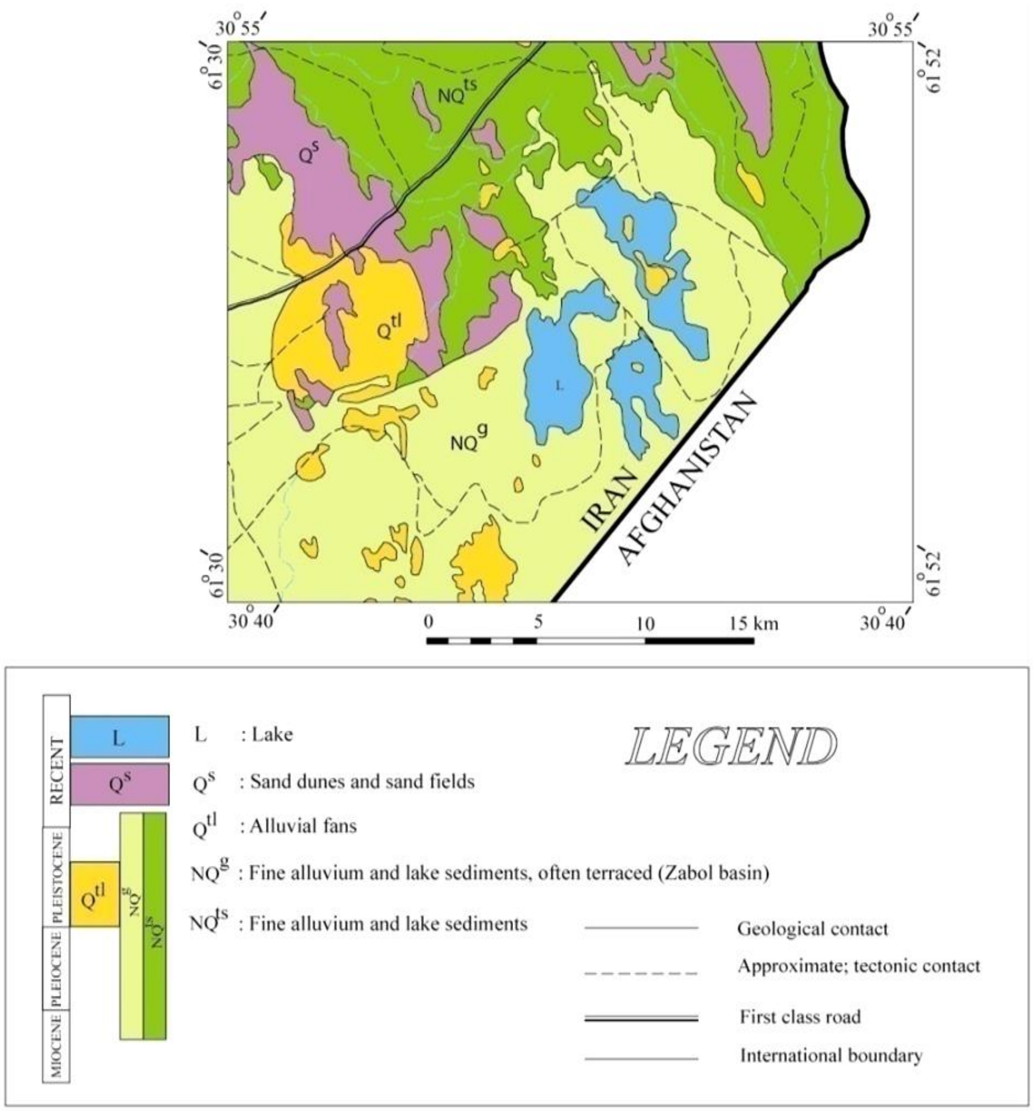


Fig. 2: Geologic map of the study area (from the Geological Map of Zabol)

In the middle parts of the hills, badland hills in the conglomerate can be seen, and its eastern part is composed of alluvial plain lands that lead to lowlands of Hamoun borders. A soft sediment level mixed with sand can be seen almost in all parts of Sistan. There is often sandy land often impenetrable layers sands alternately overlays each other and forms subterranean dust of the region. Sandy clays and fine sands in which there are sandy materials within have been existed unevenly and in a mixed form under the surface soil. There are heavy and hard soils around the lake and the farther we get from the lake, hardness and heaviness of the soil is more reduced. Flysch deposits mainly forms the creators of Sistan geology. Colored melange and Flysch deposits and also volcanic deposits are suggestive of continental collusion (Fig. 2). The main soils of region consist mainly of Loam clays, Silt loam soils, sandy loam soils, sandy soils, and loam soils. A part of the soils of the area is covered by wind sands in which Aeolian sediments are located below young surface soils. In terms of depth, soils permeability in Sistan region is estimated to be very low (approximately 1×10^{-5} cm/sec). Thus, the entire study area is covered by fine-grained silt and clay sediments of the origin of the lake with a thickness of more than 2000 m (Hafezi Moghaddas *et al*., 2012).

The condition of wind and the dust storms in the study area: Wind erosion and associated dust outflows is a common scenario in Sistan, which is considered as an active dust-storm region all year round (Rashki *et al*., 2013). The difference in pressure between the mountains of Afghanistan and Sistan plains are the factors which create and intensity winds and dust storms in Sistan Plain. These storms turn into a warm, dry wind from the North East to the South-East after passing from deserts in the Sistan Plain and causes

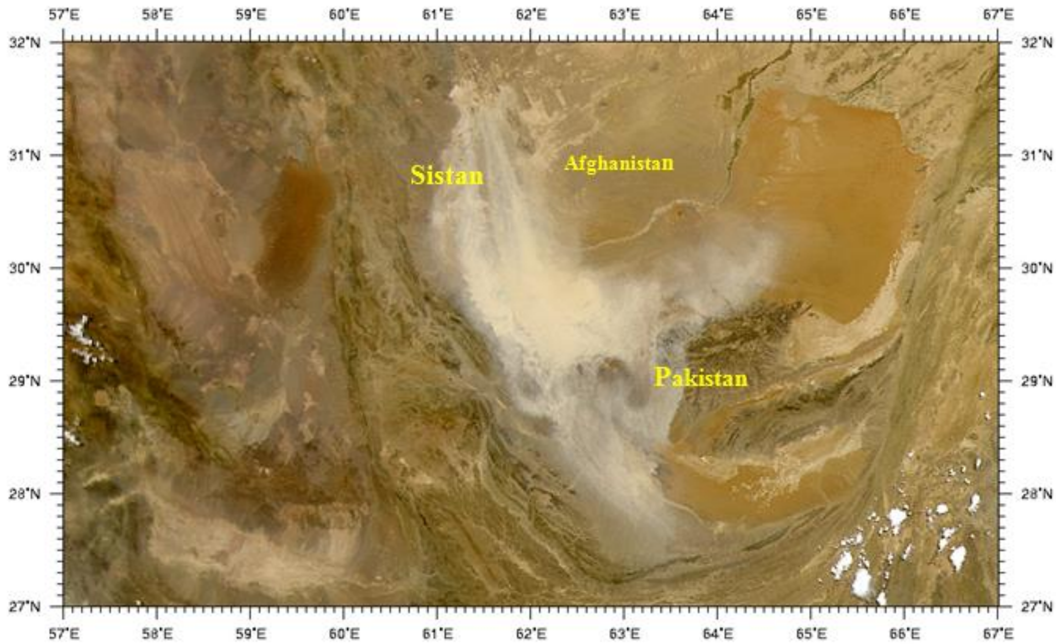


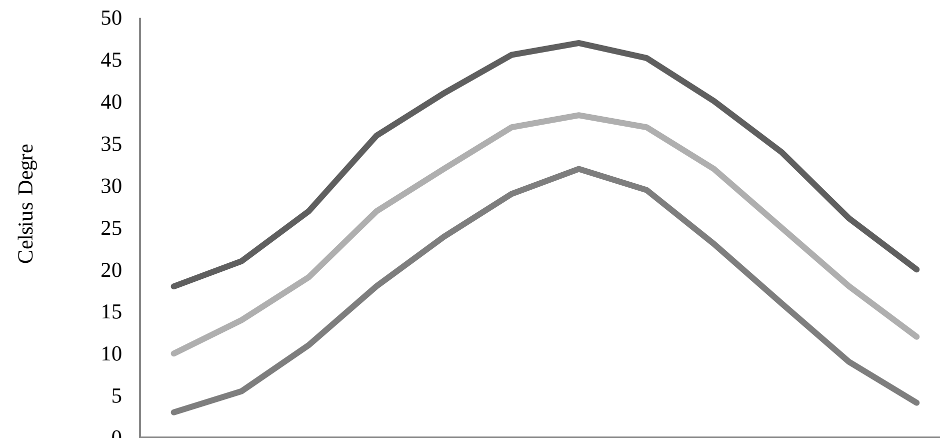
Fig. 3: Centers for dust removal and the direction of dusts in Sistan region and parts of Afghanistan and Pakistan

damages to the fields of agriculture and the vegetation. The time of blowing storm-creator winds is usually from mid-May to mid-October. The prevailing direction of 120-day winds in the Sistan region is mainly between 340 to 350° according to the statistics of Zabol Station, which indicates the northwest-southwest direction of 120-day winds in the Sistan region. Studying the winds speed indicates that it varies from the minimum of 11 m/s to the maximum of 35 m/s (about 40 to 126 km/h). Observing the satellite images taken from TERRA-MODIS satellites shows that dust storms initiate first from the northern part of Sistan region (Afghanistan) and after arriving to the Pakistan area finally comes to Afghanistan and Pakistan along with 120-day winds in the southern region of Sistan (Fig. 3).

Climate characteristics of the region:

Wind: Several factors such as wind, dust properties, moisture, Vegetation, roughness in the land surface and existing minerals in the soil are effective in moving sand dunes in Sistan Region (Heydari Nasab, 2007) in that one of the most important of them is 120-day winds in dry season of the year. The effects of these winds is intensified regarding topographical and geological condition of Sistan Plain that includes slope and main complications of low height and the abundance of fine lake and river sediments. Blowing winds in the northwest-southwest, which causes soil destruction and dust storms in the region by passing from desert areas which put at risk the ecological life of the region. The estimated made from wind potential in 60 meteorological stations shows that Zabol station allocates the highest frequency and speed (Department of Natural Resources of Sistan and Baluchestan, 2005). Of other important factors affecting the movement of sand dunes is the lack of enough vegetation in the area. Plants in the area are mostly salty and resists against wind blowing, they are therefore, an important factor against the onset of flowing sands. However, the destruction of vegetation by humans reduced its protective role. The fastest wind recorded in Zabol station during statistical period of 23 years (1983-2005) was 40.27 m/s equivalent to 145 km/h. At the end of May, beginning with the 120-day vernal winds, wind speed increases significantly compared to April and gets back to its initial speed or less than it right after 4 months beginning with fall. Moreover, the speed of 120-day winds has been increased since 1997 beginning with the period of drought in that this increase causes by the shortage of relative humidity (annual average, 28.2%), increased temperature, increased pressure changes, which in turn causes drought and more warm weather (Khosravi, 2005).

Temperature and precipitation: Temperature is one of the most important climate elements of the region which specifies the characteristics of a region in terms of climate conditions along with the amount of precipitation. A relatively small height in Sistan Plain from the sea level and lack of existing considerable heights in the plain has generally given specific features in terms of temperature for the area (Fig. 4). The climate of Sistan plain with high temperature, especially during periods of blowing winds, cutting the precipitation resources and the drought of environmental drought provides favorable environmental



	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Average maximum temperatures	18	21	27	36	41	45.6	47	45.2	40.1	34	26.1	20
Average day and night temperatures	10	14	19.1	27	32	37	38.4	37	32	25	18	12
Average minimum temperatures	3	5.5	11	18	23.9	29	32	29.5	23.1	16	9	4.1

Fig. 4: Monthly changes of temperature in Zabol (1963-2007); (Based on the environmental protection agency of Sistan and Baluchestan Province)

Table 1: Probability and return period of dusty days in Sistan region (Tavousi, 2010)

Probability (%)	2	5	10	20	50	66	90	99.5
Return Periods (year)	50	20	10	5	2	1.5	1.1	1
Frequency	186	194	202	211	220	226	231	236

conditions for blowing winds and causes dust storms by reducing soil moisture. Generally, Sistan plain has one of the lowest amount of rainfall. Due to the dry climate of Zabol, the average relative moisture in it is 39% (in different years) which is mostly provided through the impact of rainfall systems, transpiration of plants and evaporation of the surface waters of Hamoun Lake and its marshes. From September onwards, along with reducing temperature and precipitating low rains, the average relative humidity gradually increases and reaches its maximum in January. Then, increasing temperature and lack of rainfall causes reducing relative humidity of the region. According to the estimates out of the wind potential in 60 meteorological stations, Zabol station has the highest frequency and speed. Also, having the average number of 80.7 days per year over a five year period (1990-1995), this region has the second rate in terms of the occurrence of sand storms in Asia. Due to the geomorphological condition of Sistan Plain and the distribution of pressure patterns round it, wind blowing is one of the most important climate elements throughout the year, especially during the establishment of vernal 120-day winds in this region of the country (Khosravi, 2005).

Dust in the region: One of the climate features of the study area is dust. Tavousi (2010) studied the frequency process of dusty days with the Probabilities and different return periods during the year. Table 1 show that the number of dusty days is 236 days with 99.5% Probability and return period of 200 years. Also, the table shows that the frequency number of dusty days covers more than a half of the year with 50% Probability.

INTERNAL SOURCES OF SEDIMENTS

Of the regions showing the internal sources of sediments is abandoned agricultural lands in the northern part of Chah Nimeh 4 which is considered as the removal area. Also, Hamoun area in the period of drought can be mentioned which causes the initiation of transformative move of the air.

Sampling and physical and chemical analysis of sediments: Windblown transport and deposition of dust is widely recognized as an important physical and chemical concern to climate, human health and ecosystems (Rashki, 2012). To determine the origin of existing sediments in Chah-Nimheh 4, 4 samples of the overall reservoir were totally deposited (Fig. 5), and then the relative position of removal areas was estimated by doing grading operations, drawing cumulative curve and relevant statistical indices, the relative position of the deposit regions were estimated. The gradient results achieved are as follows:

Fig. 5: The geographical position of deposited samples (A1, A2, A3, A4) out of Chah-Nimheh 4

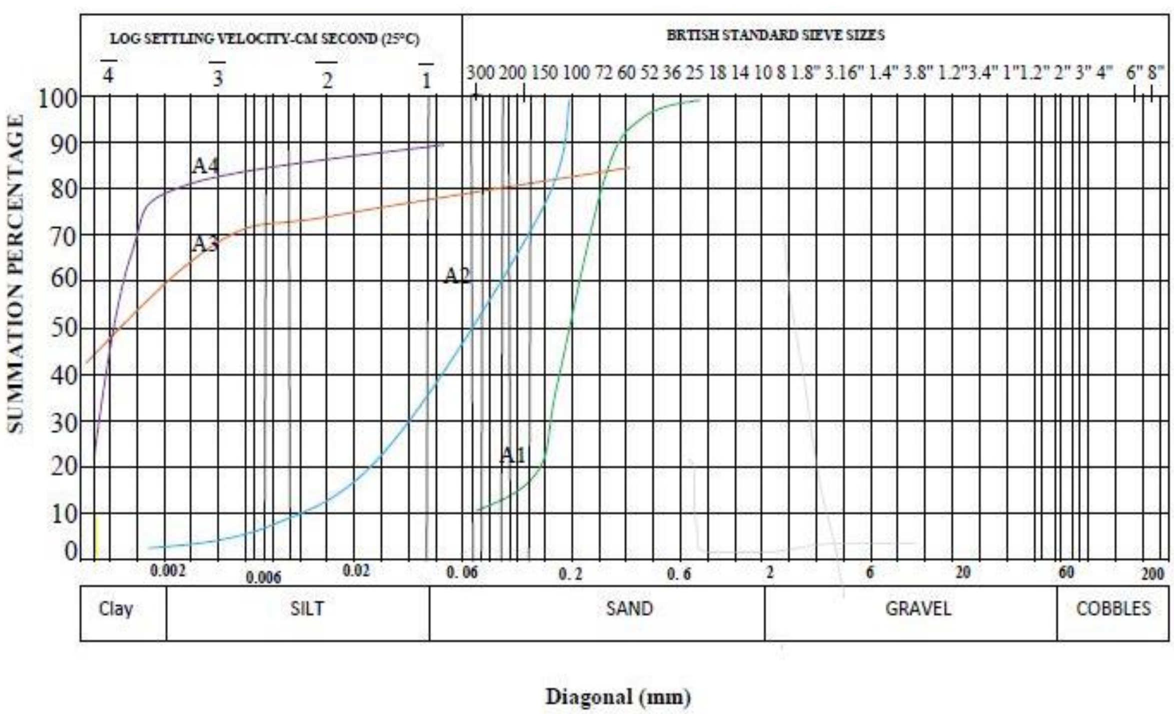


Fig. 6: The cumulative grading curves of samples 1, 2, 3 and 4

Table 2: Flow rate, globosity and quartz particles form in the coastal wells of Chah Nimeh in the northwest part of the basin's canal

Total categories	500 µ	250 µ	125 µ	63 µ	Classification based on µ
78% spherical, 22% spherical-half drawn	100% spherical	100% spherical	50% spherical and 50% spherical-half drawn	60% spherical and 40% spherical-half drawn	Sphericity-form
80% semi-rounded, semi-angular, 20 % semi-rounded, rounded	100% semi-rounded, rounded	65% semi-rounded, 35% semi-rounded-semi-angular	50% spherical and 50% spherical-semi rounded	60% spherical and 40% spherical-semi-rounded	Amount of elongation

Table 3: Rate of roundness, Sphericity and quartz particles form in the northern part of Chah Nimeh No. 2-path

Total categories	500 µ	250 µ	125 µ	63 µ	Classification based on µ
93% spherical, 7% spherical-half drawn	100% spherical	100% spherical	75% spherical and 25% spherical-half drawn	100% spherical	Sphericity-form
60% semi-rounded, semi-angular, 40 % semi-rounded	100% semi-rounded, rounded	15% semi-rounded, 35% semi-angular-85% semi-rounded	100% rounded, semi-angular	100% rounded, semi-angular	Amount of elongation

Table 4: Rate of roundness, Sphericity and quartz particles form in the dam region of Chah Nimeh, output channel

Total categories	500 µ	250 µ	125 µ	63 µ	The category in terms of Micron
75% spherical, 25% spherical-half drown	100% spherical	89% spherical and 11% spherical-half drawn	34% spherical-half drawn and 66% spherical	53% spherical-half drawn and 47% spherical	Form-Sphericity
70%semi-angular-semi-rounded, 12 % semi-angular, 18% semi rounded	100% semi-rounded	25% semi-rounded, 48% semi-angular-semi rounded	92% semi-angular, semi-rounded, 8% semi-angular	78% semi angular-semi-rounded, 22% semi-angular	Elongation

Samples No. 1, 2, 3, 4: These samples removed from reservoir No.4 have the following characteristics:

A-1: This sample has a specific weight of 2.76 g/cm^3, and it was found, after doing an analysis on it, that the average amount of clay, silt and sand of these samples are 32, 65 and 3%, respectively

This sample contained a small amount of lime and Organic Matter (OM) and the Mean Diameter (MD) of its grains is 0.006 mm. Particle diameter in millimeters are as follows: clay (0.001 to 0.002), silt (0.002 to 0.01) and sand (0.01 to 0.6 mm).

A-2: This sample has the specific weight of 2.69 grams per cubic centimeters and the average amount of clay; silt and sand in it are 31, 55 and 14%, respectively. The average grain Diameter (MD) is 0.006 mm and the sample has 19 mg calcareous materials and 2.5 mg organic materials

A-3: This sample has the specific weight of 2.67 g per cm^3 and the average amount of clay; silt and sand in it are 44, 56 and 0%, respectively. The average grain Diameter (MD) is 0.0025 mm and the sample has 19 mg calcareous materials and 2.5 mg organic materials

A-4: This sample has the specific weight of 2.68 g per cm^3 and the average amount of clay; silt and sand in it are 18, 32 and 50%, respectively. The average grain Diameter (MD) is 0.06 mm and the sample has 16.5 mg calcareous materials and 1.38 mg organic materials

Also the cumulative grading curves of samples 1, 2, 3, 4 are as in (Fig. 6).

In Table 2 to 4, flow rate, globosity, and quartz particles form in coastal wells of Chah Nimeh were analyzed.

After the mineralogy study of the samples, the following results were obtained regarding the value of roundness, Sphericity and quartz particle form:

- In 84% of the study sample, clastic carbonate particles were observed in that most of the particles (100%) was in 2 mm category and the rarest amount (Rare) was ranked in 500 microns. Distribution and dispersion of the particles in 48% of the study samples was in the ranks of the 500 to 63 microns, and in 52% the samples were between 2 mm to 63 microns
- In 28%, OPEC mineral samples were ranked between 250 to 63 micros. Distribution and dispersion of the particles in the samples in 37% was between 63 to 125 microns and in 63% of samples it was between 63 to 250 microns
- In 58%, the samples have been observed in classes of 2 mm to 63 micron in plant parts. Most of the particles (94%) were in 2 mm category and the rarest amount was ranked in 250 microns. Distribution and dispersion of these particles in 44% of samples were observed in the category of 2 mm to 63 mm and in 56% of samples it was between 250 to 63 microns
- The study samples have four detrital grains particle as quartz, feldspar, mica and rock fragments
- In 100% of the samples, rubble (rounded to semi-rounded) was observed. Most of the these particles (92%) was in the category of 2 mm. Distribution and dispersion of these particles in 70% of samples were observed in the category of 2 to 500 microns and in 30% of samples it was between 63 microns and 2 mm
- Mica minerals have been observed in 64% of samples. Most of these particles (biotitie 18% and muscovite 20%) was in the category is 125 micron. Distribution of these particles in 66% of samples was observed in the category of 125 to 63 microns

and in 34% of samples it was between 250 to 63 microns

- Feldspar minerals have been observed in 88% of samples. Most of the particles (10%) have been observed in the category of 63 microns. It is worth mentioning that the distribution of particles in 28% of the samples was observed between 63 to 250 microns, and in 72% it was observed between 63 to 125 microns
- Quartz is found in 95% of samples. Most of the particles (42%) were observed at the category of 125 micron. Distribution and dispersion of these particles are as follows: in 17% of samples it was in the category of 63 to125 microns and in 61% of samples it was between 63 to 250 microns and in 22% it was observed between 63-500 microns

CONCLUSION

According to the results obtained, deposits of the area have good elongation in that the elongation of the area's sediments are caused by water-wind process which is carried by Hirmand River from Afghanistan highlands to Iran and have been deposited in Hamoun River and are deposited in the time of drought and drying up the river by the wind and then are carried away and finally are sequestrated in the study area.

Winds has devastative role in this dry and desert area and causes irreparable damages every year. This wind is forced to leave its deposits at the foot of trees, plants, walls, etc. when its velocity is less than the threshold velocity, in that if their origins are not identified and controlled, they will be scattered gradually all the region. In recent years, due to drought caused by water slack of Hirm and River to Sistan and blowing vernal 120-day winds, the removal of sediments from the dry river's bed is started in that what is resulted is the occurrence of sand storms in the earth and sky of the region and then their sedimentation in rivers, agricultural land sand residential houses, so that the size of sand hills in the range of study will be increased and their size, extent and dangers is annually increasing.

Based on the results achieved, the origin of sediments in the reservoir of Chah-Nime-4 was the erosive winds of the area (120-day winds) were evaluated from north to northwest and with 330 to 360 angles. The main harvesting regions were abandoned lands, sandy lands, salt and puffy fields of Hamoun Lake and the northern plains (in Afghanistan) in that sand storms and the movement of sand dunes have been considered as the threatening factors.

Based on the research findings, as well as chemical and physical analysis of deposit, internal sources of sediment have been the abandoned agricultural land in the north of Chah Nime-4 which is considered as the harvest region and also Hamoun River can also be mentioned in the time of drought that causes the onset of air transport movement. The final destination of sand dune movements is directed towards Zahak to Ghalee-Nou over the water reservoirs of Chah Nimeh. If the same trend continues, this volume of sand will be inserted into the reservoirs in the next few years. The extent of roundness, Sphericity and form of the mineral quartz in the study area showed that the area's sediments have good roundness, so that the sediments' roundness are resulted from water and wind processes that are carried by Hirmand River from Afghanistan highlands to Iran and have been deposited into Hamoun River, and is harvested in the time of drought and drying the river by the wind and then carried by and are sequestrated in the study area.

The study samples have four groups of detrital particles (quartz, feldspar, mica and rock fragments) so that small stones in 100% of samples, mineral mica in 64% of samples, feldspar in 88% of samples and quartz in 95% of the samples have been observed.

Analysis of satellite images, field operations and transportation of eroded sediment into the reservoir revealed that the reservoir water wells, due to its importance in providing drinking water to the people of Sistan and also the center of the province (total population of over 1 million people), and as an important source of various industrial, agricultural source and maintaining ecological balance of the region are seriously threatened in the next few years by be sand dunes. If the influx of sand and sand dunes to these reservoirs is not prevented, the existence of this vital water source would be put at risk and the lives of the people of this region will be difficult. Therefore, given that the sand dunes are moved towards to southeast and Chah Nimeh, which is the supplier of the water to the area, are located at the southeast part of the study area, it will be the final destination for the sand hills for the next few years in that a major crisis and danger will unfortunately threats this land if the reservoirs of Chah Nimeh is filled with wind sediments. This trend shows a very serious danger in the area, and fighting against this problem requires doing extensive studies and using the experiences of successful countries in controlling wind erosion.

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