ISSN: 2476-6909; ECOPERSIA. 2020;8(4):261-268

Chemical, Physical and Mineralogical Properties of Dust Fractions in the Kermanshah Province, Iran

ARTICLE INFO

Article Type
Original Research

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How to cite this article
Sekhavati B, Sekhavati N. Chemical, Physical and Mineralogical Properties of Dust Fractions in the Kermanshah Province, Iran. ECOPERSIA. 2020;8(4):261-268.

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Article History
Received: July 11, 2019
Accepted: February 26, 2020
ePublished: September 22, 2020

ABSTRACT

Aims Dust phenomenon is one of the natural hazards affecting the arid and semi-arid regions of Iran. It carries large amounts of particulate matter, which have dangerous impacts on human health, environment and vegetation. Therefore, dust is considered as one of the most important environmental problems that have drastically increased in recent times. Recognizing the origin and size of these particles, their chemical and physical properties and their elements are important for controlling and evaluating their effects on human health and the environment.
Materials & Methods The Kermanshah province is located in the west of Iran and is one of the provinces that receive the most exposure to dust storms. For this investigation, four cities that are exposed to dust were selected: Sar-Pul-e-Zahab (SZ), Gilan-e-Gharb (GG), Islamabad (IA) and Kermanshah (K). For the installation of marble sediment traps in the Kermanshah province, 36 areas were selected. After collecting dust samples, particle size distribution analyses were conducted by using laser size analysis techniques. Chemical compositions were measured with the help of different techniques such as x-ray fluorescence and x-ray diffraction.
Findings The results showed that the sizes of dust particles varied from 0.0004 to 112 microns, putting them in the range of clay and silt. The particle size in Gilan-e-Gharb was 0.04 to 0.45, Sar-Pul-e-Zahab was 0.04 to 112, Kermanshah 0.04 to 90 and Islamabad 0.0004 to 10 microns. The mineralogical composition of the dust particles mainly constituted quartz, calcite, muscovite, plagioclase feldspar, dolomite and vermiculite. X-ray spectroscopy studies on the dust particles generally showed the presence of aluminum oxide (Al_2O_3), silicon oxide (SiO_2), calcium oxide (CaO), iron oxide (Fe_2O_3), strontium oxide (SrO) and zinc oxide (ZnO).
Conclusion In total, the results of this research work show that SrO, ZnO, silicon, aluminum, calcite, iron and their mineralogical compositions are the main oxides and elements in the dust of the Kermanshah province. Furthermore, the predominance of particle sizes in the range of clay and silt suggests that particles have been transmitted from medium to far distances alongside hinting at a similarity in their sources.

Keywords Dust; Kermanshah; Mineralogy; Particle Size Distribution

CITATION LINKS

[1] Natural and concentration factor ... [2] Road dust pollution of Cd, Cu, Ni, Pb and Zn ... [3] Asian dust storm ... [4] Transport of dust and anthropogenic aerosols ... [5] Mineralogy, geochemistry and ... [6] Modeling optical properties of ... [7] Spatio-temporal occurrences and ... [8] Size distribution, mass concentration, chemical and ... [9] Impact of Asian dust aerosol and surface albedo on ... [10] Technical note: Mineralogical, chemical, morphological, and ... [11] Investigation of chemical characteristics and ... [12] Effect of vegetation change of source area on dust ... [13] Dust storm monitoring using HYSPLIT model and ... [14] Characteristics and composition of the falling dust ... [15] Investigating the composition of dust ... [16] Tehran: Exploration ... [17] ISO 13320:2009, Particle size analysis- ... [18] ISO/IEC 17025:2017, General ... [19] Soil chemical analysis: Advanced ... [20] Dust storms and their horizontal ... [21] Desert dust in the global ... [22] Mineralogical and ... [23] Sedimentology and ... [24] Physicochemical and mineralogical characteristics of ... [25] Quantitative analysis of mineral phases ... [26] Qualitative evaluation of the mineralogical and chemical ... [27] Mineralogical composition and sources of airborne ... [28] Aeolian dust transport and deposition over crete ... [29] Geochemistry of dust aerosol ... [30] Evaluation of heavy metals ... [31] Concentration of selected heavy ... [32] Storm-wise sediment ... [33] Characteristics of dust deposited along ... [34] Particle-size analysis of ... [35] Temporal variations in PM10 and particle ... [36] Wet and dry deposition of mineral dust ... [37] Mechanism for the ... [38] Fuzzy and substructural ... [39] Investigating the structure and elements of ...

Introduction

Environmental systems have become complex due to human activities and natural process that disturb the natural development [1]. Dust includes soil-based solids, anthropogenic metal compounds and natural biogenic substances [2]. The formation of dust storms is very complex and is related to the regional climate system, short-term rainfall, soil moisture, expansion of deforestation, long-term droughts, land-use changes, land cover as well as human activity [3]. Dust aerosols exert a wide range of impacts on global climate, ambient air quality, atmospheric chemistry, and biogeochemical mechanisms [4]. Inhaling of airborne particulate matter due to dust storms has a negative impact on human health. The impact of aerosols depends on their characteristics, such as size and mineralogy [5].

The analysis of the physical properties and chemical composition of dust aerosols is important to determine aerosol sources, mixing processes and transport pathways [6].

The size of dust particles plays an important role both in raising the particles and depositing them. Larger particles are deposited closer to the source area of the atmosphere. Moreover, particle size is also an important factor that determines the rate of the inhalation of these particles and deposition in the respiratory organ [7]. Particle size distribution provides important information regarding geological, soil sciences and lithology [8].

Mineral dust plays an important role in physical and chemical processes in the atmosphere [9]. The mineralogy of dust from different geological domains differs from each other [10]. Mineralogical combines have important effects in the distribution of major oxides of dust particles and exhibit high sensitivity to weathering and erosion activities [7]. In desert and areas where dust particles are not transported long distances, these oxides are used to determine the origin or the different sources of the particles [7].

Some studies on the physical and mineralogical properties of dust particles have been carried out. Azimzadeh *et al.* [11] measured the amount of dust using sediment traps at 16 stations located in different parts of the Yazd city during a three-month period [12]. In the study of dust storms in the west of Iran showed, the main dust storms were found to have originated from Iraq. Similarly, Khamooshi *et al.* [13] indicated that dust masses originated from the western parts of Iraq and eastern Syria and were then transported by the northwest winds in the region. The amount of dust during the study period was estimated to be 13666.61 tones, which was a result of external and internal factors. A study of the features and chemical compositions of suspended dust particles in Riyadh, Saudi Arabia, by Modaihesh [14] showed that most dust particles are luminous and silt-loam sized, and their chemical properties are influenced by their source. Khosh Akhlagh *et al.* [15] studied the composition of dust in the west and southwest of Iran. Their results indicated that the main minerals of dust entering the west of Iran include calcite and quartz, and the dominant chemical composition of dust particles comprises silica oxide and calcium oxide.

As dust particles can carry pollutants, especially chemical compounds and certain minerals, it is important to identify the physical and chemical properties of dust is important. Moreover, identification of the chemical and physical composition of dust to determine the source and route of dust transport as well to recognize its effects on human health, vegetation, soil and the environment is necessary.

Due to the lack of studies on the nature of dusts in Kermanshah province, the objective of this research work is to study the mineral dust aerosol, chemistry as well as particle size distribution, which are all required for assessing the regional impact of mineral dust.

Materials and Methods

Study area

The study area, the Kermanshah province, is located in the geographical position 33°36´ to 35°15´ north latitude and 45°24´ to 48°30´ east. For studying the chemical and physical characteristics of airborne dusts, during April-July in 2017, 36 points were selected in Kermanshah (K), Islamabad (I), Sar-Pul-e-Zahab (SZ) and Gilan-e-Gharb (GG; Figure 1). The geographical positions of studied area are presented in Table 1.

Figure 1) The studied areas in Kermanshah province

Table 1) Geographical positions of the studied areas

Station	Latitude	Longitude	Elevation (m)
Kermanshah (K)	34°23´N	47°00´E	1318
Islamabad (IA)	34°06´N	46°31´E	1335
Sar-Pul-e Zahab (SZ)	34°28´N	45°51´E	550
Gilan-e-Gharb (GG)	34°09´N	45°58´E	810

Climate of the study areas

The climate of Islamabad is cold, semi-arid, with hot summers; Sar-Pul-e-Zahab is temperate semi-arid with hot summers; Gilan-e-Gharb is wet and cold, with hot summers, and the climate of Kermanshah is also cold and wet, with hot summers [15].

Geology

The regional geology of the Kermanshah province, where the study areas were located, includes the Zagros, with tilted and folded tectonic states [16].

Geography of the sites

The Kashkan formation in Islamabad consists of red and green siliciclastic sediments, including siltstone, sandstone, shale and conglomerate with thin to medium strata. The soft terrain of this formation has often been covered by alluvial deposits and been as a key unit between the two Tale-Zang and Asmari-Shaban rock units. The Kashkan formation is from the Paleocene to the middle Eocene times [16].

Radiolarian melanges are extensively distributed in Cretaceous-Jurassic in Kermanshah. This radiolarite complex is mainly composed of thin layers of pink to red color. Layers of green to yellow marl exist among them. It also contains thin layers of siliceous limestone and chert bands [16].

Sar-Pul-e-Zahab and Gilan-e-Gharb are part of Asmari formations. This formation belongs to oligomycene and contains gray limestone. Alternate layers of semi-crystalline limestone, sandy limestone and a thick creamy layer of limestone were observed [16].

Dust sampling

For this research, four areas with the highest amount of dust were selected. In order to collect dust samples from each region, buildings with approximately the same height in different parts of the city were selected. For the purpose of providing a suitable cover for the distribution of the sediment traps, they were placed on the roof of these buildings. For reducing possible errors, dust samples were gathered during four months, from April to July, in 2017. The traps were placed in three replications on tripods, 25cm height above the ground. Dust samples were gathered at these points at certain intervals. Finally, 36 dust samples were transferred to the laboratory.

Data analysis

The particle size distribution of airborne dust was performed by using the Particle Size Analyzer Cilas model (Model 1064) with the method ISO 13320-09 [17]. In this analysis, the light of particle size analyzer was scattered by particles in all directions and made an intensity pattern, depending on particle size as well as particle shape. The measured scattering pattern was assumed as the sum of the individual scattering patterns of all the particles. A volumetric particle size distribution was calculated using an optical model and a mathematical analysis (ISO 13320-09) [17].

In order to identify the oxides in dust particles, XRF analysis was performed. These samples were analyzed through a semi-quantitative method with ISO/IEC 17025: 2017 standard. In this analysis, after placing dust samples in the XRF device, the constituents of the substance were identified by measuring the length of the fluorescence emitted from the various atoms in samples, and the amount of each element was determined by measuring the intensity of the waves (ISO/IEC 17025: 2017) [18].

The mineralogy of dust samples was conducted by XRD analysis (the Philips Xpert 60 x-ray diffraction model). For identifying chemical compositions and minerals, three grams of samples were separated. These were then saturated with potassium and magnesium [19]. Finally, these samples were analyzed with the help of the XRD Analyzer. Identification of the existing phases and minerals was performed with the spectroscopy and diffraction pattern of the samples.

Data analysis was performed using SPSS 21.

Findings

Mineralogy of the dust particles (x-ray diffraction; XRD)

The results of the XRD analysis in the four sites are presented in Table 2 and Diagram 1.

According to the results in Table 2, the primary and dominant minerals in the four study areas were quartz and muscovite. Calcium carbonate and plagioclase feldspar were found only in two cities each (Kermanshah and Sar-Pul-e-Zahab and Sar-Pul-e-Zahab and Islamabad, respectively). Dolomite and vermiculite were observed only in one place each (Gilan-e-Gharb and Islamabad, respectively).

Table 2) Identified minerals based on X-ray diffraction in studied areas

Study area	Identified minerals
Kermanshah (K)	Quartz, Calcium Carbonate, Muscovite
Sar-Pul-e Zahab (SZ)	Calcium Carbonate, Quartz, Muscovite, Plagioclase Feldspar
Gilan-e-Gharb (GG)	Quartz, Dolomite, Muscovite
Islamabad (IA)	Quartz, Vermiculite, Plagioclase Feldspar

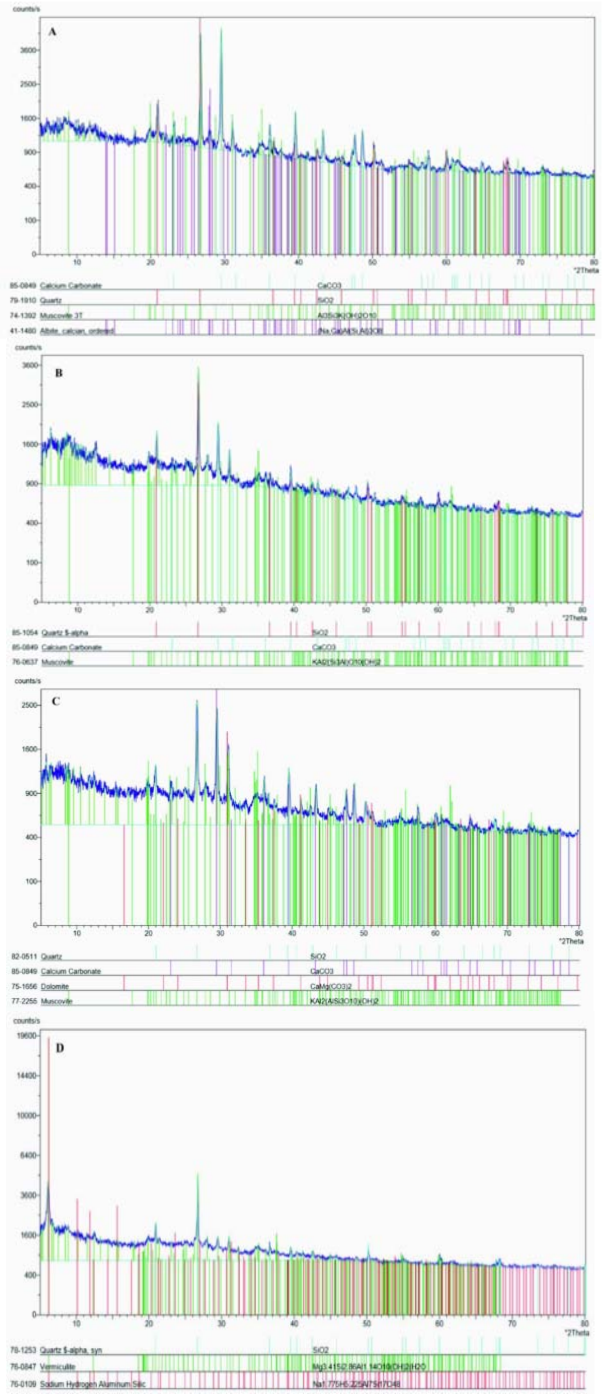

Diagram 1) XRD results of dust samples; SZ (A), K (B), GG(C), and IA (D)

X-ray fluorescence (XRF) dust elements (primary oxides)

According to the XRF results (Table 3), the major oxides in the airborne dusts examined in the four study areas were aluminum oxide (Al_2O_3), silicon oxide (SiO_2), calcium oxide (CaO), iron oxide (Fe_2O_3), strontium oxide (SrO), and zinc oxide (ZnO). These results are expressed in w/w% or ppm units (Table 3).

w/w% is the weight percent to the total weight. This unit is used in XRF analysis for very low percentages (this unit shows the oxide content of the element in 100gr of the sample).

PPM is related to the concentration of the element in the solution (milligram/liters of the element).

Comparison of some of the main oxides of dust in the Kermanshah province and the global average [7, 20] is presented in Diagram 2.

As showed in Diagram 2, the amounts of MgO, Al_2O_3 and SiO_2 in global average reflected high values, while minerals such as K_2O, CaO, and Fe_2O_3 were higher in Kermanshah.

Table 3) The results of XRF analysis in the studied cities (values in W/W%) and in parts per million (ppm)

Chemical Components	Islamabad (IA)	Kermanshah (K)	Sar-Pul-e Zahab (SZ)	Gilan-e-Gharb (GG)
MgO	1.82	1.92	1.60	2.18
Al_2O_3	7.45	7.49	7.76	7.77
SiO_2	43.91	43.19	45.06	43.42
P_2O_5	1.52	1.47	1.08	1.06
SO_3	5.19	5.88	6.76	5.07
Cl	0.44	0.49	0.25	0.28
K_2O	3.28	3.93	2.50	3.21
CaO	25.13	24.82	25.28	25.93
TiO_2	1.06	1.41	0.96	0.96
MnO	0.13	0.13	0.12	0.13
Fe_2O_3	8.98	7.76	7.97	8.78
SrO	700 ppm	600 ppm	600 ppm	600 ppm
ZnO	800 ppm	700 ppm	0.12	600 ppm
Cr_2O_3	0.10	0.11	-	0.11
I	-	0.1	-	-

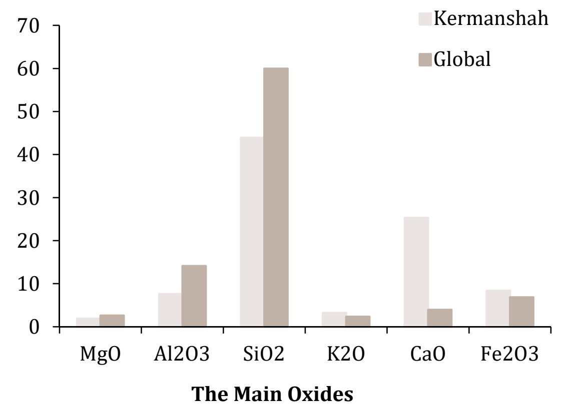

Diagram 2) Comparison of some main oxides of dust in Kermanshah and the global average

Dust particle size

The distribution of dust particles in Gilan-e-Gharb, Kermanshah, Sar-Pul-e-Zahab, and Islamabad is presented in Diagram 3.

According to Diagram 3, dust particles were in the range of 0.04 to 45 microns in Gilan-e-Gharb. These particles were from 0.04 to 112 microns in Sar-Pul-e-Zahab and from 0.04 to 90 microns in Kermanshah. Nearly 90% of the dust particles in Gilan-e-Gharb were close to 23.85 microns, in Sar-Pul-e-Zahab 46.97 microns and in Kermanshah 39.85 microns. The distribution of particle size in Islamabad was in the range of 0.0004 to 10 microns.

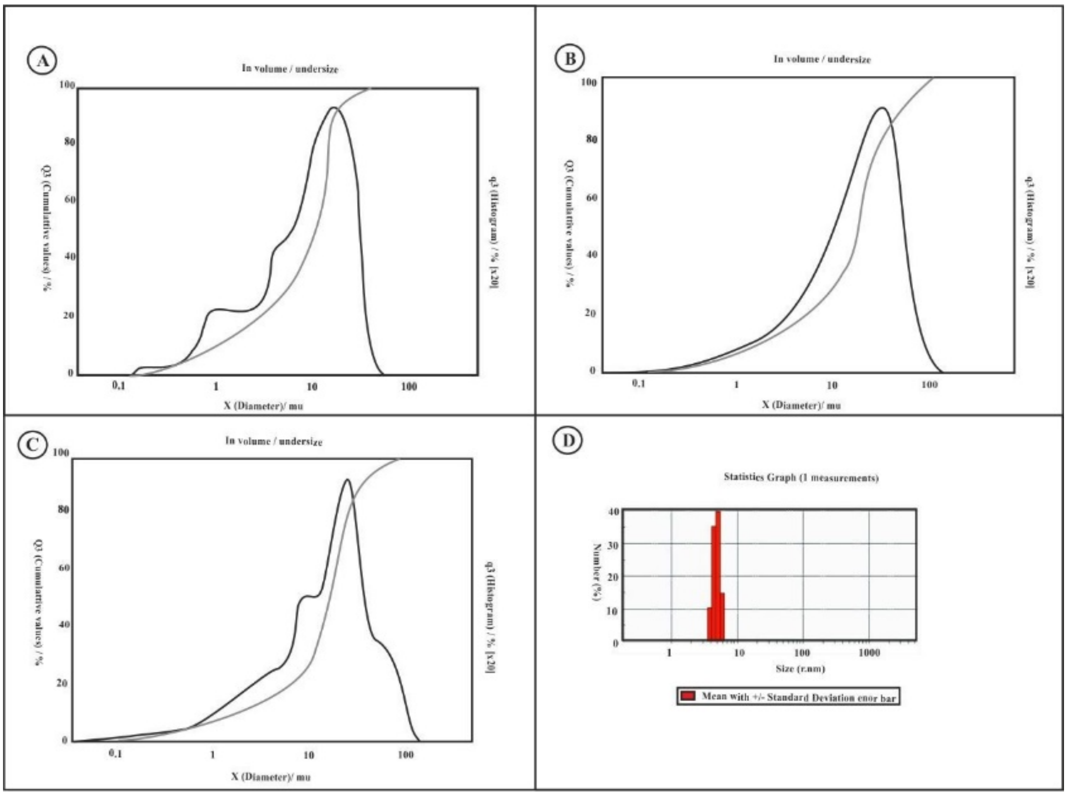

Diagram 3) Particle size distribution in GG (A), K (B), SZ (C), and IA (D)

Discussion

The mineralogy of the dust particles (XRD)

The mineralogy of the source materials is one of the most important parameters that alter the chemical composition of airborne dusts. The dusts in many areas of the northern hemisphere are mainly composed of SiO_2 (59.99%), Al_2O_3 (14.13%), Fe_2O_3 (6.85%), CaO (3.94%), MgO (2.60%), and K_2O (2.35%) as well as organic matters [21]. The recognized minerals in this study (Table 2) were quartz, calcium carbonate, muscovite, feldspar plagioclase, dolomite and vermiculite. Similar to this result, Broomandi *et al.* [22] proved that quartz, dolomite and calcite were the most abundant minerals in the Ahwaz sample dusts. Similarly, Jalilian's [23] studies showed the main minerals in the dust samples of Ahwaz to be quartz and calcite. Parallel to these results, Karimian *et al.* [24] in the study of dust mineralogy of Ahwaz, reported plenty of calcite, quartz and feldspar minerals. The calcite and quartz, which are found in abundance, are seen as the main products of degraded sedimentary environments and a completely natural source indicator of dust particles [7]. This result is also confirmed by Zarasvandi *et al.* [7], in the results of XRD analysis of dust samples of Khuzestan, which introduced calcite and quartz as the main components of dust in Khuzestan. Similarly, Diaz-Hernandez *et al.* [25], in their X-ray analysis, showed carbonates (calcite and dolomite) and phyllosilicates to be dominant in dust particles. Jiries *et al.* [26] indicated that in the dust collected from southern Jordan, quartz and calcite minerals were dominant. Moreover, Ganor *et al.* [27], by studying dust collected from Northern Occupied Palestine, found the amount of non-clay minerals, including quartz, feldspar, calcite and dolomite, to be more than that of clay minerals. Pye [28] held that dust particles full of quartz, carbonate and feldspar have a continental origin and are likely to be transported from near areas; On the contrary, dust particles containing significant amounts of clay minerals are transported from far distances.

The elements (BO) of dust by (XRF)

Determining the chemical composition of airborne dust is particularly important for identifying potential sources, quantifying climate models as well as recognizing the potential effects of dust on health, soil, rainfall, biology, chemistry, oceans and meteorological phenomena [21]. The study of the main oxides of dust particles in the various regions shows that silica is the most important oxide in dust particles in the different regions of the world. Aluminum and iron oxides are in the next ranks [15]. The results of the XRF (Table 3) also attest to this. The substantial major oxides in this study were SrO (600 to 700ppm) and ZnO (800ppm), followed by SiO_2, with an average of 43.89%, and CaO, with an average of 25% area. Fe_2O_3 (hematite), Al_2O_3 SO_3, K_2O, MgO, P_2O_5, TiO_2, Cl, MnO, Cr_2O_3 with different amounts were also observed in the four study areas. Therefore, chemical analysis of dust in the Kermanshah province showed that SrO, ZnO, silicon and calcium were the main elements of the dust particles, whereas titanium, manganese, chromium were present in a considerably lesser degree. The dominance of SiO_2 reflects the importance of quartz in airborne dust [21]. Scientists have shown that the main composition of global dust particles are SiO_2 (99.59%), Al_2O_3 (13.14%), Fe_2O_3 (85.6%), CaO (94.3%), MgO (60.2%), and K_2O (35.2%) [26]. Jalilian's [23] introduced silicon, aluminum, and iron as the main elements in Ahwaz dust.

As shown in Diagram 2, the amounts of MgO, Al_2O_3 and SiO_2 in the Kermanshah province are lower than the global average, but those of K_2O, CaO and Fe_2O_3 in Kermanshah dust are higher. One reason for this can be due to the fact that the desert is the source of most dust particles in Iran. Rainfall in the desert, especially in summer, facilitates the separation of calcium compounds and increases Ca in dust-derived deserts [29]. In the study of Zarasvandi *et al.* [7] SiO_2, CaO, Al_2O_3, and Fe_2O_3 were introduced as the major elements of dust. Khoshakhlagh *et al.* [15] also showed calcite, quartz, silica oxide and calcium oxide as the main oxides present in airborne dusts. Rajabi [30] showed the abundance of silicates (quartz) and carbonate (calcite) minerals in the dust particles of Sanandaj, Khorramabad and Andimeshk. Similarly, Karimian *et al.* [24] introduced calcite, quartz and feldspar as the main minerals of Ahwaz dust particles.

The size of the dust particles

According to the results of this study (Diagram 3), the dust particle sizes were in the range of 0.04-0.45 micron in Gilan-e-Gharb, 0.04-112 micron in Sar-Pul-e-Zahab, 0.04-90 micron in Kermanshah and 0.0004-10 micron in Islamabad. By converting these values into millimeters, in order to determine the texture of the dust particles [31], the dust texture in the four study area was in the range of clay and silt. Silt had the highest percentage of round particles. Noor Mohammadi *et al.* [32] indicated that one of the main reasons behind the high amount of sediment being produced in the gullies was the increased silt and clay content. Mahmoodi and Khademi [31] and Hojjati *et al.* [33] also found that silt was the dominant component in the dust particles. In this study, the size of the dust particles in Islamabad was from 0.0004 to 10 microns, which was in the range of clay (less than 0.002mm). It was revealed that particles under 10 microns can penetrate deeper into the respiratory system. These particles can get to the gas exchange regions of the lungs (WHO, 2006). After slit, clay particles were the most commonly found components of dust [20], which means that tiny particles are dominant in the dust of the studied regions. The results McTainsh *et al.*'s [34] study considered three sources for dust particles. They stated that tiny particles (5 micron) come from far sources, while the dust from regional regions are 20-40 microns. Dust particles in the range of 50-70 microns, with partial particles, are from local sources, such as human activities, especially livestock and vehicles, which produce coarser materials. Therefore, local dust has the greatest diversity in particle size. Similarly, Modaihesh [14], studying the dust in Riyadh, Saudi Arabia, revealed that the largest amount of dust particles were in the range of loam and silt loam. Haffmann *et al.* [35] also showed two kinds of dust with local and ultra-local origin in the study on Mongolian dust storms. The average diameter of the three-quarters of the particles in their study were 23 microns, and the largest particles measured were above 100 microns. Osada *et al.* [36] reported the distribution of dust particles in the range of 1 to 20 microns in Japan. Wang *et al.* [37], in studying the concentration, distribution and chemical composition of Chinese dust in

Shanghai, expressed the highest concentration of particles in the range of 0.5 to 1μm and 1 to 10μm; Moreover, with increasing dust, the concentration of particles below 50nm decreased, while particles from 50 to 200nm and 0.5 to 1 micron increased. Abbaspour and Qaysari [38] expressed the average size of Ahwaz dust particles to be about 20 micrometers. Zaraswandi *et al.* [7] reported the dust particles of the west of the country to be in the range of 2 to 50 microns. Sheikh Abadi [39] described the size of the Kermanshah dust particles in a distribution of 53nm to 19 microns, of which, the size of the majority of the particles was below 5 microns. Karimian *et al*. [24], studying the distribution of dust particles in Ahwaz, showed the frequency of particle size in the range of silt size. Jalilian [23] also described silt as the most abundant component of dust particles.

Conclusion

The physical, chemical and mineralogical properties of airborne dust were investigated in the Kermanshah province. The results of the particle size distribution in the Kermanshah province showed that dust particles included clay and silt. Furthermore, silt is the most abundant component of these dusts. The dominance of clay and silt in these particles indicates that they were transported from far to intermediate distances. In addition, due to the general direction of the region's winds from west to east, it can also be concluded that this dust originates mainly from the Arabian and Iraqi deserts. There was no difference in particle distribution in the study areas. These results show similarity of the dust source. Moreover, the particle size of the Islamabad area, in contrast with other sites, was in nanometers. This can cause serious threats to human health and the vegetation of this area. It also easily enters the leaf stomata of plants and causes many physiological damages for the vegetation, creating different environmental problems. In comparison with the other three sites, Islamabad, with its very fine particles and dolomite mineral, has more sensitive conditions, as dolomite has low density and hardness. Furthermore, the vermiculite is laminate, which makes this mineral detach from dust late and have less resistance to weathering and erosion than other minerals. Besides, the chemical nature of dust particles showed the presence of compounds such as Al_2O_3, SiO_2, CaO, Fe_2O_3, SrO, and ZnO. The main dust minerals in all the sites were quartz and muscovite. Other than the two mentioned abundant minerals, calcium carbonate in Kermanshah and Sar-Pul-e-Zahab, plagioclase feldspar in Sar-Pul-e-Zahab and Islamabad, dolomite in Gilan-e-Gharb and Vermiculite in Islamabad were the dominant minerals.

Acknowledgements: This investigation was funded by the Payam-e Noor University of Kermanshah.
Ethical Permission: This research was not carried out in a protected area, and no specific permission was required.
Conflicts of Interests: There is no conflict of interest in this study, and all its privileges belong to Payam-e Noor University, Kermanshah, Iran.
Authors Contribution: Sekhavati B. (First Author), Introduction Writer/Main Researcher (50%); Sekhavati N. (Second Author), Methodologist/ Statistical Analyst/Discussion Writer (50%)
Funding/Sources: The present research was supported by Payam-e Noor University of Kermanshah, Iran.

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