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Original Article

Physical Characteristics of Dust Storm Particles in the Sistan Region, Iran

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Abstract

Dust storm particles collected from the Sistan region located in southeast Iran, one of the most active dust source regions in Southwest Asia are studied for their compositional and optical characterization by using various techniques such as, energy dispersive X-ray (EDX), scanning (XRD), scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR) ultraviolet visible light (UV-Vis), etc. SEM images revealed that the size of dust storm particles is in the order of micrometer, mostly below 5 μm and with a maximum of 160 μm. The XRD and FTIR results indicated that the sample contains SiO_2, $CaCO_3$, NaCl, and feldspar ($KAlSi_3O_8$, $NaAlSi_3O_8$, and $CaAl_2Si_2O_8$). Moreover, transmittance spectrum of the dust storm particles demonstrated that more than 90% of the incident light with the wavelength of 430 to 800 nm passes through the dust particles. The energy band gap value obtained for the dust storm particles was obtained to be 5.4 eV.

Key words: Dust storm, Sistan, Optical band gap, UV-Vis

INTRODUCTION

Dust, defined as suspensions of small solid particles in a gaseous medium is a significant source of light absorption or reflection in the lower atmosphere. Particles with a size range from 0.2 to 10 μm are strong scatters of sunlight and thus, large concentrations of them can distort visibility and atmosphere color from the ground. The particles can also change the solar actinic flux at different levels of the atmosphere and at the earth's surface, thereby altering surface temperatures and weather. This occurs due to the direct effect of aerosols as the airborne and dust particles play an immediate role in affecting atmospheric temperature. Moreover, the particles can influence clouds through the so called indirect effects by becoming seed nuclei for cloud formation, lengthening cloud age or changing the water droplet size [1].

The wind often combines with loose soil, dust and other particles to form dust and sand storms. These clouds of dust storms often form in areas undergoing desertification and pose health risks to humans and animals downwind of source regions [2]. Since dust source varies with soil type, which varies with location, a number of studies have been conducted all over the world to investigate dust and its properties in various regions when carried by the wind [3, 4, 5]. The Sistan region particularly in various regions Zabol in southeast Iran is one of the most active dust source regions in Southwest Asia. The strong "120 day winds" in summer favor the uplift of large quantities of dust from the Hamoun lakes, which is located in the northern part of Sistan. After a long dry period at the end of 1990s, and due to land-use change and desiccation of the Hamoun lakes, the frequency and severity of dust storms have been significantly increased In the past few years[6].

To study the structural characteristics and physical properties of dust storms, useful information can be obtained from transfer of hazardous pollution. Moreover, optical properties show how the particles impact on the solar radiation. High concentrations of dust particles reduce visibility and cause driving accidents and also have severe negative effect on the growth of plants. The solar incident light is scattered because of dust particles and reduces the efficiency of solar cells. Among the benefits of dust particles ultraviolet energy absorption can be noted. High power UV rays are extremely damaging to the eyes and can cause cataracts, chronic disorder of the cornea or

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temporary and permanent blindness. The aim of this paper is to explain how one can determine the energy band gap in dust particles by optical results.

MATERIALS AND METHODS

The samples were collected during the summer of 2011. The wind speed was measured at over 20 m/s. The city of Zabol in Sistan and Baluchistan Province lies between 60°15' E and 61°50' E longitude and 30°5' N and 31°28' N latitude. The samples were collected by a trap at an altitude of two meters from the ground. During the storm, dust particles collided with the trap and were enclosed in it. In this research, physical characterization of the dust samples was measured using various physical techniques. The crystal structural properties of the sample were measured using X -ray diffraction (XRD). The morphology and compositional analysis of the samples were performed by scanning electron microscopy (SEM) and energy dispersive x-ray spectrometry (EDX). Furthermore, the optical characteristics were evaluated by FT-IR and UV-Visible spectra.

RESULTS AND DISCUSSION

Figure 1 shows the elements present in the sample of dust storms in the EDX spectrum. The elements available in the sample are including Fe, Ca, K, Cl, S, Si, Al, Mg, Na and O which are common to most major dust storms in other areas of the world [7, 8, 9, 10]. Si is the most common component and Fe is the only magnetic component in the samples.These results are similar to those of the previous studies [11, 12, 13] and confirmed by XRD analysis.

Figure 2 shows the XRD pattern of the dust storm sample. This pattern indicates the major components of the sample to be SiO_2, $CaCO_3$, NaCl, and feldspar (($KAlSi_3O_8$, $NaAlSi_3O_8$, $CaAl_2Si_2O_8$) [14]. The FT-IR spectrum of the sample is shown in Figure 3.

The IR spectrum has a strong peak around 3411 cm^{-1} due to the stretching vibration of O–H for the water vapour content, Furthermore, the peak at 2926 cm^{-1} pertains to the C-H stretching of the sample's hydrocarbon content, the peak at 2511 cm^{-1} pertains to the Si=O stretching of the sample's silicate content, the peak at 1432 cm^{-1} pertains to the Si-O stretching of the sample's silicate content, and the peaks in the range 875-408 cm^{-1} pertain to the metaloxy (M-O) stretching vibration of the sample's contents.

Figure 4 shows the SEM images of the morphological and structural characteristics of the dust storm particles, with various scales, including (a), (b) 100, (c) 200, and

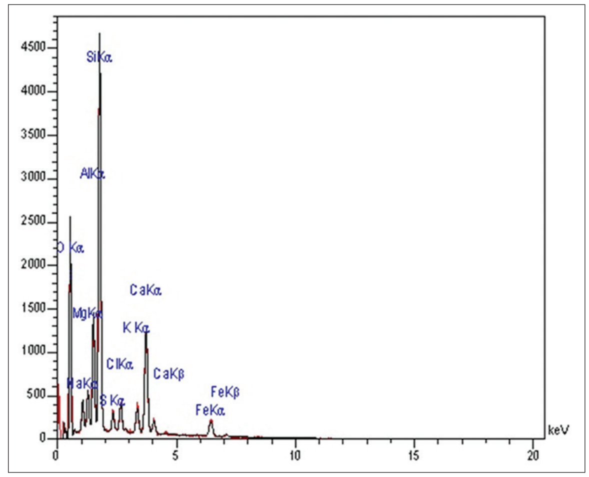

Figure 1: EDX spectra of the dust storm sample

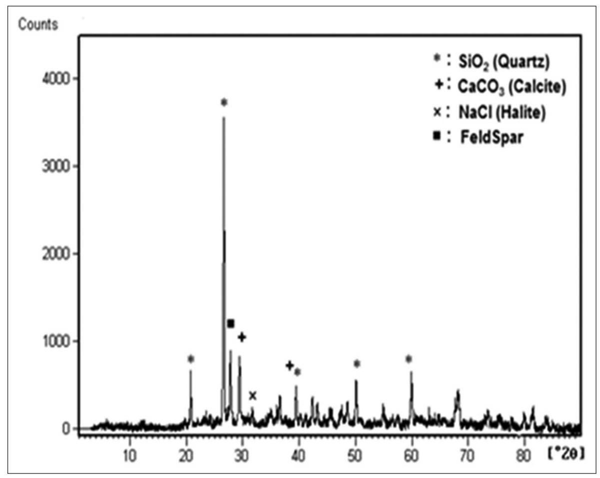

Figure 2: The XRD pattern of the dust storm sample

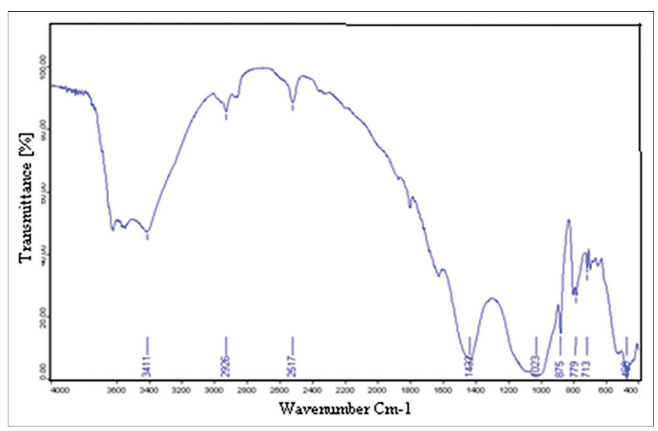

Figure 3: The FT-IR spectrum of the sample

(d) 500 μm. The images show amorphous particles with sharp edges and micron sizes.

Figure 5 demonstrates the transmittance spectrum of the dust storm particles as a function of the incident light wavelength. As seen, from the wavelength of 430 to 800 nm

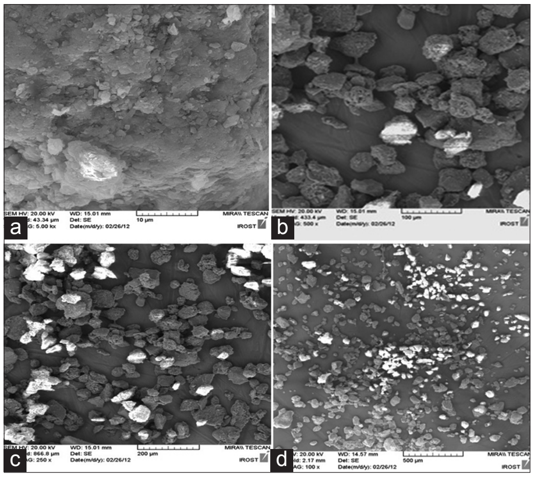

Figure 4: SEM micrographs of the dust storm sample with various scales, (a) 10 µm, (b) 100 µm, (c) 200 µm, (d) 500 µm

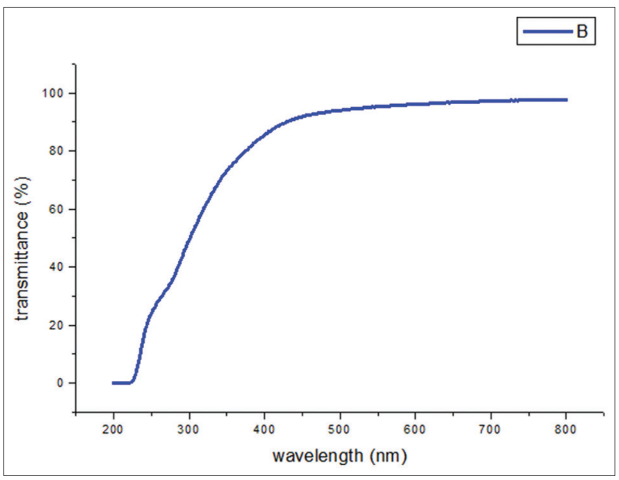

Figure 5: The transmittance spectrum of the dust storm particles

(visible range) more than 90% of the incident light passes through the dust particles. In addition, absorption mainly occurs under 300 nm. Absorption spectrum is discussed in detail in the following, after calculating the energy band gap of the particles.

Optical energy band gap ofthe dust particles could be obtained from Tauc relation [15],

$$\alpha hv = A\ (hv - E_g)^{1/2} \tag{1}$$

Where α is the absorption coefficient, A is a constant, hv is the energy of incident light, E_g is the energy band gap of the particles. On the other hand, absorption coefficient α and transmittance T are related as,

$$\alpha hv = A\ (hv - E_g)^{1/2} \tag{2}$$

So, from the equations 1 and 2, the following equation is obtained,

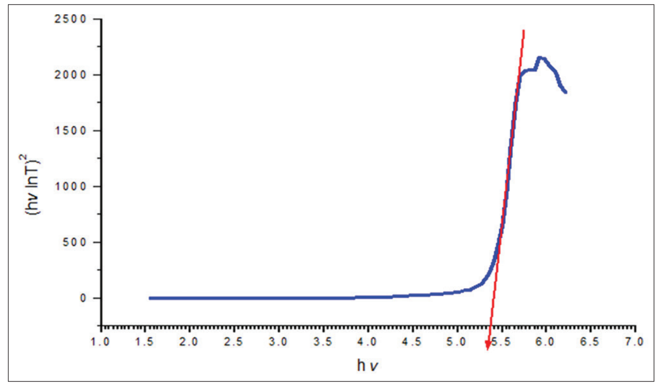

Figure 6: Determination of the optical band gap from the transmittance spectrum

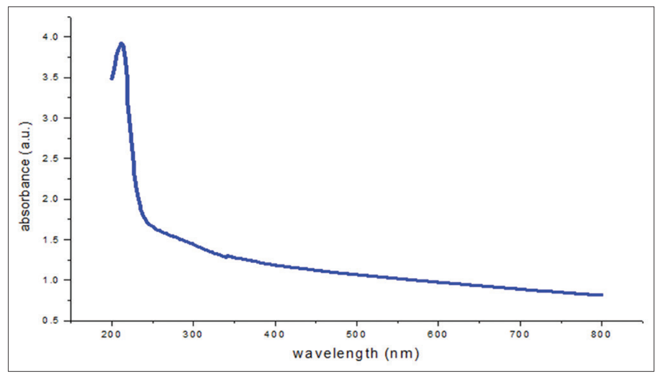

Figure 7: The absorbance spectrum of the dust storm particles

$$\alpha hv = A\ (hv - E_g)^{1/2} \tag{3}$$

The value of the optical band gap could be obtained by calculating the slope of the straight-line portion of $(hv\ lnT)^2$ against hv, as shown in Figure 6. The optical band gap value of the dust storm particles is obtained as 5.4 eV. This energy band shows that the particles have no electrical conductivity.

Figure 7 shows the optical absorbance of the dust storm particles as a function of wavelength in the UV–visible range.

The band gap E_g of the particles was calculated from Tauc relation as shown in Figure 6. Location of absorption peak on the wavelength axis (λ_a) in absorbance spectrum could be estimated by using the following formula, $\lambda_a = hc/E_g$ where h is the plank's constant, c is the speed of light and E_g is the sample energy band gap calculated in this section. The absorption peak wavelength of the sample was found to be approximately 230 nm.

Therefore, during the dust storms, light with an approximate wavelength of 230 nm has the highest absorption in the sample. Therefore, maximum absorption occurs in UV range.

CONCLUSION

In this research, properties of the particles obtained from dust storms in the Sistan region are characterized. The SEM images of the particles show that they are amorphous in shape with sharp edges. This sharpness of the particles could be endangering the health of humans and animals. The results of the EDX and XRD analysis indicate the sample to contain several elements and minerals. The acquired results from the FT-IR spectrum are in agreement with the results obtained from the XRD. In addition, the transmittance spectrum of the dust storm shows that the particles exhibit optical transparency in visible range. Moreover, the absorbance spectrum indicates maximum absorption to occur in UV range. The calculated energy band gap (5.4 eV) also demonstrates the particles to have no electrical conductivity.

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