Analysis of a Dust Storm Profile: A Case Study in Iraq

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Abstract
In recent years, many academics have investigated various aspects of dust storms as one of the environmental challenges. In this study, a Battelle laser photometer coupled to a portable computer was used to monitor, analyze, and correlate the particle size distribution to wind speed across a 24-hour period that included the dust storm from January 18–19, 2020. These were connected with wind speed data obtained from an automated weather station (F.A. 511, Wilh Lambrecht). They also examined how the ratio of fibers to particles varied when the wind speed changed during a dust storm within the same period as the aforementioned. The results show that, during storms, a rise in the number of particles occurs as a consequence of high wind speeds, local near-ground turbulence, and strong wind, which work together to effectively lift up heavier particles. Also, it demonstrates a perfect relationship between the profiles of dust particles and fibers with a time lag in relation to wind speed, and an inversion in the order of the individual particle size profiles corresponding to a critical wind speed was noticed. A time lag of around five hours relative to the wind speed profile is also observed. Despite the similar shapes and the trend of the profiles, the ratio of fiber to particle is not constant.

Keywords: Dust storm; Wind speed; Dust density; Particles; Fibers; Particle size distribution

1. Introduction
Dust storms, which regularly occur in arid and semi-arid regions, are one of the major issues facing human society (Furman, 2016; Khalidy et al., 2019). The scientific community was quite concerned about dust and sand storms (Al-Jumaily and Ibrahim, 2013). It is considered a meteorological phenomenon that has occurred in recent history in these zones (Awadh, 2012). Dust particles are a significant component of the atmospheric mixture that have an impact on radiative forcing through the atmosphere (Díaz et al., 2017). In addition to their radiative effects, dust can seriously affect the human health (Stafoggia et al., 2016). Also, it is significantly affecting solar energy installations (Ewetumo et al., 2018). Tonsillitis cases rose as a result of air pollution, particularly PM10 and PM2.5 (Cheng et al., 2021). Heavy sandstorms frequently inflict significant environmental and human harm (Zhang et al., 2016; Middleton, 2017).

The size and diameter of soil particles, as well as the intensity and speed of the wind, influence the amount of dust particles in the atmosphere. A major area for study is measuring and characterizing PM, in addition to having an influence on health, airborne particulate matter (PM) may also reduce vision.
cause material degradation, and pollute groundwater (Tian et al., 2017). Dust incidents happen anywhere in the world (Ishimoto et al., 2016). They often come from soil erosion in dry regions, are propelled to high altitudes by thermal turbulences, and are transported across great distances (Nicolae et al., 2019). Dust may increase desertification by soil erosion and movement termed as desertification (Middleton, 2017). Wind speed and direction cause a variety of pollution patterns, depending on the weight, shape, and size of polluting particles activity (Awadh, 2009).

The deserts are the primary worldwide source of dust, and mineral aerosols are thought to be the second greatest source of natural aerosol (Ajtai et al., 2020). However, a quantitative calculation of dust emission has always been a challenge (Cao et al., 2015). Iraq, Saudi Arabia, China, north India, and parts of northwest Africa have been classed as having extraordinarily high PM2.5 levels (Li et al., 2018). The majority of Baghdad's concentration of heavy metals (Cd, Ni, and Pb) is caused by traffic and smoke emissions into the roadway (Awadh, 2015). The size and diameter of soil particles, as well as the intensity and speed of the wind, influence the amount of dust particles in the atmosphere (Al-Rajehy, 2002). Many studies on the concentration, distribution, and influence of dust and sand storm particles have been conducted in recent years, which have covered a wide range of topics, including. The size distribution measurements are quite necessary for the specifications design of equipment or to test the system performance (APTI, 2000).

In the measuring of size distribution, a Scanning Electron Microscope (SEM) and image program can be used to evaluate the morphology of the dust particle and measure its size (Mazzoli and Favoni, 2012). A method based on ultrasonic changes can also be used in the characterization of dust particles, where the ultrasonic intensity produces an attenuation with the propagation distance and propagation medium. Automatic measurements of dust particle concentrations in the air are also developed by Yu et al., (2017). Regarding particle size, dust storms are classed as mud to sandy clay sand deposits, whilst grittiness dunes, are classed as silty sand sediment. Because of particle size variations, the mineral constituents of severe storms and grittiness sands are changing (Awadh, 2012). Dust storm production is influenced by factors such as moisture content of the soil, surface texture, and particle cohesiveness (Zhang, et al., 2018). Study the mechanism of the dust with the wind by analyzing the data observed, as well as, using the numerical simulations, the result of these simulations showed that, in the strong wind, the entrainment of dust mechanism is from the gusting wind (Hu et al., 2015).

In this study, the measurement, analysis, and correlation of data related to particle size distribution and wind speed were carried out during a 24-hour interval that encompasses a dust storm. The variation of dust density and fiber-to-particle ratio with the variation of wind speed during a dust storm is also examined.

The aim of the study is to examine the impact of changing wind speeds on particle size distribution as well as changes in dust density and fiber-to-particle ratio throughout the course for 24-hour dust storm.

2. The Geographical Location of Iraq

Iraq is located in the south-west of Asia between latitudes 29.6° N - 37.5° N and longitudes 38.45°E - 48.45° E, (Fig.1), and it has a total area of 437072 km². Iraq is bounded to the north by Turkey, to the east by Iran, to the south by Saudi Arabia and Kuwait, and to the west by Saudi Arabia, Jordan, and Syria. (Ahmed, 2019). It has been established that some of Iraq's bordering countries are classified as key Middle Eastern providers of dust, having a direct impact on dust exports to other areas (Goudie and Middleton, 2006).
3. Methodology, Materials and Data

For this investigation, two main devices are used:

- Laser optical photometer for automatic counting of particles and fibers in different size ranges (from Battelle). The light source of the device is a He-Ne laser. The maximum optical power is 0.8 mW, the wavelength is 632.8 nm, the sampling flow rate is 1.1 l/h, and the maximum instantaneous count rate is 6600 /sec.

- Photometer for measuring integral dust concentration (from Sigrist). This optical device's light source is a Tungsten lamp with a spectral range of 360 to 2800 nm (continuous spectrum), detected by secondary electron photo multiplier cell 931 A, and it is based on the principle of 15 scattering light, as shown in Fig. (2A). Both devices were digitally connected to a computer via A/D converters with microprocessor control units for interfacing with the portable computer, which also dosed the pulse height analysis for particle counter.

- Wind speed data were obtained from an automatic weather station (F. A 511 Wilh Lambrecht). Lambrecht Meteo is the manufacturer of all physical measuring principles for wind measurement. Mechanically rotating wind sensors with cup rotors and wind vanes, as well as ultrasonic sensors, are universally applicable for a wide range of applications in industry and meteorology. as shown in Fig. (2B). Lambrecht specifications are illustrated in Table 1.

4. Result and Discussion

Many dust storms occurred in Iraq in 2020, with one sample analyzed from occurrences on June 18-19. The variation of fiber-to-number of particle ratio with the variation of wind speed during a dust storm was examined, as shown in Fig. (3), which illustrates wind speed variation over 24 hours, the period during which the dust storm occurred. The hour 8.00 of Fig. (3) represents the onset of the dust storm. While the hour of 9.00 represents the beginning of the increase in the number of particles in all profiles. Fig. 3 demonstrates that the data for wind speed is cut off. The reason behind this is that the winds are strong and swift during a storm. In order to include all wind speed data, a larger scale should be utilized if the wind speed is shown on the same scale. Thus, this will have an impact on research into
the quantity of fibers and particles in the dust storm. An adequate scale was also utilized to analyze these particles in the storm since the study is more concerned with the quantity of particles and fibers than with wind speed.

Table 1. Specifications of LAMBRECHT weather station

<table>
<thead>
<tr>
<th>Professional Line</th>
<th>BASIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Id-No</td>
<td>00.14574.000000</td>
</tr>
<tr>
<td>Measuring range</td>
<td>0.7...50 m/s</td>
</tr>
<tr>
<td>Accuracy</td>
<td>wind speed: ± 2 % FS</td>
</tr>
<tr>
<td>Resolution</td>
<td>wind speed: 0.26 m/s</td>
</tr>
<tr>
<td>Starting value</td>
<td>0.7 m/s</td>
</tr>
<tr>
<td>Output</td>
<td>0...192 Hz</td>
</tr>
<tr>
<td>Range of application</td>
<td>-30...+70 °C • under non-icing environmental conditions</td>
</tr>
<tr>
<td>Strongest wind impact velocity</td>
<td>60 m/s</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>24 VDC (4.7...28 VDC)</td>
</tr>
<tr>
<td>Current consumption</td>
<td>max. 8 mA • &lt; 4 at 5 V</td>
</tr>
<tr>
<td>Measuring elements</td>
<td>3-armed cup rotor - fail safe</td>
</tr>
<tr>
<td>Measuring principle</td>
<td>magnetic</td>
</tr>
<tr>
<td>Weight</td>
<td>approx. 0.90 kg</td>
</tr>
</tbody>
</table>

Fig. 2. A. Tungsten Halogen Light Source, B, LAMBRECHT automatic weather station

Fig. (4), on the other hand, was not observed until 14.00, at which hour the wind speed has been at its maximum for over three hours, i.e., there is a time lag of about six hours between the onset of the storm and the onset of the dust rise. Figs. 4 and 5 show the size distribution profile as a number of particles and as a fraction of the total number, while Table 2 shows the profile orders during the same interval.

The greatest impacts are associated with a partial inversion of the order of size distribution profiles and the highest wind speed.

In Fig. (5) one can see, five of the profiles namely those corresponding to the size range 0.8-0.9, 0.9-1.0, 1.0-1.1, and 1.1-1.2 and that corresponding to sizes greater than 2 maintained their initial. Lines 0.6-0.7, and 0.7-0.8, suffered mutual inversion in order with the former maintaining its position relative to the 0.8-0.9. The 0.6-0.7 line, however, dropped below the 0.9-1.0 line.
Fig. 3. Wind speed profiles with increase in the number of particles

Fig. 4. Size distribution profiles of particles with time of 24 hours

Fig. 5. Percentage of particle size versus time.
Although all profiles undergo an upward shift as in Fig. (4), this shift is not the same for all the size profiles, which causes the partial inversion in the order of the size fraction profiles observed in Fig. (5). A complete inversion in position is observed for the 0.4-0.5 line, such that it coincides with the line representing the sizes greater than 0.2. The 0.5-0.6 line now occupies a position just above the 1.1-1.2 line. The 1.2-2.0 line experiences a position inversion, propelling it to the top of the group of profiles. It was also observed that, a similar trend in the variation of the numbers of both particles and fiber. However, a time lag of around five hours relative to the wind speed profile is also observed. Despite the similar shapes and the trend of the three profiles, the ratio of fiber to particle is not constant, as shown in Fig. 6.

Fig. 6. The ratio to particle with time.

Fig. (6) also illustrated that a rise in the number of both particles and fibers is expected as a result of the higher wind speed, local near-ground turbulence, and wirl wind, which combine to increase the life of heavier particles. The increase of the fibers-to-particle ratio from an initial value of 1% at 9.00 h to a final value of around 30% at 14.00 h bears a close correspondence to wind speed variation with the onset of the storm and attainment of maximum wind speed at 9.00 h and 14.00 h, respectively.

The rise in the fiber-to-particle ratio may consist of:

- The airborne dust is made up of a mixture of various six distribution profiles, possibly due to the wind traversing different terrains.
- Even for the same locality, the mixture of different profiles may correspond to different chemical compositions.
- For the same volume, the surface area of a fiber is greater than that of a particle, with consequently better likelihood of being airborne; that is, the airborne dust profile and that of the soil are not the same.
- When there is a large number of particles in a dust storm, any optical system, no matter how sensitive or sophisticated, may fail to resolve individual particles. strings of particles would be counted as fibers. This would amount to a breakdown of the counting system.

The last point is rejected on the basis that the number is still below the stage.

5. Conclusions

Number of particles and number of fibers measurements were carried out over a period of 24 hours, which encompassed a dust storm and wind speed. During a storm, the number of particles increases due to high wind speeds, local near-ground turbulence, and wirl wind, which combine to effectively lift up
heavier particles. In addition to lighter particles that are either already suspended or are lifted immediately upon the onset of the storm.

The interaction of the influences changes the percentage and ranking of the various airborne particle size profiles.

A close correspondence was also observed between fibers and particles and between wind speed and the fiber-to-particle ratio.

It was also observed that there was a similar trend in the variation of the numbers of both particles and fiber.

There is a time lag of approximately six hours between the onset of the storm and the onset of dust rise, as well as a time lag of approximately five hours relative to the wind speed profile.

The airborne dust is made up of a mixture of various six distribution profiles, possibly due to the wind traversing different terrains.

The surface area of a fiber is greater than that of a particle, resulting in a higher probability of being airborne for the same volume.

For the same volume, the surface area of a fiber is greater than that of a particle, resulting in a better likelihood of being airborne.

Fibers are made up of strings of particles, so when there is a great number of particles in a dust storm, any optical system, no matter how sensitive or advanced, may fail to discern individual particles. This would imply that the counting mechanism has failed.

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**References**


