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Review Article

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THE ORIGINS AND SOURCES OF DUST PARTICLES, THEIR EFFECTS ON ENVIRONMENT AND HEALTH, AND CONTROL STRATEGIES: A REVIEW

Shahram Nazari[1], Majid Kermani[2], Mehdi Fazlzadeh[3], Soodabeh Alizadeh-Matboo[3], Ahmad Reza Yari[1]*

[1] Department of Environmental Health Engineering, School of Public Health, Qom University of Medical Sciences, Qom, Iran
[2] Department of Environmental Health Engineering, School of Public Health, Iran University of Medical Sciences, Tehran, Iran
[3] Department of Environmental Health Engineering, School of Public Health, Ardabil University of Medical Sciences, Ardabil, Iran

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CORRESPONDING AUTHOR:

m.fazlzadeh@gmail.com
Tel: (+98 912)7035079
Fax: (+98 451)6612004

ABSTRACT:

Dust storms can cause certain environmental impacts such as reducing solar radiations, geochemical and biogeochemical effects, affecting marine primary producers or autotrophs, (thus reducing the disposal of carbon dioxide and global warming), affecting snow's Albedo. One reason why dust causes such global effects is its transferability range up to 20,000 km. Dust can also negatively affect the respiratory, cardiovascular, cerebral-vascular systems; cause or intensify meningitis, fever, pain, allergies, and viral infections; damage the DNA of skin and lung cells. The Sahara and West China are known as the primary sources of dust worldwide. The most important methods of dust storm prevention and controling it can be biological, sprays (water), mechanical, chemical, and engineering. Biological methods are the best-known ways of preventing dust storms and desertification. This can be achieved by creating vegetation and ecological barriers, such as forest belts. Considering the increasing number and periods of dust storms and dust effects on the environment and human health, this review article aims to determine appropriate strategies to prevent dust occurrence and explain the effects of dust on health and the environment.

REVIEW

Air pollution caused by dust storms has been a major environmental and health problem in recent years. "Suspended particles" refers to solid or liquid particles in the air. These particles are the primary and main air pollutants, can have diverse sources, and may come in variable sizes [1]. Dust storms are natural events that occur mainly in arid areas, reducing air quality and visibility. When horizontal visibility declines to less than a kilometer, dust storms are created [2]. Due to lack of vegetation in the areas prone to dust, the air starts to warm and move up, when these currents reach winds with high transfer speed, the result may be winds circulating downward. These intense winds cause dust storms near the ground's surface. Most

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often, precipitation is below 50 mm per year in these areas [3]. However, some researchers have suggested 100 mm [4]. Most epidemiological studies have considered suspended particles of 10 µm or lower in diameter as indicators of exposure, as this size includes coarse particles (diameter 2.5 to 10 µm) and fine particles (diameter less than 2.5 µm) [5, 6]. Coarse particles are derived from geological materials such as soil and other hard materials [7]. Particles less than 10 µm may damage the lungs, cause dramatic intensification effects on atmospheric chemical reactions, increase the probability of precipitation, increase fogs and clouds, reduce visibility and solar radiation, cause track time changes in temperature and biological rhythms in plant growth, and profoundly change the materials in soil [8]. The intensity of these effects depends on the particles concentration, physical and chemical compositions of particles and their sizes. Most dust storms occur in spring and summer and, less frequently, in autumn and winter. During the day, dust storms occur most often from noon until sunset in different regions of the world [9, 10]. When dust storms occur, strong winds begin, dust and sands rise, the air pressure immediately increases, and temperature suddenly drops to approximately to 5 °C [11]. Therefore, devising strategies to prevent this phenomenon seems essential.

Formation mechanism and origins of dust storms especially in areas prone to dust

In recent years, a clearer picture of the main sources of dust emission on a global scale has been obtained. Specifically, data from Total Ozone Mapping Spectrometer (TOMS) has provided a comprehensive description [12]. Using images from TOMS, the Absorbing Aerosol Index (AAI) is reached [13, 14]**.** This index utilizes daily data from the Nymbus 7 satellite, which records near ultraviolet wavelengths (380, 360 and 340 nm) emanated in the space. The AAI is based on the following formula:

$$AAI= 100\text{Log}_{10}[(\frac{1340\ nm}{1380 nm}) \text{ means} – (\frac{1340\ nm}{1380\ nm}) \text{ Calc}]$$

Here, I $_{\text{means}}$ is the return radiation measured at a given wavelength and I $_{\text{Calc}}$ is the radiation calculated at the same wavelength, using a climate model. The difference between the measured and calculated values of radiation is used as an indicator of the AAI. In this respect, non-absorbing aerosols (such as sea-salt and sulfate particles) are negative AAI values, while the short-wavelength UV-absorbing aerosols (e.g. dust) are positive. Clouds possess AAI values near zero. Most researchers use the AAI values equal to or bigger than +1 as an indicator of the occurrence of dust storms. In this way, they are able to eliminate dust days and specifically investigate stormy days only [15, 16]. This data has now proved that, in terms of sources of dust, the Sahara desert is superior to other dry regions of the world including the Middle East, Southwest Asia, the Australian Centre, South Africa, and Great Basin in the USA. Currently, most of the major sources of dust are large areas of internal drainage such as, Bodele, Taoudenni, Tarim, and Great Salt Lake. Also, the TOMS images revealed that many of the major sources of dust are located in over-dry areas with an average precipitation less than 100 mm [4]. More than 70 percent of dust storms have been associated with African deserts [17, 18]. The Sahara desert is the largest source of dust in the world. It is estimated that the emission volume of dust is about 1,000 to 3,000 million tons/year [19, 20], with 500 to 1,000 million tons/year [21, 22], the average 700 million coming from the Sahara desert in other words, about half of the world's dust originates from this desert [21, 23]. Dust from the Sahara desert is transferred to the south, the Caribbean, Bermuda and America [24]. Sahara dust can also spread towards Europe, the Middle East, and even to distances as far as thousands of kilometers (up to 20,000 km) [25]. Table 1 shows the amount of dust generated from the Sahara desert and other parts of the world as reported in various studies.

Table 1. Estimate of the amount dust from global resources and Sahara

Annual quantity million tons/years, for global scale	Annual quantity million tons / year, for source strength of the Sahara	Reference
-----------	586–665	[26]
-----------	170	[27]
-----------	130–460	[28]
3000	-----------	[29]
1654	-----------	[30]
1018	479–589	[31]
1921	-----------	[32]
1790	-----------	[32]

The wide range of figures and discrepancies may be due to adverse processes of measurement, differences of times and locations of the studies [33]. On a global scale, the discrepancies can also be traced to the application of different models and factors such as different speeds of the dust disappearance in the air [34]. These factors have caused difficulties in evaluating Sahara's contribution to the world's dust volume. For comparing the relative share of sources in the production of dust, the information obtained from TOMS is very useful. The Aerosol Index (AI) gained from TOMS shows the higher intensity of the Sahara regions compared with other major sources of dust such as deserts in China, Saudi Arabia and the Tar. Five important points are identified as the major sources of dust in the world, three of which are situated in the Sahara desert (Bode´le´ Depression of Central Sahara with AI > 30, West Sahara in Mali and Mauritania with AI > 24 and Eastern Sahara in Libya with AI > 15) [35]. Bode´le´ is located in North Africa and is the major source of dust emissions. Although the area of depression is relatively small, it produces about 6 to 18 percent of global dust. One important reason for this is the topographic surface of the depression [35]. The second major source of dust is China, the destructive power of which is considerable. Zhang et al. (2006) estimated that the amount or ratio of the annual emissions from this source is 800 million tons/year, which is comparable to figures related to the Sahara [36], Other study have reported 100 to 460 million tons/year [37]. Another major source of dust is the Arabian. Arabia (Southern Oman/Saudi border) has been recognized as one of the five major sources of severe dust with AI > 21. Vaby, a sandy area in Oman, is one of the dust producing areas in the Middle East [35, 38]. In these areas, the strongest dust storms occur during April, May, June, and July [39, 40]. Intensification of dust in these months takes place concurrently with increased activity in the northern Sahara (4) The severe area between the Saudi-Omani borders, which is a very dry region with low vegetation, is fed by the dry bed of the river that originates from Reem Mountains in Yemen and Oman [41]. Although most of the dust in the Middle East originates from local areas, a certain mount is from the Sahara [42].

Studies in the world

A considerable amount of research has been conducted and published on various topics related to dust. These include the origins, nature, characteristics, transportation routes, dust compounds, the effects and consequences of dust on towns and villages. The investigation of the dust phenomenon in the Middle East using TOMS data revealed that the greatest dust storms occur in Iran, Pakistan and over the Arabian contries during the summer. The onset of these storms is April and May, and the peak months are June and July [10, 39]. The background studies carried out shows that in Pakistan, Afghanistan, Iran and China, the occurrence of storms is severely impacted by the region's topography, such that its decrease raises dust storms [15]. A survey of the origins of El Paso hurricanes in Texas between 1932 to 2005 by Novlan et al. (2007) showed that the wind started from the heights of New Mexico and, passing the Mexican desert, picked dust and finally arrived at and affected El Paso [43]. Alles (2010) studied dust storms occurring in China and found that the storms were primarily formed in the northern cold regions and, traversing the Gobi desert and raising dust particles, created problems [44]**.** A study of dust storms in Mongolia showed that these storms occur most frequently in West Mongolia and are affected by the Gobi desert as well as the vast lakes in West Mongolia. Morevover, most of these types of storms occur in spring when the weather and soil are dry [45]. Another pertinent study revealed that cyclone activities in northern China could offer explanation for the sand storms in Mongolia. The pressure gradient between northern China and Gobi deserts and sandy areas in South and West Mongolia intensify cyclone activities [46]. Wang et al. (2005) studied synoptic characteristics dust storms formation in North East Asia. They believe that a dust storm in this region is always associated with a low-pressure or a cyclone. The dust system develops when a low-pressure system reaches this area. The amount of dust in the cyclone's warm sector achieves its maximum [47]. Surveying the characteristics of Asian dust transport in Korea, Chun (2001) concluded that strong surface winds, instability on the 1.5 km ground level, as well as strong winds from the 500 hPa level caused Asian dust transport to the Korean Peninsula [48]. Barakan et al. (2008) surveyed surface synoptic patterns of 500 and 700 hPa of dust and non-dust periods in the African desert, demonstrating a significant difference in climate variables between these two periods. During the spring, summer, and autumn of dust years in Western Europe and Northwest Africa, a strong cyclone flow caused transmission of extreme cold and decrease of geopotential height in this area. However, in East and central Sahara and central Mediterranean, the anti-cyclone flow is more dominant, with an almost high heat and increased geopotential height [49]. Kutiel and Furman (2003) studied dust storms in North and northeast Africa, and the entire Middle East region. Based on the stations, Iran, Sudan, Iraq, Saudi Arabia and all the countries in the Persian Gulf region fall into the first class, which means the highest frequency of dust storm occurrences. The study also shows that the frequency of storms is higher during warm years [9]. Some studies have measured the number of dust days. Wang (2005) and Natsagdorj et al. (2003) found that 161 to 171 days were dusty days in China [45, 47]. Nordstrom et al. (2004) counted 47 dusty days in some regions of Texas, America, during a year [50].

Formation mechanism and origins of dust storms in Iran, especially in areas prone to dust

Iran is located on the arid and semi-arid belt of earth and a vast proportion of its area is dry and devoid of vegetation. In addition, the country is partly surrounded by deserts in other countries such as Iraq, Syria, Jordan, Saudi Arabia, Kuwait, Oman, and the UAE. Moreover, African deserts are not at a far distance from the country. According to many researchers, most dust storms in Iran, especially in western provinces, have planetary nature. Results of many studies indicate that these storms originate from North Africa, and Saudi Arabia and the deserts of Iraq and Syria. Some researchers propose that the Sudani low-pressure and high-pressure are the causes of Iranian dust storms [51]. Dust and air pollution affecting most provinces and even the capital city of Iran is due to high-pressure systems in parts of southern Iraq and northern Saudi Arabia. The origin of the dusts in the west and northwest of Iran has been Baghdad. This phenomenon is due to the recent drought in southern and central Iraq as well as the western and northern Saudi Arabia. This has caused their pastures and Hurea area dry and turn into deserts eroded by wind. Drying

Hurea in southern Iraq, devegetation in southern and central regions of the country, and advancing deserts in west and southwestern Iraq is added to the range of this natural phenomenon. Of course, Arab countries and the Iraqi government's disregard of desertification should also be taken into account [52].

Studies in Iran

Dust concentration in Ahvaz was studied by Shahsavani et al. (2011). It was found that the average total suspended particulate and PM_{10} were 1481.5 and 1072.9 μg/m^3, respectively. It was also discovered that such chemical forms as NaCl, $(NH4)_2SO_4$, KCl, K_2SO_4, $CaCl_2$, Ca $(NO_3)_2$, $CaSO_4$ may exist through the TSP [53]. In another study it was discovered that the increase of these values corresponded to the increase of dust days and reduction of precipitation in Iraq. One intensifying cause of dust in Ahvaz is rise of dusty days in Iraq; dry the everglades is between the Tigris and Euphrates. One of the major causes of desertification in Iraq is the construction of dams by neighboring countries, especially Syria and Turkey, on the Tigris and the Euphrates [54]. Turkey and Syria have recently built 30 dams on these two rivers, causing water shortages in the two rivers. This has dried Mesopotamian wetlands, creating a desert of 500,000 ha. In some cases, dust from Central Africa, especially from Sudan, are intensified when flowing with intense winds, and passing over the Red sea, join dust masses in Saudi Arabia. It is worth mentioning that part of this dust which is also caused by drought originates from the Khuzestan province, Iran . Many factors are involved in the formation of storms, but the circulation of the atmosphere and land surface conditions are the main reasons [55]. Atmospheric circulation involve Azores high-pressure and west wind migratory systems, and the most important sources include deserts of Syria, Iran, Jordan, Iraq, North Africa and the Arabian Peninsula. In general, the best condition for the occurrence of a dust storm is heating–dynamic systems with inclement conditions on ground surface [56]. A study on storms in the sand plain of Ardakan, Iran, has shown that dynamic low-pressure with cold fronts and vertical air flow cause intense atmospheric instability and create strong sand storms. Another reason for the occurrence of sand storms is the passing or approaching of a trough in the west of the region, leading to intense cold weather rise and the increase of the pressure gradient on the ground [57]. A synoptic survey of dust storms during a ten-year period in the region of Khuzestan using ghemoptansial height maps, wind vector, and the sea level pressure, showed that in the warm period, a surface thermal low-pressure, and in the cold period, migratory systems and polar winds, with the trough located in the west of Iran on desert areas, play a pivotal role in the formation of these storms [58]. Another study concluded that the origins of the 120-day storms in Sistan, Iran, from the climatic point of view, were a low-pressure center in the east of Iran, and a high-pressure region in northeastern Iran and the Caspian sea [59]. Still, another study posited that the extreme droughts during the late 1990s and early 2000s have been the cause of dust storms in Sistan, the frequency of which has risen by five times [60]. In the same region, using artificial neural networks, the occurrence of dust storms was predicted, which confirms other studies in this region [61]. A survey of dust storms in Khuzestan from 1995 to 1999 revealed that during warm years, orbital convergence of low-pressure systems in Iran and Pakistan from the east, and the Azores high-pressure system from the west, and consequently the increasing slope of pressure on Khuzestan create dust in Khuzestan and its neighboring provinces. Flow of air contaminated with dust from the deserts of Iraq and Saudi Arabia is considered a key factor [62]. Dehghanpour (2005) believes that the dominance of a subtropical influence during warm years that can cause air to move down in the Arabian Peninsula is the reason of the formation of dust storms in the west of Iran [63]. The physical composition and chemical analysis of dusts in western provinces of Iran have also been studied. Results showed that many metallic and non-metallic elements including silica, calcium, potassium, and some organic elements have been observed in these regions. These researchers also believe that despite recent rumors, the chemical, microbial and nuclear contamination rate of dusts were trivial [64]. By investigating synoptic patterns of dust storms for a few storm waves in cold periods, Zolfaghari and et al. (2005) demonstrated that the landing of the middle level of atmosphere and ground cyclones are effective on the transfer of dust from the deserts of Iraq, Syria and Jordan [56]. Hemmati (1995) associated the occurrence of dust storms in the southwest of Iran, especially in the plains of Khuzestan, with cyclone systems in northern Iraq and central parts of the Arabian Peninsula [65]. Lashkari and Keykhosravi (2008) studied dust storms in the Khorasan Province. Results revealed that these storms took place due to the increase of pressure slope and slope of intense heat between the low-pressure of Southern Khorasan and Afghanistan, and the high-pressure on the Caspian sea and Turkmenistan. This pressure difference causes intense winds, especially in Southern Khorasan [66]. Omidvar (2006) studied maps of 500 and 850 hPa to discover the formation mechanism of sand storms in eastern Iran. The researcher believes that the dynamic low-pressures with cold fronts, the vertical flow of air caused the intense atmospheric instability and severe sandy storms in the region [57]. In general, climatologists believe that the movement of subtropical high-pressures toward desert areas, directions of winds, and different atmospheric levels are the meain reasons of the transfer of dust from the neighboring countries. They believe that the flow of strong over loads picks up large volumes of dust from the vast deserts in the west and southwest of Asia and carries them up to the top layer of the troposphere. Then, another strong flow transfers masses of dust to higher widths. When the horizontal flow loses energy at high tropospheric altitude, the dust falls down [62]. Amini et al. (2012) in their study with title Estimating Long-Term Chronic Exposure to PM_{10} Employing a Land use Regression Model founded that the annual-mean concentration of PM_{10} was 98μg/m^3 and ranged from 56 to 155μg/m^3. In this study was selected PM_{10} as Corresponding pollutant.

Dust impacts

Dust impacts on the environment

Atmospheric circulation and Earth's surface conditions are the main factors causing dust storms [10]. Dust particles can reflect sunlight back into space, thus cooling the weather. This phenomenon happens directly and indirectly. Dust particles can reflect the sun's rays through cloud formation indirectly. Moreover, mineral aerosols from dust can also affect cloud formation, the characteristics of clouds and precipitation. In other words, they can affect the clouds by acting as nuclei Atyken [3, 21]. Levels of sulfur dioxide in the atmosphere may be influenced by physical adsorption or heterogeneous reactions with the particles. In other words, sulfur dioxide may exert a synergistic effect in the presence of suspended particles [67]. Other effects of dust can be associated with its role in the biogeochemical cycles and soil formation [68]. Concurrent with a dust phenomenon, concentration of some heavy metals such as lead is increased by three times [35]. Also, the concentrations of toxic metals such as mercury and arsenic will increase [47]. The analysis of dust particles indicate that the concentrations of elements such as aluminum, iron, potassium, magnesium, sulfur, phosphorus, and sodium was more than 500 μg/m^3 and concentrations of elements such as manganese, barium, and vanadium was between 100-500 μg/m^3. The concentrations of heavy metals such as zinc, nickel, lead, chromium, and cobalt were 1-100 μg/m^3 [69]. Dust cycles play an important role in the transfer of iron to oceans with nutrients including phosphorus and nitrates. However, the excessive concentrations of these nutrients, especially nitrates and phosphates, can cause algal growth. Due to destruction of algae, oxygen demand for degradable organisms increases so that it leads to infectious or anaerobic condition. Of course, this phenomenon, termed eutrophication or aging of river, mostly occurs in rivers and stationary lakes [70, 71]. Impacts on primary producers, or autotrophs, and ultimately impacts on carbon dioxide were consumed by primary producers in the food chain. With the loss of this important part of the food chain, the amount of carbon dioxide disposal decreases. This greenhouse gas plays a leading role in global warming, culminating in the disastrous melting of polar icebergs [72-75]. Members of an international board have proved that dust in 2007 had enormous effect on global climate in comparison with 2001 [76, 77]. The substantial role that dust probably played in the Pleistocene is influencing on climate change, hence the rational of studying and surveying dust storms. For example, it is estimated that during the ice age, dust concentration has been at its highest. This probably decreased solar radiation and overall temperature, forming ice mountains [78, 79]. Alternatively, with large amounts of dust particles landing on the snow, its Albedo reduced, resulting in the slowdown of melting, and the increase of density [78]. In fact, simulation showed that the large emissions of dust prevented North Asia from being covered in snow. Dust played an important role in the position of and the size of the last plates of dust [80]. It is believed that although dust reduces the Albedo of snow, it may significantly affect the retreat rate of ice plates [81]. It is also claimed that dust may have asymmetrized glacial cycles [82]. Moreover, several studies show that dust transfer can affect the geochemical conditions of the receptive area. For example, dust from the Sahara desert has affected the nature of the Anode soil [83], the Canary Islands [84], vast areas of Barbados, the Bahamas, Florida [85] and Mount Cameroon [86]. Indeed, the long distance dust can travel accounts for its global effects [87]. For instance, dust from Lake Eyre basin, Australia, may accumulate in the east of the South Pole [88], dust from the Sahara and Asia may be transferred to North America via over the Pacific Ocean [89], and dust storms from North America may enter the Channel Islands of California and the East Pacific [90]. Large amounts of dust from the Sahara is transferred to the South and Gulf of Guinea [91]. Sahara may also be considered as a major source of dust deposition for the Mediterranean and neighboring countries [92]. Also, dust may be transferred from Ukraine to the Czech Republics, Poland, and Germany [24].

Dust impacts on human health

Dust storms may affect the human life in a variety of ways, one aspect of which is health. Usually air-borne particles range from 0.001-500 µm, the major part of which is composed of particulate material within the range of 0.1-10 µm. approximately 40% of particles sized 1-2 µm will remain in the bronchi and air sacs. The particles sized between 0.25 to 1 µm are less likely to remain in the respiratory system. Particles tinier than 0.25 µm will remain longer in the respiratory system due to the Brownian motion. Moreover, during a dust phenomenon of 10 h, the average 1.29 g dust/m^3 air, an average person with 10 hours of activity and 17 breaths per minute will inhale 6.624 g dust [5, 6, 93]. Thus, particle size is important because of its impact on our health [7]. Dust emissions containing fine particles, salts, and chemicals such as herbicides are worth considering, as well. These may cause respiratory as well as other critical diseases [94]. These risk factors can be either on a continental or a global scale [95-97] and transmit pathogens such as bacteria and fungi [98]. Desert soil contains 10^7 bacteria/g, with a variety of 10^4 bacteria [93, 99]. The highest number of fungal spores in dust storms was 10^6 per m^3 in tropical climates. They were of 44 genera and 102 species, the most dominant of which was Aspergillus [100]. However, other researchers' studies indicated that there are 10^4 bacteria per gram of soil and one million tons of soil is annually transferred into the atmosphere, resulting in 10^{16} bacteria suspended in the air. Of course, this estimate does not include the population of fungi and viruses [101]. A study conducted at Hiroshima university in

Japan separated Bacillus subtilis, Bacillus cereus, Staphylococcus epidermiditis, and gross bacillus from dust using PCR method (16S rRNA). There was a striking similarity of 99.7% to 100% with soil samples from the Gobi Desert [102]. Another study on microbial loads of dust examined samples taken from two dust phenomena in the Palestinian territories. The dominant populations of fungi included Alternaria, Aspergillus fumigatus, A. Niger, A. thomii, Cladosporium cladosporioides, Penicillium chrysogenum, and P. griseoroseum. Most of these fungi are allergens causing asthma, eye irritation, asthma and non-asthmatic pneumonia. The concentrations of visible bacteria were nine times a usual day. The total concentration of visible microbes (fungi and bacteria together) was 1,200 during the dust events and 233 colonies/m^3 during usual days [23]. A study on microorganisms in Virginia Islands revealed that 25% of the microorganisms separated were pathogenic for plants and 10% opportunistic to humans [103]. Still, in another study on the identification of microorganisms in Mali, samples were collected during the occurring of the dust event. Results showed that 10% of bacteria were pathogenic to animals, 5% pathogenic to plants, and 27% opportunistic pathogenic to humans. The different microbial populations of bacteria identified in this study are due to different sources of dust in these areas. Separated bacteria in Mali included many species of Bacillus, some of which caused gastrointestinal diseases and septicemia (blood infection) [104]. Some researchers believe that all microorganisms in volumes of dust are destroyed by the ultraviolet radiation (UV) of the sun, lack of nutrients, and drying over multi-day trips. But, some species of Bacillus bacteria and most fungi can form types with spores, which are resistant to drought, heat, UV, and poor nutrient conditions. It should be noted that due to differences in the culture medium used and lack of standard methods, the resultant figures are not the same [105]. The WHO declared that the activity of dust storms in downstream areas of the Sahara caused bacterial meningococcal meningitis [105, 106]. Dust storms brought about a Valley Fever epidemic caused by fungus coccidis immitis in 1998 in the United States [107]. The prevalence of coccidioidomycosis in southwest U.S. was imputed to dust storm activities [108]. Therefore, dust storms may lead to injuries and death. A study carried out in Taiwan and Korea indicated that for every 10 μg/m^3 increase in the concentration of suspended particles smaller than 10 μm (PM_{10}) in a dust event, the mortality rate increased by one percent [109]. In a study by Khorasani et al. (2002) in Isfahan and Tehran, Iran, in 9% of the days air pollution was above standard. This indicates that populations in different cities of Iran with air pollution are at risk [110]. WHO reported that the contribution of airborne suspended particles to premature deaths is 800,000 annually [111, 112]. It was also reported that the annual cost of healthcare for diseases caused by air pollution in Switzerland, Austria, and France was about £30 billion [112]. In another study, the WHO reported that 500,000 people died premature because of exposure to airborne suspended particles [113]. In some cases, the concentration of the particles in the storm is over 6,000 μg/m^3 [112]. However, the WHO states that the outdoor 24-h average of PM_{10} is 50 and the annual average is 20 μg/m^3 [7]. Based on similar reports, 700 annual deaths due to acute respiratory infections in children aged four and lower in European countries were imputed to PM_{10} [114]. In another study, it was confirmed that with a 100 μg/m^3 increase in 24 h and average concentration of PM_{10}, incidence of pneumonia rose by 19% and chronic pulmonary diseases by 27% [115]. Peters (2005) examined the relationship between heart diseases and suspended particles based on epidemiological records. Results showed a close relationship between daily changes in outdoor concentrations of suspended particles and mortality due to cardiovascular diseases, symptom intensification, hospitalization, premature physiological reactions [116]. Wellenius et al. (2006) investigated the relationship between particulate air pollution and admissions of patients with myocardial infarction in seven U.S. cities. Results showed that increased levels of air pollution (higher than the standard set by the USEPA) raised the number of patients with myocardial infarction. Moreover, it was demonstrated that a rise of 10 μg/m^3 in the concentration of particles smaller than 10 μm lead to a 10% increase of admissions [117]. A group of researchers studied 850 school students in the UAE and concluded that the rate of prevalence of asthma was 13.6% and that of allergies was 73%, hence a positive and direct relationship between the prevalence of the conditions and the amount of exposure to dust [118]. The prevalence of asthma was also investigated in the Caribbean Islands from 1973 to 1996 Results revealed that during the period asthma had increased by 17%. [93]. Research in the Republic of Korea on the effects of Asian dust on skin cells showed that Asian dust damage skin cells and cause genetic changes in these cells [119].

Chinese researchers tested the effects of Asian dust samples collected from particles smaller than 2.5 μm ($PM_{2.5}$) on the lung DNAs of mice and macrophage cells. Extracts of these particles damaged the DNAs [120]. A study on the prevalence of asthma in children living in the Aral Sea region indicated the intensifying and not the initiating role of dust in asthma [5]. Cerebral-vasculature impacts, allergies, viral diseases, damage to skin cell DNAs and lungs are other other complications of dust [98].

Forecast and tracking methods

Because of restrictions on direct sampling from the desert air and the impossibility of direct sampling from the total suspended particles, it is not possible to sample particles smaller than 30 μm. Consequently, indirect detection methods are preferred to determine the source of dust [121]. Generally, for simulating and predicting storms different approaches have been adopted. Most of these methods are based on extensive studies and atmospheric measurements. Moreover, using meteorological satellite data and models are very expensive and require an extensive network of observation stations [36, 122]. Some have been reviewed below.

Use of satellite images

Satellite images are valuable in determining the origins and transmission routes of dust. Some common satellites are *TERRA, Aqua, TOMAS,* and *MODIS*. With a wide optical spectrum and equipped with modern technologies, MODIS is one of the best meteorological sensors for monitoring weather phenomena. It is particularly beneficial in studying dust storms and low-pressure systems. Sensor MODIS covers all Earth, collects data in 36 bands, and possess the spatial resolutions of 1,000, 500 and 250 m. The high spatial and spectral resolution of this sensor furnishes enhanced visibility of dust being transferred on land and water. This provides the opportunity of analyzing and examining dust storm activity in a certain area. Research shows that satellite images from TERRA and Aqua with MODIS sensors serve as optimum satellite data to examine the specifications of dust storms (including its strength and direction) [77].

Lagranzhyny model

In this model, retroviral tracing of dust particles up to 48 h before the occurrence of the storm can be possible. This model also provides the route on both horizontal and vertical axes. Finally, the output has three isometropia patterns including pair, a west wave trough, and high pressure [21].

Artificial neural networks

Artificial neural network models inspired by biological nerves have recently been utilized as a top choice. These models can operate with minimum variables and output measurements and predictions of considerable accuracy. Fascination with neural network models is due to their ability in solving nonlinear, bulky, and error-prone problems. Moreover, these models are capable of solving fuzzy problems and recognizing patterns [123]. The using of different methods of artificial intelligence in the prediction of vague nonlinear processes has become very common in all scientific fields. Artificial neural networks (ANNs) are subsumed under artificial intelligence and are increasingly taken advantage of in various sciences such as meteorology and management. AANs were used by Huang et al. (2006) to predict dust storms in northwest China. They could forecast 71.6 and 68.2 percent of dust storms [124]. They have satisfactorily been used for predicting other climatic variables such as evapotranspiration and other parameters in the field of water sources and hydrology [125]. AANs also have the ability to extract hidden relationships between the input and output of certain models. This structure is composed of many processing elements or neurons, used to solve complex problems. Put simply, these networks build up experiences of different cases, like a human, and then, drawing on them, can learn pattern recognition or classification of data. Various types of neural networks with a range of applications exist. The most common type is called *Multilayer Perceptron*, which comprises three units. An input layer is connected to a hidden layer, and this layer in turn is connected to the output layer [126]. Researchers usually design neural networks with one or two hidden layers as neural networks with more hidden layers. After multiplying by the corresponding weights, the total inputs of each neuron are applied in a function called the stimulus function. Based on the specific needs of a problem to be solved by the neural network, it can be linear or nonlinear. In fact, the stimulus function can estimate the relationship between input and output nodes and the network [127]. Computational models, which can help in the study of particle emissions for development of this phenomenon, and Eulerian transport models are some other ways of detecting the sources of dust storms [128]. Studies on tracking dust using the calcium/aluminum ratio proved the reliability of the approach for tracking the origin is dust. The dust ratio of calcium/aluminum is measured and compared with the same ratio in different regions to find the matching figure [129].

Methods of preventing and controlling dust storms biological methods

There are key solutions to overcome dust storms such as planting vegetation or forestation, and creating ecological barriers such as a forest belt [130, 131].

Methods of sprinkler sprays

Using water is the most common way to remove, albeit with limited practicality. Certain additives will increase water's ability to remove dust, keeping in mind that additives must be eco-friendly. Materials helpful to the environment can also be used. *Afri* is an international method of using water to remove dust used in most countries. Products of this scheme are designed to help stabilize the level that can significantly reduce water consumption and other expenses [132].

Methods of removing dust using water sprays in Afri [132].

1) Dust control of roads using trucks or sprinkler diffusers installed along the roads.
2) Aqueous solutions in the form of mist
3) High-pressure systems that combine surfactant in aqueous solution with dry mist

Methods of dust sampling and reporting to the control room for calculating the volume of water and other additives required [132]

1) Using the dust monitoring method to measure airborne particle concentration.
2) Using personal romes to measure dust concentrations. These romes are equipped with alarms which go off when full.
3) Recording data can help retrieve collection and save times, print and present fluctuations in dust.

Using this data, the dust concentration can be obtained and dust can be properly controlled. Also equipment and materials needed and the effects of dust on the environment and human health can be recognized. Research has shown that at least 1L H_2O_2/m^2 is required for soil precipitation or dust removal. The simplest way to understand the water needed is using a tray sized 1 m × 1 m × 50 mm. A truck is driven through a place where water is sprayed from the tray. The volume of water consumed is measured and the driver is asked to drive more slowly or faster based on the volume of water sprayed. This continues until achieving the ideal speed, which is 1L H_2O_2/m^2 of soil surface. A graph is drawn subsequently. This simple method is to obtain the optimum amount of water, and to increase the effectiveness and remove considerable dust. By drawing a graph, water needed for different speeds can be estimated

Mechanical methods

Mechanical measures include covering sand dunes to stabilize them by wheat straw, rice, sand, gravel, sawdust, Monte Murylent, leaves, lignin, plant or animal fertilizers. These materials are widely used in China. In addition, synthetic materials such as polymeric cover (acrylic polymer emulsion and polyacrylic acid) and polyethylene are used in some regions of the U.S. [131].

Engineering techniques

In dry areas in China with high population, wire fences are used in order to protect pastures as a means of preventing desertification [131].

Chemical methods

In Iran, oil mulch, a form of oil waste, is used to stop movement of sand dunes. In China, chemicals and plastic mulch is used in dry areas. Chemical methods adversely affect the environment, soil, and groundwaters. Oil mulch is effective in stabilizing sands but destroys soil [131].

CONCLUSIONS

In recent years many studies have been done on dust storms. These studies have shown that dust storms can wreck havoc on the environment and human health. Dust storms enter large amounts of mineral aerosols into the atmosphere, causing climate change and biogeochemical cycling changes. In addition, dust can be travel over long distances and seriously affect the arrivals. Also, certain diseases may become prevalent due to dust events. We must have the ability to identify the origins and qualities of dust. Recognizing the sources and answering whether it was human-made or natural can help us manage the situation more efficiently. Knowledge of dust periods and how various periods occur at different times is incumbent on us. A dynamic thermal system (thermal low-pressure on the surface and trough in the West Region) along with unfavorable ground conditions pave the way for dust storms. In actual fact, ground conditions and the formation of cyclonic currents, along with instability and strengthening of the situation have helped the formation of many dust storms. The persistence of dust favorable conditions has caused their recurrence in many countries. There is evidence that dust storms in some parts of the world have been brought under control. Management strategies such as forestation, planting vegetation, banning vehicles from driving on dust-prone areas, and irrigation are some effective approaches. On the other hand, drought, the drying up of lakes, prevention from plants growth (e.g. by means of erecting dams), and other processes have led to a rise of dust storms. These factors have also influenced Iran—the building of unrestrained dams on the Tigris and the Euphrates, and upstream rivers and lakes of dust storms in many provinces of Iran. Therefore, with management strategies the number and periods of dust can be reduced and prevented.

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COMPETING INTERESTS

The authors declare no competing interests.

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ETHICAL CONSIDERATIONS

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/ or falsification, double publication and/ or submission, redundancy, etc) have been completely observed by the authors.

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