Investigating the role of fine dust caused by drought and its impact on the health of Middle Eastern countries

Investigar o papel da poeira fina causada pela seca e o seu impacto na saúde nos países do Médio Oriente

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Abstract

The challenge of dust and fine dust has been affecting the southwestern regions of Iran for several years, and every year large parts of the arid and semi-arid regions of the world, especially southwest Asia, are affected by the dust phenomenon. The present study aimed to investigate the role of fine dust caused by drought and its effect on the health of Middle Eastern countries. Present study was conducted based on library resources (articles published in international databases) and descriptive analysis. In the present study, 48 articles and reports presented in reputable Persian databases (Civilica, MagIran, and Scientific Information Database – SID) and English databases such as PubMed, Scopus, Embase, and Web of Science, and Google Scholar search engine were obtained and reviewed separately. The selected keywords for searching the databases were: fine dust, drought, drought, Middle Eastern, and health. The main cause of the current dust is related to the drought caused by external centers, more information and arrangements should have been thought of, and we even expect that forest fires will increase again in the summer season. The investigations of this study showed that the number of dust foci has increased 3.5 times in the past two decades in the countries where the dust originates, and the latest origin of storms in the southwestern regions of Iran, Syria and Iraq have been determined in 14 individual centers.

Keywords: Fine Dust. Drought. Health. Environmental sustainability.

Resumo

O problema do pó e da poeira fina tem vindo a afetar cada vez mais as regiões do sudoeste iraniano. Todos os anos, muitas regiões áridas e semi-áridas do mundo, especialmente no sudoeste asiático, são assoladas por este fenómeno. O presente estudo procura investigar o papel da poeira fina decorrente da seca, bem como os seus efeitos na saúde em países do Médio Oriente, a partir de artigos publicados em bases de dados internacionais e de uma análise descritiva dos mesmos. Tiveram-se em conta 48 artigos e relatórios apresentados

Cadernos de Geografia

doi: https://dx.doi.org/10.14195/0871-1623_52_6

Received on:
October 5, 2024
Accepted on:
July 21, 2025

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em reputadas bases de dados persas (Civilica, MagIran, e Scientific Information Database – SID) e inglesas (como a PubMed, Scopus, Embase, Web of Science e a Google Scholar), que foram analisados individualmente. As palavras-chave selecionadas nas bases de dados foram: poeira fina, seca, Médio oriente e saúde. A principal causa para este problema radica na seca provocada por fatores externos. Importará obter melhor informação e adotar medidas, até porque se espera que durante o verão os incêndios florestais recrudesçam. As investigações deste estudo mostraram que o número de focos de pó aumentou 3.5 vezes nas últimas duas décadas nos países onde as partículas de pó se formam. Determinaram-se 14 centros na base das mais recentes tempestades ocorridas no sudoeste iraniano, da Síria e do Iraque.

Palavras-chave: Poeira fina. Seca. Saúde. Sustentabilidade ambiental.

1. Introduction

According to the definition of scientists, when the wind speed in desert areas exceeds a certain limit, which is generally considered to be 8 meters per second, fine particles enter the atmospheric flow and produce dust (Ansari et al., 2021). This process takes place according to factors such as the roughness of the surface elements, soil moisture, particle size, vegetation, soil texture, the degree of adhesion of soil particles, and the height and elevation of the land (Al Nasser et al., 2025). The World Meteorological Organization (WMO) divides dust into 4 categories based on its intensity and its impact on visibility: "dust storm", "blowing dust", "suspended dust" and "severe dust storm" (Hassan et al., 2023). In a dust storm, fine soil particles are effectively lifted into the atmosphere by strong winds, especially when wind speeds exceed the threshold necessary for particle entrainment (Wang et al., 2021).

This phenomenon is the most intense type of dust and causes the air to become completely dusty and reduce horizontal visibility to less than a thousand meters. Severe dust storms sometimes reduce visibility to zero. This phenomenon, which is mainly specific to arid and semi-arid regions, creates a dense cloud of dust that can reach high altitudes in the atmosphere and can accommodate large amounts of dust per square kilometer of air (Hassan et al., 2023). These storms are able to travel very long distances and sometimes completely cover a country or even a part of a continent. Dust and sand are moderate in intensity.

This phenomenon is mainly caused by winds that have a medium height (1.5 m) and carry amounts of dust and sand with them (Boloorani et al., 2023). This phenomenon can increase the horizontal visibility to a thousand meters. Suspended dust, which ranks third in the classification of the World Meteorological Organization, is less intense than the previous cases. In this phenomenon, fine dust is suspended in the lower part of the "troposphere" (Junkermann & Hacker, 2018), which is considered the lowest layer of the earth's atmosphere, and then the horizontal visibility reaches less than ten thousand meters (Hassan et al., 2023). Today, the phenomenon of dust is one of the most important global challenges and these storms always affect different regions of the globe including North Africa, Southwest America, Northeast and Southwest Asia, including countries in the Middle East region (Lian et al., 2022). At

least since several decades ago, numerous storms have been reported every year for countries in the Middle East region, including Iran. The important and remarkable thing about the occurrence of the mentioned storms is that in the last few years, its characteristics such as the concentration, size of suspended particles in the storm, the duration of the time period, the number of occurrences, the extent and time of activity are very different from the previous similar cases. The Middle East region is a part of the dust belt that extends from the Great Sahara of Africa to the west and central Asia (Mahmoudi & Ikegaya, 2023), and during recent years, the occurrence of dust storms with a duration of several weeks and a very high concentration has increased, and in large areas caused serious disruption to people's lives (Hamzeh et al., 2021). These conditions have not only narrowed the field for any useful activities of the people, but due to the small size of suspended particles in the storm, the possibility of many respiratory, lung, eye and skin diseases has also increased. The phenomenon of dust is a multifaceted phenomenon and many studies have been conducted from different perspectives in the country, but due to the different aspects and dimensions of this phenomenon, there is always a need for many studies in this regard (Goudie, 2014).

There have been many droughts in Iran. From 1999 to 2000, i.e., the country experienced drought for three consecutive years (Zarch et al., 2011). Then another severe drought in the crop year 2008 – 2009 and from the summer of 2008 onwards we witnessed the dust phenomenon in Tehran and the western half of the country (Javadian et al., 2019). In fact, the present dust is a consequence of the occurrence of drought in the country and in the years when the spring rainfall is low and in fact the vegetation does not grow and disappears. The dust phenomenon will affect Khuzestan and Southwest Iran more strongly during the early summer months (Hamzeh et al., 2021).

The main causes of this phenomenon and the main origin of these widespread and severe storms that affect many provinces of the country are most of the northeastern areas of Syria and northern Iraq, especially the Mesopotamia region, which have suitable conditions for the formation of dust in these areas and provided its transmission to large parts of Iran. In other words, it can be said that in the past, the sources of dust production were mostly in the southern regions of Iraq, parts of Jordan, Kuwait and northern Arabia, which often affected parts of the southwest of the country with the southwest or northwest winds. But now with the development and creation of springs in northern Iraq and northeastern Syria, a large part of the country, including the western half and the central regions of Iran, are affected by this phenomenon with more intensity, frequency and durability (Beyranvand et al., 2023). The first occurrence of the dust phenomenon was reported in the western and northwestern regions of Iran and Iraq between 1984 and 1988.

Looking at the formation process of this destructive phenomenon, we find that this phenomenon was transient until 2008, but in the following years, this phenomenon gradually spread in southern cities. So that in 2012, it covered 18 provinces of the country and created many negative effects in the field of human health, environment and even the country's economy (Abadi, et al., 2022). Considering the great damage caused by this phenomenon and the possibility of its occurrence in

the coming years, it is necessary to pay more attention to it by the government and to quickly prevent the escalation of this phenomenon by implementing appropriate solutions. Therefore, it is necessary to find suitable ways to deal with it by having sufficient information about this phenomenon and sufficient knowledge of the manner and causes of its occurrence before implementing operational plans. Other countries also benefited in this field so that by using correct and principled methods, a fundamental step can be taken in this way (Allahbakhshi et al., 2019).

The present study aimed to investigate the role of fine dust caused by drought and its effect on the health of Middle Eastern countries.

2. Literature review

Hristova et al. (2024) studied the psychological factors influencing pro-environmental behaviors, focusing on the roles of self-efficacy, personality traits, and environmental attitudes. Regression analyses revealed that environmental attitudes were the strongest predictors of overall pro-environmental behavior, while behavioral commitment, self-efficacy, and extraversion played key roles in altruistic engagement and voluntary environmental activities. The findings of this study suggested that the influence of personality traits on pro-environmental behavior may be context-dependent, with certain traits playing a more significant role in situations involving direct social interaction. Moreover, the results emphasized the importance of strengthening environmental commitment as a primary driver of sustainable environmental behavior, rather than relying solely on personality dispositions or individual self-efficacy (Hristova et al., 2025). In another study, Sankararaman et al. (2023) examined the complex relationship between air pollutants and the Air Quality Index (AQI) using fractal analysis and complex network analysis. New Delhi was selected as the study area due to its high levels of pollution, and hourly air quality data from 2015 to 2017 were utilized. Findings underscore the necessity of addressing pollution caused by human activities in order to mitigate associated socio-economic and health challenges (Sankararaman, 2023).

Huang et al. (2023) investigated the factors influencing the adoption of protective behaviors against air pollution, utilizing the Knowledge-Attitude-Behavior model. The findings revealed that the adoption of protective behaviors could be explained through three main pathways. The first pathway showed that knowledge significantly influenced individual's attitudes, which in turn increased the likelihood of their engagement in protective behaviors. The second pathway showed that attitudes served as a mediating factor. Perceived susceptibility and severity of risk were associated with attitudes, which subsequently influenced the adoption of protective behaviors. The third pathway showed that individuals who perceived fewer barriers were more likely to engage in these actions. This study addressed the gap in understanding the determinants of proactive protective behavior adoption against air pollution and emphasized the importance of increasing public awareness and reducing barriers to promote individual actions aimed at mitigating the negative effects of air pollution (Huang et al., 2024). Clougherty et al. (2009) examined the growing role of gender analysis in air pollution epidemiology. The finding showed that the majority of stud-

ies focusing on adults reported stronger air pollution effects in women, particularly among the elderly or in studies where exposure assessment was based on residential location. Studies on children indicated that stronger effects were observed in boys early in life, whereas in later childhood, the effects were more pronounced in girls. (Clougherty, 2010). In a separate study, Kalkstein et al. (1993) examined the potential impacts of global warming on various aspects of human health. The findings indicated that with global warming, heat-related mortality would significantly increase in all four countries, particularly in China and Egypt. The most vulnerable regions were those experiencing extreme yet irregular heat events. In the United States, it appears that air pollution does not have a significant impact on daily mortality under extreme weather conditions, although it may have a mild effect under non-stressful weather conditions (Kalkstein & Smoyer, 1993).

MalAmir et al. (2025) examined the economic impacts of dust storms (SDSs) on human health, agriculture, and migration in Khuzestan. The findings revealed that respiratory diseases incurred financial losses of approximately 14 million USD, with over 450 individuals requiring hospitalization from April to July 2022. Cardiovascular diseases related to dust storms amounted to more than 1.9 million USD during the same period. (MalAmiri et al., 2025).

Abadi et al. (2025) investigated long-term spatiotemporal analysis, distribution, and trends of dust events in Iran. This study provided a comprehensive assessment of dust events in Iran using synoptic data from 286 meteorological stations. Suspended dust reached its highest levels from March to July in southwestern Iran, which was closely associated with northwesterly (northerly) winds, while dust storms in the blowing dust category peaked from April to August in the south and east of Iran. Trend analysis showed a significant increase in the frequency of dust events during the 1994 – 2023 period in the western parts of Iran. An inverse correlation between dust events and rainfall anomalies was observed, with years of abnormal rainfall (e.g., 2019, with a 138% increase) being associated with a significant decrease in dust occurrences. Over an 11-year period, surface dust concentrations exceeded the annual PM10 threshold (50 $\mu g/m^3$) on more than 800 days. This highlights the urgent need for effective management strategies to mitigate the impact of dust storms on air quality and public health in Iran (Abadi, Hamzeh, Kaskaoutis, Opp & Kazemi, 2025). In another study, Ziapour et al. (2013) examined responsible and irresponsible environmental behaviors in rural and urban areas of Kermanshah Province. The findings indicated that people's behaviors in Kermanshah Province were generally responsible toward the environment, and there was no significant relationship between environmental knowledge and environmental behavior. Moreover, environmental behaviors were found to be more responsible in rural areas compared to urban ones, among older individuals compared to younger ones, among married individuals compared to singles, and among women compared to men. The results suggested that in order to promote and develop responsible environmental behaviors for the protection of nature, it is necessary to change human behavior and lifestyle in relation to the natural environment (Ziapour et al., 2013).

Three factors that are considered the most dangerous causes include the presence of soft and clayey soils in the above region, the occurrence of severe and extensive

drought, and the meteorological conditions, considering that these regions are located in more northern latitudes than the previous regions, are more favorable for the production of dust. The occurrence of drought, followed by dust and the lack of proper management of water, soil and air in the country, has had various consequences, especially in the border areas of the country, in addition to migration and unemployment, there are also popular disputes in these areas for the exploitation of water (Al Ameri et al., 2019). Currently, there are two hubs, one in north Africa, which is located in Barcelona (Banchelli et al., 2025), and the other is the East Asian, which is located in China (An et al., 2022). In addition to these issues, abandoned agricultural lands in Iraq and Syria, extensive dam constructions in Iraq and destruction of land such as rainfed agriculture in our country are highly influential in the occurrence of dust (Sissakian et al., 2013).

3. Method

Present study was conducted based on library resources (articles published in international databases) and descriptive analysis. Initially, articles and reports presented in reputable Persian databases (Civilica, MagIran, and Scientific Information Database (SID)) and English databases such as PubMed, Scopus, Embase, and Web of Science, and Google Scholar search engine were obtained and reviewed separately. The selected keywords for searching the databases were: fine dust, drought, drought, Middle Eastern, and health.

Selection criteria: All studies published in Persian and English were selected; studies that investigated strategies for controlling and dealing with health-related dust. All review studies, letters to the editor, and conferences were excluded from the study.

After an initial review of 86 titles and 48 abstracts of the received articles, all those that were not relevant to the purpose of the present study were excluded (n=39) and the remaining articles and scientific documents were reviewed in more detail (n=9). Finally, the results of the study conducted in this field are summarized in the results section.

4. Result

The most important and basic strategy to control and deal with dust showed in Figure 1. These strategies include:

1. Comprehensive land management based on climatic potential under the conditions of global warming and precise determination of the criteria of the dust center
2. The mechanisms governing the focal activity
3. The threshold of creation and the intensity of dust activity
4. The spatial extent of the dust source area
5. The national and regional sphere of influence, the climate situation, the ability to manage and measure future activities

6. The ability to monitor the environment, national and regional stakeholders, and demographic, economic and social issues.

Therefore, first, internal and external sources of dust should be prioritized and then based on environmentally friendly methods, their management and control should be put on the agenda.

Figure 1. The most important and basic strategy to control and deal with dust.

Table 1 shows the characteristics of the type of dust particles, based on which storms are divided into two categories: sandstorms and dust storms.

Table 1. Classification of types of dust

Variable	Grouping		Subgroup	Size
Wind erosion storms	type of dust particles	Sand storms	Sand	soil particles
		dust storms		(0.6–1 mm)
			dust	< 0.6 mm
			dust storms	< 0.1 mm
			Blown dust	Visibility < 1000 m
			occasional dust	Visibility < 11 km

According to Figure 2, the monthly survey of the dust phenomenon showed that the highest frequency occurred in the months of May, April, June and July. In total, the highest frequency of dust storms occurred in spring and summer.

Also, the least incidence of dust phenomenon has occurred in autumn and winter seasons. Statistical analysis shows that the phenomenon of dust has continued since the past; however, in recent years, it has occurred with greater intensity and persistence. Iran was classified into five different clusters in terms of frequency of dust

storms with visibility less than 1000 and 500 meters in each season. The highest frequency of storms was seen in spring and summer, respectively, and the lowest in autumn and winter, respectively. Autumn and winter included the least number of days with dust (Mahmoudi & Ikegaya, 2023).

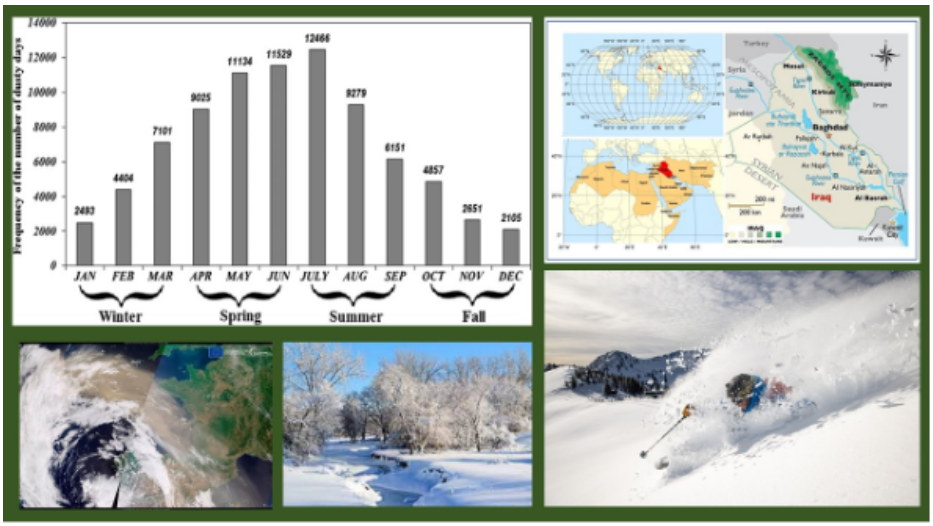

Figure 2. Frequency of dusty days during the seasons in Iran.

According to Figure 3, most effects of summer low pressure create instability and shallow ascent to low altitudes of the atmosphere and often causes local dust (Figure 3).

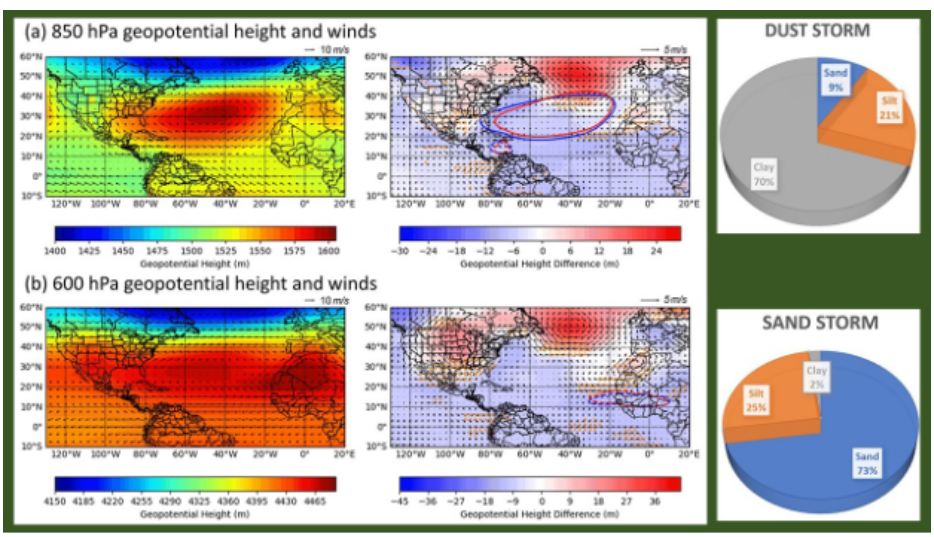

Figure 3. The conditions for deep ascent and the formation of dust storms.

5. Discussion

Considering that a major part of these dusts is of external origin, which requires regional and international cooperation, but to face these cases, the discussion of risk management and vulnerability reduction is based on quick and timely warnings (Escap, 2018). The use based on the climatic capacity is a very important issue, because our region has a special climatic capacity and the response capacity of this area is not suitable for livestock breeding. In general, the most important method to prevent air pollution and the production of suspended dust particles is to control the sources of pollutants and critical centers. Considering the extent and dimensions of critical centers in dry areas, controlling these centers is time-consuming and often difficult (Taghizadeh et al., 2023). The management of external dust centers requires serious follow-up by the ministry of foreign affairs and the environmental protection organization with the target countries and international forums. A part of these dust centers, which is related to the Mesopotamian basin and has suitable humidity, can be managed in a regional cooperation with the development of arboriculture.

North Africa is a source of dust for deposition in southern Europe, or dust from China is deposited in the Pacific Ocean (Karami et al., 2024). While Rubab al-Khali hills in Arabia produce sandstorms, that is, the cover of these hills is sandy and does not create dust (Prakash et al., 2015). Another way to classify dust storms is to use indicators such as wind speed and visibility during the storm. For example, Giuseppe in 1980 divided the storms occurring in northeast India into three categories: Weak dust storms: when the wind speed is equal to 6 degrees Beaufort and the visibility is between 500 and 1000 meters; Moderate dust storms: when the wind speed is equal to 8 degrees Beaufort and the visibility is 200 to 500 meters; Strong dust storms: when the wind speed is equal to 9 degrees Beaufort and the visibility is less than 200 meters (Wang, 2015); The same division is considered in China. The only difference is that strong storms also divided into two degrees; Strong storms: when the wind speed is 50 meters per second and the visibility is less than 200 meters; Dangerous storms: when the wind speed is 25 meters per second and the visibility is 0 to 50 meters, which is also called the black devil (Balme & Greeley, 2006).

The upper levels of Iran's plateau are dominated by high pressure tropical cyclone in summer and low thermal pressure spreads on the surface of the earth. Depending on the place of formation, low pressure over Iraq and Syria and the north of the Arabian Peninsula creates suitable conditions for the ascent of a huge amount of dust into the air. If the area is dry, westerly upper-level currents carry the dust and sand to the middle levels of the atmosphere over the southwestern and western regions of Iran (Beyranvand et al., 2024). Surveys showed: A new critical area has been formed in the northwest of Iraq as a new focus of creating a dust storm, which did not have this behavior previously and has brought the western and even central provinces of the country to the circle of thick dust (Ismail, Halos & Al-Abudi, 2025); Closed low pressures over Iraq and northern Arabia create suitable conditions for a huge amount of dust to rise into the air, which if the region is dry and the southwest and westerly currents of the upper levels of this dust, and dust are carried to the middle levels by the wind. The atmosphere of southwestern and western regions of Iran is transferred

(Karami et al., 2022); In some conditions, the unstable situation created in the Iraqi plain would not transferred to the Iranian plateau, if the conditions are relatively stable on the west of the Iranian plateau. The dust created due to the stillness and stability of the air over the region lasts longer in terms of time and the process their settling to the ground and air conditioning from dust will last between 3 to 5 days and sometimes more (Hamzeh et al., 2021); The revealed pattern on the surface of the earth indicates the formation of a relative low pressure over Iraq and Syria, and in the upper levels there is a relatively deep trough in the Middle East region (Al-Nassar et al., 2020); The outputs of the HYSPLIT model showed that, in general, the main sources of dust for dust storms in southwestern Iran are the range between the center and northern Iraq, eastern Syria and northern Arabia (Alzaid et al., 2024); In the autumn and winter months, a very noticeable decrease in the frequency of dust storms can be seen in all the northwestern regions of the country compared to the spring and summer seasons, which is the reason for the entry of external systems with instability and moisture from the west that enters the country (Shahkooeei & Rahmani, 2019).

In these seasons, in the December, when no dust event was seen, and in the October and November, the frequency of dust storms was the highest. In the winter season, as in the autumn season, the frequency of dust occurrence has decreased significantly (Abadi et al., 2025). In the winter season, all of Iran is under the influence of western winds, their disturbances and humidity, and cyclone tracks formed on the surface of the earth. Therefore, different stations and regions of Iran benefit from different precipitations and humidity according to the distance and proximity to moisture sources, the path of cyclones and fronts (Ghasemifar, Hardy, & Minaei, 2023). In the winter season, all of Iran is under the influence of western winds, their disturbances and humidity, and cyclone tracks are formed on the surface of the earth. More than half of the area of the country is desert or semi-desert. Among these, one fifth of the country's area is among the real deserts of the world (Ghasemi & Khalili, 2008).

The soil air mass that moves towards the southwest and west is related to the lower levels of the atmosphere, which due to the strong change in the pressure of the earth's surface, goes to the western and southwestern provinces such as Khuzestan (Dargahian, Mousivand, Razavizadeh, & Lotfinasabasl, 2023). In general, to create a dust storm, the presence of a low pressure in the deserts of Iraq and Syria is necessary, but it is not sufficient, for example, the summer low pressure can only climb up to a maximum height of 850 and finally up to 700 millibars and create instability. Nevertheless, when which is coordinated and thermodynamically connected with a ship in the middle levels of the atmosphere, the most suitable conditions for the formation of a dust storm on the mentioned deserts provided (Jasim, 2018).

Summer low pressure is possible to spread to those areas due to the warming of the mentioned deserts, but there is no upper level of the atmosphere and due to the stability of the upper atmosphere and the high altitude of the tropical side. The conditions for deep ascent and the formation of dust storms are not provided (Negah et al., 2016).

Studies have shown that particulate matter has serious and widespread health effects (Kim et al., 2015; Mukherjee & Agrawal, 2017; Sacks et al., 2011); children and the elderly are at high risk of health hazards from exposure to particulate matter(Johnson et al., 2021; Odo et al., 2023; L. Zhang et al., 2021; W. Zhang et al., 2022). Also it was found that very small dust particles can penetrate the respiratory tract and cause many diseases such as asthma, bronchitis, and chronic obstructive pulmonary disease (Esmaeil, Gharagozloo, Rezaei,& Grunig, 2014; Fallahian, 2019; Georgakopoulou et al., 2024). On the other hand, researchers have shown that long-term exposure to dust particles is a cause of lung cancer (Ali et al., 2023; van Zandwijk et al., 2023). Dust particles can also carry bacteria, viruses, and fungi, and can increase infectious diseases and allergic reactions (Al Hallak et al., 2023; S. A. Jasim et al., 2024; Vergadi et al., 2022). Given the connection between the prevalence of fine dust and human health, ignoring this crisis could have irreparable effects.

6. Conclusion

Human concerns about the environment in national, regional and global dimensions became evident when the industrial development and the use of limited renewable and non-renewable resources of the inhabited earth increased. According to the findings the number of dust foci has risen 3.5 times in the past two decades in the countries where the dust originates, and the newest origin of storms in the southwestern areas of Iran, Syria and Iraq have been found in 14 separate centers. In general, the main reasons for the activation of dust centers would be the occurrence of drought, weather conditions and climate changes, sustainable development, land destruction and productivity of natural resources exceeding the climatic capacity of attitude. It should be mentioned that the present dust in the Middle East is mainly because of the drought created by external centers. Also, the increase in fine dust caused by drought can be considered a health alarm, and if careful planning is not carried out, the health of millions of people in these areas may be at risk, so more information and precautions should have been considered in this regard.

References

Abadi, A. R. S., Hamzeh, N. H., Kaskaoutis, D. G., Opp, C., & Kazemi, A. F. (2025). Long-term spatio-temporal analysis, distribution, and trends of dust events over iran. *Atmosphere*, *16*(3), 334.

Abadi, A. R. S., Hamzeh, N. H., Ooi, M. C. G., Kong, S. S.-K., & Opp, C. (2022). Investigation of two severe shamal dust storms and the highest dust frequencies in the south and southwest of iran. *Atmosphere*, *13*(12), 1990.

Al Ameri, I. D., Briant, R. M., & Engels, S. (2019). Drought severity and increased dust storm frequency in the middle east: A case study from the tigris–euphrates alluvial plain, central iraq. *Weather*, *74*(12), 416–426.

Al Hallak, M., Verdier, T., Bertron, A., Roques, C., & Bailly, J.-D. (2023). Fungal contamination of building materials and the aerosolization of particles and toxins in indoor air and their associated risks to health: A review. *Toxins*, *15*(3), 175.

Ali, T., Eqani, S. A. M. A. S., Sadiq, M., Khanam, T., Ullah, I., Pongpiachan, S., et al. (2023). Dust effects and human health. In *Dust and health: Challenges and solutions* (pp. 1–15). Springer.

Allahbakhshi, K., Ghomian, Z., Jazani, R. K., & Khorasani-Zavareh, D. (2019). Preparedness challenges of the iranian health system for dust and sand storms: A qualitative study. *Journal of Education and Health Promotion*, *8*(1), 114.

Al-Nassar, A. R. T., Pelegrí, J. L., Sangrà, P., Alarcón Jordán, M., & Jansà, A. (2020). Cut-off low systems over iraq: Contribution to annual precipitation and synoptic analysis of extreme events [Journal, volume and pages not specified].

AlNasser, F., Chehbouni, A., & Entekhabi, D. (2025). Influences of soil moisture and vegetation cover on dust emission using satellite observations. *Aeolian Research*, *72*, 100961.

Alzaid, A. S., Ismail, A., & Aga, O. (2024). Simulation and assessment of episodic dust storms in eastern saudi arabia using hysplit trajectory model and satellite observations. *Atmosphere*, *15*(12), 1515.

An, T., Wu, X., Lao, B., Guo, S., Xu, Z., Lv, W., et al. (2022). Status and progress of china ska regional centre prototype. *Science China Physics, Mechanics & Astronomy*, *65*(12), 129501.

Ansari Ghojghar, M., Pourgholam-Amiji, M., & Araghinejad, S. (2021). Investigating the relationship between drought and trend of the frequency of dust storms in the west and southwest of iran. *Iranian Journal of Soil and Water Research*, *51*(11), 2839–2852.

Asadi Zarch, M. A., Malekinezhad, H., Mobin, M. H., Dastorani, M. T., & Kousari, M. R. (2011). Drought monitoring by reconnaissance drought index (rdi) in iran. *Water Resources Management*, *25*, 3485–3504.

Balme, M., & Greeley, R. (2006). Dust devils on earth and mars. *Reviews of Geophysics*, *44*(3).

Banchelli, F., Garcia-Gasulla, M., Mantovani, F., Vinyals, J., Pocurull, J., Vicente, D., et al. (2025). Introducing marenostrum5: A european pre-exascale energy-efficient system designed to serve a broad spectrum of scientific workloads.

Beyranvand, A., Azizi, G., & Alizadeh, O. (2024). The role of summer and winter shamal winds in the occurrence of dust storms in western iran. *Physical Geography Research*, *56*(4), 1–19.

Beyranvand, A., Azizi, G., Alizadeh, O., & Darvishi Boloorani, A. (2023). Dust in western iran: The emergence of new sources in response to shrinking water bodies. *Scientific Reports*, *13*(1), 16158.

Clougherty, J. E. (2010). A growing role for gender analysis in air pollution epidemiology. *Environmental Health Perspectives*, *118*(2), 167–176.

Dargahian, F., Mousivand, Y., Razavizadeh, S., & Lotfinasabasl, S. (2023). Identifying dust sources affecting southwestern iran (khuzestan province) using remote sensing techniques and hysplit model. *Journal of the Indian Society of Remote Sensing*, *51*(3), 565–583.

Darvishi Boloorani, A., Soleimani, M., Papi, R., Neysani Samany, N., Teymouri, P., & Soleimani, Z. (2023). Sources, drivers, and impacts of sand and dust storms: A global view. In *Dust and health: Challenges and solutions* (pp. 31–49). Springer.

Esmaeil, N., Gharagozloo, M., Rezaei, A., & Grunig, G. (2014). Dust events, pulmonary diseases and immune system. *American Journal of Clinical and Experimental Immunology*, *3*(1), 20–27.

Fallahian, F. (2019). Respiratory effects of long-term exposure to dust outbreaks. *Global Research Journal of Public Health and Epidemiology*, *6*(11), 205–221.

Georgakopoulou, V. E., Taskou, C., Diamanti, A., Beka, D., Papalexis, P., Trakas, N., & Spandidos, D. A. (2024). Saharan dust and respiratory health: Understanding the link between airborne particulate matter and chronic lung diseases. *Experimental and Therapeutic Medicine*, *28*(6), 460.

Ghasemi, A. R., & Khalili, D. (2008). The association between regional and global atmospheric patterns and winter precipitation in iran. *Atmospheric Research*, *88*(2), 116–133.

Ghasemifar, E., Hardy, S., & Minaei, M. (2023). Climatology of cyclones in western and northwestern iran using reanalysis and remote sensing data. *International Journal of Climatology*, *43*(1), 382–404.

Goudie, A. S. (2014). Desert dust and human health disorders. *Environment International*, *63*, 101–113.

Hamzeh, N. H., Karami, S., Kaskaoutis, D. G., Tegen, I., Moradi, M., & Opp, C. (2021a). Atmospheric dynamics and numerical simulations of six frontal dust storms in the middle east region. *Atmosphere*, *12*(1), 125.

Hamzeh, N. H., Kaskaoutis, D. G., Rashki, A., & Mohammadpour, K. (2021b). Long-term variability of dust events in southwestern iran and its relationship with the drought. *Atmosphere*, *12*(10), 1350.

Hassan, E. M., Fattahi, E., & Habibi, M. (2023). Application of a regional climate model on autumn dust events over the urmia basin. *Atmospheric Pollution Research*, *14*(11), 101904.

Hristova, V., Haralampiev, K., Vlaev, I., & Karabeliova, S. (2025). Predicting pro-environmental behavior: The leading influence of environmental attitudes. *Behavioral Sciences*, *15*(3), 291.

Huang, Y.-J., Lee, P.-H., Hsieh, S.-H., Chiu, Y.-C., & Chan, T.-C. (2024). Understanding factors influencing adoption of air pollution protective measures using the knowledge-attitude-behavior model. *Scientific Reports*, *14*(1), 28414.

Ismail, R. R., Halos, S. H., & Al-Abudi, B. Q. (2025). Detection of the most frequent sources of dust storms in iraq during 2020–2023 using space tools. *Kuwait Journal of Science*, *52*(1), 100328.

Jasim, F. H. (2018). Meteorological analysis of severe dust storm over middle east. *Al-Mustansiriyah Journal of Science*, *29*(2), 1–9.

Jasim, S. A., Mohammadi, M. J., Patra, I., Jalil, A. T., Taherian, M., Abdullaeva, U. Y., et al. (2024). The effect of microorganisms (bacteria and fungi) in dust storm on human health. *Reviews on Environmental Health*, *39*(1), 65–75.

Javadian, M., Behrangi, A., & Sorooshian, A. (2019). Impact of drought on dust storms: Case study over southwest iran. *Environmental Research Letters*, *14*(12), 124029.

Jish Prakash, P., Stenchikov, G., Kalenderski, S., Osipov, S., & Bangalath, H. (2015). The impact of dust storms on the arabian peninsula and the red sea. *Atmospheric Chemistry and Physics*, *15*(1), 199–222.

Johnson, N. M., Hoffmann, A. R., Behlen, J. C., Lau, C., Pendleton, D., Harvey, N., et al. (2021). Air pollution and children's health—a review of adverse effects associated with prenatal exposure from fine to ultrafine particulate matter. *Environmental Health and Preventive Medicine*, *26*(1), 72.

Junkermann, W., & Hacker, J. M. (2018). Ultrafine particles in the lower troposphere: Major sources, invisible plumes, and meteorological transport processes. *Bulletin of the American Meteorological Society*, *99*(12), 2587–2602.

Kalkstein, L., & Smoyer, K. (1993). The impact of climate change on human health: Some international implications. *Experientia*, *49*(11), 969–979.

Karami, S., Ghassabi, Z., & Rezazadeh, P. (2022). Investigating the mechanism of dust transferring from iraq to the north of alborz mountains in iran. *Journal of Air Pollution and Health*, *7*(4), 375–398.

Karami, S., Kaskaoutis, D. G., Pytharoulis, I., Sotiropoulou, R.-E. P., & Tagaris, E. (2024). Dust transport from north africa to the middle east: Synoptic patterns and numerical forecast. *Atmosphere*, *15*(5), 531.

Kim, K.-H., Kabir, E., & Kabir, S. (2015). A review on the human health impact of airborne particulate matter. *Environment International*, *74*, 136–143.

Lian, S., Zhou, L., Murphy, D. M., Froyd, K. D., Toon, O. B., & Yu, P. (2022). Global distribution of asian, middle eastern, and north african dust simulated by cesm1/carma. *Atmospheric Chemistry and Physics*, *22*(20), 13659–13676.

Mahmoudi, L., & Ikegaya, N. (2023). Identifying the distribution and frequency of dust storms in iran based on long-term observations from over 400 weather stations. *Sustainability*, *15*(16), 12294.

MalAmiri, N., Rashki, A., Al-Dousari, A., & Kaskaoutis, D. G. (2025). Socioeconomic and health impacts of dust storms in southwest iran. *Atmosphere*, *16*(2), 159.

Mukherjee, A., & Agrawal, M. (2017). A global perspective of fine particulate matter pollution and its health effects. In *Reviews of environmental contamination and toxicology, volume 244* (pp. 5–51).

Negah, S., Mesakatee, A.-H., Hajjam, S., & Kamali, A. (2016). Investigation of the atmospheric mesoscale circulation patterns and their simulation with wrf-chem model of the dust storm occurrence over the southern coast of the caspian sea. *Arabian Journal of Geosciences*, *9*, 1–17.

Odo, D. B., Yang, I. A., Dey, S., Hammer, M. S., van Donkelaar, A., Martin, R. V., et al. (2023). A cross-sectional analysis of ambient fine particulate matter ($pm_{2.5}$) exposure and haemoglobin levels in children aged under 5 years living in 36 countries. *Environmental Research*, *227*, 115734.

Sacks, J. D., Stanek, L. W., Luben, T. J., Johns, D. O., Buckley, B. J., Brown, J. S., & Ross, M. (2011). Particulate matter–induced health effects: Who is susceptible? *Environmental Health Perspectives*, *119*(4), 446–454.

Sankararaman, S. (2023). From fractals to networks: Exploring the complex interplay of pollutants and air quality index in new delhi. *The European Physical Journal Plus*, *138*(10), 951.

Shahkooeei, E., & Rahmani, T. (2019). Dust risk assessment in northwest of iran. *Spatial Planning*, *9*(2), 57–80.

Sissakian, V., Al-Ansari, N., & Knutsson, S. (2013). Sand and dust storm events in iraq. *Journal of Natural Science*, *5*(10), 1084–1094.

Taghizadeh, F., Mokhtarani, B., & Rahmanian, N. (2023). Air pollution in iran: The current status and potential solutions. *Environmental Monitoring and Assessment*, *195*(6), 737.

UN ESCAP. (2018). Sand and dust storms in asia and the pacific: Opportunities for regional cooperation and action.

van Zandwijk, N., Marshall, H. M., & Fong, K. M. (2023). Lung cancer: Removing toxic dust from our environment. *Respirology*, *28*(6).

Vergadi, E., Rouva, G., Angeli, M., & Galanakis, E. (2022). Infectious diseases associated with desert dust outbreaks: A systematic review. *International Journal of Environmental Research and Public Health*, *19*(11), 6907.

Wang, J. X. (2015). Mapping the global dust storm records: Review of dust data sources in supporting modeling/climate study. *Current Pollution Reports*, *1*, 82–94.

Wang, R., Li, Q., Wang, R., Chang, C., Guo, Z., Li, J., & Zhou, N. (2021). Influence of wind velocity and soil size distribution on emitted dust size distribution: A wind tunnel study. *Journal of Geophysical Research: Atmospheres*, *126*(7), e2020JD033768.

Zhang, L., Ou, C., Magana-Arachchi, D., Vithanage, M., Vanka, K. S., Palanisami, T., et al. (2021). Indoor particulate matter in urban households: Sources, pathways, characteristics, health effects, and exposure mitigation. *International Journal of Environmental Research and Public Health*, *18*(21), 11055.

Zhang, W., Ma, R., Wang, Y., Jiang, N., Zhang, Y., & Li, T. (2022). The relationship between particulate matter and lung function of children: A systematic review and meta-analysis. *Environmental Pollution*, *309*, 119735.

Ziapour, A., Kianipour, N., & Nikbakht, M. (2013). The sociological analysis of the environment and the people's behavior towards it in rural and urban areas in kermanshah. *Environmental Education and Sustainable Development*, *1*(2), 55–67.