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Mitigation strategies of healthcare centers for dust hazard: A systematic review

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Abstract:

Exposure to dust can disrupt healthcare services and severely affect all activity domains of the health system. This study aimed to present an overview of mitigation strategies taken in healthcare centers during dust storms. A systematic review was conducted in November 2022 according to the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines. The keywords "Desert Dust," "Sand Storm," "Yellow Dust," "Yellow Sand," "Dust Storm," "Haboob," "Saharan Dust," "Risk," "Risk Management," "Risk Assessment," "Risk Reduction," "Risk Governance," "Risk Evaluation," "Mitigate," "Mitigated," "Mitigates," "Mitigating," "Mitigation*," "Mitigative," "Mitigator*," and "Mitigation strategy" were used in combination with Boolean operators OR and AND. ISI Web of Science, PubMed, Scopus, Scientific Information Database, Islamic World Science Citation Center, Magiran, Cochrane, and Google Scholar search engine were searched. The study was performed based on the PRISMA guidelines. The quality of the articles was assessed using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist. A total of 601 documents were extracted and 10 articles including one case–control study, one cross sectional study, and eight retrospective studies that investigated the mitigation strategies taken in healthcare centers when exposed to dust storms were selected for the final analysis. A review of the selected articles showed that the most important mitigation measures by healthcare centers include risk assessment, establishment and improvement of the early warning system, and inter sectoral coordination between private and public sectors. The findings showed that adopting effective strategies and measures to reduce vulnerability to dust storms can help health policymakers and planners contribute to promoting the resilience of healthcare centers so that they can continue providing their services and reduce the economic, social, health, and functional consequences in the affected community.

Keywords:

Dust, hazard, healthcare centers, mitigation, sand

Introduction

Disasters are sudden and unexpected events that lead to loss of life and health, environmental damage, destruction or loss of property and assets, and adverse effects on the social and economic structures of a region or country.[1] According to the United Nations Office for Disaster Risk Reduction (UNDRR), between 1998 and 2017, geophysical and climatic disasters killed 1.3 million people and left 4.4 billion people injured, homeless, displaced, or in need of emergency assistance, and economic damage worth $2908 billion. Most of the casualties were caused by earthquakes and tsunamis, and 91% of all these disasters were caused by floods, storms, droughts, heat waves, and other severe weather events.[2]

More than 90% of the total number of injured people and 50% of the financial and life losses of natural disasters are related to the Asian continent. Besides, Iran, due

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to its climatic and geographical location, is one of the most high-risk countries in the world in terms of the occurrence of accidents and disasters. One of the natural hazards is dust, which is defined by the World Meteorological Organization (WMO) as the effects of surface winds that bring a large amount of dust into the air and reduce eye-level visibility (1.8 meters) to less than 1000 meters.[3] Dust storms are also divided into four categories based on horizontal visibility: weak dust with a visibility of less than 10 km, moderate dust with a visibility of 1 to 10 km, severe storms with a visibility of 200 to 1000 meters, and very severe storms with visibility of less than 200 meters.[4-6] Sand and dust storms (SDS) are one of the major hazards in dry areas.[5,7] They contain small particles with allergenic and polluting properties.[6,8-10] Depending on the source of the dust, these particles include minerals, organic substances, and pathogenic microorganisms,[11-13] in which elements, such as aluminum, iron, potassium, magnesium, sulfur, phosphorus, sodium, manganese, barium, zinc, nickel, lead, chromium, and cobalt,[14,15] and sometimes wide range of anthropogenic pollutants and salts are found.[16] According to the U.S. Environmental Protection Agency, particles less than or equal to 10 microns are respirable. Particles less than 2.5 microns may enter the bloodstream with serious consequences and can cause asthma, pneumonia, aspergillosis, and allergic rhinitis in the respiratory system.[17]

Air pollution caused by dust storms has been one of the most important environmental and health problems in recent years. According to the World Health Organization (WHO), Iranian cities are among the 24 most polluted cities in the world with the highest average annual PM10 concentration.[18] Thus, this phenomenon has always had health, economic, and social consequences in the affected areas. One of the most important effects of dust storms is their immediate and long-term impacts. The immediate effects include immediate human health problems (e.g., respiratory problems and mortality; annual and permanent product damage) and infrastructure damage (e.g., their construction, electrical, and telecommunication structures), while long-term effects include human health problems (e.g., bronchitis, cardiovascular, and other disorders), the deposition of heavy metals and salts, and precipitation changes.[19]

According to the report of The United Nations Environment Programme (UNEP), the cost of asthma caused by dust in Australia is estimated at 10 to $50 million per year, and dust and sandstorms caused a loss of $6 billion to the economy of China in 2003.[12] Jeong[20] (2008) evaluated the socioeconomic costs of yellow dust in South Korea and showed that dust and sandstorms in South Korea imposed transportation, health, and welfare costs amounting to $5600 million. Edward *et al*. (2019) assessed the risk of dust storms in the gas and oil industry in Kuwait and showed that dust storms have led to a loss of $824,311 to oil export and air flights in Kuwait from 2001 to 2014.[17] Moreover, Houthuijs *et al*.[21] (2001) showed that particles smaller than 2.5 microns seriously affect health and increase death caused by respiratory, cardiovascular, and lung cancer diseases. Besides, long-term exposure to these particles causes a 6% increase in mortality for every 10 micrograms increase in concentration per cubic meter. The same amount of increase in particle concentrations will increase cardiovascular diseases by 12% and lung cancer by 14%. Dust storms have always had health, economic, and social consequences in the affected provinces in Iran. Thus, during dust storms, the number of lung patients admitted to healthcare centers in Ahvaz has increased by 70%. Moreover, dust damage to summer vegetables and products, corn, and wheat has been predicted to range from 15% to 20%. In addition, the damage caused by unfavorable health conditions and the closure of schools, airports, and offices have been estimated at more than 4 thousand billion Tomans per year.[14] Khaniabadi *et al*.[22] (2017) investigated the effects of SDS on human health in Ilam and showed that there is a direct relationship between the excess number of hospitalizations for chronic obstructive pulmonary disease (COPD) and the number of excess respiratory deaths. Following the prevention, preparedness, response, and recovery (PPRR) approach, the basic disaster management steps to improve the effectiveness of health response in disasters involve the prevention and mitigation of effects, preparedness, response, and recovery.[23,24] The damage prevention and mitigation stage is one of the important stages of disaster management, where some measures are taken to reduce the harmful effects of disasters. Besides, the vulnerability of the community to risks is assessed and the necessary corrective measures are taken before any disaster.[25] The measures taken at this stage are divided into structural, non-structural, and functional measures.[26] Given the unpredictable and uncertain nature of disasters, if they are not managed effectively, they will have much more severe destructive economic, social, environmental, and infrastructural consequences.[27] The health system (also known as the healthcare system) is the organization of people and resources that provide health and care services to meet the needs of the target population. The main goal of this system is to promote, restore, and maintain public health through the continuous provision of healthcare services.[28] Healthcare centers play a central role in providing health services to the community. The geographical expansion of healthcare centers throughout the country and the easy access of people to services even in remote and less privileged areas, which are more exposed to the risk of dust as indicated in the literature, are one of the main advantages

of these centers. Thus, maintaining these centers to provide services to the community affected by dust storm hazard is essential. Furthermore, in the absence of effective disaster risk management plans and strategies, the occurrence of various hazards, including dust, can cause many structural, non-structural, and functional challenges in these centers, disrupting all activity domains of the health system because the occurrence of such hazards leads to an increase in emergency medical dispatches due to respiratory problems, an increase in hospitalizations and admissions of cardiovascular and respiratory patients, and an increase in daily visits, leading to an increase in the workload in healthcare centers.[29] Dust hazards may also lead to significant economic losses to the health system. As a case in point, these losses are estimated to be USD 66 million in Zabol, Iran, and USD 306 million in Iraq.[30] As no systematic and comprehensive study has addressed mitigation strategies taken in healthcare centers, this study aims to investigate the latest mitigation strategies taken by healthcare centers before the occurrence of dust hazards.

Moreover, our investigations indicated that the healthcare centers do not have any comprehensive dust hazard mitigation plans and strategies. As a result, the strategies identified in this study can be effective in developing mitigation plans. Besides, if managers of health systems consider the significance of planning as a competitive advantage, they can enhance the resilience of these systems against various hazards, including dust.

Materials and Methods

This study was a systematic review of publications relating to mitigation strategies taken in healthcare centers during sandstorms. The study was performed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[31]

Search strategy

This study was conducted in November 2022 and reviewed English papers published in the field of mitigation strategies adopted by healthcare centers during dust storms. For this purpose, we searched ISI Web of Science, PubMed, Scopus, SID, ISC, Magiran, and Cochrane databases. Besides, the Google Scholar search engine was used for manual searching from January 1, 2000, to November 1, 2022. The search keywords included "Model *"OR "framework * "OR "theory *" OR "pattern * "OR "organize*" OR "structure * "OR "guide *" OR "plan *" OR "program *" OR "science *" OR "outline "OR "map "OR "diagram "OR "perspective" OR "illustration " OR "platform " OR "database" OR "chart*" AND "Risk" OR "Risk Management" OR "Risk Assessment" OR "Risk Reduction" OR "Risk Governance" OR "Risk Evaluation" OR "Mitigate" OR "Mitigated" OR "Mitigates" OR "Mitigating" OR "Mitigation*" OR "Mitigative" OR "Mitigator*" OR "Mitigation strategy". AND "Healthcare System" OR "Health System" OR "Healthcare Centers" OR "Health Services" OR "Hospital*" OR "Emergency Medical Service*" OR "Emergency Medical System" OR "Health Center" OR "Community Health" OR "Health Facility* OR "Primary Care Center" OR "Primary Healthcare Center" OR "Rural Health" OR "Urban Health" OR "Outpatient Clinic" OR "Ambulatory Health Center AND "Desert Dust" OR "Sand Storm" OR "Yellow Dust" OR "Yellow Sand" OR "Dust Storm" OR "Haboob" OR "Saharan Dust" Using OR and AND. Keywords were combined and written in the search box of databases. All synonyms of the keywords were included using MeSH strategies. For example, the PubMed search strategy is provided in Table 1.

Selection of articles and documents

EndNote was used to manage retrieved articles. The duplicate articles were identified and removed after entering all the articles into the software. Then, two raters screened the remaining articles by reviewing their titles, abstracts, and keywords based on the inclusion and exclusion criteria. After removing the irrelevant articles, the full text of the remaining articles was evaluated separately by two raters. Any inter-rater disagreement was resolved by a third rater.

Quality assessment

The quality of the article was assessed using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist. The checklist contains 22 items. The items with a Yes response are scored 1 and those answered No or Not Specified are scored 0.[32]

Inclusion criteria

All articles whose full text was available and used

Table 1: Search strategy in PubMed database

Databases	Search Strategy
PubMed	"desert dust" OR "sand storm" OR "sandstorm" OR "yellow dust" OR "yellow sand" OR "dust storm" OR "Haboob" OR "Saharan dust"AND"risk"[MeSH Terms] OR "risk"[All Fields] OR "Risk Management"[All Fields] OR "Risk Assessment"[All Fields] OR "Risk Reduction"[All Fields] OR "Risk Governance"[All Fields] OR "Risk Evaluation"[All Fields] OR "mitigate"[All Fields] OR "mitigated"[All Fields] OR "mitigates"[All Fields] OR "mitigating"[All Fields] OR "mitigation"[All Fields] OR "mitigations"[All Fields] OR "mitigative"[All Fields] OR "mitigator"[All Fields] OR "mitigators"[All Fields] AND" Model *"[tiab] OR" framework *"[tiab] OR "theory *" [tiab] OR "pattern *" [tiab] OR" organize*" [tiab] OR "structure *" [tiab] OR "guide *" [tiab] OR" plan *"[tiab] OR" program *" [tiab] OR"science *""[tiab] OR "outline" [tiab] OR "map" [tiab] OR" diagram" [tiab] OR "perspective" [tiab] OR "illustration" [tiab] OR "platform" [tiab] OR "database"[tiab] OR" chart*" [tiab]

well-structured methods and data, and addressed mitigation strategies adopted in healthcare centers were included in this study.

Exclusion criteria

The articles published in any language other than English and Persian, letters to the editor, review studies, case reports, conference articles, and studies that had not addressed healthcare were excluded.

Data extraction

A total of 601 records were retrieved from the mentioned databases. In the next step, duplicate articles were removed and the number of articles was reduced to 527 articles. Using systematic screening, the titles related to mitigation strategies taken by healthcare centers in the dust hazard were reviewed and 109 articles were selected. In the next step, the abstracts of the articles were reviewed and 44 articles were selected for a full review. In this step, 69 articles were removed. Afterward, all the selected articles were reviewed in detail, and then, only 10 articles including one case–control study, one cross-sectional study, and eight retrospective studies that addressed the mitigation strategies taken in healthcare centers during dust storms were selected for the final analysis. Figure 1 shows the search strategy and selection of articles according to the PRISMA guidelines.

Results

Demographics

The results showed that 20% of the articles addressed healthcare centers,[33,34] 50% of the articles studied hospitals,[22,35-38] 10% of the articles addressed the health sector,[39] and 20% of the articles[40,41] indirectly assessed health effects of dust storms, such as the increased number of hospitalizations, admissions, deaths, especially in vulnerable groups (older adults, children, and people with underlying diseases), physical and functional effects on healthcare facilities and personnel, and mitigation strategies. The studies were mainly conducted in Asian countries including Iran,[22,34,35,37,41] China,[40] Kuwait,[33] Australia,[36] Greece,[39] and Taiwan.[38]

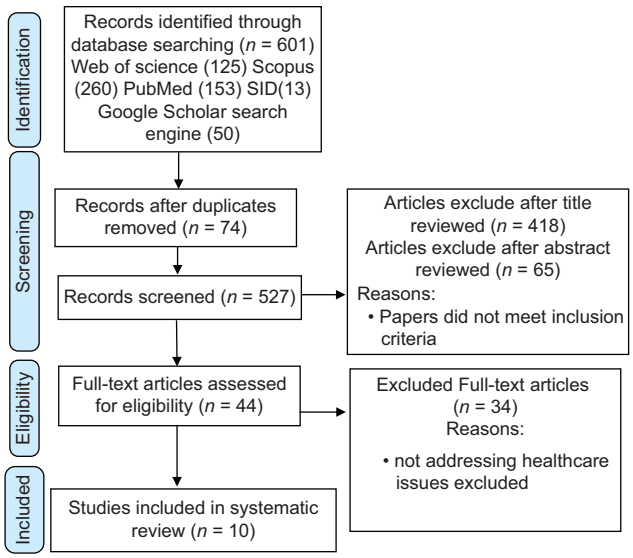

Figure 1: Flow diagram showing a selection of articles reviewed

Main results

A review of the selected articles showed that the most important mitigation measures taken in healthcare centers can be divided into intra-organizational and extra-organizational measures. The intra-organizational measures involve regular and periodical hazard and vulnerability assessments of health facilities, establishment, and improvement of the early warning system, inter-sectoral coordination between private and public sectors, retrofitting primary health centers (PHCs) to improve their resilience, organizing and holding training courses to increase the risk perceptions of managers and employees, using proper ventilation, and using suitable personal protective equipment (PPE). Furthermore, the main extra-organizational measures involve the allocation of financial resources by relevant organizations to prevent or reduce the effects of dust, implementing green infrastructure, improving water management, mulching, and improving the ability to make forecasts.

Data analysis revealed that 20% of the articles addressed dust risk assessment and risk and vulnerability monitoring,[34,40] 50% of articles focused on establishing and upgrading the early warning system,[33,36,38-40] 10% of the articles discussed inter-sectoral coordination in the private and public sectors,[33] 10% of the studies highlighted the need for retrofitting of PHCs to improve resilience,[34] 20% of the studies referred to holding training courses to increase managers' and employees' perceptions of risk,[37,41] 20% of the studies recommended proper ventilation,[36,41] 10% pointed to the use of effective PPE,[41] 10% highlighted the allocation of financial resources by relevant organizations,[34] 30% of the studies focused on the implementation of green infrastructure,[22,35,37] 20% of the articles emphasized the improvement of water management,[22,35] 10% of the articles addressed the need for mulching,[35] and 10% of the articles discussed improving the ability to make predictions.[39]

According to the results of this study, the most important intra-organizational measures to mitigation of healthcare centers against dust include the following: conducting regular risk and vulnerability assessments, retrofitting primary healthcare centers to improve their resilience considering the lower cost compared to hospitals, implementation of early warning system, being in

indoor spaces with air conditioning, and design and implementation of training programs both in public and through mass media, and the most important extra-organizational measures to mitigation of healthcare centers against dust include the following: increasing the green space, improving the ability of countries to make predictions and observations of SDS in time and with high quality, mulching, managing water resources, risk communication, and implementing appropriate monitoring measures to deal with air pollution.[34,36,39-41]

Moreover, the summaries of each paper related to mitigation strategies taken in healthcare centers during dust storms are shown in Table 2. Studies quality assessment in this study showed quality of the articles varied from 16 to 19 as shown in Table 3.

Discussion

In this study, the most high-ranking scientific databases were searched to find articles and studies addressing measures to reduce the health effects of dust storms.

Depending on their origin and pathways, sand and SDS may transport heavy metals and chemical residues including fertilizers, pesticides, herbicides, dioxins, toxic hydrocarbons, radionuclide pollutants, and radioactive isotopes.

Fine dust particles, bacteria, pollen, and fungi carried by SDS also have significant harmful effects on human health. Airborne substances can be inhaled and cause serious respiratory disorders if they accumulate in the respiratory system.[42-45]

The results showed that risk assessment before the occurrence of dust storms using two risk and vulnerability indicators and the inclusion of risk assessment and vulnerability indicators of healthcare centers in the national health information system can play a vital role in reducing the effects of dust storms.[34,40] Reducing the impact of SDS requires a systematic assessment of them as a hazard and source of impacts to develop a clearer and more evidence-based understanding of these phenomena on local to global scales. Such assessments can provide knowledge to effectively mitigate the negative impacts of this hazard on human life and health.[46]

Various studies have assessed different tools for mitigating dust hazards, including satellite images, evaluation of the Farsi Hospital Safety Index (FHSI), and models to evaluate the health impacts of these risks, such as AirQ and generalized additive model (GAM).[30,47,48] Constant monitoring of the formation and transmission of particles through data obtained from satellites and meteorological stations to predict and issue early warnings through SMS alerts or national and local media plays a very effective role in reducing the impacts of dust storms[36,39,40] as indicated in other studies in the literature[29,30,49] Thus, developing an SDS forecasting and warning system can help people prone to asthma take preventive measures to reduce exposure to this phenomenon. Moreover, the application of this policy will contribute to reducing medical expenses, especially for the population at risk (preschool children, middle-aged people, and older adults).[38]

The relevant authorities should evaluate the most effective means of disseminating warnings to the public including media coverage, websites, messaging through social media, and smartphone apps. Besides, defining the target population, identifying vulnerable populations that could be particularly affected by SDS, and providing other facilities and infrastructure that may be required for such events are important messages, and warnings commonly issued by authorities include the following: staying indoors (necessary in many circumstances), avoiding exposure exercise, following asthma programs (for asthma patients), driving carefully, and seeing a doctor in case of respiratory or cardiovascular symptoms.[50,51]

This systematic review study also indicated cooperation between organizations in the public and private sectors, such as the Department of Environment, industries, and the transportation sector, can lead to the effective use of existing capacities, increasing adaptability, and reducing health impacts of climate change.[33]

Various studies have suggested that inter-sectoral cooperation in organizations, such as the Department of Environment, Agriculture Jihad Organization, Natural Resource Organization, Department of Education, and Department of Meteorology, can be effective in managing dust storms as they can be indirectly controlled by measures, such as mulching, creating green spaces, training, planting native plants, sustainable land management, natural resource restoration, forecasting, and timely warning.[48,50,52,53]

Besides, the retrofitting of primary healthcare centers due to their lower cost compared to hospitals can lead to the improvement of resilience and eventually reduce the consequences of various natural hazards.[34] Various studies have suggested the use of double-glazed windows as an important measure to adapt to dust episodes and the use of the WHO guidelines for resilient healthcare facilities as an adaptation and mitigation strategy against climate change consequences.[49,52] This study showed that holding public educational programs and awareness-raising through mass media can play a positive role in promoting risk perception in the

Table 2: Summary of papers related to mitigation strategies taken in healthcare centers during dust storms

Title	Author(s)	Methodology	Setting	Location	Structure	Main concepts
A 2-year assessment of particulate air pollution and sources in Kuwait.[33]	Barrak Alahmad *et al*.[33]	Cross-sectional	Two populated residential locations in Kuwait City and Ali Sabah Al-Salem	Kuwait	Extra-organizational	Extra-organizational measures to reduce the vulnerability of health centers to air pollution: —Awareness-raising and monitoring measures to cope with air pollution —Developing national and regional mitigation strategies to comply with air quality standards —Formulating annual standards by the Department of Environment for PM 2.5 (25 mg/m3), PM10 (50 mg/m3), and related interventions —Secondary prevention strategies, such as keeping houses tight during dust storms —Human resource interventions —Setting stricter traffic and industrial standards —Local measures, such as using better fuels for cars, complying with traffic regulations, and preparing industrial emissions lists —Regional measures and cooperation in line with local measures to reduce air pollution and its health effects —Having an air sampling program and updating it to improve air quality —Regular monitoring of air quality
Impacts of Natural Hazards on Primary Health Care Facilities of Iran: A 10-Year Retrospective Survey.[34]	Ardalan *et al*.[34]	A retrospective survey	Primary health centers (PHCs)	Iran	Intra-organizational	Intra-organizational measures to reduce damage to primary healthcare centers in natural hazards —Creating an Iranian health system registry to monitor the impact of natural hazards on health facilities, policymaking, planning, and resource allocation —Conducting regular risk and vulnerability assessments —Strengthening mitigation measures and preparedness —Creating facilities for healthcare centers considering their vital role in disasters —Retrofitting PHCs to improve their resilience due to the lower cost compared to hospitals —Developing a plan to integrate disaster risk reduction into the PHC network —Forming a strategic committee to deal with the physical vulnerability of primary healthcare facilities —Requiring all centers to have an insurance plan —Assessment of risks and vulnerability of centers —Analyzing the costs and benefits of retrofitting vulnerable centers —Applying comprehensive standards to reduce the effects of disasters in the construction of new facilities —Developing emergency hazard plans, especially for floods and dust/sandstorms —Incorporating risk assessment and vulnerability indicators of PHCs into the national health information system

Contd...

Table 2: Contd...

Title	Author(s)	Methodology	Setting	Location	Structure	Main concepts
Influences of socioeconomic vulnerability and intra-urban air pollution exposure on short-term mortality during extreme dust events.[40]	Hung Chak Ho *et al*.[40]	A retrospective survey	Census and Statistics Department	Hong Kong	Intra- and extra-organizational	Internal and external measures to reduce health damage caused by dust hazards: —Identifying vulnerable areas, vulnerable people, and populations at risk and prioritizing this group in disaster risk programs —Formulating health protocols —Implementing an early warning system —Risk assessment to develop a mitigation protocol —Establishing a comprehensive assessment mechanism to assess the consequences of extreme dust events —Considering the socioeconomic situation at the individual level for disaster risk management —Transferring knowledge by prioritizing vulnerable people, such as older adults and people with poor socioeconomic status —Developing social networks and social awareness systems for disaster risk management
Impact of Middle Eastern dust storms on human health.[22]	Omidi Khaniabadi *et al*.[22]	A retrospective survey	Hospitals	Iran	Intra- and extra-organizational	—Water resource management —Planting new plant species —Implementing green infrastructure in urban areas —Reducing daily activities in dusty areas for vulnerable people, such as older adults, children, and people with underlying diseases
Hospital admissions in Iran for cardiovascular and respiratory diseases attributed to the Middle Eastern dust storms.[35]	Omidi Khaniabadi *et al*.[35]	A retrospective survey	Hospitals	Iran	Intra- and extra-organizational	—Developing a green belt on the borders between countries —Water resource management —Providing health advice, especially for vulnerable people —Mulching —Washing the streets —Planting plants to trap airborne contaminants
Health effects of the September 2009 dust storm in Sydney, Australia: did emergency department visits and hospital admissions increase.[36]	Merrifield *et al*.[36]	A retrospective survey	Hospitals	Sydney	Intra-organizational	Intra-organizational measures to reduce the damages caused by dust hazards in healthcare centers —Performing public health measures, including issuing warnings, and prioritizing patients with underlying conditions, especially asthma patients —Health warnings —Media coverage on health effects and measures to reduce damage caused by dust storms —Staying in air-conditioned buildings —Not doing outdoor sports —Regular use of medicines by asthma patients and following asthma programs —Sending warning messages via SMS and news media to the subscribers of the Environment Department and the Air Quality Warning website and other stakeholders

Contd...

Table 2: Contd...

Title	Author(s)	Methodology	Setting	Location	Structure	Main concepts
Multi-sectoral impact assessment of an extreme African dust episode in the Eastern Mediterranean in March 2018.[39]	Alexandra Monteiro.[39]	A retrospective survey	The health sector	Crete, Greece	Intra- and extra-organizational	Intra- and extra-organizational measures to reduce the harmful effects of dust on health —Predicting peak respiratory emergencies in hospitals based on accurate operational dust predictions —Developing an early warning system to raise public awareness —Applying and developing effective strategies to reduce environmental and health damage —Cleaning solar panels —Empowering countries to make timely and high-quality SDS forecasts and observations —Warning through local and national media —Preventing traffic and performing tough activities and sports in open spaces, especially for people with breathing, heart, kidney problems, immune system problems, or vulnerable groups, such as children or older adults over 65 years —Applying strict restrictions in schools on student outdoor activities —Developing an action plan to improve air quality —Risk communication to the public —Staying in air-conditioned indoor spaces —Providing adequate medication to asthma patients —Using solar panels in national or regional power grids —Using sensors to accurately measure dust and airborne particles
Estimation of PM10 pollutant and its effect on total mortality (TM), hospitalizations due to cardiovascular diseases (HACD), and respiratory disease (HARD) outcomes.[37]	Tahery *et al*.[37]	A retrospective survey	Hospitals	Ahvaz and Bishkek, Kyrgyzstan	Intra- and extra-organizational	Intra- and extra-organizational measures to reduce damage to healthcare centers during air pollution: —Taking legal measures to prevent the cutting of trees and the destruction of pastures —Public awareness-raising activities —Development of public transportation —Improving fuel quality —Monitoring air pollutants —Developing clean energy —Extending green spaces
The threat of Asian dust storms on asthma patients: A population-based study in Taiwan.[38]	Wang *et al*.[38]	A retrospective survey	Hospitals	Taiwan	Intra-organizational	Intra-organizational measures taken in healthcare centers during dust storms: —Developing a forecasting and warning system with a focus on the population at risk (preschool children, middle-aged people, and older adults) —Avoiding outdoor activities, especially in the first 3 or 4 days of the dust episode with a focus on the populations at risk
The effect of education based on the health belief model on the consistency of protective behaviors against dust pollution in teachers.[41]	Ashrafi Hafez *et al*.[41]	Case–control	Primary schools for girls	Ahvaz	Intra-organizational	Intra-organizational measures to reduce health damage due to dust hazards: —Organizing and holding training programs both publicly and through mass media —Reducing the time of outdoor activities —Avoiding tough physical activity —Using air-conditioning systems —Avoiding outdoor exercises and sports —Covering food —Using standard masking on dusty days

Table 3: Quality of the reviewed articles using the STROBE checklist

Article	1	2	3	4	5	6	7	8	9	10
Title and abstract	*	*	*	*	*	*	*	*	*	*
Introduction										
Background/rationale	*	*	*	*	*	*	*	*	*	*
Objectives	*	*	-	*	*	*	*	*	*	*
Methods										
Study design	*	*	*	*	*	*	*	*	*	*
Setting	*	*	*	*	*	*	*	*	*	*
Participants	-	-	*	*	-	*	-	-	-	*
Variables	*	*	*	*	*	*	*	*	*	*
Data sources/measurement	*	*	*	*	*	*	*	*	*	*
Bias	*	*	-	-	-	-	-	-	-	-
Study size	*	*	*	*	-	*	*	*	*	*
Quantitative variables	*	*	*	*	*	*	*	*	*	*
Statistical methods	*	*	*	*	*	*	*	*	*	*
Results										
Participants	-	-	*	-	*	*	-	*	*	*
Descriptive data	-	-	*	-	-	-	-	-	*	*
Outcome data	*	*	*	*	*	*	*	*	*	*
Main results	*	*	*	*	*	*	*	*	*	*
Other analyses	*	*	-	-	*	-	-	-	-	-
Discussion										
Key results	*	*	*	*	*	*	*	*	*	*
Limitations	*	*	*	-	-	-	*	*	*	*
Interpretation	*	*	*	*	*	*	*	*	*	*
Generalizability	*	*	*	*	*	*	*	*	*	*
Other information										
Funding	-	*	*	-	-	-	*	*	-	-
STROBE grade	18	19	19	16	16	17	17	18	18	19

community and contribute to mitigating the negative effects of dust episodes.[41]

Educating at-risk people about SDS not only improves the capacity to response after receiving an alert but also improves the level of individual and social preparedness for SDS. This preparedness is important when SDS threats are imminent, but it can also lead to those at risk taking additional actions before an alert is issued or received, to reduce the actual impact of SDS.[54] Previous studies have also reported that holding training courses and workshops, awareness raising through social media, conferences, mass media, and distributing educational brochures can alert people and promote the preparedness of health systems in response to the risk of dust storms.[30,47,53] Furthermore, the use of ventilation systems is another strategy highlighted in previous studies to reduce the vulnerability to dust storms because ventilation systems that are capable of filtering dust particles prevent fine dust particles from entering space. Additionally, mitigating measures, such as installing air filtration systems or early warning systems, can reduce the impact on the affected area and ensure that members of high-risk populations stay indoors.[55] According to Salehi (2021), staying in covered and air-conditioned spaces improves people's resilience during dust storms.[53] In addition, the characteristics of the building, that is, the degree of its sealing and whether it has an air transmission system, and if so, what are its characteristics or the air cleaning system for dust particles and gases, are very important because the central air transfer/conditioning system can be effective in removing particles and protecting against dust particles.[56] The use of effective PPE is a low-cost and easy protective behavior and can reduce the number of visits to healthcare centers during dust hazards. Various studies reported that the use of N95 filtering facepiece respirators or wet handkerchiefs and towels (if such respirators are not available) are important measures to adapt to dust hazards.[30,53] Such equipment can lead to the protection of public health against the adverse effects of air pollution, eliminating or reducing exposure to those pollutants that are known or likely to be dangerous.[51] Furthermore, allocating financial resources for retrofitting and constructing health centers following comprehensive disaster risk management standards and creating facilities are other extra-organizational measures to reduce the effects of dust. Various studies reported that allocating research funds and providing financial and technical resources by the government to predict and control dust centers and combat desertification can lead to adaptation to climate change and reduce its effects.[30,47] The implementation of green infrastructure, such as strengthening vegetation, designing and implementing forestry projects, developing green spaces, and creating green belts, can play a role in reducing the risk of dust storms.[22,35,37,39] Studies have pointed to creating green roofs and walls, protecting forests to control dust centers, and planting perennial trees resistant to heat and cold as strategies to adapt to climate change.[49,53] Planting resistant grasses, shrubs, or trees, especially species resistant to harsh climatic conditions, is considered a preventive measure. Such plants can contribute to reducing wind speed, trapping dust particles, and protecting against sand movement.[53,57,58] Effective water management is another important measure to reduce the effects of dust storms. Studies have confirmed a direct relationship between water resource management, controlling dust centers, reducing the frequency of dust storms, maintaining soil moisture, and reducing soil erosion.[22,35] Studies have also shown that the link and relationship between the public health sector and other sectors, such as water and sewage, agriculture, forestry, crisis management, environment, media, natural resources, and watershed management organizations, and protection of water resources in areas prone to increasing water stress can lead to adaptation to climate change.[49,53] According to the data in this study, mulching of dust centers, including oil and biological mulching, plays an important role in stabilizing quicksand and controlling dust centers, contributing to mitigating the

adverse effects of dust storms.[35] It also reduces the time of emptying the soil during the cropping season and leads to the stability and resistance of the soil against separation and erosion.[59,60] Toure *et al*.[61] (2011) also showed that mulching can play a role in controlling soil erosion and thus reducing the frequency of dust storms, as confirmed in this study. Observations of dust transport and concentration in the atmosphere are very important for early warning and risk mitigation in various health, transportation, education, and industrial sectors.[46] If SDS data are collected in real-time and the necessary warnings are issued based on the collected data, the necessary plans can be formulated to reduce the effects of SDS before their incidence.

Making accurate forecasts of respiratory emergencies in hospitals with a focus on the population at risk (preschool children, middle-aged people, and older adults) is another important mitigation as was confirmed in this study.[39]

Various studies reported that accurate operational dust forecasts using new and modern technologies, such as geographic information system (GIS), remote sensing, and satellite technologies (LiDAR networks and radiometers), equipping meteorological stations for more accurate forecasts, and global cooperation with the United Nations and WMO to transfer modern technologies to predict the occurrence of decision support system (DSS), can contribute to reducing the effects of dust storms and improve the preparedness of systems against dust hazards.[30,50,52,62]

Limitations

One of the limitations of this study was the unavailability of the full text of some articles. Thus, we retrieved these articles by contacting their corresponding authors. The lack of a study on structural mitigation of healthcare centers in dust hazards was another limitation of this study.

Conclusion

This systematic review presented a detailed and comprehensive review of mitigation strategies that are adopted in comprehensive health centers. To the best of the researchers' knowledge, this is the first study to investigate mitigation strategies adopted in healthcare centers during dust hazards. A review of previous studies showed that the most important mitigation measures adopted by healthcare centers during dust hazards include risk assessments, establishment, and improvement of an early warning system, inter-sectoral coordination between private and public sectors, retrofitting PHCs to improve their resilience, holding training courses to increase the risk perceptions of managers and employees, using proper ventilation, using effective PPE as the main intra-organizational measures, and allocation of financial resources by relevant organizations to prevent or reduce the effects of dust, implementing green infrastructure, improving water management, mulching, and improving the ability to make forecasts as the extra-organizational measures. The geographical expansion of health centers throughout the country and the easy access of people to services even in remote and less privileged areas are one of the main advantages of these centers. Thus, maintaining these centers to provide services to the community affected by dust storms is essential. Thus, adopting effective strategies and measures to reduce people's vulnerability to dust storms can minimize various structural, non-structural, and functional challenges faced by healthcare centers. Furthermore, the adoption of such strategies can help health policymakers and planners contribute to promoting the resilience of comprehensive health centers so that they can continue providing their services and reduce the economic, social, health, and functional consequences of dust storms in the affected community.

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Ethics approval and consent to participate

The Ethics Committee of the Kerman University of Medical Sciences approved this study. A cross-sectional design was employed in 2021. The research code was 401000295, and the code of ethics was IR.KMU.REC.1401.260. All procedures were performed following the relevant guidelines and regulations.

Availability of data and materials

The data sets generated during this study are available from the corresponding author.

Author contributions

HF conceived the concept and design of the study. KB conducted the survey, and AT was involved in data analysis and manuscript writing. MA supervised the study and critically reviewed the manuscript. All the authors read and reviewed the final manuscript.

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Conflicts of interest

There are no conflicts of interest.

References

1. Srivastava K. Disaster: Challenges and perspectives. Ind Psychiatry J 2010;19:1.
2. United Nations Office for Disaster Risk Reduction, Global

assessment report on disaster risk reduction. Geneva; 2009.
3. McTainsh G, Pitblado J. Dust storms and related phenomena measured from meteorological records in Australia. Earth Surf Processes Landforms 1987;12:415-24.
4. Kaskaoutis D, Kosmopoulos P, Kambezidis H, Nastos P. Aerosol climatology and discrimination of different types over Athens, Greece, based on MODIS data. Atmosp Environ 2007;41:7315-29.
5. Shao Y, Wyrwoll K-H, Chappell A, Huang J, Lin Z, McTainsh GH, *et al*. Dust cycle: An emerging core theme in Earth system science. Aeolian Res 2011;2:181-204.
6. Crooks JL, Cascio WE, Percy MS, Reyes J, Neas LM, Hilborn ED. The association between dust storms and daily non-accidental mortality in the United States, 1993–2005. Environ Health Perspect 2016;124:1735-43.
7. Maleki S, Miri A, Rahdari V, Dragovich D. A method to select sites for sand and dust storm source mitigation: Case study in the Sistan region of southeast Iran. J Environ Plann Manag 2021;64:2192-213.
8. Vodonos A, Friger M, Katra I, Krasnov H, Zahger D, Schwartz J, *et al*. Individual effect modifiers of dust exposure effect on cardiovascular morbidity. PLoS One 2015;10:e0137714.
9. Almeida-Silva M, Almeida SM, Freitas M, Pio C, Nunes T, Cardoso J. Impact of Sahara dust transport on cape verde atmospheric element particles. J Toxicol Environ Health A 2013;76:240-51.
10. Ardon-Dryer K, Mock C, Reyes J, Lahav G. The effect of dust storm particles on single human lung cancer cells. Environ Res 2020;181:108891. doi: 10.1016/j.envres. 2019.108891.
11. Daryanoosh M, Goudarzi G, Rashidi R, Keishams F, Hopke PK, Mohammadi MJ, *et al*. Risk of morbidity attributed to ambient PM10 in the western cities of Iran. Toxin Rev 2018;37:313-8.
12. Momtazan M, Geravandi S, Rastegarimehr B, Valipour A, Ranjbarzadeh A, Yari AR, *et al*. An investigation of particulate matter and relevant cardiovascular risks in Abadan and Khorramshahr in 2014–2016. Toxin Rev 2018;38. doi: 10.1080/15569543.2018.1463266.
13. Morovati P, Valipour A, Geravandi S, Karimyan A, Behrooz HRA, Mohammadi MJ. Association of air quality index related to criteria air pollutants in Abadan, Iran. Fresenius Environ Bull 2018;27:4023-8.
14. Middleton N, Tozer P, Tozer B. Sand and dust storms: Underrated natural hazards. Disasters 2019;43:390-409.
15. Krueger BJ, Grassian VH, Cowin JP, Laskin A. Heterogeneous chemistry of individual mineral dust particles from different dust source regions: The importance of particle mineralogy. Atmos Environ 2004;38:6253-61.
16. Middleton N. A geography of dust storms in South‐west Asia. J Climatol 1986;6:183-96.
17. Derbyshire E. Natural minerogenic dust and human health. AMBIO 2007;36:73-7.
18. Goudie AS. Desert dust and human health disorders. Environ Int 2014;63:101-13.
19. Shepherd G, Terradellas E, Baklanov A, Kang U, Sprigg W, Nickovic S, *et al*. Global assessment of sand and dust storms. Published by the United Nations Environment Programme (UNEP) Nairobi, Kenya. 2016. p. 139.
20. Jeong D-Y. Socio-economic costs from yellow dust damages in South Korea. Korean Soc Sci J 2008;35:1-29.
21. Houthuijs D, Breugelmans O, Hoek G, Vaskövi E, Miháliková E, Pastuszka JS, *et al*. PM10 and PM2. 5 concentrations in Central and Eastern Europe: Results from the Cesar study. Atmospheric Environ 2001;35:2757-71.
22. Khaniabadi YO, Daryanoosh SM, Amrane A, Polosa R, Hopke PK, Goudarzi G, *et al*. Impact of Middle Eastern dust storms on human health. Atmos Pollut Res 2017;8:606-13.
23. Tabesh P, Vera DM. Top managers' improvisational decision-making in crisis: A paradox perspective. Management Decision. 2020;58:2235-56.
24. Schipper L, Pelling M. Disaster risk, climate change and international development: Scope for, and challenges to, integration. Disasters 2006;30:19-38.
25. Hessam S, Yazdanpanah A. Factors affecting disaster management: Hospitals of Hormozgan province. J Health Admin 2018;20:52-67.
26. Khademipour GH, Sheikhbardsiri H. Disaster risk assessment of primary healthcare facilities in South East of Iran: A study with approach of disaster risk reduction. Disaster and Emergency Medicine Journal 2022;7:11-20.
27. Hetu SN, Gupta S, Vu V-A, Tan G. A simulation framework for crisis management: Design and use. Simul Model Pract Theory 2018;85:15-32.
28. Frenk J. The global health system: Strengthening national health systems as the next step for global progress. PLoS Med 2010;7:e1000089. doi: 10.1371/journal.pmed.1000089.
29. Aghababaeian H, Ostadtaghizadeh A, Ardalan A, Asgary A, Akbary M, Yekaninejad MS, *et al*. Global health impacts of dust storms: A systematic review. Environ Health Insights 2021;15:11786302211018390. doi: 10.1177/11786302211018390.
30. Allahbakhshi K, Khorasani-Zavareh D, Jazani RK, Ghomian Z. Preparedness components of health systems in the Eastern Mediterranean region for effective responses to dust and sand storms: A systematic review. F1000Res 2019;8:146. doi: 10.12688/f1000research.17543.1.
31. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al*. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. Int J Surg 2021;88:105906. doi: 10.1016/j.ijsu.2021.105906.
32. Da Costa BR, Cevallos M, Altman DG, Rutjes AW, Egger M. Uses and misuses of the STROBE statement: Bibliographic study. BMJ Open 2011;1:e000048. doi: 10.1136/bmjopen-2010-000048.
33. Alahmad B, Al-Hemoud A, Kang C-M, Almarri F, Kommula V, Wolfson JM, *et al*. A two-year assessment of particulate air pollution and sources in Kuwait. Environ Pollut 2021;282:117016. doi: 10.1016/j.envpol.2021.117016.
34. Ardalan A, Mowafi H, Homa Yousefi K. Impacts of natural hazards on primary health care facilities of Iran: A 10-year retrospective survey. PLoS Curr 2013;5. doi: 10.1371/currents.dis.ccdbd870f5d1697e4edee5eda12c5ae6.
35. Khaniabadi YO, Fanelli R, De Marco A, Daryanoosh SM, Kloog I, Hopke PK, *et al*. Hospital admissions in Iran for cardiovascular and respiratory diseases attributed to the Middle Eastern Dust storms. Environ Sci Pollut Res 2017;24:16860-8.
36. Merrifield A, Schindeler S, Jalaludin B, Smith W. Health effects of the September 2009 dust storm in Sydney, Australia: Did emergency department visits and hospital admissions increase? Environ Health 2013;12:1-7.
37. Tahery N, Geravandi S, Goudarzi G, Shahriyari HA, Jalali S, Mohammadi MJ. Estimation of PM 10 pollutant and its effect on total mortality (TM), hospitalizations due to cardiovascular diseases (HACD), and respiratory disease (HARD) outcome. Environ Sci Pollut Res 2021;28:22123-30.
38. Wang C-H, Chen C-S, Lin C-L. The threat of Asian dust storms on asthma patients: A population-based study in Taiwan. Global Public Health 2014;9:1040-52.
39. Monteiro A, Basart S, Kazadzis S, Votsis A, Gkikas A, Vandenbussche S, *et al*. Multi-sectoral impact assessment of an extreme African dust episode in the Eastern Mediterranean in March 2018. Sci Total Environ 2022;843:156861. doi: 10.1016/j.scitotenv.2022.156861.
40. Ho HC, Wong MS, Yang L, Chan T-C, Bilal M. Influences of socioeconomic vulnerability and intra-urban air pollution exposure on short-term mortality during extreme dust events. Environ Pollut 2018;235:155-62.
41. Ashrafi Hafez A, Ramezankhani A, Doostifar K, Motesaddi Zarandi S, Marashi T, Ghanbari S, *et al*. The effect

of education based on health belief model on maintenance of protective behaviors in teachers exposed to dust air pollution. J Health Care 2015;17:116-27.
42. Deroubaix A, Martiny N, Chiapello I, Marticorena B. Suitability of OMI aerosol index to reflect mineral dust surface conditions: Preliminary application for studying the link with meningitis epidemics in the Sahel. Remote Sens Environ 2013;133:116-27.
43. Middleton NJ. Desert dust hazards: A global review. Aeolian Res 2017;24:53-63.
44. Sprigg WA. Dust storms, human health and a global early warning system. Extreme Weather, Health, and Communities: Interdisciplinary Engagement Strategies. Springer: California State University Northridge; 2016. p. 59-87.
45. Péwé TL, American Association for the Advancement of Science. Desert Dust: Origin, Characteristics, and Effect on Man. Geological Society of America INC; Colorado: 1981.
46. Wang W, He S, Guo H, Abuduwaili J, Samat A, De Maeyer P, *et al*. Sand and Dust Storm Risk Assessment in Arid Central Asia: Implications for the Environment, Society, and Agriculture. International Journal of Disaster Risk Science 2024;15:703-18.
47. Ekhtesasi M, Sepehr A. Investigation of wind erosion process for estimation, prevention, and control of DSS in Yazd–Ardakan plain. Environ Monit Assess 2009;159:267-80.
48. Liu X, Li N, Xie W, Wu J, Zhang P, Ji Z. The return periods and risk assessment of severe dust storms in Inner Mongolia with consideration of the main contributing factors. Environ Monit Assess 2012;184:5471-85.
49. Bikomeye JC, Rublee CS, Beyer KM. Positive externalities of climate change mitigation and adaptation for human health: A review and conceptual framework for public health research. Int J Environ Res Public Health 2021;18:2481. doi: 10.3390/ijerph18052481.
50. Middleton N, Kang U. Sand and dust storms: Impact mitigation. Sustainability 2017;9:1053.
51. Yoo W. How risk communication via Facebook and Twitter shapes behavioral intentions: The case of fine dust pollution in South Korea. Journal of Health Communication 2019;24:663-73.
52. Salehi S, Ardalan A, Ostadtaghizadeh A, Garmaroudi G, Zareiyan A, Rahimiforoushani A. Conceptual definition and framework of climate change and dust storm adaptation: A qualitative study. J Environ Health Sci Eng 2019;17:797-810.
53. Salehi S, Ardalan A, Ostadtaghizadeh A, Zareiyan A, Garmaroudi G, Rahimiforoushani A. Strategies and experiences for sand and dust storm adaptation: A qualitative study in Iran. J Environ Health Sci Eng 2021;19:1753-63.
54. Middleton N, Kang U. Sand and dust storms: Impact mitigation. Sustainability 2017;9:1053.
55. Middleton N, Al-Hemoud A. Sand and Dust Storms: Recent Developments in Impact Mitigation. Sustainability. 2024;16:7121.
56. WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. ISBN 978-92-4-003422-8 (electronic version). Available from: https://iris.who.int/bitstream/handle/10665/345329/9789240034228-eng.pdf?sequence=1&,2023. [Last accessed on 2023 Oct 02].
57. Wegner G, Pascual U. Cost-benefit analysis in the context of ecosystem services for human well-being: A multidisciplinary critique. Global Environ Change 2011;21:492-504.
58. Al-Hemoud A, Al-Dousari A, Misak R, Al-Sudairawi M, Naseeb A, Al-Dashti H, *et al*. Economic impact and risk assessment of sand and dust storms (SDS) on the oil and gas industry in Kuwait. Sustainability 2019;11:200.
59. Biazin B, Sterk G, Temesgen M, Abdulkedir A, Stroosnijder L. Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa–a review. Phys Chem Earth Part A/B/C, 47 2012. p. 139-51.
60. Schwilch G, Liniger HP, Hurni H. Sustainable land management (SLM) practices in drylands: How do they address desertification threats? Environ Manag 2014;54:983-1004.
61. Toure AA, Rajot JL, Garba Z, Marticorena B, Petit C, Sebag D. Impact of very low crop residues cover on wind erosion in the Sahel. Catena 2011;85:205-14.
62. Fatemi F, Moslehi S, Ardalan A. Preparedness functions in disaster: Lesson learned from Tehran dust storm 2014. Nat Hazards 2015;77:177-9.