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REVIEW ARTICLE

Sand and Dust Storms as an Emerging Ambient Air Quality Threat to Population Health in Central Asia: A Communal Hygiene Perspective

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Abstract

Sand and dust storms (SDS) are increasingly recognized as a major source of ambient particulate matter and a public health threat in arid and semi-arid regions, including Central Asia, where the desiccation of the Aral Sea has created the new Aralkum desert. This structured narrative analytical review synthesized evidence on the exposure burden, health effects, and preventive management of SDS from a communal hygiene perspective. Searches were designed for PubMed/MEDLINE, Web of Science, Scopus, and Google Scholar, supplemented by WHO, WMO, UNCCD, and World Bank sources. Priority was given to systematic reviews, meta-analyses, multicenter studies, and authoritative reports published from 2020 to 2026, while earlier landmark studies from the Aral Sea region were retained. According to WMO, SDS affect about 330 million people in more than 150 countries, and 3.8 billion people were exposed to dust levels exceeding the WHO threshold in 2018–2022. A 2025 meta-analysis of 71 studies found that dust days were associated with increased all-cause mortality (RR 1.0121), cardiovascular mortality (RR 1.0252), and respiratory morbidity (RR 1.0693). In the Aral Sea region, airborne dust is mixed with salts and agrochemical residues, yet local epidemiological evidence remains limited and inconsistent. The review indicates that effective prevention requires integrated air quality monitoring, early warning systems, protection of vulnerable groups, indoor exposure reduction, and landscape restoration of dust source areas.

Keywords: *sand and dust storms, ambient air pollution, particulate matter, PM10, communal hygiene, Aral Sea, Central Asia, mortality, early warning, prevention.*

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Introduction

Ambient air quality is one of the central objects of communal hygiene, and particulate matter is the air pollutant with the most extensive evidence of adverse health effects. In addition to anthropogenic combustion sources, a substantial share of airborne particles in arid and semi-arid regions originates from wind erosion of soils and dry lake beds. Sand and dust storms (SDS) are meteorological hazards that lift large quantities of mineral particles into the atmosphere and transport them over hundreds and even thousands of kilometers, affecting both source regions and distant receptor areas [1–3].

According to the WMO Airborne Dust Bulletin, about 2 billion tonnes of dust enter the atmosphere every year, and SDS affect about 330 million people in more than 150 countries. A sand and dust storm indicator developed by WMO and WHO showed that 3.8 billion people, nearly half of the world population, were exposed to dust levels exceeding the WHO threshold in 2018–2022, a 31% increase compared with 2.9 billion people in 2003–2007 [1]. During SDS events, particulate matter concentrations may exceed 10 000 μg/m³ close to sources and 1000 μg/m³ in receptor areas, whereas evidence on long-term health effects remains scarce [3]. In recognition of this problem, the United Nations General Assembly proclaimed 2025–2034 the United Nations Decade on Combating Sand and Dust Storms, noting that SDS threaten the achievement of 11 of the 17 Sustainable Development Goals [15].

Central Asia is one of the regions where this problem has acquired particular significance. The desiccation of the Aral Sea since the 1960s has created the Aralkum, a new desert of about 60 000 km², almost half of which is located in the Republic of Karakalpakstan. According to a World Bank study, SDS from the

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Aralkum carry 15 to 75 million tonnes of sand, dust, and salt every year across Uzbekistan and neighboring countries [12]. Unlike natural desert dust, this dust is mixed with salts and residues of agricultural pesticides and fertilizers that accumulated on the former sea bed [7, 8].

The objective of this review was to synthesize recent evidence on the exposure burden and health effects of sand and dust storms, to analyze available data from the Aral Sea region, and to integrate monitoring, early warning, and protective measures into a practical communal hygiene model for Central Asian conditions.

Materials and Methods

This study was designed as a structured narrative analytical review rather than an empirical statistical study or a formal meta-analysis. Searches were designed for PubMed/MEDLINE, Web of Science, Scopus, and Google Scholar, with supplementary searches of the World Health Organization (WHO), World Meteorological Organization (WMO), United Nations Convention to Combat Desertification (UNCCD), United Nations Development Programme (UNDP), and World Bank resources. The core search period emphasized publications from January 2020 through October 2026, while earlier landmark studies from the Aral Sea region were retained because they provide the only available local epidemiological evidence.

The search strategy combined free-text concepts related to dust exposure and health outcomes. Representative terms included: (sand and dust storm OR desert dust OR dust event OR Aral Sea OR Aralkum) AND (mortality OR morbidity OR cardiovascular OR respiratory OR children OR health) AND (particulate matter OR PM10 OR PM2.5 OR air quality) AND (prevention OR early warning OR monitoring OR mitigation). Additional searches addressed dust composition, pesticides and salinity in the Aral Sea region, air quality guidelines, and individual protective measures.

Eligible sources were peer-reviewed systematic reviews, meta-analyses, multicenter time-series studies, field studies from the Aral Sea region, atmospheric modeling studies, and authoritative guidance and reports of international organizations directly relevant to SDS exposure, health effects, or prevention. Sources were excluded when they lacked relevance to human health or to the communal hygiene aspects of air quality. Reference lists of key reviews were also checked for relevant publications.

Because this article is a narrative analytical review, PRISMA was used as a methodological reference for transparency of search and selection principles, but the study is not presented as a PRISMA-compliant systematic review or meta-analysis. No pooled effect size was calculated and no new participant-level data were analyzed. Quantitative estimates are reported as presented by the original authors, with the study period, region, and unit of measurement indicated.

Results

The most comprehensive recent synthesis is a systematic review and meta-analysis conducted for the WHO Global Air Pollution and Health Technical Advisory Group. It included 71 studies with time-series data from 1993 to 2024, most of them on Asian dust from the Gobi and Taklamakan deserts (n = 33) and on Saharan dust (n = 24). Compared with non-dust days, dust days were associated with increased all-cause mortality (RR 1.0121; 95% CI 1.0045–1.0199), cardiovascular mortality (RR 1.0252; 95% CI 1.0100–1.0407), cardiovascular morbidity (RR 1.0094; 95% CI 1.0014–1.0174), and respiratory morbidity (RR 1.0693; 95% CI 1.0188–1.1224), whereas the association with respiratory mortality was not statistically significant (RR 1.0001; 95% CI 0.9773–1.0277) [5].

A nationwide multicenter time-series study in China analyzed 1 495 724 deaths and 2024 SDS events in 2013–2018. SDS were associated with increased mortality from a spectrum of circulatory and respiratory causes and showed significant added effects on ischemic stroke, chronic lower respiratory disease, and chronic obstructive pulmonary disease mortality [6]. A Lancet Planetary Health viewpoint reported that 150 countries are directly affected by SDS, more than 100 of them being non-source regions, and identified research on long-term exposure and on populations in source regions as key priorities [4].

In Central Asia, atmospheric modeling showed that simulated dust emissions from the Aralkum region increased from 14.3 to 27.1 Tg per year between the 1980s and the 2010s, an increase driven solely by

changes in surface water. The dry lake bed added about 7% more dust over Central Asia, and over two-thirds of Aralkum emissions occurred under overcast skies, which limits satellite observation. In a one-year case study (2015–2016), Tashkent and Ashgabat were the major cities most affected by Aralkum dust, with dust levels exceeding WHO recommendations for 2–3 days per year [7].

Field studies have documented specific hazards of Aral dust. Dust deposition rates in eastern Turkmenistan were found to be among the highest in the world, and the dust was contaminated with pesticides [8]. A recent study in Karakalpakstan assessed organochlorine pesticides and salinity as environmental health risks associated with the Aral Sea crisis [11]. The World Bank estimated that SDS from the Aralkum cause economic damage to Karakalpakstan of more than 44 million US dollars per year (about 2% of the region's GDP), and that properly planned landscape restoration could significantly reduce air pollution at a distance of up to 100–200 km from the former coastline [12]. In 2025, UNDP and Uzbekistan completed a large-scale study on combating dust storms in the Southern Aral Sea region [16].

Local epidemiological evidence remains limited. In a survey of children aged 7–10 years in 18 communities of six regions in the Aral Sea area, no association was found between local annual dust deposition and respiratory symptoms, although high dust exposure during summer may have had an adverse effect on lung function [9]. A systematic review of children's health in the Aral Sea area concluded that links between persistent organic pollutant exposure and body burdens are clear, whereas no clear evidence for a link between dust exposure and respiratory function was identified [10].

WHO global air quality guidelines recommend that the 24-hour mean PM10 concentration should not exceed 45 μg/m³ and the annual mean 15 μg/m³ [13]. WHO notes that current government responses to SDS rely largely on knowledge of short-term health effects and on limited early warning systems [2]. At the individual level, the American Heart Association statement on personal protective actions describes portable air cleaners with HEPA filters and reduction of outdoor exertion during pollution peaks as practical measures for susceptible persons [14].

Discussion

The evidence indicates that SDS are not merely a meteorological nuisance but a recognized determinant of population health. The recent meta-analysis demonstrates consistent short-term increases in all-cause and cardiovascular mortality and in respiratory morbidity on dust days [5], and the Chinese multicenter study confirms that these effects extend to specific causes of death, including ischemic stroke and chronic obstructive pulmonary disease [6]. At the same time, the non-significant association with respiratory mortality and the heterogeneity of studies show that the health effects of dust may depend on particle composition, size distribution, and the characteristics of exposed populations.

This consideration is particularly important for Central Asia. Most pooled evidence comes from Asian and Saharan dust, whereas Aral dust differs in being mixed with salts and agrochemical residues [7, 8, 11]. The available studies from the Aral Sea region are few, mostly older, cross-sectional, and did not demonstrate a clear dust–respiratory association [9, 10]. Therefore, the risk for the population of Karakalpakstan and other parts of Uzbekistan cannot be directly extrapolated from international estimates, and in our search we did not identify time-series studies of dust-related mortality in Uzbekistan. Modeling data showing that Tashkent is among the cities affected by Aralkum dust [7] indicate that the problem extends beyond the immediate Aral Sea zone.

From a communal hygiene perspective, these findings support a multilevel preventive model. At the population level, it includes expansion of continuous PM10 and PM2.5 monitoring, especially in Karakalpakstan and Khorezm; integration of national monitoring with WMO dust forecasting and early warning systems; and timely public alerts during dust events. At the settlement level, it includes urban greening, protective forest belts, and landscape restoration of the Aralkum as source control [12]. At the household and institutional level, it includes keeping windows closed during dust events, using air cleaners with HEPA filters in homes, schools, and medical facilities, reducing outdoor physical activity of children, elderly people, and patients with cardiopulmonary diseases, and protecting drinking water and food from dust

deposition [13, 14].

The principal methodological limitation is that this article is a structured narrative review rather than a full systematic review with duplicate independent screening, formal risk-of-bias assessment, and quantitative meta-analysis. The search strategy and eligibility criteria were made explicit to improve reproducibility. Future research in Uzbekistan should include time-series and case-crossover studies linking daily PM10 and dust events with mortality and hospital admissions, chemical characterization of Aral dust, and evaluation of the effectiveness of early warning and protective measures.

Conclusion

Sand and dust storms are an emerging ambient air quality threat that affects hundreds of millions of people worldwide and is associated with increased all-cause and cardiovascular mortality and respiratory morbidity. In Central Asia, the Aralkum has become a significant anthropogenic dust source whose particles are mixed with salts and agrochemical residues, while local epidemiological evidence remains insufficient.

The most appropriate preventive framework is a comprehensive communal hygiene system: monitor particulate matter and dust events, warn the population in advance, reduce indoor and outdoor exposure of vulnerable groups, and control dust at its sources through landscape restoration and greening. This approach is consistent with current WHO and WMO guidance and the goals of the United Nations Decade on Combating Sand and Dust Storms, and it provides a practical basis for protecting population health in Uzbekistan.

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