

Extreme desert dust storms and COPD morbidity on the island of Crete

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Introduction and objectives: Short-term extreme increases in desert-derived particulate-matter with aerodynamic diameter below 10 μm (PM_{10}) may affect emergency department (ED) visits due to COPD exacerbations.

Research question: Our aim was to identify the effect of extreme increases in desert-derived PM_{10} on ED visits for dyspnea and COPD exacerbations and on the related hospital admissions.

Methods: We performed a retrospective analysis of dyspnea-related ED visits and hospital admissions in Heraklion, Crete, during four consecutive storms of desert-derived PM_{10} that happened during March 2018. We collected data from over 17,000 ED visits and recorded patients with atopic symptoms, COPD exacerbations, and dyspnea, as well as admissions to the departments of pulmonary medicine, internal medicine, and cardiology. PM_{10} data were collected from a monitoring station in the same geographic area.

Results: Four desert dust storms were recorded during the study period with 238, 203, 1138, and 310 $\mu\text{g}/\text{m}^3$ average-daily PM_{10} and 652, 308, 4262, and 778 $\mu\text{g}/\text{m}^3$ hourly mean day-peak PM_{10} , respectively. There was no clinically important increase in total ED visits, total admissions or admissions to the departments of cardiology, pulmonary medicine, or internal medicine, during PM_{10} peaks. However, during the desert dust storm with daily-average PM_{10} above 500 $\mu\text{g}/\text{m}^3$, there was a striking increase in dyspnea-related ED visits (including COPD exacerbations, 3.6-fold increase), while there was no clinically important increase in non-asthma allergy-related ED visits.

Conclusion: Extreme desert dust storm episodes may cause meaningful increases in ED visits for dyspnea and COPD exacerbations/admissions.

Keywords: desert dust storms, emergency department overcrowding, particulate-matter, COPD

Plain language summary

Increased urban particulate-matter with aerodynamic diameter below 10 μm (PM_{10}) may compromise respiratory function in patients with preexisting respiratory diseases. Apart from urban PM_{10} , Southern Europe experiences desert dust PM_{10} storms due to climatic change. Previous studies have failed to show a significant impact of desert dust storms on emergency department visits for respiratory complaints. We describe the effect of a unique and extreme desert dust PM_{10} storm with daily average $\text{PM}_{10} > 1000 \mu\text{g}/\text{m}^3$ on emergency department overload, focusing on respiratory and especially COPD pathology, in the southernmost region of the European Union, the island of Crete. We conclude that while most desert dust storms do not affect COPD admissions, extreme desert dust storms with a threshold of PM_{10} above at least 500 $\mu\text{g}/\text{m}^3$ may indeed increase ED visits for dyspnea and COPD exacerbations/admissions.

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Introduction

Southern European areas frequently experience dust storms caused by certain, well characterized, meteorological conditions that promote transportation of particles from the adjacent Sahara desert. These desert particles consist of fine particulate-matter (PM) and are able to penetrate deep in the respiratory system. This is especially true regarding PM with an aerodynamic diameter of less than 10 μm , abbreviated as PM₁₀. PM₁₀ includes desert dust (crustal material), re-suspended dust (crustal and anthropogenic material), sea-salt, anthropogenic inorganic and organic components, and biogenic components.^{1–3} Although PM₁₀ is expected to compromise respiratory function, especially in patients with preexisting respiratory diseases,⁴ several previous studies failed to show a statistically significant impact of desert dust storms on emergency department (ED) visits for respiratory complaints.^{5,6} However, these studies focused mostly on urban areas that are characterized by high levels of human activity derived PM₁₀. Even when adjusting for non-desert PM₁₀, these studies reported relatively small increases in desert-derived PM₁₀ (<100 $\mu\text{g}/\text{m}^3$ increases compared to non-desert storm days). Less is known about the short-term effect of the extreme desert dust storms lasting several hours with PM₁₀ levels higher than 200 $\mu\text{g}/\text{m}^3$.

The aim of our study was to report the short-term effect of consecutive extreme increases in desert-originating PM, on ED visits for respiratory symptoms and acute exacerbation of COPD (AECOPD) in the Southmost point of Europe; the island of Crete.

Materials and methods

Study design, setting, and statistical analysis

This is a retrospective analysis of ED visits at the two hospitals located in the city of Heraklion in Crete, the University Hospital of Heraklion (PAGNI, 739 beds) and Venizelion Hospital (440 beds), from March 1st to March 31st, 2018. Both Hospitals cover the Municipality of Heraklion ($\geq 300,000$ inhabitants), with a rotating on-call system (every day one of the hospitals is on-call and the other one is on alert). The two hospitals are about 15 km apart and both have fully developed pulmonary medicine departments.

Population

All data regarding the number of ED visits were available for both hospitals, while administrative data from the University Hospital of Heraklion ED were also fully available. The number of patients visiting the ED for allergies (hives, angioedema, or anaphylactic shock), COPD exacerbations, dyspnea

unrelated to other well-documented causes (eg, pleural effusion, pneumonia, pulmonary embolism, heart disease, etc.) were recorded. Data regarding the number of admissions to the departments of internal medicine, pulmonary medicine, and cardiology, including admission diagnosis, from both hospitals, were also analyzed. The study design and execution were in compliance with the Declaration of Helsinki. Patient consent to review their medical records was not required by the University Hospital of Heraklion/Venizeleion Hospital Bioethics Committee since only administrative data were collected and patient data anonymity and confidentiality were guaranteed.

Statistical analysis

One-Way ANOVA and Pearson Correlation (PC) with Bonferroni correction for multiple comparisons were performed with IBM SPSS Statistics 21.0 (IBM, Armonk NY, USA)

PM₁₀ data collection

PM₁₀ data were collected and measured by an FH 62 I-R particulate monitor (Thermo TSM Anderson) continuously operating in Heraklion city center. PM₁₀ mass measurements are based on b-attenuation and are conducted in the range 0–10,000 $\mu\text{g}/\text{m}^3$ with a resolution of 1 $\mu\text{g}/\text{m}^3$. They are found in very good agreement with gravimetric measurements.¹

Results

Long-term monitoring of aerosols on Crete is based on PM₁₀ measurements (Figure 1). PM_{2.5} measurements are not available for the studied period. However, size-segregated PM observations performed over a period of 2 years

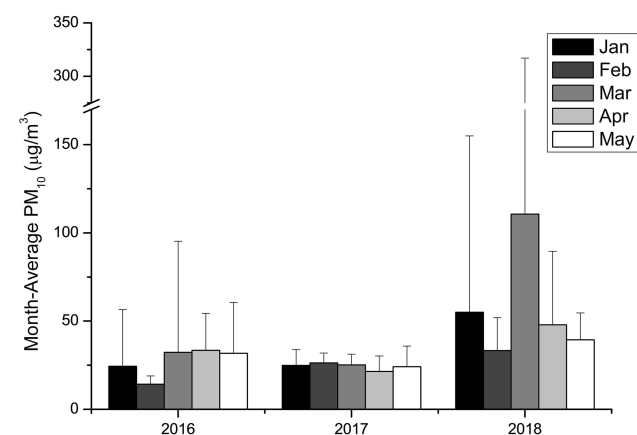


Figure 1 Monthly mean of PM₁₀ aerosols in Heraklion, Crete from January to May for the years 2016–2018. Values represent the monthly mean ($\mu\text{g}/\text{m}^3$) + standard deviation.

have shown a good correlation between PM_{10} and $PM_{2.5}$ measurements with $PM_{2.5}$ accounting on average for 60% of the PM_{10} mass.⁷ Dust storms were defined by PM_{10} levels above $100 \mu\text{g}/\text{m}^3$, a limit that has been previously used for Asian dust storms.^{8,9} We, therefore, used 24 hrs PM_{10} average concentration above $100 \mu\text{g}/\text{m}^3$, to characterize four desert dust storm episodes during the study period. These were between March 3rd and 5th, on March 7th, on March 22nd, and during March 26th-27th with top daily-average (hourly mean day-peak) PM_{10} values of 238 (652), 203 (308), 1138 (4262), and 310 (778) $\mu\text{g}/\text{m}^3$, respectively. The monthly and the non-peak days PM_{10} average were 112 and $24 \mu\text{g}/\text{m}^3$, respectively and were higher compared to previous years (Figure 2A).

Overall, there were 17,239 ED visits in both hospitals. During PM_{10} peaks we did not identify clinically important increases in the number of total ED visits, the number of all

hospital admissions or the number of admissions to the departments of cardiology, pulmonary medicine, or internal medicine (Figure 2B and C and Table 1).

In the extreme desert dust storm ($PM_{10} > 1000 \mu\text{g}/\text{m}^3$), there was a striking increase (a) in the number of patients presenting to the ED with dyspnea (including COPD exacerbations, 3.6 times vs other days), and (b) in admissions due to COPD exacerbation (4.2 times vs other days) (Figure 2D).

Using Pearson correlation coefficient with Bonferroni correction for multiple comparisons (Table 2) a significant correlation was observed between (a) PM_{10} concentrations and ED visits for dyspnea (Pearson Correlation 0.929, $p < 0.00001$), and (b) PM_{10} concentrations and admissions for COPD exacerbations and dyspnea (PC 0.813, $p < 0.0001$ and PC 0.718, $p < 0.001$) respectively. There was no significant increase in the number of patients visiting the ED for allergies. Regarding the rest of the environmental factors, temperature,

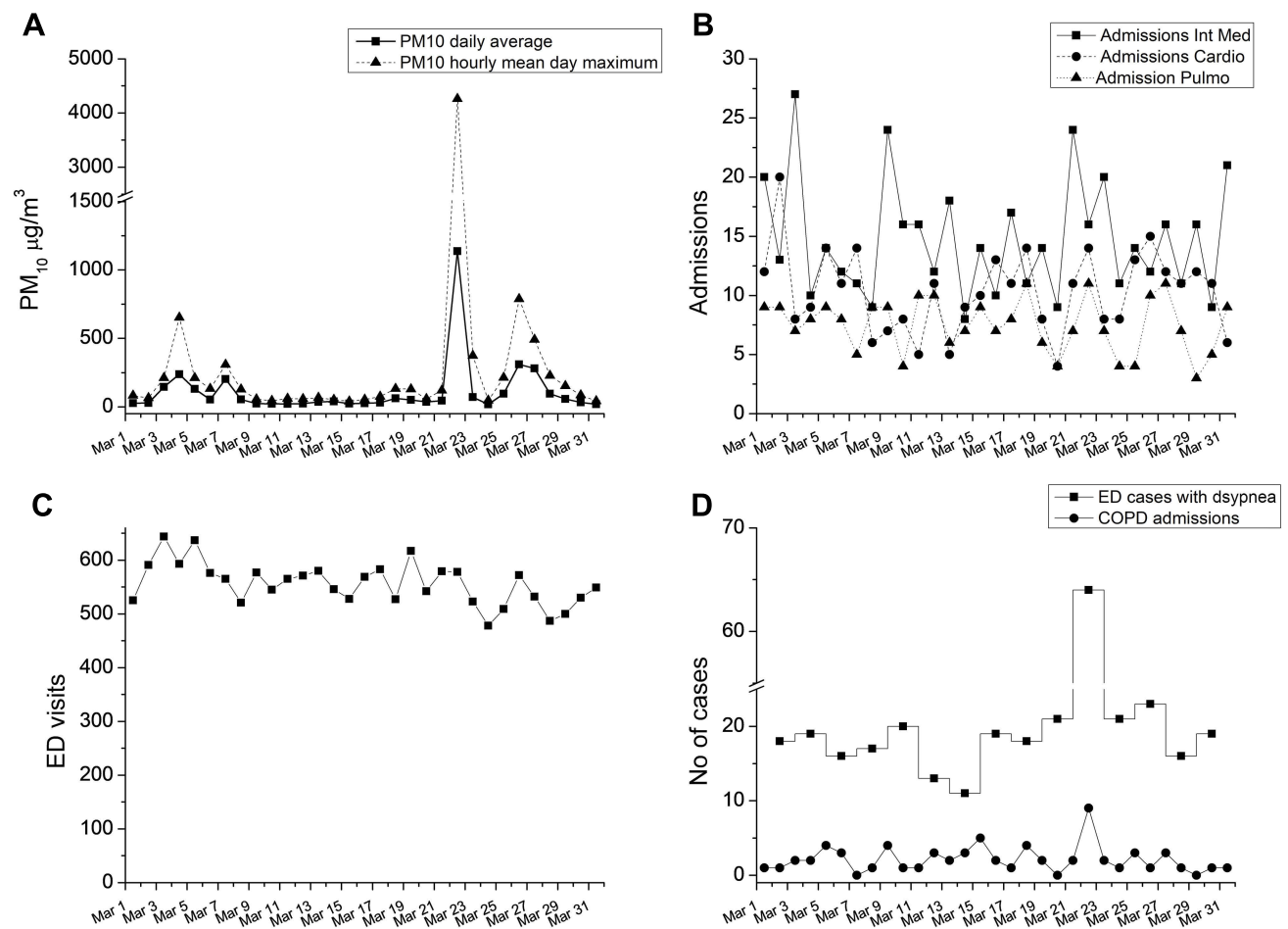


Figure 2 (A) Particulate matter with aerodynamic diameter below $10 \mu\text{m}$ (PM_{10}) daily average and hourly mean day maximum during March 2018 in the geographic area of Heraklion. (B) Admissions to the departments of internal medicine (Int Med), cardiology (Cardio) and pulmonary (Pulmo) medicine during March 2018. (C) Total emergency department (ED) visits in Heraklion during the study period. (D) ED cases with dyspnea and COPD admissions at the University Hospital of Heraklion during the study period. We did not identify any increases in the studied parameters the days ensuing a desert dust storm.

Table 1 Comparison of environmental and clinical information between days with and without desert dust storm. It is reasonable to have mostly southern winds during desert dust storms

Studied parameters (Average±95% CI)	Desert storm days (including March 22nd)	Non-desert storm days	P-value (One-way ANOVA)	Desert storm March 22nd
PM ₁₀ (µg/m ³)	309.5 (129.0–489.9)	29.5 (20.8–38.3)	0.011	1137.5
Temperature (°C)	13.2 (10.9–15.4)	12.0 (10.9–13.1)	NS	11.2
Humidity (%)	46.0 (39.0–53.1)	55.1 (51.3–59.0)	NS	44.8
Wind speed (m/s)	10.3 (0.0–25.1)	6.6 (4.8–8.5)	NS	2.8
Wind direction (azimuth degrees, North =0°)	174.9 (162.2–187.7)	269.4 (240.4–298.3)	3.7 × 10 ⁻⁴	187.9
ED cases	588.7 (559.1–618.3)	546.6 (532.6–560.6)	NS	578
ED Patients with dyspnea	30.0 (4.4–55.6)	14.8 (12.7–16.8)	NS	56
ED patients with allergies	12.0 (6.8–17.2)	9.5 (7.2–11.8)	NS	17
Pulmonary medicine admissions	8.7 (7.1–10.4)	7.1 (6.2–8.1)	NS	11
COPD admissions	3.0 (0.8–5.2)	1.9 (1.3–2.5)	NS	9
Internal Medicine admissions	15.1 (10.9–19.4)	14.5 (12.7–16.4)	NS	16
Dyspnea admissions(all)	9.3 (1.8–16.9)	4.4 (3.4–5.5)	NS	17
Cardiology admissions	12.3 (10.3–14.3)	9.8 (8.3–11.2)	NS	14

Table 2 Pearson correlation results for the parameters tested. Significant results after Bonferroni correction of p ($\leq 0.05/9=0.0056$) are presented in bold

Parameter studied	Pearson correlation coefficient	p-Value
ED cases	0.313	0.128
ED dyspnea cases	0.929	0.000
ED allergy cases	0.464	0.041
Admissions Pulmonary medicine Department (Dept)	0.467	0.040
Admissions Pulmonary medicine Dept for COPD exacerbation	0.813	0.000
Admissions Internal Medicine Dept	0.527	0.022
Admissions Internal Medicine Dept for dyspnea	0.718	0.001
Admissions Cardiology Dept	0.178	0.263
Admissions Internal Medicine and Pulmonary medicine Dept	0.634	0.006

wind speed, and humidity did not correlate with ED visits or COPD admissions and were not further examined as confounding factors. Wind direction, as expected correlated with clinical events since South wind direction is a prerequisite for the transfer of Sahara dust to the island of Crete.

Discussion

The main finding of this study was that only extreme desert dust storms seem to be related to increased ED visits and hospital admissions for dyspnea and COPD. However, even at extreme levels, they do not acutely affect the number of allergic or cardiovascular disease-related events. Although such extreme conditions are rare and currently difficult to predict, emergency physicians and pulmonary medicine specialists in Southern Europe should be aware of the expected high incidence of patients with respiratory compromise, when they occur. Dust storms with lower levels of PM₁₀ do

not seem to affect the workload of emergency medicine and pulmonary medicine departments.

Previous studies and meta-analysis on PM effects on health have focused mostly on pollution-related increases of PM₁₀.³ In studies that concentrated on desert dust storms, the reported outcomes are mostly mortality and hospitalizations,⁵ and the reported increases of PM₁₀ were much less compared to the phenomena experienced in Crete on March 2018. A previous study in Athens reported a higher incidence of ED visits for asthma, COPD and respiratory infections by 38%, 57%, and 60%, respectively, for daily PM₁₀ increases in the range of 36.5–78.5 µg/m³.⁶ However, in this study, the percentage of increases described are very small compared to the extreme event described in our report, while human-activity related PM₁₀ levels could be a significant confounding factor. Vodonos et al, have also reported a significant correlation between

desert dust storms and COPD exacerbations in Israel.⁴ In accordance with our study, a significant increase in ED respiratory disorders visits, and no effect on all causes hospital admissions, was reported in Sydney, Australia during September 2009 when peak dust storm PM₁₀ levels reached 11,000 µg/m³.¹⁰ However, in contrast to our results, they reported increases in all-cause ED visits. This difference may be attributed to the higher PM₁₀ levels in the Australian event.

Our research presents, to our best knowledge, the most extreme event of desert dust storm within Europe (for images visit <https://www.youtube.com/watch?v=O5gUvUK8FDM>). The comparison of the extreme dust storm of March 22nd with the other dust storms during that month, suggests for the first time, that there exists a threshold of daily-average PM₁₀ around (or above) 500 µg/m³. Above this level, Emergency Services should expect a clinically important increase in the number of patients presenting with respiratory compromise. However, more research is necessary in order to confirm this threshold. A limitation of our study is its short duration. We also did not identify any lag effect between the change of PM₁₀ and the measured effects. A more extended study covering more desert dust storms and a larger population would be more efficient in identifying such effects. However, the desert dust storms sequence during this small period provided us with a unique opportunity to study health effects without major influence from seasonal variations of ED visits and AECOPD due to infections, while the absence of a lag between the massive event on March 22nd and the measured clinical effects suggests that such high levels of desert dust derived PM₁₀ can induce acute (within hours) effects in COPD patients. Another limitation of our study is the use of the administrative data to define admission diagnosis, instead of a per-patient clinical analysis. However, it is unlikely to introduce a significant bias as the same approach was also used for the reference day's data.

Conclusion

Intense desert dust storms with a threshold of PM₁₀ above at least 500 µg/m³ may cause clinically important increases in ED visits for COPD exacerbations as well as COPD-related admissions. Climatic change may lead to an increased incidence of extreme desert dust storms in Southern Europe. Early identification or prediction of extreme desert dust storms will allow the prompt issue of health warnings for patients with COPD and other preexisting pulmonary diseases to avoid exposure to such irritating conditions and will allow EDs to

prepare for climaxes of dyspnea-related cases during these events.

Author contributions

All authors contributed towards data analysis, drafting and critically revising the paper, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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