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# QUANTIFYING THE EFFECTS OF DUST ON HEALTH IN KUWAIT & IRAQ

## AN EPIDEMIOLOGICAL STUDY

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**PART OF THE PROJECT:**

Improved Resilience to Sand and Dust Storm in Kuwait and Southern Iraq

UN-HABITAT

الصندوق الكويتي للتنمية
KUWAIT FUND FOR DEVELOPMENT

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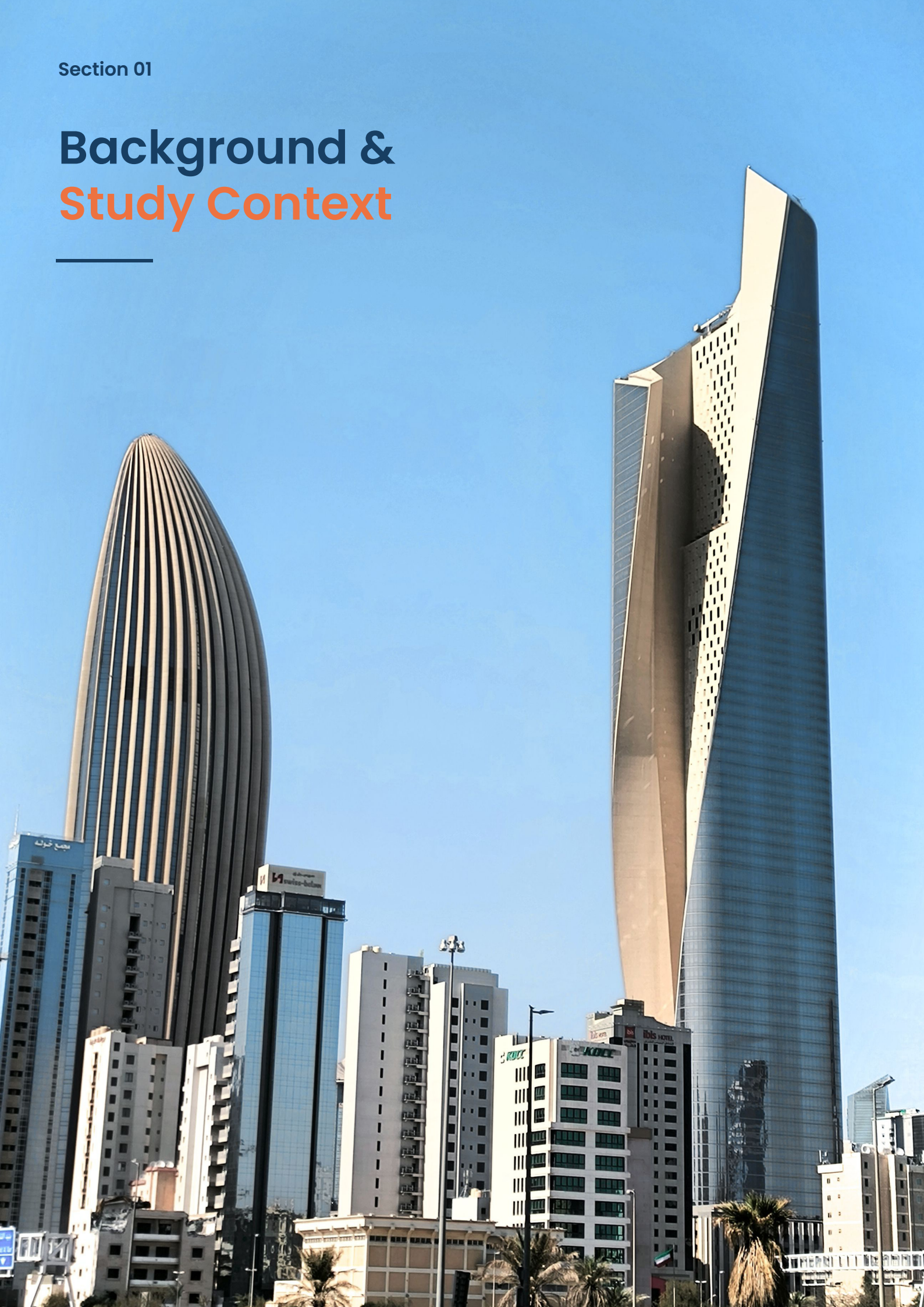
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Section 01

# Background & Study Context



# Executive Summary

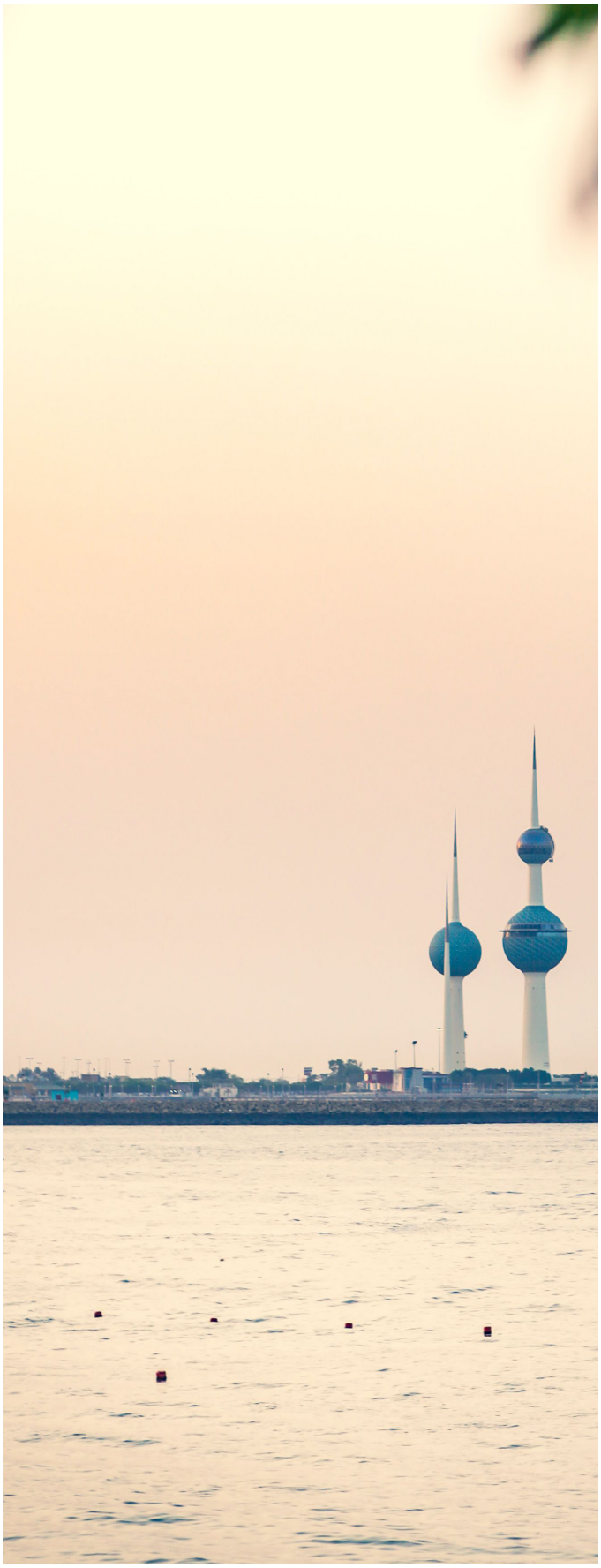
This is a UN-Habitat commissioned epidemiological study to establish new baseline relationships linking air pollution and dust events to hospital admissions for Kuwait and southern Iraq.

Hospital admissions were limited to those for cardiovascular and respiratory causes (combined = cardiopulmonary). The study analyzed a total of 380,862 cases in Kuwait and 371,437 cases in southern Iraq (a total of 752,299 cardiopulmonary cases included in the analysis).

In Kuwait, we used gold-standard quantitative measurement of $PM_{2.5}$ and we found that:

- A 10 µg/m³ increase in $PM_{2.5}$ was associated with a 1% increase in cardiopulmonary hospital admissions.
- Under a hypothetical 10 µg/m³ reduction in $PM_{2.5}$ , Kuwait could avert an estimated 403 cardiopulmonary hospital admissions per year.
- In southern Iraq (Muthana & Qadisiyah), we used monthly number of dust events and found that:
- A dust event was associated with a 2% (small dust event) to 4% (large dust event) increase in cardiopulmonary hospital admissions.
- Under a hypothetical 20% reduction in suspended dust events, Muthana and Qadisiyah could avert an estimated 899 cardiopulmonary hospital admissions per year.

This approach allows for rapid estimation of health benefits of future exposure reductions without waiting to collect new health data, and without re-estimating the exposure-response relationship with newer data. Once dust mitigation shows that $PM_{2.5}$ concentrations or dust events have declined, the associations established in this study can then be applied directly to estimate the expected number of potentially averted hospital admissions.



The study analyzed a total of

**380,862**

**Cases in Kuwait**

**371,437**

**Cases in Southern Iraq**

# Background

Sand and dust storms are a recurrent environmental hazard across Iraq and Kuwait. These episodes degrade air quality and can acutely worsen cardiopulmonary health. Unlike larger particles ($PM_{10}$), fine particulate matter ($PM_{2.5}$) can penetrate deep into the respiratory tract, reach the alveoli, and enter the bloodstream and other organs[1,2], triggering inflammation and oxidative stress that can increase hospital admissions and premature deaths[3,4]. Two health outcomes are of interest: 1) cardiovascular diseases and 2) respiratory diseases.

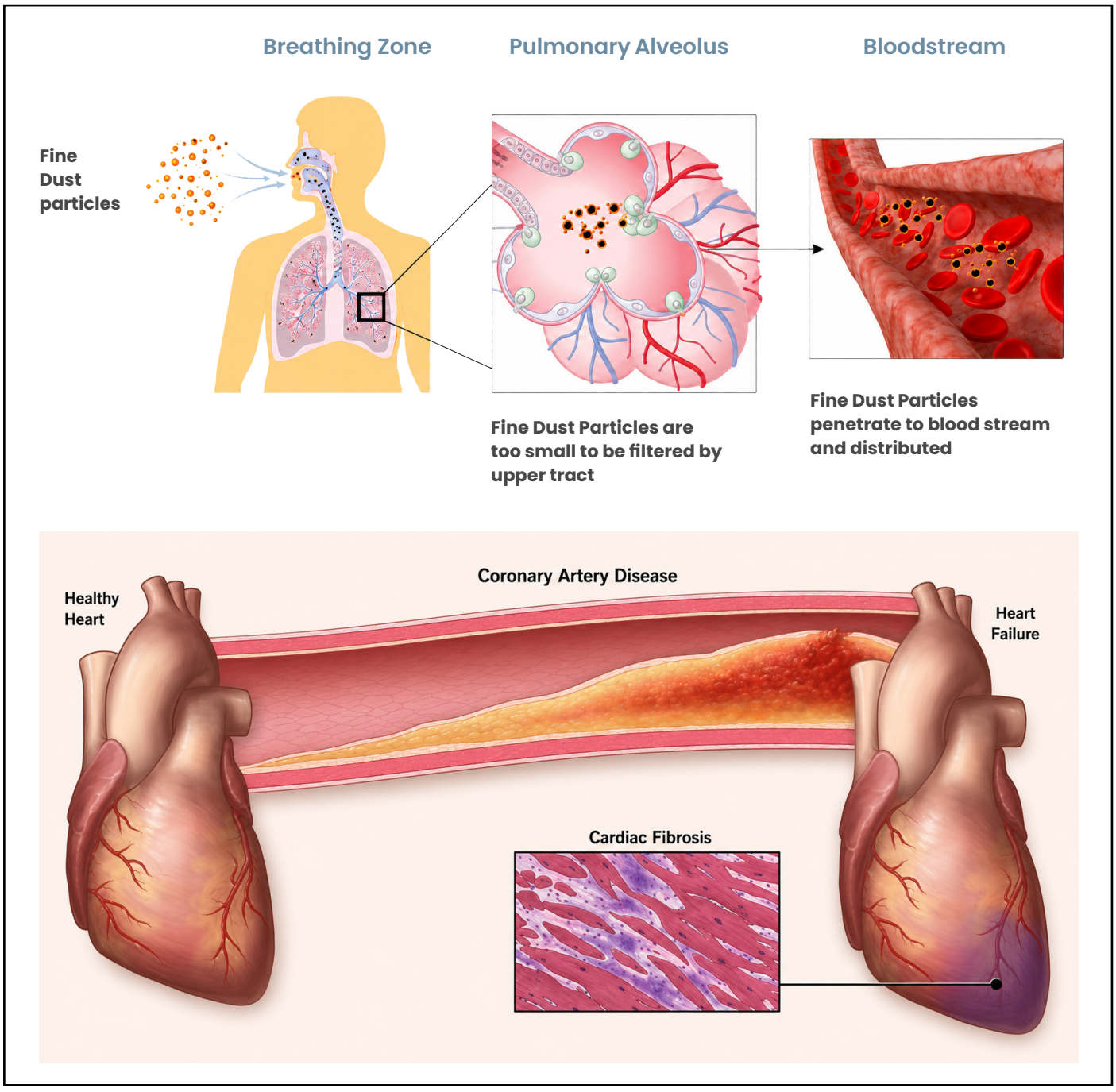



**Figure 1.** Penetration of pollution particles into the lungs and heart. Short-term exposure (hours to days) to $PM_{2.5}$ can rapidly trigger acute inflammatory and oxidative responses in the respiratory and cardiovascular systems. Inhaled particles generate reactive oxygen species (ROS), which activate inflammatory pathways, impair endothelial function, and increase blood clotting potential, especially in coronary arteries (resulting in heart attacks and heart failure[5]). **Adapted from Rajagopalan & Landrigan (2021).**

Section 02

# Data & Methods



# Study Context

The Harvard team in Kuwait has conducted a series of air pollution and health studies[28–32]. We know of no study that quantified effects of pollution on health in Iraq.

UN-Habitat has commissioned this analysis to produce practical evidence on the short-term health impacts of sand and dust storms in both countries, and to convert that evidence into decision support for policy and preparedness.

# Goal

The immediate goal is to quantify short-term acute health effects of dust in Kuwait and Iraq in a way that can be translated into metrics that health and environmental authorities can use for planning, alerts, and mitigation. Two key questions here:

1. **What are the dust-specific health effects in all governorates in Kuwait?**
   For example, how much excess hospital admissions can be attributed to a 5 µg/m³ or 10 µg/m³ increase in dust?
2. **What are the dust-specific health effects in southern governorates in Iraq?**
   For example, how many excess hospital admissions can be attributed to each additional dust event?

Should we see effects of dust on health, then the third question becomes:

3. **If we are to reduce dust storms, how many hospital admissions can we 'avert' in Kuwait and in southern Iraq?**

The 3 questions were crafted after multiple rounds and iterations with stakeholders in both countries. This report will provide the baseline dust-health relationship to quantify expected increases in hospital admissions. For example, if this report estimates that every 10 µg/m³ increase in dust is associated with a X% increase in hospital admissions, then the same relationship can be used in reverse. If restoration activities (by UN-Habitat) later reduce dust by 10 µg/m³, we can estimate the number of hospital admissions that may have been avoided **without having to repeat the full health study from the beginning.** In other words, this means that the project does not need to wait until the end of the restoration intervention to start collecting new health data and re-measuring health benefits - the current modeling here would suffice.

# Data Inventory

In this effort we compiled a first-of-its-kind data inventory for the two countries. This includes health data from hospitals and across governorates as well as environmental exposure data for dust, temperature, meteorological conditions, satellite imagery and other data sources.

For Kuwait: health data were obtained from the Ministry of Health, National Center for Health Information and included daily respiratory and cardiovascular hospital admissions from 2010 to 2022 in every public hospital in Kuwait. Environmental data for Kuwait were obtained from the Harvard Study and included daily dust estimates from 2017 to 2019, daily overall $PM_{2.5}$ from 2001 to 2018. Daily meteorological conditions from 2000 to 2024 were obtained from the Kuwait Meteorological Services (based at Kuwait Airport).

For Iraq: health data were obtained from the Governorate Directorates of Health in Muthana and Qadisiyah and included monthly respiratory and cardiovascular hospital admissions from 2014 to 2020. Data were provided for Nasiriyah/Thi Qar but for a different study period - the analysis was, therefore, restricted to Qadisiyah and Muthana to align with the project geography and available environmental exposure data. Environmental data for Iraq were obtained from Muthana University with the help of the Iraqi Meteorological Organization & Seismology Department. These included monthly dust estimates from 1994 to 2020, and monthly meteorological conditions from 1994 to 2020. Daily overall $PM_{2.5}$ were obtained from the Harvard Study[32–34].

**Table 1:** Data inventory collected during this project

| | Kuwait | Iraq ‡ |
|---|---|---|
| **Health data** | **Source:** Ministry of Health | **Source:** Governorate Directorate of Health |
| Respiratory Hospital Admissions | Daily (2010-2022) | Monthly (2014-2020) |
| Cardiovascular Hospital Admissions | Daily (2010-2022) | Monthly (2014-2020) |
| **Environmental data** | **Source:** Harvard Study | **Source:** Muthana University + Harvard Study |
| Dust | Daily (2017-2019) | Monthly (1994-2020) |
| Overall $PM_{2.5}$ | Daily (2001-2018) | Daily (2022-2024) |
| Meteorological conditions* | Daily (2000-2024) | Monthly (1994-2020) |

* Includes wind direction, wind speed, ambient temperature, and relative humidity
‡ Data included Nasiriyah/Thi Qar but analysis was restricted to Qadisiyah and Muthana

**Access to a full data repository is made available for Kuwait Fund for Arab Economic Development (KFAED), UN-Habitat, and other partners.**

# Data limitations

A key difference between the two countries is the temporal resolution of the data. Kuwait has daily hospital admission data, which allows the analysis to capture short-term acute changes in admissions following daily changes in dust exposure. Iraq has monthly hospital admission data, which limits us to a medium-term assessment of how changes in monthly dust levels are associated with monthly hospital admissions.

This project faced a number of different data limitations in Kuwait and Iraq (Table 2). We adapted the analysis accordingly. In Kuwait, direct dust concentration data were replaced with total $PM_{2.5}$ , which significantly extended the analysis period. In Iraq, 1) daily health and environmental data were not available, and 2) dust concentration data were not available. We decided to conduct the analysis at the monthly scale and interpreted it as a medium-term assessment. In addition, we used the available meteorological classification of dust versus non-dust periods to estimate the health effects of dust occurrence.

**Table 2:** Inherent data limitations and statistical solutions

| | Data Limitations | Statistical Solutions |
|---|---|---|
| **Kuwait** | > Dust concentration data only available from 2017-2019<br><br>> Small number of admissions | > We first used the available dust concentration data to estimate dust-specific health effects. After confirming that the dust-related effect estimates were similar by mass to the $PM_{2.5}$ effect estimates, we used the longer $PM_{2.5}$ time series to extend the analysis period.<br><br>> We used a combined category of respiratory + cardiovascular admissions (to increase sample size) |
| **Iraq** | > No daily data<br><br>> No dust concentration data | > We analyzed the data at the monthly scale and framed the Iraq analysis as a "medium-term" assessment (vs. gold-standard "short-term" assessment)<br><br>> We used binary (dust =1 vs. no-dust =0) variable available from meteorology |

# Dust exposure classification

Dust exposure was measured differently in Kuwait and Iraq because the available environmental data was substantially different between the two countries. In Kuwait, dust was measured directly and quantitatively in exact µg/m³ using custom-designed Harvard impactor samplers[32]. These samplers collect particles on filters and provide a high-quality, reference-grade measurement of airborne particles weight. These devices are particularly valuable in desert environments because they can collect dust components accurately without being overwhelmed during severe dust conditions[35,36]. Once filters are collected, dust can be speciated using source apportionment data analysis techniques (from analyzing concentrations of fingerprint elements). Ultimately, this "dust quantification" allows the Kuwait analysis to estimate health effects per specific increase in dust concentration, such as per 5 or 10 µg/m³.

In Iraq, direct dust concentration measurements were not available. Instead, dust exposure was classified using meteorological observations coded as binary indicators (1 = present vs. 0 = not present): dust storm, rising dust, and suspended dust. These classifications are useful because they identify whether a dust condition occurred, but they do not measure how much dust was in the air, how intense the event was, or the exact concentration people were exposed to. Additionally, these were available on monthly level rather than daily.

**Table 3:** Methods used to classify dust in Kuwait and Iraq

| | Dust Classification | |
|---|---|---|
| **Kuwait** | **Measured in exact µg/m³**<br>Using custom-designed Harvard samplers in Kuwait.[32,36] These devices are able to accurately measure dust components in the air without getting overwhelmed during severe conditions. |  |
| **Iraq** | **1. Dust Storm (1 vs. 0)**<br>A severe dense wall or cloud of dust moving across the landscape, often sharply reducing visibility. |  |
| | **2. Rising Dust (1 vs. 0)**<br>Dust being lifted from the ground by wind near the observation site, but usually without the large wall-like structure of a full dust storm. |  |
| | **3. Suspended Dust (1 vs. 0)**<br>A dusty or hazy sky where fine dust remains in the air, often reducing visibility, but without obvious active lifting from the ground nearby. |  |

While photographs can help illustrate the differences, the categories of dust storm, rising dust, and suspended dust are meteorological observation categories rather than purely visual categories depending on present-weather observations, visibility, and whether dust is actively being raised by wind at or near the station.

# Study Design

## Kuwait, daily

This was a conventional time-series study design to estimate dust-$PM_{2.5}$ effect estimate for short-term associations with cause-specific hospital admissions. We used generalized additive models (GAM)[37] with a negative binomial distribution to estimate the association between daily $PM_{2.5}$ exposure and daily hospital admissions for cardiopulmonary conditions. After checking for non-linearity, the final model included a linear term for $PM_{2.5}$ exposure, fixed effects for each hospital service area, and adjustments for long-term trends, seasonality, and day of the week patterns. Long-term trends and seasonality were modeled using a natural spline with 4 degrees of freedom per year (total of 36 degrees of freedom for years of data included). Day-of-week effects were included as categorical variables (Sunday to Saturday). To control for potential confounding by ambient temperature, we used a distributed lag nonlinear model (DLNM)[38,39] with a maximum lag of 30 days. Specifically, we constructed a cross-basis function for daily mean temperature, using natural cubic splines with internal knots placed at the 10th, 75th, and 90th percentiles of the temperature distribution, and spline knots for lag structure were placed at logarithmically equally spaced intervals. We used DLNM model parameters that were previously tested and optimized for Kuwait[40].

**Example interpretation from Kuwait model:**

xx% increase in hospital admissions for every 10 µg/m³ increase in $PM_{2.5}$

## Iraq, monthly

This analysis used a monthly panel time-series design to estimate medium-term associations between dust events and cause-specific hospital admissions in southern Iraq. We used generalized additive models with a negative binomial distribution to account for overdispersed monthly hospital admission counts. The outcome was the monthly number of hospital admissions with fixed effects included for each governorate to control for time-invariant differences across governorates. Because direct dust concentration measurements were not available, dust exposure was modeled as the monthly number of events in each meteorological dust category: dust storm, rising dust, and suspended dust. Each dust category was modeled separately to estimate its independent association with hospital admissions. Models were adjusted for long-term trends and seasonality using natural splines with 4 degrees of freedom per year. We also adjusted for predominant wind and ambient temperature using linear terms.

**Example interpretation from Iraq model:**

xx% increase in hospital admissions for every 1 additional dust event

**To quantify the public health burden associated with pollution exposure we converted to numeric potentially avoided cases (assuming causality)[41,42]:**

$$\text{Avoided cases (Kuwait)} = \text{Baseline cases} \times [1 - \exp(\beta \times \Delta PM_{2.5})]$$

$$\text{Avoided monthly cases (Iraq)} = \text{Baseline monthly cases} \times [1 - \exp(\beta \times \Delta \text{DustEvents})]$$

Where β is the model coefficient for a 1 µg/m³ increase in $PM_{2.5}$ or the model coefficient for one additional dust event in a given month.

# Description of Data

In both countries, we identified cardiovascular and respiratory (cardiopulmonary) conditions using the World Health Organization, International Classification of Diseases, Tenth Revision (ICD-10), specifically codes J00-J99 for respiratory diseases (e.g., asthma, chronic obstructive pulmonary disease, pneumonia), I00-I99 for cardiovascular diseases (e.g., heart attack, heart failure, hypertension), and the combined category for both sets (cardiopulmonary; J00-J99 & I00-I99).

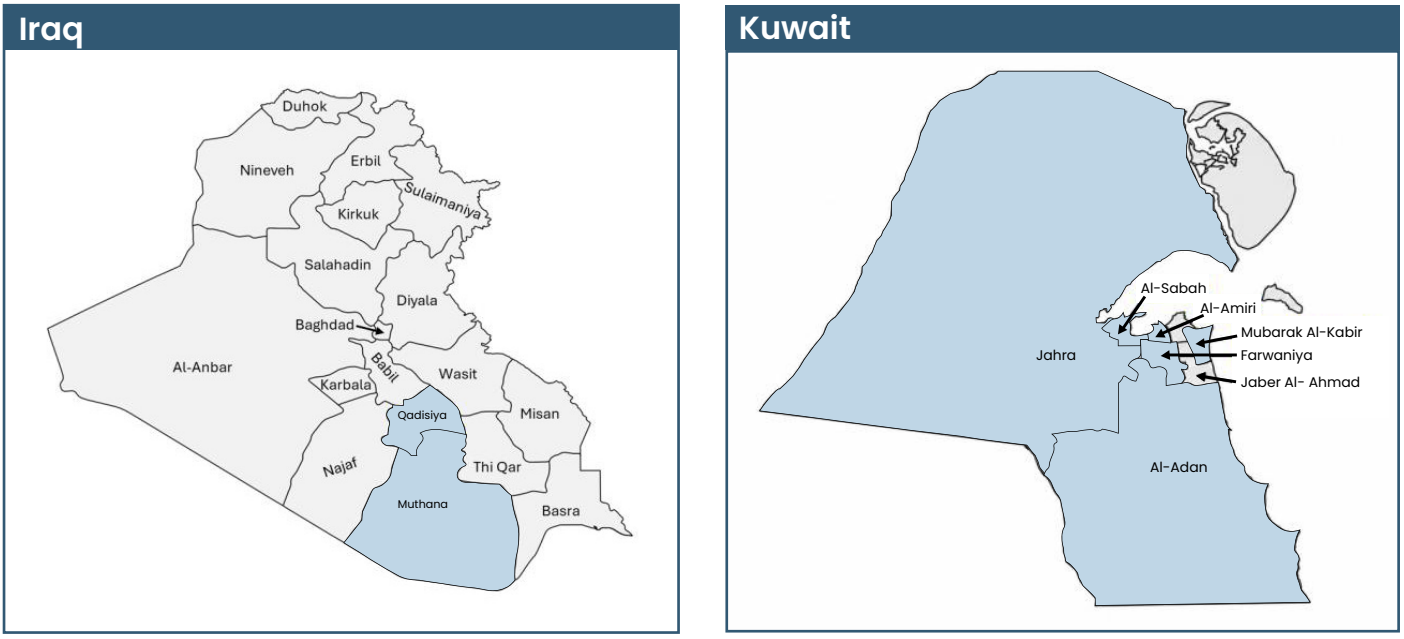



**Figure 2. Geographic units included in the analysis, highlighted in blue.** In Iraq, the analysis was restricted to the governorates of Qadisiyah and Muthana, and Thi Qar was excluded because of major data limitations. In Kuwait, the analysis was conducted by health district rather than governorate; Jaber Al-Ahmad Hospital was excluded because of insufficient data availability after its opening in 2018.

**Table 4:** Total cases used for analysis by geographic units

| | Cardiopulmonary Hospital Admissions | | |
|---|---|---|---|
| | **Total** | **Average per year** | **Average per month** |
| **Kuwait †** | | | |
| Al-Adan | 77,131 | 8,570 | 714 |
| Al-Amiri | 45,617 | 5,069 | 422 |
| Al-Sabah | 49,010 | 5,446 | 454 |
| Farwaniya | 82,169 | 9,130 | 761 |
| Jahra | 64,908 | 7,212 | 601 |
| Mubarak Al-Kabir | 62,027 | 6,892 | 574 |
| **Iraq ‡** | | | |
| Qadisiyah | 113,570 | 16,224 | 1,352 |
| Muthana | 257,867 | 23,442 | 1,954 |

† The baseline study period used was 2010-2018
‡ There were overlapping data availability years; 2010-2020 in Muthana and 2014-2020 in Qadisiyah

Section 03

# Exposure & Findings



We analyzed a total of 380,862 cardiopulmonary cases in Kuwait and 371,437 cardiopulmonary cases in Iraq (a total of 752,299 cases included in the analysis). The average monthly cases ranged from 400 to 700 in Kuwaiti hospitals and almost 1,300 to 2,000 cases in southern Iraqi governorates (Table 4). On daily basis, this translates into 14 to 25 cases per hospital per day in Kuwait. The analysis then calculates how much of these cases are 1) attributed to dust, and 2) can be averted should dust be lowered.

# Pollution Levels

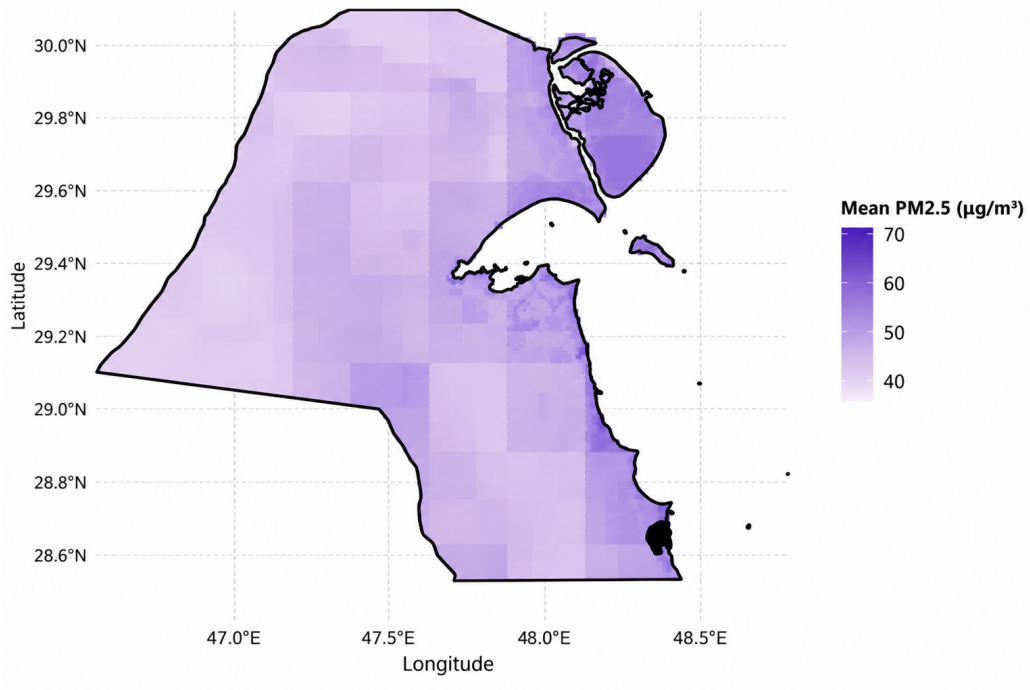



**Figure 3. Spatiotemporal modeling of air pollution across every 1 km x 1 km in Kuwait.** Spatial distribution of annual mean $PM_{2.5}$ concentrations across all hospital service areas in 2018.

Overall, average $PM_{2.5}$ was 39.3 µg/m³ across Kuwait (Figure 3). The distributions of daily population-weighted $PM_{2.5}$ concentrations for each hospital service area in were right-skewed (episodic high-exposure days). Mubarak Al-Kabir had the highest mean daily $PM_{2.5}$ concentration (41.0 µg/m³), followed by Farwaniya (39.3 µg/m³) and Al-Amiri (38.2 µg/m³). Jahra had the lowest average exposure (35.8 µg/m³). Maximum daily concentrations exceeded 180 µg/m³ in all hospitals. More than 40% of the $PM_{2.5}$ in Kuwait is from dust.

In Iraq, across both governorates, suspended dust was the most frequent category, followed by rising dust, while dust storms were the least common. Muthana consistently experienced more dust events than Qadisiyah across all three categories. Muthana recorded 1,920 suspended dust events compared with 1,665 in Qadisiyah, for the period from 1994 to 2020. Dust storms were much less frequent, with just 193 total events in Muthana and 166 in Qadisiyah, averaging less than 1 event per month in both governorates. (Detailed description of the distribution of dust events in the two governorates are found in Figure 4, Figure 5 and Table 5)

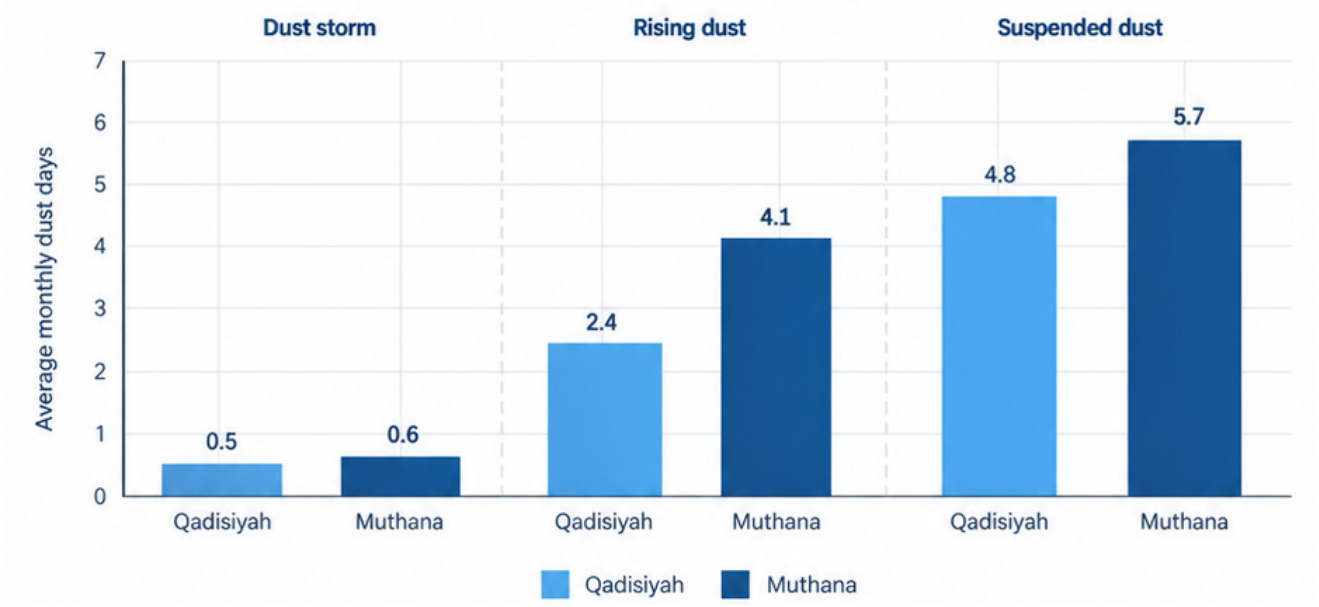



**Figure 4. Average monthly dust days by dust classification in Qadisiyah and Muthana.** Suspended dust was the most frequent dust category in both governorates, followed by rising dust, while dust storms were relatively uncommon (less than 1 event per month). Across all three classifications, Muthana had a higher average number of monthly dust days than Qadisiyah.

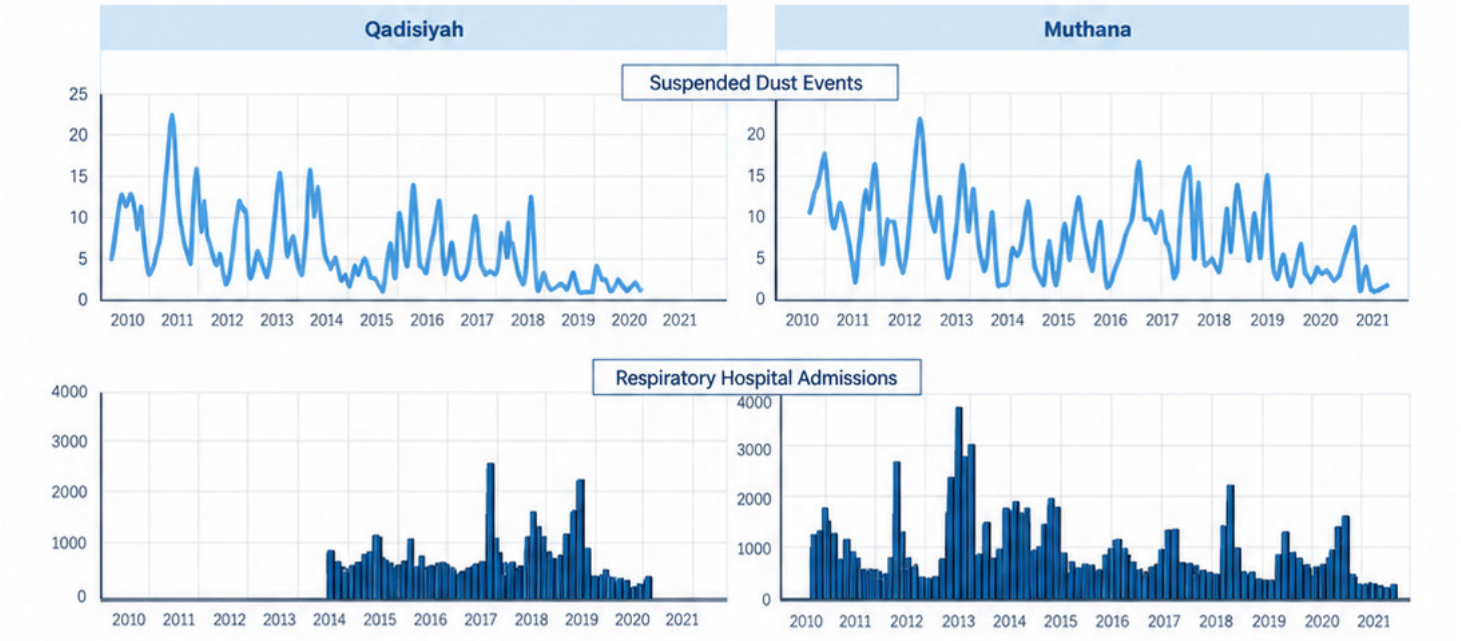



**Figure 5. Monthly suspended dust events and respiratory hospital admissions in Qadisiyah and Muthana.** Periods with higher suspended dust activity appear to coincide with some spikes in respiratory admissions. However, this figure is intended only as a visual comparison and should not be interpreted as evidence of causation. The formal exposure-response associations from the epidemiological study design are presented elsewhere in the report.

**Table 5:** Dust events in Qadisiyah and Muthana from 1994 to 2020

| | Qadisiyah | | | Muthana | | |
|---|---|---|---|---|---|---|
| | Total Events | Total per year | Average per month | Total Events | Total per year | Average per month |
| Dust Storms | 166 | 5.7 | 0.5 | 193 | 6.9 | 0.6 |
| Rising Dust | 848 | 29.2 | 2.4 | 1,350 | 48.2 | 4.1 |
| Suspended Dust | 1,665 | 57.4 | 4.8 | 1,920 | 68.6 | 5.7 |

# Baseline Estimation

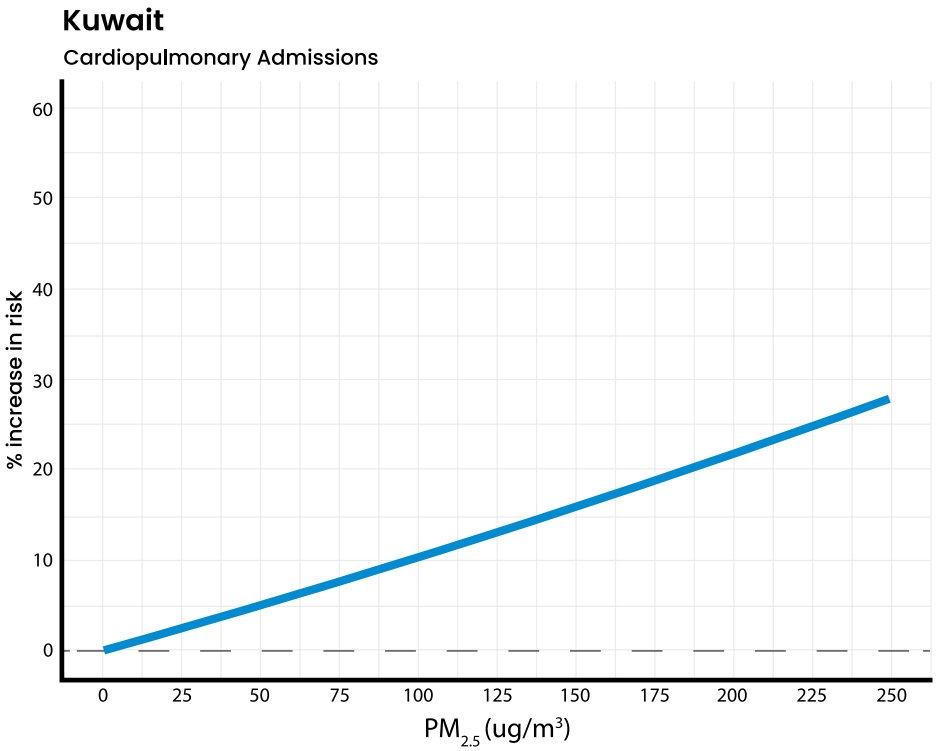
In Table 6, we establish the baseline relationship used to translate pollution changes into expected changes in cardiopulmonary hospital admissions in both countries. In Kuwait, where pollution was measured quantitatively as $PM_{2.5}$, each 1 µg/m³ increase was associated with a 0.10% increase in cardiopulmonary admissions. A 10 µg/m³ increase would increase cardiopulmonary admissions by about 1% (dust-$PM_{2.5}$ has been shown to have similar coefficients in Kuwait, described elsewhere).

In Iraq, where direct dust concentrations were not available, the baseline relationship was estimated using the number of monthly dust events. Each additional dust event was associated with a 2 to 4% increase in cardiopulmonary admissions. These results provide the baseline coefficients needed to estimate how many hospital admissions could potentially be avoided if $PM_{2.5}$ concentrations in Kuwait or dust events in Iraq are reduced.

**Table 6:** New established baseline associations for pollution and hospital admissions

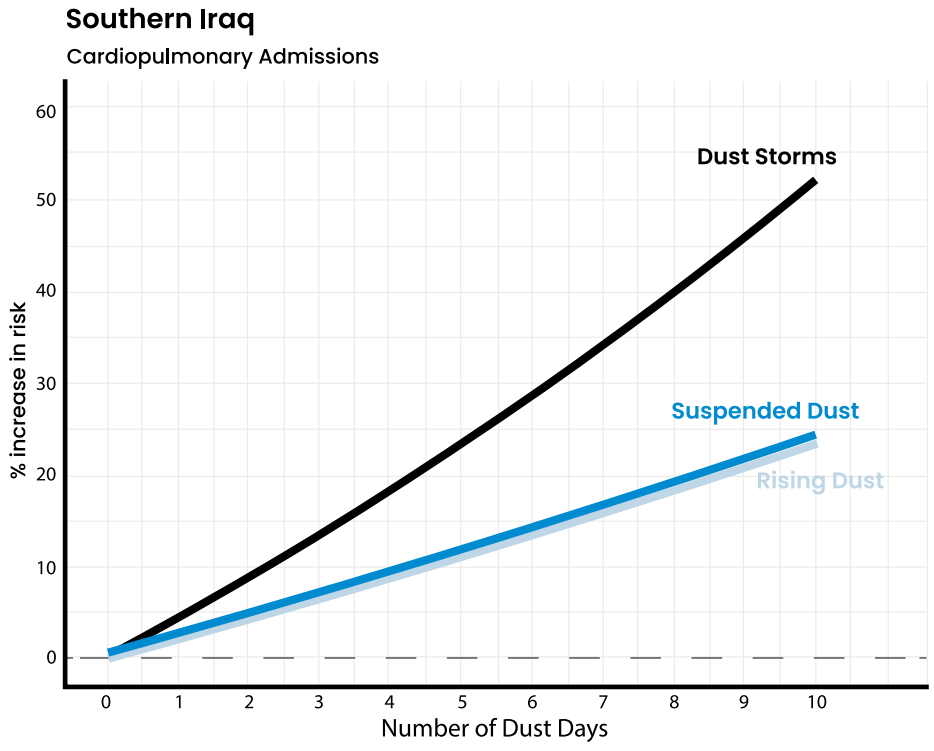
| Cardiopulmonary Hospital Admissions | | |
|---|---|---|
| | % increase | Range^ |
| **Kuwait †** | | |
| Per 1 µg/m³ increase | 0.10% | (0.06% to 0.14%)* |
| Per 5 µg/m³ increase | 0.45% | (0.30% to 0.68%)* |
| Per 10 µg/m³ increase | 1.00% | (0.61% to 1.37%)* |
| Per 20 µg/m³ increase | 2.00% | (1.22% to 2.76%)* |
| **Iraq ‡** | | |
| Dust Storm (per 1 additional event) | 4.28% | (-1.85% to 10.78%) |
| Rising Dust (per 1 additional event) | 2.12% | (0.15% to 4.12%)* |
| Suspended Dust (per 1 additional event) | 2.16% | (0.94% to 3.40%)* |

† Short-term effect: models are adjusted for time and temperature
‡ Medium-term effect: models are adjusted for seasonality, long term trends, predominant wind, and temperature
^ Range represents the 95% confidence intervals calculated from the standard errors of the coefficients
* Statistically significant to the alpha level of 0.05




Source: *UN Habitat Analysis, Alahmad et al. (2025)*

**Figure 6. Baseline exposure-response relationship in Kuwait (short-term).** Pooled results from all hospital service areas (and their corresponding governorates) for the period from 2010 to 2018 using "daily" hospital admissions and pollution levels.

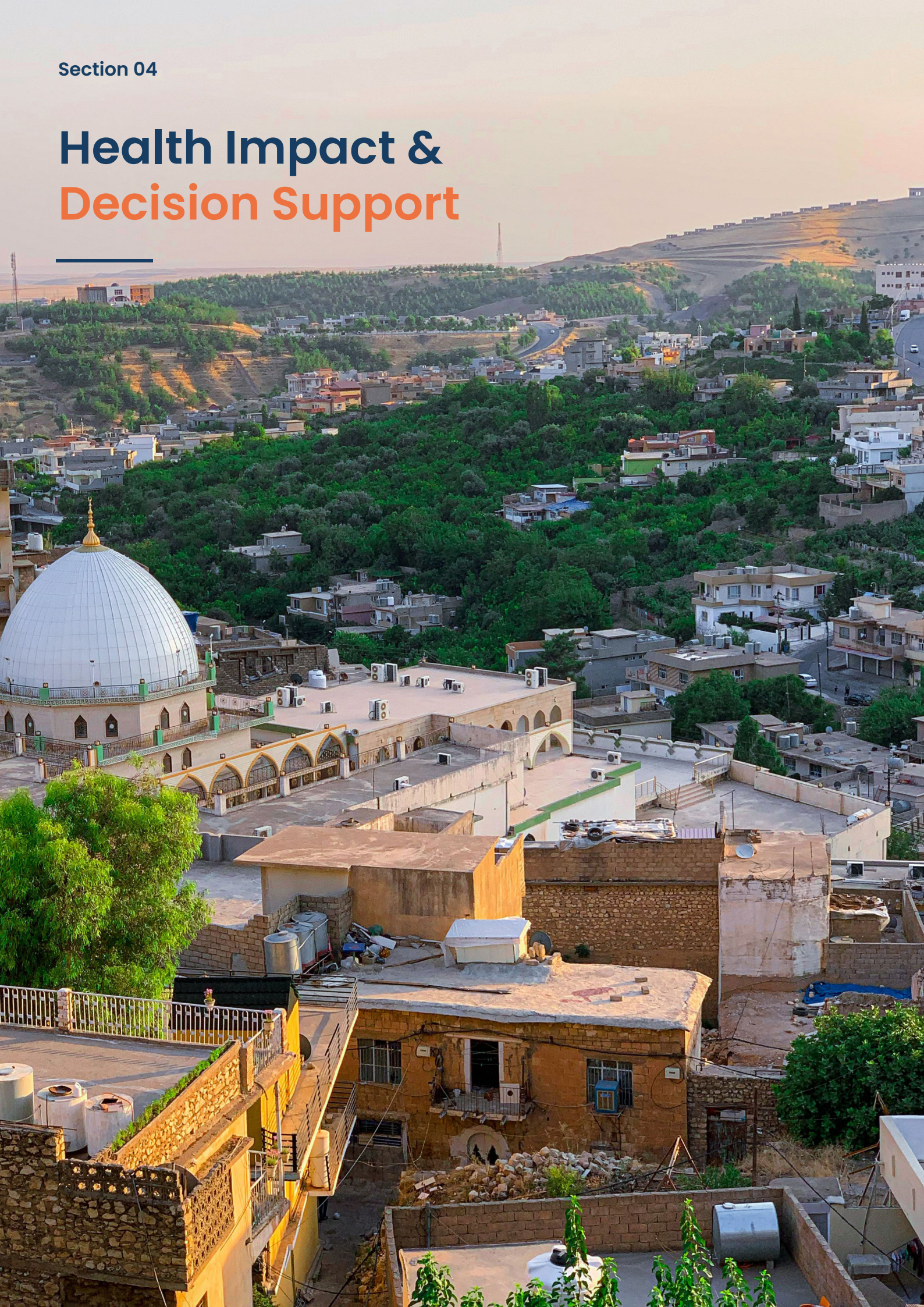



Source: *UN Habitat Analysis*

**Figure 7. Baseline exposure-response relationship in Southern Iraq (medium-term).** Pooled results from Muthana and Qadisiyah governorates for the period from 2010 to 2020 using "monthly" hospital admissions and dust events.

Section 04

# Health Impact & Decision Support



# Decision Support Scenarios

**Table 7:** Burden of cardiopulmonary hospital admissions and impact of mitigation scenarios

| | % of Cases Attributable to Pollution (Range) | Number of Cases Attributable to Pollution per Year (Range) | Number of Averted Cases per Year (Range) |
|---|---|---|---|
| **Kuwait** | | | |
| **Scenario 1: Do nothing, continue business-as-usual** | | | |
| Al-Adan | 3.6% (2.2-4.9%) | 306 (190-419) | 0 |
| Al-Amiri | 3.6% (2.2-4.9%) | 181 (113-249) | 0 |
| Al-Sabah | 3.7% (2.3-5.1%) | 202 (126-277) | 0 |
| Farwaniya | 3.7% (2.3-5.1%) | 338 (210-464) | 0 |
| Jahra | 3.4% (2.1-4.6%) | 243 (151-334) | 0 |
| Mubarak Al-Kabir | 3.9% (2.4-5.3%) | 266 (166-365) | 0 |
| **Scenario 2: Reduce $PM_{2.5}$ by 10 µg/m³ (hypothetical)** | | | |
| Al-Adan | 2.6% (1.6-3.6%) | 224 (139-308) | 82 (51-111) |
| Al-Amiri | 2.6% (1.6-3.6%) | 133 (83-183) | 48 (30-66) |
| Al-Sabah | 2.8% (1.7-3.8%) | 150 (93-206) | 52 (33-71) |
| Farwaniya | 2.8% (1.7-3.8%) | 251 (156-345) | 87 (54-119) |
| Jahra | 2.4% (1.5-3.3%) | 174 (108-239) | 69 (43-95) |
| Mubarak Al-Kabir | 2.9% (1.8-4.0%) | 201 (125-276) | 65 (41-89) |
| **Scenario 3: Reduce $PM_{2.5}$ by 20 µg/m³ (hypothetical)** | | | |
| Al-Adan | 1.7% (1.0-2.3%) | 141 (88-195) | 165 (102-224) |
| Al-Amiri | 1.7% (1.0-2.3%) | 84 (52-116) | 97 (61-133) |
| Al-Sabah | 1.8% (1.1-2.5%) | 98 (61-134) | 104 (65-143) |
| Farwaniya | 1.8% (1.1-2.5%) | 163 (101-225) | 175 (109-239) |
| Jahra | 1.5% (0.9-2.0%) | 105 (65-144) | 138 (86-190) |
| Mubarak Al-Kabir | 2.0% (1.2-2.7%) | 135 (84-185) | 131 (82-180) |
| **Iraq** | | | |
| **Scenario 1: Do nothing, continue business-as-usual** | | | |
| Qadisiyah | 8.2% (3.8-12.3%) | 1,335 (611-1,999) | 0 |
| Muthana | 15.4% (7.2-22.5%) | 3,599 (1,689-5,269) | 0 |
| **Scenario 2: Reduce suspended dust‡ events by 20% (hypothetical)** | | | |
| Qadisiyah | 6.7% (3.0-10.1%) | 1,085 (493-1,638) | 250 (119-361) |
| Muthana | 12.6% (5.8-18.6%) | 2,950 (1,366-4,372) | 649 (323-897) |
| **Scenario 3: Reduce suspended dust‡ events by 30% (hypothetical)** | | | |
| Qadisiyah | 5.9% (2.7-8.9%) | 957 (433-1,451) | 378 (179-548) |
| Muthana | 11.1% (5.1-16.6%) | 2,614 (1,202-3,897) | 986 (487-1,371) |

‡ Detailed scenarios by type of dust exposure and governorate are available in the Appendix of this report

The decision-support scenarios (Table 7) are based on the epidemiological study commissioned by the UN-Habitat (baseline associations are described in Table 6, Figure 6, and Figure 7, in this report). The goal of these decision-support scenarios is to translate the study findings into practical estimates that can inform planning, restoration, and mitigation decisions.

This approach allows authorities to rapidly estimate the potential health benefits of future exposure reductions without waiting to collect new health data, and without re-estimating the exposure-response relationship with newer data. Once environmental monitoring shows that $PM_{2.5}$ concentrations or dust events have declined, the coefficients established in this study can then be applied directly to estimate the expected number of potentially averted hospital admissions.

For example, using Table 8 (which shows the total number of averted cases), if the mitigation resulted in 10 µg/m³ reduction in $PM_{2.5}$ in Kuwait and a 20% reduction in suspended dust events in southern Iraq (a conservative estimate), a total of 1,302 cases of cardiovascular and respiratory hospitalizations can be averted in just 1 year (assuming causal relationship). If this benefit remains constant over five years, the total would be 6,510 potentially averted hospitalizations. If baseline hospitalizations increase by 5% per year because of population growth or other demand pressures, the five-year total would be approximately 7,194 potentially averted hospitalizations.

**Table 8:** Estimated total averted hospital admission cases based on dust mitigation scenarios

| | Cardiopulmonary Hospital Admissions | |
|---|---|---|
| | Number of 'averted' cases per year | Range^ |
| **Kuwait†** | | |
| Scenario 1: Do nothing, continue business-as-usual | 0 | - |
| Scenario 2: Reduce $PM_{2.5}$ by 10 µg/m³ (hypothetical) | 403 | (252 to 551) |
| Scenario 3: Reduce $PM_{2.5}$ by 20 µg/m³ (hypothetical) | 810 | (505 to 1,109) |
| **Iraq‡** | | |
| Scenario 1: Do nothing, continue business-as-usual | 0 | - |
| Scenario 2: Reduce suspended dust events by 20% (hypothetical) | 899 | (442 to 1,258) |
| Scenario 3: Reduce suspended dust events by 30% (hypothetical) | 1,364 | (666 to 1,919) |

† Summed for the 6 major public hospitals in Kuwait - excluding Jaber Al-Ahmad Hospital and private hospitals
‡ Summed for only 2 southern governorates (Muthana & Qadisiyah)
^ Range represents the 95% confidence intervals calculated from the standard errors of the coefficients and the attributable fractions that are then applied to attributable numbers

Section 05

# Appendix & References



# APPENDIX 1

## Burden of cardiopulmonary hospital admissions in southern Iraq, by dust classification

| | % of cases attributable to pollution (range) | number of cases attributable to pollution, per year (range) | number of averted cases, per year (range) |
|---|---|---|---|
| **Iraq (Qadisiyah)** | | | |
| **Scenario 1: Do nothing, continue business-as-usual** | | | |
| Dust storm‡ | 1.2% (-0.6 to 2.7%) | 191 (-89 to 444) | 0 |
| Rising dust | 1.8% (0.1 to 3.4%) | 290 (21 to 545) | 0 |
| Suspended dust | 8.2% (3.8 to 12.3%) | 1,335 (611 to 1,999) | 0 |
| **Scenario 2: Reduce dust‡ events by 20% (hypothetical)** | | | |
| Dust storm‡ | 0.9% (-0.4 to 2.2%) | 154 (-71 to 361) | 37 (-18 to 83) |
| Rising dust | 1.4% (0.1 to 2.7%) | 233 (17 to 440) | 57 (4 to 105) |
| Suspended dust | 6.7% (3.0 to 10.1%) | 1,085 (493 to 1,638) | 250 (119 to 361) |
| **Scenario 3: Reduce dust‡ events by 30% (hypothetical)** | | | |
| Dust storm‡ | 0.8% (-0.4 to 2.0%) | 135 (-62 to 318) | 56 (-27 to 125) |
| Rising dust | 1.3% (0.1 to 2.4%) | 204 (15 to 387) | 85 (6 to 158) |
| Suspended dust | 5.9% (2.7 to 8.9%) | 957 (433 to 1,451) | 378 (179 to 548) |

| | % of cases attributable to pollution (range) | number of cases attributable to pollution, per year (range) | number of averted cases, per year (range) |
|---|---|---|---|
| **Iraq (Muthana)** | | | |
| **Scenario 1: Do nothing, continue business-as-usual** | | | |
| Dust storm‡ | 1.5% (-0.7 to 3.4%) | 341 (-162 to 787) | 0 |
| Rising dust | 8.4% (0.6 to 15.1%) | 1,962 (150 to 3,543) | 0 |
| Suspended dust | 15.4% (7.2 to 22.5%) | 3,599 (1,689 to 5,269) | 0 |
| **Scenario 2: Reduce dust‡ events by 20% (hypothetical)** | | | |
| Dust storm‡ | 1.2% (-0.5 to 2.7%) | 275 (-129 to 642) | 66 (-33 to 145) |
| Rising dust | 6.8% (0.5 to 12.4%) | 1,592 (120 to 2,910) | 370 (30 to 634) |
| Suspended dust | 12.6% (5.8 to 18.6%) | 2,950 (1,366 to 4,372) | 649 (323 to 897) |
| **Scenario 3: Reduce dust‡ events by 30% (hypothetical)** | | | |
| Dust storm‡ | 1.0% (-0.5 to 2.4%) | 242 (-112 to 567) | 99 (-49 to 220) |
| Rising dust | 6.0% (0.4 to 11.0%) | 1,403 (105 to 2,580) | 559 (45 to 963) |
| Suspended dust | 11.1% (5.1 to 16.6%) | 2,614 (1,202 to 3,897) | 986 (487 to 1,371) |

^Range represents the 95% confidence intervals calculated from the standard errors of the coefficients and the attributable fractions that are then applied to attributable numbers.

‡Dust storm estimates are not statistically significant (the 95% confidence interval for the coefficient crosses the null), so the attributable range includes negative values and should be read as compatible with no effect.

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