Additional file 2

Supplementary statistical results and sensitivity analyses

Assessed Adaptive Capacity of Healthcare Facilities for Air-Pollution Episodes in Dust-Storm-Prone Khuzestan, Iran: A Cross-Sectional Study

Scope. This supplementary file contains analyses that directly support findings reported in the manuscript: complete item-level comparisons, prespecified sensitivity analyses, exploratory county-level social-vulnerability analyses, and measurement-property summaries.

Data-quality note. The final analytical frame comprised 52 independently assessed organisational units (24 county-level health-network units and 28 hospitals). One out-of-range binary value (11) was verified and corrected to 1 before scoring; no item-level values were missing and no imputation was required. Six stored facility-domain totals differed from totals reconstructed from item responses; item-derived scores were used for the primary analyses and corrected stored totals were examined in sensitivity analysis.

Table S1. Full item-level hospital–health-network-unit comparisons

Item	Domain	Operational statement	Health-network units n/N (%)	Hospitals n/N (%)	Difference (pp)	Fisher p	BH-FDR p	OR (95% CI)
1	Policies and governance	The health centre or hospital has specific plans to address the health consequences of air pollution.	19/24 (79.2%)	23/28 (82.1%)	3.0	1.000	1.000	1.21 (0.32 to 4.54)
2	Policies and governance	The health centre or hospital regularly updates health policies related to air pollution.	7/24 (29.2%)	20/28 (71.4%)	42.3	0.005	0.098	5.63 (1.74 to 18.15)
3	Policies and governance	The health centre or hospital effectively complies with laws and regulations related to air pollution.	22/24 (91.7%)	26/28 (92.9%)	1.2	1.000	1.000	1.18 (0.19 to 7.42)
4	Policies and governance	The health centre or hospital's policies specifically address protection of vulnerable groups, such as children, older adults, and patients with cardiovascular disease, from air pollution.	23/24 (95.8%)	26/28 (92.9%)	-3.0	1.000	1.000	0.68 (0.08 to 5.52)
5	Policies and governance	The health centre or hospital allocates sufficient resources to manage increases in air-pollution-related illness.	15/24 (62.5%)	17/28 (60.7%)	-1.8	1.000	1.000	0.93 (0.31 to 2.80)
6	Policies and governance	The health centre or hospital has effectively prepared its systems for emergencies caused by air pollution.	19/24 (79.2%)	16/28 (57.1%)	-22.0	0.139	0.592	0.37 (0.11 to 1.23)
7	Policies and governance	The health centre or hospital actively participates in implementing government policies to reduce air pollution.	10/24 (41.7%)	18/28 (64.3%)	22.6	0.163	0.592	2.43 (0.81 to 7.29)
8	Infrastructure and resources	The health centre or hospital is equipped with the equipment and technologies required to manage air-pollution-related illnesses, such as respiratory support devices and appropriate ventilation systems.	14/24 (58.3%)	26/28 (92.9%)	34.5	0.007	0.098	7.68 (1.68 to 35.12)
9	Infrastructure and resources	The health centre or hospital is adequately equipped to receive patients with illnesses caused or exacerbated by air pollution.	5/24 (20.8%)	14/28 (50.0%)	29.2	0.044	0.307	3.55 (1.07 to 11.70)
10	Infrastructure and resources	The health centre or hospital has explicit protocols for the diagnosis and treatment of air-pollution-related illnesses.	17/24 (70.8%)	26/28 (92.9%)	22.0	0.064	0.364	4.54 (0.96 to 21.48)
11	Infrastructure and resources	The health centre or hospital is prepared for increased patient volumes during air-pollution emergencies.	16/24 (66.7%)	17/28 (60.7%)	-6.0	0.775	0.985	0.78 (0.26 to 2.39)
12	Infrastructure and resources	The health centre or hospital has ventilation systems capable of limiting the entry of outdoor air pollution into indoor spaces.	16/24 (66.7%)	23/28 (82.1%)	15.5	0.220	0.734	2.20 (0.63 to 7.63)
13	Infrastructure and resources	The health centre or hospital has sufficient resources to provide health services during air-pollution emergencies.	7/24 (29.2%)	15/28 (53.6%)	24.4	0.096	0.482	2.68 (0.87 to 8.25)
14	Staff training and empowerment	Health-centre or hospital staff receive regular training in the management of air-pollution-related illnesses.	21/24 (87.5%)	27/28 (96.4%)	8.9	0.324	0.865	2.98 (0.41 to 21.93)
15	Staff training and empowerment	Physicians and nurses have been adequately trained to diagnose and treat respiratory and cardiovascular illnesses related to air pollution.	23/24 (95.8%)	28/28 (100.0%)	4.2	0.462	0.985	3.64 (0.14 to 93.54)
16	Staff training and empowerment	Health-centre or hospital staff receive regular training on methods to reduce patients' air-pollution risks.	23/24 (95.8%)	25/28 (89.3%)	-6.5	0.615	0.985	0.47 (0.06 to 3.41)
17	Staff training and empowerment	The health centre or hospital provides training programmes to increase staff awareness of the consequences of air pollution and methods of prevention.	21/24 (87.5%)	25/28 (89.3%)	1.8	1.000	1.000	1.19 (0.24 to 5.81)
18	Staff training and empowerment	The health centre or hospital has the capacity to manage high patient volumes during air-pollution emergencies.	15/24 (62.5%)	20/28 (71.4%)	8.9	0.562	0.985	1.48 (0.47 to 4.61)
19	Air-quality monitoring and evaluation	The health centre or hospital regularly receives air-quality data from reliable sources.	8/24 (33.3%)	12/28 (42.9%)	9.5	0.573	0.985	1.47 (0.49 to 4.45)
20	Air-quality monitoring and evaluation	The health centre or hospital uses air-quality data to set priorities for health-service provision.	6/24 (25.0%)	10/28 (35.7%)	10.7	0.549	0.985	1.62 (0.50 to 5.21)

Item	Domain	Operational statement	Health-network units n/N (%)	Hospitals n/N (%)	Difference (pp)	Fisher p	BH-FDR p	OR (95% CI)
21	Air-quality monitoring and evaluation	The health centre or hospital actively monitors air-quality conditions across different areas of the province.	10/24 (41.7%)	18/28 (64.3%)	22.6	0.163	0.592	2.43 (0.81 to 7.29)
22	Air-quality monitoring and evaluation	The health centre or hospital uses warning systems to notify patients during air-pollution episodes.	18/24 (75.0%)	19/28 (67.9%)	-7.1	0.760	0.985	0.72 (0.22 to 2.35)
23	Air-quality monitoring and evaluation	The health centre or hospital effectively communicates air-quality updates to staff and patients.	19/24 (79.2%)	24/28 (85.7%)	6.5	0.716	0.985	1.54 (0.39 to 6.11)
24	Air-quality monitoring and evaluation	The health centre or hospital uses air-quality data to adjust working hours and patient intake on polluted days.	21/24 (87.5%)	26/28 (92.9%)	5.4	0.652	0.985	1.73 (0.31 to 9.64)
25	Public awareness and risk communication	The health centre or hospital provides air-pollution awareness programmes for patients and their families.	23/24 (95.8%)	26/28 (92.9%)	-3.0	1.000	1.000	0.68 (0.08 to 5.52)
26	Public awareness and risk communication	The health centre or hospital educates patients and the public about air-pollution risks and preventive measures.	22/24 (91.7%)	27/28 (96.4%)	4.8	0.590	0.985	2.04 (0.25 to 16.63)
27	Public awareness and risk communication	The health centre or hospital provides targeted air-pollution information programmes for vulnerable groups, such as patients with respiratory or cardiovascular disease.	21/24 (87.5%)	25/28 (89.3%)	1.8	1.000	1.000	1.19 (0.24 to 5.81)
28	Public awareness and risk communication	The health centre or hospital advises patients on methods to reduce exposure to air pollution, such as using an appropriate mask or avoiding outdoor activity.	20/24 (83.3%)	25/28 (89.3%)	6.0	0.690	0.985	1.60 (0.35 to 7.26)
29	Public awareness and risk communication	The health centre or hospital effectively informs patients and staff about air-pollution emergencies, such as elevated pollutant levels.	11/24 (45.8%)	21/28 (75.0%)	29.2	0.046	0.307	3.37 (1.07 to 10.57)
30	Public awareness and risk communication	The health centre or hospital has programmes for timely dissemination of air-quality information, particularly during emergencies.	8/24 (33.3%)	14/28 (50.0%)	16.7	0.269	0.828	1.94 (0.64 to 5.84)
31	Response and recovery capacity	The health centre or hospital has specific protocols for responding to air-pollution emergencies.	21/24 (87.5%)	27/28 (96.4%)	8.9	0.324	0.865	2.98 (0.41 to 21.93)
32	Response and recovery capacity	The health centre or hospital can respond to large patient volumes during air-pollution emergencies.	13/24 (54.2%)	17/28 (60.7%)	6.5	0.779	0.985	1.30 (0.44 to 3.83)
33	Response and recovery capacity	During severe air pollution, the health centre or hospital effectively reallocates resources and equipment to meet increased needs.	12/24 (50.0%)	24/28 (85.7%)	35.7	0.007	0.098	5.44 (1.52 to 19.48)
34	Response and recovery capacity	The health centre or hospital responds rapidly to changes in air-quality conditions and adjusts resources effectively.	14/24 (58.3%)	24/28 (85.7%)	27.4	0.033	0.307	3.94 (1.09 to 14.20)
35	Response and recovery capacity	During an air-pollution emergency, the health centre or hospital effectively provides health services to vulnerable groups, including patients with respiratory or cardiovascular disease, older adults, and children.	20/24 (83.3%)	26/28 (92.9%)	9.5	0.397	0.985	2.33 (0.45 to 12.12)
36	Response and recovery capacity	The health centre or hospital has protocols to assess and follow the long-term health consequences of air pollution.	11/24 (45.8%)	14/28 (50.0%)	4.2	0.788	0.985	1.17 (0.40 to 3.43)
37	Response and recovery capacity	The health centre or hospital uses air-quality data to evaluate the effectiveness of its health-service response during emergencies.	11/24 (45.8%)	13/28 (46.4%)	0.6	1.000	1.000	1.02 (0.35 to 2.99)
38	Intersectoral collaboration	The health centre or hospital collaborates with governmental and non-governmental organisations to manage air-pollution emergencies.	14/24 (58.3%)	15/28 (53.6%)	-4.8	0.785	0.985	0.83 (0.28 to 2.44)
39	Intersectoral collaboration	The health centre or hospital actively participates in provincial or county working groups and committees concerned with air-pollution management.	24/24 (100.0%)	26/28 (92.9%)	-7.1	0.493	0.985	0.22 (0.01 to 4.73)
40	Intersectoral collaboration	The health centre or hospital collaborates with other agencies, such as municipalities and environmental authorities, to reduce air pollution.	24/24 (100.0%)	26/28 (92.9%)	-7.1	0.493	0.985	0.22 (0.01 to 4.73)

Difference is hospital minus health-network-unit affirmative percentage. Fisher exact p values were calculated from the original 2×2 tables. When a zero cell occurred, 0.5 was added to all four cells solely for estimation of the odds ratio and its 95% confidence interval. Benjamini–Hochberg false-discovery-rate (BH-FDR) adjustment was applied across all 40 item-level comparisons. No individual item remained statistically significant after FDR adjustment.

Table S2. Prespecified sensitivity analyses of facility-type domain differences

Domain	Primary diff.	Primary FDR p	Ahvaz combined diff.	FDR p	Corrected stored totals diff.	FDR p	Paired-area diff.	Paired p	Paired FDR p
Policies and governance	6.0	0.359	7.4	0.289	7.6	0.281	2.0	0.731	0.748
Infrastructure and resources	19.9	0.031	20.6	0.029	19.2	0.051	16.7	0.020	0.142
Staff training and empowerment	3.5	0.552	4.1	0.493	3.5	0.552	1.9	0.666	0.748

Domain	Primary diff.	Primary FDR p	Ahvaz combined diff.	FDR p	Corrected stored totals diff.	FDR p	Paired-area diff.	Paired p	Paired FDR p
Air-quality monitoring and evaluation	7.9	0.359	9.8	0.252	6.6	0.391	4.8	0.367	0.643
Public awareness and risk communication	9.2	0.253	10.4	0.168	10.5	0.145	6.3	0.162	0.379
Response and recovery capacity	13.3	0.195	14.4	0.143	13.3	0.145	10.9	0.053	0.187
Intersectoral collaboration	-6.3	0.359	-5.7	0.384	-6.3	0.388	1.6	0.748	0.748

Domain scores range from 0 to 100; differences are expressed as hospital minus health-network-unit percentage points. The Ahvaz-combined analysis contained 51 administrative analytical units. The corrected-stored-totals analysis used the corrected aggregate domain-total file. The paired analysis included 21 operational areas containing both facility types. The direction and approximate magnitude of the infrastructure difference were maintained across analyses, although multiplicity-adjusted statistical significance was not retained in every sensitivity analysis.

Table S3. County-level Spearman correlations between social vulnerability and adaptive-capacity domains

Domain	Health-network units ρ (bootstrap 95% CI)	p	FDR p	Hospitals ρ (bootstrap 95% CI)	p	FDR p
Policies and governance	-0.123 (-0.516 to 0.321)	0.586	0.849	0.129 (-0.365 to 0.573)	0.578	0.759
Infrastructure and resources	0.103 (-0.329 to 0.512)	0.649	0.849	0.185 (-0.279 to 0.598)	0.422	0.759
Staff training and empowerment	-0.259 (-0.627 to 0.167)	0.244	0.849	0.147 (-0.307 to 0.588)	0.524	0.759
Air-quality monitoring and evaluation	-0.068 (-0.489 to 0.404)	0.765	0.849	0.331 (-0.150 to 0.720)	0.143	0.759
Public awareness and risk communication	0.043 (-0.410 to 0.481)	0.849	0.849	0.229 (-0.221 to 0.609)	0.318	0.759
Response and recovery capacity	-0.186 (-0.553 to 0.270)	0.406	0.849	-0.001 (-0.450 to 0.461)	0.998	0.998
Intersectoral collaboration	0.202 (-0.258 to 0.609)	0.368	0.849	-0.105 (-0.590 to 0.397)	0.651	0.759

The published Q index was used as the county-level social-vulnerability measure; higher Q indicates greater vulnerability. Health-network-unit correlations used 22 current-county summaries and hospital correlations used 21 current-county summaries. Confidence intervals are percentile bootstrap intervals from 10,000 resamples of geographic units using fixed seed 20260803. BH-FDR adjustment was applied separately across the seven domain correlations within each facility type. None of the correlations remained statistically significant after FDR adjustment.

Table S4. Exploratory facility-level cluster-robust models

Domain	Hospital coefficient (95% CI)	p	FDR p	Q coefficient per 0.01 (95% CI)	p	FDR p	N / county clusters
Policies and governance	2.9 (-8.0 to 13.8)	0.586	0.586	8.7 (0.9 to 16.6)	0.030	0.071	52/22
Infrastructure and resources	18.3 (6.4 to 30.1)	0.004	0.031	4.7 (-1.3 to 10.6)	0.117	0.164	52/22
Staff training and empowerment	2.8 (-5.7 to 11.2)	0.502	0.586	1.9 (-4.4 to 8.2)	0.542	0.542	52/22
Air-quality monitoring and evaluation	4.5 (-6.1 to 15.1)	0.390	0.586	9.6 (2.0 to 17.3)	0.016	0.071	52/22
Public awareness and risk communication	7.0 (-2.3 to 16.4)	0.134	0.313	6.2 (-0.4 to 12.7)	0.066	0.115	52/22
Response and recovery capacity	12.3 (2.2 to 22.4)	0.019	0.068	2.7 (-6.1 to 11.6)	0.527	0.542	52/22
Intersectoral collaboration	-4.3 (-18.6 to 10.0)	0.539	0.586	-5.7 (-10.4 to -1.0)	0.020	0.071	52/22

Each model included facility type and the continuous county social-vulnerability Q index. The hospital coefficient compares hospitals with county-level health-network units. Q coefficients are expressed per 0.01 increase in Q. Standard errors were clustered by current county using a finite-sample-corrected cluster-robust covariance estimator. These models were exploratory because only 22 county clusters were available.

Table S5. Sensitivity of social-vulnerability coefficients to geographic specification

Domain	Primary model Q coefficient (95% CI); FDR p	Excluding Karkheh/Dezpart proxies Q coefficient (95% CI); FDR p	Excluding Ahvaz Q coefficient (95% CI); FDR p
Policies and governance	8.7 (0.9 to 16.6); FDR 0.071	9.4 (2.7 to 16.1); FDR 0.030	-2.2 (-11.6 to 7.1); FDR 0.958
Infrastructure and resources	4.7 (-1.3 to 10.6); FDR 0.164	4.9 (-0.6 to 10.4); FDR 0.108	-2.7 (-13.5 to 8.1); FDR 0.958
Staff training and empowerment	1.9 (-4.4 to 8.2); FDR 0.542	2.3 (-3.5 to 8.1); FDR 0.408	-3.0 (-14.3 to 8.4); FDR 0.958
Air-quality monitoring and evaluation	9.6 (2.0 to 17.3); FDR 0.071	10.3 (3.8 to 16.7); FDR 0.024	-2.0 (-14.2 to 10.2); FDR 0.958
Public awareness and risk communication	6.2 (-0.4 to 12.7); FDR 0.115	7.0 (1.6 to 12.5); FDR 0.032	-0.9 (-12.4 to 10.6); FDR 0.958

Domain	Primary model Q coefficient (95% CI); FDR p	Excluding Karkheh/Dezpart proxies Q coefficient (95% CI); FDR p	Excluding Ahvaz Q coefficient (95% CI); FDR p
Response and recovery capacity	2.7 (-6.1 to 11.6); FDR 0.542	3.6 (-3.7 to 10.9); FDR 0.369	-10.0 (-21.8 to 1.7); FDR 0.634
Intersectoral collaboration	-5.7 (-10.4 to -1.0); FDR 0.071	-5.3 (-10.6 to -0.1); FDR 0.082	0.3 (-9.6 to 10.2); FDR 0.958

The proxy-exclusion analysis removed units assigned parent-county Q values for Karkheh and Dezpart (N=49; 20 county clusters). The Ahvaz-exclusion analysis removed all Ahvaz units (N=43; 21 county clusters). Several positive Q associations strengthened after exclusion of the proxy-assigned counties, whereas exclusion of Ahvaz attenuated or reversed the associations. This sensitivity to geographic specification precluded interpretation as stable county-level gradients.

Table S6. Measurement-property summary

Scale/domain	Items	Pilot Cronbach α	Main-sample KR-20	Interpretive note
Policies and governance	7	0.85	0.526	Operational grouping; internal consistency interpreted descriptively.
Infrastructure and resources	6	0.78	0.584	Operational grouping; internal consistency interpreted descriptively.
Staff training and empowerment	5	0.71	0.650	Operational grouping; internal consistency interpreted descriptively.
Air-quality monitoring and evaluation	6	0.83	0.554	Operational grouping; internal consistency interpreted descriptively.
Public awareness and risk communication	6	0.71	0.549	Operational grouping; internal consistency interpreted descriptively.
Response and recovery capacity	7	0.81	0.657	Operational grouping; internal consistency interpreted descriptively.
Intersectoral collaboration	3	0.66	0.308	Three-item grouping; coefficient interpreted cautiously.
All 40 adaptive-capacity items	40	—	0.883	Descriptive overall binary-item coefficient; not evidence of a single latent construct.
Managers' perceived-preparedness instrument	20	0.91	Not recalculated	Pilot total-scale alpha; item-level manager responses were unavailable in the revision archive.

Pilot Cronbach alpha values are from archived instrument-development records. Main-sample KR-20 coefficients are descriptive internal-consistency estimates for the dichotomously scored operational item sets and do not establish unidimensionality or construct validity. Archived records reported overall CVR/CVI values of 0.80/0.79 for the primary instrument and 0.89/0.85 for the managers' instrument; the exact item-to-scale aggregation method for these overall coefficients could not be reconstructed from the available records. CVR, Content Validity Ratio; CVI, Content Validity Index; KR-20, Kuder–Richardson Formula 20.

Statistical conventions

Primary robustness procedures used 10,000 stratified bootstrap replications and 50,000 two-sided label permutations with fixed seed 20260803. Unless otherwise stated, p values are two-sided. CI, confidence interval; FDR, false discovery rate; OR, odds ratio; pp, percentage points; Q, published county social-vulnerability index.