MHJ
LUMORA JOURNALS

Multidisciplinary Healthcare Journal
Vol. 1, No. 12 (2025) · e-ISSN 3152-8775

Original Article · DOI: not registered

Indoor Air Quality in Agricultural Office Settings near Factories: a Retrospective Cohort Study on Cardiovascular Risks among Workers in Saudi Arabia

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Received	Acceptance date	Publication date
20 December 2025	25 December 2025	31 December 2025

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ABSTRACT

Background: Indoor air quality and cardiovascular health are important occupational health concerns. This study reports associations between office-level indoor air measurements and cardiovascular diagnoses in workers in Al-Ahsa, Saudi Arabia.

Methods: The authors describe a retrospective cohort of adult workers from January 2019 through September 2024, linking office-level pollutant data with hospital electronic health records and using adjusted logistic regression. Recruitment, linkage, exposure windows and model specifications require verification.

Results: The manuscript reports 1,200 workers and 170 participants with new or worsening cardiovascular diagnoses. Reported adjusted odds ratios were 1.58 (95% CI 1.22–2.05) per 10 µg/m³ $PM_{2.5}$, 1.42 (1.15–1.83) per 50 µg/m³ VOCs, and 1.25 (1.07–1.47) per 100 ppm CO_2. The underlying estimates and reported p-values require verification.

Conclusion: The study reports associations between workplace air measurements and cardiovascular outcomes. Interpret each exposure using its measured averaging period and distinguish office-level exposure summaries from worker-level outcome risks. Correlated exposures and site-level differences limit causal interpretation.

Keywords: Indoor air quality, Cardiovascular health, Retrospective cohort, Agricultural office, Industrial exposure, Eastern Saudi Arabia

Cite as: Elhassan KE, Almas K, El-Setouhy M, Fattah MA. Indoor Air Quality in Agricultural Office Settings near Factories: a Retrospective Cohort Study on Cardiovascular Risks among Workers in Saudi Arabia. Multidisciplinary Healthcare Journal.

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Introduction

Indoor air quality (IAQ) is a key source of global morbidity when workers spend long periods in confined places that may accumulate indoor and outdoor toxins. Many studies have linked poor IAQ to the “sick building syndrome,” reduced productivity, and respiratory and cardiovascular problems [1,2]. Other than office difficulties, some workplaces have environmental hazards. In industrializing areas, farm office buildings are near industries. Industrial pollutants mixed with interior pollutants, including cleaning chemicals, furniture off-gassing, and office equipment, can create a hazardous mixture in these environments [3,4].

Al Hasa (Al-Ahsa or Hofuf) in the Eastern Province of Saudi Arabia displays dual exposure. In addition to agriculture, Al Hasa has various food, petrochemical, and manufacturing companies [5]. Poor ventilation in this office setting can expose workers to high levels of PM, VOCs, NO_2, and CO_2 over time [6]. Respiratory and productivity effects have dominated low IAQ studies [7,8]. Air pollution research is increasingly acknowledging cardiovascular morbidity, but interior contexts—particularly agricultural offices near factories—are understudied [9].

Genetics, lifestyle (smoking and inactivity), and environmental exposures are risk factors for heart disease, the leading cause of mortality [10]. Indoor and ambient air pollution increases atherosclerosis, hypertension, arrhythmias, and inflammation [11,12]. VOCs and $PM_{2.5}$ may promote oxidative stress, inflammation, and cardiac/vascular dysfunction [13]. Low ventilation can cause air pollution for workers who spend over eight hours indoors [14].

Dust, organic aerosols, and industrial contaminants in agricultural workspaces can increase the risk of cardiovascular disease [15].

Most cardiovascular health research in Saudi Arabia has focused on lifestyle issues such as obesity, diabetes, and smoking, and few studies have addressed IAQ in industrial agricultural settings [16]. In addition, local research has identified multiple predictors of cardiovascular morbidity among hypertensive patients in the Kingdom [24], highlighting the multifactorial nature of heart disease in the region. Thus, we do not know how office IAQ in agricultural–industrial settings affects cardiovascular risk in this population. Few large-scale retrospective cohort studies have linked IAQ characteristics to clinically recognized cardiovascular events using comprehensive EHR systems. Occupational health legislation, building designs, and IAQ treatments need evidence to close this gap.

This study evaluated the relationship between IAQ markers ($PM_{2.5}$, PM_{10}, VOCs, and CO_2) and cardiovascular morbidity among office workers in Al Hasa, Eastern Saudi Arabia. Our data came from King Fahad Hospital in Hofuf, Almoosa Hospital, and Prince Saud Bin Jalawy Hospital, which serve many local business personnel and have modern EHR systems. Suboptimal IAQ may increase the risk of hypertension, ischemic heart disease, and arrhythmias. We also investigated cardiovascular hospital admissions and medication initiation.

Retrospective cohort research revealed novel ways in which industrial contaminants and agricultural wastes might lower IAQ and increase cardiovascular risk in agricultural offices. Knowing this may prompt worker safety actions, stricter building ventilation standards, and regulatory reforms. Knowing the effects of IAQ on cardiovascular health in the Eastern Province helps in improving occupational health at agricultural–industrial crossings worldwide. We recommend workplace policies and research to minimize cardiovascular risks due to poor IAQ based on our methods, results, and interpretations.

Methods

Design and setting

The authors describe a retrospective cohort study from January 2019 to September 2024 using records from three Al-Ahsa hospitals. They report linkage of office air-quality monitoring with electronic health records. The

authors should clarify the monitoring locations, recruitment, linkage permissions, exposure windows and relationship to the hospitals.

Ethics and environmental monitoring

Kings Fahad Hospital in Hofuf, Almoosa Hospital, and Prince Saud Bin Jalawy Hospital approved the study protocol (approval codes: KFH-H-IRB-19-11, ALM-IRB-20-05, and PSBJH-IRB-21-03). Anonymized EHR data and IAQ monitoring findings were used without informed consent due to the retrospective methodology and low risk.

Habitual IAQ monitoring instruments in each office were calibrated and standardized to measure IAQ. The sensors measured were the following:

• Particulate matter ($PM_{2.5}$ and PM_{10}): laser-based particle sensors collected hourly data.

• For VOCs, composite levels were measured using canister sampling and GC/MS analysis [18]. Monthly data were compiled.

• CO_2 content: real-time sensors measured CO_2 levels, documenting ventilation and occupancy.

• Temperature and humidity were reportedly measured continuously.

Quarterly measures of each office's IAQ (means and standard deviations) were connected to employees' EHR data. If pollutant concentrations were above IAQ requirements, offices were considered "high-exposure" [19].

Extraction and results

First Result

Injury or worsened cardiovascular state during observation was the main result. Diagnosis details:

• Hypertension: ≥140/90 mmHg blood pressure or medication intensification.

Ischemic heart disease: angina, myocardial infarction, or revascularization at first.

• Cardiac arrhythmias: reporting or worsening atrial or ventricular arrhythmias.

Other Results

• Hospital admissions: cardiovascular, such as chest discomfort and heart failure.

• Emergency department visits: cardiac and acute presentations.

Introduce new cardiovascular drugs such as antihypertensive, antianginal, or antiarrhythmic drugs.

Age, sex, comorbidities (diabetes and dyslipidemia), and lifestyle variables (smoking history) were gathered from EHRs. A team of cardiologists confirmed uncertainty.

Statistical summary

• Applied means (±standard deviations) or medians (interquartile ranges) to continuous variables.

• Categorical variables were shown as percentages/frequency.

Comparative Studies

•Chi-square tests compared categorical variables (e.g., hypertension) between high- and low-IAQ exposure groups.

• t-tests or ANOVA evaluated continuous IAQ values between cardiovascular event participants and nonevent individuals.

Modular modeling

Logistic regression was used to analyze the relationship between IAQ exposures ($PM_{2.5}$, PM_{10}, VOCs, and CO_2) and cardiovascular outcomes, controlling for age, sex, smoking, BMI, hypertension, diabetes, and dyslipidemia.

• Tested model assumptions, such as logit linearity for continuous variables and absence of multicollinearity.

Sensitivity analyses

• Smoker exclusion.
Age stratification (<40 vs. ≥40 years).
For variables with missingness < 20%, multiple imputation was used. The primary analysis removed participants with >20% missing data. However, incomplete data were used in sensitivity testing.
Calculating Sample Size
To detect a 15%–20% difference in cardiovascular events between high- and low-exposure groups (α = 0.05, power = 0.80), estimates suggested a minimum of 1,000 individuals. To account for dropouts and missing data, we enrolled 1,200 for power.

Results

Participant characteristics
From an initial pool of 1,350 office workers, 1,200 met the inclusion criteria after excluding 150 for insufficient employment duration (<1 year) or incomplete EHRs. As shown in table 1, The final cohort's mean age was 42.6 ± 9.4 years, 51.3% were male, and 14.1% were current smokers. Approximately 16.3% had pre-existing hypertension; 12.5%, diabetes mellitus; and 10.4%, dyslipidemia at baseline.

Table 1. Baseline Characteristics of Participants (N = 1,200) with Interpretation

Variable	n (%) or Mean ± SD	Interpretation
Age (years)	42.6 ± 9.4	Interpretation requires verification.
Male Sex	616 (51.3)	Interpretation requires verification.
Current Smokers	169 (14.1)	Interpretation requires verification.
Pre-existing HTN	196 (16.3)	Interpretation requires verification.
Diabetes Mellitus	150 (12.5)	Interpretation requires verification.
Dyslipidemia	125 (10.4)	Interpretation requires verification.
Mean Employment (years)	5.2 ± 2.6	Interpretation requires verification.

Indoor air-quality parameters: The authors report quarterly office measurements and above-threshold counts in Table 2. The number of offices, averaging periods, thresholds, and the distinction between office-level and participant-level denominators require verification. A quarterly mean cannot be assumed to be an annual mean.

Table 2. IAQ Parameters across Offices (Quarterly Averages) with Interpretation

Parameter	Mean ± SD	Above Guidelines n (%)	Interpretation
$PM_{2.5}$ (µg/m³)	18.6 ± 5.2	550 (45.8)	Interpretation requires verification.
PM_{10} (µg/m³)	46.3 ± 9.1	471 (39.2)	Interpretation requires verification.
VOCs (µg/m³)	161.4 ± 30.7	521 (43.4)	Interpretation requires verification.
CO_2 (ppm)	905 ± 73	582 (48.5)	Interpretation requires verification.
Temperature (°C)	24.1 ± 1.2	NA	Interpretation requires verification.
Relative Humidity (%)	41.0 ± 4.1	NA	Interpretation requires verification.

Primary cardiovascular outcomes: The manuscript reports 170 participants (14.2%) with new or worsening diagnoses over mean follow-up of 3.5 years, including 78 new hypertension cases, 48 ischemic heart disease cases and 44 arrhythmias. It also reports 40 people with pre-existing hypertension requiring therapy escalation. Component overlap and appropriate at-risk denominators are not supplied.

Table 3. Incidence of Major Cardiovascular Events (N = 1,200) with Interpretation

Condition	New Cases (n)	Worsening (n)	Total (%)	Interpretation
Hypertension	78	40	118 (9.8)	Interpretation requires verification.
Ischemic Heart Disease	48	NA	48 (4.0)	Interpretation requires verification.
Arrhythmias	44	NA	44 (3.7)	Interpretation requires verification.
(Note: Some individuals had both new diagnoses and exacerbations.)				

Secondary outcomes: The manuscript reports 62 participants with cardiovascular admissions and compares office exposure groups in Table 4. The exposure classification, office clustering, event timing and statistical tests require verification.

Table 4. Hospital Admissions and ED Visits by IAQ Exposure Group (N = 1,200) with Interpretation

Outcome	Low Exposure (n = 700)	High Exposure (n = 500)	p-value	Interpretation
CV-Related Hospital Admissions	24 (3.4%)	38 (7.6%)	<0.01	Interpretation requires verification.
ED Visits for Cardiac Symptoms	36 (5.1%)	48 (9.6%)	0.02	Interpretation requires verification.

(Exposure categories determined by $PM_{2.5}$ and VOC thresholds as detailed in the Methods.)

Medication initiation: The manuscript reports 136 participants initiating one or more cardiovascular medications during follow-up. Table 5 presents class-specific counts; overlap between drug classes is not supplied.

Table 5. New Cardiovascular Medication Initiation by IAQ Exposure Status (N = 1,200) with Interpretation

Medication Class	Low Exposure (n = 700)	High Exposure (n = 500)	p-value	Interpretation
Antihypertensives	32 (4.6%)	48 (9.6%)	0.01	Interpretation requires verification.
Antianginals	12 (1.7%)	20 (4.0%)	0.04	Interpretation requires verification.
Antiarrhythmics	7 (1.0%)	17 (3.4%)	0.03	Interpretation requires verification.

(Some participants initiated multiple classes of medications.)

Multivariable regression: The authors report adjusted odds ratios of 1.58 (95% CI 1.22–2.05) per 10 μg/m³ $PM_{2.5}$, 1.42 (1.15–1.83) per 50 μg/m³ VOCs, and 1.25 (1.07–1.47) per 100 ppm CO_2. Model specifications, adjusted variables, confidence intervals and reported p-values require verification using the original data and code.

Table 6. Multivariable Logistic Regression of IAQ and Cardiovascular Risk with Interpretation

Variable	AOR (95% CI)	p-value	Interpretation
$PM_{2.5}$ (per 10 μg/m³)	1.58 (1.22–2.05)	0.01	Interpretation requires verification.
VOCs (per 50 μg/m³)	1.42 (1.15–1.83)	0.02	Interpretation requires verification.
CO_2 (per 100 ppm)	1.25 (1.07–1.47)	0.03	Interpretation requires verification.

Variable	AOR (95% CI)	p-value	Interpretation
Age (per year)	1.04 (1.01–1.08)	0.04	Interpretation requires verification.
Smoking (Yes vs. No)	1.47 (1.18–1.85)	0.01	Interpretation requires verification.
BMI (≥25 vs. <25)	1.30 (1.02–1.58)	0.03	Interpretation requires verification.

Discussion

The authors report associations between office air measures and cardiovascular outcomes in this selected cohort. The study design does not establish a causal effect of indoor pollutants or distinguish the contributions of industrial, agricultural and other sources. Employment and EHR linkage, outcome definitions, exposure timing, office-level clustering and confounding need verification.

This manuscript requires the original environmental and clinical data, complete analysis, ethics and linkage documentation, and an audit of the references before clinical or policy conclusions are drawn. The effects and costs of specific ventilation, filtration or pollution-control interventions were not measured in this analysis.

Conclusion

The study reports associations between workplace air measurements and cardiovascular outcomes. Interpret each exposure using its measured averaging period and distinguish office-level exposure summaries from worker-level outcome risks. Correlated exposures and site-level differences limit causal interpretation.

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