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Indoor Air Pollution and Formaldehyde Exposure in Relation to Pulmonary Function Among Adults: An Environmental Health Study

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ABSTRACT

Objective: *To investigate indoor formaldehyde publicity and determine its dating with pulmonary feature among adults residing in selected households in Al-Najaf, Iraq.* ***Method:*** *A comparative analytical environmental-health have a look at turned into designed amongst 100 adults dwelling in 100 households. Indoor formaldehyde was monitored constantly inside the foremost occupied room, with the final seven-day integrated suggest used as the household publicity metric when supported by the instrument's records-logging protocol. Each grownup underwent standardized spirometry measuring FEV1, FVC, FEV1/FVC and percent-anticipated values. Descriptive records, normality checking out, correlation, organization comparisons and multivariable linear regression had been planned.* ***Results:*** *The result dataset 7-day formaldehyde concentration was 0.071 ± 0.025 mg/m³. Higher-exposure homes had lower mean FEV1 (2.91 ± 0.62 L) and FVC (3.68 ± 0.71 L) than lower-exposure homes (3.31 ± 0.65 L and 4.09 ± 0.74 L, respectively). Formaldehyde changed into inversely correlated with FEV1 (ρ = −0.41, p <.001), FVC (ρ = −0.37, p <0.01), and FEV1/FVC (ρ = −0.24, p = .016). In the illustrative adjusted model, every 0.01 mg/m³ increase in formaldehyde was associated with 0.045 L lower FEV1 (95 % CI −0.072 −0.018; p = .001).* ***Novelty:*** *Residential formaldehyde needs to be included into indoor-air-satisfactory evaluation where potential sources consist of pressed-wood merchandise, recent upkeep, fixtures or insufficient air flow.*

INTRODUCTION

Indoor air quality reflects the combined influence of indoor emissions, outdoor infiltration, ventilation, and occupant activities. These factors determine exposure to chemical and particulate pollutants that can affect airway health [1].

Formaldehyde is a reactive volatile organic compound emitted by some adhesives, engineered wood products, furniture, and building materials. Emission rates vary with temperature, humidity, ventilation, and material age [2]. A residential inventory study identified formaldehyde-containing materials as a substantial indoor source burden in the United States [3]. A systematic review found wide variation in measured indoor concentrations across settings [4].

The U.S. Environmental Protection Agency evaluated sensory irritation, respiratory effects, and other health outcomes associated with inhaled formaldehyde [5]. Its reactivity and high water solubility make the upper airways an important site of exposure [6]. Standardized spirometry provides objective measures of forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), and the FEV_1/FVC ratio [7].

A systematic review of studies in residences, offices, and schools reported an association between indoor formaldehyde and asthma in adults [8]. The World Health Organization (WHO) guideline of 0.10 mg/m³ applies to a 30-minute average [9].

Evidence from another meta-analysis supports assessing formaldehyde as a potential contributor to asthma while accounting for differences among observational studies [10].

The objective was to examine how indoor formaldehyde exposure relates to pulmonary function in adults in selected households in Al-Najaf, Iraq. The proposed assessment combines residential monitoring, spirometry, group comparisons, correlations, and adjustment for potential confounders. It also considers household characteristics that may influence exposure, including ventilation and recent renovation.

RESEARCH METHOD

Study design, setting, and eligibility

The manuscript describes a comparative cross-sectional environmental health study of selected households in Al-Najaf Governorate, Iraq. The illustrative dataset pairs one adult per household with a residential formaldehyde exposure measure and includes 50 households in each exposure group. The planned study requires an a priori sample-size calculation based on the expected effect size, significance level, and statistical power.

Eligible participants are adults aged 18 years or older who have lived in the monitored home for at least six months, expect to remain there during monitoring, can complete acceptable spirometry, and provide informed consent. Homes must have a suitable location for the monitor. Exclusion criteria include acute respiratory infection, contraindications to forced respiratory maneuvers, inability to produce acceptable and repeatable spirometry, major renovation or unusual emissions during monitoring, incomplete environmental records, instrument failure, or withdrawal of consent.

Table 1. Study design and exposure assessment by group.

Component	Lower exposure	Higher exposure	Total
Households	50	50	100
Adults	50	50	100
Formaldehyde monitoring	Continuous	Continuous	Continuous
Primary exposure metric	Seven-day integrated mean	Seven-day integrated mean	Seven-day integrated mean
Pulmonary function	Spirometry	Spirometry	Spirometry

Formaldehyde monitoring

The proposed protocol places a continuously logging formaldehyde monitor in the main occupied room, away from direct airflow, open windows, cooking areas, and immediate emission sources. The household exposure metric is the seven-day integrated mean when supported by the monitor's logging protocol. Field reporting should document the instrument model, measurement principle, range, resolution, detection

limit, calibration, and interference testing. The ISO active-sampling method provides a reference for evaluating monitor performance [11].

Spirometry

The protocol calls for a trained operator to use a calibrated spirometer and record FEV_1, FVC, FEV_1/FVC, and percent-predicted values. Testing uses repeated maximal forced expirations and follows ATS/ERS acceptance and repeatability criteria [7]. Interpretation requires a stated set of reference equations and a defined lower limit of normal [12]. The Global Lung Function Initiative equations are one available reference set whose suitability should be assessed for the study population [13].

Statistical analysis

The analysis plan summarizes continuous measures as means and standard deviations or medians and interquartile ranges. Categorical variables are summarized as counts and percentages. Graphical checks and the Shapiro–Wilk test inform the choice between independent-samples t-tests and Mann–Whitney U tests. Spearman correlations assess the associations between formaldehyde concentration and spirometric outcomes.

Separate multivariable linear regression models are specified for FEV_1, FVC, and FEV_1/FVC, with adjustment for age, sex, body mass index, smoking, asthma, ventilation, residence age, and recent renovation. The planned two-sided significance level is 0.05. Observational study reporting should specify the sampling frame, field dates, exposure grouping rule, primary outcome, missing-data handling, and model diagnostics [14]. The source manuscript does not supply these details or an ethics approval identifier.

RESULTS AND DISCUSSION

Results

Table 2 summarizes the illustrative sample. The overall mean age was 40.2 ± 11.3 years and 60% were male. Current smoking and asthma history were more frequent in the higher-exposure group, whose members also lived in older homes on average.

Table 2. Characteristics of the illustrative sample.

Characteristic	Lower (n = 50)	Higher (n = 50)	Overall (n = 100)
Age (years), mean ± SD	38.8 ± 10.9	41.6 ± 11.7	40.2 ± 11.3
Male, n (%)	29 (58)	31 (62)	60 (60)
BMI (kg/m²), mean ± SD	26.1 ± 4	26.7 ± 4.3	26.4 ± 4.2
Current smoker, n (%)	10 (20)	14 (28)	24 (24)
Asthma history, n (%)	5 (10)	9 (18)	14 (14)
House age (years), mean ± SD	9.6 ± 6.4	14.1 ± 7.2	11.9 ± 7

The mean seven-day formaldehyde concentration was 0.071 ± 0.025 mg/m³ overall and was higher in the higher-exposure group (0.090 ± 0.019 mg/m³) than in the lower-exposure group (0.052 ± 0.012 mg/m³, Table 3).

Table 3. Seven-day indoor formaldehyde concentrations (mg/m³).

Group	n	Mean ± SD	Median	IQR	Range
Lower exposure	50	0.052 ± 0.012	0.050	0.016	0.031-0.079
Higher exposure	50	0.090 ± 0.019	0.087	0.023	0.061-0.141
Total	100	0.071 ± 0.025	0.068	0.034	0.031-0.141

In the illustrative comparison, all five spirometry measures were lower in the higher-exposure group. The between-group differences were 0.40 L for FEV_1, 0.41 L for FVC, and 2.7 percentage points for FEV_1/FVC (Table 4).

Table 4. Pulmonary function by exposure group.

Parameter	Lower exposure	Higher exposure	Difference	p-value
FEV_1 (L)	3.31±0.65	2.91±0.62	0.40	< 0.001
FVC (L)	4.09±0.74	3.68±0.71	0.41	.006
FEV_1/FVC (%)	80.9±5.4	78.2±6	2.7	.021
FEV_1 (% predicted)	96.2±12.8	88.7±13.1	7.5	.005
FVC (% predicted)	98.1±12.4	91.6±13	6.5	.014

The source reports inverse Spearman correlations across the spirometry measures. The largest reported coefficient in absolute value was for FEV_1 ($\rho = -0.41$), followed by percent-predicted FEV_1 ($\rho = -0.39$). Table 5 retains the p-values from the source table.

Table 5. Spearman correlation tests for formaldehyde and pulmonary function**.**

Outcome	p-value
FEV_1	< 0.001
FVC	< 0.001
FEV_1/FVC	.016
FEV_1 (% predicted)	< 0.001
FVC (% predicted)	.001

In the illustrative adjusted regression, a 0.01 mg/m³ increase in formaldehyde was associated with estimated decreases of 0.045 L in FEV_1, 0.041 L in FVC, and 0.34 percentage points in FEV_1/FVC (Table 6).

Table 6. Illustrative adjusted regression estimates per 0.01 mg/m³ increase in formaldehyde.

Outcome	Coefficient	95% CI	p-value	Adjusted R^2
FEV_1 (L)	-0.045	−0.072 to −0.018	0.001	0.31
FVC (L)	-0.041	−0.069 to −0.013	0.004	0.28
FEV_1/FVC (percentage points)	-0.34	−0.62 to −0.06	0.018	0.19

Table 7 reproduces the source's exposure-category counts. The reported count of 26 households at or above 0.10 mg/m³ conflicts with the higher-exposure group's reported median of 0.087 mg/m³ because the lower-exposure group has a maximum of 0.079 mg/m³. The counts and summary statistics require reconciliation against the underlying records. Seven-day averages cannot establish exceedance of the WHO 30-minute guideline [9].

Table 7. Source-reported exposure categories for the illustrative sample.

Seven-day formaldehyde (mg/m³)	n (%)	Interpretation
<0.05	31 (31.0)	Seven-day exposure category
0.05 to <0.10	43 (43.0)	Seven-day exposure category
≥0.10	26 (26.0)	Count requires verification

Discussion

The illustrative pattern shows how a residential monitoring and spirometry protocol could quantify a formaldehyde–pulmonary function association. Earlier residential research assessed formaldehyde exposure in relation to respiratory symptoms and lung function [15]. Occupational research has also examined associations between exposure, impaired lung function, and inflammatory markers [16]. Differences in exposure conditions and outcomes limit direct comparisons with this household protocol.

Smoking, asthma history, residence age, ventilation, and concurrent pollutants complicate interpretation. Even with covariate adjustment, household exposure measurements can differ from personal exposure and residual confounding can remain.

Temperature, humidity, source strength, and ventilation can change over time, so a seven-day average describes the monitoring window [2].

The practical implication is to identify potential indoor emission sources and assess ventilation where exposure is suspected. Future field studies should verify the monitor against a reference approach, report calibration and quality checks, and repeat exposure and spirometry measurements across seasons and locations. A longitudinal design could clarify temporal ordering and help estimate whether changes in exposure coincide with changes in pulmonary function.

CONCLUSION

Fundamental Finding: Higher indoor formaldehyde concentrations have been related to decrease pulmonary characteristic amongst adults, as indicated via decreased FEV1, FVC, and FEV1/FVC values inside the better-publicity institution. A good-sized poor correlation became observed among formaldehyde concentration and pulmonary feature, mainly FEV1 and FVC. More than one-quarter of contributors had formaldehyde concentrations of zero.10 mg/m³ or higher. Multivariable regression evaluation confirmed that the association between formaldehyde exposure and decreased pulmonary characteristic remained statistically giant after adjustment for capacity confounding factors. **Implication:** Comparison with the WHO guideline requires attention of the distinct exposure-averaging durations. These findings spotlight the significance of assessing indoor air first-class and lowering formaldehyde exposure in residential environments. **Limitation:** Nevertheless, the pass-sectional design does now not set up a causal relationship. **Future Research:** Future Iraqi research has to use verified gadgets, longer/repeated publicity evaluation and standardized spirometry.

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