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Original article

Impaired Respiratory Function among Workers and Residents Exposed to an Organic Fertilizer Plant in Swani, Libya

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Abstract
Occupational exposure to air pollutants in fertilizer production poses a significant risk to respiratory health. This study assessed the respiratory efficiency of workers and residents near an organic fertilizer factory in the Swani area, Libya. A cross-sectional study was conducted with 235 male participants, aged 20-59 years, who were free of pre-existing respiratory or cardiac diseases. Subjects were divided into three groups: Group I (control, unexposed to major air pollution sources), Group II (workers directly exposed at the factory), and Group III (residents living nearby). The primary measure of respiratory function was the Peak Expiratory Flow Rate (PEFR). Data were analyzed using paired t-tests with SPSS-PC software. Forty-seven patients completed the follow-up protocol. A statistically significant reduction in VAS scores for nasal obstruction was observed at all postoperative time points compared to preoperative baselines ($p<0.05$). Symptomatic improvement commenced at the first postoperative week and was sustained through the 3-month assessment. While a minor recrudescence in symptoms was noted at the 6-month follow-up, the mean VAS score remained significantly improved over the preoperative value ($p < 0.05$). Overall, 89.4% of patients reported satisfactory symptomatic improvement over the 6-month study period. Workers and residents in proximity to the fertilizer factory in Libya are at an elevated risk of developing occupationally and environmentally related pulmonary impairments. These findings underscore the urgent need for enhanced control measures for vapors and gases at existing sites.
Keywords. Occupational Health, Peak Expiratory Flow Rate, Air Pollution, Libya.

Introduction

Industrialization, while crucial for economic development, often introduces significant occupational and environmental health risks, primarily through air pollution. Workplace pollution is defined by the presence of hazardous materials, with airborne contaminants including particulate matter, vapors, and gases representing the most common form of exposure [1]. Prolonged inhalation of these pollutants, even at low concentrations, is associated with a spectrum of adverse health effects, contributing substantially to global morbidity and mortality [1,2]. The burden is particularly acute in developing nations, where challenges such as inadequate waste management and limited regulatory oversight can exacerbate exposure levels [3].
The human health impacts of air pollution are profound and well-documented. Environmental pollutants are significant contributors to a range of human diseases, affecting climate change and overall health, and leading to increased rates of illness and death [3]. Pulmonary function is often the first to be impaired upon exposure. A key tool for assessing respiratory health is the measurement of Peak Expiratory Flow Rate (PEFR), which is the maximal expiratory flow rate sustained for at least 10 milliseconds, expressed in liters per minute [4]. As a simple, reliable, and reproducible test, PEFR is widely used both in clinical settings for managing asthma and in occupational health for screening populations exposed to respiratory hazards [4, 5]. Its proper technique and interpretation are essential for accurate assessment [6].
Despite global recognition of these risks, significant knowledge gaps persist, specifically regarding the respiratory health of populations exposed to emissions from specific industries, such as organic fertilizer production, in regions with limited empirical data. A systematic understanding of the relationship between environmental hazards and health effects is often hindered by the difficulty in quantifying exposure and the lack of systematic monitoring [3]. This study, therefore, aims to investigate the respiratory efficiency, as measured by PEFR, among two exposed groups: workers and nearby residents of an organic fertilizer factory in the Swani area of Libya. By comparing their pulmonary function with an unexposed control group, this research seeks to provide localized evidence to inform public health policy and occupational safety measures.

Methods

Study Design and Population

A cross-sectional study was conducted involving a total of 235 male participants between the ages of 20 and 59 years. The study population was divided into three distinct groups. The first group, comprising 100 individuals, served as the control group and included participants with no occupational exposure to air pollution. These individuals were matched to the exposed groups in terms of age, sex, and socioeconomic status to ensure comparability. The second group consisted of 85 workers employed at the Swani organic fertilizer factory, who were directly exposed to vapors and gases during the course of their occupational activities. The third group included 50 residents living in proximity to the factory, who were environmentally

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exposed to emissions originating from the facility. Participants with a history of respiratory or cardiovascular diseases were excluded from the study to eliminate potential confounding factors. All individuals enrolled in the study provided voluntary informed consent prior to participation.

Data Collection
A structured questionnaire was administered to collect data on demographics, smoking status, occupational history, and exposure duration. Anthropometric measurements (height, weight) were recorded for all subjects.

Pulmonary Function Assessment
Peak Expiratory Flow Rate (PEFR) was measured using a mini-Wright peak flow meter, following the standardized 10-step protocol recommended by the American Lung Association (2022) and clinical guidelines [1, 2]. PEFR, expressed in liters per minute (L/min), was defined as the maximum expiratory flow rate sustained for at least 10 milliseconds.

Statistical Analysis
Data were analyzed using SPSS-PC version 14 [3]. Descriptive statistics (mean ± standard deviation) were computed for all variables. Group comparisons were performed using Student's t-test, with statistical significance set at $p < 0.05$. Data visualization was conducted using Microsoft Excel.

Results
Demographic and Baseline Characteristics
The study comprised a total of 235 male participants, distributed into a control group (Group I, n=100, 42.6%), factory workers (Group II, n=85, 36.2%), and nearby residents (Group III, n=50, 21.2%). The age distribution of the entire cohort is detailed in Table 1. The majority of participants (43.8%) were aged 30-39 years.A comparison of key anthropometric parameters revealed no statistically significant differences in age or height between the control group and either exposed groups, ensuring the groups were well-matched for these variables. While a numerical difference in mean weight was observed for residents, it was not statistically significant. These results are summarized in Table 2.

Table 1. Age Distribution of the Study Population (N=235)

Age Group (Years)	Frequency (n)	Percentage (%)
20 – 29	65	27.6
30 – 39	103	43.8
40 – 49	48	20.4
50 – 59	19	8.2

Table 2: Comparison of Anthropometric Parameters Between Groups (Mean ± SD)

Variable	Group I (Control) (n=100)	Group II (Workers) (n=85)	p-value	Group III (Residents) (n=50)	p-value
Age (years)	34.36 ± 0.80	34.18 ± 0.93	0.825	35.68 ± 1.29	0.404
Height (cm)	172.73 ± 0.63	173.29 ± 0.74	0.563	171.20 ± 1.09	0.200
Weight (kg)	77.91 ± 1.15	73.04 ± 1.48	0.090	88.70 ± 2.17	0.215

**A p-value less than 0.05 was considered statistically significant.*

Peak Expiratory Flow Rate (PEFR)
Analysis of the primary respiratory outcome, PEFR, demonstrated a significant impairment in both exposed groups compared to the unexposed controls.

Analysis of All Participants
As shown in Table 3, factory workers (Group II) exhibited a 14.8% reduction in mean PEFR compared to the control group (491.80 ± 16.61 L/min vs. 577.50 ± 6.69 L/min, $p < 0.001$). Residents (Group III) also showed a significant 9.9% reduction (520.59 ± 11.00 L/min, $p < 0.001$). The difference in PEFR between the two exposed groups (workers vs. residents) was not statistically significant ($p = 0.13$).

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Table 3: Comparison of PEFR (L/min) Among All Study Groups (Mean ± SD)

Comparison	Group I (Control)	Group II (Workers)	Group III (Residents)	% Decrease	p-value
Control vs. Workers	577.50 ± 6.69	491.80 ± 16.61	-	14.83%	**<0.001***
Control vs. Residents	577.50 ± 6.69	-	520.59 ± 11.00	9.85%	**<0.001***
Workers vs. Residents	-	491.80 ± 16.61	520.59 ± 11.00	5.53%*	0.130

**A p-value less than 0.05 was considered statistically significant.*

Sub-analysis of Non-Smokers

To control for the confounding effect of smoking, a sub-analysis was conducted on non-smoking participants (Table 4). The results consistently showed significant reductions in PEFR among non-smoking workers (12.4% decrease, $p < 0.001$) and non-smoking residents (6.0% decrease, $p = 0.02$) compared to non-smoking controls. The difference between non-smoking workers and residents remained non-significant ($p = 0.10$).

Table 4: Comparison of PEFR (L/min) Among Non-Smoking Participants (Mean ± SD)

Comparison	Group I (Control) (n=65)	Group II (Workers) (n=43)	Group III (Residents) (n=27)	% Decrease	p-value
Control vs. Workers	581.88 ± 8.48	510.00 ± 19.14	-	12.35%	**<0.001***
Control vs. Residents	581.88 ± 8.48	-	547.05 ± 13.24	5.95%	**0.02***
Workers vs. Residents	-	510.00 ± 19.14	547.05 ± 13.24	6.77%	0.100

**A p-value less than 0.05 was considered statistically significant.*

Discussion

This cross-sectional study provides significant evidence of respiratory impairment among both occupational workers and community residents exposed to emissions from an organic fertilizer factory in Libya. The substantial reduction in Peak Expiratory Flow Rate (PEFR) observed in exposed groups compared to carefully matched controls demonstrates clear adverse pulmonary effects from this environmental exposure. These findings contribute to the growing body of evidence linking industrial air pollution to respiratory health deterioration in both occupational and community settings.

The pathophysiological mechanisms underlying the observed PEFR impairment are well-documented in environmental health literature. Organic fertilizer production generates complex mixtures of particulate matter (PM2.5 and PM10), endotoxins, ammonia, hydrogen sulfide, and volatile organic compounds that function as potent respiratory irritants and sensitizers [1,2]. These pollutants can trigger inflammatory cascades in the respiratory epithelium, leading to bronchoconstriction, increased airway hyperresponsiveness, and elevated mucus production - all contributing to the reduced expiratory flow rates measured in our study [3,4]. The significant impairment among factory workers (Group II) demonstrates the particular severity of direct occupational exposure, consistent with findings from other industries with high inhalational risks, including agriculture and waste management [5,6].

The substantial PEFR reduction observed in nearby residents (Group III) extends our understanding of this public health issue beyond traditional occupational boundaries into environmental health. This pattern indicates that factory emissions are not confined to the immediate workplace but affect the broader community through atmospheric dispersion. This finding aligns with global evidence demonstrating that environmental air pollution contributes significantly to cardiopulmonary morbidity, with the World Health Organization estimating that air pollution causes approximately 7 million premature deaths annually worldwide [7,8]. The comparable degree of impairment between directly exposed workers and environmentally exposed residents suggests that continuous, lower-level community exposure may produce effects similar to higher-intensity occupational exposure, though through potentially different exposure dynamics.

Our methodological approach using PEFR measurement proved particularly effective for this population-based assessment. As established by Miller et al. (1992) and validated by Mrindha et al. (2011), PEFR provides a simple, reliable, and reproducible measure of ventilatory function, making it especially valuable for field studies and initial respiratory screening in resource-limited settings [9,10]. The consistency of our findings with studies employing more comprehensive spirometric measures, such as Juntarawijit's (2019) research on restaurant workers and Kaur et al.'s (2013) population studies, further validates PEFR's utility in detecting early-stage respiratory impairment in various exposure scenarios [5,11].

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The comparable PEFR reduction between workers and residents, despite their different exposure profiles, merits careful consideration. While workers experience more concentrated, direct exposure during working hours, residents face continuous, lower-level environmental exposure. This pattern has been observed in other industrial settings where both occupational and community exposures produce similar respiratory effects, suggesting that duration of exposure may compensate for intensity in determining overall health impact [12,13]. Furthermore, the cross-sectional nature of our study and sample size limitations may affect our ability to detect more subtle differences between these exposure groups.
Several methodological considerations should be acknowledged. The cross-sectional design establishes association rather than causation, though the strength of the association and its biological plausibility support a potential causal relationship. The use of PEFR as our primary outcome, while practical and validated, does not provide the comprehensive assessment of lung function that full spirometry would offer. Additionally, while we controlled for major confounders including smoking status, age, and height, residual confounding from factors such as nutritional status, previous respiratory infections, or indoor air pollution exposure cannot be entirely excluded.

Conclusion

This study demonstrates a significant association between exposure to organic fertilizer factory emissions and impaired lung function in both workers and nearby residents. The findings underscore an urgent need for a multi-level public health response. Immediate measures should include implementing factory engineering controls, mandating personal protective equipment for workers, and establishing respiratory health surveillance programs. Long-term solutions require stricter industrial zoning to separate factories from residential areas and public health education initiatives. Future research should employ longitudinal designs with direct exposure monitoring to better characterize health risks and guide effective prevention policies.

Conflict of interest. Nil

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