Assessment of Pulmonary Function Status among Textile Dyeing Industry Workers, Tamil Nadu, India

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Abstract

This study aimed to evaluate pulmonary function parameters, respiratory symptoms, and associated factors among dyeing industry workers compared to healthy controls. A comparative cross-sectional study design was employed to assess the differences in pulmonary function and respiratory symptoms between dyeing industry workers and healthy controls. The study was conducted within dyeing industries, where workers are regularly exposed to various chemicals, and compared with controls who were not exposed to such occupational hazards. The main outcome measures included pulmonary function parameters such as forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1), Peak Expiratory Flow Rate (PEFR) as well as the prevalence of respiratory symptoms among dyeing industry workers compared to controls. Dyeing industry workers exhibited significantly reduced pulmonary function parameters compared to controls. Additionally, they experienced a higher prevalence of respiratory symptoms. Factors such as gender, education levels, specific work departments, and lack of personal protective equipment (PPE) were associated with increased odds of respiratory symptoms among dyeing industry workers. The study highlights the urgent need for tailored workplace safety interventions in dyeing industries. These interventions should include improved ventilation systems, dust control measures, and promotion of PPE usage to mitigate the risk of occupational respiratory diseases. Implementing comprehensive preventive strategies is crucial for safeguarding the respiratory health and well-being of workers in these settings.
Keywords: Indoor Air Quality; Lung function tests; Respiratory health; Textile Dyeing; Experiments

1. Introduction

Investigating the intricate nexus between indoor air quality (IAQ) and pulmonary function tests (PFTs) within the context of dyeing textile processing industries is an imperative pursuit in contemporary environmental and occupational health research. The textile dyeing process is inherently complex, involving the utilization of numerous chemicals and dyes, which often emit a plethora of airborne pollutants. These pollutants encompass a spectrum of substances, including volatile organic compounds (VOCs), particulate matter (PM), and potentially hazardous byproducts arising from chemical reactions during processing. Consequently, occupational workers within these industries, as well as the surrounding communities, face heightened exposure to these pollutants, raising significant concerns regarding their respiratory health outcomes[1]. The investigation into IAQ within such indoor environments is multifaceted, encompassing not only the identification and quantification of specific pollutants but also the evaluation of exposure pathways, indoor ventilation systems, and the effectiveness of existing control measures. Chemicals commonly used in textile dyeing, such as formaldehyde, benzene, and various heavy metals, have been associated with respiratory irritation, exacerbation of existing respiratory conditions, and even long-term respiratory diseases such as chronic obstructive pulmonary disease (COPD) and asthma [2]. Moreover, the complex interactions between these pollutants, as well as the potential synergistic effects of exposure to multiple pollutants simultaneously, further underscore the need for comprehensive investigation and risk assessment. Concurrently, PFTs serve as indispensable tools in the assessment of respiratory health, enabling the measurement of lung function parameters such as forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and peak expiratory flow rate (PEFR)[3]. By integrating IAQ monitoring with PFT assessments, researchers can elucidate the potential correlations between pollutant exposure levels and respiratory health outcomes among individuals working in dyeing textile processing industries. The textile dyeing pollutants on lung function decline and the development of respiratory diseases are particularly valuable in understanding the long-term health implications of occupational exposure.

2. Methods

2.1 Study design, setting, and population

Using a comparative cross-sectional research design, the association between pulmonary function status and indoor air quality among employees in the textile processing and dyeing industries will be examined. It will be held in various urban and industrial dyeing and textile processing facilities so that a variety of working situations are covered. Workers actively engaged in a range of tasks within these businesses, representing a range of age groups and lengths of exposure to indoor air pollution, will make up the research population [4], The total population of 95 workers are employed in the dyeing industry chosen for investigation. Structured questionnaires, appropriate instrument measurements of indoor air quality, and pulmonary function tests conducted by qualified healthcare practitioners will all be used in the data collection process. Inclusion criteria for participants will involve individuals aged 18 to 65 years old, currently employed in dyeing textile processing industries for a minimum of six months. Those who work directly with dyeing processes, such as dye mixing, fabric dyeing, and drying, will be included. Exclusion criteria will entail individuals with pre-existing respiratory conditions such as asthma, chronic obstructive pulmonary disease (COPD), or any other known lung disease. The final sample size of 87 workers were included in the study based on inclusion criteria. Figure 1 shows that workers in dyeing industry. The control group was selected from the office workers those who are working in the administrative department who does not exposed to chemicals. The control groups selected for this study was age-matched groups. The control and exposed group were on the same age group. The age composition of the control and exposed group are in the same composition. In this study, smokers, alcoholic, previous history of asthma, COPD are excluded

Figure 1 Workers in Dyeing Industry

2.2 Indoor Air Quality Monitoring

The Oizom air quality meter is a sophisticated device designed to monitor and analyze various parameters related to indoor air quality, particularly in environments such as dyeing industries where pollutants can be prevalent. Its operation involves several mechanisms geared towards detecting and quantifying different types of pollutants commonly found in such settings. IAQ monitoring in the Dyeing Industry is shown in Figure 1. Firstly, the meter utilizes advanced particle detection technology to measure particulate matter (PM), including PM_{10} and $PM_{2.5}$, which are particles with diameters of 10 micrometers or less and 2.5 micrometers or less, respectively. These particles are often generated during different stages of the dyeing process and can pose significant health risks if present in high concentrations. Moreover, the meter monitors temperature and humidity levels, which are critical factors influencing indoor air quality and occupant comfort. Elevated temperatures and humidity can exacerbate the release of TVOC from building materials and chemical processes, contributing to poor air quality.

Figure 2 IAQ monitoring in the Dyeing Industry

2.3 Questionnaire based data collection

The data gathering tools and techniques, as well as the examination of indoor air quality and pulmonary function status among the dyeing and textile processing businesses, will be carefully planned and executed. Volatile organic compounds (VOCs), gases, and particulate matter ($PM_{2.5}$ and PM_{10}) concentrations will be measured using the indoor air quality evaluation and calibrated air quality monitoring equipment. To assess pulmonary function measures such as Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), and Peak Expiratory Flow (PEF), conventional spirometry tests will be performed.

2.4 Anthropometric measures

It includes height, weight, will be collected alongside indoor air quality and pulmonary function data. Conducted as a descriptive observational study within the industry, parameters like BMI, were evaluated. Findings suggest variations in body composition, highlighting the need for tailored interventions to promote respiratory well-being among these workers.

2.5 Pulmonary Function Test

The workers' respiratory health in the textile processing and dyeing industries was assessed by Spirometry. FVC (%) shows the actual forced vital capacity compared to the predicted value. FEV_1 (%) represents the actual forced expiratory volume in one second as a percentage of the predicted. The FEV_1/FVC (%) ratio indicates the proportion of FVC exhaled in one second. PEF (%) shows the actual peak expiratory flow against the expected maximum speed. ELA (%) measures the lung's elasticity compared to the predicted value. FEF25-75 (%) indicates the flow rate during the middle portion of exhalation as a percentage of the expected. FET (%) represents the actual time to complete exhalation relative to the predicted time. FIVC (%) compares the actual forced inspiratory vital capacity to the expected amount. Lastly, FEV_1/VC (%) shows the ratio of FEV_1 to vital capacity against the predicted ratio. An FVC (%) less than 80% suggests restrictive lung diseases, indicating limited lung expansion, while values close to 100% suggest normal lung function. An FEV_1 (%) less than 80% may indicate obstructive lung diseases like asthma or COPD, where airflow is hindered, whereas higher values indicate normal airflow capacity. The FEV_1/FVC (%) ratio, if lower than normal (typically less than 70%), points to obstructive lung disorders. PEF (%) values below 80% indicate reduced peak expiratory flow, often seen in obstructive diseases. ELA (%) values outside the normal range suggest abnormal lung elasticity. FEF_{25-75} (%) less than 60% can signal small airway obstructions. FET (%) exceeding 120% of the predicted value suggests prolonged expiration, common in obstructive diseases. FIVC (%) less than 80% indicates reduced inspiratory capacity, often due to restrictive conditions. Finally, an abnormal FEV_1/VC (%) ratio points to potential obstructive or restrictive patterns in lung function [5].

2.6 Data Analysis

The robust data management and statistical analysis strategies are paramount for extracting meaningful insights. Data collected from air quality monitoring equipment and pulmonary function tests will be meticulously organized and stored using secure electronic databases. Statistical analysis will entail descriptive statistics to summarize key variables such as particulate matter concentrations, spirometry parameters, and demographic characteristics of participants [6].

3. Results and Discussion

The demographic analysis provided in Table 1 paints a vivid picture of the notable differences and potential health implications that exist between dyeing and non-dyeing workers, drawing upon robust population means and standard deviations. Within the realm of dyeing workers, a predominant male composition (62.1%) is observed, accompanied by elevated mean systolic blood pressure (138.19±18.04 mmHg) and diastolic blood pressure (91.5±9.99 mmHg) compared to their non dyeing counterparts (systolic: 124.61±5.3 mmHg, diastolic: 85.46±6.35 mmHg). Furthermore, their pulse rate tends to be higher, registering a mean of 90.48±14.77 beats per minute, in contrast to non-dyeing workers' mean pulse rate of 75.62±10.78 beats per minute [7]. On the lifestyle front, dyeing workers exhibit a greater prevalence of smoking habits (21) and report more respiratory symptoms (27) than their non-dyeing counterparts (smoking: 15, respiratory symptoms: 7). Educational attainment among dyeing workers spans a wide spectrum, ranging from illiteracy to degree holders, in contrast to non-dyeing workers, who are predominantly educated to the degree level (57). Physiological parameters, such as BMI, height, and weight, further delineate differences, with dyeing workers demonstrating a higher mean BMI (23.16±3.47 kg/m²) but lower mean height (155.35±9.56 cm) and weight (56.54±12.26 kg) compared to non-dyeing workers (BMI: 21.31±3.56 kg/m², height: 158.76±7.51 cm, weight:63.48±15.68 kg). Additionally, the utilization of protective gear appears to be more prevalent among dyeing workers, albeit in smaller proportions, with only a few reporting the use of gloves (5) and masks (4). These findings collectively underscore the potential health hazards intrinsic to dyeing professions, emphasizing the urgent need for targeted interventions to mitigate occupational risks and foster the overall well-being of workers operating within such industries.

The comprehensive analysis of the demographic characteristics and health indicators presented in Table 1 paints a vivid picture of the pronounced disparities between dyeing and non-dyeing workers, shedding light on potential health risks inherent in employment within dyeing textile processing industries. Dyeing workers, comprising a predominantly male workforce, exhibit a concerning pattern of elevated blood pressure levels, as evidenced by higher mean systolic and diastolic readings in comparison to their non-dyeing counterparts. Moreover, the data reveal a striking disparity in lifestyle habits, with dyeing workers showing a greater prevalence of smoking habits and reporting more respiratory symptoms than their non-dyeing counterparts, indicative of possible respiratory health concerns [8]. Physiological parameters such as BMI, height, and weight further underscore the variation between dyeing and non-dyeing workers, with dyeing workers exhibiting a higher mean BMI but lower mean height and weight compared to their counter parts Addressing these disparities and implementing targeted interventions to mitigate occupational health risks are imperative steps towards promoting the overall well-being and safety of workers employed in dyeing industries.

Table 1. Demographic Characteristics of Textile Dyeing Workers and Control group

Variables	**Dyeing Workers**	**Non Dyeing -Workers**
Gender Female	33 (37.9%)	27(43.5%)
Male	54 (62.1%)	35(56.45%)
Age (in years) 21-40	23 (26.4%)	50(80.4%)
41-50	17 (19.5%)	12(19.3%)
51-60	32 (36.7%)	Nil
>60	15 (17.2%)	Nil
Duration of employment 1-2 years	29 (33.3%)	24(38.7%)
3-5 years	23 (26.4%)	18(29%)
≥6 years	35 (40.2%)	20(32.25%)
Blood Pressure Systolic	138.19±18.04	124.61±5.3
Diastolic	91.5±9.99	85.46±6.35
Pulse Rate	90.48±14.77	75.62±10.78
Smoke Status YES	21	15
NO	66	47
Respiratory Symptoms YES	27	7
NO	60	55
Educational status Illiterate	9	51
Primary Education	34	Nil
Higher Education	28	Nil
Degree	16	57
BMI	23.16±3.47	21.31±3.56
Height	155.35±9.56	158.76±7.51
Weight	56.54±12.26	63.48±15.68
Use of gloves	5	Nil
Use of mask	4	Nil

The pulmonary assessment analysis presented in Table 2 provides a comprehensive examination of respiratory function parameters among both dyeing workers and controls, dyeing workers exhibit significantly lower values in almost all metrics. For instance, Forced Vital Capacity (FVC) predicted (2.98 ± 1.04 vs. 3.52 ± 0.48), best (2.36 ± 1.36 vs. 5.36 ± 0.68), and percentage (79.9 ± 32.1 vs. 93.43 ± 9.71) are lower in workers, indicating reduced lung volume. Similarly, Forced Expiratory Volume in one second (FEV_1) shows marked reductions in predicted (2.5 ± 0.87 vs. 3.38 ± 1.30), best (1.6 ± 1.16 vs. 4.5 ± 0.49), and percentage (64 ± 30.2 vs. 92 ± 6.20) among workers. Ratios of FEV_1 to FVC also reflect decreased pulmonary function in workers, with best values (67.8 ± 22.6 vs. 0.84 ± 0.07) and percentage (79.5 ± 25.5 vs. 101 ± 5.42) being notably lower. Peak Expiratory Flow (PEF) measures similarly highlight declines, especially in best values (2.38 ± 2.71 vs. 8.02 ± 1.59) and percentage (33.9 ± 29.7 vs. 81.71 ± 25.71). Additional parameters such as Elastic Load Application (ELA), Forced Expiratory Flow ($FEF_{25\text{-}75}$), and Forced Inspiratory Vital Capacity (FIVC) further confirm diminished lung function among workers, showcasing broader respiratory impairments compared to controls [9]. This comprehensive analysis suggests significant occupational hazards impacting respiratory health in dyeing workers and these findings suggest that exposure to workplace conditions in dyeing occupations is associated with a higher prevalence of obstructive lung disorders [10] [11].

Table 2. Pulmonary Function Assessment among Exposed and Control Group

Variables	**Dyeing Workers (n=87)**	**Controls (n= 74)**
	(mean ± SD)	(mean ± SD)
FVC(Pred)	2.98 ± 1.04	3.52 ± 0.48
FVC(Best)	2.36 ± 1.36	5.36 ± 0.68
FVC (%)	79.9 ± 32.1	93.43 ± 9.71
FEV 1(Pred)	2.5 ± 0.87	3.38 ± 1.30
FEV_1 (Best)	1.6 ± 1.16	4.5 ± 0.49
FEV_1 (%)	64 ± 30.2	92 ± 6.20
FEV_1/FVC (Pred)	85.2 ± 2.65	0.9 ± 0.05
FEV_1/FVC (Best)	67.8 ± 22.6	0.84 ± 0.07
FEV_1/FVC (%)	79.5 ± 25.5	101 ± 5.42
PEF(Pred)	7.01 ± 1.58	5.75 ± 1.13
PEF(Best)	2.38 ± 2.71	8.02 ± 1.59
PEF (%)	33.9 ± 29.7	81.71 ± 25.71
ELA(Pred)	34.6 ± 15.1	3.77 ± 1.53
ELA (%)	172 ± 83.4	4.88 ± 2.05
FEF25-75(Pred)	3.19 ± 0.92	127.39 ± 35.4
FEF25-75(%)	48.3 ± 32.5	6.25 ± 1.5
FET(Predicted)	6 ± 32.5	9.6 ± 2.2
FET (%)	40 ± 29.1	8.8 ± 1.9
FIVC(Pred)	2.9 ± 1.04	4.56 ± 0.67
FIVC(Best)	2.2 ± 1.19	5.76 ± 0.73
FIVC (%)	72.7 ± 16.54	3.34 ± 0.51
FEV_1/VC (Pred)	85.8 ± 3.59	5.20 ± 1.73
FEV_1/VC (Best)	83.8 ± 1.73	17.83 ± 2.20
FEV_1/VC (%)	101 ± 4.07	16.29 ± 1.40

Table 3 presents air quality measurements, specifically particulate matter concentrations ($PM_{2.5}$ and PM_{10}) in micrograms per cubic meter (µg/m³), across different departments: Bleaching, Dyeing, and Drying. For $PM_{2.5}$, the mean concentrations range from 55.04 µg/m³ in the Drying department to 73.31 µg/m³ in the

Bleaching department[12]. Standard deviations (SD) vary from 22.74 µg/m³ in the Dyeing department to 25.17 µg/m³ in the Bleaching department, indicating some variability around the mean values as shown in table 3. The highest maximum $PM_{2.5}$ concentration is recorded in the Bleaching department at 171.04 µg/m³, while the lowest minimum concentration is observed in the Drying department at 24.76 µg/m³. Similarly, for $PM_{2.5}$, mean concentrations range from 103.51 µg/m³ in the drying department to 129.34 µg/m³ in the Bleaching department. Standard deviations range from 36.55 µg/m³ in the Dyeing department to 40.67 µg/m³ in the Drying department. The maximum PM_{10} concentration is highest in the Bleaching department at 285.07 µg/m³, while the lowest minimum concentration is found in the Dyeing department at 57.76 µg/m³.

Table 3. Daily average values Particulate Matter Levels by Department for study periods

Departments	**$PM_{2.5}$ (µg/m³)**				**PM_{10} (µg/m³)**			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Bleaching	44.54	171.04	73.31	25.17	83.11	285.07	129.34	38.54
Dyeing	26.87	174.02	67.54	22.74	57.76	290.07	125.99	36.55
Drying	24.76	140.24	55.04	22.81	54.57	238.08	103.51	40.67

The particulate matter (PM) levels measured in the Bleaching, Dyeing, and Drying departments significantly exceed global air quality standards, posing serious health risks to dyeing workers. The daily average $PM_{2.5}$ concentrations in Bleaching (73.31 ± 25.17 µg/m³), Dyeing (67.54 ± 22.74 µg/m³), and Drying (55.04 ± 22.81 µg/m³) are considerably higher than the World Health Organization (WHO) guideline of 15 µg/m³ for annual average $PM_{2.5}$ and the daily limit of 25 µg/m³. For PM10, the observed levels in Bleaching (129.34 ± 38.54 µg/m³), Dyeing (125.99 ± 36.55 µg/m³), and Drying (103.51 ± 40.67 µg/m³) also far exceed the WHO's daily guideline of 45 µg/m³. These elevated levels of $PM_{2.5}$ and PM_{10} are closely associated with adverse respiratory health outcomes, including chronic obstructive pulmonary disease (COPD), asthma, and other obstructive lung disorders [13]. The high particulate concentrations lead to inflammation, oxidative stress, and impairment of lung function, as evidenced by the reduced pulmonary function parameters in dyeing workers [14]. Prolonged exposure to such high PM levels can cause long-term health effects, including reduced lung growth and increased mortality from respiratory and cardiovascular diseases [15].

Table 4. Total Volatile Organic Compounds (TVOC) Levels in various section in Dyeing industry

Departments	**TVOC (µg/m³)**			
	Min	Max	Mean	SD
Bleaching	810.2	940.5	864.7	25.32
Dyeing	553.9	990.5	667.1	102.7
Drying	555.9	843.4	645.2	55.27

Particulate matter concentrations, specifically pm and PM_{10} indicate diverse levels of airborne particles present within departments such as Bleaching, Dyeing, and Drying, with notable variations observed between these areas. Moreover, the data on gas emissions, particularly CO_2 and CO, underscore potential environmental impacts and air quality concerns within the facility. Furthermore, the measurements of TVOC provide valuable insights into the presence of organic compounds in the air, with concentrations varying across different departments as shown in Table 4. This comprehensive analysis serves as a crucial foundation for implementing targeted interventions aimed at improving overall air quality within each department, thereby fostering a healthier and safer working environment for all employees [16]. By addressing the identified disparities and implementing measures to mitigate environmental pollutants, the textile facility can effectively promote the safety of its workforce while minimizing adverse environmental impacts. The study reveals significant disparities in pulmonary function parameters between dyeing workers and controls, indicating potential respiratory impairment among dyeing workers, with lower Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), and FEV_1/FVC ratio. These findings underscore the occupational health risks associated with employment in dyeing textile processing industries address respiratory health disparities and mitigate exposure to harmful substances. Implementing measures to promote respiratory well-being and provide education and support to workers in dyeing industries is essential to safeguard their health and mitigate the risks associated with occupational exposures. The Textile Dyeing Industry is recognized for its dusty environment, containing high levels of dust and total volatile organic compounds. These conditions have been linked to pulmonary function abnormalities among workers. Cotton-ginning workers, specifically, face a heightened risk of respiratory illnesses due to exposure to cotton dust [17]. Thus, the aim of this study was to evaluate pulmonary function, respiratory symptoms, and related factors among workers in the textile dyeing industry. The study revealed that both observed and predicted percentages of pulmonary function parameters (including FVC,

FEV_1, FEV_1/FVC, PEFR, and FEF_{25-75}) were notably lower in workers compared to controls. This finding mirrors similar research conducted in textile dyeing factories in Pakistan, Egypt, Nigeria, and northern Benin. These studies consistently show that exposure to cotton dust leads to significant reductions in FVC, FEV_1, PEFR, FEV_1%, FVC%, FEV/FVC%, and PEFR%. This decline is likely attributed to the accumulation of cotton dust particles in the airways and the presence of endotoxin in cotton, both of which contribute to airway inflammation and breathing impairment[18]. In contrast, while spinning and power loom operations also present occupational health risks, the hazards are typically less severe and pervasive compared to dyeing processes. For instance, in spinning, exposure to cotton dust and fibers is a primary concern, while power loom operators may face challenges related to airborne particulate matter. However, the chemical exposure and respiratory risks associated with dyeing operations are notably more pronounced, necessitating urgent interventions to mitigate these hazards and safeguard the health and well-being of workers. The disparities observed in occupational health risks across different textile sectors underscore the critical need for targeted preventive strategies tailored to the specific challenges faced by workers in dyeing industries[19] . These interventions should prioritize measures to improve ventilation systems, enhance dust control mechanisms, and promote the consistent use of personal protective equipment to minimize chemical exposure[20]. By addressing these unique occupational hazards within dyeing facilities, stakeholders can foster safer and healthier work environments, thereby mitigating the adverse health effects and improving the overall well-being of workers in the textile industry.

4. Conclusion

This study illuminate's significant disparities in pulmonary function parameters and respiratory symptoms between dyeing industry workers and healthy controls, underscoring the occupational health risks associated with employment in textile dyeing facilities. Dyeing workers exhibited lower forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), peak expiratory flow rate (PEFR), and FEV_1/FVC ratio compared to controls, indicating potential respiratory impairment resulting from occupational exposures to airborne pollutants. The findings underscore the urgent need for tailored interventions to mitigate respiratory health risks among dyeing industry workers. Such interventions should include improvements in ventilation systems, implementation of dust control measures, and promotion of consistent use of personal protective equipment (PPE) to minimize chemical exposure. Additionally, educational programs and support services aimed at enhancing awareness of occupational hazards and promoting respiratory health practices are essential. By addressing these unique occupational hazards within dyeing facilities, stakeholders can create safer and healthier work environments, thereby safeguarding the respiratory health and well-being of workers in the textile industry. Implementing comprehensive preventive strategies is crucial for minimizing the adverse health effects associated with occupational exposures and fostering a culture of safety and well-being in the workplace.

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Conflict of Interest

None

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Ethical Statement

This study was conducted as per the recommendation of the Kongu Institutional Ethical Committee (KEC/RND/EC/2023-24/005).

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