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Original Research Article

PULMONARY FUNCTION IMPAIRMENT AMONG SUGAR INDUSTRY WORKERS: A REGIONAL STUDY OF TAMIL NADU

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ABSTRACT

Background: Occupational health risks are (indeed) inherent in several industries, including sugar manufacturing. Workers in this field confront (chronic) exposure to dust and various chemical by-products. This study investigates pulmonary function impairments among sugar factory workers in Tamil Nadu; it focuses on the prevalence, types and risk factors associated with respiratory health issues. However, the complexities of these risks are multifaceted and it's crucial to understand (the) implications of long-term exposure. Although the data is compelling, more research is needed, because the health of these workers is paramount.

Materials and Methods: A cross-sectional study (conducted among 272 sugar factory workers) had participants who possessed at least one year of employment. Data collection involved semi-structured interviews and spirometry tests that measured Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1) and FEV1/FVC ratios. Workers were classified into exposure levels (based on their job roles) and logistic regression was performed to analyze risk factors. However, this approach has its limitations. Although the sample size is adequate, the findings may not be generalizable to all sugar factory workers because of potential confounding variables.

Results: The occurrence of pulmonary impairments stands at 27.9%, with restrictive impairments being the most prevalent (15.1%), followed by obstructive (9.9%) and mixed (2.9%) types. Interestingly, the prevalence of impairment escalated with dust exposure: it was 14.1% for mild exposure, 27.1% for moderate and 42.3% for severe exposure. Prolonged employment (>15 years) and smoking, combined with inconsistent use of respiratory protective devices, significantly elevated the risk of impairment. However, this multifactorial scenario underscores the need for better protective measures, because the consequences can be detrimental to health. Although some individuals may underestimate these risks, the data clearly suggests a strong correlation.

Conclusion: Workers in the sugar industry face a significant risk of developing pulmonary impairments because of chronic exposure to dust. Enhanced protective measures are crucial; however, routine health screenings and education on respiratory health are also necessary to mitigate risks. Findings indicate that targeted interventions are needed to safeguard worker health in high-risk occupational settings. Although these measures could be

effective, their implementation can be challenging. This is particularly important because the health consequences may be severe, thus emphasizing the urgency of addressing these concerns.
Keywords: Pulmonary function, sugar factory workers, occupational disease, dust exposure.

INTRODUCTION

All occupations have their own effects on health. The joint committee by International Labour Organization (ILO) and World Health Organization (WHO) in 1950 defined Occupational Health as the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations.[1]

The sugar industry (which is essential to both global commerce and local economies) serves as a major employer and a key contributor to agricultural income, particularly in countries like India. As the world's second-largest producer, India has witnessed its sugar industry expand rapidly, driven by a workforce predominantly sourced from rural areas. Tamil Nadu and Pondicherry, for instance, account for over 20% of India's sugar production, with approximately 40-50 sugar factories dispersed throughout the region.[2] This growth, however, is accompanied by considerable occupational health risks for workers who are exposed to dust particles and chemical by-products in the sugarcane processing environments. Although organic dust inhalation is a well-documented health hazard, studies consistently reveal significant pulmonary function impairments among sugar industry workers, largely because of chronic exposure to bagasse—a by-product recognized for causing hypersensitivity pneumonitis, commonly referred to as "bagassosis."[3,4,5]

Historically, research on occupational respiratory diseases within the sugar industry has primarily concentrated on regions such as Maharashtra. Here, studies have consistently documented diminished pulmonary function among factory workers who are exposed to bagasse dust. Findings have indicated reductions in various parameters, including forced vital capacity (FVC) and peak expiratory flow rate (PEFR), when compared to populations that are unexposed. For example, a study conducted in Maharashtra in 2012 identified pulmonary impairment rates of 31.97%. However, other research has pointed out significant reductions in lung volumes among individuals working in the more exposure-prone areas of sugar processing plants. Although these findings raise concern, they also underscore the need for further investigation into the long-term effects of such occupational hazards.[6,7,8]

Despite these insights, no extensive studies (on a large scale) have been conducted in Tamil Nadu or Pondicherry, which highlights a significant gap in regional occupational health. The current study addresses this gap by estimating the prevalence and extent of pulmonary impairment among sugar factory workers in Tamil Nadu and Pondicherry. By focusing on a new geographic region, this research aims to inform local health policies and interventions tailored to the needs of this under-researched worker population. With insights into both the prevalence of respiratory symptoms and the magnitude of impairment, the study hopes to emphasize the necessity of health protections, preventive measures and health education within the industry. However, the findings may be limited (because) they are specific to a particular context, but they could serve as a basis for further research in similar settings. Although the implications are significant, more comprehensive studies are needed to truly understand the full impact on worker health.

MATERIALS AND METHODS

The research endeavor sought to elucidate the prevalence of obstructive, restrictive and mixed pulmonary impairments among laborers in a sugar manufacturing facility located in Tamil Nadu. This investigation was conducted while also examining the correlation between lung function deficiencies and various occupational determinants. Moreover, the study aimed to compare pulmonary function metrics across disparate sections of the factory. In pursuit of these objectives, the researchers carried out a cross-sectional study involving eligible workers who possessed a minimum of one year of tenure at the facility and satisfied health criteria, which notably excluded individuals with recent surgical interventions or myocardial infarctions. Data acquisition encompassed a semi-structured interview methodology alongside spirometry assessments, thereby facilitating the collection of extensive demographic, occupational, personal health and respiratory symptomatology data. Additionally, this approach enabled the measurement of specific pulmonary function parameters. However, the complexity of the data necessitated careful consideration of potential confounding variables.

The methodology encompassed a seven-part interview process, meticulously crafted to elucidate factors pertinent to pulmonary health. The initial segments of the interview delved into participants' demographic details—such as age, education, socioeconomic status and familial context—to discern possible social determinants of health. The occupational history segment (which was crucial) amassed data regarding each worker's specific job function, the factory environment in which they were employed, their type of employment (be it

seasonal or permanent) and their aggregate years of service. This concentrated approach enabled researchers to scrutinize prospective exposure risks, predicated on the workplace milieu and duration of employment. Such insights are essential in probing the occupational connections to lung impairment; however, the complexity of these relationships demands rigorous analysis.

The personal health segment encompassed inquiries regarding lifestyle choices, placing particular emphasis on smoking and alcohol consumption—two factors which can profoundly influence lung functionality and heighten susceptibility to respiratory maladies. This section also meticulously documented information concerning the utilization of protective gear, notably respiratory masks and gloves, alongside any pertinent personal medical history related to cardiovascular or other chronic health ailments. Such data yielded valuable insights into potential individual health risk determinants for lung impairment, which may confound or exacerbate occupational exposure hazards.

The interview encompassed a range of specific inquiries regarding pre-lung function tests, which included (but were not limited to) questions on recent cigarette consumption, the prevalence of respiratory infections and any medications that could potentially influence the outcomes of the tests. The physical examinations conducted during this process meticulously measured height, weight, BMI, pulse and blood pressure. Furthermore, spirometry assessments, aimed at quantifying Forced Vital Capacity (FVC) and Forced Expiratory Volume (FEV1), were executed using a Schiller spirometer to evaluate lung function; notably, each worker performed the test three times to ensure the accuracy of the results. Ethical clearance was secured from Sri Ramachandra University and consent was duly obtained from both factory management and the participants involved. In addition, a pilot study carried out in a neighboring sugar factory proved instrumental in refining the questionnaire.

The pre-lung function assessment inquiries were instrumental in establishing the optimal timing for spirometry, taking into account recent smoking habits, respiratory infections, or pharmacological interventions that could potentially skew the results. Clinical examinations were meticulously executed to document baseline health metrics, which encompassed weight, height, BMI, pulse rate and blood pressure; such data were crucial for further refining the analysis by accounting for the overall health status and any extraneous (non-occupational) influences on pulmonary function. Spirometry tests, which are vital for the comprehensive evaluation of lung function, were conducted utilizing a Schiller spirometer to gauge key parameters: Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1) and the FEV1/FVC ratio. These measurements facilitated the categorization of pulmonary impairments into three distinct classifications: obstructive (characterized by a reduction in FEV1, a normal FVC and a low FEV1/FVC ratio), restrictive (defined by a diminished FVC with normal FEV1 and a normal or elevated FEV1/FVC ratio) and mixed impairments (marked by reductions in both FVC and FEV1, accompanied by a low FEV1/FVC ratio). Each participant underwent the spirometry assessment thrice, thus ensuring the consistency of the results. However, it is important to note that variations may still occur due to individual physiological differences.

The key respiratory impairments evaluated encompassed obstructive (characterized by narrowed airways), restrictive (defined by reduced lung expansion) and mixed pulmonary impairment. These classifications were predicated on the FVC and FEV1 ratios; however, BMI was computed to consider potential weight-related health effects. This process utilized criteria established by the World Health Organization (WHO), because understanding these metrics is essential for comprehensive pulmonary assessment. Although these classifications provide valuable insights, one must remain vigilant to the complexities inherent in respiratory health.

The investigation meticulously examined the disparities in pulmonary functionality among laborers situated in diverse sections of a factory, systematically classified according to their respective exposure levels. Workers engaged in departments such as accounts, human resources (HR) and security experienced negligible dust exposure; conversely, those employed in electrical and engineering roles encountered moderate exposure. However, individuals in cane processing and manufacturing were subjected to the highest concentrations of dust. This categorization not only facilitated a comparative analysis of lung function across the delineated exposure tiers but also delved into the ramifications of specific factory roles on respiratory health. The employed methodology—integrating comprehensive interviews, spirometric assessments and occupational exposure classification—enabled researchers to evaluate the prevalence of lung impairment and scrutinize the intricate associations linking pulmonary health with occupational determinants and job-specific exposure. Although this approach aligns with the overarching objectives of the study, it also underscores the complexity inherent in examining workplace health dynamics.

RESULTS

This investigation encompassed a cohort of 272 individuals employed in sugar manufacturing, primarily directed towards evaluating their pulmonary functionality and scrutinizing variables associated with pulmonary compromise. The participants exhibited a diverse age spectrum, ranging from 20 to 65 years, with a calculated mean

age of 42.7 years (SD = 8.4). Notably, the predominant demographic was male, accounting for 70.6% of the sample, whereas females constituted 29.4%. Demographic analysis disclosed a mean stature of 163.4 cm (SD = 6.1) coupled with a mean body weight of 68.3 kg (SD = 8.9), which culminated in a mean body mass index (BMI) of 25.5 kg/m² (SD = 4.2). This finding suggests that the majority of workers fell within the normal or marginally overweight BMI classification. However, it is worth noting that these physical characteristics exhibited no significant discrepancies between those employed seasonally and their permanent counterparts.

Pulmonary function tests (PFTs) have elucidated critical insights into the respiratory well-being of the workforce. Across the examined cohort, the mean Forced Vital Capacity (FVC) registered at 3.0 L (SD = 0.6), while the mean Forced Expiratory Volume in one second (FEV1) was recorded at 2.42 L (SD = 0.5). The calculated average FEV1/FVC ratio was 80.4% (SD = 6.8), a figure that comfortably resides within established normal parameters. However, pronounced sex-based disparities emerged within these metrics; females exhibited marginally elevated average values for both FVC (3.11 L) and FEV1 (2.49 L) in comparison to their male counterparts, whose values were FVC: 2.99 L and FEV1: 2.41 L. Although permanent and seasonal employees demonstrated analogous PFT outcomes, a subtle decline in pulmonary function was observed concomitant with extended years of employment and heightened exposure levels, because of the cumulative effects of environmental and occupational factors.

Prevalence of Pulmonary Impairment

Pulmonary impairment, characterized by deviations from normative pulmonary function test (PFT) values, was discerned in 76 workers, which constitutes 27.9% of the entire sample. Among these individuals, the predominant impairment detected was restrictive lung disease, affecting 41 workers (15.1%); however, obstructive impairments were noted in 27 workers (9.9%), with mixed impairments observed in 8 workers (2.9%). When evaluating impairment rates based on employment status, it is evident that permanent workers exhibited a marginally higher prevalence of impairment (30.1%) compared to their seasonal counterparts (24.7%). This discrepancy may suggest potential cumulative effects resulting from prolonged exposure to respiratory hazards within the sugar industry. Furthermore, the prevalence of impairment escalated significantly in accordance with increased dust exposure levels. Specifically, among workers experiencing mild dust exposure, the prevalence of any impairment was recorded at 14.1%; this figure rose dramatically to 27.1% for those with moderate exposure and reached 42.3% in individuals subjected to severe exposure. This discernible trend indicates a compelling association between dust exposure levels and respiratory impairments, thereby supporting the hypothesis that heightened occupational exposure to airborne particulates constitutes a considerable risk factor for the deterioration of pulmonary function.

Analysis of Risk Factors

In order to elucidate the intricate relationship between pulmonary impairment and a variety of occupational as well as personal factors, a logistic regression analysis was performed. A noteworthy association emerged between the length of employment within the industry and the degree of pulmonary impairment. Workers who had been employed for over 15 years in the sugar sector displayed nearly double the risk of impairment (Odds Ratio [OR] = 1.91; 95% Confidence Interval [CI]: 1.11–3.28) when juxtaposed with their counterparts who had fewer years of service. The prolonged exposure to dust and diverse respiratory irritants likely contributes to this heightened risk—this observation aligns with findings from analogous industrial inquiries. Furthermore, smoking represents another significant risk factor. Smokers exhibited 1.9 times the likelihood of developing pulmonary impairment compared to non-smokers (OR = 1.90; 95% CI: 1.09–3.32). Smoking not only exacerbates respiratory symptoms but also may hasten the decline of lung function in individuals already subjected to occupational pollutants. Because of this, a compounded effect on respiratory health becomes evident. This situation underscores the imperative for smoking cessation initiatives that are specifically designed for workers engaged in high-risk industries.

The utilization of respiratory protective devices (e.g., masks) has been shown to exert a significant protective effect. Workers who fail to employ respirators regularly exhibit more than double the odds of experiencing pulmonary impairment (OR = 2.14, 95% CI: 1.11–4.12) in comparison to their counterparts who consistently don such equipment. This salient finding underscores the critical nature of protective gear in alleviating the detrimental impacts of occupational dust exposure. Respiratory protection becomes particularly imperative in segments of the factory where dust concentration reaches its zenith, notably in the crushing and milling zones. However, a comparative analysis of pulmonary function across varying exposure levels reveals important insights into the necessity of these protective measures.

The analysis of FVC, FEV1 and FEV1/FVC ratios was conducted across varying levels of exposure (mild, moderate, severe) to ascertain the existence of a dose-response relationship between dust exposure and pulmonary function. Workers categorized under mild exposure exhibited average FVC and FEV1 values of 3.2 L and 2.5 L, respectively, accompanied by an FEV1/FVC ratio of 81%. Conversely, those within the severe exposure group reported average FVC and FEV1 values of 2.8 L and 2.3 L, respectively, along with an FEV1/FVC ratio of 79%. However, despite the subtlety of these

changes, the observed trend indicates a dose-dependent deterioration in lung function as exposure levels increase. This decline, although not deemed clinically significant in every instance, implies a potential cumulative impact of exposure on pulmonary health.

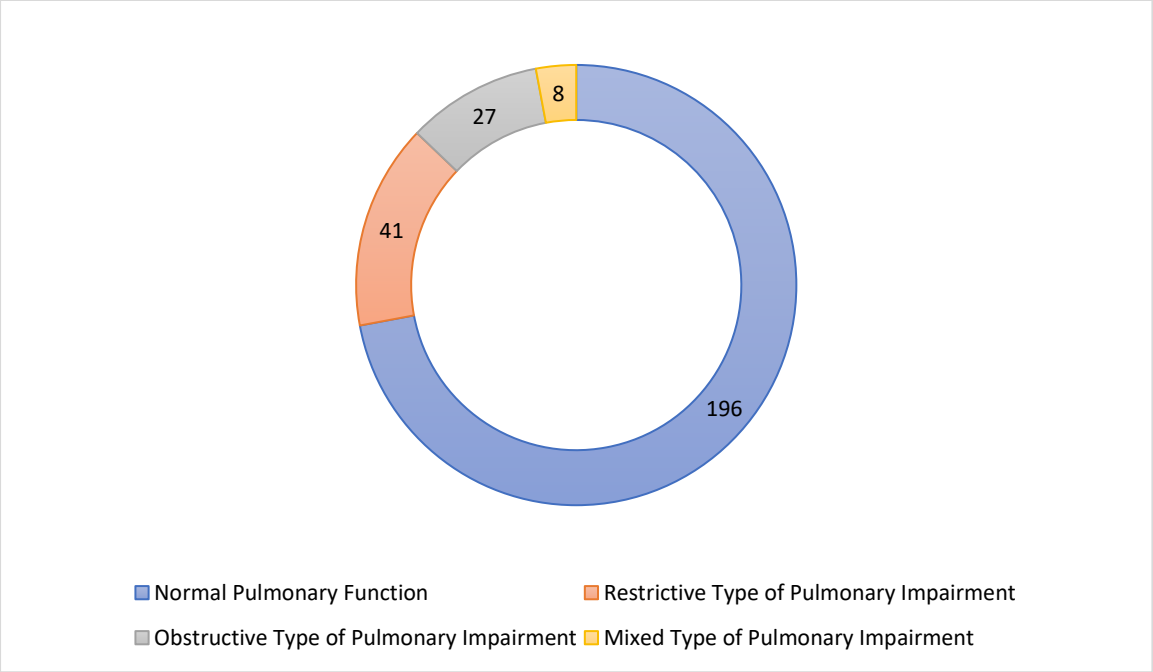

Figure 1: Pulmonary Function Result of the Workers

Table 1: Pulmonary function results among selected factors

Type of job status	Pulmonary Function			
	Normal	Restrictive	Obstructive	Mixed
Permanent	114	23	21	5
Seasonal	82	18	6	3
Exposure to Cane Dust	**Pulmonary Function**			
	Normal	**Restrictive**	**Obstructive**	**Mixed**
Mild	97	4	12	0
Moderate	35	3	9	1
Severe	64	20	20	7
Gender	**Pulmonary Function**			
	Normal	**Obstructive**	**Restrictive**	**Mixed**
Male	196	23	39	8
Female	15	4	2	0

Table 2: Association between pulmonary function impairment and selected factors

No. of years of work	N	Pulmonary Impairment		Odds Ratio	95% CI
		Present	Absent		
>15 years	137	47	90	1.91	1.11 to 3.28
≤15 years	135	29	106		
Type of work	**N**	**Pulmonary Impairment**		**Odds Ratio**	**95% CI**
		Present	**Absent**		
Seasonal	109	27	82	0.76	0.44 to 1.3
Permanent	163	49	114		
Hours of work per day	**N**	**Pulmonary Impairment**		**Odds Ratio**	**95% CI**
		Present	**Absent**		
>8hours	37	14	23	1.69	0.82 to 3.50
8 hours	235	62	173		
Exposure to cane dust	**N**	**Pulmonary Impairment**		**Odds Ratio**	**95% CI**
		Present	**Absent**		
Moderate & Severe	159	60	99	3.67	1.98 to 6.82
Mild	113	16	97		
Tobacco Smoking	**N**	**Pulmonary Impairment**		**Odds Ratio**	**95% CI**

		Present	Absent		
Smoker	83	31	52	1.90	1.09 to 3.32
Non – smoker	189	45	144		
Use of respirator mask	**N**	**Pulmonary Impairment**		**Odds Ratio**	**95% CI**
		Present	**Absent**		
No	194	62	132	2.14	1.11 to 4.12
Yes	78	14	64		

Table 3: Association between smoking status and PFT parameters

Smoking History	N	FVC Mean ±S.D	t – test	p – value
Smoker	83	2.96 ± 0.57	0.73	P = 0.46
Non – smoker	189	3.02 ± 0.64		
Smoking History	**N**	**FEV1 Mean ±S.D**	**t – test**	**p – value**
Smoker	83	2.39 ± 0.58	0.53	p = 0.59
Non – smoker	189	2.43 ± 0.57		
Smoking History	**N**	**FEV1/FVC Mean ±S.D**	**t – test**	**p – value**
Smoker	83	80.18 ± 9.25	0.25	p = 0.79
Non – smoker	189	80.47 ± 8.22		

DISCUSSION

The investigation elucidates a substantial correlation between employment in the sugar sector and an elevated susceptibility to pulmonary complications; this is particularly pronounced among individuals subjected to prolonged exposure to sugarcane dust, those lacking adequate respiratory safeguards and smokers. Workers predominantly exhibited restrictive impairments, presumably resulting from chronic inhalation of dust that induces fibrosis (i.e., scarring) within the pulmonary tissues. This observation accentuates the imperative for enhanced health protection measures in the workplace, including, but not limited to, routine respiratory evaluations, more rigorous enforcement of protective mask mandates and smoking cessation initiatives aimed at bolstering workers' respiratory well-being. The research quantified the Forced Vital Capacity (FVC) and Forced Expiratory Volume (FEV1) among sugar factory personnel, revealing that those exposed to diverse concentrations of cane dust demonstrated analogous FVC and FEV1 metrics across varying exposure gradients. These results resonate closely with antecedent investigations, such as those conducted by Nitin SN et al., which documented comparable FVC and FEV1 means among sugar factory employees across distinct functions.[6] However, minor discrepancies noted among studies were ascribed to factors including work environment, type of dust and demographic variables.

The investigation revealed a pulmonary impairment prevalence of 27.9% among laborers, with the restrictive variant being predominant (53.9%), succeeded by obstructive and mixed impairments. However, a separate study conducted by Nitin SN indicated a more elevated overall impairment rate, wherein obstructive impairment was more prevalent [6]. This discrepancy may be attributed to factors such as obesity among the workforce, climatic conditions, variations in equipment and differing usage of protective gear. Although these distinctions are apparent, they underscore the necessity for customized protective protocols and equipment standards specifically tailored for workers in the sugar manufacturing sector.

The data elucidated a correlation between respiratory symptoms and various determinants, including age, duration of employment and smoking history. Workers exceeding the age of 35 exhibited a heightened propensity for developing respiratory complications in comparison to their younger counterparts. Those with over 15 years of employment experience faced a marginally elevated risk; however, this increase lacked statistical significance. Notably, workers who refrained from utilizing respiratory masks were more than twice as likely to manifest respiratory symptoms when juxtaposed with those who adhered to consistent mask usage, thereby revealing a substantial association. Furthermore, smoking demonstrated a robust correlation with respiratory symptoms in a study conducted by Francis NDE among woodworkers, indicating that smoking exacerbates respiratory health in environments laden with dust (this is particularly crucial for occupational safety).[9]

In examining the occupational factors associated with pulmonary impairment, it becomes evident that prolonged tenure in the sugar factory markedly escalates the risk of such afflictions among workers, particularly those who have been employed for a duration exceeding 15 years. Permanent employees exhibit a higher susceptibility to impairment compared to their seasonal counterparts. Furthermore, smokers are identified as being nearly twice as likely to develop lung impairments than non-smokers. The utilization of respirator masks emerges as a pivotal factor; workers who neglect to employ this protective gear face a doubled risk of impairment, underscoring the essential nature of safety equipment in mitigating respiratory issues. Comparisons to other research—exemplified by P.

Vaidya's investigation involving educators—indicate analogous trends concerning diminished lung capacity among smokers.[10] However, this current inquiry did not reveal significant variances in Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1) between smokers and non-smokers. Although the findings affirm that smoking universally detracts from pulmonary function, they also suggest that the specific characteristics of the work environment can modulate this relationship.

The investigation also scrutinized pulmonary function among workers who reported chronic cough or phlegm production, revealing that individuals exhibiting a cough demonstrated markedly diminished FVC and FEV1 values compared to those devoid of respiratory symptoms. This outcome suggests that cough and phlegm may serve as preliminary indicators of respiratory deterioration, potentially exacerbated by dust exposure. These findings correspond with other occupational research indicating cough as an initial sign of dust-related pulmonary impairment.[11] Overall, the elevated incidence of restrictive impairment among sugar factory workers underscores long-term exposure to cane dust as a considerable risk factor for lung damage.[12] This study compels the factory health department to undertake regular pulmonary screenings to identify early signs of impairment, encourage the utilization of masks, mitigate smoking habits and provide education regarding respiratory health. Implementing these measures can prevent further respiratory complications and enhance overall worker health in the sugar industry, however, it necessitates a committed approach from all stakeholders involved.

CONCLUSION

The sugar industry in India, the second largest agro-based industry, employs half a million workers. However, the success of the sugar industry has come at the cost of worker's health due issues such as respiratory illness and pulmonary impairment that are caused by virtue of exposure to the workers to sugarcane dust. Pulmonary impairment was 27.9%, with restrictive impairment being the most common type. Factors such as smoking, work duration, and not using a respiratory mask were found to contribute to pulmonary impairment. The health unit division should screen workers' pulmonary function regularly, provide prompt treatment, and consider changing work stations to reduce bagasse exposure. Adequate health education on personal hygiene, respirator mask use, smoking cessation, and occupational health hazards is crucial. A supportive workplace environment and regular medical examinations are also essential.

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