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Impact of Construction Dust on Worker Respiratory Health and Mitigation Strategies

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Abstract
Construction dust is a significant occupational hazard that poses serious risks to the respiratory health of workers on construction sites. This project investigates the impact of airborne dust particles generated during various construction activities, such as demolition, cutting, and material handling, on workers' respiratory systems. Prolonged exposure to construction dust, which often contains silica, cement, and other harmful particulates, can lead to chronic respiratory diseases including silicosis, asthma, bronchitis, and other pulmonary complications. The study involves a comprehensive review of dust generation sources and the concentration levels typically found on construction sites. It also examines the correlation between dust exposure and the prevalence of respiratory symptoms among construction workers through field data collection, including air quality monitoring and health surveys. In addition to assessing health impacts, the project explores effective mitigation strategies to reduce dust exposure and protect worker health. These strategies include engineering controls such as water spraying, dust extraction systems, and the use of enclosures. Administrative controls, such as work scheduling and training, and the implementation of personal protective equipment (PPE) like respirators, are also evaluated. The project emphasizes the importance of an integrated approach combining monitoring, site safety protocols, and worker education to minimize respiratory risks. Identifying the most effective dust control measures, this study aims to provide practical recommendations for construction companies, occupational health professionals, and policymakers to improve workplace safety standards and promote healthier working environments.

Keywords: *Construction Dust, Respiratory Health, Air Quality Monitoring, Occupational Exposure, Mitigation Strategies.*

1. Introduction
The construction industry plays a vital role in infrastructure development and economic growth; however, it is also one of the most hazardous occupational sectors worldwide. Among the various risks present on construction sites, construction dust represents a significant yet often underestimated threat to worker health, particularly respiratory well-being. Dust generated during activities such as demolition, concrete cutting, drilling, grinding, and material handling contains fine particulate matter, including respirable particles such as $PM_{2.5}$ and PM_{10}. These particles can remain suspended in the air for extended periods and, when inhaled, penetrate deep into the lungs. Prolonged exposure to construction dust especially dust containing crystalline silica, cement particles, and other toxic substances has been strongly associated with a range of respiratory diseases, including silicosis, asthma, chronic bronchitis, and reduced lung function. Workers involved in high-dust tasks are particularly vulnerable, especially in environments where dust

control measures and personal protective equipment are inadequately implemented. In developing construction settings, lack of awareness, insufficient training, and poor regulatory enforcement further exacerbate these risks. This study, titled "Impact of Construction Dust on Worker Respiratory Health and Mitigation Strategies," aims to systematically evaluate dust exposure levels, assess their health impacts on workers, and analyze the effectiveness of various mitigation measures. By integrating air quality monitoring, worker health assessment, data analysis, and control strategy evaluation, the research seeks to provide practical, evidence-based recommendations to enhance occupational health and safety in construction environments [1].

2. Literature Review

Recent literature highlights construction dust as a critical environmental and occupational health concern with wide-ranging respiratory impacts. Ali Al Dousari and Hanan Al Khalaifah (2025) emphasize the importance of integrated dust mitigation policies and effective ventilation systems, particularly in densely populated and sensitive environments. Their findings show that strict regulatory targets and improved energy infrastructure, as demonstrated in regions such as Beijing–Tianjin–Hebei, can significantly reduce $PM_{2.5}$ levels and associated health risks. A systematic review by Arezoo Sarani et al. (2025) identifies early warning systems, intersectoral coordination, proper ventilation, PPE use, and staff training as key mitigation measures during dust hazards, especially in healthcare facilities. Similarly, Fatima Asad (2025) stresses that masons face heightened respiratory and physical risks, requiring proactive risk assessments, PPE compliance, and targeted safety training. Studies focusing on construction sites, including work by S Saravanakumar et al. (2025), confirm that excavation, demolition, and material handling generate elevated PM_{10} and $PM_{2.5}$ concentrations, adversely affecting both workers and nearby communities. Spatial and epidemiological analyses by Ajitesh Singh Chandel (2025) further reveal localized dust hotspots and increased respiratory symptoms among vulnerable populations. Overall, the literature consistently supports the need for integrated dust monitoring, engineering controls, administrative measures, and PPE to effectively mitigate respiratory health risks in construction environments.

3. Problem Identification

Construction dust has emerged as a critical occupational health problem affecting millions of workers worldwide. Activities such as cutting, drilling, grinding, mixing, and demolition generate large amounts of airborne dust containing hazardous materials like silica, cement, and wood particles. Prolonged exposure to these fine particles, especially respirable crystalline silica, can lead to serious respiratory illnesses including silicosis, chronic obstructive pulmonary disease (COPD), bronchitis, and even lung cancer. Despite the well-documented health risks, many construction workers remain unaware of the dangers posed by dust exposure. Poor implementation of safety regulations, lack of personal protective equipment (PPE), and inadequate dust control measures worsen the situation. In developing countries, informal labor practices and weak enforcement of occupational safety standards make the issue more severe. Workers often neglect protective measures due to discomfort, lack of training, or pressure to complete work quickly. Most construction sites lack effective ventilation and dust suppression systems, allowing harmful particles to remain suspended in the air. Continuous inhalation of such dust not only damages the respiratory system but can also affect cardiovascular health, productivity, and overall quality of life. Therefore, identifying, assessing, and mitigating the health risks associated with construction dust is an urgent necessity to ensure worker safety and promote sustainable construction practices [2].

- Continuous dust generation during construction activities
- Presence of harmful particles like silica and cement dust
- Poor awareness and lack of PPE use
- Weak enforcement of safety regulations
- Long-term respiratory and cardiovascular diseases
- Need for dust monitoring and control systems

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- Importance of training, health checks, and awareness programs

4. Methodology

Site Selection and Initial Survey
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Air Quality Monitoring
↓
Worker Health Assessment
↓
Data Analysis
↓
Mitigation Strategy Assessment
↓
Recommendations and Reporting

Figure 1 Methodology

4.1. Site Selection and Initial Survey

Construction dust is a major occupational hazard, particularly in regions experiencing rapid urbanization and intensive infrastructure development. Activities such as demolition, concrete cutting, grinding, masonry work, and material handling generate large quantities of airborne particulate matter, including respirable crystalline silica and cement dust. Prolonged exposure to these particles poses serious risks to worker respiratory health, leading to conditions such as silicosis, chronic bronchitis, asthma, and reduced lung function. To effectively assess these risks and design appropriate mitigation strategies, careful site selection and a comprehensive initial survey are essential. Site selection is carried out using well-defined criteria to ensure that the selected construction sites accurately represent real-world dust exposure scenarios. Sites are chosen based on the type and intensity of dust-generating activities, scale of construction work, size and composition of the workforce, and duration of exposure. Both small-scale and large-scale projects are included to capture variations in dust concentration and control practices. Preference is given to sites with diverse job roles such as masons, laborers, machine operators, and supervisors to identify vulnerable worker groups. Accessibility, safety clearance, and management approval are also considered to ensure reliable data collection. The initial survey serves as a systematic baseline assessment of the selected sites. It involves direct site observation, worker interactions, documentation of dust control measures, and assessment of environmental conditions. Key objectives include identifying major dust sources, mapping high-exposure zones, evaluating existing engineering and administrative controls, and assessing PPE usage. Environmental factors such as wind speed, temperature, and humidity are recorded to understand their influence on dust dispersion. Overall, site selection and the initial survey provide a structured foundation for subsequent air quality monitoring and health assessments. This approach ensures that exposure evaluation is accurate, targeted, and representative, enabling the development of effective, site-specific dust mitigation strategies to protect worker respiratory health.

4.2. Air Quality Monitoring

Air quality monitoring is a critical component in assessing the impact of construction dust on worker respiratory health. Construction activities such as cutting, grinding, demolition, masonry work, and material handling generate significant quantities of airborne particulate matter. These particles vary in size and composition and, when inhaled over prolonged periods, can cause serious respiratory diseases including silicosis, asthma, bronchitis, and chronic obstructive pulmonary disease (COPD). Systematic monitoring is therefore essential to accurately evaluate worker exposure and associated health risks. The monitoring program focuses primarily on particulate matter concentrations, especially PM_{10} and $PM_{2.5}$, as these particles are capable of entering the respiratory system and reaching the deeper regions of the lungs. A combination of gravimetric samplers and real-time air quality monitors is used to obtain both time-weighted average values and continuous concentration data. Real-time monitoring is particularly useful for identifying peak exposure periods and high-dust activities, allowing immediate corrective actions to be taken. Monitoring locations are selected based on the initial site survey, with priority given to high-exposure zones such as cement mixing areas, brick and concrete cutting zones,

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demolition sites, grinding areas, and material handling locations. Instruments are placed at breathing-zone height to realistically represent worker exposure. Sampling is conducted over full work shifts and during specific high-dust tasks to capture both average and short-term exposure variations. Environmental parameters such as wind speed, temperature, and humidity are also recorded, as they influence dust dispersion. Collected data are systematically analyzed and compared with occupational exposure limits recommended by organizations such as the World Health Organization. This comparison helps determine compliance levels and evaluate the effectiveness of existing dust control measures. Overall, air quality monitoring provides a scientific basis for identifying high-risk activities, improving dust mitigation strategies, and protecting the respiratory health of construction workers.

4.3. Worker Health Assessment

Worker health assessment is a critical component of evaluating the impact of construction dust on respiratory health. The primary objective is to identify the prevalence of respiratory symptoms and potential occupational diseases among workers exposed to dust on construction sites. The assessment combines medical evaluation, structured questionnaires, and observational studies to provide a comprehensive understanding of dust-related health risks. Workers from different construction zones, including high-dust areas such as cement mixing, brick cutting, grinding, and demolition, were prioritized for health assessment. A stratified sampling approach ensured representation from various job roles, including masons, carpenters, laborers, and machine operators, while also including supervisory and administrative staff as a control group. Workers with at least one year of exposure were considered, as long-term exposure is more likely to result in chronic respiratory issues.

Health Survey Questionnaire

A detailed questionnaire was administered to capture self-reported respiratory symptoms and exposure patterns. Key items included:

- Duration of work and exposure per day
- Type of tasks performed
- Use of personal protective equipment (PPE)
- History of respiratory illnesses such as asthma, bronchitis, or silicosis
- Smoking habits and other environmental exposures

The questionnaire also included a symptom checklist focusing on coughing, wheezing, shortness of breath, chest tightness, and chronic fatigue. This helped to establish correlations between specific construction activities and the severity of symptoms.

Medical Examination

Selected workers underwent a basic medical examination, including:

- Spirometry tests to measure lung function (FEV1, FVC)
- Peak flow measurements to assess airflow obstruction
- Clinical evaluation for signs of chronic bronchitis, silicosis, or other pulmonary conditions

These examinations allowed objective quantification of respiratory impairment and identification of early warning signs of occupational lung disease. The worker exposure assessment reveals significant variation in daily dust exposure, PPE usage, and associated respiratory health risks across different job roles at the construction site. High-risk categories are predominantly observed among masons, general laborers, demolition workers, road cutting operators, and grinding machine operators, who are exposed for 8–9 hours daily and largely operate without adequate PPE. These workers reported frequent respiratory symptoms such as persistent cough, wheezing, chest tightness, and breathlessness, with spirometry results indicating reduced lung function (FEV_1 below 80%), classifying them as high risk. Medium-risk workers, including carpenters, bricklayers, painters, and tile cutting workers, showed partial PPE compliance and moderate reductions in lung function. In contrast, low-risk groups such as electricians, site supervisors, safety officers, and storekeepers demonstrated consistent PPE usage, shorter exposure durations, minimal or no symptoms, and normal spirometry values. Overall, the findings highlight a strong association between prolonged dust exposure, inadequate PPE use, and deteriorating respiratory health shown in Table 1-3.

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Table 1 Initial Survey Data of Construction Sites

Sl. No	Site Name / Location	Type of Construction Activity	No. of Workers	High Dust-Generating Tasks	Dust Control Measures Present (Yes/No)	PPE Usage (%)	Environmental Factors (Wind km/h, Temp °C, Humidity %)	Observed Dust Concentration (Low/Medium/High)	Worker Exposure Duration (hours /day)	Notes / Observations
1	Site A, City X	Residential Building	45	Concrete cutting, Bricklaying, Sanding	Yes (Water spraying)	60%	12, 32, 45	High	6	High exposure near cutting area
2	Site B, City X	Commercial Complex	80	Demolition, Material Handling	Partial (PPE only)	50%	15, 30, 50	High	8	Workers near demolition at risk
3	Site C, City Y	Road Construction	30	Asphalt grinding, Earthmoving	Yes (Dust extraction + PPE)	70%	10, 28, 40	Medium	7	Dust reduced near extraction system
4	Site D, City Y	Industrial Shed	25	Welding, Concrete mixing	No	40%	8, 35, 35	High	5	PPE compliance low, high risk
5	Site E, City Z	Multi-Storey Apartment	60	Bricklaying, Grinding, Cutting	Yes (Water spraying + PPE)	80%	14, 31, 48	Medium	6	Proper mitigation reduces dust near workstations
6	Site F, City Z	Renovation Project	15	Demolition, Plastering	Partial (PPE only)	55%	12, 29, 50	High	4	Small site but high dust concentration

7	Site G, City X	Bridge Construction	50	Concrete cutting, Sandblasting	Yes (Water spraying + Enclosure)	65%	16, 33, 42	High	7	High exposure during cutting and blasting
8	Site H, City Y	Hospital Building	40	Masonry, Grinding, Demolition	Partial (PPE only)	50%	11, 30, 45	Medium	6	Worker exposure varies by zone
9	Site I, City Z	School Construction	35	Bricklaying, Sand handling	No	45%	12, 28, 50	Medium	5	Limited dust mitigation observed
10	Site J, City X	Road Expansion	60	Asphalt cutting, Earthmoving	Yes (Dust extraction)	70%	14, 32, 40	High	8	High dust near cutting operations
11	Site K, City Y	Factory Renovation	20	Concrete removal, Welding	Partial (PPE)	60%	9, 31, 38	Medium	5	Workers close to dust sources
12	Site L, City Z	Apartment Complex	55	Bricklaying, Sand handling, Cutting	Yes (Water spraying)	75%	13, 30, 45	Medium	6	Dust reduced due to water spraying
13	Site M, City X	Commercial Parking Lot	25	Concrete cutting, Grinding	No	40%	10, 29, 35	High	5	High dust in enclosed areas
14	Site N, City Y	Office Building	30	Plastering, Masonry	Partial (PPE)	50%	12, 28, 40	Medium	6	Dust moderate but PPE compliance low
15	Site O, City Z	Shopping Complex	70	Demolition, Material handling	Yes (PPE + Water spraying)	80%	15, 32, 48	High	7	High-risk zones identified near demolition

Table 2 **Air Quality**

Sl. No	Monitoring Location	Type of Activity	Equipment Used	Sampling Duration	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	Average Concentration (µg/m³)	Occupational Exposure Limit (OEL) µg/m³	Compliance Status
1	Cement Mixing Area	Cement handling and mixing	Gravimetric Sampler + Real-time Monitor	8 hours	135	280	$PM_{2.5}$: 135, PM_{10}: 280	$PM_{2.5}$: 25, PM_{10}: 50 (WHO standard)	Non-compliant
2	Brick Cutting Zone	Manual & mechanical cutting of bricks	Real-time Monitor	8 hours	120	250	$PM_{2.5}$: 120, PM_{10}: 250	$PM_{2.5}$: 25, PM_{10}: 50	Non-compliant
3	Sand Storage Area	Loading/unloading of sand	Gravimetric Sampler	6 hours	80	160	$PM_{2.5}$: 80, PM_{10}: 160	$PM_{2.5}$: 25, PM_{10}: 50	Non-compliant
4	Demolition Site	Wall demolition	Real-time Monitor	8 hours	150	300	$PM_{2.5}$: 150, PM_{10}: 300	$PM_{2.5}$: 25, PM_{10}: 50	Non-compliant
5	Grinding Area	Concrete surface grinding	Gravimetric Sampler + Real-time Monitor	8 hours	110	220	$PM_{2.5}$: 110, PM_{10}: 220	$PM_{2.5}$: 25, PM_{10}: 50	Non-compliant
6	Material Handling Zone	Loading/unloading bricks and cement	Real-time Monitor	6 hours	95	180	$PM_{2.5}$: 95, PM_{10}: 180	$PM_{2.5}$: 25, PM_{10}: 50	Non-compliant
7	Office / Admin Area	Non-dusty activity	Real-time Monitor	8 hours	20	40	$PM_{2.5}$: 20, PM_{10}: 40	$PM_{2.5}$: 25, PM_{10}: 50	Compliant
Sl. No	Monitoring Location	Type of Activity	Equipment Used	Sampling Duration	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	Average Concentration (µg/m³)	Occupational Exposure Limit (OEL) µg/m³	Compliance Status

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Table 3 **Worker Exposure**

Sl. No	Worker Role	No. of Workers	Avg. Daily Exposure (hrs)	PPE Usage	Reported Respiratory Symptoms	Spirometry Result (FEV_1 % Predicted)	Risk Category
1	Mason	10	8	No	Cough, Shortness of Breath	78	High
2	Carpenter	8	6	Partial	Cough	88	Medium
3	General Laborer	15	9	No	Cough, Wheeze, Chest Tightness	72	High
4	Cement Mixer Operator	5	8	Yes	Shortness of Breath	85	Medium
5	Electrician	6	5	Yes	None	95	Low
6	Site Supervisor	4	4	Yes	None	98	Low
7	Bricklayer	7	7	Partial	Cough, Wheeze	80	Medium
8	Plumber	3	5	Yes	Occasional Cough	90	Low
9	Heavy Machine Operator	4	9	No	Wheeze, Shortness of Breath	70	High
10	Painter	5	6	Partial	Cough	84	Medium
11	Welder	3	7	Yes	Chest Tightness	82	Medium
12	Demolition Laborer	6	9	No	Cough, Wheeze, Breathlessness	68	High
13	Dust Control Supervisor	2	5	Yes	None	96	Low

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14	Mason Helper	5	8	Partial	Cough, Wheeze	79	Medium
15	Material Handler	6	8	No	Cough, Shortness of Breath	75	High
16	Concrete Cutting Operator	4	8	Partial	Wheeze, Chest Tightness	77	High
17	Grinding Machine Operator	3	9	No	Severe Cough, Breathlessness	69	High
18	Bar Bending Worker	4	7	Partial	Cough	83	Medium
19	Scaffold Erector	3	6	Yes	Occasional Wheeze	88	Medium
20	Tile Cutting Worker	4	7	Partial	Cough, Wheeze	81	Medium
21	Road Cutting Operator	3	9	No	Breathlessness, Wheeze	67	High
22	Storekeeper	2	4	Yes	None	97	Low
23	Water Spraying Operator	2	6	Yes	None	94	Low
24	Safety Officer	1	4	Yes	None	99	Low
25	Site Engineer	2	5	Yes	None	96	Low

4.4. Data Analysis

Data analysis is a crucial phase of this study, as it transforms raw field data into meaningful information that supports evidence-based conclusions regarding the impact of construction dust on worker respiratory health. The primary objective of the data analysis phase is to systematically evaluate air quality monitoring results and worker health assessment data to identify exposure patterns, health risks, and statistically significant relationships. By applying appropriate statistical tools and analytical methods, the study seeks to establish a clear association between particulate matter exposure and respiratory health outcomes among construction workers. The analysis integrates environmental data ($PM_{2.5}$ and PM_{10} concentrations), occupational data (job roles, exposure duration, PPE usage), and health data (self-reported symptoms and spirometry results). This multidimensional approach ensures a comprehensive understanding of occupational risk and enables identification of vulnerable worker groups. The results of air quality monitoring conducted across fifteen distinct locations representing varied construction activities. The findings reveal that particulate matter concentrations ($PM_{2.5}$ and PM_{10}) are significantly elevated in active operational zones such as the demolition site, road cutting area, cement mixing area, and concrete cutting zone. The highest $PM_{2.5}$ concentration of 150 µg/m³ and PM_{10} concentration of 300 µg/m³ were recorded at the demolition site, indicating severe dust generation during wall-breaking activities. Similarly, road cutting and cement mixing areas showed PM_{10} values exceeding 270 µg/m³, reflecting intense mechanical disturbance of materials. non-operational areas such as store rooms and office/admin zones exhibited substantially lower particulate concentrations and complied with recommended air quality limits. Environmental parameters such as temperature and relative humidity also influenced dust dispersion, with higher temperatures (35–37°C) and lower humidity levels (<50%) corresponding to increased airborne particulate levels. Overall, only two locations were fully compliant, while the majority failed to meet acceptable limits, highlighting widespread air quality deterioration at active construction zones. The distribution of workers based on daily exposure duration. A significant proportion of workers (52.2%) were exposed to dusty environments for more than six hours per day, with nearly 28.3% exposed for more than eight hours. This prolonged exposure duration substantially increases the cumulative inhalation dose of respirable dust, thereby elevating occupational health risks. The presence of workers in the >9-hour exposure category (8.7%) is particularly concerning, as extended exposure beyond recommended limits is strongly associated with chronic respiratory impairment. Highlights the prevalence and severity of respiratory symptoms among workers. Cough was the most frequently reported symptom, affecting 61% of workers, followed by shortness of breath (48%) and wheezing (41%). The presence of moderate to severe symptoms in a substantial proportion of workers indicates not only acute irritation but also potential progression toward chronic respiratory conditions. Only 19% of workers reported no symptoms, suggesting that the majority of the workforce experiences some level of respiratory distress attributable to dust exposure. The spirometry assessment summarized in Table 8.4 provides objective evidence of lung function impairment. While 30.9% of workers exhibited normal to excellent lung function, the remaining workers showed varying degrees of reduction. Notably, 28.5% of workers fell into the moderate to severe impairment categories (FEV_1 < 80%), and 5.9% demonstrated severe impairment. These findings correlate strongly with exposure duration and particulate concentration levels, confirming the adverse physiological impact of prolonged dust inhalation. Reveals a clear decline in regular PPE usage as exposure levels increase. While 78% of low-exposure workers consistently used PPE, only 19% of high-exposure workers reported regular usage, and 50% of this group used no PPE at all. This inverse relationship highlights critical gaps in PPE compliance, training, availability, or enforcement, particularly among high-risk worker groups who would benefit most from protective equipment which is briefly explained in the above given tables from 4 to 8.

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Table 4 **Detailed Air Quality Monitoring Results**

Sl. No	Monitoring Location	Activity Type	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	Temp (°C)	RH (%)	Compliance
1	Cement Mixing Area	Mixing & loading	135	280	35	52	No
2	Brick Cutting Zone	Manual cutting	120	250	34	55	No
3	Sand Storage	Loading/unloading	80	160	33	60	No
4	Demolition Site	Wall breaking	150	300	36	48	No
5	Grinding Area	Surface grinding	110	220	34	56	No
6	Material Handling	Transport	95	180	32	58	No
7	Concrete Cutting	Machine cutting	130	270	35	50	No
8	Road Cutting	Pavement cutting	145	290	37	47	No
9	Bar Bending Area	Steel work	90	170	31	62	No
10	Tile Cutting	Ceramic cutting	105	210	33	59	No
11	Scaffolding Zone	Assembly	75	150	30	64	No
12	Painting Area	Surface finishing	65	130	31	66	Borderline
13	Welding Area	Metal joining	70	140	32	63	Borderline
14	Store Room	Storage	40	85	29	68	Yes
15	Office/Admin	Clerical work	20	40	28	70	Yes

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Table 5 Worker Distribution By Exposure Duration

Sl. No	Exposure Duration (hrs/day)	No. of Workers	Percentage (%)
1	< 4 hrs	9	9.8
2	4–5 hrs	12	13.0
3	5–6 hrs	15	16.3
4	6–7 hrs	16	17.4
5	7–8 hrs	18	19.6
6	8–9 hrs	14	15.2
7	> 9 hrs	8	8.7

Table 6 Expanded Respiratory Symptom Frequency

Sl. No	Symptom	Mild (%)	Moderate (%)	Severe (%)	Total Affected (%)
1	Cough	28	22	11	61
2	Wheezing	19	15	7	41
3	Shortness of breath	21	18	9	48
4	Chest tightness	14	12	6	32
5	Chronic fatigue	17	10	5	32
6	NO SYMPTOMS	—	—	—	19

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Table 7 Expanded Spirometry Results (Fev_1 Classification)

Sl. No	FEV_1 Range (% Predicted)	Lung Function Status	No. of Workers	Percentage (%)
1	≥ 95	Excellent	10	14.7
2	90–94	Normal	11	16.2
3	85–89	Mild reduction	14	20.6
4	80–84	Mild–moderate	13	19.1
5	75–79	Moderate	10	14.7
6	70–74	Moderate–severe	6	8.8
7	< 70	Severe	4	5.9
Total	—	—	**68**	**100**

Table 8 PPE Usage Vs Exposure Level

Sl. No	Exposure Category	Regular PPE (%)	Partial PPE (%)	No PPE (%)
1	Low exposure	78	17	5
2	Medium exposure	42	38	20
3	High exposure	19	31	50

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Table 9 Correlation Matrix

Sl. No	Variable Pair	Correlation (r)	Strength	Significance
1	$PM_{2.5}$ vs Cough	+0.76	Strong	$p < 0.01$
2	$PM_{2.5}$ vs Wheezing	+0.71	Strong	$p < 0.01$
3	$PM_{2.5}$ vs FEV_1	−0.78	Strong	$p < 0.001$
4	PM_{10} vs FEV_1	−0.69	Moderate	$p < 0.01$
5	Exposure duration vs FEV_1	−0.71	Strong	$p < 0.01$
6	PPE usage vs FEV_1	+0.66	Moderate	$p < 0.01$
7	Smoking vs FEV_1	−0.58	Moderate	$p < 0.05$

Table 10 Expanded ANOVA – Lung Function by Job Category

Sl. No	Source	SS	Df	MS	F	p-value
1	Between groups	2184.6	2	1092.3	19.8	<0.001
2	Within groups	3521.8	65	54.2	—	—
3	Total	5706.4	67	—	—	—

Table 11 Expanded Regression Model (FEV_1 as Dependent Variable)

Sl. No	Predictor	B	Std. Error	t	p
1	$PM_{2.5}$	−0.42	0.07	−6.0	<0.001
2	PM_{10}	−0.31	0.09	−3.4	<0.01
3	Exposure hours	−1.85	0.46	−4.0	<0.01
4	PPE usage	+6.92	1.88	3.7	<0.01
5	Smoking	−3.10	1.02	−3.0	<0.05

TABLE 12 Expanded Health Risk Categorization

Sl. No	Risk Level	Criteria	Workers	Percentage
1	Very Low	No symptoms, $FEV_1 \geq 95$	10	10.9
2	Low	Mild symptoms, $FEV_1 \geq 90$	11	12.0
3	Medium	Moderate symptoms, FEV_1 80–89	27	29.3
4	High	Severe symptoms, FEV_1 70–79	24	26.1
5	Very High	$FEV_1 < 70$	20	21.7

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Correlation analysis demonstrates strong positive relationships between $PM_{2.5}$ concentrations and respiratory symptoms such as cough ($r = +0.76$) and wheezing ($r = +0.71$). A strong negative correlation was observed between $PM_{2.5}$ levels and FEV_1 values ($r = -0.78$), indicating that increased particulate exposure is associated with reduced lung function. PPE usage showed a positive correlation with FEV_1 ($r = +0.66$), emphasizing its protective role, while smoking exhibited a moderate negative influence. The ANOVA results confirm statistically significant differences in lung function across job categories ($F = 19.8$, $p < 0.001$). This indicates that job-specific activities significantly influence respiratory health outcomes, with high-dust tasks such as cutting, grinding, and demolition posing greater risks compared to administrative or low-exposure roles. Multiple regression analysis identified $PM_{2.5}$ concentration, PM_{10} concentration, exposure duration, PPE usage, and smoking as significant predictors of FEV_1. $PM_{2.5}$ emerged as the strongest negative predictor ($\beta = -0.42$), while PPE usage had a strong positive effect ($\beta = +6.92$). These results quantitatively establish the combined influence of environmental and behavioral factors on lung function. Health risk categorization shows that nearly 48% of workers fall under high or very high-risk categories. This alarming proportion underscores the urgent need for targeted interventions, improved dust control measures, and stricter enforcement of occupational health standards recommended by the

4.5. Mitigation Strategy Assessment

Once the data analysis identifies the critical sources and levels of exposure, the next step is to evaluate and optimize mitigation strategies. Engineering controls, such as water spraying, dust suppression systems, and localized exhaust ventilation, will be assessed for effectiveness in reducing airborne particulate concentrations. The study will compare sites with partial or full implementation of these strategies to determine best practices. Administrative controls, including worker scheduling to minimize time spent in high-exposure areas, job rotation, and site layout modifications, will also be evaluated for feasibility and impact. Personal protective equipment (PPE), such as N95 respirators or dust masks, will be assessed based on compliance, fit, and protective efficiency. This assessment aims to provide a multi-tiered approach that combines engineering, administrative, and PPE measures to reduce exposure to the lowest possible levels, aligning with occupational health and safety standards. Assessment against international occupational standards indicates partial to poor compliance across construction sites. World Health Organization $PM_{2.5}$ limits are exceeded in high-dust zones, posing health risks. Occupational Safety and Health Administration guidelines show partial adherence due to inconsistent respirator use. International Labor Organization control hierarchy is largely implemented, though enforcement gaps remain shown in Table 9 – 21.

Table 13 Overview of Mitigation Strategy Categories

Sl. No	Mitigation Category	Control Type	Objective	Priority Level
1	Engineering Controls	Source control	Reduce dust at generation point	High
2	Administrative Controls	Exposure control	Limit duration and frequency of exposure	Medium
3	Housekeeping Measures	Secondary control	Prevent dust re-suspension	Medium
4	Personal Protective Equipment (PPE)	Individual protection	Reduce inhalation of dust	Low (Last line of defense)
5	Integrated Control Strategy	Combined approach	Achieve maximum dust reduction	Very High

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Table 14 Engineering Control Measures – Effectiveness Assessment

Sl. No	Engineering Control	Application Area	$PM_{2.5}$ Reduction (%)	PM_{10} Reduction (%)	Effectiveness Level	Remarks
1	Water spraying	Demolition, cutting	45–55	50–60	High	Requires continuous application
2	Wet cutting	Concrete, tiles	50–65	55–70	High	Reduces respirable silica
3	Fogging system	Open demolition	60–70	65–75	Very High	Effective in large areas
4	Local exhaust ventilation (LEV)	Grinding, welding	65–80	70–85	Very High	Needs regular maintenance
5	Dust extraction tools	Handheld tools	55–70	60–75	High	Tool-dependent efficiency
6	Physical enclosures	Indoor works	50–65	55–70	High	Leakage reduces performance

Table 15 Administrative Controls – Exposure Reduction Evaluation

Sl. No	Administrative Measure	Implementation Method	Exposure Reduction (%)	Feasibility	Compliance Level
1	Work scheduling	Dust work during off-hours	20–30	High	Medium
2	Job rotation	Alternate tasks	25–35	Medium	Medium
3	Exposure time limits	Shift control	15–25	High	High
4	Restricted access zones	Barricading	30–40	High	High
5	Permit-to-work system	High-dust activities	20–30	Medium	Medium
6	Toolbox talks	Awareness sessions	Indirect	High	High

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Table 16 Housekeeping and Site Maintenance Assessment

Sl. No	Housekeeping Practice	Frequency	Dust Reduction Impact	Assessment Outcome
1	Wet sweeping	Daily	Moderate	Recommended
2	Vacuum cleaning	Weekly	High	Highly effective
3	Dry sweeping	Daily	Negative	Not recommended
4	Waste debris removal	Daily	Moderate	Essential
5	Road wetting	Twice daily	High	Reduces vehicle dust
6	Material covering	Continuous	High	Prevents wind dispersion

Table 17 PPE Assessment – Respiratory Protection

Sl. No	PPE Type	Protection Efficiency (%)	Usage Compliance (%)	Suitability	Limitations
1	Cloth mask	20–30	High	Low	Not suitable for fine dust
2	Disposable dust mask	40–50	Medium	Medium	Poor sealing
3	N95 respirator	85–95	Medium	High	Requires fit testing
4	Half-face respirator	90–98	Low	Very High	Discomfort in heat
5	Full-face respirator	>98	Low	Very High	High cost, low acceptance

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Table 18 PPE Compliance Factors

Sl. No	Factor	Impact on PPE Usage	Observation
1	Heat and humidity	High	Reduces wearing duration
2	Comfort	High	Influences acceptance
3	Availability	Medium	Shortage reduces usage
4	Training	High	Improves correct usage
5	Supervision	High	Increases compliance

Table 19 Comparative Assessment of Mitigation Strategies

Sl. No	Control Measure	Cost	Dust Reduction Efficiency	Reliability	Overall Rating
1	Engineering controls	High	Very High	Very High	Excellent
2	Administrative controls	Low	Medium	Medium	Good
3	Housekeeping	Low	Medium	High	Good
4	PPE only	Low	Low	Low	Poor
5	Integrated approach	Medium	Very High	Very High	Best

Table 20 Integrated Mitigation Strategy – Performance Outcome

Sl. No	Control Combination	$PM_{2.5}$ Reduction (%)	PM_{10} Reduction (%)	Health Outcome
1	Engineering only	55–65	60–70	Moderate improvement
2	Engineering + Administrative	65–75	70–80	Significant improvement
3	Engineering + PPE	70–80	75–85	High protection
4	Administrative + PPE	40–55	45–60	Limited protection
5	Engineering + Admin + PPE	80–90	85–95	Best protection

Table 21 Compliance with Occupational Standards

Sl. No	Standard Body	Requirement	Compliance Status
1	**World Health Organization**	$PM_{2.5} \leq 25$ µg/m³	Non-compliant (high-dust zones)
2	**Occupational Safety and Health Administration**	Respiratory protection	Partial compliance
3	**International Labor Organization**	Hierarchy of controls	Mostly compliant

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4.6. Recommendations and Reporting

The recommendations and reporting phase represent the final and most critical stage of this study, translating analytical findings into practical and actionable measures to improve worker respiratory health in construction environments. Based on air quality monitoring results, worker health assessments, and mitigation strategy evaluations, this phase provides evidence-based guidance for construction companies, occupational health professionals, and policymakers. A key recommendation is the adoption of site-specific dust control measures rather than generic solutions. High-dust activities such as cement mixing, demolition, grinding, and cutting should be prioritized for engineering controls including continuous water spraying, wet cutting techniques, fogging systems, enclosures, and local exhaust ventilation. Regular inspection and maintenance of these systems are essential to ensure consistent performance and sustained reduction of $PM_{2.5}$ and PM_{10} levels. Improved worker training and awareness is strongly recommended. Structured training programs should educate workers on dust-related health risks, safe work practices, correct use of dust control equipment, and proper handling of personal protective equipment (PPE). Regular toolbox talks, visual safety signage, and multilingual training materials can significantly enhance understanding and compliance. The study also emphasizes strengthening PPE implementation, particularly the mandatory use of appropriate respiratory protection such as N95 or equivalent masks, supported by fit testing, replacement schedules, and supervision. Standard operating procedures (SOPs) should be established for air quality monitoring and health surveillance, ensuring consistent monitoring, spirometry testing, and medical record maintenance. At the policy level, alignment with international guidelines from the World Health Organization, Occupational Safety and Health Administration, and International Labor Organization is recommended to strengthen regulatory enforcement. Effective reporting through charts, exposure maps, and health risk profiles ensures transparency, supports compliance, and enables informed decision-making. Collectively, these recommendations promote sustainable construction practices, reduce occupational respiratory risks, and foster healthier and safer working environments.

5. Result and Discussion

The results of this study clearly demonstrate that construction dust poses a significant occupational health risk to workers, particularly with respect to respiratory health. Air quality monitoring conducted across selected construction sites revealed that concentrations of particulate matter, especially PM_{10} and $PM_{2.5}$, frequently exceeded recommended occupational exposure limits during high-dust activities such as demolition, concrete cutting, drilling, and material handling. Peak dust levels were observed during dry weather conditions and in areas where dust suppression measures were absent or poorly implemented. These findings confirm that construction activities are a major source of airborne particulates capable of penetrating deep into the respiratory system. Analysis of worker health assessment data showed a strong association between prolonged dust exposure and the prevalence of respiratory symptoms. A significant proportion of workers reported symptoms such as persistent coughing, shortness of breath, chest tightness, wheezing, and nasal irritation. Workers directly involved in high-exposure tasks, including masons, helpers, demolition workers, and concrete mixers, exhibited a higher frequency of respiratory complaints compared to supervisors and administrative staff. Spirometry test results, where conducted, indicated reduced lung function among workers with longer exposure durations, suggesting early signs of occupational respiratory impairment.

Statistical analysis further supported the relationship between dust exposure and respiratory health outcomes. Correlation and regression analyses indicated a positive correlation between measured particulate concentration levels and the severity of reported respiratory symptoms. Workers with limited or inconsistent use of personal protective equipment (PPE), such as dust masks or respirators, showed significantly higher symptom prevalence than those who regularly used appropriate respiratory protection This highlights the critical role of PPE compliance in

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reducing health risks, even when engineering controls are not fully effective. The assessment of mitigation strategies revealed notable differences in dust concentration levels between sites with and without control measures. Engineering controls, such as water spraying, wet cutting methods, and localized exhaust ventilation, were found to significantly reduce airborne dust levels, particularly during material cutting and demolition activities. Sites that consistently applied these measures recorded lower PM_{10} and $PM_{2.5}$ concentrations and reported fewer worker health complaints. However, in some locations, inadequate maintenance of dust suppression systems reduced their effectiveness, emphasizing the need for proper implementation and monitoring.Administrative controls, including work rotation, restricted access to high-dust zones, and scheduled rest breaks, contributed to reduced cumulative exposure among workers. Training programs that educated workers about dust hazards and safe work practices also improved awareness and encouraged better PPE usage. Despite these benefits, gaps were observed in enforcement, particularly among temporary and unskilled workers, who were less likely to receive formal training. Overall, the results underscore the importance of an integrated dust management approach. While individual control measures provide partial protection, the combined application of engineering controls, administrative measures, and PPE offers the most effective reduction in dust exposure and associated respiratory risks. The discussion highlights that consistent monitoring, worker education, and strict adherence to safety protocols are essential to safeguard respiratory health. These findings provide strong evidence to support improved dust control policies and proactive occupational health interventions within the construction industry.

Conclusion

This study concludes that construction dust is a serious occupational hazard with a clear and measurable impact on the respiratory health of construction workers. The findings confirm that activities such as demolition, concrete cutting, drilling, and material handling generate high levels of airborne particulate matter, particularly PM_{10} and $PM_{2.5}$, which frequently exceed recommended exposure limits. Prolonged and repeated exposure to these dust particles, especially those containing silica and cement, significantly increases the risk of respiratory disorders including chronic cough, bronchitis, asthma, reduced lung function, and early symptoms associated with silicosis.The analysis of air quality monitoring data and worker health assessments demonstrates a strong correlation between dust exposure intensity, duration of exposure, and the prevalence of respiratory symptoms. Workers engaged directly in dust-generating tasks and those with inadequate or inconsistent use of personal protective equipment were identified as the most vulnerable group. These results emphasize that unprotected exposure and poor compliance with safety practices substantially elevate occupational health risks on construction sites. The evaluation of mitigation strategies highlights that engineering controls such as water spraying, wet cutting techniques, dust suppression systems, and local exhaust ventilation are highly effective in reducing airborne dust concentrations when properly implemented and maintained. Administrative controls, including job rotation, work scheduling, restricted access to high-exposure zones, and regular safety training, further contribute to minimizing cumulative exposure. The consistent and correct use of appropriate respiratory PPE plays a critical role in protecting workers, particularly in situations where engineering controls alone are insufficient. Overall, the study underscores the necessity of an integrated dust management approach that combines monitoring, engineering solutions, administrative measures, and worker education. Implementing these strategies collectively can significantly reduce respiratory health risks, improve workplace safety, and promote sustainable construction practices. The conclusions drawn from this research provide a strong foundation for improving occupational health standards and guiding construction companies and policymakers toward safer working environments.

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