International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133
Received: 25-07-2026, Accepted: 24-08-2026, Published: 08-09-2026
Volume 8, Issue 3, 2026, Page No. 34-39

Determination of workplace environmental conditions in spice processing units of Jorhat, Assam, India

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DOI: https://doi.org/10.66856/ijees.2026.8.3.8067

Abstract
Aim: The present study aimed to assess selected workplace environmental conditions, namely Air Quality Index (AQI), ambient temperature, and relative humidity, in small-scale spice processing units of Jorhat district, Assam, and evaluate their compliance with recommended reference limits.
Background: Small-scale spice processing units constitute an important component of the agro-processing sector and involve operations such as grinding, sieving, blending, drying, sorting, and packaging. These activities may influence environmental conditions within the workplace through the generation of airborne particulate matter and heat. In addition, the climatic conditions of Assam, particularly relatively high temperature and humidity, may further affect indoor workplace conditions.
Methods: A cross-sectional analytical study was conducted in eight registered spice processing units selected through simple random sampling from a sampling frame of 40 registered units in Jorhat district, Assam. Environmental monitoring was conducted during active production hours in March-April 2025. Parameters assessed included ambient temperature, relative humidity and indoor air quality were assessed using calibrated real-time air quality monitoring instruments. The observed values were summarized using minimum, maximum and mean values and compared with relevant recommended reference limits.
Results: The findings revealed that the average workplace temperature (30.6°C), with values ranging from 27.7°C to 33.1°C. Relative humidity ranged from 63.0% to 73.0%, with a mean of (68.4%) which exceeded recommended comfort limits. Both the mean temperature and relative humidity were above the reference comfort ranges considered in the study.
Conclusion: The study indicates that small-scale spice-processing units in Jorhat may present unfavourable environmental conditions in terms of air quality, thermal stress and relative humidity. The findings highlight the urgent need for improved ventilation systems, dust-control measures, regular environmental monitoring, and appropriate occupational health interventions to ensure safer working conditions and protect worker health.

Keywords: Air Quality Index, temperature, relative humidity, spice processing, workplace environment, thermal comfort, indoor air quality

Introduction
Spice processing is an important component of the agro-processing sector in India, with spices such as chilli, ginger, turmeric, and blended spice products processed through variety of small-and- medium scale operations. Assam contributes to the production and processing of several important spices, while small-scale processing units provide employment and support local economic activity (Srinivasan et al., 2023). However, there exists dearth of research on the occupational hazards occurring in spice processing units specifically focusing on environmental exposures and ergonomic risks. The working environment of a spice-processing unit can be influenced by the nature and intensity of processing operations. Activities such as grinding, sieving, blending, drying, sorting, and handling of spices may generate airborne particulate matter and alter the conditions within the processing area. At the same time, heat generated by machinery and processing activities, together with the prevailing climatic conditions, may contribute to elevated workplace temperature and humidity. The combined effect of these conditions can influence indoor air quality and thermal comfort. Temperature and relative humidity are important environmental parameters because their combined effect influences the thermal conditions experienced by workers. Exposure to elevated temperature and humidity may increase thermal discomfort and contribute to fatigue and reduced concentration. Previous studies have reported associations between unfavourable thermal conditions and worker discomfort and productivity. Krishnamurthy et al. (2017) reported occupational heat stress and its effects on health and productivity among industrial workers, while Deb et al. (2018) reported thermal discomfort among workers exposed to unfavourable workplace environmental conditions. Studies have also highlighted the influence of high indoor humidity and inadequate ventilation on thermal comfort. Air quality is another important consideration in spice-processing workplaces. Processing activities, particularly grinding and handling of dry spices, can generate airborne particulate matter. Occupational exposure to particulate matter originating from spices has been identified as an important workplace health concern. Upadhyay et al. (2019) specifically examined occupational health hazards associated with particulate matter originating from spices.

Thus, assessment of workplace air quality is particularly relevant in spice-processing environments where dust-generating activities are routinely performed.
The environmental conditions of a workplace may also be influenced by local climatic characteristics. Jorhat district experiences a humid subtropical climate, with seasonal variation in temperature and relatively high humidity. These external climatic conditions, together with processing activities and workplace ventilation, may influence the indoor environmental conditions of small-scale processing units. Although occupational hazards in industrial environments have been studied extensively, comparatively limited information is available regarding the specific environmental conditions of small-scale spice-processing units in Assam. In particular, there is a need for field-based assessment of air quality, temperature, and relative humidity during active processing operations.
Therefore, the present study was undertaken to assess selected workplace environmental parameters Air Quality Index (AQI), ambient temperature, and relative humidity in small-scale spice-processing units of Jorhat district, Assam. The study further aimed to compare the observed values with relevant recommended reference limits in order to identify potentially unfavourable workplace environmental conditions. The main objective of this study was: To measure environment factors such as air quality index (AQI), Temperature, Relative Humidity, in spice processing unit. And to compare observed environment conditions against recommended industrial standard to find out possible occupational hazards.

Materials and Methods

Study Design and Setting

This paper presents findings from a cross-sectional analytical study conducted between March and April 2025 to assess the environmental conditions at workplaces (small scale) in spice processing units for various spices including chilli, turmeric, ginger, garlic and blended spices. Jorhat District experiences a humid subtropical climate with high humidity levels and seasonal fluctuation temperatures that can affect the indoor workplace environments.

Selection of Spice Processing Units

Sampling frame for this study consists of (40) registered spice processing units functioning at Jorhat district. Eight units were randomly sampled using simple random method to have adequate representation of the local spice processing sector. The units were active and involved in routine processing activities during the course of the study.

Participants

Participants comprised 100 workers (56 males and 44 females) selected through a process of proportionate random sampling among the various operational sections viz., grinding, sieving, blending, drying, packing, sorting and raw material handling. Workers having at least a period of employment of one-year and engaged in production activities were eligible to participate in this study while administrative staff and those workers having period of occupational exposure less than one year were excluded.

Environmental Monitoring

Environmental monitoring was conducted during active production hours. Three measurements were obtained during the working period i.e., morning, mid-shift, and late shift to capture variations in workplace environmental conditions.
Three principal environmental parameters were assessed:

1. Air Quality Index (AQI)
2. Ambient temperature (°C)
3. Relative humidity (%)

A calibrated real-time air quality monitoring instrument was used to assess indoor air quality and simultaneously record ambient temperature and relative humidity. Air-quality measurements were taken within the workers' breathing zone to represent the environmental conditions experienced during work.

Reference Standards

The observed environmental conditions were compared with relevant recommended reference values obtained from recognized standards and guidelines, including those associated with the Bureau of Indian Standards (BIS), Central Pollution Control Board (CPCB), National Ambient Air Quality Standards (NAAQS), and other occupational and environmental references.
For temperature and relative humidity, the reference ranges considered in the study were:

- **Summer temperature:** 22.2–26.6°C
- **Summer relative humidity:** 40–60%

AQI values were interpreted according to the classification adopted in the study.

Data Analysis

Descriptive statistical techniques were employed to summarize the environmental monitoring data. Minimum, maximum, mean, and standard deviation values were calculated for each environmental parameter. The observed measurements were compared with recommended occupational standards to assess the adequacy of workplace environmental conditions and identify potential health risks associated with occupational exposure.

Results and discussions

Health risks associated with occupational exposure in spice-processing units arise from the interaction of multiple factors, including environmental conditions, workplace practices, and inadequate safety measures. Environmental stressors such as high temperature and relative humidity can further aggravate these risks by increasing workers' physical discomfort, fatigue, and susceptibility to heat stress. Prolonged exposure to airborne contaminants, particularly spice dust, may contribute to respiratory problems, while excessive workplace noise can increase the risk of hearing impairment. Collectively, these occupational stressors may reduce workers' comfort, productivity, and work efficiency. The International Labour Organization (ILO) has reported that millions of workers worldwide are affected by occupational diseases each year, with respiratory disorders representing an important category of work-related health problems. Similarly, the Health and Safety Executive (HSE, 2015) identified exposure to airborne contaminants and excessive noise in industrial workplaces as important occupational risk factors associated with respiratory conditions such as asthma and noise-induced hearing impairment.

Observations on the characteristics of spice processing unit workers showed that most of the respondents, 34 percent, belonged to the age group of 30-40 years, followed by 26 percent in the age group of 25-30 years, depicting the predominance of the economically productive age groups. The proportion of workers belonging to the age group of 40-50 years was 22 percent, while only 5 percent were above 50 years of age. Education levels of the respondents were such that 38 percent had attained secondary education, (34%) had completed up to the high school education level, while 28 percent were graduates. With regards to occupational exposure, 39 percent of the respondents had a maximum of four years of exposure, 33 percent had 4-7 years of occupational exposure while (19%) had exposure of over 10 years. Longer period of involvement showed increased presence of respiratory and musculoskeletal problems, as found in earlier observations. Concerning the work practices, 70 percent of respondents worked in the day shifts, while 30 percent worked in night shifts, especially in the smaller scale industries during peak production seasons. Daily working hours showed that 56 percent of the respondents worked for 6-8 hours, while 33 percent worked for more than 8 hours.

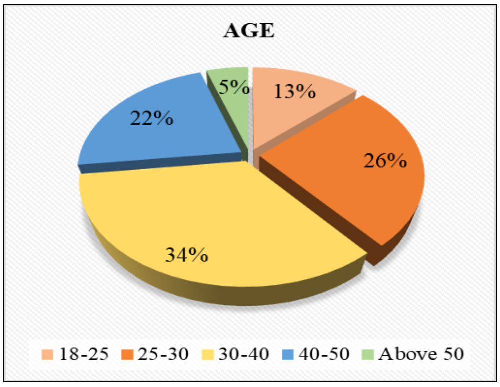

Fig. 1: Distribution of respondents according to their age

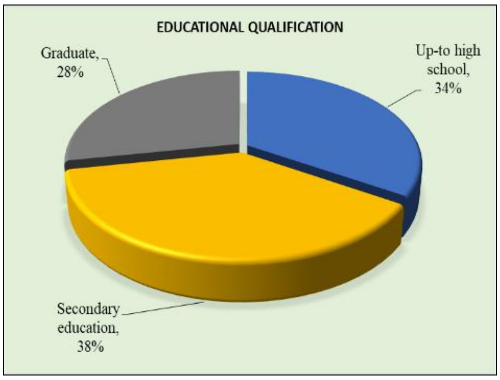

Fig 2: Distribution of respondents according to their educational qualification

Table 1: Distribution of respondents according to their activity profile N=100

Sl. No.		f	%
	A. Year of involvement		
1.	4 years	39	39.00
2.	4-7 years	33	33.00
3.	7-10 years	19	19.00
4.	More than 10 years	9	9.00
	Total	100	100
	B. Shift pattern		
5.	Day shift	70	70.00
6.	Night shift	30	30.00
	Total	100	100
	C. Duration of work		
7.	4-6 hours	11	11.00
8.	6-8 hours	56	56.00
9.	>8 hours	33	33.00
	Total	100	100

Environmental parameters

Environmental parameter assessment is important in small-scale spice-processing units because mechanical processing operations can generate considerable amounts of dust and heat and may contribute to increased relative humidity within the workplace. These environmental conditions can collectively influence indoor air quality, thermal comfort, and the respiratory well-being of workers. Occupational exposure to airborne dust and other workplace pollutants is an important occupational health concern, while poor working environments are recognized as contributing factors to occupational diseases. In India, authorities such as the Central Pollution Control Board (CPCB) and the Bureau of Indian Standards (BIS) have established standards and guidelines for several environmental parameters relevant to occupational and industrial environments. Considering the climatic conditions of Assam and the operational characteristics of small-scale spice-processing units, the present study assessed selected environmental parameters, including Air Quality Index (AQI), temperature, and relative humidity, to evaluate the prevailing workplace conditions and their potential implications for workers' health and comfort.

Air Quality Index (AQI)

Air quality was assessed during active spice-processing operations using a calibrated real-time air-quality monitoring instrument. Three readings were obtained for each unit at intervals of approximately 10–15 minutes, and minimum, maximum, and average AQI values were determined. The AQI values recorded across the selected spice-processing units ranged from 90 to 123, with an overall average of 108.8. Thus, the average AQI exceeded 100, indicating an unfavourable air-quality condition according to the classification adopted in the study.

The elevated AQI observed in the processing units may be related to the nature of spice-processing activities, particularly operations involving grinding, sieving, blending, and handling of dry spices. Such activities have the potential to release particulate matter into the workplace air. The presence of airborne particulate matter is particularly relevant in spice-processing environments because workers may remain in the processing area for several hours during routine production.

The findings are consistent with the concern reported by Upadhyay et al. (2019), who examined occupational health hazards associated with particulate matter originating from spices. Therefore, regular assessment of workplace air quality is important in small-scale spice-processing units, particularly in areas where dust-generating operations are carried out. The observed AQI values demonstrate that air quality should be considered an important component of environmental assessment in spice-processing workplaces. Improving ventilation and controlling the generation and accumulation of airborne dust may help improve workplace air-quality conditions.

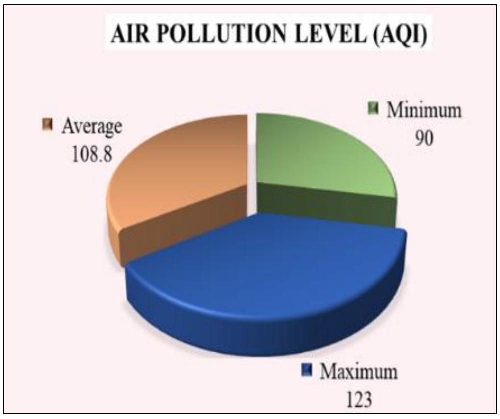

Fig 3: Distribution of Maximum and Minimum Air Pollution Level in Spice Processing Units

Ambient Temperature

Ambient temperature was recorded during active production hours along with the other environmental parameters. The workplace temperature ranged from 27.7°C to 33.1°C, with a mean temperature of 30.6°C. The mean temperature was higher than the summer reference range of 22.2–26.6°C considered in the present study. The results therefore indicate that workers were exposed to relatively elevated workplace temperatures during the monitoring period.

The elevated temperature may be influenced by both the climatic conditions of Jorhat and the characteristics of the processing environment. Mechanical processing operations and machinery may contribute to heat generation within the workplace, while limited ventilation can restrict the removal of accumulated heat.

Elevated workplace temperature can increase thermal discomfort and may contribute to fatigue and reduced concentration, particularly when workers are exposed for extended periods. Krishnamurthy et al. (2017) reported the health and productivity implications of occupational heat stress among industrial workers. Similarly, Deb et al. (2018) reported thermal discomfort among workers exposed to unfavourable workplace conditions.

In the context of small-scale spice-processing units, the observed mean temperature of 30.6°C indicates the importance of considering thermal conditions alongside air quality when evaluating the workplace environment.

Relative Humidity

Relative humidity was assessed simultaneously with ambient temperature during active production hours. The recorded relative humidity ranged from (63.0 % to 73.0 %), with a mean value of (68.4%).

The mean relative humidity exceeded the summer reference range of 40–60 percent considered in the study. Thus, the workplace conditions were characterized not only by elevated temperature but also by relatively high humidity.

High humidity can reduce the body's ability to dissipate heat through evaporation and may consequently increase thermal discomfort when combined with elevated temperature. The simultaneous occurrence of elevated temperature and humidity is therefore particularly relevant for assessing thermal conditions in the selected spice-processing units.

The findings are comparable with observations reported by Sangma and Kalita (2021), who reported relatively high indoor humidity associated with inadequate ventilation. Deb et al. (2018) also documented thermal discomfort among workers exposed to unfavourable workplace environmental conditions.

The mean relative humidity of (68.4%) observed in the present study indicates that humidity should be considered an important component of workplace environmental monitoring in spice-processing units, particularly under the climatic conditions of Assam

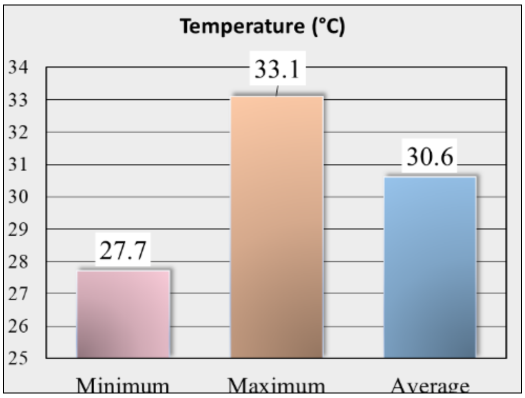

Fig 4: Distribution of Maximum and Minimum Temperature in Spice Processing Units

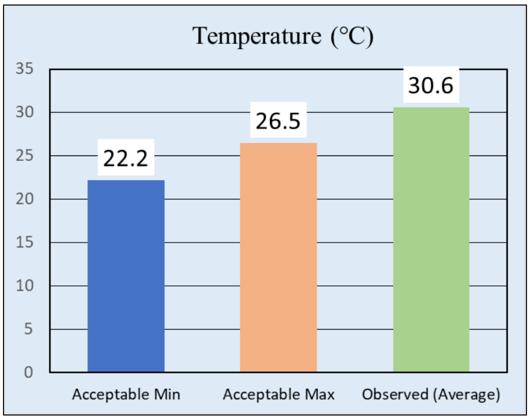

Fig 5: Distribution of Observed (Avg.) And Acceptable Limit of Temperature in Spice Processing Units

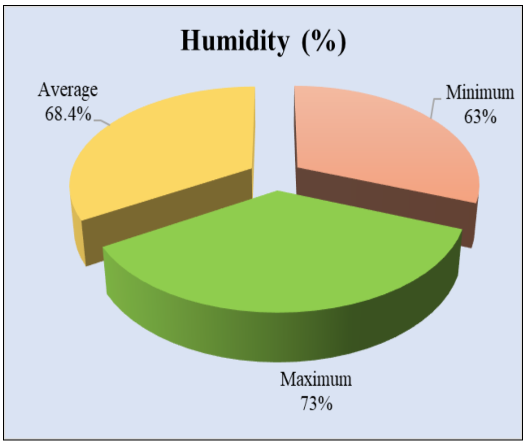

Fig 6: Distribution of Maximum and Minimum Humidity Levels in Spice Processing Units

Table 2: Distribution of Maximum, Minimum and Average Temperature and Relative Humidity in Spice Processing Units

Temperature (°C)			
Minimum	**Maximum**	**Average**	**Acceptable limit**
27.7	33.1	30.6	Summer season -22.2 °C to 26.6 °C Winter season -20 °C to 23.3 °C
Humidity (%)			
Minimum	Minimum	Minimum	Minimum
63.0	73.0	68.4	Summer season-40-60% Winter season-40-45%

Conclusion

The present study assessed three important workplace environmental parameters Air Quality Index, ambient temperature, and relative humidity in selected small-scale spice-processing units of Jorhat district, Assam. The findings revealed that the workplace environment was characterized by elevated temperature, high relative humidity, and unfavourable air-quality conditions. The recorded temperature ranged from 27.7°C to 33.1°C, with a mean of 30.6°C, while relative humidity ranged from (63.0% to 73.0%), with a mean of (68.4%). Both mean temperature and relative humidity exceeded the reference ranges considered in the study. AQI values ranged from 90 to 123, with an average of 108.8. The findings indicate that air quality and thermal environmental conditions require greater attention in small-scale spice-processing workplaces. The combination of airborne particulate exposure, elevated temperature, and high relative humidity may contribute to an unfavourable working environment, particularly during active processing operations. Regular monitoring of AQI, temperature, and relative humidity should therefore be encouraged in spice-processing units. Adequate ventilation, effective dust-control practices, and measures to improve thermal conditions may help in maintaining a healthier and more comfortable workplace environment.

Implications for Practice

Based on the findings of the study, the following measures are recommended:

1. **Regular environmental monitoring:** AQI, temperature, and relative humidity should be monitored periodically, particularly during active production hours.

2. **Improved ventilation:** Adequate natural or mechanical ventilation should be provided to facilitate the removal of airborne dust and accumulated heat.

3. **Dust-control measures:** Dust-generating operations such as grinding, sieving, and blending should be provided with appropriate local or general ventilation and dust-control measures.

4. **Thermal-comfort measures:** Workplace arrangements should be improved to reduce excessive heat and humidity, particularly during warmer periods.

5. **Worker awareness:** Workers should be informed about the importance of workplace air quality and thermal conditions and encouraged to report symptoms of excessive heat discomfort or respiratory irritation.

6. **Continued environmental assessment:** Periodic assessment of AQI, temperature, and relative humidity can help identify changes in workplace conditions and support timely preventive measures.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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