Analysis of Ventilation Survey in Cement Sector Packing Plant

RAVI KUMAR MISHRA[1], TARUN PRASAD SONWANI[2], GULAB CHAND SAHU[3], OMPRAKASH THAKARE[4]

[1]*M.Tech. Student, Department of Health Safety and Environmental Engineering Shri Rawatpura Sarkar University, Raipur (C.G)*

[2,3,4]*Assistant Professor, Department of Mechanical Engineering, Shri Rawatpura Sarkar University, Raipur (C.G)*

Abstract- Ventilation is a key factor in ensuring good air quality, occupational safety, and comfort in industrial settings. This thesis outlines the findings of a detailed ventilation assessment carried out in a cement packing plant located in Durg during September 2024. The primary aim of the study was to evaluate how effectively the plant's natural ventilation system operates and whether it meets legal standards set by the Indian Factories Act (1948) and international guidelines, including those from ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). Measurements were taken using anemometers and temperature sensors at various points throughout the facility. The results show that airflow, temperature, and humidity levels fall within the acceptable range, ensuring a safe and comfortable working environment. This research highlights the critical need for regular monitoring and improvement of ventilation systems and provides suggestions for boosting air movement through both design modifications and operational changes.

Indexed Terms- Ventilation, Air Quality, Occupational Safety, Worker Comfort, Cement Packing Plant, Natural Ventilation System, ASHRAE Standards, Airflow, Temperature, Humidity.

I. INTRODUCTION

In addition to being essential for human existence, clean air is also critical for preserving the productivity and well-being of those who work in enclosed industrial areas. Large volumes of dust and other pollutants are released throughout the production process in industries like cement manufacture, thus a dependable and efficient ventilation system is crucial. In addition to keeping interior air quality, temperature, and humidity within safe and acceptable bounds, proper ventilation aids in the removal of dangerous airborne particles. Without proper ventilation, workers in the cement sector are at serious danger for health problems due to the high quantities of dust. Regular ventilation evaluations are essential for assessing the state of affairs and pinpointing areas in need of improvement. The immediate practical significance of this study in raising industrial facilities' safety and health requirements makes it significant. Air is essential to life, and the most basic need for all living things is access to fresh, clean air. Without oxygen, death happens in a matter of minutes; breathing is vital to life, and the human body cannot operate properly without clean air. As a result, a well-thought-out ventilation system that consistently delivers clean air is essential. The main goals of ventilation are to maintain healthy oxygen levels in the atmosphere and to reduce or completely eradicate hazardous amounts of airborne pollutants like dust or aerosols.

II. LITERATURE REVIEW

1. Importance of Ventilation in Industrial Environments: Ventilation in industrial workplaces is not merely for comfort; it is a crucial element in ensuring occupational health and maintaining operational efficiency. According to the World Health Organization (WHO, 2010), poor air quality is a major contributor to respiratory illnesses, especially in workplaces with high concentrations of airborne contaminants like dust, gases, and fumes. In cement

manufacturing, the continuous movement of powdered materials can release large volumes of fine particulate matter. Without adequate ventilation, these pollutants can accumulate, creating a hazardous environment. ASHRAE (2004) affirms that proper ventilation helps dilute these pollutants, supplies fresh air, and maintains oxygen levels essential for health and safety.

2. Occupational Health and Safety Implications: Prolonged exposure to industrial pollutants like fine dust particles are associated with chronic respiratory conditions such as silicosis and bronchitis. The World Health Organization (2018) links occupational exposure to poor air quality to a significant portion of the global disease burden. In environments like cement packing plants, fine particulates released during handling and packaging can be especially harmful when inhaled over time. Ventilation systems that ensure continuous and adequate air exchange are recognized as essential for removing contaminants and maintaining a healthy atmosphere (NIOSH, 2015). Additionally, proper airflow regulates thermal comfort, helping to prevent heat-related illnesses such as heatstroke, particularly in warmer climates (OSHA, 2019).

3. Regulatory Framework and Standards: Industrial ventilation is subject to both national and international regulations. In India, the Factories Act (1948) requires factories to provide adequate ventilation and maintain acceptable temperature and humidity levels. Specific standards, such as ensuring a minimum air movement of 30 feet per minute and keeping wet-bulb temperatures within prescribed limits, are mandatory. Internationally, ASHRAE Standard 62.1-2010 recommends a minimum ventilation rate of 10 cubic feet per minute per person for general manufacturing facilities to maintain indoor air quality (ASHRAE, 2010). Failure to comply with such standards can lead to regulatory penalties, legal claims, and reputational damage.

4. Impact on Equipment and Operational Efficiency: Ventilation systems also contribute significantly to the longevity and performance of industrial equipment. Heat generated during machine operation, if not properly dissipated, can result in reduced performance or system failure. High humidity may lead to corrosion and electrical failures, particularly in sensitive components. In cement plants, airborne dust can clog filters, interfere with moving parts, and cause frequent maintenance issues (Singh & Sharma, 2017). Effective ventilation helps reduce such risks by minimizing dust accumulation and stabilizing environmental conditions, thereby improving machinery reliability and process efficiency.

5. Productivity and Human Performance: A well-ventilated workplace has a direct impact on employee performance. Studies from ASHRAE (2004) and NIOSH (2015) indicate that improved air quality leads to fewer sick days, higher concentration, and greater energy levels among workers. Conversely, inadequate ventilation may result in symptoms grouped under “Sick Building Syndrome,” including headaches, eye irritation, and fatigue, which adversely affect productivity. Good ventilation also boosts morale and supports worker retention by promoting a healthy and comfortable work environment (Sundell et al., 2011).

6. Sustainability and Energy Efficiency: Ventilation also plays a critical role in sustainable industrial design. Natural ventilation strategies—such as roof vents, wall louvers, and window placement—can reduce the need for mechanical ventilation, lowering energy consumption and environmental impact. These strategies support certifications like LEED (Leadership in Energy and Environmental Design), which prioritize energy-efficient design and occupational health (USGBC, 2015). Moreover, sustainable ventilation practices align with corporate ESG (Environmental, Social, and Governance) commitments, offering both health and environmental benefits.

III. RESEARCH METHODOLOGY

This research adopts a quantitative methodology to assess the efficiency of natural ventilation systems in a cement sector packing plant. The study was conducted through an on-site ventilation survey at a cement packing facility located in Durg during September 2024. Key environmental parameters such as air velocity, temperature, and relative humidity were measured using calibrated instruments including anemometers, digital thermometers, and hygrometers.

Data were recorded at multiple operational zones within the packing area during working hours to capture realistic exposure conditions. The collected data were systematically analyzed and compared against the prescribed norms outlined in the Indian Factories Act (1948) and international benchmarks, particularly ASHRAE Standard 62.1. The goal was to determine the adequacy of air circulation, identify zones with substandard ventilation, and assess potential health and safety risks to workers. Based on the findings, the study also recommends structural and operational improvements to enhance air quality, thermal comfort, and regulatory compliance.

Regulatory Framework

Several national and international organizations have set specific ventilation standards to ensure workplace safety. Among the most recognized are:

In industrial settings, ventilation is not merely a technical necessity for maintaining indoor air quality—it is also a statutory obligation enforced by regulatory authorities. These regulations are designed to protect worker health, promote safety, and sustain optimal working conditions in industrial environments. The regulatory framework for ventilation covers essential parameters such as air exchange rates, allowable temperature and humidity levels, and limits on the concentration of airborne pollutants.

This section highlights the key regulatory standards relevant to industrial ventilation, focusing especially on Indian legal provisions and globally accepted guidelines such as those issued by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers).

(A). TheFactoriesAct, 1948(India)

The Factories Act, 1948 is the primary legislation in India that governs the health, safety, and welfare of workers in factories. It includes specific provisions for ventilation and temperature control to ensure comfortable and safe working conditions.

Section12: Ventilation and Temperature

According to Section12, every factory must make effective arrangements for:

- Adequate ventilation by the circulation of fresh air
- Maintaining a temperature that will secure workers' comfort and prevent health risks *Schedule of Maximum Permissible Wet-Bulb Temperatures*

To ensure compliance, the Act sets limits on the maximum wet-bulb temperature in workplaces based on dry-bulb temperature readings, with measurements taken at a height of 1.5 meters above floor level—the average breathing zone. The following schedule is mandated:

Dry Bulb Temperature(°C)	Maximum Wet Bulb Temperature(°C)
30°C– 34°C	29.0°C
35°C– 39°C	28.5°C
40°C– 44°C	28.0°C
45°C– 47°C	27.5°C

Table1-PermissibleWet-BulbTemperature Thresholds for Workplaces

In addition, air movement must not fall below 30meters per minute (approximately100ft/min), which helps prevent stagnant air, thermal stress, and the accumulation of pollutants. Failure to comply with these parameters constitutes a violation of the Act, and can result in penalties, factory shutdowns, or legal actions against employers.

(B).ASHRAE Standards (International)

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is one of the most widely recognized global authorities on indoor environmental quality. ASHRAE’s standards are frequently used as bench marks for assessing ventilation effectiveness in both developed and developing countries, including India.

ASHRAE62.1–2010: Ventilation for Acceptable Indoor Air Quality

This standard defines the minimum ventilation rates and other measures intended to provide indoor air quality that is acceptable to human occupants. For general manufacturing facilities, ASHRAE recommends a ventilation rate of 10 cubic feet per minute (cfm) per person. The rate varies based on the type of industrial process and the potential for contaminant generation.

It also mandates consideration of:

- Outdoor air intake rates
- Contaminant control and exhaust
- Recirculation and filtration practices

ASHRAE55–2004: Thermal Environmental Conditions for Human Occupancy

This standard focuses on human thermal comfort and provides recommended ranges for temperature and humidity:

Temperature:

- Summer: 20°C to 24.5°C
- Winter: 22.5°C to 26.6°C
- Relative Humidity: 30% to 60%

These values are derived from empirical research on human thermal comfort and are intended to prevent fatigue, heat-related illnesses, and productivity loss. Although these standards are voluntary, they are often adopted into national occupational health codes or corporate environmental, health, and safety (EHS) policies.

IV. INSTRUMENTS USED

To measure various environmental parameters, the following instruments were employed:

1. Anemometer

An anemometer is a device used to measure air velocity (wind speed), which is critical in determining the effectiveness of ventilation. In this survey, the anemometer was used to capture air movement at different strategic points—corners and the center of the Packer Floor—to assess the natural airflow patterns.

Figure1- Anemometer

Principle of Operation

There are several types of anemometers, but the one used in this study was a rotating vane anemometer, which operates on the principle that the rotation speed of the vane is directly proportional to the air velocity. As air moves across the blades, they spin, and this rotational speed is measured and converted into a velocity reading in feet per minute (ft/min) or meters per second (m/s)

- Purpose: To measure air velocity (ft./min)
- Application: Readings were taken at multiple points—corners and center of the Packer Floor

Calibration and Usage

Prior to use, the anemometer was calibrated using a known airflow source or by cross-referencing
with a standard unit. During the survey:

- The device was held at a consistent height (1.5 meters above the floor, per regulatory
- guidelines)
- Readings were taken at multiple locations (North, South, East, West, and Center)
- Values were recorded manually and averaged to ensure representativeness.

2. Temperature Meter

Monitoring the ambient temperature is essential for ensuring thermal comfort and verifying
compliance with both Factory Act guidelines and ASHRAE standards. In hot working
environments, temperature can significantly influence worker health and equipment performance

Figure 2 - Temperature Meter Principle of Operation

Principle of Operation

The temperature meter used in the study was a digital dry bulb thermometer, which measures the air temperature using a thermostat or thermocouple sensor. The sensor's electrical resistance changes with temperature and this is processed to provide a precise temperature reading.

- Purpose: To measure dry bulb temperature
- Application: Temperature readings were taken at 1.5 meters above ground, aligning with
- statutory requirements Field Use Protocol
- The temperature meter was placed in each location for 2–3 minutes to allow for stabilization
- Readings were recorded at 1.5 m above ground to match regulatory observation height
- where fluctuations were noted, multiple readings were averaged

Data Collection Procedures

The data collection process followed a structured and systematic approach:

- Location Points: Measurements were taken at five critical positions in the plant: North, South, East, West, and Center of the Packer Floor.
- Air Velocity Readings: Multiple readings were recorded at each location to minimize error.

The success of a ventilation survey largely depends on a systematic and well-structured data collection process. For this study, data was collected to evaluate key parameters such as air velocity, air change rate (ACR), temperature, and relative humidity. These variables were recorded at various representative points within the Packing Plant Unit of the cement factory Musing field-tested instruments under real operating conditions. This section outlines the detailed procedures used to collect accurate, repeatable, and representative data to assess the effectiveness of natural ventilation in the study area.

Instrument Deployment and Measurement Method

Each instrument was used systematically across all sampling points. The measurement protocol followed the steps below:

1. Air Velocity (ft/min)

- The anemometer was held 1.5 meters above the ground (worker breathing zone height), consistent with the Factories Act, 1948.
- Air velocity was recorded at each location with the instrument facing into the direction of airflow.
- For consistency, three readings per location were taken over a 2-minute interval and then averaged.
- Any sudden gusts or temporary disturbances were ignored or re-measured.

2. Temperature (°C)

- The digital thermometer was also positioned at 1.5 meters height, away from machinery or heat sources to avoid skewed readings.
- At each of the five points, the meter was allowed to stabilize for 2–3 minutes before recording.
- Readings were noted under steady-state conditions, not during transitions (e.g., doors being opened /closed).

3. Relative Humidity (%)

- A digital hygrometer (integrated or standalone) was used alongside the thermometer.
- RH readings were captured simultaneously with temperature to maintain temporal alignment.
- Special care was taken to avoid exposure to direct sunlight or localized moisture that could affect results.

Once all data was collected:

- Averages were calculated for air velocity and temperature at each location.
- Airflow (CFM) was computed using the formula:

Calculation of Air Flow (CFM):

- CFM=Area (in sq.feet) × Average Air Velocity (ft/min) $V_{avg} = \frac{V1+V2+V3+V4+V5}{5}$

Air Change Rate (ACR):

$$\mathbf{ACR} = \frac{\textbf{Air flow (CFM)} \times \mathbf{60}}{\textbf{Room Volume (cubic feet)}}$$

V. FOR VENTILATION SURVEY

The Ventilation Survey carried out by monitoring Air velocity at different locations of different floors of various locations. The sampling was conducted using different testing equipment's. Samples for Air Velocity were collected and there recording were noted on-site.

Air Velocity: - readings at different location of Cement packing plant (corners & center of the source) of the same taken.

Calculated the Average value of the readings I.e. Average= [(Reading 1+2+3+4+5)/ readings].
Considering the area of the Cement packing plant unit in sq. feet

Calculation:
Air Flow (in CFM) = Area of (in sq. feet) x Average Air Velocity (in ft./min].

Worker Observations and Subjective Feedback

In addition to quantitative data, informal discussions were held with workers operating on the floor during the survey. The aim was to gather subjective feedback related to:

- Breathing comfort
- Perceived heat and humidity
- Any history of ventilation-related complaints

This qualitative insight added a human-centered dimension to the data analysis and helped validate whether recorded environmental conditions aligned with user experience.

Calculation Methods:

The ventilation survey conducted at the packing plant relied heavily on quantitative methods to analyze the effectiveness of the existing natural ventilation system. The primary parameters evaluated were Air Flow (CFM), Air Change Rate (ACR/hr), Temperature, and Relative Humidity. These values were then compared against statutory benchmarks and international standards to determine whether environmental conditions met the necessary criteria for health, comfort, and safety.

This section explains the mathematical formulas, assumptions, and calculation steps used to derive key ventilation performance metrics

A. Air Velocity Measurement and Averaging
At each selected location on the Packer Floor (North, South, East, West, and Center), three to five air velocity readings were taken using an anemometer. These readings were recorded in feet per minute (ft/min).

To eliminate random fluctuations and ensure reliability, the average air velocity for each location was calculated using the arithmetic mean formula:

$$\text{Average Air Velocity (V\_avg)} = \frac{V_1 + V_2 + V_3 + \ldots + V_n}{n}$$

Where:
- V1, V2, Vn V_1, V_2, \l dots V_nV1, V2, Vn are the air velocity readings at a specific location
- nnn is the total number of readings (typically 3 to 5) 32

This average velocity was used in subsequent calculations to determine airflow and air change rate.

B. Calculation of Air Flow Rate (CFM)

The air flow rate, commonly expressed in cubic feet per minute (CFM), represents the volume of air that passes through a given area per unit of time. CFM is a key metric used to evaluate the adequacy of ventilation.

The following formula was used:

C. Calculation of Air Change Rate (ACR/hr)

The Air Change Rate per hour (ACR/hr) quantifies how many times the air within a defined space is replaced or cycled every hour. ACR is a crucial parameter used by standards like ASHRAE 62.1-2010 to determine adequate ventilation in enclosed environments.
Where:

$$\mathrm{ACR/hr} = \frac{\mathrm{CFM} \times 60}{\mathrm{Room\ Volume\ (cubic\ feet)}}$$

CFM is the calculated airflow

60 convert minutes to hours

Room Volume is the total volume of the space (length × width × height)

D. Temperature and Humidity Comparisons
Although no calculations were required for temperature and relative humidity, the readings were compared with acceptable limits defined by ASHRAE standards:

Parameter	ASHRAE Recommended Range
Temperature (Summer)	20°C to 24.5°C
Temperature (Winter)	22.5°C to 26.6°C
Relative Humidity (RH)	30% to 60%

Table 2- ASHRAE Recommended Temperature and Humidity Ranges

Any deviations were noted and analyzed in the context of seasonal variation, worker feedback, and the potential need for mechanical assistance (e.g., exhaust fans, cooling solutions).
In the observed data:

- Average temperature was 33°C (within acceptable summer range for India and consistent with factory norms)
- Relative humidity was 54%, comfortably within ASHRAE's recommended 30–60% band

These comparisons helped determine whether the current natural ventilation system maintains thermal comfort and prevents excessive moisture accumulation.

Sample Data Point Calculation (based on provided sheet):

Parameter	Value
Air Change Rate (ACR/hr)	7.2and6.9
ASHRAE Required ACR	6–12
Air Movement	164ft./min(outside)
Recorded Air Temp	33°C
ASHRAE Temp Range	30–34°C(compliant)
Humidity Recorded	54%
ASHRAE Humidity Range	30–60%(compliant)

Table 3- Table of Sample Measured Parameters and Compliance Status

The observed data were found to be within permissible ranges.

The plant is having natural Ventilation system
Natural Ventilation System of Plant

Figure 3 - Natural Ventilation System of Plant

The total area of the packing plant unit is approximate (LxW) 78.6 X 39m, The Natural ventilation system of plant consists of windows & doors and openings approximately 20 % of floor area.

VI. RESULTS AND DATA ANALYSIS

This chapter presents the data collected during the ventilation survey and evaluates its compliance with relevant statutory and international standards. The results have been organized and analyzed using tabulated formats for clarity and ease of interpretation.

Ventilation Survey Data Summary

The ventilation survey was conducted at five strategic locations within the Packing Plant (Packer Floor). The parameters measured include Air Change Rate (ACR), air velocity, temperature, and humidity.

Table 4 Ventilation Data Summary

SN	Location	ACR/hr	ACR Standard (ASHRAE 62.1-2010)	Air Movement (ft/min)	emp (°C)	ASHRAE Temp Range (°C)	nidity (%)	ASHRAE Humidity Range (%)
1	Packing Plant (Packer Floor1)	7.2	6–12	164	33	30–34	54	30–60
2	Packing Plant (Packer Floor2)	6.9	6-12	164	33	30-34	54	30-60

Graphical Representation

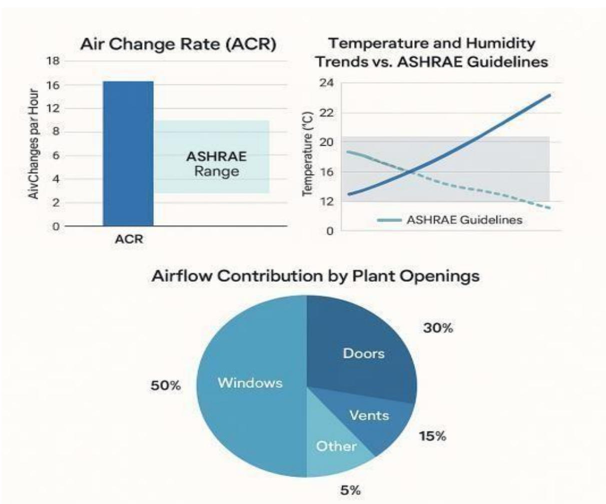

Figure 4- Graphical Representation of Ventilation Data — ACR Comparison, Temperature and Humidity Trends, and Airflow Distribution

Compliance Check with Standards

1. Air Change Rate (ACR)

The measured ACR is 7.2/hr and 6.9/hr, which falls within the ASHRAE-prescribed range of 6–12/hr, indicating effective air replacement.

2. Air Movement

The outdoor air velocity was recorded at 164 ft./min, surpassing the minimum threshold of 30 ft./min required under the Factories Act, 1948. This confirms that air circulation is adequate.

3. Temperature

With an average measured temperature of 33°C, the values are within ASHRAE's acceptable summer range of 30–34°C.

4. Humidity

The relative humidity stood at 54%, within the ASHRAE's safe range of 30–60%, ensuring comfort and reduced chances of microbial growth or corrosion.

CONCLUSION

The study on ventilation in a packing facility used in the cement industry emphasizes how crucial efficient ventilation is to maintaining a safe and healthy working environment. It discovered that because of constant operations and extensive material handling, packing areas frequently experience high dust concentrations, high temperatures, and inadequate air circulation. Inadequate ventilation has an influence on operational efficiency and productivity in addition to the health of employees. The report emphasizes that in order to keep air quality below acceptable exposure levels; both mechanical and natural ventilation systems are required. To reduce airborne particulate matter, high-capacity exhaust fans, dust extraction devices, and air filtering systems must be installed. Workplace safety can be further improved by routine monitoring, ventilation equipment maintenance, and staff awareness initiatives.

REFERENCES

[1] World Health Organization (WHO). (2010). *WHO guidelines for indoor air quality: selected pollutants*. World Health Organization. https://www.who.int/publications/i/item/9789289002134

[2] ASHRAE. (2004). *ASHRAE Handbook – HVAC Systems and Equipment*. American Society of Heating, Refrigerating and Air-Conditioning Engineers.

[3] World Health Organization (WHO). (2018). *preventing disease through healthy environments: A global assessment of the burden of disease from environmental risks*. https://www.who.int/publications/i/item/9789241565196

[4] National Institute for Occupational Safety and Health (NIOSH). (2015). *Hierarchy of Controls*. Centers for Disease Control and Prevention (CDC). https://www.cdc.gov/niosh/topics/hierarchy

[5] Occupational Safety and Health Administration (OSHA). (2019). *Heat Stress: Guide for Employers*. https://www.osha.gov/heat-exposure

[6] Factories Act of India. (1948). *The Factories Act, 1948*. Government of India. https://labour.gov.in/sites/default/files/Factories_Act_1948.pdf

[7] ASHRAE. (2010). *ANSI/ASHRAE Standard 62.1-2010: Ventilation for Acceptable Indoor Air Quality*. American Society of Heating, Refrigerating and Air-Conditioning Engineers.

[8] Singh, R., & Sharma, V. (2017). *Maintenance Practices in Cement Industry*. International Journal of Engineering Research and Applications, 7(9), 22–29.

[9] Sundell, J., et al. (2011). *Ventilation rates and health: multidisciplinary review of the scientific literature*. Indoor Air, 21(3), 191–204. https://doi.org/10.1111/j.1600-0668.2010.00703.x

[10] United States Green Building Council (USGBC). (2015). *LEED v4 for Building Design and Construction*. https://www.usgbc.org/resources/leed-v4-building-design-and-construction-current-version