

# **Occupational Exposure to Flour Dust and Its Mitigation Through Portable Ventilation: Evidence from a Case Study**

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## **Abstract**

Indoor air pollution is a major health risk for workers, especially in industries where fine particles are generated. Flour milling and packaging are two activities that are especially likely to release flour dust into the air. This is a known respiratory hazard and can also cause combustible dust explosions. At the Second Mills Company flour-packing plant in Riyadh, there was an excessive amount of flour dust building up around the carousel packing machine. This raised concerns about workers' safety and whether the company complied with industrial hygiene standards. To deal with this problem, a field study was carried out to measure exposure levels and test an affordable engineering control. An Exttech VPC300 optical particle counter was used to collect thirty air samples at three significant locations during two work shifts. A Vevor portable ventilation fan with a five-meter flexible duct was installed in place at the main source of dust after baseline measurements were taken. Normality testing and a paired t-test were applied to statistically validate the effectiveness of the intervention. This study emphasizes the swift implementation and quantitative validation of a straightforward ducted local exhaust system through multi-channel real-time particle counting, contrasting with prior research that predominantly utilized gravimetric sampling or long-term modeling. Results showed a 55-62% drop in 0.5  $\mu\text{m}$  particle counts and a change in severity rating from "hazardous" to "safe/low caution." This shows that a portable ducted ventilator is a practical and cost-effective way to improve indoor air quality and protect the health of workers in flour milling facilities.

## **Keywords**

Indoor air quality (IAQ), Occupational health and safety, Flour dust exposure, Portable ventilation fan, and Particle counter monitoring

## **1. Introduction**

Indoor air pollution (IAP) is widely recognized as a serious global public health concern. IAP refers to the presence of pollutants inside buildings or structures, such as volatile organic compounds (VOCs) and particulate matter (PM) all of which may have harmful effects on the human body. Waste gasses, cigarette smoke, pesticides, solvents, cleaning agents, particulates, dust, mold, fibers, and allergies are all released by humans throughout their everyday activities, and these pollutants contribute to IAP (Tran et al. 2020). The World Health Organization (WHO) report stated that air pollution, both outdoor and indoor, causes millions of premature deaths each year, largely due to respiratory and cardiovascular diseases (WHO 2025). Air pollution can be defined as contamination of the atmosphere by gaseous, liquid, or solid wastes that can endanger life, attack materials, and reduce visibility (Choudhary and Garg 2013). While the public often associates air pollution with outdoor sources such as traffic or industrial emissions, evidence indicates that indoor air can harbor concentrations of pollutants two to five times higher than outdoor levels

(EPA 2025). Because people spend up to 90% of their time inside, the air quality in closed spaces is crucial for health and well-being (EPA 2025).

Workplaces, particularly those involving industrial processing, represent settings where indoor air pollution can reach levels far exceeding those encountered in homes or offices. Indoor air pollution may be caused by a variety of sources, including dust, mold, solvents, pesticides, smoking, pet dander, and gases (Yadav et al. 2023; Ahmed et al. 2021). Flour dust, composed of finely milled cereal or non-cereal grains, is a well-documented occupational hazard. Its small particle size allows deep penetration into the human respiratory tract, where it can trigger allergic reactions, chronic bronchitis, and rhinitis (Houba et al. 1996). Epidemiological studies have shown that workers exposed to inhalable flour dust experience higher rates of asthma-like symptoms and diminished lung function compared with unexposed populations (Stobnicka and Górny 2015).

Health risks are not the only concern. Flour dust is also combustible; when dispersed in air at sufficient concentration, it can create explosive atmospheres if an ignition source is present (Abbasi and Abbasi 2007). Catastrophic flour-dust explosions have been recorded in milling plants worldwide, causing fatalities, injuries, and massive property damage (Özbakır 2024). These incidents underscore the dual imperative of controlling flour dust: protecting workers' respiratory health and preventing potentially devastating fires and explosions.

Controlling such hazards typically follows the established "hierarchy of controls" in occupational hygiene: elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE) (Morris and Cannady 2019). Of these, engineering controls, particularly ventilation, are considered the most reliable and sustainable means to reduce airborne contaminants at their source (Li 2023). Ventilation can be implemented as general dilution ventilation or as local exhaust ventilation (LEV). LEV systems capture contaminants at or near the point of release and are often preferred when a specific process generates high concentrations of dust (Old and Methner 2008). However, the installation of permanent LEV systems in existing industrial plants may be costly, disruptive, and time-consuming.

Portable ventilation equipment provides a flexible alternative. Portable fans with ducting can be rapidly deployed to direct dust-laden air away from workers and towards filtration or safe discharge points, without major structural modification of the facility (Cao et al. 2024). Such systems are particularly attractive in settings where dust sources are localized and where production layouts change or where budgets and timeframes do not allow for permanent LEV installation. Despite these advantages, there is a limited body of peer-reviewed literature evaluating the real-time effectiveness of portable ventilation interventions in flour-milling environments, especially in the Middle East. Much of the published research has focused on gravimetric sampling of dust concentrations or on long-term health outcomes, leaving a gap in evidence for rapid, quantitative assessment of low-cost engineering controls using real-time particle counters (Shao et al. 2021).

Saudi Arabia's food processing sector, including large flour-milling operations, has grown rapidly in response to national food security initiatives and population growth. This expansion underscores the need for local data on occupational exposure and effective control strategies. The Second Mills Company, one of the country's leading flour producers, operates large-scale milling and packaging lines in Riyadh. Within its flour packing area, workers and management observed persistent accumulation of airborne flour dust despite routine housekeeping practices. Concerns arose regarding both the potential respiratory health impact on workers and the risk of combustible dust incidents. The company's industrial safety department, therefore, sought an evidence-based, practical intervention that could be implemented quickly and evaluated scientifically.

The present study was designed to fill this gap by conducting a comprehensive exposure assessment and testing a cost-effective engineering control. Thirty air samples were collected at three critical locations near the carousel packing machine during two consecutive work shifts. Sampling was performed with an Extech VPC300 optical particle counter, which provides real-time measurements across six particle-size channels, including sub-micron fractions relevant to respiratory health. After establishing baseline dust levels, a Vevor portable ventilation fan with a five-meter flexible duct was installed adjacent to the primary dust source. This setup was intended to capture and remove flour dust at its point of generation, thereby improving the breathing environment for workers without requiring permanent infrastructure changes.

To rigorously evaluate the effectiveness of this intervention, the data were subjected to statistical tests. The statistical approach allowed the determination of whether the observed differences in particle counts before and after installation of the ventilator were significant rather than due to random variation. This combination of rapid, multi-channel particle counting and formal statistical validation provides a novel methodological contribution compared with earlier studies that have typically relied on slower gravimetric sampling or subjective assessments of air quality.

This research study integrates principles of industrial hygiene, occupational health, and engineering control design to address a pressing workplace hazard in a Saudi flour-milling facility. By documenting both the baseline exposure levels and the measurable improvement achieved through a simple portable ventilation system, the study contributes new evidence to the limited literature on low-cost dust control in food-processing industries. The findings offer practical guidance for plant managers and safety professionals seeking efficient strategies to protect workers and to comply with occupational exposure standards in rapidly growing industrial sectors.

## **1.1 Objectives**

The major objective of this study is to assess and improve indoor air quality in the flour packing area of the Second Mills Company in Riyadh. Particularly, the objectives can be expressed as follows:

1. **Quantify baseline exposure:** Measure airborne flour dust concentrations at multiple workstations within the packing line using a six-channel Extech VPC300 optical particle counter to capture particle-size distribution down to sub-micron levels.
2. **Identify critical exposure zones:** Compare particle counts at three strategically selected locations (A, B, and C) and across two work shifts to determine where and when workers experience the highest exposure.
3. **Implement a low-cost engineering control:** Deploy a Vevor portable ventilation fan with a five-meter flexible duct adjacent to the main dust source (carousel packing machine) to act as a localized exhaust ventilation system without major structural modification.
4. **Validate effectiveness statistically:** Apply normality testing and a paired t-test to the pre- and post-intervention data to determine whether observed reductions in particle counts are statistically significant.
5. **Evaluate practical impact:** Translate the measured improvement in particle concentration into implications for worker respiratory health and occupational safety, and provide recommendations for similar flour-milling and food-processing environments.

## **2. Literature Review**

As mentioned earlier, IAP is increasingly recognized as a major threat to human health and workplace safety. The United States Environmental Protection Agency reports that concentrations of many indoor pollutants can be two to five times higher than those found outdoors, making indoor air quality (IAQ) a critical factor in occupational health (EPA 2025). Industrial environments are especially prone to IAP due to the emission of particulate matter and gases during production processes (Smith et al. 2000).

Among industrial airborne contaminants, flour dust is a well-documented hazard in bakeries and flour-milling facilities. Flour dust consists of finely milled cereal or non-cereal grain particles that can be readily inhaled and deposited deep within the respiratory tract (Kim et al. 2017). Occupational exposure has been strongly associated with allergic respiratory conditions such as rhinitis, chronic bronchitis, and the so-called “baker’s asthma,” a form of occupational asthma characterized by wheezing and shortness of breath (Baur et al. 1998). Houba et al. (1996) established a dose-response relationship between exposure to wheat allergens and the development of sensitization. Stobnicka et al. (2015) documented that inhalable flour dust concentrations in bakeries and mills frequently exceed recommended occupational limits. The American Conference of Governmental Industrial Hygienists (ACGIH) therefore set a threshold limit value (TLV) of 0.5 mg m<sup>-3</sup> for inhalable flour dust to reduce the risk of respiratory sensitization (ACGIH 2025).

The hazards of flour dust are not limited to health effects. Finely dispersed organic dust can also create explosive atmospheres when combined with oxygen and an ignition source (Abbasi and Abbasi 2007). Historical analyses have shown that dust explosions in flour mills have caused numerous fatalities and extensive property damage (Amyotte 2013). Eckhoff (2003) described how common ignition sources, such as mechanical friction, static electricity, and overheated equipment, can ignite combustible dust clouds, leading to chain-reaction explosions. These dual threats of respiratory illness and explosion underscore the importance of effective flour-dust control strategies.

Occupational hygiene follows a hierarchy of controls, with engineering controls, especially ventilation, ranked above administrative measures and PPE as a sustainable means of hazard reduction (Morris and Cannady 2019). LEV is often preferred for capturing contaminants at their source. Permanent LEV installations, however, can be expensive and disruptive to retrofit in existing plants. Portable ventilation systems offer a flexible, lower-cost alternative that can be deployed rapidly to address localized dust sources (Sankurantripati and Duchaine 2024). Cao et al. (2024) demonstrated that portable ducted fans can significantly reduce worker exposure to welding fumes, suggesting similar potential for flour-dust control. Despite these advantages, most published studies have relied on gravimetric sampling or long-term exposure modelling (Shao et al. 2021), and relatively few have reported real-time quantitative evaluation of low-cost portable ventilation in food-processing environments.

While the health and explosion hazards of flour dust are well established, there is limited empirical evidence, particularly in the Gulf region, on the effectiveness of portable, ducted ventilation fans as a rapid engineering control. Few studies have combined real-time multi-channel particle counting with formal statistical validation to quantify dust reduction. This study addresses that gap by implementing and statistically evaluating a low-cost portable ventilation intervention in a Saudi flour-milling facility.

### **3. Methods**

This section describes the experimental design adopted to evaluate flour dust exposure and the effectiveness of a portable ventilation fan in reducing airborne particulate concentrations. The methodology follows the classical stages of industrial hygiene assessment: baseline characterization, engineering control implementation, and post-intervention evaluation.

#### **3.1 Study Site**

The investigation was carried out in the flour packing area of the Second Mills Company in Riyadh, Saudi Arabia. It has been noticed that workers in the Second Mills factory are exposed to high levels of flour dust, especially in the flour packing area, and this could be hazardous for the workers. The packing hall consists of four parallel production lines where flour is filled into bags of different sizes. Each line operates three shifts per day, with approximately twelve workers distributed across the lines. The carousel packing machine, where flour bags are initially filled, was identified as the primary source of airborne flour dust.

#### **3.2 Sampling Locations and Shifts**

During the flour packing operation, the flour is loaded into bags of different weights. These products (flour bags) are received by supermarkets and bakeries. Flour packing is the last process and the most dangerous due to the operations that lead to high levels of flour dust. The flour packing area contains 4 production lines and 12 workers. There are 3 shifts, each shift works 8 hours.

To represent typical worker exposure, three sampling locations (labeled A, B, and C) were selected within one production line, all in proximity to the carousel machine. Location A was closest to the source, while B and C were progressively downstream of the packing process. Two work shifts were monitored: the morning shift (7:00 a.m.–3:00 p.m.) and the evening shift (3:00 p.m.–11:00 p.m.). This allowed for comparison of dust levels across different operational periods. As shown in Figure 1, this is the sequence of operations in the flour packing area. Since all 4 production lines are identical, only one production line is shown in this layout.

#### **3.3 Instrumentation**

Airborne particle concentrations were measured using an Extech VPC300 optical particle counter. This device provides real-time counts across six particle size channels (0.3  $\mu\text{m}$ , 0.5  $\mu\text{m}$ , 1.0  $\mu\text{m}$ , 2.5  $\mu\text{m}$ , 5.0  $\mu\text{m}$ , and 10  $\mu\text{m}$ ). It also records temperature and relative humidity, enabling a comprehensive characterization of the indoor air environment. The VPC300's built-in color-coded severity indicators (green, yellow, red) were used to classify the level of particulate pollution for each size channel.

#### **3.4 Engineering Control Intervention**

Following the baseline survey (as explained in data collection section), a Vevor portable ventilation fan was installed as an engineering control. The fan has a 30-cm diameter, a high-speed motor operating up to 3400 rpm, and is connected to a five-meter flexible duct. The fan was positioned adjacent to the carousel packing machine (sampling

location A) so that the duct captured dust directly at the source. The system was configured to exhaust the dust-laden air away from the workspace, thereby reducing airborne flour particles in the workers' breathing zone (Figure 1).

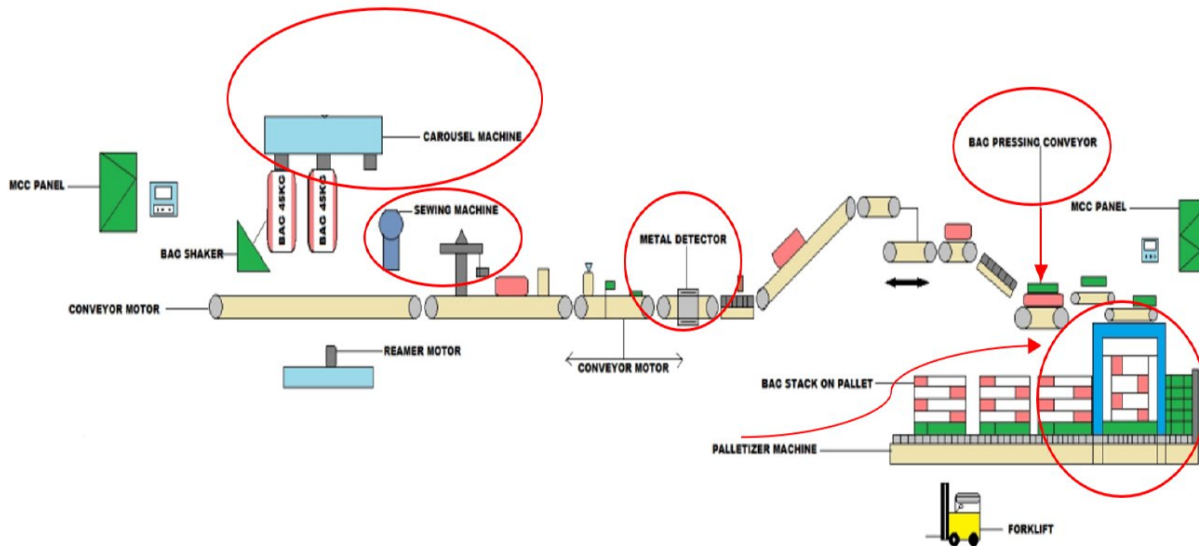


Figure 1. Flour packing area layout

### 3.5 Data Analysis

To evaluate the effectiveness of the intervention:

- **Normality Testing:** The distribution of 0.5  $\mu\text{m}$  particle counts, the channel identified as the primary severity indicator, was assessed using a normality test. A p-value greater than 0.05 indicated that the data followed a normal distribution.
- **Paired t-Test:** Pre- and post-intervention measurements for each location were compared using a paired t-test to determine whether reductions in particle counts were statistically significant.
- **Improvement Percentage:** The percentage reduction in particle counts was calculated for each location and particle size channel to quantify the magnitude of improvement achieved.

### 3.6 Quality Assurance and Limitations

Sampling was performed by trained personnel to ensure consistent instrument handling and placement. The particle counter was calibrated according to the manufacturer's instructions before the study. Limitations include the absence of gravimetric mass concentration data ( $\text{mg}/\text{m}^3$ ), which prevented direct comparison with ACGIH threshold limit values, and the short-term nature of sampling, which did not capture long-term seasonal variations.

## 4. Data Collection

The data collection procedure was designed to obtain reliable and representative measurements of airborne flour dust in the flour packing area, both before and after the installation of the engineering control. The following steps outline the approach.

### 4.1 Preparation and Instrument Setup

Prior to sampling, the Extech VPC300 optical particle counter was calibrated according to the manufacturer's instructions to ensure accuracy of particle counts. The instrument was set to record particles in six size channels (0.3, 0.5, 1.0, 2.5, 5.0, and 10  $\mu\text{m}$ ) and to log ambient temperature and relative humidity concurrently. The sampling probe was mounted at a height of approximately 150 cm, corresponding to the breathing zone of a standing worker, to capture air that workers typically inhale.

#### 4.2 Baseline Measurements

Baseline data were collected to characterize the typical exposure conditions during normal plant operation. Three sampling locations, designated A, B, and C, were selected along a single production line based on proximity to the carousel packing machine, which was identified as the primary source of flour dust. The severity assessment of flour packing machines was based on the factors shown in Table 1. Moreover, Figure 2 shows the simple flour packing area layout, with severity and sampling locations. Figure 3 shows the actual picture of the sampling locations at factory (Table 1).

Table 1. Severity assessment factors

Machine	Distance from the source (in m)	Number of affected people	Duration of exposure	Severity
Carousel machine	0	2	8 hrs per shift	High
Sewing machine	2	1	8 hrs per shift	Medium
Metal detector	4	0	-	Low
Bag pressing conveyor	6	0	-	Low
Palletizer machine	8	0	-	Low

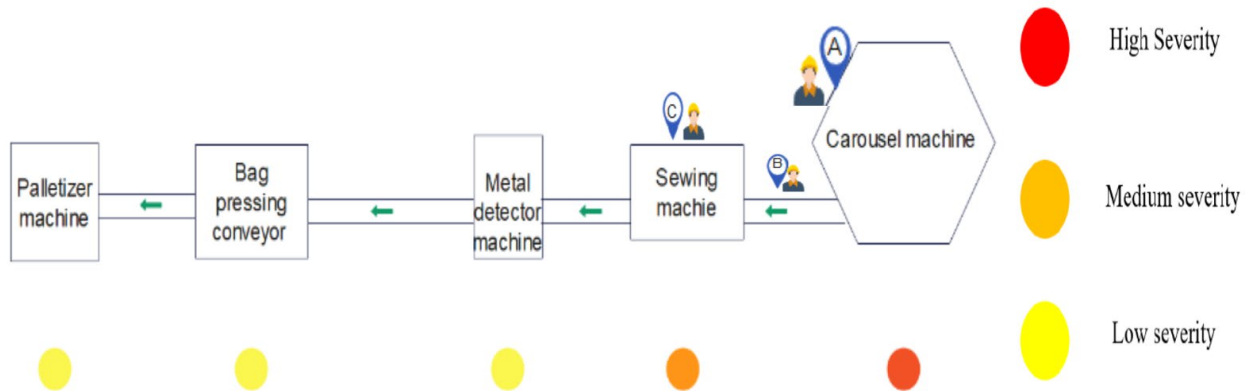


Figure 2. Simple flour packing area layout with severity and sampling locations

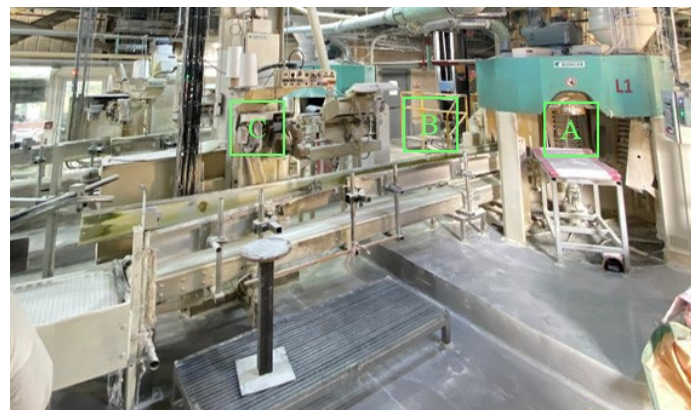


Figure 3. Sampling locations in actual factory

*Sampling frequency:* At each location, five random samples per shift were taken, resulting in a total of 15 samples per shift and 30 baseline samples overall. Each sample consisted of a continuous particle count reading recorded once the instrument stabilized for at least one minute.

### 4.3 Intervention and Post-Intervention Measurements

After completion of the baseline survey, the Vevor portable ventilation fan with a five-meter flexible duct was installed adjacent to location A to act as a localized exhaust ventilation system. Once the fan had operated for sufficient time to achieve steady airflow conditions, the same sampling procedure was repeated. Thirty additional air samples were collected (15 per shift) at the identical three locations using the same breathing-zone placement and one-minute measurement protocol. The particle counter's built-in severity color codes (green, yellow, red) were noted for each particle size channel to classify the level of airborne contamination.

### 4.4 Data Logging and Handling

All readings, particle counts for each size channel, temperature, and relative humidity, were recorded in standardized data sheets immediately after each measurement. Each entry included the date, time, location, shift, and sampling condition (pre- or post-intervention). These data sheets were later digitized and checked for transcription errors before statistical analysis.

## 5. Results and Discussion

### 5.1 Baseline Flour Dust Exposure

The following Table 2 shows the samples that were collected in the flour packing area at locations A, B, and C using VPC300 during the first shift.

Table 2. Collected data for shift 1

No.	Location	0.3um	0.5um	1.0um	2.5um	5.0um	10um
1	A	632426	325754	129813	89555	8118	5495
2		618947	292784	130024	85609	10429	6626
3		485427	410720	121510	80866	9108	7245
4		581622	320909	125091	84654	9537	6784
5		698459	352192	117450	78905	8984	5934
6	B	478785	257822	118873	82464	9003	6595
7		574986	300669	96688	63394	7832	6149
8		617660	260452	92322	58416	7090	4625
9		486394	251301	66255	40944	5192	4143
10		483075	217338	79820	53868	5627	3780
11	C	469167	185768	71705	44401	5175	3613
12		480095	215086	79486	53370	5878	4179
13		476739	200239	51851	33745	4891	3698
14		516595	184732	54142	35787	3429	2606
15		515814	201248	44778	27654	4369	3525

Table 3. Collected data for shift 2

No.	Location	0.3um	0.5um	1.0um	2.5um	5.0um	10um
16	A	494041	395725	139849	93336	10420	8089
17		514112	329826	129647	90452	12452	8900
18		639624	311911	116494	79105	8313	5549
19		656386	342882	142550	100436	10302	6617
20		624655	316869	117832	85537	8540	5947
21	B	534839	254429	75088	47668	5823	4039
22		595696	284522	75840	51818	5216	4005
23		480396	254333	77295	49764	4337	3480
24		478562	218397	75216	48746	5838	4103
25		617040	241901	78145	53072	5038	3686
26	C	508090	202361	70069	42971	5101	3416
27		588541	207976	70542	46072	4422	3198
28		510487	214919	64179	43165	4863	3274
29		476150	185523	62843	40087	4618	3322
30		500673	200598	69222	44078	5342	3639

Initial measurements confirmed that the flour packing area experienced high airborne particle concentrations, especially at the carousel packing machine (Location A), the primary dust source. For the key particle size of 0.5 µm, selected as the main severity indicator, the mean counts across the first and second shifts consistently exceeded 250,000 particles/L, which, according to the VPC300 criteria, corresponds to a “hazardous” (red) severity level. Locations B and C, progressively farther from the carousel machine, recorded slightly lower particle counts, but most readings for sub-micron channels (0.3 µm and 0.5 µm) remained in the red zone. The normality test applied to all size channels and locations yielded p-values > 0.05, indicating that the data followed a normal distribution and were therefore suitable for parametric analysis (Table 3).

A paired t-test comparing morning and evening shift data found no statistically significant difference ( $p > 0.05$ ) in particle counts between shifts, suggesting that flour dust exposure levels were stable across the workday. This is consistent with a continuous dust generation process linked to the packing operation rather than time-specific events.

## 5.2 Impact of the Portable Ventilation Fan

After installing the Vevor portable ventilation fan with a five-meter flexible duct adjacent to the carousel machine, a second round of measurements was taken under the same conditions. Figure 4 shows the portable fan with duct.



Figure 4. Vevor Portable ventilation fan

In a similar manner (tabular form as shown in Table 4, and Table 5), data after fan installation were collected. Particle counts across all six size channels dropped markedly at every sampling location. For the critical  $0.5 \mu\text{m}$  channel, mean particle counts fell from roughly 300,000-350,000 particles/L to about 110,000-125,000 particles/L at Location A, a reduction of approximately 55-62 %. Locations B and C showed similar percentage decreases, and most readings for larger particle channels ( $1.0 \mu\text{m}$  and above) moved from the red or yellow zone to the “safe/low caution” (green–yellow) category.

Normality testing of the post-intervention data again yielded  $p$ -values  $> 0.05$ , validating the use of paired  $t$ -tests. The paired  $t$ -tests comparing pre- and post-intervention counts for each location and channel demonstrated highly significant reductions ( $p < 0.05$ ), confirming the statistical effectiveness of the ventilation fan in lowering airborne flour dust.

Table 6 shows the improvement percentage after installing the Vevor portable ventilation fan.

Table 4. Collected data for shift 1 after fan installation

No.	Location	0.3um	0.5um	1.0um	2.5um	5.0um	10um
31	A	357531	120459	39968	23082	2949	2268
32		295022	122974	39069	16262	2571	2010
33		292583	124540	38194	14783	2295	1734
34		285323	111633	32484	12401	2091	1596
35		253092	107818	32260	11752	1607	1193
36	B	223830	95671	27653	8883	1239	850
37		246937	105818	30974	10679	1604	1192
38		229871	97846	26683	7693	900	563
39		230082	97570	28964	9411	1421	978
40		279201	107063	31401	13813	1788	1355
41	C	218823	94964	25624	7444	897	603
42		206685	90206	24579	6994	926	683
43		208133	87574	25220	7807	1103	711
44		225269	94373	26533	8615	1277	874
45		197361	85198	23507	6890	891	568

Table 5. Collected data for shift 2 after fan installation

No.	Location	0.3um	0.5um	1.0um	2.5um	5.0um	10um
46	A	311307	123853	35681	13629	2180	1609
47		281851	117490	34808	12712	2018	1520
48		278133	109552	32385	11038	1786	1290
49		289099	119618	34610	13026	1955	1430
50		276243	112444	32819	12984	2177	1596
51	B	223711	97160	28552	9731	1507	1043
52		264059	106449	32710	13697	2024	1564
53		231447	102090	29994	9862	1493	1034
54		242246	95232	27609	8253	884	586
55		232094	96450	28007	11395	1685	1278
56	c	204931	90353	24896	6627	736	463
57		208106	87824	25168	7022	851	538
58		217608	94868	26955	8562	1200	813
59		194124	81502	22640	6346	799	504
60		207360	87810	24703	6977	897	595

Table 6. Improvement percentage

Location	0.3um	0.5um	1.0um	2.5um	5.0um	10um
A	50.89%	65.57%	72.27%	83.69%	77.52%	75.82%
B	55.05%	60.59%	64.99%	81.20%	76.15%	76.59%
C	58.32%	54.85%	60.45%	82.06%	79.88%	81.52%

These results clearly demonstrate that a low-cost, portable ventilation system can achieve a substantial and statistically significant reduction in flour dust exposure. The magnitude of the decrease, exceeding 50 % for the fine (0.5  $\mu\text{m}$ ) particles most strongly linked to respiratory sensitization, suggests a meaningful improvement in the workers' breathing environment.

This finding is notable because most published studies of flour dust control focus on permanent LEV or large-scale industrial dust collectors [10–12]. While such systems are effective, they often require significant capital investment and downtime for installation. In contrast, the portable fan used in this study can be deployed quickly, occupies minimal space, and requires little structural modification, making it attractive for small-to-medium mills or for interim control while permanent systems are planned.

The results align with earlier reports that portable ducted ventilation can effectively capture airborne particulates in other industrial settings [15], but provide new quantitative evidence specific to flour milling in the Gulf region. By using a multi-channel real-time particle counter and applying formal statistical tests, the present study strengthens the case for such low-cost interventions.

One limitation is that the Exttech VPC300 provides particle number counts but not mass concentrations ( $\text{mg m}^{-3}$ ), so direct comparison with the ACGIH threshold limit value of 0.5  $\text{mgm}^{-3}$  is not possible. Additionally, the study was limited to short-term measurements and did not evaluate long-term maintenance of the control or seasonal variations. Future work could include gravimetric sampling to convert number counts to mass and assess the durability and cost-benefit of portable ventilation over extended periods.

## 6. Conclusion

This study assessed occupational exposure to airborne flour dust in the packing area of a large Saudi flour mill and evaluated a simple, low-cost engineering control. Baseline measurements using a six-channel optical particle counter revealed consistently hazardous concentrations of fine particles, particularly near the carousel packing machine, with no significant variation between morning and evening shifts.

Installation of a Vevor portable ventilation fan with a five-meter duct produced a statistically significant reduction in airborne dust, lowering 0.5  $\mu\text{m}$  particle counts by roughly 55–62 % across all monitored locations and shifting the severity rating from “hazardous” to “safe/low caution.” These findings demonstrate that a portable, ducted ventilation fan can provide a practical and cost-effective means of improving indoor air quality in flour-milling operations. The approach offers a rapid, flexible solution for plants that cannot immediately install permanent local exhaust systems and contributes regional evidence to the limited literature on low-cost dust control strategies in food-processing industries.

Although this study was conducted in a flour milling facility, the underlying principles and outcomes have broader applicability to other industries where airborne particulate exposure is a major occupational hazard. Many manufacturing and processing sectors, such as grain handling, animal feed milling, cement packaging, chemical powder handling, and food processing, face similar challenges of controlling localized dust emissions. The demonstrated effectiveness of a simple, portable, and low-cost ventilation system offers a scalable and flexible control strategy that can be rapidly deployed in these environments without requiring major infrastructure modifications. Such interventions can complement existing industrial hygiene programs, helping facilities meet occupational exposure standards and improve worker health and safety outcomes.

Future research directions include long-term monitoring and mass-based measurements, economic and operational assessments, health outcome studies, optimization of engineering controls, and comparative studies across industries and climates.

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## **Biography**

**Ibrahim Almuhaideb** is an Assistant Professor of Industrial Engineering Department at King Saud University, Saudi Arabia. He received a BS in Industrial Engineering from King Saud University, Saudi Arabia, and a M.Sc. in Safety Management from West Virginia University, USA and a Ph.D. in Occupational Safety and Health from West Virginia University, USA. He possesses extensive practical experience in the field of management and risk, Also, he previously served as the chairman of the Industrial Engineering Department at the College of Engineering at King Saud University and as a risk management coordinator within the same collage. His teaching experience includes ergonomics, industrial safety engineering, risk management, and engineering management. Ibrahim's research focuses on occupational safety and health, industrial fires, process improvement, physiological impacts of workplace environments on employees, and indoor and outdoor air pollution.