# Exposure to dust and associated respiratory outcomes among workers at a flour mill in KwaZulu-Natal province, South Africa

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**Keywords**
spirometry, flour dust occupational exposure limit, flour millers, pulmonary function, personal dust sampling

**How to cite this paper**
Hoopdeo S, Ghuman S, Onwubu SC, Naidoo V. Exposure to dust and associated respiratory outcomes among workers at a flour mill in KwaZulu-Natal province, South Africa. Occup Health Southern Afr. 2025; 31(3):140-145. doi: 10.62380/ohsa.2025.31.3.3

## ABSTRACT

***Background:*** Inhalation of flour dust is associated with respiratory health effects, but there has been little research conducted on flour mill workers in South Africa. South Africa has an occupational exposure limit (OEL) for grain dust, but no OEL for flour dust. The former is used as the OEL for flour dust, despite the difference in composition and particle size of the two dusts. Flour mill workers report work-related respiratory health effects; therefore, it is essential to establish an OEL for flour dust.

***Objectives:*** We assessed reported respiratory symptoms and pulmonary function amongst workers in a flour milling company, and associated factors.

***Methods:*** This cross-sectional study was conducted at a flour mill in KwaZulu-Natal province, South Africa, amongst 63 employees: 48 mill workers and 15 office workers. Self-reported symptoms (chest tightness/breathing difficulties, dry cough, sneezing, and running/blocked nose) and work-related factors were elicited in 2021, using a questionnaire. Pulmonary function data were obtained from medical records; personal dust exposures from 2017, 2019, and 2021 were obtained from environmental monitoring reports. Categorical data, including respiratory symptoms and pulmonary function, were summarised using frequencies and percentages. Logistic regression was used to assess the association between exposure and respiratory symptoms, with odds ratios (ORs) and 95% confidence intervals (CIs) reported. Multiple linear regression was used to identify predictors of pulmonary function.

***Results:*** The proportions of mill and office workers who reported respiratory symptoms was similar (50.0% and 46.7%, respectively). Mill workers had slightly higher adjusted odds of reported respiratory symptoms than office workers, but this was not statistically significant. In general, the forced expiratory volume in one second/forced vital capacity ($FEV_1$/FVC) ratios of the office workers and the laboratory staff were higher than those of the mill workers in other departments. The $FEV_1$/FVC ratios were slightly higher amongst all participants in 2020, during the severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2) pandemic, than in 2019. Age was a predictor of pulmonary function ($\beta$ = -0.377 (p = 0.007) in 2019 and $\beta$ = -0.393 (p = 0.006) in 2020). Some mill workers were exposed to dust at concentrations exceeding the OEL for grain dust.

***Conclusion:*** Although mill workers had slightly poorer pulmonary function than office workers, the prevalences of reported respiratory symptoms were similar. However, the high dust exposures in the milling and packing departments indicate that there is a need for improved dust control measures. The establishment of an OEL for flour dust will go a long way to protecting worker health.

## INTRODUCTION

The American Conference of Governmental Industrial Hygienists (ACGIH) defines 'flour' as a complex organic dust used in baking; it comprises cereals such as wheat, rye, sorghum, barley, oats, rice, or corn (maize), or a combination of these, which have been processed by milling grains.[1,2] Flour dust refers to the particles that are created when cereals or non-cereal grains, such as wheat, are finely milled, and may contain contaminants such as silica, fungi, aflatoxins, insects, mites, pesticides, and herbicides.[3]

Exposure to flour dust has been linked to several adverse health effects, especially among bakers, and grain and flour millers.[3] For example, a study in Norway, published in 2004, found that flour dust exposure was associated with decreased pulmonary function among bakery workers.[4] Similarly, respiratory symptoms, such as cough and wheezing, were reported among workers exposed to flour dust in grain processing facilities in Egypt by Mohammadien et al. in 2013.[2] Only a few studies have been published about flour dust exposure in South Africa.[5-8]

While South Africa has an occupational exposure limit (OEL) for grain dust, there is none for flour dust. The grain dust OEL is used to assess over-exposure to flour dust, even though both dusts are organically different. In 2021, the grain dust OEL was reduced from 10 mg/m$^3$ to 8 mg/m$^3$.[9,10]

In this paper, we describe exposure to dust and associated respiratory outcomes (symptoms and pulmonary function measured as forced expiratory volume in one second/forced vital capacity ($FEV_1$/FVC) among employees in a flour mill, and factors associated with both outcomes.

## METHODS

This was a descriptive cross-sectional study. The flour mill is located in Durban, KwaZulu-Natal province, South Africa. General milling processes are conducted, namely wheat purchasing, wheat receiving and storage, main production line activities, packaging, treatment, storage, and despatch. There are eight departments: administration, mill, maintenance, packing, laboratory, bakery, warehouse, and despatch. The mill operates 24 hours a day, seven days a week. Day shift employees work eight-hour shifts and night shift employees work 12-hour shifts for five or six days a week. Office workers are responsible for administrative tasks, while mill workers are involved in manufacturing, packaging, quality control, maintenance, storage, and dispatch in the mill and warehouse, and in the laboratory. The two work areas – mill and office – were used as proxies for flour dust exposure. The study population comprised 65 permanent employees aged 18 years or older, who had worked in the company for at least one year since 2020.

**Table 1. Grading of pulmonary function**

| | Degree of pulmonary impairment | | | |
|---|---|---|---|---|
| **Parameter (%)** | **None** | **Mild** | **Moderate** | **Severe** |
| FVC | ≥ 80 | 60–79 | 51–59 | ≤ 50 |
| $FEV_1$ | ≥ 80 | 60–79 | 41–59 | ≤ 40 |
| $FEV_1$/FVC | ≥ 75 | 60–74 | 41–59 | < 40 |

$FEV_1$: forced expiratory volume in one second, FVC: forced vital capacity

*Source: Govender, 2024*[12]

**Table 2. Demographic and work characteristics of study participants (N = 63)**

| Characteristic | n | % |
|---|---|---|
| Age (years) | | |
| 18–25 | 10 | 15.9 |
| 26–35 | 24 | 38.1 |
| 36–45 | 19 | 30.2 |
| 46–55 | 6 | 9.5 |
| > 55 | 4 | 6.3 |
| Race | | |
| Black | 50 | 79.4 |
| White | 9 | 14.3 |
| Indian | 3 | 4.8 |
| Coloured | 1 | 1.5 |
| Sex | | |
| Male | 56 | 88.9 |
| Female | 7 | 11.1 |
| Work area | | |
| Office | 15 | 23.8 |
| Mill | 48 | 76.2 |
| Department | | |
| Administration | 15 | 23.8 |
| Milling | 18 | 28.6 |
| Maintenance | 3 | 4.8 |
| Packing | 16 | 25.4 |
| Laboratory | 5 | 7.9 |
| Warehouse | 6 | 9.5 |
| Duration of employment (years) | | |
| 1–3 | 26 | 41.3 |
| 4–6 | 22 | 34.9 |
| 7–10 | 8 | 12.7 |
| > 10 | 7 | 11.1 |
| Highest education level | | |
| Primary | 7 | 11.1 |
| Secondary | 37 | 58.7 |
| Vocational training | 5 | 8.0 |
| National diploma | 10 | 15.9 |
| University degree | 4 | 6.3 |

Posters describing the study and inviting workers to participate were displayed in common areas. Data were collected, using a self-administered questionnaire, from February to April 2021. The questionnaire was divided into three sections, viz. demographic characteristics (age, race, and sex), work-related questions (work area, duration of employment, FFP2 dust mask usage, and access to basic first aid), and questions regarding lifestyle and medical history (smoking, allergies, and respiratory symptoms, viz. chest tightness/breathing difficulties, dry cough, sneezing, and running/blocked nose). The questionnaire was provided in both English and isiZulu.

Pulmonary function results from spirometry tests from 2019 and 2020 were obtained from medical records and were used to assess pulmonary function. No spirometry tests were conducted during 2021, due to the severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2) pandemic. The assessment of pulmonary function was based on the $FEV_1$/FVC ratio (Table 1).

Personal dust sampling is conducted every 24 months in accordance with the South African Department of Labour's Occupational Health and Safety Act No. 85 of 1993,[11] and the company's policy of measuring the dust exposure of at least one person from each work area, with a maximum of 10 people in total. The measurement of dust followed the National Institute for Occupational Safety and Health (NIOSH) Method 0500, which uses a 37-mm closed-face cassette and gravimetric analysis.[11] This method measures total dust, rather than flour dust specifically. Dust measurements from 2017, 2019, and 2021 were extracted from company records.

Permission was obtained from the occupational medical practitioner working in the company to amend the medical questionnaires used, to enable the collection of the data required for the study. Ethics approval was obtained from the Durban University of Technology's Institutional Research Ethics Committee (clearance certificate no. IREC 150/20).

### Data analysis

The data were captured on Google forms and downloaded into a Microsoft Excel spreadsheet, after which they were imported into SPSS version 26 software for analysis. Respiratory symptoms and pulmonary function were compared between the office and mill workers. Frequencies and percentages were used to summarise demographic and work-related characteristics, and reported respiratory symptoms. The presence of any of the respiratory symptoms was categorised as 1, and the absence as 0. Logistic regression analysis was used to assess the association between work area – as a proxy for exposure (independent

variable) and respiratory symptoms (dependent variable). In the adjusted analysis, potential confounding factors, viz. age, sex, highest education level, and access to basic first aid were controlled for. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were reported and statistical significance was set at $p < 0.05$. Multiple linear regression analysis was used to assess the influence of work area, age, use of FFP2 dust mask, and smoking (independent variables), on pulmonary function (dependent variable) for the years 2019 and 2020. The model was evaluated for its overall fit, including assumptions of linearity, normality of residuals, homoscedasticity, and multicollinearity among the predictors. The regression coefficients (β), standard errors (SEs), and p-values are reported for each variable.

## RESULTS

Sixty-three of the 65 employees who fulfilled the inclusion criteria for the study agreed to participate (96.9% response rate). Forty-eight of the study participants were mill workers (76.2%), while 15 (23.8 %) were office workers. Most participants were aged 26–45 years (n = 43, 68.3%) as shown in Table 2. Most were black (n = 50, 79.4%), and the majority were male (n = 56, 88.9%). The largest staff complements were in the milling, packing, and administration departments. Forty-one percent (n = 26) of the study participants had been employed for 1–3 years, and most (n = 37, 58.7%) had secondary school as their highest education level.

### Dust concentrations

Table 3 shows the personal dust exposure concentrations for the years 2017, 2019, and 2021 by work area, department, and job title. Those working in the packing and milling departments had the highest exposures to dust across the three years, with several exposed to concentrations higher than the grain OEL. None of the office workers were exposed to dust above the grain OEL in any of the three years.

### Respiratory symptoms

Table 4 shows the frequencies of the reported respiratory symptoms based on work area. Twenty-four mill workers (50.0%) and seven (46.7%) office workers reported one or more respiratory symptoms.

**Table 3. Personal dust exposures, 2017, 2019, and 2021**

| Year | Work area | Department | Job title | Mean TWA dust concentration (mg/m$^3$) |
|---|---|---|---|---|
| 2017 | Office | Administration | Administration cleaner | 0.48 |
| | Mill | Milling | Miller | 2.43 |
| | | Packing | Packing supervisor | 0.28 |
| | | | Packer #1 | **15.37** |
| | | | Packer #2 | 2.72 |
| | | Laboratory | Laboratory technician | 0.08 |
| | | Warehouse and dispatch | Warehouse supervisor | 0.20 |
| | | | Forklift driver #1 | 0.11 |
| | | | Forklift driver #2 | 0.53 |
| 2019 | Office | Administration | Administration cleaner | 0.50 |
| | Mill | Milling | Mill cleaner | **27.13** |
| | | | Miller | **23.98** |
| | | | Maintenance assistant | **13.18** |
| | | Packing | 12.5 kg mixer packer | 7.07 |
| | | | Packer #2 | **12.75** |
| | | | Carousel operator | 7.12 |
| | | Laboratory | Laboratory technician | 0.12 |
| | | Warehouse and dispatch | Vehicle assistant | 1.87 |
| | | | Forklift driver | 0.44 |
| 2021 | Office | Administrative | Weighbridge operator/ administrator | 0.25 |
| | Mill | Milling | Maintenance assistant | 1.20 |
| | | | Mill cleaner | 1.68 |
| | | | Mill packer | **12.24** |
| | | | Miller | 0.23 |
| | | | Mill cleaner | 1.39 |
| | | Packing | Packer #1 | **8.58** |
| | | | Packer #2 | **13.92** |
| | | Laboratory | Laboratory technician | 2.10 |
| | | Warehouse and dispatch | Forklift driver | 0.86 |

TWA: time-weighted average

Table 5 shows the association between work area and reported respiratory symptoms. There were no statistically significant associations between sociodemographic or work-related characteristics and respiratory symptoms.

### Pulmonary function

The $FEV_1$/FVC ratios declined gradually with age (Table 6). The $FEV_1$/FVC ratios remained relatively stable from 2019 to 2020 in the different departments, with the exception of the laboratory, where lung function values were higher in 2020 than in 2019. Office workers and laboratory workers had marginally higher $FEV_1$/FVC ratios (better pulmonary function) than those working in the other departments. Overall, the ratios across all categories were within the normal range, indicating no pulmonary impairment within the study participants.

Table 7 shows the results of the linear regression analysis for the 2019 and 2020 data. Age was negatively associated with $FEV_1$/FVC in both years. For every one-year increase in age, the $FEV_1$/FVC decreased by 0.377% (p = 0.007) in 2019, and by 0.393% (p = 0.006) in 2020. Although smoking was significantly associated with an increase in $FEV_1$/FVC in 2019 (β = 0.317, p = 0.022), there was no association in 2020 (β = 0.116, p = 0.361). Work area was also not associated with pulmonary function.

**Table 4. Reported respiratory symptoms**

| Respiratory symptom | Work area | | | |
|---|---|---|---|---|
| | Office n = 15 | | Mill n = 48 | |
| | n | % | n | % |
| Chest tightness/breathing difficulties | 2 | 13.3 | 12 | 25.0 |
| Dry cough | 3 | 20.0 | 8 | 16.7 |
| Sneezing, running/blocked nose | 3 | 20.0 | 16 | 33.3 |
| None | 8 | 53.3 | 24 | 50.0 |
| Any respiratory symptom | 7 | 46.7 | 24 | 50.0 |

## DISCUSSION

We assessed the respiratory outcomes (reported symptoms and pulmonary function) amongst mill and office workers exposed to flour dust, and factors associated with these outcomes. Globally, research has linked flour dust exposure to decreased pulmonary function and other adverse health effects.[2, 3, 13-16]

Some mill workers (those in the milling and packing departments) were exposed to concentrations of dust that were much higher than the grain dust OEL – almost four times higher in one case. The mill workers work closely with flour – typically within an arm's length – for prolonged periods, using only FFP2 dust masks for protection against exposure. The office workers are located in an enclosed area, which is isolated from the production areas. The laboratory workers are similarly physically removed from the dust as the laboratory is also enclosed and, therefore, relatively dust free. This might explain the better lung function of study participants who worked in these two departments, compared to those who worked in departments where there are no physical barriers to protect them from dust exposure.

Several factors, other than the department in which a person works, can affect exposure to dust in these workers. For example, the workers rotate job tasks within departments, e.g. from placing bags on pallets to filling bags with flour. Dust exposure is likely to differ during these different tasks. Dust extraction efficiency also differs within the mill. The extractor fans are positioned approximately 4 metres above the ground to remove hot air, while free-standing fans are placed on the floor to reduce temperatures. While heat stress is mitigated in this way, the dust is airborne and dispersed throughout the work area. Vibrations from milling operations can cause deterioration of equipment, leading to perforations and malfunctions, which, in turn, lead to dust spillages. Regardless of the reason for the high dust exposures in some departments in the mill, they are a cause for concern.

**Table 5. Association between work area and reported respiratory symptoms among study participants**

| | | n | OR | 95% CI | p value | AOR | 95% CI | p value |
|---|---|---|---|---|---|---|---|---|
| Work area | Office | 15 | Reference | | | Reference | | |
| | Mill | 48 | 1.1 | 0.33–3.36 | 0.933 | 25.6 | 0.80–820.37 | 0.067 |
| Age group (years) | 18–25 | 10 | Reference | | | | | |
| | 26–35 | 24 | 0.2 | 0.04–1.06 | 0.059 | 0.3 | 0.04–1.56 | 0.140 |
| | 36–45 | 19 | 0.9 | 0.18–4.90 | 0.930 | 2.4 | 0.34–16.21 | 0.382 |
| | 46–55 | 6 | 0.2 | 0.02–1.88 | 0.164 | 0.4 | 0.04–4.18 | 0.434 |
| | ≥ 55 | 4 | a | | | a | | |
| Sex | Male | 56 | Reference | | | Reference | | |
| | Female | 7 | 1.5 | 0.32–7.52 | 0.595 | 5.97 | 0.36–99.45 | 0.213 |
| Highest education | Primary | 6 | Reference | | | | | |
| | Secondary | 37 | 1.7 | 0.28–10.45 | 0.567 | 2.4 | 0.28–20.72 | 0.423 |
| | Vocational | 5 | 1.3 | 0.11–15.70 | 0.819 | 1.3 | 0.07–24.95 | 0.843 |
| | National diploma | 10 | 4.7 | 0.53–40.89 | 0.164 | 56.7 | 0.99–3245.6 | 0.051 |
| | University degree | 5 | 1.3 | 0.11–15.07 | 0.819 | 2.9 | 0.10–81.46 | 0.535 |
| Access to first aid | Yes | 53 | Reference | | | Reference | | |
| | No | 8 | 1.2 | 0.27–5.35 | 0.803 | 0.7 | 0.13–4.48 | 0.762 |
| | unsure | 2 | a | | | a | | |

AOR: adjusted odds ratio, OR: odds ratio, CI: confidence interval, a: not calculated as no respiratory symptoms were reported

While the frequency of reported respiratory symptoms varied slightly between office and mill workers, with mill workers reporting more symptoms, there was no association between work area and respiratory symptoms. Mohammadien et al. (2013)[2] showed a statistically significant relationship between reported respiratory symptoms, work area (links to level of flour dust exposure), and tobacco smoking in a study in Egypt; 96.8% of workers with high exposures reported respiratory symptoms. In 2009, the NIOSH reported that employees in a poultry breading plant – who were exposed to high levels of flour, spices, etc. – reported more work-related runny nose, stuffy nose, and frequent sneezing symptoms than the low-exposure group.[11] According to Brisman et al. (2000)[17] and Bohadana et al. (1994),[18] there is a risk of developing rhinitis even at low exposure levels to flour dust. Exposure to flour dust concentrations higher than 1 mg/m$^3$ may increase the risk of developing rhinitis (Brisman et al.).[17]

Pulmonary function is typically assessed using spirometry. Mohammadien et al. (2013)[2] place a large emphasis on duration of employment when interpreting spirometry results, and Kakouei et al. (2005)[19] state that job activities also influence these results. Study participants who did not work in the administration department or the laboratory had the lowest $FEV_1$/FVC ratios, possibly due to dust exposure. The $FEV_1$/FVC ratios were slightly higher amongst all participants in 2020 – during the SARS-CoV-2 pandemic – than in 2019, which might have been due to the increased usage of masks. Age was negatively associated with pulmonary function in both 2019 and 2020, as expected. Pulmonary maturity is obtained between the ages of 20 and 25 years – after which, pulmonary function steadily declines – particularly $FEV_1$, FVC, and $FEV_1$/FVC ratios (Barroso et al. (2018).[20] Smoking is associated with pulmonary impairment.[3] In our study, smoking was significantly associated with an increase in $FEV_1$/FVC in 2019 (but not in 2020). This unexpected association of smoking with an increase in $FEV_1$/FVC may be due to the small number of participants in our study.

**Table 6. Mean $FEV_1$/FVC by age group, duration of employment, and work area, 2019 and 2020**

| | | Year | |
|---|---|---|---|
| | | 2019 | 2020 |
| Variable | | $FEV_1$/FVC (%) | $FEV_1$/FVC (%) |
| Age (years) | | | |
| 18–25 | | 89 | 88 |
| 26–35 | | 84 | 86 |
| 36–45 | | 83 | 84.4 |
| 46–55 | | 82 | 84 |
| > 55 | | 79 | 86.5 |
| Duration of employment (years) | | | |
| 1–3 | | 85.2 | 86.3 |
| 4–6 | | 83.6 | 85.7 |
| 7–10 | | 84.3 | 85.3 |
| 11–15 | | 83.7 | 81.3 |
| > 15 | | 86 | 86.3 |
| Work area | | | |
| Office | | 87 | 87.8 |
| Mill | Laboratory | 87.5 | 94 |
| | Packing | 84.2 | 84.1 |
| | Warehouse | 83.3 | 85 |
| | Mill | 82 | 84.3 |
| | Maintenance | 82 | 83.5 |

### Limitations

Our inability to detect any associations between reported respiratory symptoms and pulmonary function, and exposure (work area) may be due to the small number of study participants. Nevertheless, we did find that workers in some departments had high exposures to dust – much higher than the OEL for grain dust. The dust sampling method used measures total dust, not flour dust specifically. The results from the personal dust sampling reports, thus, reflect exposure to all types of dust that an employee may have been exposed to during a work shift. Respiratory symptoms could be due to exposure to contaminants and not to the flour dust component. Available data were limited in that no spirometry tests were conducted in 2021 due to the coronavirus disease-2019 (COVID-19) lockdown in South Africa. Personal dust sampling is influenced by the task, worker behaviour, ventilation, the condition of equipment, and other factors, which were not available for inclusion in the analysis.

### Recommendations

It is imperative that the relevant South African governing bodies differentiate between grain dust and flour dust in determining appropriate OELs for each. The NIOSH 0500 dust sampling method is inadequate for measuring exposure to flour dust, as it is used to measure total dust. A better method needs to be identified to measure flour dust specifically. Regular inspections and planned maintenance programmes must be entrenched practices in the company to minimise exposure of workers to dust.

## CONCLUSION

Although we found no associations between exposure to dust and reported respiratory symptoms or pulmonary function, our findings do provide evidence for enhancing health and safety regulations and policies within flour mills. The high dust exposures in the milling and packing departments indicate that there is a need for improved dust control measures. The establishment of an OEL for flour dust will go a long way to protecting worker health.

**Table 7. Factors associated with pulmonary function in study participants, 2019 and 2020**

| | Year | | | | | |
|---|---|---|---|---|---|---|
| | 2019 | | | 2020 | | |
| Variable | β | SE | p value | β | SE | p value |
| Age | -0.377 | 0.804 | 0.007 | -0.393 | 0.758 | 0.006 |
| Work area | -0.098 | 0.653 | 0.500 | -0.178 | 0.551 | 0.193 |
| Use of FFP2 dust mask | 0.188 | 1.873 | 0.204 | 0.145 | 1.073 | 0.288 |
| Smoking | 0.317 | 2.090 | 0.022 | 0.116 | 0.922 | 0.361 |

β: standardised beta coefficient, SE: standard error

## KEY MESSAGES

1. Flour mill workers in some departments were exposed to dust concentrations way above the OEL for grain dust.
2. Pulmonary function appears to be lower in workers in departments where workers are exposed to high dust concentrations.
3. An OEL for flour dust will assist in protecting the respiratory health of workers.

## DECLARATION

The authors declare that this is their own work; all the sources used in this paper have been duly acknowledged and there are no conflicts of interest.

## AUTHOR CONTRIBUTIONS

Conception and design of the study: SH, SG, VN
Data acquisition: SH
Data analysis: SCO, SH
Interpretation of the data: SH, SCO, SG
Drafting of the paper: SH, SG, SCO
Critical revision of the paper: SG, SH, SCO, VN

## ACKNOWLEDGEMENTS

The authors thank the Durban University of Technology for providing funds for this study.

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