

# PARTICULATE MATTER AND LUNG FUNCTION ASSESSMENT AMONG INCENSE STICK WORKERS IN MALANG REGENCY, INDONESIA

Tika Dwi Tama<sup>1</sup>, Dian Mawarni<sup>1</sup>, Anindya Hapsari<sup>2</sup>, Dina Fauziah<sup>2</sup>,  
Nurul Setyowati<sup>1</sup> and Zirroh Alin Zariroh<sup>1</sup>

<sup>1</sup>Department of Public Health, Faculty of Sport Science, <sup>2</sup>Department of Medicine,  
Faculty of Medicine, Universitas Negeri Malang, Malang, East Java, Indonesia

**Abstract.** Incense sticks are generally used in a variety of rituals all around the world. Most products are made in home-based incense stick industries. These industries have a lot of environmental and occupational risks. This study was conducted in 5 incense stick home factories in Malang Regency from July to August 2023. It aimed to measure particulate matters of 2.5 and 10 microns (PM<sub>2.5</sub> and PM<sub>10</sub>) and the respiratory health of factory workers. PM<sub>2.5</sub> and PM<sub>10</sub> were measured using Particulate Counter while the lung functions (forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1)) of 45 workers were measured by the spirometer. The average concentration of PM<sub>2.5</sub> in Factories 1-5 were 108.75 ± 56.41, 90.0 ± 19.39, 97.25 ± 40.36, 90.75 ± 25.32, and 82.5 ± 21.75 µg/m<sup>3</sup>, respectively while the average PM<sub>10</sub> concentrations in those 5 factories were 235.25 ± 94.53, 331.5 ± 186.34, 223.0 ± 98.78, 197.25 ± 44.56, and 163.75 ± 46.23 µg/m<sup>3</sup>, respectively. Particulate matters in every study site exceeded the National Environmental Quality Standards. In Factories 1-5, the average temperatures were 27.61 ± 0.09, 27.69 ± 0.12, 31.47 ± 0.11, 31.23 ± 0.44, and 29.66 ± 1.11 degree Celsius, respectively while the average the relative humidity values were 69.27 ± 0.31, 69.70 ± 0.53, 59.95 ± 2.89, 61.95 ± 1.86, and 64.17 ± 1.87 percents, respectively. More than three-fourth of the total workers have abnormal FVC and FEV1. Therefore, raising awareness about the use of personal protective equipment and placing more of an emphasis on eliminating environmental workplace hazards should be taken into consideration.

**Keywords:** particulate matter, worker's health, incense stick industry, respiratory

Correspondence: Tika Dwi Tama, Department of Public Health, Faculty of Sport Science, Universitas Negeri Malang, Jl. Semarang No.5, Malang, East Java 65145, Indonesia  
Tel: + 62 341 551312 E-mail: tika.dwi.fik@um.ac.id

## INTRODUCTION

Respiratory disease is known as one of the work-related fatalities according to the Global Report of World Health Organization (WHO) and International Labour Organization (ILO) Joint Estimate (WHO and ILO, 2021). Chronic obstructive pulmonary which is the most fatalities attributable to work contributed to more than 450,000 deaths (WHO and ILO, 2021). This elevated risk is inextricably linked to the existence of hazards that affect respiratory health. WHO and ILO reported that occupational particulate matter, gasses, and fumes are the occupational risk factor that correlates with work-related deaths (WHO and ILO, 2021). Workers who are exposed to dust at work may experience respiratory issues that negatively impact their respiratory health as well as other organs like the lungs, eyes, nose, and airways.

Incense stick workers are more likely to inhale dust and be exposed to a variety of toxic chemicals. Incense powder, sawdust, and chemicals are just a few of the hazardous raw materials utilized in the creation of joss sticks and incense (Siripanich *et al*, 2014). Wood dust, mold, chemicals (heavy metals, aromatic compounds), dangerous machinery and equipment, adopting awkward working postures, and infrequent usage of personal protective equipment were among the health risks discovered during the process of making incense sticks (Siripanich *et al*, 2014).

Most of the earlier research focused on the negative effects of incense smoke on health (Adnyana *et al*, 2023; Lee *et al*, 2021; Lin *et al*,

2008; Yadav *et al*, 2022). Incense burning emits a large number of particles and various studies have described the chemical characterization of the particulate phase (Lin *et al*, 2008; Shrestha, 2020; Silva *et al*, 2021). The results reveal high emission levels, proving that using those goods without sufficient ventilation poses a health risk. The consequence of producing joss sticks and incense on occupational health has only been the subject of a few studies (Baskaran, 2014; Siripanich *et al*, 2014). A study in Thailand reported that small household enterprises that produced incense and joss sticks faced serious risks from dust and toxins (Siripanich *et al*, 2014). In dissolved dye and joss sticks, several heavy metals were discovered. These included lead, manganese, and barium. The largest concentration of dust and aerosols was created by rolling and shaking procedures (Siripanich *et al*, 2014). Respiratory health problems were experienced by 80% of incense stick workers (Baskaran, 2014).

In Malang Regency, Dalisodo Village serves as a center to produce incense sticks. Incense sticks that are produced in Dalisodo Village are still unfinished and unscented. Most of the population has been employed as incense artisans for many years. There are no records of industrial activity-related exposure to air pollution or particulate matter. It has also not been documented how incense smoke affects workers' health and respiratory conditions. Therefore, this study aimed to assess the particulate matter ( $PM_{2.5}$  and  $PM_{10}$ ) exposure in incense stick factories and impaired lung function among the workers. This study offers a research basis for environmental and health issues and theoretically supports additional investigation of pollutant emissions in incense stick factories. It provides a solid groundwork for regional government planning and community public health improvement. Furthermore, the preventative actions that can be taken to limit the hazards posed, especially for those who are exposed daily, will be revealed.

## MATERIALS AND METHODS

This study was carried out using a descriptive cross-sectional study design. Data collection was conducted in July-August 2023. A total of 5 factories and all workers (45 workers) were recruited as sample study. Environmental parameters data, such as  $PM_{2.5}$ ,  $PM_{10}$ , temperature, and humidity, were collected in this study. Air quality parameters were measured by the HTI HT-9600 Particle Counter (Dongguan Xintai Instrument Co Ltd, Dongguan City, PR China). Temperature and relative humidity were measured by SNDWAY-SW-572 High Accuracy Digital Thermometer, Humidity and Temperature Sensor (Dongguan Sndway Electronic Co Ltd, Guangdong, PR China). The data of air quality parameters were measured four times in each factory. Data that were collected at the individual level included respondent's characteristics (age, sex, length of work, use of personal protective equipment (PPE), smoking status) and lung function parameters namely Forced Vital Capacity (FVC: the maximum amount of air that can be exhaled after taking the deepest possible breath) and Forced Expiratory Volume in one second (FEV1: the amount of air exhaled in one second). Respondent characteristics were collected using a questionnaire. For lung function parameters, measurements were carried out using SP-10 Pocket Spirometer (Ontec Medical Systems Co Ltd, Hebei Province, PR China). FVC and FEV1 were classified as abnormal when those are less than 80% of the predicted value (Ruppel, 2003). Frequency and percentages for categorical variables were used to represent the characteristics of the study participants and lung function parameters. Meanwhile, environmental parameter data were presented according to the measurement results. The mean and standard deviation (SD) were also expressed for the result of environmental parameter measurements, including  $PM_{2.5}$ ,  $PM_{10}$ , temperature, and humidity.

An ethical review has been submitted to the Malang Health Polytechnic Ethics Committee to ensure that all parts of this research are appropriate and meet ethical rules. This research received an ethical certificate with No. 726/VII/KEPK POLKESMA/2023.

## RESULTS

There were 45 home-based incense stick factory workers in Dalisodo Village taking part in this study. The majority of them were female (53.3%) and aged between 26 and 45 years old (51.1%). The length of employment in incense factories ranged from 1 to more than 10 years, with the highest proportion falling into the group of one to five years (48.9%). More than half of them did not use PPE properly (53.3%) while working. Based on their smoking status, as many as 60% of them had never smoked, while the proportion of current smokers was 35.6%. Table 1 displays the distribution of respondents' characteristics.

Environmental parameter measurements were carried out in 5 home-based incense stick factories. The measurement results showed that the levels of  $PM_{2.5}$  and  $PM_{10}$  in the factory environment did not meet the National Environmental Quality Standard which is  $65 \mu\text{g}/\text{m}^3$  for  $PM_{2.5}$  and  $150 \mu\text{g}/\text{m}^3$  for  $PM_{10}$ . The average concentration of  $PM_{2.5}$  in Factory 1 was  $108.75 \pm 56.41 \mu\text{g}/\text{m}^3$  (76-193  $\mu\text{g}/\text{m}^3$ ), whereas in Factories 2-5, they were  $90.0 \pm 19.39 \mu\text{g}/\text{m}^3$  (76-118  $\mu\text{g}/\text{m}^3$ ),  $97.25 \pm 40.36 \mu\text{g}/\text{m}^3$  (64-156  $\mu\text{g}/\text{m}^3$ ),  $90.75 \pm 25.32 \mu\text{g}/\text{m}^3$  (68-126  $\mu\text{g}/\text{m}^3$ ), and  $82.50 \pm 21.75 \mu\text{g}/\text{m}^3$  (68-114  $\mu\text{g}/\text{m}^3$ ), respectively (Table 2). Also shown in Table 2, the average  $PM_{10}$  concentrations in those 5 factories were  $235.25 \pm 94.53 \mu\text{g}/\text{m}^3$  (172-372  $\mu\text{g}/\text{m}^3$ ),  $331.50 \pm 186.34 \mu\text{g}/\text{m}^3$  (172-591  $\mu\text{g}/\text{m}^3$ ),  $223.0 \pm 98.78 \mu\text{g}/\text{m}^3$  (135-363  $\mu\text{g}/\text{m}^3$ ),  $197.25 \pm 44.56 \mu\text{g}/\text{m}^3$  (164-263  $\mu\text{g}/\text{m}^3$ ), and  $163.75 \pm 46.23 \mu\text{g}/\text{m}^3$  (131-231  $\mu\text{g}/\text{m}^3$ ), respectively.

Table 1  
 Characteristics of respondents in the home-based incense stick factories in Malang  
 Regency, Indonesia (N = 45)

Characteristic	Frequency <i>n</i> (%)
Sex	
Male	21 (46.7)
Female	24 (53.3)
Age	
≤25 years old	8 (17.8)
26-45 years old	23 (51.1)
>45 years old	14 (31.1)
Length of work	
≤5 years	22 (48.9)
6-10 years	9 (20.0)
>10 years	14 (31.1)
Use of PPE	
No	21 (46.7)
Yes	24 (53.3)
Smoking status	
Yes	16 (35.6)
Have stopped smoking	2 (4.4)
Never	27 (60.0)

PPE: personal protective equipment

Other environmental parameters measured in the factory were temperature and humidity. The average temperature in Factory 1 was  $27.61 \pm 0.09$  °C (27.52-27.72 °C), while the temperatures recorded in Factories 2-5 were  $27.69 \pm 0.12$  °C (27.52-27.79 °C),  $31.47 \pm 0.11$  °C

(31.33-31.56 °C),  $31.23 \pm 0.44$  °C (30.91-31.88 °C), and  $29.66 \pm 1.11$  °C (28.57-31.07 °C), respectively. The relative humidity levels in Factories 1-5 were as follows:  $69.27 \pm 0.31$  (69.0-69.6),  $69.70 \pm 0.53$  (69.0-70.2),  $59.95 \pm 2.89$  (56.1-63.1),  $61.95 \pm 1.86$  (59.2-63.1), and  $64.17 \pm 1.87$  (62.0-66.3) percents, respectively (Table 2).

Apart from measuring environmental parameters, the lung functions (FVC and FEV1) of each worker were also measured. According to the measurement results, 75.6% of all workers had abnormal FVC. Workers who had abnormal FEV1 values reached 77.8%, which was not substantially different from the results of the FVC assessment. The measurement results are shown in Table 3.

## DISCUSSION

Most environmental parameters that were measured in incense stick factories, including particulate matter ( $PM_{2.5}$  and  $PM_{10}$ ), temperature, and humidity, exceeded the National Environmental Quality Standard. As being the major air pollutants,  $PM_{2.5}$  and  $PM_{10}$  have a significant negative influence on human health. The  $PM_{2.5}$  concentration which is allowed to be in ambient air is  $65 \mu\text{g}/\text{m}^3$ , while the threshold limit value of  $PM_{10}$  is  $150 \mu\text{g}/\text{m}^3$  (Ministry of Environment and Forestry, 2020). The  $PM_{10}$  concentrations in all incense stick factories were almost similar to the results of a study conducted in Thailand (Siripanich *et al*, 2014);  $PM_{10}$  concentrations in this study ranged from  $131 \mu\text{g}/\text{m}^3$  to  $591 \mu\text{g}/\text{m}^3$ , while the study in Thailand,  $PM_{10}$  concentrations ranged between  $220 \mu\text{g}/\text{m}^3$  to  $540 \mu\text{g}/\text{m}^3$ .

The sort of incense-producing industry in Indonesia and Thailand, which are both domestic industries, is relevant to this finding. The incense factories are typically located inside or close to the home.

Table 2  
 Measurements of the environmental parameters in home-based incense stick factories in Malang Regency, Indonesia

Environmental parameter	Values reported by each home-based incense stick factory, Mean $\pm$ SD (Minimum-Maximum)					Overall result (Mean $\pm$ SD)
	Factory 1	Factory 2	Factory 3	Factory 4	Factory 5	
PM <sub>2.5</sub> ( $\mu\text{g}/\text{m}^3$ )	108.75 $\pm$ 56.41 (76-193)	90.0 $\pm$ 19.39 (76-118)	97.25 $\pm$ 40.36 (64-156)	90.75 $\pm$ 25.32 (68-126)	82.5 $\pm$ 21.75 (68-114)	141.40 $\pm$ 33.21
PM <sub>10</sub> ( $\mu\text{g}/\text{m}^3$ )	235.25 $\pm$ 94.53 (172-372)	331.5 $\pm$ 186.34 (172-591)	223.0 $\pm$ 98.78 (135-363)	197.25 $\pm$ 44.56 (164-263)	163.75 $\pm$ 46.23 (131-231)	364.00 $\pm$ 140.96
Temperature ( $^{\circ}\text{C}$ )	27.61 $\pm$ 0.09 (27.52-27.72)	27.69 $\pm$ 0.12 (27.52-27.79)	31.47 $\pm$ 0.11 (31.33-31.56)	31.23 $\pm$ 0.44 (30.91-31.88)	29.66 $\pm$ 1.11 (28.57-31.07)	29.78 $\pm$ 1.93
Relative humidity (%)	69.27 $\pm$ 0.31 (69.0-69.6)	69.70 $\pm$ 0.53 (69.0-70.2)	59.95 $\pm$ 2.89 (56.1-63.1)	61.95 $\pm$ 1.86 (59.2-63.1)	64.17 $\pm$ 1.87 (62.0-66.3)	64.18 $\pm$ 5.82

$^{\circ}\text{C}$ : degree Celsius;  $\mu\text{g}/\text{m}^3$ : micrograms per cubic meter of air; PM<sub>2.5</sub>: particulate matter 2.5 microns in size; PM<sub>10</sub>: particulate matter 10 microns in size; RH: relative humidity; SD: standard deviation

Table 3

Results of lung function measurements in incense stick workers in Malang Regency, Indonesia (N = 45)

Lung function parameter	Frequency <i>n</i> (%)
FVC	
Abnormal	34 (75.6)
Normal	11 (24.4)
FEV1	
Abnormal	35 (77.8)
Normal	10 (22.2)

Note: FVC is considered abnormal when the value is less than 80% of the predicted value. It is classified as normal when the FVC value is equal to or greater than 80% (Ruppel, 2003).

FEV1 is considered abnormal when the value is less than 80% of the predicted value, otherwise it's normal (Ruppel, 2003).

FEV1: forced expiratory volume in 1 second; FVC: forced vital capacity

The main materials from the incense making process, *ie* wood dust, spreads throughout the home and contaminates the environment (Siripanich *et al*, 2014). Due to the use of simple technology and machinery, dust particles produced throughout the incense-making process are quite a lot. Making incense sticks essentially involves three steps: preparing the bamboo, which serves as the primary material; combining various incense powders; and rolling wood powders onto the incense sticks (Siripanich *et al*, 2014).

The lung function parameters that were measured in this study were FVC and FEV1. FVC and FEV1 are often used to determine airway obstruction, bronchoconstriction, or bronchodilator disorders (Ponce

*et al*, 2022). Most workers in this study had abnormal FVC and FEV1 values. Wood dust that spreads in the factory environment is known to impair mucociliary clearance which is the pulmonary system's first line of defense (Lin *et al*, 2008; Uzeloto *et al*, 2021). A decrease in mucociliary clearance may raise the risk of respiratory infections, lung damage, and other respiratory disorders (Uzeloto *et al*, 2021). Previous studies also informed that prolonged exposure to wood dust can cause asthma, nasopharyngeal cancer, chronic bronchitis, and decreased lung function, especially FEV1, FVC, FEV1/FVC values (Baran *et al*, 2009; Löfstedt *et al*, 2017; Jacobsen *et al*, 2021). Wood dust has also been labeled as carcinogenic by the International Agency for Research on Cancer (IARC), particularly for cancers of the paranasal sinuses and nasal cavities (Binazzi *et al*, 2021).

Employee health and wellness are an essential asset for any business. Employee productivity can go up when they are healthy, which benefits both them and the business. Health conditions are brought on by unhealthy working conditions, such as reduced lung function in workers. Consideration should be given to increasing the emphasis on removing environmental workplace hazards.

In summary, all home-based incense stick factories had high concentrations of particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>). Factories 1-5 had average PM<sub>2.5</sub> concentrations of 108.75 ± 56.41, 90.0 ± 19.39, 97.25 ± 40.36, 90.75 ± 25.32, and 82.5 ± 21.75 µg/m<sup>3</sup>, respectively, while their average PM<sub>10</sub> concentrations of 235.25 ± 94.53, 331.5 ± 186.34, 223.0 ± 98.78, 197.25 ± 44.56, and 163.75 ± 46.23 µg/m<sup>3</sup>, respectively. These concentrations of particulate matters exceeded the National Environmental Quality Standards. Most workers had abnormal lung function based on FVC and FEV1 parameters. Therefore, raising awareness about the use of personal protective equipment and placing more of an emphasis on eliminating environmental workplace hazards should be taken into consideration.

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## CONFLICT OF INTEREST DISCLOSURE

The authors declare that there is no conflict of interest.

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