Conference Paper

# Particulate Matter 2.5 Concentration and Subjective Acute Respiratory Effects among Production Workers at a Cement Factory

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## Abstract

Particulate matter ($PM_{2.5}$) is an air contaminant produced by cement factoriesthatcan affect the respiratory function of the workers. This study aimed to analyze the relationship between the personal exposure concentrations of $PM_{2.5}$and the subjective acute respiratory effect seen among production workers at the cement factory PT. X. The levels of$PM_{2.5}$ concentration among34 production patrol workers were measured using a Leland Legacy Pump and a Sioutas Cascade Impactor during work hours on patrol reclaimer, raw mill,firing (pre-heater, rotary kiln, cooler), finish mill, and packhouse work areas. Subjective acute respiratory effects were reported via participant questionnaire that adapted from the American Thoracic Society standard. The average personal $PM_{2.5}$ exposure concentration among patrol workers at the PT. X cement factory was 1,495.65 μg/$m^3$. All of the patrol workers experienced subjective acute respiratory effects, and the effects seen most frequently were sore throat and sneezing (64.7%). Since all subjects hadacute respiratory effects, these symptoms might be caused by $PM_{2.5}$ exposure.Further research is needed to determine the association of $PM_{2.5}$concentrations and respiratory effects.

**Keywords:** $PM_{2.5}$, respiratory effects, cement factory

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## 1. INTRODUCTION

Particulate matter ($PM_{2.5}$) is water vapor and/or solid particles smaller than 2.5 micrometers that are suspended in the air and can contribute torespiratory disease.[1] $PM_{2.5}$ can be classified asprimary particles and secondary particles. Primary particles can be found during building construction,coming out of factory smokestacks, and in wildfire debris, while secondary particles appear after a chemical reaction between SOx and NOx atfactories and as a result of some forms of transportation.[1]

Long-term and short-term $PM_{2.5}$ exposure can lead to respiratory disorders. A particle smaller than 2.5 micrometers canpenetrate and be deposited inside the pulmonary system, especially in the alveolus. This can cause adecline of lung function, chronic bronchitis, chronic obstructive pulmonary disease (COPD), and pneumonia.[4] Every 10 μg/$m^3$increase of $PM_{2.5}$ exposure leads toan additional 1.3 times the risk of ischemic heart disease and an additional 0.6 times the risk of developing COPD.[5] High exposure to $PM_{2.5}$ in the short term can cause health problems such as asthma, acute bronchitis, respiratory irritation, eyeirritation, sore throat, coughing, sneezing, shortness of breath, and even,if a patient has heart disease,heart attack.[6] Some of the chemical compositions of $PM_{2.5}$are also present in cement dust, including $SiO_2$, $Al_2O_3$, $Fe_2O_3$, CaO, MgO, and $SO_3$ derived from limestone, clay, silica sand, and gypsum, all of which could have an adverse impact on health.[7] Some studies also indicate that $PM_{2.5}$is generated from the cement factory.[8, 9]

One of the largest sources of $PM_{2.5}$ in Beijing is the cement manufacturing process.[8] Research conducted by Kakooei et al. [10] indicated that,in a cement factory,the packaging area produces the most particulate matter, followed by the cement mill, kiln, maintenance, and administration.Research from Tianjin, China showed that $PM_{2.5}$ levels are influenced by secondary sulfates and organic carbon (26.2%), the burning of coal (24.6%), the crust of dust and cement dust (20.3%), secondary nitrate (14.9%) and traffic emissions (14%).[9]

Previous studies have shown that the average$PM_{2.5}$personal exposure concentrations in cement factory patrol workers is438.941μg/$m^3$. The most prevalent acute respiratory symptoms in the workers exposed to high $PM_{2.5}$ were nasal congestion (85%), shortness of breath (47%), and sneezing (45%).[11] These studies show the potential for exposure to $PM_{2.5}$ to cause health problems incement factory patrol workers. This study aimed to measurethe personal exposure concentrations of $PM_{2.5}$ for patrol production workers in the cement factory of PT. X in 2016,and to illustrate the related subjective acute respiratory effects.

## 2. METHODS

This was a descriptive study performed using a quantitative approach. $PM_{2.5}$ exposure concentration measurements in the cement factory were carried out for approximately one month. The distribution of the concentration ofparticulates exposure was obtained using the gravimetric method.The acute respiratory effects were obtained subjectively using a questionnaire.

This study was conducted at the PT. Xcement factory in Bogor, West Java. $PM_{2.5}$ measurements were performed at each cement processing area, which have the highest particulates exposure rates compared to other areas (purposive sampling). The production areas measured for $PM_{2.5}$ were the reclaimed, raw mill, firing, finish and packhouse areas.Purposive sampling was conducted based on high exposure to particulate matter when compared with another area in the cement factory. The subjects of this research were 34 patrol workers in the production area.

Personal exposure measurements were taken using a Leland Legacy pump and a Sioutas Cascade Impactor with a quartz fiber filter. Workers were affixed with a clip impactor near their breathing area. A Sioutas Cascade Impactor consists of four impaction stages with filters and an after filter: stage A (≥2.5μm), stage B (1–2.5μm), stage C (0.5–1μm), stage D (0.25–0.5μm), and after filter (≤0.25μm). Measurements were taken for 8 hours with a flow rate of 9 L/min. To subjectively determine the acute respiratory effects,a questionnaire adapted from the American Thoracic Society was given to the workers. The questionnaire asked about their complaints or acute respiratory effect symptoms.

### 2.1. Analysis of $PM_{2.5}$ Concentration

The gravimetric method was used to determine the concentrations of $PM_{2.5}$. This method involved weighing the filter before and after measurement, then dividing by the volume of the pump used for measurement. The placement of the filter in this method must be precise and it must be put in a desiccator for 24 hours before and after weighing.[12, 13] The filter accumulated weight after sampling. The volume of the air sample was determined by counting the sampling time (minutes) and the flow rate.

## 3. RESULTS

### 3.1. Distribution of Particulate Matter 2.5 Concentration Production Areas

One exposure characterization is the source of exposure. Sources of exposure in this study werevarious locations in the cement factory, such as the reclaimer, raw mill, firing (pre-heater, rotary kiln, and cooler), finish mill, and packhouse.Table 1 shows that the highest concentration of exposure was found in the packhouse area. The

Table 1: Distribution of $PM_{2.5}$ Concentration in Production Areas

| Particle size | Production Area | | | | |
|---|---|---|---|---|---|
| | Reclaimer | Raw mill | Firing | Finish mill | Packhouse |
| >2.5 | 152.10 | 374.23 | 461.65 | 801.81 | 768.10 |
| 1 – 2.5 | 68.18 | 140.09 | 118.58 | 241.18 | 212.64 |
| 0.5 – 1 | 51.14 | 69.61 | 67.77 | 81.16 | 149.03 |
| 0.25 – 0.5 | 46.00 | 351.94 | 626.03 | 118.25 | 151.01 |
| <0.25 | 236.57 | 400.57 | 523.97 | 1483.27 | 2350.43 |
| $PM_{2.5}$ | 397.18 | 962.22 | 1336.34 | 1923.92 | 2863.10 |

Table 2: Overview of Subjective Acute Respiratory Effects

| Subjective Acute Respiratory Effect | Total | |
|---|---|---|
| | N | % |
| Yes | 34 | 100 |
| No | 0 | |
| Total | 34 | 100 |

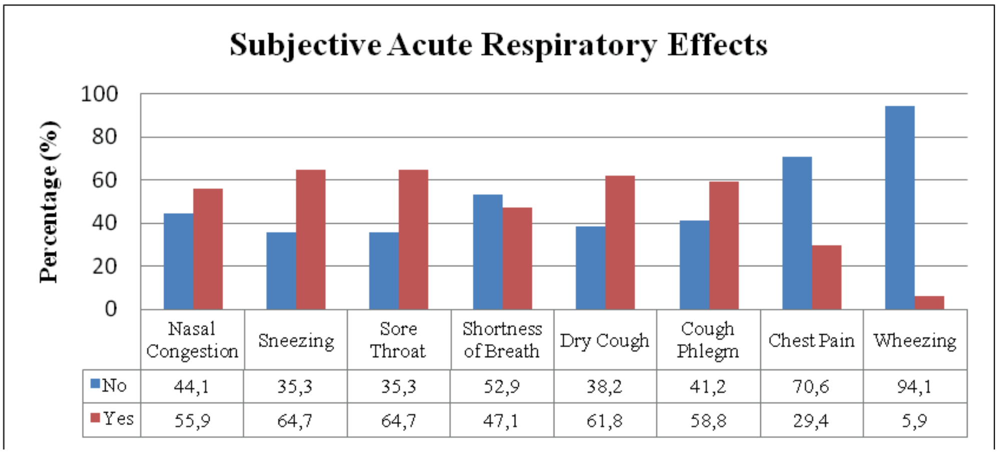


**Figure** 1: Subjective Acute Respiratory Effects.

average personal exposure concentrations of patrol workers in the packhouse area was 2863.101 μg/m3.

Table 2 shows that all the production patrol workers had an acute respiratory effect symptom (100%). Furthermore, there was a wide variety of acute respiratory symptoms reported by the production patrol workers.

## 3.2. Subjective Acute Respiratory Effect Distribution

The acute respiratory effects most commonly experienced by workers were sore throat and sneezing. Meanwhile, wheezing was the least often experienced acute respiratory effect.

Table 3: Distribution of Average $PM_{2.5}$ Exposure Based on the Subjective Acute Respiratory Effect.

| Respiratory Effect | Total | Mean ($PM_{2.5}$) | p-value |
|---|---|---|---|
| Nasal Congestion | | | |
| Yes | 19 | 1489.85 | 0.567 |
| No | 15 | 1502.98 | |
| Sneezing | | | |
| Yes | 22 | 1617.86 | 0.056 |
| No | 12 | 1271.59 | |
| Sore Throat | | | |
| Yes | 22 | 1460.72 | 0.885 |
| No | 12 | 1559.68 | |
| Shortness of Breath | | | |
| Yes | 16 | 1953.26 | 0.112 |
| No | 18 | 1088.88 | |
| Dry Cough | | | |
| Yes | 21 | 1475.73 | 0.658 |
| No | 13 | 1527.81 | |
| Cough Phlegm | | | |
| Yes | 20 | 1477.76 | 0.151 |
| No | 14 | 1521.20 | |
| Chest Pain | | | |
| Yes | 10 | 1286.13 | 0.910 |
| No | 24 | 1582.94 | |
| Wheezing | | | |
| Yes | 2 | 945.17 | 0.1 |
| No | 32 | 1530.05 | |

### 3.3. $PM_{2.5}$ Concentration (μg/$m^3$) and Health Effect of Sore Throat

The highest exposure concentration of $PM_{2.5}$ was in the packhouse area (2,863.10 μg/$m^3$), while the effect of sore throatwas seen most often by workersin the firing process (75%). See Figure 2.

## 4. DISCUSSION

### 4.1. Distribution of Particulate Matter 2.5 Concentration in Production Areas

The average personal exposure concentration of $PM_{2.5}$on production patrol workers at the cement factory PT. X was 1495.651 μg/$m^3$. This could be the highest amount recorded, as previous research involving a Nigerian cement factory showed that the

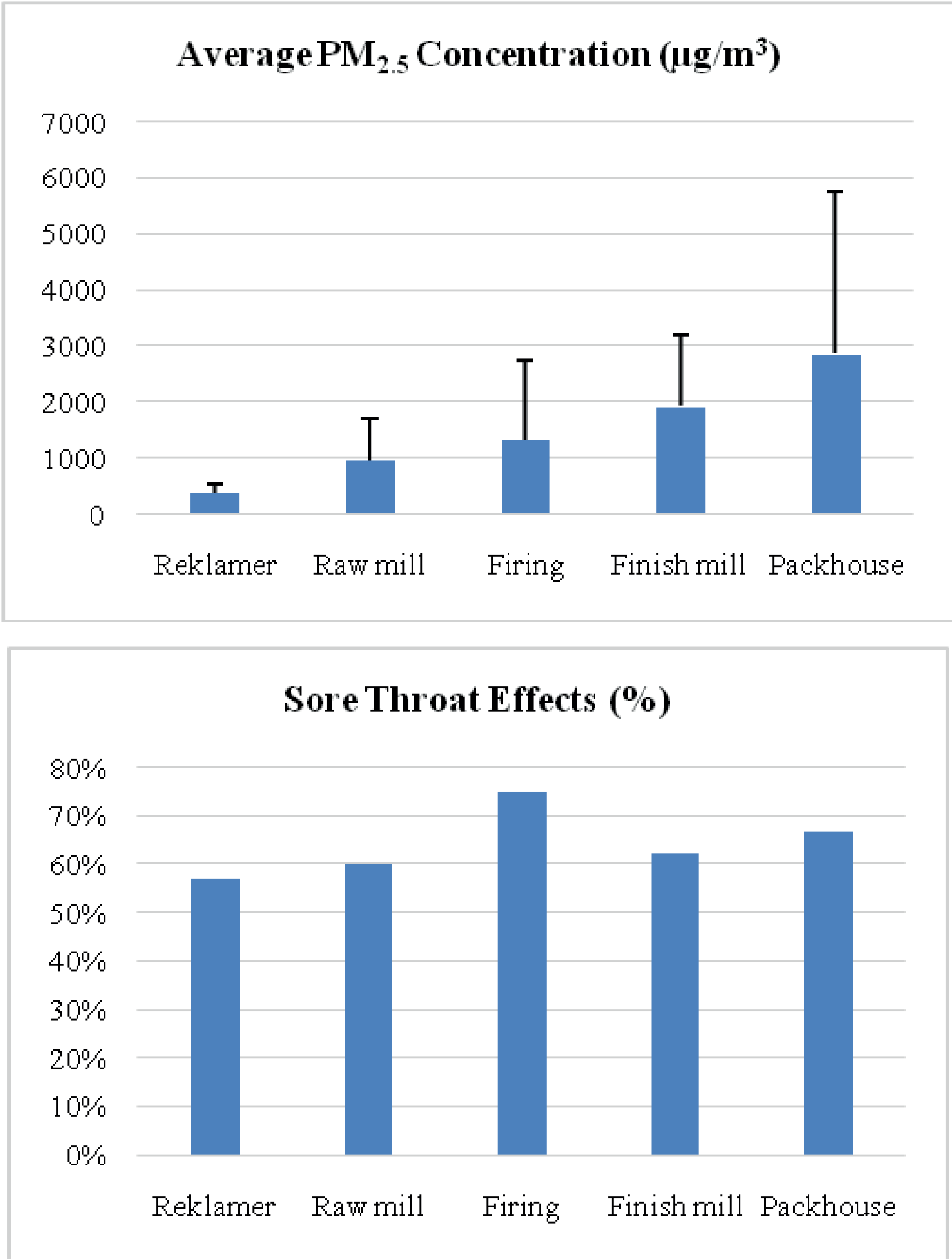


**Figure** 2: Average $PM_{2.5}$ Concentration and Occurrence of Sore Throat by Location.

environmental exposure concentrations of $PM_{2.5}$ in the dry season ranged from 9.33–112.14 µg/m$^3$. These measurements were taken in Ajobiewe, which is located 1000 meters from the cement factory.[14] It should be noted that the research conducted on the Nigerian cement factory was environmental, and not personal, sampling. A significant difference is possible since there is a high exposure to $PM_{2.5}$ in cement factories when compared to the surrounding areas. This is because each step of the production process produces dust and fine particles that are respirable and can cause respiratory disease in the factory workers that are near the production. The raw materials used in production also contain dust with a particle size of less than 2.5 μm, such as fly ash, silica, limestone, gypsum, iron sand, and others.

Bielawska and Wardencki [15] showed that low wind velocity can influence high concentrations of $PM_{2.5}$and some production process areas of cement factories have little air ventilation. There is also $PM_{2.5}$ emission from the mobilization of heavy transportation (trucks) for raw material transporting or dumping in the production area. Based on diesel engine exhaust data from the EPA [16], fine and ultrafine particles are contained in heavy transportation diesel exhaust emissions.

The packaging area has a higher particulate exposure level than the cement mill, rotary kiln, maintenance, and administration areas.[10] Exposure to the highest concentration of $PM_{2.5}$ is seen specifically on the packer operator due to the repetitive work required to reach daily production targets. Two operators run one packer machine, which can fill approximately 1,290–3,225 bags/hour.The speed commonly used while operating the machine is 2,000–2,500 bags/hour, resulting in the production of 12,500 bags per shift with a weight of 40kg and 10,000 bags per shift with weight of 50kg.

Cement spillage,or bursts cement from the machine packer,frequently occurs in the short distance between the operator and the machine, releasing particles that can be easily breathed in by the operators.In addition, the cement bag design has an air permeability of 65–75% to allow easy checking for breakage. The high air permeability of the bag allows fine particles to exit the bag after it has been filled with cement, however, further exposing operators. Cement grinding and the lack of ventilation also increase the concentration of $PM_{2.5}$to which the packer operators are exposed. Based on data from the Process Engineering department at PT. X, cement products produced in the packhouse are of various particle sizes: 12.75% are<2.5 μm, 85.93% are 2.5–100 μm, and 1.35% are 100–2000 μm.

The reclaimer area had a low average exposure concentration of $PM_{2.5}$at 397.177 μg/m$^3$. This is because the reclaimer is an outdoor area and thus experiences high wind speed.[15] Furthermore, patrol workers operate the reclaimer in a machine cabin, so they are not often exposed to $PM_{2.5}$, and any exposure duration is limited. According to Zhang [17], increasing concentrations of $PM_{2.5}$are related to the decline of lung function, causing illnesses such as asthma and COPD. For every 10 μg/m$^3$increase in short term $PM_{2.5}$ exposure, there are increases in the risk of is chemic heart disease by an additional 1.3 times and the risk of COPD by an additional 0.6 times.

### 4.2. Distribution of Subjective Acute Respiratory Effects

The most common subjective acute respiratory effects reportedby production patrol workers were sneezing and sore throat (64.7%). This is similar to research by Zeleke [11] that showed that sneezing, nasal congestion, and wheezing are caused by the high level of particulate exposure ina cement factory. The average concentration of $PM_{2.5}$ in workers who reported sneezing was 1617.86 μg/m$^3$. Exposure concentration of $PM_{2.5}$ increases the prevalence of subjective acute respiratory effects.[18] Short term exposure to $PM_{2.5}$dust cancause health problems as asthma, acute bronchitis, respiratory infection, nose irritation, sore throat, sneezing, cough, shortness of breath, runny nose.[6]

### 4.3. $PM_{2.5}$ Concentration (μg/m$^3$) and Sore Throat Symptoms

As seen in Figure 2, the highest exposure concentration of $PM_{2.5}$was in the packhouse area (2,863.101 μg/m$^3$), while the most common subjective acute respiratory effect was sore throat seen in the firing process area (75%). The firing process area is a production area that includes a preheater, rotary kiln, and cooler. The preheater uses hot air from a rotary kiln and calciner to preheat raw materials after the raw mill process. The preheater process in PT. X uses a 4 cyclone method consisting of an Inline Calciner (ILC) for heating the material and a Separator Line Calciner (SLC). The preheater machine in a cement factory occasionally leaks and will release particlesinto the air. Patrol workers are required to check every process in the preheater area, potentially exposing them to these particles quite frequently. Some jobs that require hands-on work, such as water blasting on the riser duct to clean the plaque,controlling the silo blending, and checking the cooler area, can contribute further to the release of and exposure to particles. The high number sore throats reported by workers in the firing area was likely caused by the cement particle leakage that occasionally happens.Also, the firing area is large, has auniquecomposition of chemical compounds, and has various hands-on requirements for patrol workers,all of which could have contributed to the sore throat effectsthat were reported.

## 5. CONCLUSIONS

The average exposure concentration of $PM_{2.5}$ among production patrol workers at the cement factory was 1495.651μg/m$^3$. The packhouse was the production area with the highest average concentration of $PM_{2.5}$ (2863.101 μg/m$^3$), while there claimer area had the lowest average concentration of $PM_{2.5}$(397.177 µg/$m^3$). Based on the results of the questionnaire, there were 22 workers (64.7%) who experienced sneezing and sore throat. In addition, there were 21 workers (61.8%) who had a dry cough and 20 workers (58.8%) who perceived coughing phlegm (sputum).

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