

## Health Risk Analysis of Particulate Matter (PM<sub>2.5</sub> and PM<sub>10</sub>) Exposure Towards Street Sweeper in South Jakarta, Indonesia in 2020



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**Abstract**— In 2019, Jakarta's average annual PM<sub>2.5</sub> concentration exceeded WHO's air quality standard with a concerning 49.4  $\mu\text{g}/\text{m}^3$ . In most urban areas including Jakarta, street sweeping is done to reduce pollutants and remove debris and sediments from roads. However, with constant exposure to pollutants and minimum personal safety equipment, the street sweepers become population at risk of particulate matter exposure. This study aims to assess the health risk of particulate matter to street sweepers in Jakarta. This is a cross-sectional study using environmental health risk analysis method through Risk Quotient (RQ) (non-carcinogenic risk) and Excess Cancer Risk (ECR) (carcinogenic risk) to determine health risks in a total of 58 street sweepers. The level of PM<sub>2.5</sub> and PM<sub>10</sub> were collected in four (4) locations in Jakarta. Result showed the concentrations of PM<sub>2.5</sub> and PM<sub>10</sub> at the four measurement points have exceeded the national threshold values, with the lowest found in point 2 (325  $\mu\text{g}/\text{m}^3$ ) and the highest in point 3 (339  $\mu\text{g}/\text{m}^3$ ). 57 respondents (98.3%) have a non-carcinogenic risk of PM<sub>2.5</sub> exposure in each location (RQ>1), and 58 respondents (100%) have carcinogenic risk (ECR>E-4 (10<sup>-4</sup>)). Meanwhile, those who have a non-carcinogenic risk of PM<sub>10</sub> exposure are found at points 1, 2, and 4. There was no significant association between concentration variables, respondent characteristics, respondent behavior, and environmental conditions with non-carcinogenic risk of PM<sub>10</sub> exposure to street sweepers. The high risk coming from particulate matter exposure calls for better regulation and protection for street sweepers.

**Keywords:** Environmental health risk analysis, Health risk analysis, Particulate matter, Street sweeper, Urban environmental health.

### 1. Introduction

The level of air pollution is increasingly worrying from year to year along with the dominant risks in the form of respiratory diseases. According to the World Health Organization (2020), outdoor air pollution causes at least 4.2 million deaths every year. According to the World Health Organization (2020) the cause is none other than 91% of countries or about 9 out of 10 people breathing air with air quality having passed the safe threshold set by WHO. Based on WHO, the death rate due to ambient air pollution in Indonesia was 36 people (per 100,000 population) which occurred in both men and women in 2016 (World Health Organization, 2016).

Indonesia is one of the countries in the world with the worst air pollution levels. Previous studies has showed that Jakarta exceeded ambient air quality standard with worst impacts including visibility reduction and dust exposure (Agustine et al., 2018). Based on IQAir (2019) in Jakarta the average annual PM<sub>2.5</sub> concentration in 2019 was 49.4 µg/m<sup>3</sup> which has exceeded the WHO threshold value with an annual average PM<sub>2.5</sub> quality standard of 10 µg/m<sup>3</sup> (IQAir, 2019). In addition, based on data from the South Jakarta Administration City Environment Sub-department on the results of Roadside Monitoring activities throughout the South Jakarta Administrative City from 3 representative locations, it was stated that the concentration of ambient air pollutant of PM<sub>10</sub> parameter was 79.67 µg/m<sup>3</sup> in 2019, exceeding WHO's threshold value of 20 µg/m<sup>3</sup>.

Airborne particulate matter (APM) consists of carbonaceous material, metals, water-soluble ions, and mineral oxides. Street dust, which consists of suspended particles, vehicle exhaust, dust, and aerosols are significant contributors to urban pollution (Santoso et al., 2020; Li et al., 2021). In many developing countries where street cleaning machines aren't available, street sweepers are important in maintaining the urban health and hygiene. Street cleaning is predominantly done by hand sweeping by an individual worker or a group (Van Kampen et al., 2020). However, with minimum surveillance and limited accommodation, street sweepers are exposed to a variety of risk factors such as dust, bioaerosols, volatile organic matter and mechanical stress that make them susceptible to certain occupational diseases (Sabde and Zodpey, 2008; Van Kampen et al., 2020).

Street sweepers are exposed to a variety of inhalable agents such as dust, toxins and traffic emissions, which make them prone occupational respiratory diseases (Van Kampen et al., 2020). Respiratory disease refers to several types of diseases or disorders that prevent the lungs from functioning properly. Other morbidities that may be caught by street sweepers include several hazards such as infection, cut wounds, injuries, skin problems, gastric problems, hearing problems, allergies, heatstroke, and exposure to a high level of noise (Gebremedhn and Raman, 2020).

No research has been conducted on the health status of street sweepers in Jakarta. With constant exposure to pollutants and minimum personal safety equipment, the street sweepers become population at risk of the poor air quality. In this study, we aim to assess the health risk of prolonged particulate matter exposure to street sweepers in Jakarta using Risk Quotient and Excess Cancer Risk.

## **2. Method**

### **2.1 Study desain**

This study used a cross sectional research design and environmental health risk analysis which includes the stages of hazard identification, exposure analysis and intake calculation, dose response analysis, risk characterization, and risk management.

### **2.2 Population and sample**

The population of this study were street sweepers in Jagakarsa District, South Jakarta with a total of 80 people. The sample was taken using a total sampling technique. 22 people dropped

out during the research, resulting 58 people as the respondents.

### 2.3 Data collection

PM<sub>2.5</sub> and PM<sub>10</sub> concentration data were collected using DustTrak DRX 8533 at four points in Jagakarsa District, South Jakarta. Respondents' data was collected using an online questionnaire (google form) which was distributed through the street sweeper whatsapp group in Jagakarsa District. Respondent data consisted of respondent identity (name, age, gender, length of exposure), respondent behavior (use of personal protective equipment, smoking history, exercise habits, disease history), and anthropometric data (height and weight).

### 2.4 Data analysis

The data that has been collected were processed and analyzed for univariate, bivariate, and multivariate using IBM SPSS Statistics 20 software. Street sweeper health risk is calculated using the Risk Quotient (RQ) formula for non-carcinogenic risk and Excess Cancer Risk (ECR) for carcinogenic risk. Before calculating the estimated risk level (RQ and ECR), the estimated intake of each risk agent (PM<sub>2.5</sub> and PM<sub>10</sub>) was calculated using the CDI or LADD formula. The results of the calculation of the estimated intake of risk agents (PM<sub>2.5</sub> and PM<sub>10</sub>) are then used to calculate the estimated risk level (RQ and ECR).

## 3. Result and Discussion

Results showed that generally the respondents were male (56 people) with only 2 females. The average age of the respondents is 39.86 years with the youngest respondent being 24 years old and the oldest being 55 years old. The average working time of the respondents is 7.93 hours/day, with the shortest working time of 1 hour/day and the longest being 10 hours/day. The provisions for working time in Indonesia based on Law Number 13 of 2003 concerning Manpower are 7 hours/day for 6 working days a week or 8 hours/day for five working days a week (Presiden Republik Indonesia, 2003), which showed that some respondents exceeded the applicable working time provisions. The average tenure of the respondents is 6.28 years, with a minimum working period of 1 year and a maximum of 21 years. Only 3 respondents (5.2%) had a history of hypertension. In addition, 1 respondent (1.7%) had been diagnosed of having asthma by doctor and had suffered from other respiratory disorders such as pneumonia or emphysema. As many as 2 respondents (3.4%) had allergies to certain foods, drugs, or chemicals.

*Table 1 Respondent's characteristic*

| Variable          | Frequency | Percentage |
|-------------------|-----------|------------|
| <b>Gender</b>     |           |            |
| Female            | 2         | 3%         |
| Male              | 56        | 97%        |
| <b>Mask Usage</b> |           |            |
| Medical Mask      | 10        | 17%        |

|                      |    |     |
|----------------------|----|-----|
| Cloth Mask           | 47 | 80% |
| Others               | 2  | 3%  |
| <b>Smoking Habit</b> |    |     |
| Yes                  | 31 | 53% |
| No                   | 27 | 47% |

Based on the survey results, a description of the respondent's behavior in the form of PPE usage, smoking history, and exercise habits was also obtained. The behavior of using PPE on respondents is quite good because all respondents use masks when working. 47 people used masks made of cloth, 10 people use medical masks, and 2 people use other kind of mask. Although all respondents have complied with the use of masks while working, there are still some respondents who do not know the treatment in using mask. There were 2 people (3.4%) who used the same medical masks repeatedly and 4 people (6.9%) who washed cloth masks 2-3 times a week. This could attribute to heighten the risk for street sweepers, as previous study has shown that not cleaning PPE after use is significantly associated with acute respiratory infection (Eneyew *et al.*, 2021).

31 respondents are smoker, while 27 others do not smoke. The respondents' average period of smoking was 7.91 years, with the shortest smoking period being 1 year and the longest being 32 years. The average number of cigarettes consumed by respondents was 4.75 cigarettes per day, with the minimum number of cigarettes being 1 cigarette per day and the highest being 16 cigarettes per day. A total of 57 people (98.3%) had a habit of exercising and 1 person (1.7%) did not. The average length of exercise carried out by respondents was 3.70 hours per week, with the shortest duration of exercise being 1 hour per week and the longest being 30 hours per week.

Table 2 Average concentration

| Variable          | Min                     | Max                     |
|-------------------|-------------------------|-------------------------|
| PM <sub>2.5</sub> | 0,297 mg/M <sup>3</sup> | 0,325 mg/M <sup>3</sup> |
| PM <sub>10</sub>  | 0,304 mg/M <sup>3</sup> | 0,339 mg/M <sup>3</sup> |

The results of measurements of PM<sub>2.5</sub> and PM<sub>10</sub> concentrations at 4 measurement points showed that the minimum, maximum, and average concentrations of the two parameters from each point have exceeded the quality standards for PM<sub>2.5</sub> and PM<sub>10</sub> concentrations set by the US EPA (0.035 mg/M<sup>3</sup> and 0.15 mg/M<sup>3</sup> respectively) and Indonesian ambient air quality standards listed in Government Regulation no. 41 of 1999 (0.065 mg/M<sup>3</sup> and 0.15 mg/M<sup>3</sup> respectively) (United States Environmental Protection Agency, 2012) (Presiden Republik Indonesia, 1999). The highest average concentration of PM<sub>2.5</sub> was detected in point 2 (0.325 mg/M<sup>3</sup>), while the lowest was detected in point 4 (0.297 mg/M<sup>3</sup>). The highest average concentration for PM<sub>10</sub> was found in point 3 (0.339 mg/M<sup>3</sup>), while the lowest was also detected in point 4 (0.304 mg/M<sup>3</sup>).

Table 3 Risk Quotient for All Location

| Location | RQ PM <sub>2,5</sub> | PQ PM <sub>10</sub>       |
|----------|----------------------|---------------------------|
| Point 1  | 1.75                 | 7.77 x 10 <sup>(-1)</sup> |
| Point 2  | 1.79                 | 7.87 x 10 <sup>(-1)</sup> |
| Point 3  | 1.77                 | 8.12 x 10 <sup>(-1)</sup> |
| Point 4  | 1.63                 | 7.26 x 10 <sup>(-1)</sup> |

Risk characterization is done to determine the level of danger of a risk agent that is present in a population. Risk characteristics are expressed as Risk Quotient (RQ) for non-carcinogenic effects and Excess Cancer Risk (ECR) for carcinogenic effects. In the characterization of non-carcinogenic risks, if the RQ value < 1 then it can be said that exposure has not been at risk of causing non-carcinogenic health effects and is still considered safe, while if the RQ value > 1 then the exposure risks causing non-carcinogenic health effects and needs to be controlled. In the characterization of carcinogenic risk, if the ECR value < E-4 (10<sup>-4</sup>) then exposure is not at risk of causing carcinogenic health effects and is still considered safe, while if the ECR value > E-4 (10<sup>-4</sup>) then exposure is already at risk of causing carcinogenic health effects and needs to be controlled.

The non-carcinogenic risk level (RQ) of PM<sub>2,5</sub> for all location points shows RQ value > 1 for (Point 1 RQ = 1.75; Point 2 RQ = 1.79; Point 3 RQ = 1.77; Point 4 RQ = 1.63), which means that PM<sub>2,5</sub> exposure has a risk of causing non-carcinogenic health effects in the population of street sweepers and needs to be controlled. Only 1 (1,7%) individual does not have a non-carcinogenic risk (RQ) in individual level. This may be influenced by the time of exposure (hours/day) to PM<sub>2,5</sub> because there is 1 individual with a working duration of less than 8 hours, which is only 1 hour. The time of exposure (hours/day) will affect the duration of exposure (years). It is also shown that ECR value both in population and individual level for PM<sub>2,5</sub> in every point exceeded E-4(10<sup>-4</sup>), meaning that exposure already has carcinogenic risk in the span of 30 year.

The non-carcinogenic risk level (RQ) of PM<sub>10</sub> for all location points shows a value < 1 (Point 1 RQ = 7.77 × 10<sup>(-1)</sup>; Point 2 RQ = 7.87 × 10<sup>(-1)</sup>, Point 3 RQ = 8.12 × 10<sup>(-1)</sup>, Point 4 RQ = 7.26 × 10<sup>(-1)</sup>), which means that PM<sub>10</sub> exposure did not pose a risk of non-carcinogenic health effects in the street sweeper population. On individual level, 7 people had a non-carcinogenic risk. at points 1, 2, and 4 only 2 people (3.4%) had a non-carcinogenic risk (RQ), and at point 3 only 5 people (8.6%) had a non-carcinogenic risk (RQ). This is affected by the amount of PM<sub>10</sub> concentration, where point 3 has the highest average PM<sub>10</sub> concentration among other points due to many vehicles passing the area.

association with non-carcinogenic risk of PM<sub>10</sub> and PM<sub>2,5</sub> in street sweeper (p= 0.265; p = 1.000). Other environmental condition such as temperature (p = 0.404), humidity (p = 0.339), and wind speed (p = 0.955) did not have significant relation with non-carcinogenic risk (RQ) of both PM<sub>2,5</sub> and PM<sub>10</sub> exposure to street sweepers.

In relation to respondent’s characteristic, it is shown that age (p<sub>point 1, 2, 4</sub> = 0.748 and p<sub>point 3</sub> = 0.508) and work period (p<sub>point 1, 2, 4</sub> = 0.477 and p<sub>point 3</sub> = 0.353), gender, and medical

history did not have significant relation with non-carcinogenic risk of PM<sub>10</sub> in street sweeper. Same result was also shown in PM<sub>2.5</sub> RQ relation with age, where no significant relation is found ( $p_{\text{point 1, 2, 3, 4}} = 0.729$ ). However, it is found that work period has significant relation with RQ value of PM<sub>2.5</sub> ( $p_{\text{point 1, 2, 3, 4}} = 0.024$ ). ~~This result is in line with previous study from~~

Result showed that the use of PPE, smoking status ( $p = 1.000$ ), and exercise habits ( $p = 1.000$ ) did not have a significant association with the risk of non-carcinogenic (RQ) exposure to PM<sub>10</sub> exposure to street sweepers. Similarly, the non-carcinogenic risk of PM<sub>2.5</sub> has no significant association with PPE use, smoking status ( $p = 0.280$ ), and exercise habits ( $p = 0.894$ ).

Risk management needs to be done considering non-carcinogenic and carcinogenic risk level of PM<sub>2.5</sub> already exceeded 1 and E-4 (10<sup>-4</sup>). Such high levels of exposure risk can be affected by high or prolonged PM<sub>2.5</sub> concentrations and long exposure durations. Exposure duration (ED), exposed skin area, and exposure frequency, which are all critical variables affecting risk, are higher in adults than in children (Li *et al.*, 2021). The first stage of risk management is eliminating hazards, which can be done by controlling air pollution as listed in Government Regulation of the Republic of Indonesia Number 41 of 1999 on Air Pollution Control; such as the implementation of emission quality standards for polluting sources from industry, motor vehicles, etc so that air emissions released by the source do not exceed the established quality standards and pollute the air (Novirsa and Achmadi, 2012).

In DKI Jakarta Province itself, it already has regulations governing the implementation of emissions tests listed in the Regulation of the Governor of the Special Region of the Capital of Jakarta No. 66 of 2020 on Motor Vehicle Exhaust Emissions Test which has just been imposed in 2020. In addition, pollution control can also be done by replacing fossil fuels that are not environmentally friendly with environmentally friendly fuels so as not to produce air emissions with high concentrations of pollutant parameters. In addition, risk management can be done to the street sweeper population by shortening working hours to lessen the exposure and educating them about mask usage. The government should also equip the street sweepers with appropriate PPE in the form of masks that can filter dust particle.

#### 4. Conclusion

Concentration of PM<sub>2.5</sub> and PM<sub>10</sub> have exceeded the national threshold values with the average of PM<sub>2.5</sub> concentration was 325 µg/m<sup>3</sup> and PM<sub>10</sub> was 339 µg/m<sup>3</sup>. There is no significant results between concentration variables, respondent characteristics, respondent behavior, and environmental conditions with non-carcinogenic risk of PM<sub>10</sub> exposure to street sweepers in Jagakarsa District, South Jakarta however risk calculation of PM<sub>2.5</sub> effect showed there is RQ > 1 and ECR > E-4 (10<sup>-4</sup>) in most respondents.

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