AMBIENT QUALITY OF PIYUNGAN LANDFILL AND ITS HEALTH RISK INDEX POTENSI

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ABSTRACT
The rate of population growth that continues to increase in the Special Region of Yogyakarta impacted the volume of waste that needs to be processed in Piyungan Landfill. However, landfill operation contributes pollutants in the air that can cause health problems. This study attempts to quantify the composition of the TSP, PM_{10}, and $PM_{2.5}$ and their metals content (Pb, Cd, and Fe) in the ambient air around Piyungan Landfill, comparing the results with the air quality threshold in Indonesia, and assess the risk of Pb and Cd exposures. The sampling method was undertaken according to the National Standard of Indonesia, SNI 7119-3:2017 (ambient air quality sampling), SNI 7119-3:2017 (TSP analysis), SNI 7119.15:2016 (PM_{10} analysis), SNI 7119.14:2016 ($PM_{2.5}$ analysis), and SNI 19-7119-4:2005 (metal analysis). Furthermore, the health risk analysis refers to the Environmental Health Risk Analysis Guideline of the Ministry of Health of Republic Indonesia. Based on this research, the concentrations of TSP, PM_{10}, and $PM_{2.5}$ still meet the permissible limit of the national quality standard (PP 22/2021). This study also presents that Pb and Cd of health exposures in various particulates still meet the acceptable limit of non-carcinogenic effects (H.Q. <1).

Keywords: Ambient Quality, Piyungan landfill, Health Risk

1. INTRODUCTION
The population growth in the Special Region of Yogyakarta is comparable to an increase in the consumption level of daily products. The phenomenon could impact the volume of solid waste that requires to be processed daily in the Piyungan Landfill. The operation of the landfill has effects, especially on the environment. One of them is air pollution, such as increasing the concentration of dust and particulate [1]. In the atmosphere, particulate classified into various sizes of fraction, dust particles or Total Suspended Particulate (TSP) with a diameter <100 µm, coarse particles (PM_{10}) with a diameter <10 µm, and fine particles ($PM_{2.5}$) with a diameter <2.5 µm [2].
Exposure to these three types of particulate must provide the health impacts and severity that depend on their size and compound. Exposure to dust and coarse particulates can

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irritate the eyes and respiratory system. At the same time, fine particulate exposure is more dangerous because it can penetrate the lungs and even enter the blood flow, causing severe diseases such as liver, lungs, and blood disorders and even death [3]. Particulate matter ($PM_{2.5}$) contributed some diseases, such as COPD (Chronic Obstructive Pulmonary Disease), LRIs (Lower Respiratory Infections). Lung Cancer (LC), Stroke, and so on, in top nine countries. In Indonesia, especially, the death cases because of particulate matter in 2017 reached up to 94,000 [4].

In addition, health effects can be worsened by a contaminant contained in the particulates. Particulate is a complex compound of pollutants because it includes other elements that vary, such as metals. Lead (Pb), cadmium (Cd), and iron (Fe) are many contained in TSP, PM_{10}, and $PM_{2.5}$ [5]. Metal pollution sources in the air around landfill can be derived from the waste, Pb, produced by materials like batteries, paint, and cans. Materials like batteries also contained Cd. Its suspected iron-based tools or packages could have Fe [6].

Heavy metal exposure has harmful effects. Some impacts caused by its exposure are a disorder of the nervous system and intelligence, reproductive system disturbance, abnormality of the vertebral, and systemic effects [7]. Besides, inhaling particulates with Cd contained in it is toxic matter. It could cause respiratory disorders, pneumonitis, bronchitis, kidney damage, liver damage, cancer, and even death [8]. Iron is an essential metal for the body, and it is vital to keep its metabolism at a specified number. When it exceeds the number, it can be toxic for the body [9]. Fe concentration >1 mg/l can damage the walls of the intestines, nausea, irritation, and headache [10]. It is contained according to the impacts caused by exposure to particulates and heavy metals. Therefore this study aims to know the quality of ambient air around Piyungan Landfill, Bantul Yogyakarta, related to TSP, PM_{10}, and $PM_{2.5}$. Also, Pb, Cd, and Fe contain various particulate sizes. Furthermore, the health risk index is also investigated to determine pollutant exposure.

2. MATERIALS AND METHODS

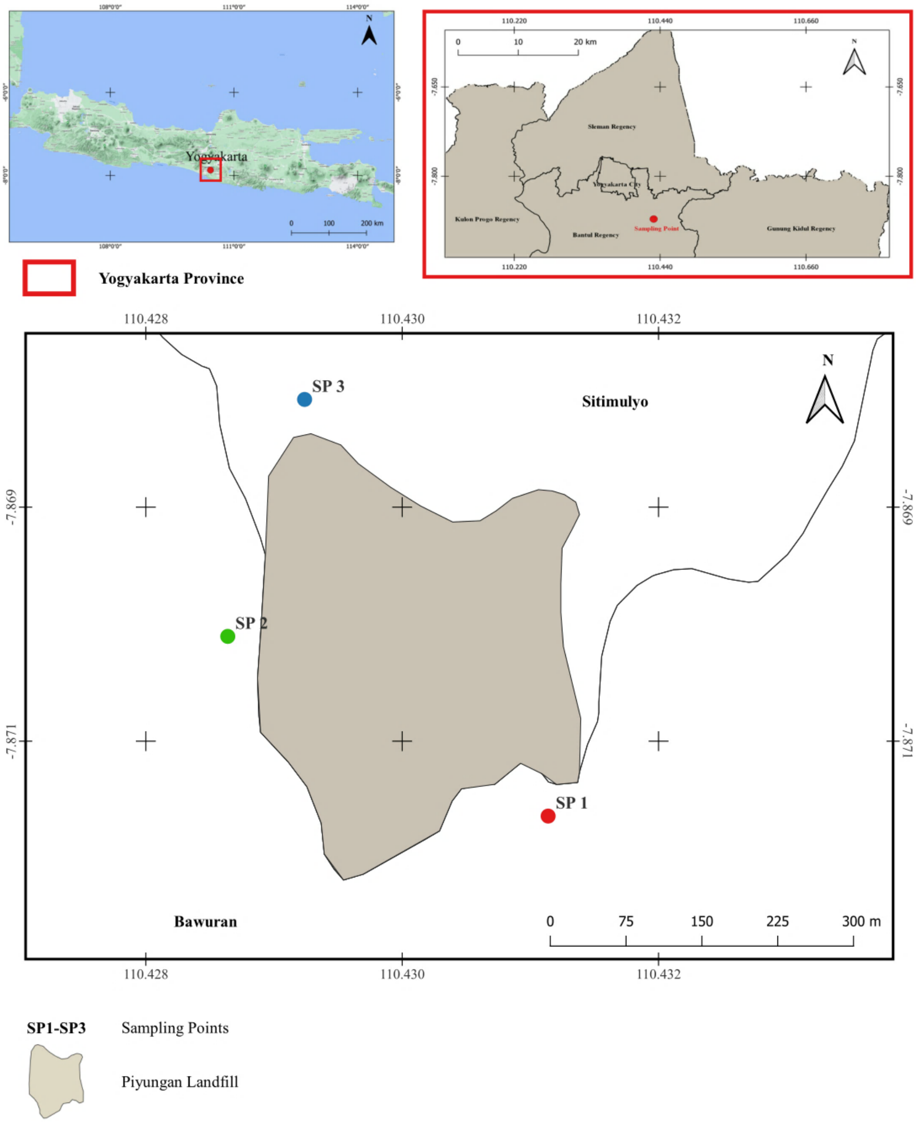
2.1. Study Area

Piyungan Landfill is located in Ngablak Hamlet, Sitimulyo Village, Piyungan Sub-District, Bantul Regency, the Special Region of Yogyakarta. It started to operate in 1996, currently serving trash and garbage from Sleman Regency, Bantul Regency, and Yogyakarta City [11]. The research was conducted in residential areas around Piyungan Landfill. There are 3 (three) sampling points, SP1 at a distance <50 m, SP2 at a space between 50 and 100 m, and SP3 length of>100 m. The determination of the sampling point also considers the requirements according to SNI 19-7119.6-2005 about the decision of the sampling locations for ambient air quality monitoring test. The sample collection is done once at each point within 24 hours duration. The sample was taken in March 2022 in rainy weather. The coordinates sampling point of this study explained in Table 1. The map of sampling points' locations is shown in Figure 1.

Table 1. Sampling Coordinates Points

Sampling points	Coordinates
SP1	-7.8714723S 110.4312088E
SP2	-7.8698582S 110.4283342E
SP3	-7.8677266S 110.4290225E

Figure 1. Study Area of Piyungan Landfill



2.2. Particulates and Metals Analysis

The particulate was collected according to SNI 7119-3:2017 for the TSP analysis, SNI 7119.15:2016 for the PM_{10} analysis, and SNI 7119.14:2016 for $PM_{2.5}$ analysis. The instrument and materials used in this research were a High Volume Air Sampler (HVAS) (FTSP HVAS-01; 05; 04; 10) and filter paper Whatman No. 1 (CAT 1001-125) with porosity <0.3 µm. The air flow speed of HVAS set up in the 1.1 m^3/minute to 1.7 m^3/minute. The weight of particles accumulated with the gravimetric methods analyzed the filter paper to collect particulates matter.

The Pb, Cd and Fe metal content test used Atomic Absorption Spectrophotometry (AAS) series type GBC SavantAA with wet digestion method carried out at the Environmental Quality Laboratory, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia. Reference to metal concentration testing according to SNI 19-7119-4:2005 concerning How to Test Lead (Pb) Concentration with Wet Digestion Method Using Atomic Absorption Spectrophotometer (AAS) - Flame. The spectra wavelengths for Pb, Cd, and Fe metal tests, respectively, were 283.3 nm, 228.8 nm, and 248.3 nm. Then, particulate matter and metal concentrations are compared against ambient air quality thresholds in Indonesian Government Regulation Number 22 of the Year 2021 [12]. The steps of calculating particulate concentrations (based on SNI 7119.3-2017) as explained below:

a. Flow Rate Correction

$$Qs = Qo\left[\frac{Ts \times Po}{To \times Ps}\right]^{\frac{1}{2}} \quad (1)$$

Qs = corrected flow rate at standard condition (m^3/minute)
Qo = measured flow rate (m^3/minute) (1.1 to 1.7 m^3/minute)
Ts = temperature standard, 298 K
To = absolut temperature (273+t measured) at Qo
Ps = baromatic pressure standard, 101,3 kPa (760 mmHg)
Po = baromatic pressure at Qo (mmHg)

b. Air Sampled Volume

$$V = \frac{Qs_1 \times QS_2}{2} \times T \quad (2)$$

V = sampled air volume (m^3)
Qs_1 = corrected initial flow rate (m^3/ minute)
QS_2 = corrected final flow rate (m^3/ minute)
T = the duration of sampling (minute)

c. Particulate Concentration

$$C = \frac{(W_2 - W_1) \times 10^6}{V} \quad (3)$$

C = particulate concentration (µg/m^3)
W_1 = initial filter weight (g)
W_2 = final filter weight (g)
V = volume udara sampel (m^3)

The concentration of Pb, Cd, and Fe was calculated according to SNI 19-7119.4-2005:

d. Metal Concentration

$$C = \frac{(Ct - Cb) \times Vt \times \frac{S}{St}}{V} \quad (4)$$

C = metal concentration in the air (µg/m^3)
Ct = metal concentration in sample (µg/ml)
Cb = metal concentration in blanko (µg/ml)
Vt = solution volume (ml)
S = exposed filter area (mm^2)
St = total filter area used (mm^2)
V = air sampled volume at normal condition 25°C, 760 mmHg (m^3)

2.3. Risk Analysis

Risk analysis is carried out by following the Environmental Health Risk Analysis Guidelines (ARKL) of the Directorate PPPL of the Ministry of Health [13], including:

a. Hazard Identification
This phase is used to identify the potential risk factors for health issues, the volume of material, and the likelihood that environmental media would cause the disturbance.

b. Dose-Response Assessment

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This step is to identify potential pathways for risk agent exposure, comprehend the impacts of rising risk agent concentrations, and calculate RfD, RfC, and SF from risk agents.

c. Exposure Assessment

In this study, heavy metal intake was through inhalation. Thus, the calculation of the intake is calculated by using the equation:

$$\boldsymbol{I} = \frac{\boldsymbol{C \times R \times Te \times Fe \times Dt}}{\boldsymbol{Wb \times tavg}} \quad \textbf{(5)}$$

I = intake (mg/kg.day)
C = concentration of the agent on the air medium (mg/m^3)
R = inhalation rate or volume of incoming air per hour (m^3/h)
Te = duration of exposure each day (hours/day)
Fe = number of days of exposure each year (days/year)
Dt = number of years of exposure (realtime exposure) (years)
Wb = exposed human weight (kg)
Tavg = average time period (30 years x 365 days/year for non-carcinogen effects)

d. Risk Characterization

The risk level was calculated based on non-casinogenic effects using the equation:

$$\boldsymbol{HQ} = \frac{\boldsymbol{I}}{\boldsymbol{RfC}} \quad \textbf{(6)}$$

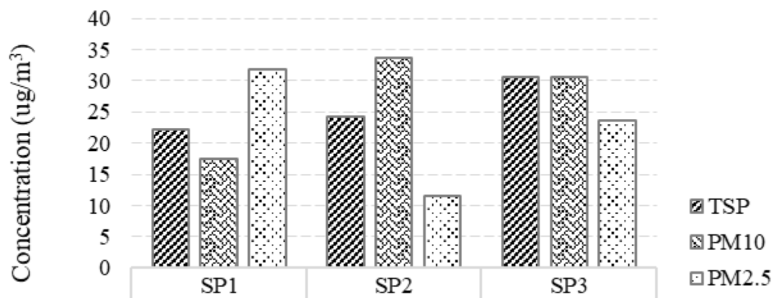
I = intake (mg/kg.day)
HQ = hazard quotien
RfC = reference concentration (mg/kg.day)

3. RESULTS AND DISCUSSIONS

3.1. Particulates Concentration in Ambient Air Quality

The results of the particulate concentration analysis in ambient air around TPST Piyungan are presented in Figure 2. The concentration value is also compared to Indonesian Government Regulation Number 22 of 2021 regarding ambient air standard quality. The results showed that the concentration of particulates was below the maximum threshold value. Based on Figure 2, the noticeable finding is that the concentration of the three types of particulate matter in SP3 is relatively equal, with a slight difference. SP3 is a location with a distance of more than 100 m from the Piyungan Landfill location. This location is adjacent to the road where the vehicle traffic of the Piyungan Landfill expansion project is located. Particulate concentrations in SP3 also tend to be high because the wind direction at the sampling time tends to move towards the northwest and north according to the location of SP3 from Piyungan Landfill. Wind direction and wind speed affect the distribution of pollutants in the air. Wind direction influences the direction of the exposure area, while wind speed affects how far pollutants will be carried away [14].

Particulates may also be produced from natural sources like soil dust or paved and unpaved areas. Piyungan landfill is a kind of hill, and the open dumping area is located in the center of the Piyungan landfill and is surrounded by high-elevation regions. The soil type in Piyungan Subdistrict is composed of latosol soil [14]. The characteristics of latosol soils derived from weathering sediments and metamorphic rocks or soils that have undergone heavy weathering make it easier for the ground to overlap and produce dust. In addition, the soil tends to be infertile because it contains high iron and aluminum [16].



	SP1	SP2	SP3
TSP	22.15	24.19	30.67
PM10	17.42	33.71	30.52
PM2.5	31.74	11.51	23.56
TSP Standard	230	230	230
PM10 Standard	75	75	75
PM2.5 Standard	55	55	55

Figure 2. TSP, PM10, and PM2,5 Concentrations

3.2. Metals Concentration in Particulates

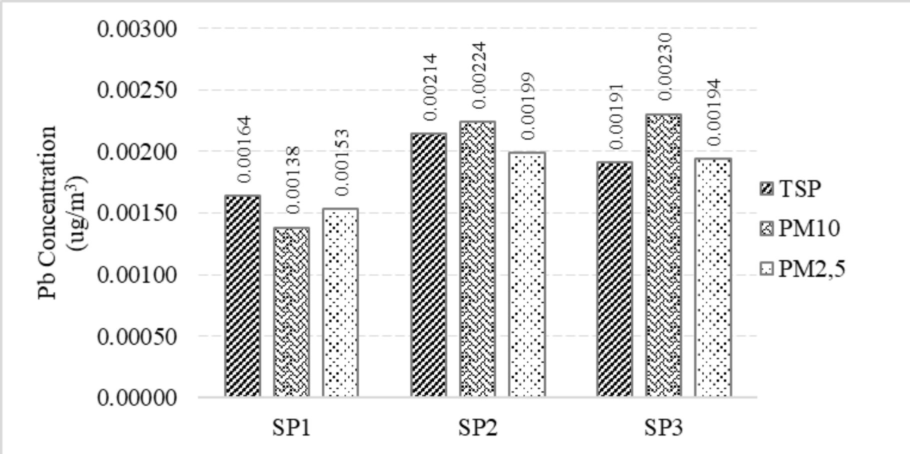
The concentration of Pb, Cd, and Fe metals is shown in Figure 3. The highest to low concentration values of the three metals are Fe > Pb > Cd. Metal concentration is due to the value of the chemical affinity to particles in the atmosphere. Fe metals have the highest value compared to Pb and Cd metals, followed by Pb and Cd metals [17].

Based on the results of the concentration analysis, the Pb concentration is relatively high at SP2 and SP3. From the observation results, one of the Pb sources in the Piyungan TPST area came from garbage transport vehicles with an average of 281 units a day. The condition makes the garbage unloading area and roads the largest source of Pb distribution in the area. The average concentration of Pb at SP2 and SP3 is high because the locations are located northwest of the garbage unloading area. Additionally, the road is in the direction of the wind when sampling. One of the factors affecting the distribution of pollutants is the wind direction, and wind direction determines the area of exposure [14]. In contrast, SP3 has the lowest Pb concentration because the location, although close to the garbage unloading area, is located in the southeastern part, so it is opposite the wind direction.

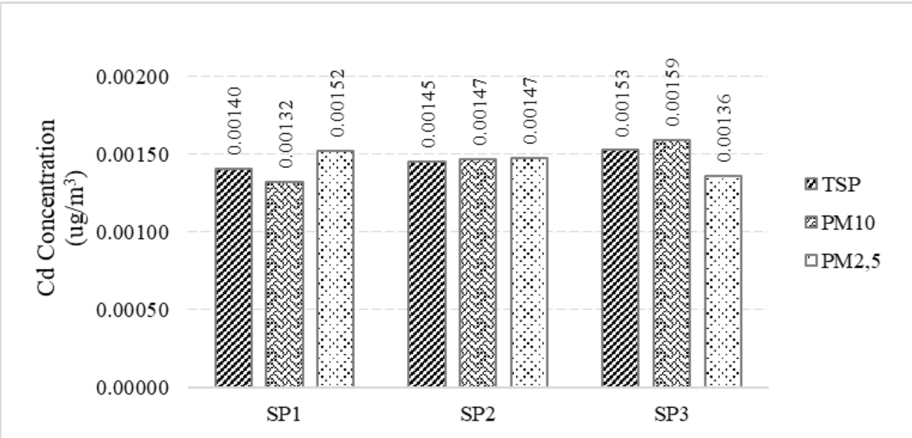
The amount of Cd concentration obtained relatively consistent results from the analysis results in three types of particulates at all three points of location. The source of Cd metal in the air of the Piyungan TPST area comes from the garbage. Cd content can be found in production materials such as batteries, dyestuffs, or inks and materials containing Polyvinyl Chloride (PVC) [18].

The concentration of Fe also shows the same pattern as the three types of particulates, with the highest Fe concentration value obtained at the SP3, which is close to the Piyungan Landfill expansion project. The possibility gives the source of Fe that comes from project activities and heavy equipment. The work of machinery and heavy equipment is one of the sources of Fe dust pollutants [6]. In addition, around SP3 is an empty landfill that allows soil dust to be scattered. Soil types of latosol type have the characteristics of infertile and high iron content [16].

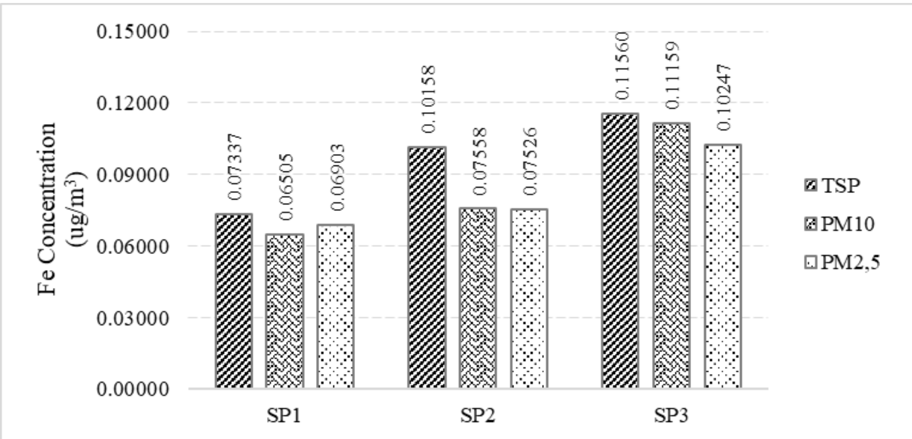
On the other hand, Fe metals tend to predominate in all three sizes of particulate fractions [19]. Based on Figure 3, Fe concentrations show the same pattern as TSP concentrations in Figure 2. In addition, the concentration of Fe metal in TSP is relatively high compared to other particulate fractions, and this is because Fe metals have a very high correlation to TSP [20].



(a)



(b)



(c)

Figure 3 Metals Concentrations in Particulate Matters

(a) Pb; (b) Cd; and (c) Fe

3.3. Meterological Data

When sample measurements are carried out, meteorological-related parameters are also measured. Some of these data include temperature, humidity, and air pressure. The data is presented in Table 2.

Table 2 Meteorological Conditions

Sampling Point	Sampling Date	Temperature (°C)	Humidity (%)	Air Pressure (mmHg)	Description
1	**March 10th – 11th, 2022**	**27.3**	**84.0**	**742.6**	**Cloudy bright, evercast, rain at 06.00 – 11.00 PM**
2	**March 08th – 09th, 2022**	**28.1**	**83.8**	**746.1**	**Cloudy bright, rain at 01.30 – 03.00 AM**
3	**March 07th – 08th, 2022**	**28.1**	**79.1**	**741.6**	**Cloudy bright, rain at 04.00 – 07.30 PM**

Based on weather conditions, data during samples were taken, the lowest average air temperature was 27.3°C at SP1, and the highest average air temperature was 28.1°C at sampling at SP2 and SP3. The lowest air humidity is 79.1% at SP3, and the highest humidity is 84.0% at the sampling point of SP1. In comparison, the most increased air pressure was obtained in sampling at SP2 of 746.1 mmHg and the lowest air pressure at the sampling point at SP3.

Temperature and humidity have a mutually influencing correlation. If the temperature increases, it will be followed by a decrease in air humidity. If the results of measuring environmental conditions are associated with the study, the result shows if the temperature is high, then the air humidity is low, and vice versa [21]. Air pressure has a strong correlation that negates each other to precipitation; if rainfall is low, the air pressure will tend to be high [22].

Meteorological factors in Table 1 influence the concentration of particulates in the air. When sampling, the temperature will have an inversely proportional effect on the concentration of particulates, and air pressure provides a correlation proportional to the attention of particulates. Meanwhile, rainy conditions will significantly influence the cleaning of coarse particles in the air, while fine particles only have a negligible impact [14].

3.4. Exposure Assessment and Risk Calculation

Exposure to metals in particulates can cause both non-carcinogenic and carcinogenic effects in humans depending on the types of metal, exposure concentration, frequency, and duration of exposure. The exposure calculation is carried out to determine the size of the inhalation intake for both children and adults. The body weight used is 15 kg for children and 55 kg for adults. The intake calculation is a life with a standard exposure duration of 30 years. Studies related to the Reference Concentration (RfC) value of Fe metals are still unavailable, so the calculation of the non-cancer risk of Fe metals is not

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carried out. Risk analysis through inhalation by exposure of Pb and Cd is shown in Table 3 and Table 4.

Table 3 The Values of Intake of Children and Adults

Particulate			TSP			PM_{10}			$PM_{2.5}$		
Metal			**Pb**	**Cd**	**Fe**	**Pb**	**Cd**	**Fe**	**Pb**	**Cd**	**Fe**
SPI	1	**Children**	**1.3 x 10^{-6}**	**1.1 x 10^{-6}**	**5.6 x 10^{-5}**	**1.1 x 10^{-6}**	**1.0 x 10^{-6}**	**5.0 x 10^{-5}**	**1.2 x 10^{-6}**	**1.2 x 10^{-6}**	**5.3 x 10^{-5}**
		Adults	**0.6 x 10^{-6}**	**0.5 x 10^{-6}**	**2.6 x 10^{-5}**	**0.5 x 10^{-6}**	**0.5 x 10^{-6}**	**2.3 x 10^{-5}**	**0.5 x 10^{-6}**	**0.5 x 10^{-6}**	**2.4 x 10^{-6}**
SPI	2	**Children**	**1.6 x 10^{-6}**	**1.1 x 10^{-6}**	**7.8 x 10^{-5}**	**1.7 x 10^{-6}**	**1.1 x 10^{-6}**	**5.8 x 10^{-5}**	**1.5 x 10^{-6}**	**1.1 x 10^{-6}**	**5.8 x 10^{-5}**
		Adults	**0.7 x 10^{-6}**	**0.5 x 10^{-6}**	**3.5 x 10^{-5}**	**0.8 x 10^{-6}**	**0.5 x 10^{-6}**	**2.6 x 10^{-5}**	**0.7 x 10^{-6}**	**0.5 x 10^{-6}**	**2.6 x 10^{-5}**
SPI	2	**Children**	**1.5 x 10^{-6}**	**1.2 x 10^{-6}**	**8.9 x 10^{-5}**	**1.8 x 10^{-6}**	**1.2 x 10^{-6}**	**8.6 x 10^{-5}**	**1.5 x 10^{-6}**	**1.0 x 10^{-6}**	**7.9 x 10^{-5}**
		Adults	**0.7 x 10^{-6}**	**0.5 x 10^{-6}**	**4,0 x 10^{-5}**	**0.8 x 10^{-6}**	**0.6 x 10^{-6}**	**3.9 x 10^{-5}**	**0.7 x 10^{-6}**	**0.5 x 10^{-6}**	**3.6 x 10^{-5}**

Table 4 The Hazard Quotien (HQ) Values of Children and Adults

Particulate			TSP		PM_{10}		$PM_{2.5}$	
Metal			**Pb**	**Cd**	**Pb**	**Cd**	**Pb**	**Cd**
SP1	**HQ**	**Children**	**6.3 x 10^{-3}**	**5.4 x 10^{-3}**	**5.3 x 10^{-3}**	**5.1 x 10^{-3}**	**5.9 x 10^{-3}**	**5.8 x 10^{-3}**
		Adults	**2.4 x 10^{-3}**	**2.4 x 10^{-3}**	**2.4 x 10^{-3}**	**2.3 x 10^{-3}**	**2.7 x 10^{-3}**	**2.6 x 10^{-3}**
SP2	**HQ**	**Children**	**8.2 x 10^{-3}**	**5.6 x 10^{-3}**	**8.6 x 10^{-3}**	**5.6 x 10^{-3}**	**7.6 x 10^{-3}**	**5.7 x 10^{-3}**
		Adults	**3.7 x 10^{-3}**	**2.5 x 10^{-3}**	**3.9 x 10^{-3}**	**2.6 x 10^{-3}**	**3.5 x 10^{-3}**	**2.6 x 10^{-3}**
SP3	**HQ**	**Children**	**7.3 x 10^{-3}**	**5.9 x 10^{-3}**	**8.8 x 10^{-3}**	**6.1 x 10^{-3}**	**7.4 x 10^{-3}**	**5.2 x 10^{-3}**
		Adults	**3.3 x 10^{-3}**	**2.6 x 10^{-3}**	**4.0 x 10^{-6}**	**2.8 x 10^{-3}**	**3.4 x 10^{-3}**	**2.4 x 10^{-3}**

Based on the non-cancer risk calculation analysis of the intake lifetime results, it is known that both Pb and Cd metals do not indicate the possibility of a non-carcinogenic risk for public health because the HQ value < 1. Based on the Environmental Risk Analysis Guidelines, the HQ value > 1 indicates that non-cancer HQ values can cause non-cancer health effects, so heavy metal exposure poses a health risk. On the other hand, if the HQ value is < 1, the health risk due to heavy metal exposure is still considered safe for humans. The HQ value is influenced by the duration of exposure, the age of the respondent, and the rate of contact [14].

The toxic effects arising from metal exposure are closely related to the level and duration of exposure. The higher the metal concentration and the longer the exposure period, the greater the toxic effect. The effects are in line with the calculation of the non-cancer risk of intake lifetime in this study, whose value is getting higher in line with the longer the duration of the respondent staying in that location [23]. Non-cancer risks that can be caused by exposure to Pb include the body quickly feeling tired, pale, and lethargic, headaches, vomiting, seizures, decreased ability of the body to absorb calcium, reduced brain function, and damage to essential enzymes [24]. Cadmium accumulates in the body and can cause non-cancer risks in kidney dysfunction, impaired calcium absorption, and obstructive lung disease [25].

4. CONCLUSIONS

To summarize, our findings show that the concentrations of TSP, PM10, and PM2.5 also its metal contents (Pb, Cd, and Fe) in ambient air around Piyungan Landfill still meet the air quality threshold in Indonesia. The exposures of Pb and Cd in various fraction sizes still meet the acceptable limit of a non-carcinogenic effect.

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