Acta Scientific MEDICAL SCIENCES (ISSN: 2582-0931)

Volume 4 Issue 9 September 2020

Research Article

Risk Assessment of Airborne $PM_{2.5}$ Exposure of Forest and Land Fire Haze to Petrol-Pump Officers in Pekanbaru

Elisa Moetiara*

Occupational Health and Safety Department, Faculty of Public Health, Universitas Indonesia, Indonesia

***Corresponding Author:** Elisa Moetiara, Occupational Health and Safety Department, Faculty of Public Health, Universitas Indonesia, Indonesia.

Received: August 04, 2020

Published: August 31, 2020

Abstract

The forest and land fire situation in Sumatra have led to a haze disaster that contain harmful particulate matter exposing Pekanbaru population. Number of studies concerned with associations between respiratory and cardiovascular health effects and exposure to fine fractions of particulate matter ($PM_{2.5}$) on polluted air have been reviewed by Kim [1]. Although studies have proven significance difference of health effect due to haze, currently there is no study to estimate the potential health risk to population exposed to haze in Pekanbaru. This study aims to estimate the risk of $PM_{2.5}$ in ambient air during haze period that exposed Petrol-pump officers. The risk magnitude is represented by Risk Quotient (RQ) that determined by comparing the $PM_{2.5}$ exposure intake with exposure dose-response of the workers using the Environmental Health Risk method from The International Programme on Chemical Safety (IPCS). Intake value is generated based on the concentration of PM in the environment, individual activity patterns and anthropometric values. Concentration of $PM_{2.5}$ was using secondary data generated by real-time PM measurement for Pekanbaru. The activity patterns and anthropometric values were collected using questionnaire to 20 Petrol-Pump Officers from 5 different gas stations in Pekanbaru. The calculation of lifetime risk showed that Petrol-Pump Officers who were exposed longer since 2015 haze period, has four times greater health risk compared to those who are just exposed in 2019. Petrol-Pump Officers who just got exposed to $PM_{2.5}$ in 2019 has RQ ≤ 1, hazard was not a threat - however risk still need to be maintained under 1. While RQ for $PM_{2.5}$ exposure to Petrol-Pump Officers who has worked since 2015 is > 1, means $PM_{2.5}$ in haze that exposes Petrol-Pump Officers cause the adverse health effects and the risk needs to be managed.

Keywords: Haze; Forest Fire; Exposure Assessment; Particulate Matters; Risk Management

Introduction

Haze from forest and land fire has become the major source of particulate matter (PM) pollution and has been proved by studies being responsible to adverse health effect to the exposed population. It has become health-threatening situation to people who breathed the air. While earlier studies find correlation of PM and its health effect, Author on this paper focuses the point of view from the worker population that is exposed with PM. This study is to estimate the magnitude of potential health problems that the worker has by being exposed to PM while working outdoors in haze period. An analysis is provided to provide input for policymakers so that more stringent program to reduce forest and land fires and to protect the exposed-population from health effect risks.

Methods

This study is a risk assessment of $PM_{2.5}$ in Pekanbaru, a city in Riau Province, an area of intense haze contains particulate matters released from fire of forest and land in Sumatra. The risk estimation of potential health problems due to particulate matters exposure is studied on Petrol-pump officers whose along of their working time being exposed to haze in outdoors. Exposure and dose-response assessments conducted by estimating the intake of inhaled $PM_{2.5}$

concentration by the workers using Environmental Health Risk method from IPCS.

Risk assessment methodology was applied to estimate risk quotient in two scenarios of exposure according to haze period exposing Respondents, first whom just got exposed in 2019 as the most recent haze period, and whom had exposed since 2015 as the last haze period experienced in the region. $PM_{2.5}$ concentration taken from real-time data monitoring station. Due to limitation of active monitoring station in Pekanbaru city, $PM_{2.5}$ concentration data in ambient air taken from Rumbai station which located 27 km to Pekanbaru.

The magnitude of risk described as RQ (Risk Quotient) which calculated by comparing the Intake with Dose-response. If RQ > 1, means hazards cause the adverse health effects and are a detriment to public health; risk need to be managed. If the RQ ≤ 1, means hazards are not considered a threat to public health, and need to be maintained not over than 1.

$$RQ = \frac{I}{RfD}$$

Figure 1: Equation of risk quotient calculation.

Intake (I) is a daily amount of risk agent received by individual (mg/kg/day) with equation (1) on below:

$$I = \frac{C \times R \times tE \times fE \times Dt}{Wb \times tavg}$$

Figure 2: Equation of intake calculation.

Concentration (C) is the agent concentration amount (mg/m^3); R is the intake rate (US-EPA default 0.83 m^3/hour); t_E is daily exposure duration (hour/day), f_E is exposure frequency (day/year), W_b is body weight (kg), dan t_{avg} is average exposure time in a year. Refer to US-EPA, lifetime exposure duration related to life expectancy default for PM (carcinogenic) is 70 years x 365 days/year.

Reference Dose (R*f*D) is an estimate of a continuous inhalation exposure unlikely to cause adverse health effects during a person's lifetime, the calculation is using equation on figure 3 below. The exposed-population that studied is Petrol-pump officers as they spend all of their working time outdoors. Exposed-population information for R*f*D calculation were collected thru survey to have information of respondent's weight, and exposure time in daily and yearly basis. Calculation of dose-response R*f*D (mg/kg/day) as daily safe dose reference for lifetime $PM_{2.5}$ exposure, refers to the US-EPA National Ambient Air Quality Standards (NAAQS) Concentration Reference 0.035 mg/m^3, R is the inhalation rate refers to US-EPA 0.88 m^3/hour as default for adult, and body weight is the average of respondents' body weight, t_E is exposure duration (hour/day), f_E is exposure frequency (day/year), W_b is body weight (kg), and t_{avg} is average exposure time in a year. Refer to US-EPA, lifetime exposure duration related to life expectancy default for PM (carcinogenic) is 70 years x 365 days/year.

$$RfD = \frac{RfC \times R \times tE \times fE}{Wb \times tavg}$$

Figure 3: Equation of dose-response calculation.

Results

Concentration of $PM_{2.5}$ in ambient air

$PM_{2.5}$ concentration in ambient air taken from Rumbai real-time data monitoring station which located 27 km to Pekanbaru. $PM_{2.5}$ concentration in Pekanbaru ambient air for both 2015 and 2019 haze period has exceed the US-EPA TLV, 0.035 mg/m^3, (Table 1). $PM_{2.5}$ concentration in Pekanbaru ambient air during September - October 2015 (13 times TLV) was worse than $PM_{2.5}$ concentration during July - August 2019 (4 times TLV).

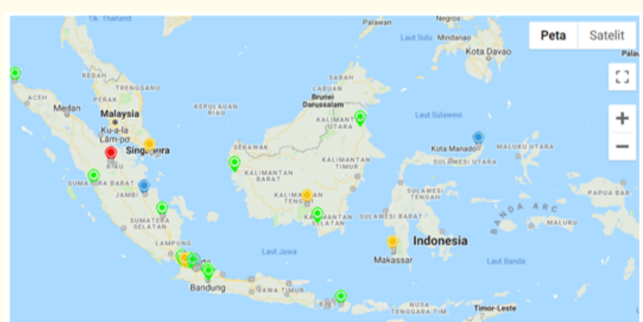

Figure 4: Air pollutant standard index Pekanbaru.

Source: KLHK [2].

Period	$PM_{2.5}$
Jul - Aug 2019	0.143
Aug - Sep 2015	0.466

Table 1: Time weighted average (TWA) PM concentration in pekanbaru ambient air (mg/m^3).

Exposure scenarios

This study performed two scenarios for risk assessment of $PM_{2.5}$, according to the year when Petrol-Pump Officers respondent got exposed with haze during his working time. The first scenario to estimate risk quotient of $PM_{2.5}$ exposing Respondents who just got exposed with haze period in July - August 2019 (n = 11), and second scenario to estimate risk quotient of $PM_{2.5}$ exposing Respondents who were already worked as Petrol-Pump Officers and got exposed since 2015 haze period (n = 9).

Anthropometric and activity pattern characteristics

Survey was conducted to 20 Petrol-Pump Officers from 5 different gas stations in Pekanbaru to get individual characteristic figure of anthropometric and activity pattern such as body weight, daily exposure time, yearly exposure frequency, and exposure duration along their service time as Petrol-pump officer (Table 2). The respondents are workers in productive age range. Most of the respondents are in age group (years-old) 20 - 24 (50%), and the rest are in group of age 25 - 29 (15%), 30 - 34 (10%), 40 - 44 (10%), 15 - 19 (5%), 35 - 39 (5%) and 45 - 49 (5%). To calculate intake and dose response, inhalation rate is 0.88 m^3/hour as default for adult refer to US-EPA.

Figure 5: Gas station of respondent's work location in a Pekanbaru city map.

Source: Google Map.

Note: Blue dots are respondent's work location.

In average, haze polluted Pekanbaru air for two months in a year (0.16 year) and exposed respondents who work as Petrol-pump officer 8 hours in a day. From the survey, the longest service year of respondents was 20 years (started work in 1999). As forest and land fire happened repeatedly since 1982, 1991, 1997, 2007, 2012, 2015, include August 2019. However, this study focuses only to estimate risk quotient specific for last two haze period experienced, year 2019 and year 2015. The average results are used to calculate intake (Table 3).

Characteristics	Average	Median	Modus	Min.	Max.	Std. Deviation
Body Weight (Wb) (kg)	57.36	49.00	82.00	43.00	82.00	15.55
Exposure duration (t_E) (hour/day)	8	8	8	8	8	0
Exposure frequency (f_E) (day/year)	47	47	47	47	47	0
Real time exposure duration (D_{real}) (year)	0.13	0.13	0.13	0.13	0.13	0.00
Inhalation Rate (R) (mg/m^3)	0.88	0.88	0.88	0.88	0.88	0.00

Table 2: Anthropometric and respondents activity pattern characteristics for petrol-pump officers just exposed to haze in 2019 during work (n = 11).

Characteristics	Average	Median	Modus	Min.	Max.	Std. Deviation
Body Weight (Wb) (kg)	59.56	58.00	65.00	50.00	82.00	10.26
Exposure duration (t_E) (hour/day)	8	8	8	8	8	0
Exposure frequency (f_E) (day/year)	60	60	60	60	60	0
Real time exposure duration (D_{real}) (year)	0.16	0.16	0.16	0.16	0.16	0.00
Inhalation Rate (R) (mg/m^3)	0.88	0.88	0.88	0.88	0.88	0.00

Table 3: Anthropometric and respondents activity pattern characteristics for petrol-pump officers had exposed to haze since 2015 during work (n = 9).

Elements	Value
Body Weight (W_b) (kg)	57.36
Exposure duration (t_E) (hour/day)	8
Exposure frequency (f_E) (day/year)	47
Lifetime exposure duration (D_t) (year)	0.13
Inhalation Rate (R) (mg/m^3)	0.88

Table 4: PM intake calculation elements of haze exposure in 2019.

Elements	Value
Body Weight (W_b) (kg)	59.56
Exposure duration (t_E) (hour/day)	8
Exposure frequency (f_E) (day/year)	60
Lifetime exposure duration (D_t) (year)	0.16
Inhalation Rate (R) (mg/m^3)	0.88
Concentration (C) (mg/m^3) $PM_{2.5}$	0.466

Table 5: PM intake calculation elements of haze exposure in 2015.

Year of Exposure	I (mg/kg/day)	R*f*D (mg/kg/day)	RQ	Remarks
2019	0.0000041	0.0000079	0.5	Not at Risk
2015	0.0000213	0.000097	2.2	At Risk

Table 6: Intake, dose-response, and risk analysis of $PM_{2.5}$ haze exposure.

Intake analysis

Intake calculation was using equation on figure 2, with values as detailed on table 4 for PM exposure in 2019 and table 5 for PM exposure since 2015. Average exposure duration (t_{avg}) was using 70 years (US-EPA life expectancy default) x 365 days/year for carcinogenic. Betha [3] concluded Cadmium and Nickel in $PM_{2.5}$ exposure from forest and land fire haze, contributed to cancer as the long-term effect. Concentration value for $PM_{2.5}$ is based on TWA measurement result during haze period in Pekanbaru year 2019 and 2015. Intake calculation result in table 6.

Figure 6: Haze covers Pekanbaru air.

Source: Personal photographs.

Dose-response analysis

The calculation is using equation on figure 3 with Concentration Reference from the National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ is 0.035 mg/m^3. Result of dose-response calculation for $PM_{2.5}$ exposure displayed in table 6.

Risk characterization

Risk Characterization calculated by comparing intake to dose-response (R*f*D) values as per equation on figure 1. Risk analysis calculation conducted for two different scenarios: first scenario is to estimate risk quotient of $PM_{2.5}$ to Respondents who just got exposed with haze period in July - August 2019 (n = 11), and second scenario to estimate risk quotient of $PM_{2.5}$ exposing Respondents who were already worked as Petrol-Pump Officers and got exposed since 2015 haze period (n = 9).

Risk characterization result displayed in table 6, where Petrol-Pump Officers who just got exposed to $PM_{2.5}$ in 2019 has RQ ≤ 1, hazards are not considered a threat. While RQ for $PM_{2.5}$ exposure to Petrol-Pump Officers who has worked since 2015 is > 1, means $PM_{2.5}$ in haze that exposes Petrol-Pump Officers cause the adverse health effects and the risk needs to be managed.

The lifetime risk calculation for respondents who are exposed longer (since year 2015) has 4.2 times greater risk than those who are just exposed in year 2019 (Table 6). Besides, the concentration of $PM_{2.5}$ in 2015 was 3.25 times greater and the exposure frequency was 13 days longer in a year than in 2019 (Table 4 and Table 5). This data shows that being exposed to a greater $PM_{2.5}$ concentration, in longer duration, and more frequent, are giving more risk to the exposed person in having an adverse health effect.

Discussion

This study was conducted in Pekanbaru, the densest population in Riau as the capital of the province in Indonesia. The city has been known as one of the worst haze-impacted regions due to the Sumatra forest and land fire repeatedly since 1982, 1991, 1997, 2007, 2012, 2015, include August 2019. The worst haze disaster in 1997 and 2012, haze not only covers Sumatra area, but also even spread through other neighbor countries for months, called transboundary haze [4].

The forest and land fire in Riau were triggered by the expansion of palm oil plantation, where Riau was established as the biggest palm oil plantation concession area in Indonesia, compared to other provinces. While Riau's palm oil industry brought economic benefits, the irresponsible diversion of forest and land function using fire, has led disaster to Riau itself. Burnt biomass from the forest and land fire released a huge amount of airborne particulate matters which harmful to circulation and cardiovascular systems [5]. And several other publications that specifically studied the impact of haze exposure form Sumatran forest and land fire showed significance of the increase number of hospital patients in Kuala Lumpur [6]. While in long term, Betha [4] estimated 0.5% of Kalimantan population who were exposed to forest and land fire haze in the region, will have cancer due to carcinogenic metal (Cadmium and Nickel) in $PM_{2.5}$. Besides adverse health effect, long term effect on haze pollution might resulted in other form such as decreased of work performance, loss of job, or decreased in economic welfare [7]. These studies result provide overview of risk severity that Riau population could suffer as impact of being exposed to $PM_{2.5}$ in haze, if no effort to reduce and mitigate the risk.

On this exposure assessment, we use the theoretical approach by calculating exposure dose from the air pollution concentration and exposure time. Although this approach still has significant limitations, but since there was no study before to estimate the risk of $PM_{2.5}$ exposure to Pekanbaru population, this study is worth to get the estimate risk of $PM_{2.5}$ in haze period that exposed Petrol-Pump Officers whose job working 8 hours daily outdoors.

As expected, Petrol-Pump Officers who had longer years of service and experienced the haze period which concentration in ambient was higher in 2015, and also longer duration of exposed with haze period in a year, have 5 times higher $PM_{2.5}$ intake and 4 times higher RQ compared to officers who just experienced the haze period while performing job as Petrol-Pump Officers on year 2019. This risk magnitudes are concerning since studies show long-term exposure to $PM_{2.5}$ associated with circulation, cardiovascular systems, and also cancer. In addition to that, survey to 20 respondents, only 2 of them who was having surgical mask as their personal protective equipment, while surgical mask will not prevent $PM_{2.5}$ get into respiratory system.

Petrol-pump officers, by nature of their job, they are required to work outdoors included during haze period and without proper protection which made them a vulnerable population. This condition made them exposed openly to the $PM_{2.5}$ polluted ambient air along their 8 working hours in daily basis, and lead them in having higher risks to adverse health effect - therefore risk management is required to reduce the risk in protecting the workers' health. Risk management can be implemented by manipulating the hazard factor as well as the exposure factor. $PM_{2.5}$ in haze as the hazard factor, was known due to forest and land fire in Sumatra area. The burnt biomass released particulate matters polluted the air which also happened as the working environment for people who works outdoors. Effort to prevent or reduce the forest and land fires could control the $PM_{2.5}$ as the airborne hazard, while continuous $PM_{2.5}$ concentration monitoring in ambient air could help government maintain the $PM_{2.5}$ under the threshold limit value or daily safe concentration for lifetime $PM_{2.5}$ exposure (0.035 mg/m^3), and to early identify whether precaution needs to be implemented during certain level of $PM_{2.5}$ concentration. Risk control effort by managing exposure to worker can be done by manipulating the working shift to manage the daily exposure time. Determination of safe daily exposure time can be calculated by considering the Intake = R*f*D.

Although RQ for Petrol-Pump Officers who has just exposed in 2019 less than1, it does not mean that no precaution needed to be done to protect the workers from exposure. The Concentration of $PM_{2.5}$ in 2019 was only 30% Concentration of $PM_{2.5}$ in 2015. If the Concentration is getting higher, there is probability the RQ would increase when Intake is increased. Therefore, risk management opportunity efforts to prevent the risk getting higher need to be identified as mitigation. Active continuous monitoring and communication of $PM_{2.5}$ concentration to public would be very beneficial in raising awareness so necessary precaution can be implemented early.

As part to manage the exposure daily duration for workers working outdoors with $PM_{2.5}$ exposure in 2015 detailed in table 4 while considering the Intake value refer to table 6 for year 2015 is 0.0000213 mg/kg/day, the daily safe exposure duration for a worker is 3.7 hours/day. And as addition to protect the worker from $PM_{2.5}$ gets to the lung, Petrol-pump employers are advised to provide N-95 mask or HEPA mask to the worker who works outdoors during haze pollution period.

Limitations that should be highlighted are in the real-time measures to represents the $PM_{2.5}$ concentration, and lack of consensus for PM R*f*C and inhalation rate measurements obtained from other studies conducted. In relation to the R*f*C, we used the reference concentration of US-EPA TLV for $PM_{2.5}$ in ambient air [8-12].

Conclusion

The calculation of lifetime risk showed that Petrol-Pump Officers who were exposed longer since 2015 haze period, has four times greater health risk compared to those who are just exposed in 2019 haze period. Petrol-Pump Officers who just got exposed to $PM_{2.5}$ in 2019 has RQ ≤ 1, hazard was not a threat - however risk still need to be maintained under 1. While RQ for $PM_{2.5}$ exposure to Petrol-Pump Officers who has worked since 2015 is > 1, means $PM_{2.5}$ in haze that exposes Petrol-Pump Officers cause the adverse health effects and the risk needs to be managed. Some of risk management effort advise that suggested to stakeholders are strengthened policy implementation in protecting forest and land from fire to reduce the $PM_{2.5}$ that released as airborne hazard from burnt biomass, conduct continuous $PM_{2.5}$ concentration monitoring in ambient air to maintain the $PM_{2.5}$ under TLV (0.035 mg/m^3), public education to raise awareness and educate mitigation plan to reduce the health risk of being exposed to haze, for employer to manage exposure to worker by managing the working shift to manage the daily exposure time during haze period, provide N-95 mask or HEPA mask to protect the worker who works outdoors during haze pollution period.

This study is one of the first about risk assessment of $PM_{2.5}$ in haze from forest and land fires and implement a methodology that could be applicable to estimate and compare levels of risk with different time of exposure in a group. Knowing the estimated $PM_{2.5}$ exposure risk and its level of magnitude, hopefully this study can illuminate and raise awareness of all stakeholders, public, academics, employers, and government as policy maker to give extra attention and efforts to manage the risk for a better health in future for workers and citizen in Pekanbaru. For future studies, it is suggested to match the location of real-time concentration ambient data with the respondent's location. This is to make more represents the concentration of airborne hazard in the working area of respondents.

Conflict of Interest

The Author declare we have no competing interests.

Acknowledgment

This study was made possible by support of Author's family and friends completing this research.

Bibliography

1. Ki-Hyun Kim., *et al*. "A review on the human health impact of airborne particulate matter". *Environment International* 74 (2015): 136-143.
2. Kementerian Lingkungan Hidup dan Kehutanan. Direktorat Pengendalian Pencemaran Udara (2019).
3. R Betha., *et al*. "Chemical speciation of trace metals emitted from Indonesian peat fires for health risk assessment". *Atmospheric Research* 122 (2013): 571-578.
4. Kunii O., *et al*. "The 1997 haze disaster in Indonesia: its air quality and health effects". *IRTS Archives of Environmental Health SciTech Premium Collection* (2012): 16.
5. J Othman., *et al*. "Transboundary smoke haze pollution in Malaysia: Inpatient health impacts and economic valuation". *Environmental Pollution* 189 (2014): 194-201.
6. M Brauer and HH Jamal. "Fires in Indonesia: crisis and reaction". *Environmental Science and Technology* (1998): 404-407.
7. Y Kim., *et al*. "Long-run health consequences of air pollution: Evidence from Indonesia's forest fires of 1997". *Economics and Human Biology* 26 (2017): 186-198.
8. Abdur Rahman Sukadi. Analisis Risiko Kesehatan Pajanan PM10 dan SO2 di Kelapa Gading Jakarta Utara tahun 2014. FKM UI (2014).
9. INCHEM, International Programme on Chemical Safety. "Environmental Health Criteria 27". Guidelines on Studies in Environmental Epidemiology.
10. Oliveira Beatriz Fátima Alves., et. al. "Risk assessment of PM2.5 to child residents in Brazilian Amazon region with biofuel production". *Environmental Health* 11 (2012): 64.
11. Randy Novirsa and Umar Fahmi Achmadi. "Risk Analysis of PM2.5 Exposure in Ambien Air at Noon towards Community in Cement Industrial Estate". *Jurnal Kesehatan Masyarakat Nasional* 7.4 (2012): 173-179.
12. United States Environmental Protection Agency. NAAQS Table (2017).