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ENVIRONMENTAL HEALTH RISK ASSESSMENT OF AIR POLLUTANTS IN ONLINE MOTORCYCLE TAXI DRIVERS IN THE SPECIAL CAPITAL REGION OF JAKARTA

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Abstract

Introduction: *Online motorcycle taxi drivers spend most of their time outside as either driving or waiting for their customers. Therefore, chances of exposure to various air pollutants are higher and may cause various health problems, especially the respiratory problems.* ***Methods:*** *This is a descriptive study that used the Environmental Health Risk Analysis method to estimate the Risk Quotient (RQ) from exposure to PM_{10}, SO_2, CO, O_3, and NO_2 in drivers. The RQ was calculated based on exposure concentrations from the Special Capital Region of Jakarta Environment Agency; daily working hours, working days in a year, and working period obtained from interviews; additionally, body weight measurement, reference concentration (RfC), and the default value of inhalation intake were also collected. The population of this study was adult online motorcycle taxi drivers who operate around areas which become the air quality measurement stations in the Special Capital Region of Jakarta with a total sample of 81 people.* ***Results and Discussion:*** *The RQ for all minimum, average, and maximum concentrations of SO_2, CO, and NO_2 were <1. While for the average and maximum concentrations of PM_{10} and the maximum concentration of O_3, the RQ was >1. The safe concentrations, work duration, and the number of working days also surpassed the maximum safety limit levels.* ***Conclusion:*** *PM_{10} and O_3 ambient exposures are categorized unsafe for drivers. Environmental health efforts are necessary to reduce the concentration of air pollutants, and the guidelines to reduce pollutants exposure should be provided for drivers.*

INTRODUCTION

The Indonesian population is estimated to reach 305,652,400 people by 2035. The rise of industrial development and transportation advancement have continuously developed. In 2012, the number of cars in this country increased by 1.3 million units per year, and the number of motorcycles doubled (1). These various motorized vehicles emit air pollution to their surroundings. At once, contaminate the ambient air with industrial exhaust or another source of air pollution. Hence, vehicle emissions remain climate and public health issues even after air pollution policies have been implemented (1−2).

High levels of air pollution can cause various environmental, wildlife, and human health problems, especially for people who are constantly on the road (3). The drivers of public transportation are one of the groups considered vulnerable to these impacts (4).

The increased activity of motor vehicles is driven by needs for transportation. Online motorcycle taxis, known as "*ojek online*", contribute to the increase in the number of motor vehicles that alternatively facilitates community mobility. There were approximately 4 million online motorcycle taxi drivers in Indonesia based on data in 2020, and 25% of them worked in the Jabodetabek area (5). The number of online motorcycle taxi drivers has increased in recent years. However, there are no official occupational health guidelines despite being vulnerable to health risks.

Based on the Indonesian Law No. 22 of 2009 concerning Road Traffic and Transportation, drivers of public motor vehicles should only work for a maximum

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of eight hours a day and rest for a minimum of half an hour after driving for four consecutive hours. However, these working hour guidelines do not generally apply. Most online motorcycle taxi drivers work more than eight hours a day (6−7).

The Indonesian Ministry of Environment and Forestry has monitored ambient air quality by setting up some automatic air quality measurement stations (*Stasiun Pemantauan Kualitas Udara*) throughout Indonesia. The data would then be compiled to generate an Air Pollution Standard Index (*Index Standar Pencemar Udara*) which could be accessed by the public to provide them with ambient air quality information at certain locations and times. This index is used to show the level of pollutants in the air collected over the last 24 hours each day (1).

Based on data from the 26 air quality monitoring stations accumulated from 2017 to 2019, 74% of Indonesia's ambient air status was in the good category, 16% moderate, 2% unhealthy, 0.2% very unhealthy, and 0.21% dangerous (1). The Special Capital Region of Jakarta has five air quality measurement stations located in Bundaran HI, Kelapa Gading, Jagakarsa, Lubang Buaya, and Kebon Jeruk. However, the Environmental Agency of Special Capital Region of Jakarta in 2020 found that several parameters (PM_{10}, SO_2, O_3, and NO_2) were above the specified quality standards (8). According to the WHO's quality standard, the air quality index in the province was unhealthy in the certain times (9).

Environmental Health Risk Analysis (ARKL) is a method used to estimate the health risks received due to exposure to a certain agent (10). From this study, the health risk for online motorcycle taxi drivers was estimated based on the exposure concentration, the rate of inhalation intake, daily duration of work, working days for a year, body weight and working period, as well as reference concentrations (RfC).

METHODS

This descriptive study analyzed health risks received by drivers due to exposure to air pollutants by using the Environmental Health Risk Analysis technique. Data collection was conducted in the Air Quality Measurement Stations in the Special Capital Region of Jakarta, specifically Bundaran HI, Kelapa Gading, Jagakarsa, Lubang Buaya, and Kebon Jeruk in November 2021.

The air pollutant concentration was collected from secondary data of PM_{10}, SO_2, CO, O_3, and NO_2 at the Air Quality Measurement Stations from August 2020 to July 2021. Eligible results represent the amount of exposure concentrations on drivers in general. Data regarding the characteristics and health complaints of respondents were collected through a questionnaire, while weight data were obtained through direct measurements by using digital scales and applying standard procedures.

The health complaints related to symptoms of acute exposure to PM_{10}, SO_2, CO, O_3, and NO_2 from various literature include coughing, sneezing, shortness of breath, wheezing, chest pains, headaches, sore eyes, dizziness, and sore throat. The symptoms are likely experienced when the drivers partake in activities close to the areas. The data will support the results if the risk quotient shows unsafe air pollutant concentrations for drivers.

This study's population was online motorcycle taxi drivers who often picked up, dropped off, and rested in the areas covered by the Air Quality Measurement Stations in the Special Capital Region of Jakarta for at least one year before data collection and who were 18 years of age or older. A history of asthma and pneumonia were excluded from the criteria at the beginning of the interviews. All of the interviews were conducted with informed consent. The sample in this study was estimated by the formula below:

$$n = \frac{z^2 \alpha\, p\,(1-p)}{d^2}$$

$$= \frac{2.58^2\ 0.5\ (1-0.5)}{0.15^2} = 73.96 \approx 74$$

The number of samples was added by 10% to prevent the possibility of dropouts. Therefore, this study had a total of 81 respondents. It was conducted after receiving ethical clearance based on the ethics letter No: 501/SK.KEPK/UNR/X/2021 issued by the Institute for Research and Community Service of Universitas Respati Indonesia.

The characterization risk in this study was calculated based on the values of intake and RfC using the following formulas:

$$RQ = \frac{I}{RfC} \text{ .... Formula 1}$$

The non-carcinogenic inhalation intake (I) of air pollutants was calculated with the following formula:

$$I_{nk} = \frac{C x R x\, t_E x f_E x D_t}{W_b x t_{avg}} \text{ ....Formula 2}$$

The formula used for *RfC* is:

$$RfC = \frac{C x R x\, t_E x f_E}{W_b x t_{avg}} \text{ ....Formula 3}$$

RESULTS

All of the respondents are male with an average age of 36 years (20-61 years). The respondents were selected by Air Quality Measurement Stations; hence, there were 16 respondents at four locations (Bundaran HI, Kelapa Gading, Jagakarsa, and Kebon Jeruk) and 17 respondents at the Lubang Buaya area.

Hazard Identification

The quality standard of air pollutants in Indonesia is determined through the Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Protection and Management. The National Ambient Air Quality Standards include PM_{10} = 75 µg/m³, SO_2 = 150 µg/m³, CO = 10,000 µg/m³, O_3 = 150 µg/m³, and NO_2 = 200 µg/m³.

In March 2020, large-scale social restrictions were implemented in Jakarta to reduce the spread of Covid19. The impact was also seen in the changes in Jakarta's air quality, which appeared to decrease by 15.74% for PM_{10}, 6.26% for SO_2, 29.17% for CO, and 18.34% for NO_2, as well as an increase of 4.06% for O_3 (11).

The concentrations of PM_{10}, SO_2, CO, O_3, and NO_2 in the air were provided by the Environmental Service of DKI Jakarta (12). The data were the results of parameters measured from August 2020 to July 2021. The minimum, maximum, and average concentrations of air pollutants can be seen in Table 1.

Table 1. Air Pollutants Concentration

Air Pollutant Concentration	PM_{10}		SO_2		CO		O_3		NO_2	
	µg/m³	mg/m³	µg/m³	mg/m³	µg/m³	mg/m³	µg/m³	mg/m³	µg/m³	mg/m³
C min	12	0.012	2	0.002	3	0.003	3	0.003	1	0.001
C max	96	0.096	112	0.112	135	0.135	162	0.162	148	0.148
C average	53	0.053	28	0.028	12	0.012	31	0.031	16	0.016

**C = concentration*

Response Dose

The Reference Concentration (RfC) for SO_2 and NO_2 was taken from the US EPA in 1990 (13). Meanwhile, CO, O_3, and PM_{10} concentrations were calculated based on the quality standards of pollutants in the Indonesian National Ambient Air Quality Standard (NAAQS) since the RfC for these three pollutants are not stated in the Integrated Risk Information System (IRIS) and Minimum Risk Level (MLI).

Table 2. RfC of Air Pollutant

Pollutant	RfC
PM_{10}*	0.005
SO_2**	0.026
CO*	0.699
O_3*	0.010
NO_2**	0.020

**Calculated based on Indonesian National Air Quality Standard;*
***Based on US EPA (13)*

RfC was calculated based on the quality standard exposure concentration, R = 0.83 m³ /hour, in the work environment (t_E = 8 hours/day, f_E = 250 days/year), average weight of respondents (Wb = 65 kg), and the average of period (t_{Avg} = 365 days) (10).

Exposure Analysis

The real-time intake was the driver's actual exposure time. Therefore, data required on participants' characteristics include the period of exposure each day (hours) (t_E), frequency of exposure for a year (days) (f_E), duration time (years) (D_t), and body weight (Wb).

Table 3. Driver's Characteristics

Characteristic	Median
Time of exposure (hours/day) (t_E)	10.7
Frequency of exposure (days/year) (f_E)	312
Duration (year) (D_t)	3.5
Weight of body (kg) (Wb)	65.2

Most of the drivers usually waited for customers on the side of the street (86.4%), and the duration was added to the period of exposure. The rate (R) of inhalation in this study followed the adult default of 0.83 m³/hour, and the time average (t_{avg}) used was the median value of the driver's work period (3.5 years) multiplied by 365 days to obtain the value of 1,278 days.

Risk Characterization

Based on the results of the RQ calculation (Table 4), it was found that the average and maximum concentrations of the PM_{10} and O_3 showed an RQ > 1. Thus, these are categorized as unsafe for a driver with a bodyweight of 65 kg to inhale the pollutants for 11 hours a day for 312 days/year for up to 3.5 years. Meanwhile, the minimum concentration of all pollutants is still in the safe category.

The minimum, maximum, and average concentrations of SO_2, CO, and NO_2 ambient exposure were classified as safe. These results may be due to the maximum concentration from August 2020 to July 2021 below the quality standard (SO_2 = 112 µg/m³ <150 µg/m³; CO = 135 µg/m³ <10,000 µg/m³; NO_2 = 148 µg/m³ <200 µg/m³). The driver's work period was also not that long (3.5 years) compared to earlier studies that used a longer time period when calculating the risk.

Table 4. Risk Characterization of Air Pollutant to Drivers

Air Pollutant Concentration	Intake									
	PM_{10}		SO_2		CO		O_3		NO_2	
	I	RQ	I	RQ	I	RQ	I	RQ	I	RQ
C Min	0.0014	0.2736	0.0002	0.0092	0.0004	0.0005	0.0004	0.0342	0.0001	0.0060
C Max	0.0115	2.1885*	0.0134	0.5153	0.0161	0.0231	0.0194	1.8465*	0.0177	0.8852
C Average	0.0063	1.2082*	0.0033	0.1288	0.0014	0.0021	0.0037	0.3533	0.0019	0.0957

**RQ>1, categorized as unsafe*

Risk management

Pollutant risk management could be provided by setting a safe limit of exposure. Table 5 shows the safe limits in terms of safe concentrations, exposure times, and exposure frequencies seen from the average concentration of PM_{10} and the maximum concentration of O_3.

Table 5. Maximum Concentration and Maximum Exposure Rate

Pollutant	Safe Concentration*	Max Time of Exposure**	Max Frequency of Exposure***
PM_{10}	44 μg/m³	9 hours/day	257 days/year
O_3	87 μg/m³	6 hours/day	168 days/year

**For exposure 11 hours/day, 312 days/year for 3.5 years*
*** For exposure to ambient air pollutants (PM_{10}=53 μg/m³; O_3=162 μg/m³), 312 days/year for 3.5 years*
**** For exposure to ambient air pollutants (PM_{10}=53 μg/m³; O_3=162 μg/m³), 11 hours/day for 3.5 years*

DISCUSSION

Motorcyclists are exposed to more air pollution than drivers of other transportation modes, such as cars or trains. Previous studies have found that driving with the enclosed transportation can protect motorists from exposure to traffic-related air pollutants (14). However, this method cannot be applied to motorcyclists. Studies have found that compared to motorcycle taxi drivers, car taxi drivers tended to have better respiratory functions. Moreover, motorcycle drivers have uncertain break schedules because of uncertain trip demands; hence, they are more likely to rest with their vehicles and spend all day on the street close to emissions from transportation (15).

Drivers can experience various potential hazards, one of which is exposure to air pollutants. Various human activities such as industrial waste and motor vehicle exhausts cause various pollutants such as SO_2, CO, O_3, and NO_2 particulates to be present in ambient air. These air pollutants can cause various health problems for the population.

Particulate matter (PM) has a very small diameter and can be inhaled into the respiratory system and lead to respiratory and cardiovascular diseases, reproductive dysfunction, central nervous system issues, and even cancer. Sulfur dioxide is associated with increased health facility visits due to pneumonia and cerebrovascular accidents. Nitrogen dioxide is also considered a harmful pollutant if inhaled by humans as it is related to myocardial infarction. Carbon monoxide can even cause immediate poisoning if inhaled in high concentrations. Ozone acts as a shield for the earth against UV radiation in the stratosphere. However, at the ground level, high concentrations of ozone dangerously cause respiratory and cardiovascular problems, as well as heart failure (16−17).

Moreover, some evidence suggests that high concentrations of PM_{10}, SO_2, NO_2, and ozone can influence the spread and transmission of SARS-CoV-2 (18). Another study found that exposure to SO_2, CO, and $PM_{2.5}$ made an area more susceptible to Covid19 infection. Nonetheless, this result is also closely related to climatic factors such as temperature, precipitation, and wind speed (11).

This study's findings showed several health problems experienced by the drivers because of PM_{10} and O_3 exposure in the work environment. Based on the interviews, most of the drivers (71.6%) experienced health complaints such as coughing (50.6%), sore eyes (42%), headaches (40.7%), dizziness (35.8%), chest pains (17.3%), shortness of breath (9.9%) and sore throat (7.4%) which could be indicators of exposure to PM_{10} and O_3 exceeding the quality standards.

These complaints emerged when the respondents were actively working on the street. Some respondents reported that the complaints disappeared after they were away from the street (63.8%; 37/58), while some still experienced the symptoms despite working away from the street (36.2%; 21/58).

Health Risk of PM_{10}

The risk assessment found that PM_{10} exposure (average and maximum concentrations) received by the drivers was classified as unsafe. It could be considered safe if the concentration in the environment was 44 μg/m³. However, the average and maximum PM_{10} levels in the ambient air passed this number ($C_{average}$ = 53 μg/m³; $C_{maximum}$ = 96 μg/m³). The maximum concentration of PM_{10} exceeded the quality standard of 75 μg/m³.

The results showed that the maximum period of exposure for 53 μg/m³ of PM_{10} was for nine hours. In other words, a driver who had 65 kg of weight and was exposed to PM_{10} during 312 working days/year for 3.5 years would be safe if the exposure period was 9 hours/day. Meanwhile, for the same level of exposure and work duration of 11 hours/day, the safe frequency of exposure for 3.5 years is 257 days/year. However, the average driver worked for 11 hours/day for 312 days/year.

Therefore, this condition can induce some health problems. PM_{10} has acute effects such as coughing, shortness of breath, chest pain, eye irritation (19−20). Particulate dust has also been shown to be associated with the rapid worsening of chronic obstructive pulmonary disease (COPD) and exerts a harmful effect such as mortality even at very low concentrations (17,21). Hospital visits due to arrhythmia, cerebrovascular disease, high blood pressure, and ischemic heart disease can also be affected by exposure to an increase in 10 μg/m³ PM_{10} concentration. It is predicted that men and the elderly are more susceptible to PM_{10} exposure (22). Another study also stated that an increase in PM_{10} level was associated with an escalation of respiratory disorder cases, and individuals in the age group under 5 years and over 60 years are more susceptible (23).

In their work environment, motorcycle taxi drivers are directly exposed to air pollution, and their lung function may degrade more than drivers of enclosed vehicles, such as taxicabs or trains, especially when they are exposed to ≥ 50 μg/m³ of PM_{10} (24). The high concentration of pollutant exposure is directly proportional to the risk of health problems. This is supported by previous research which found that higher concentrations, longer durations, and more frequent exposure to PM_{10} would increase the possibility of health risks. These results are also influenced by body weight, where the heavier a person is, the smaller the intake will be, and the lower the possibility of health risks (25).

PM_{10} can contain As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Zn, and the highest components in PM_{10} are Al and Fe (26). These results may indicate the possibility of other health problems that can be caused by exposure to PM_{10}. For example, lead absorbed into the human body could result in direct poisoning (16).

A significant difference was found in the analysis of Serum Glutamic Pyruvic Transaminase (SGPT) and Serum Glutamic Oxaloacetic Transaminase (SGOT) levels in online motorcycle taxi drivers who were exposed to motor vehicle fumes. The SGPT and SGOT levels were caused by lead particulates. Lead particles can bind to erythrocytes and circulate to the soft tissue, especially the liver, and damage the liver cells. This results in the release of aminotransferase enzymes, SGOT and SGPT as markers of liver cell damage or abnormalities (27).

Around 61.5% of drivers who experience symptoms such as coughing, sneezing, shortness of breath, wheezing, chest pain, or sore throat while on the road also had a smoking habit. Smoking is the main factor causing respiratory disorders, especially if it is combined with exposure to air pollutants. Lung capacity disorders were likely experienced by bus drivers who had a smoking habit and got exposed to various air pollutants, including PM_{10} for about 13 hours/day (28).

Observation in Covid19 patients also found that long-term exposure to PM_{10} likely influenced the severity and contributed to death compared to some comorbidities of this infectious disease, such as COPD, asthma, diabetes, or obesity. It was stated that the increased PM_{10} level by 1 μg/m³ likely worsened the severity by 3.06% and mortality by 2.68% (29).

Earlier study has found that pollution exposure was established lowered cognitive performance, heightened aggression, and higher levels of impatience. Driving safely relies on cognitive performance, while the impulsive behavior while in traffic may increase the accident. A study found particulates in ambient air ($PM_{2.5}$) correlated to 0.3-0.6% of the increase in the number of vehicles in accidents per day. These findings suggest that particulate exposure likely have unexpected impacts and lead to the unsafe street air (30). In another study, air pollutant levels also affected the number of accidents despite a different level. It was observed that a 1 μg/m³ increase in $PM_{2.5}$ concentration increased the number of accidents by about 4% in a day (31).

Health Risk of O_3

The current risk assessment found that it was unsafe for online motorcycle taxi drivers with 65 kg of weight who work around the areas of Special Capital Region of Jakarta as they were exposed to O_3 for 11 hours a day and 312 days in a year for up to 3.5 years. For an equivalent period of exposure, O_3 is declared safe if the concentration in the environment is 87 μg/m³. However, within the period examined in this study, the maximum level of ozone in ambient air (162 μg/m³) had exceeded the safe exposure concentration of 87 μg/m³ and the quality standard of 150 μg/m³.

The safe period of exposure for 162 μg/m³ O_3 is 6 hours. This means that a driver with 65 kg of weight exposed to O_3 would be safe for 3.5 years during 312 working days/year if their exposure to O_3 was limited to six hours a day. For an identic condition of exposure for 11 hours/day, the safe frequency of exposure for 3.5 years would be 168 days/year. This result is similar to PM_{10} exposure. The current period and frequency of exposure of online motorcycle taxi drivers to O_3 was 11 hours/day, and the average number of working days was 312 days/year. All of the numbers are beyond the safe limit.

Ozone as a strong oxidant may induce oxidative damage to cells and the lining fluids of the respiratory tract as well as cause immune-inflammatory responses within and beyond the lungs. Therefore, high levels of ozone induce some respiratory and lung problems (32). Exposure to O_3 may also cause eye, nose, and throat irritation, which result in reactions such as choking, coughing, lethargy, chest pain, coughing, headaches, loss of coordination, difficulty in expressing and moving, severe dizziness, and pulmonary edema if people are exposed to high concentrations. Ultimately, these symptoms vary depending on the concentration of O_3 and the duration of exposure (20).

Professional motorcyclists are likely at high risk due to long-term exposure to air pollution. The effects of continuous exposure to high levels of O_3 on professional motorcyclists are estimated to develop oxidative stress and genetic damage (33).

Furthermore, a study found that exposure to very low concentrations with a short-exposure duration of ozone may result in a decreased lung function in children. Although the effects have not been proven in adults, elderly people also experience similar conditions (34). Other research has also found that an increase of 10 $\mu g/m^3$ in O_3 exposure could lead to an increase in the number of deaths because of respiratory system disorders by 1.35%, and the effects would be more dangerous in men and elderly (35).

Short-term exposure to ambient O_3 was also significantly associated with an escalated incidence of cardiac arrhythmias, which might occur as a result of worsening an autonomic function and myocardial injury (36). Additionally, long-term exposure to O_3 has also been found to be related to various respiratory diseases. Therefore, reducing exposure is expected to lessen the risk of the health problems (37).

People who are required to work on the street are likely to get exposure to air pollution, but safety guidelines for professional drivers have not been implemented. Some drivers are self-employed or on temporary contracts. Therefore, some occupational safety and health regulations for jobholders may not apply to them. Understanding their activity patterns is critical in providing comprehensive information on how to reduce exposure during the workday through effective and low-cost mitigation actions. Industry and academia can work together to create a reliable and portable sensor that can indicate exposure levels to diesel exhausts alongside GPS devices to increase awareness regarding exposure to air pollutants. The data could then be used as evaluation material for policymakers (38).

Establishing research centers for monitoring national air quality and air pollution levels and allocating greater investments in green technology are important. These centers allow for collaboration across multiple disciplines and help discover scientific findings that could be turned into national agendas and policies. It is necessary to adopt strict guidelines for air quality on a national level. Nevertheless, the implementation of measures that may significantly reduce particle levels requires cooperation from industrial and health authorities (39).

Although public policy makers should have a role in reducing air pollution and improving ambient air quality, every individual can also make personal efforts to eliminate exposure. Some applicable efforts are limiting outdoor physical activities at certain times when there are high pollutant levels, utilizing air quality information to plan activities, and wearing face masks to reduce exposure (40). This study promotes the importance of reducing air pollutants and decreasing exposure to improve public health by implementing and monitoring the industry's compliance with air pollutant emissions policies and providing clean rooms, air purifiers, and masks (17,35).

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CONCLUSION

PM_{10} and O_3 exposure were classified as unsafe for online motorcycle taxi drivers who were 65 kg weighed and worked around the Air Quality Measurement Stations for 11 hours of exposure each day and 312 working days/year for 3.5 years. Meanwhile, the exposure to SO_2, CO, and NO_2 were categorized as safe. The average and maximum concentrations of ambient PM_{10} and the maximum concentration of O_3 ambient have exceeded the maximum level of safe exposure concentrations. The duration and frequency of exposure surpassed the safe exposure rate as well. Scientists from multiple disciplines, the industry sector, and health authorities have to improve their commitment and support to reduce air pollutants, especially PM_{10} and O_3. The Indonesian Ministry of Labor and online transportation companies should also collaborate to establish guidelines for driver's health and safety as well as encourage efforts that may decrease the level of exposure by providing masks or other personal protective equipment.

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