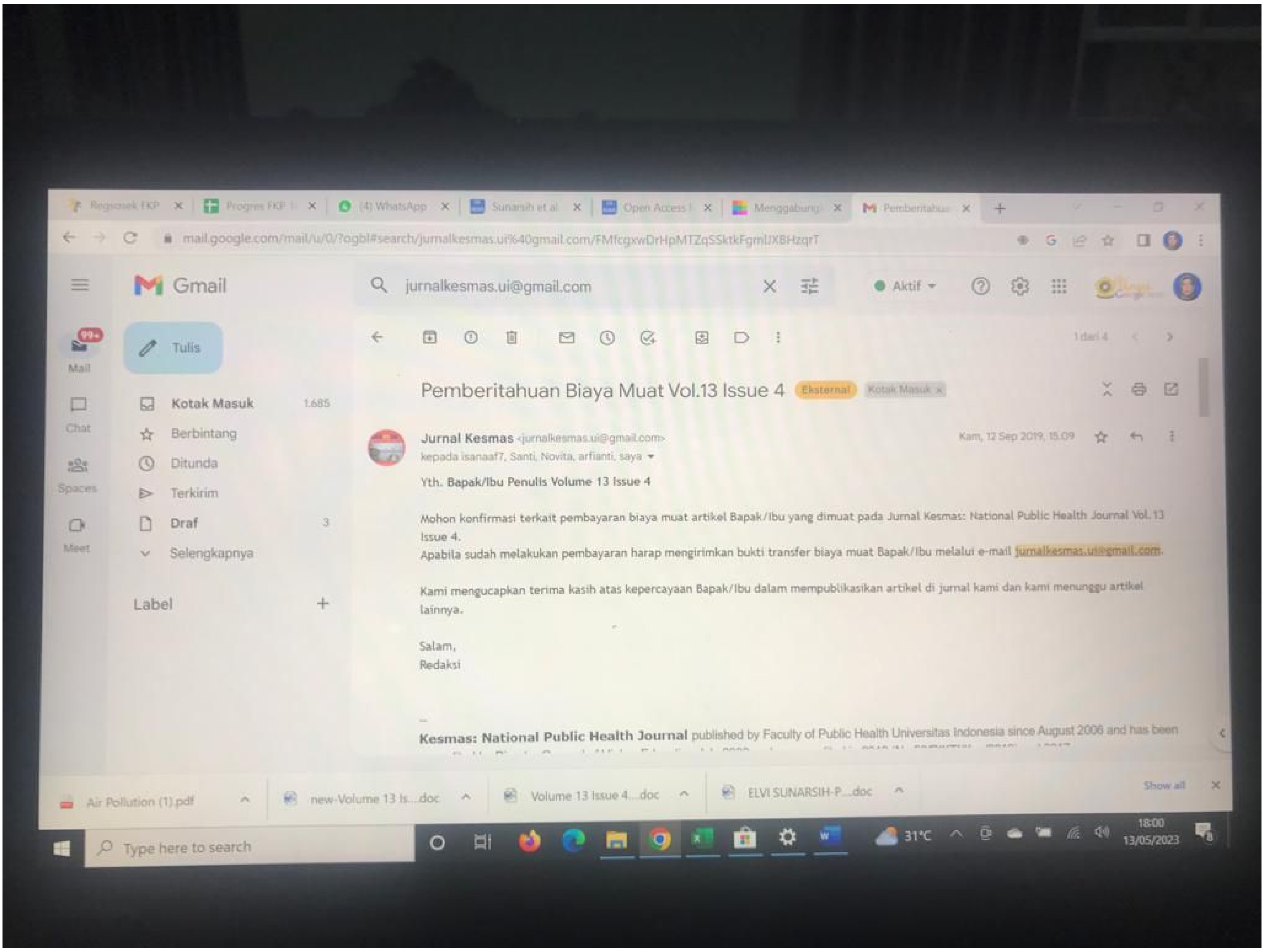

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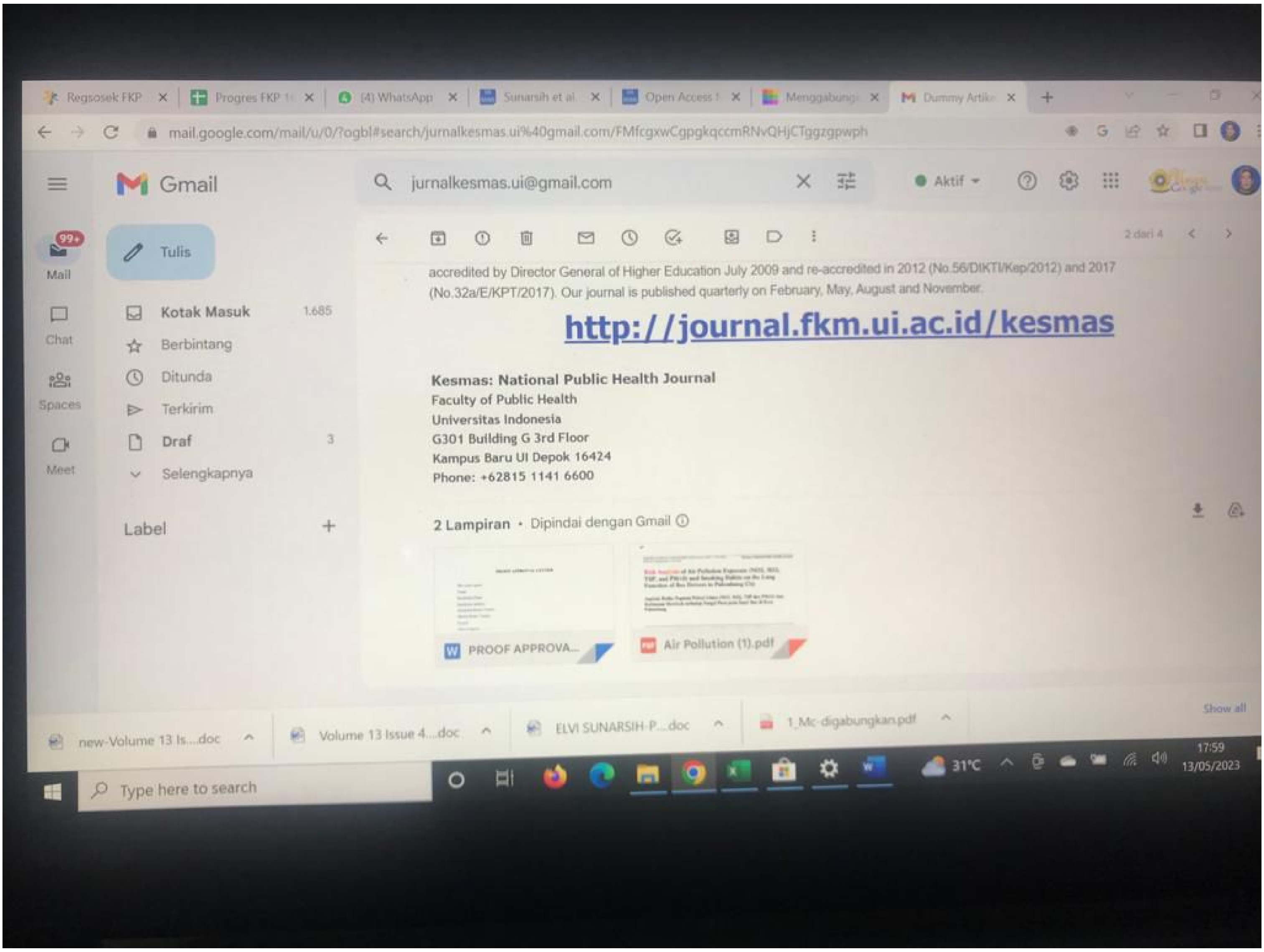
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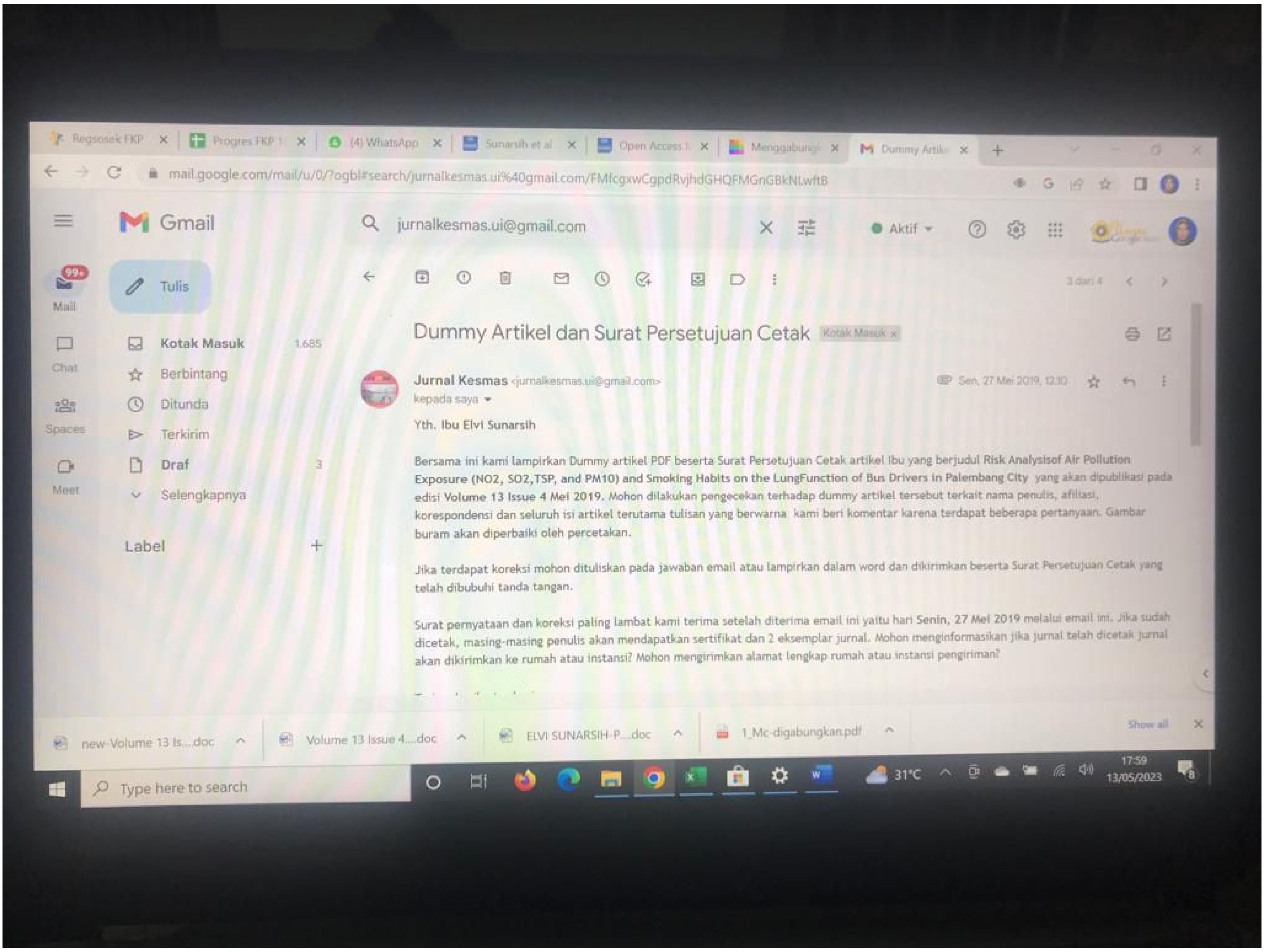
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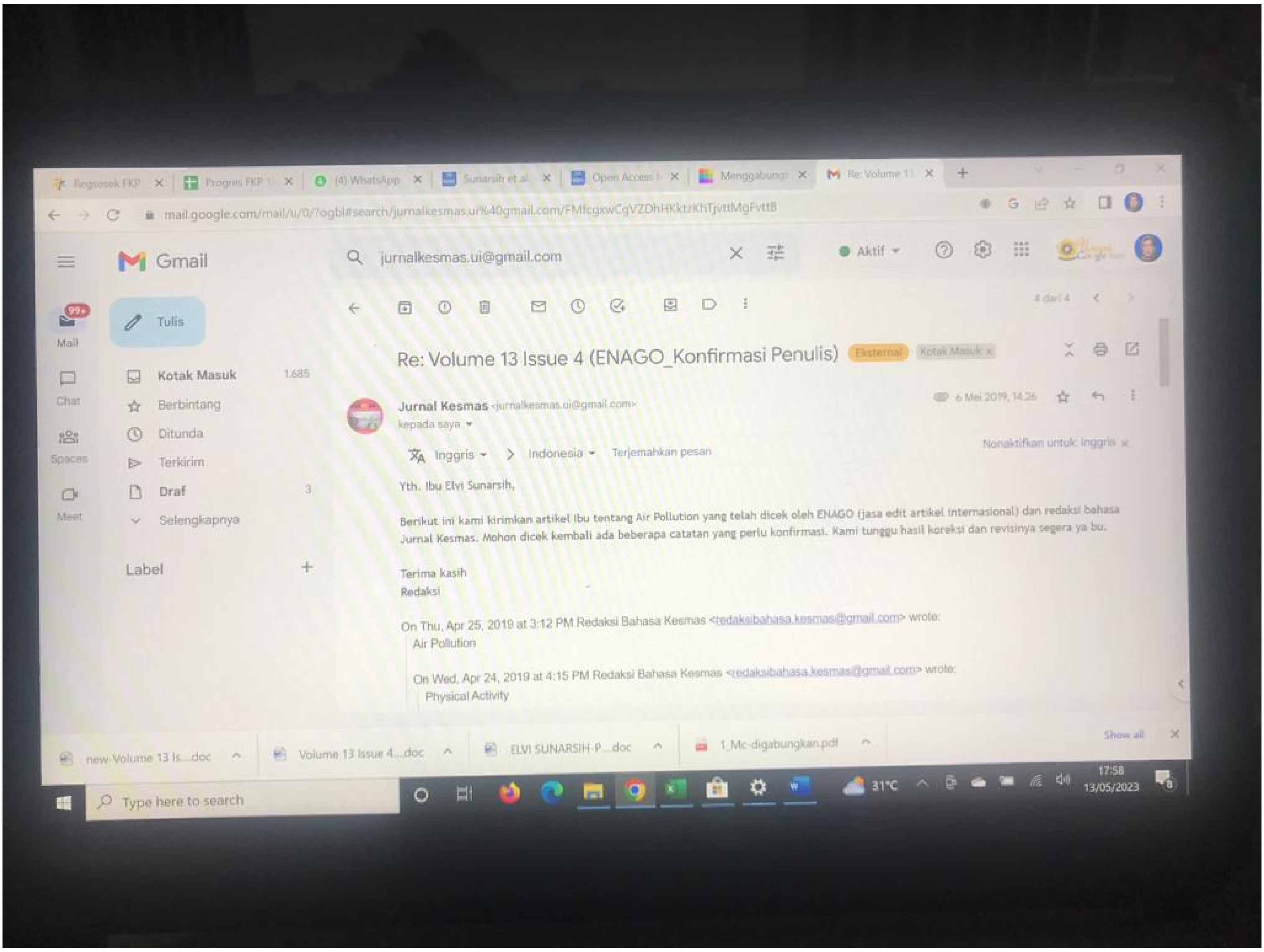
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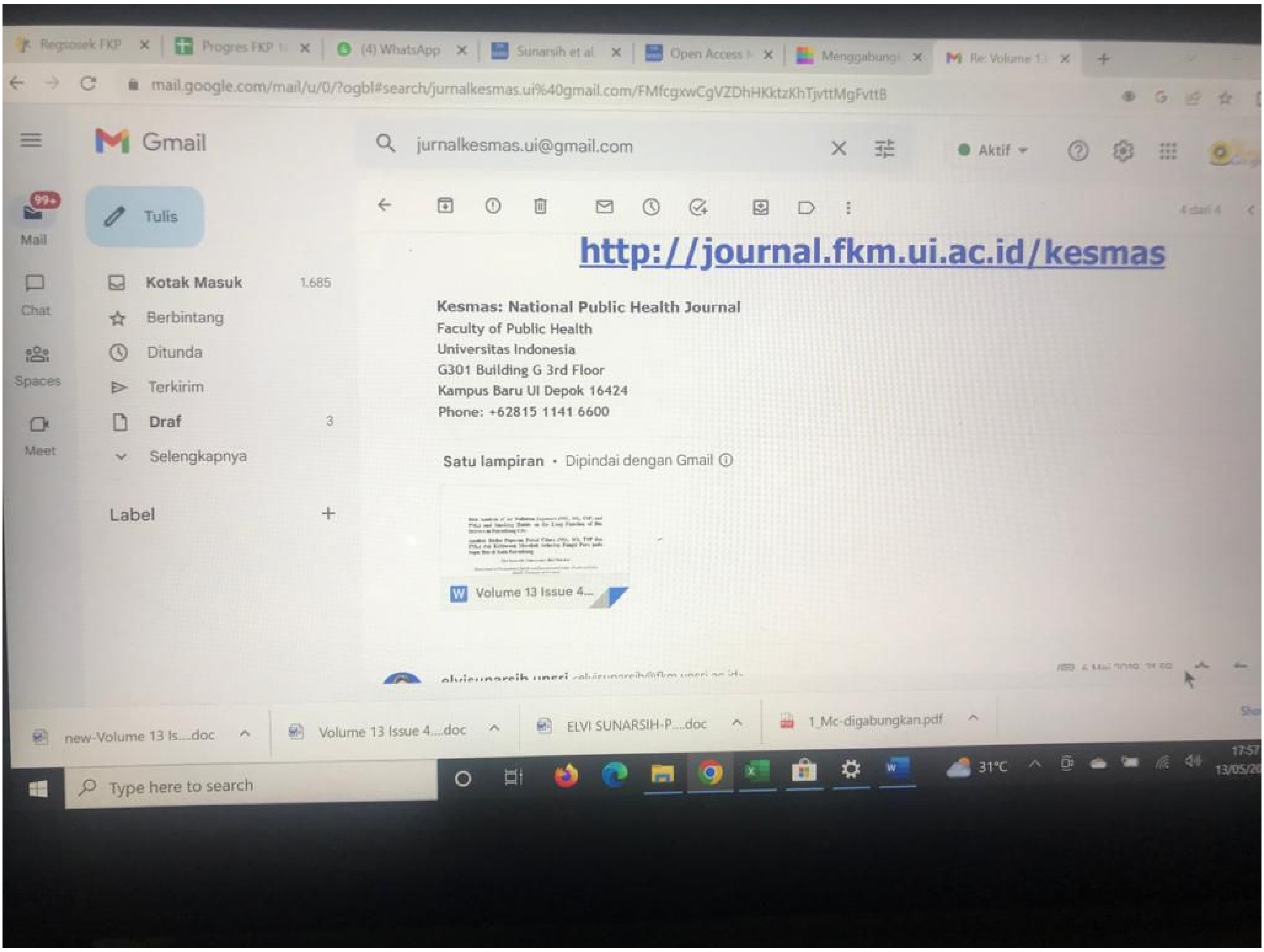
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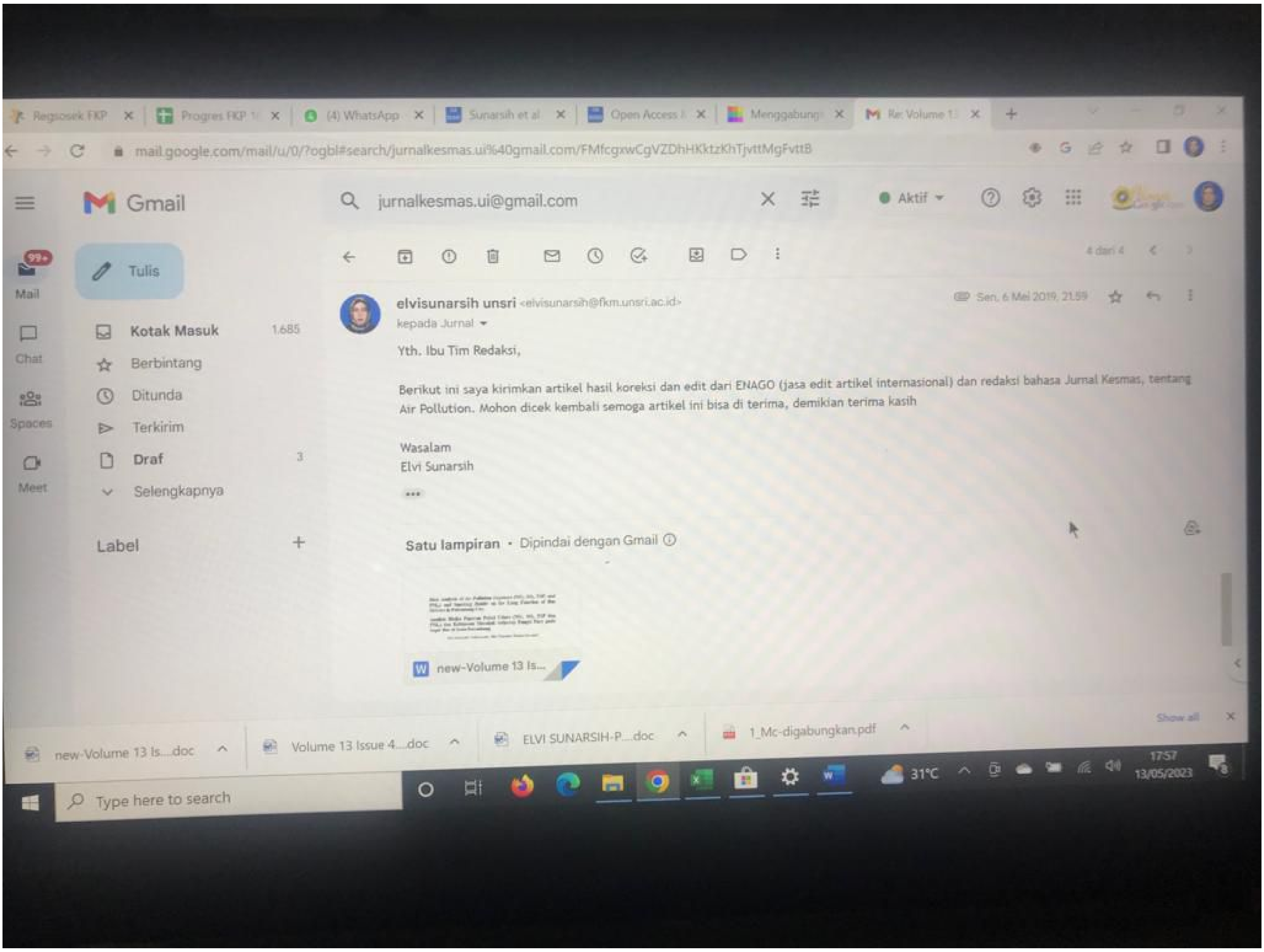
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Risk Assesment of Air Pollution Exposure (NO2, SO2, TSP, and PM10) and Smoking Habits on the Lung Function of Bus Drivers in Palembang City

Abstract

Nitrogen dioxide (NO2), sulfur dioxide (SO2), particulate matter (PM10), and total suspended particulate (TSP) are the most common and harmful air pollutants to humans. In a short period, air pollution exposure at 5 ppm for 10 minutes in humans causes dyspnea, and when the level is increased to 800 ppm could cause 100% mortality in animals. This study was an analytical study with implementing a cross-sectional design and risk analysis. One hundred subjects were involved in this study. The results showed that the mean value of the non-cancer Hazard Index (HI) for real-time exposure was NO2: 1.85; SO2: 2.92; TSP: 7.09; and PM10: 11.7 (HI value ≥1). Test for forced vital capacity lung capacity to non-cancer risk estimation of NO2, SO2, TSP, and PM10 indicated that there was no significant relationship (p-value >.05). The variable of smoking habit is the most dominant variable in this research (odds ratio [OR] = 12.542) which affects respiratory disorders. The exposure to NO2, SO2, TSP, and PM10 in Palembang City bus drivers is considered hazardous to the health of subjects without cancer. ~~so control is needed~~.

Keywords: Health risk analysis, nitrogen dioxide (NO2), particulate matter (PM10), sulfur dioxide (SO2), total suspended particulate

Introduction

Air pollution has been a matter of great concern globally because of the associated health risks to individuals. The situation is getting worse in developing countries with more urbanization, industrialization, and more importantly, the rapidly growing population, posing a threat to human life in the form of pulmonary, cardiovascular, carcinogenic, or asthmatic diseases by accumulating toxic pollutants, harmful gases, metals, hydrocarbons, and other dangerous substances.[1]

The rise in the number of vehicles also affects the increase in vehicle exhaust emissions level. The United States Environtmental Protection Agency released six types of pollutants that dominate the air and are most commonly encountered, which are ozone (O3), particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO2), and lead (Pb). Approximately 50% of NOx emissions are generated by vehicles. The effect of exposure to air pollution can occur in chronic or acute conditions. In the short term, air pollutant gas (Pb, NO2, SO2, TSP, and dust) may cause respiratory disorders such as weakness, coughing, shortness of breath, bronchopneumonia, pulmonary edema, cyanosis, and methemoglobinemia.

The increasing amount of gases and solid pollutants emitted into the atmosphere has a considerable impact on both human health and environmental ecosystems. Specifically, long exposure to high concentrations of pollutants may lead to a shortening of life by several years because of cardiovascular and respiratory diseases and contributes to an increased risk of death. Recent studies also indicate that cancer occurrences are related to some pollutants, namely PM. These pollutants are hazardous because of not only their physical parameters, but mainly to their content of many dangerous organic compounds, such as hydrocarbons, polyaromatic hydrocarbons and their derivatives, and both inorganic elements such as Pb, Pt, Cd, As, Cu, Zn, and compounds such as nitrates, ammonia ions, sulfates, and various others.[2]

According to Ministry of Transportation (2009), the current growth rate of vehicles in Indonesia has increased significantly. This number increased in 2009, 2010, and 2011 by the amount of 67,290,816 units, 77,170,306 units and 85,601,351 units, respectively.

Until 2012, the total number of motor vehicles in Indonesia has increased almost half the times the number of motor vehicles has in 2008.

Smoking habits have a negative impact on health, especially on the respiratory system, but the prevalence of the number of smokers continues to increase. According to the data from the World Health Organization (WHO) in 2013, the highest prevalence of smoking was in Europe with 28% and Asia was fifth at 19%. Tobacco-related illnesses will be the leading major health problems and cause 8.4 million deaths every year. This study aimed to create a model of air pollution exposure (NO2, SO2, TSP, and dust) and smoking habits on the lung function of bus drivers in Palembang City.

Methods

This study was a risk assesment with cross-sectional study design to estimate health risks of the population who were at risk because of exposure to NO2, SO2, TSP, and dust. The non-cancer risk characteristic was expressed as the non-cancer Hazard Index (HI). This index required the values of NO2, SO2, TSP, and dust as the Reference of Concentration (RFC), anthropometric data (inhalation rate and body weight), and exposure pattern (time, frequency, and duration of NO2, SO2, TSP, and dust exposure). The non-cancer value is the ratio between intake and RFC where the intake results from the calculation of exposure assessment. ~~This study had a cross-sectional study design aimed at testing~~ The hypothesis of the correlation between the risk value of the health status of NO2, SO2, TSP, dust, and lung capacity and respiratory disorders.[3] The study was conducted in four phases, including the initial survey and field observation of the study population for initial data collection of risk assessment, spirometry measurement and collection of selected air sample data (NO2, SO2, TSP, dust), laboratory analysis and spirogram readings, and modeling of risk factors of air pollution exposure and smoking habits of bus drivers.

The study site was in Palembang City, South Sumatra Province, Indonesia. The study subjects were all bus drivers in Palembang City who were a high-risk population. Subjects were taken using the purposive sampling technique. The minimum sample size was calculated using the sample size 2.0 application which obtained 78.88 (rounded to 80) subjects needed. In this study, the Z score at the 1- /2 confidence interval of two-tailed hypothesis testing was 1.96 with a minimal error of 0.1 for a health study. The proportion of respiratory tract disorders (lung capacity function) was taken from the previous study on the risk analysis of respiratory tract disorders among bus drivers in Palembang City, which was 0.389.

In consideration of conditions in the field to avoid any loss to follow up or sample drop out, the sample size was increased by at least 20% or 16 subjects. Therefore, the minimum sample size required in this study was 96 subjects, hence the sample size we accepted was 100 subjects. Proportional random sampling was applied as the sample collection method, which divided the number of samples proportionally in each terminal. Of nine bus stations in Palembang City, four bus stations were selected as study sites, which were Jakabaring Bus Station, 7 Ulu Bus Station, Ampera Bus Station, and Plaju Bus Station. The number of respondents that have been calculated proportionally was taken from each bus station. Measurements of TSP and PM10 concentrations were performed at 4-point measurements. The determination of the measurement point was based on SNI 197119.9-2005 using Haz-Dust EPAM-5000. OdaLog 7000 was used for the measurement of NO2 and SO2 concentrations was used. This study used univariate, bivariate, and multivariate data analysis. Univariate analysis was used to describe variables, bivariate analysis was used to see the relationship and significance between two variables, and multivariate analysis knew the dominant risk factors of lung capacity disorders and made a risk model of a non-cancer control.

Table 1. Levels of NO_2, SO_2, TSP, PM_{10} at bus stations in Palembang City

Bus Station	Level of NO_2 (mg/m^3)	Level of SO_2 (mg/m^3)	Level of TSP (mg/m^3)	Level of PM_{10} (mg/m^3)
Jakabaring Bus Station	0.42	0.84	4.81	2.38
7 Ulu Bus Station	0.41	0.83	6.8	2.65
Ampera Bus Station	0.40	0.91	8.09	2.84
Plaju Bus Station	0.37	0.86	4.65	2.31
Mean	0.41	0.84	5.55	2.54

Notes: NO2= Nitrogen Dioxide, CO= Carbon Monoxide, SO2= Sulfur Dioxide, TSP= Total Suspended Particulate, PM10= Particulate Matter

Table 2. Distribution of Inhalation intake of NO_2, SO_2, TSP and PM_{10} at bus station of Palembang city

Description	*Intake* NO_2 (mg/kg/day)	*Intake* SO_2 (mg/kg/day)	*Intake* TSP (mg/kg/day)	*Intake* PM_{10} (mg/kg/day)
Mean	0.037	0.077	0.504	0.230
Median	0.037	0.075	0.476	0.256
Minimum	0.022	0.064	0.284	0.091
Maximum	0.055	0.087	0.828	0.373

Notes: NO2= Nitrogen Dioxide, CO= Carbon Monoxide, SO2= Sulfur Dioxide, TSP= Total Suspended Particulate, PM10= Particulate Matter

Results

The mean levels of NO2, SO2, TSP, and PM10 at Palembang City Bus Station were 0.416 mg/m3 for NO2; 0.848 mg/m3 for SO2; 5.559 mg/m3 for TSP, and 2.543 mg/m3 for PM10. The most critical very high-risk air pollutant is TSP (5.559 mg/m3) since every year the TSP HI increases. The air pollutant with a low risk to pulmonary function is NO2 (0.416 mg/m3). Exposure assessment was used to calculate the dose or the number of risk agents (pollutants or toxic substances) received individually and expressed as "intake". Further exposure pattern assessment was determined by the frequency of exposure, length of exposure, and route or path of exposure. The assessment of exposure frequency, duration/time of exposure, and duration of exposure in this study were obtained from the calculation of data directly. The exposure route of NO2, SO2, TSP, and PM10 in this study was through inhalation. The mean exposure time was 8 hours/day, the minimum value of exposure frequency was 142 days/year, the duration of exposure was at least two years, and the mean weight of subjects was 58.19 kg. The inhalation rate in this study was based on the standard from the U.S. Environmental Protection Agency (EPA) by taking the value of the inhalation rate on a long-term exposure level 31–41 years. The recommended inhalation rate obtained was 16 m3/day. After unit conversion, the rate of inhalation per hour was 0.66 m3/hour. The exposure analysis to determine the value of the inhalation intake was calculated using the following formula:

$$I = \frac{C R t_e f_e D_t}{W_b t_{avg}}$$

Notes : I = intake [mg/(kgxhari)], C = concentration (mg/M3), R = rate of inhalation (M3/hour), te = time of exposure (hour/day), fe = frequency of exposure (day/year), Dt = duration of time (year), Wb = weight (kg), tavg = average time period (Dt x 365 day/year).

Distribution of Inhalation intake of NO2, SO2, TSP, and PM10 for each subject can be seen in Table 2. The lowest inhalation intake of NO2 was 0.022 mg/kg/day, and the highest intake was 0.056 mg/kg/day. The lowest SO2 inhalation intake was 0.066 mg/kg/day, and the highest intake was 0.089 mg/kg/day. The lowest TSP inhalation intake was 0.288 mg/kg/day, and the highest intake was 0.842 mg/kg/day. The lowest inhalation intake of PM10 was 0.092 mg/kg/day, and the highest intake was 0.379 mg/kg/day.

Risk characteristics were derived from two parts of the assessment, exposure assessment and dose-response assessment. The value of HI for real-time exposure using the mean values as described previously was 1.85 for NO2; 2.92 for SO2; 7.09 for TSP; and 11.7 for PM10 (HI value 1).

Therefore, it can be concluded that exposure of bus drivers to NO2, SO2, TSP, and PM10 in Palembang City is already considered hazardous to the health of drivers without cancer, so control is needed.

The result of the multivariate analysis shows that the smoking habit variable is the most dominant variable related to respiratory disorders in bus drivers, with an odds ratio (OR) = 12.542 means that a bus driver who has a smoking habit is 12.542 times more likely to suffer from a respiratory disorder compared with a bus driver who has no smoking habit (Table 3).

Table 3. Model of Multivariate Analysis

Variabel	β	*p value*	OR	95% CI
Non-cancer risk PM_{10}	0,156	0,026	1,168	1,018-1,341
Smoking habit	2,529	0,001	12,542	2,940-53,500
Exposure duration	1,453	0,006	4,275	1,529-11,951
Records of the disease	1,393	0,028	4,026	1,160-13,967
Constant	-9,326			

Notes: β= Beta, p value = probability value, OR = Odds Ratio, 95%CI= 95% confidence level

Discussion

The risk analysis showed that the demand for risk management was greater if HI > 1. The results of this study indicated that risk management was needed to control the health effects caused by NO2, SO2, TSP, and PM10 exposure. Control was done in various ways, which could be formulated quantitatively by modifying the standard or quality standard. HI values >1 could be controlled by controlling the intake value of NO2 inhalation because the RFC value was derived from experimental data that could not be modified (because it was a reference). Therefore, the value that had to be lowered was I to make it harmless. The mean value of I was 0.038 with 0.056 being the highest. The same equation from the non-cancer risk analysis equation to decrease the value of I to the acceptable RFC level of 0.02. However, the RFC values of SO2, TSP, and PM10 were taken from previous studies because they were not yet available in the EPA's Integrated Risk Information System list or the Minimum Risk Level ATSDR table.

When subjects were enrolled at age 16 years old, then they would have about two years more of exposure to NO2, SO2, TSP, and PM10 assuming that they did not quit or move their jobs. Then, there would be an increase in risk according to the scenario with a noncancer risk control simulation framework of NO2, SO2, TSP, and PM10. At Palembang City bus stations, it was assumed that there was no interaction between existing risks when considering the mean concentrations of NO2 (0.038 mg/m3), SO2 (0.078 mg/m3), TSP (0.512 mg/m3), and PM10 (0.234 mg/m3), respectively. These concentrations increase every year as the rate of vehicles increases, which has been 5% per year (considering the trend of the growth rate of vehicle data from the Central Statistics Agency 1987–2013). The total exposure was considered constant based on a mean value of 8 hours/day. The inhalation rate, using the default value of 0.66 m3/hr, and the frequency of working days was 142 days/year, and the mean body weight at the time of the study was 58.19 kg. The simulation model 1 for exposure started from the second year to the sixth year. The results of the risk analysis showed that HI >1. Based on the EPA, this indicated that risk management was needed to control the health effects due to exposure to NO_2, SO_2, TSP, and PM_{10}. The risk control simulation framework also showed that there was another contributing source of exposure besides NO_2, SO_2, TSP, and PM_{10} in Palembang City bus station, which was cigarette smoke that exposed subjects. For the primary source of exposure (NO_2, SO_2, TSP, and PM_{10}) in bus stations, the control was done in various ways, but the aim was to reduce the exposure risk by formulating the recommended standard value quantitatively to modify the standard or quality standard.

The study from Zhengzhou City, China showed that the data from six monitoring stations in Zhengzhou City analyzed the changing trend in concentrations of SO_2, NO_x/NO_2, and TSP/PM_{10} in 1996–2008, based on the non-parametric Mann-Kendall test and Sen's slope estimator. The overall air pollution level was evaluated by the Multi-Pollutant Index. It was found that the concentration of each pollutant exceeded the WHO guideline value by an apparent amount, but the changing trend varied: SO_2 and NO_2 significantly increased mainly due to an increase in coal consumption and vehicle number, while NO_x, TSP, and PM_{10} decreased. The air pollution was serious, and differed markedly among the three functional regions: it is the most severe in the Industrial and Residential Area, followed by the Transportation Hub and Business District, and then the High-tech, Cultural and Educational Area.[4] The same study on lung function showed that work period, the use of Personal Protective Equipment (PPE), and the total dust level were factors which affect pulmonary function impairment in workers.[5]

The decrease in lung function over time was associated with both smoking habits and duration of occupational dust exposure. Specifically, occupational quartz exposure negatively influenced annual lung function parameters. Implementation of stricter occupational limit values for dust exposure resulted in a highly signi ficant deceleration of the annual decrease in respiratory function.[6] Cough-related symptoms were associated with incident obstructive lung physiology and emphysema, whereas shortness of breath was associated with restrictive lung physiology. When placed in a clinical context, these are not surprising. Cough or phlegm and episodes of bronchitis may be more "exposure-driven" (including exposure beyond merely cigarette smoking, such as dusty work environments or air pollution) and indicate susceptibility.[7]

The study of smokers in the Netherlands showed that a total of 255 participants were followed up (49%). The point prevalence rate of nonsmoking at follow up was 18% (N Z 47), and 9%, assuming that all non-respondents were smokers. This rate was not lower than the expected rate of quitting in the Dutch population (8%–9%), and primary "care as usual" in smokers screened with abnormal lung function (10%; $p > .05$ for all comparisons). The average decline in post-bronchodilator Forced Expiratory Volume (FEV_1) was 26 ml/year, which was unrelated to smoking status at follow up. In contrast, non-smokers showed a clinically meaningful and statistically significant reduction in post-bronchodilator FEV_1 ($p < .001$).[8]

Factory workers had lower spirometric functions, especially those with high dust exposure. There was a dose-response relation between the duration of dust exposure and FEV_1 and Forced Vital Capacity (FVC), the adjusted effect of 21 years of exposure on FEV_1 being - 240 ml (−100 to −380 ml) and on FVC −300 ml (−140 to −460 ml). The adverse effect of dust on lung function was more substantial in current smokers and suggested a synergism between smoking and tile dust exposure.[9]

The lung capacity disorders most bus drivers in Palembang City had were caused by smoking habits with exposure to NO_2, SO_2, TSP, and PM_{10} with an average length of exposure of 13 hours/day. Dust is among the strong risk factors for pulmonary dysfunction depending on both the level and duration of exposure. In public transportation drivers, workers are in high levels of pollutants for a long time. This prolonged exposure will cause a build up of pollutants with small particles in the alveoli, resulting in changes in lung function. The longer the bus driver works in the terminal area, the longer the exposure to the pollutants is, then the occurrence of lung function disorders will also be greater. However, it also depends on the concentration of pollutants and the mechanism of clearance of each individual.

Conclusion

Most bus drivers who have lung capacity disorders are caused by smoking habits with exposure to NO2, SO2, TSP, and PM10 with an average length of exposure of 13 hours/day. The highest risk air pollutant is TSP since every year the TSP HI increases. Smoking habit variable was the most dominant variable, which influences respiratory disorders.

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Risk Analysis of Air Pollution Exposure (NO2, SO2, TSP, and PM10) and Smoking Habits on the Lung Function of Bus Drivers in Palembang City

Analisis Risiko Paparan Polusi Udara (NO2, SO2, TSP dan PM10) dan Kebiasaan Merokok terhadap Fungsi Paru pada Sopir Bus di Kota Palembang

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Abstract

Nitrogen dioxide (NO2), sulfur dioxide (SO2), particulate matter (PM10), and total suspended particulate (TSP) are the most common and harmful air pollutants to humans. In a short period, air pollution exposure at 5 ppm for 10 minutes in humans causes dyspnea, and when the level is increased to 800 ppm could cause 100% mortality in animals. This study was an analytical study with implementing a cross-sectional design and risk analysis. One hundred subjects were involved in this study. The results showed that the mean value of the non-cancer Hazard Index (HI) for real-time exposure was NO2: 1.85; SO2: 2.92; TSP: 7.09; and PM10: 11.7 (HI value ≥1). Test for forced vital capacity lung capacity to non-cancer risk estimation of NO2, SO2, TSP, and PM10 indicated that there was no significant relationship (p-value >.05). The variable of smoking habit is the most dominant variable (odds ratio [OR] = 12.542) which affects respiratory disorders. The exposure to NO2, SO2, TSP, and PM10 in Palembang City bus drivers is considered hazardous to the health of subjects without cancer, so control is needed.

Keywords: Health risk analysis, nitrogen dioxide (NO2), particulate matter (PM10), sulfur dioxide (SO2), total suspended particulate

Abstrak

Nitorgen Dioksida (NO2), Sulfur Dioksida (SO2), Particulate Matter (PM10) dan Total Suspended Particulate (TSP) merupakan pencemar udara yang paling umum dan berbahaya bagi manusia. Dalam jangka waktu pendek, pemajanan polusi udara dengan kadar 5 ppm selama 10 menit terhadap manusia mengakibatkan kesulitan dalam bernapas, dan kadar sebesar 800 ppm akan mengakibatkan 100% kematian pada binatang-binatang. Penelitian analitik, dengan desain potong lintang dan analisis risiko. Besar sampel yang diambil sebanyak 100 sampel. Hasil penelitian menunjukkan bahwa Non-cancer Hazard Index (HI) untuk pajanan *realtime* dengan nilai rata-rata adalah NO2 sebesar 1,85; SO2 sebesar 2,92; TSP sebesar 7,09 ; dan PM10 sebesar 11,7 (nilai HI ≥1). Hasil uji analisis hubungan nilai kapasitas paru dengan estimasi risiko non-kanker NO2, SO2, TSP dan PM10 menunjukkan bahwa tidak terdapat hubungan yang signifikan (p-value > 0,05). Variabel kebiasaan merokok merupakan variabel yang paling dominan (OR = 12,542) yang memengaruhi gangguan pernapasan. Pemajanan NO2, SO2, TSP dan PM10 pada sopir bus di Kota Palembang sudah dianggap berisiko terhadap kesehatan non-kanker, sehingga perlu dilakukan pengendalian.

Kata kunci: Analisis risiko kesehatan, nitrogen dioksida, particulate matter, sulfur dioksida, total suspended particulate

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Introduction

Air pollution has been a matter of great concern globally because of the associated health risks to individuals. The situation is getting worse in developing countries with more urbanization, industrialization, and more importantly, the rapidly growing population, posing a threat to human life in the form of pulmonary, cardiovascular, carcinogenic, or asthmatic diseases by accumulating toxic pollutants, harmful gases, metals, hydrocarbons, and other dangerous substances.[1]

The rise in the number of vehicles also affects the increase in vehicle exhaust emissions level. The United States Environtmental Protection Agency released six types of pollutants that dominate the air and are most commonly encountered, which are ozone (O3), particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO2), and lead (Pb). Approximately 50% of NOx emissions are generated by vehicles. The effect of exposure to air pollution can occur in chronic or acute conditions. In the short term, air pollutant gas (Pb, NO2, SO2, TSP, and dust) may cause respiratory disorders such as weakness, coughing, shortness of breath, bronchopneumonia, pulmonary edema, cyanosis, and methemoglobinemia.[2]

The increasing amount of gases and solid pollutants emitted into the atmosphere has a considerable impact on both human health and environmental ecosystems. Specifically, long exposure to high concentrations of pollutants may lead to a shortening of life by several years because of cardiovascular and respiratory diseases and contributes to an increased risk of death. Recent studies also indicate that cancer occurrences are related to some pollutants, namely PM. These pollutants are hazardous because of not only their physical parameters, but mainly to their content of many dangerous organic compounds, such as hydrocarbons, polyaromatic hydrocarbons and their derivatives, and both inorganic elements such as Pb, Pt, Cd, As, Cu, Zn, and compounds such as nitrates, ammonia ions, sulfates, and various others.[3]

According to Ministry of Transportation (2009), the current growth rate of vehicles in Indonesia has increased significantly. This number increased in 2009, 2010, and 2011 by the amount of 67,290,816 units, 77,170,306 units and 85,601,351 units, respectively. Until 2012, the total number of motor vehicles in Indonesia has increased almost half the times the number of motor vehicles has in 2008.

Smoking habits have a negative impact on health, especially on the respiratory system, but the prevalence of the number of smokers continues to increase. According to the data from the World Health Organization (WHO) in 2013, the highest prevalence of smoking was in Europe with 28% and Asia was fifth at 19%. Tobacco-related illnesses will be the leading major health problems and cause 8.4 million deaths every year. This study aimed to create a model of air pollution exposure (NO2, SO2, TSP, and dust) and smoking habits on the lung function of bus drivers in Palembang City.

Methods

This study was a risk analysis study to estimate health risks of the population who were at risk because of exposure to NO2, SO2, TSP, and dust. The non-cancer risk characteristic was expressed as the non-cancer Hazard Index (HI). This index required the values of NO2, SO2, TSP, and dust as the Reference of Concentration (RFC), anthropometric data (inhalation rate and body weight), and exposure pattern (time, frequency, and duration of NO2, SO2, TSP, and dust exposure).4 The non-cancer value is the ratio between intake and RFC where the intake results from the calculation of exposure assessment. This study had a cross-sectional study design aimed at testing the hypothesis of the correlation between the risk value of the health status of NO2, SO2, TSP, dust, and lung capacity and respiratory disorders.5 The study was conducted in four phases, including the initial survey and field observation of the study population for initial data collection of risk assessment, spirometry measurement and collection of selected air sample data (NO2, SO2, TSP, dust), laboratory analysis and spirogram readings, and modeling of risk factors of air pollution exposure and smoking habits of bus drivers.

The study site was in Palembang City, South Sumatra Province, Indonesia. The study subjects were all bus drivers in Palembang City who were a high-risk population. Subjects were taken using the purposive sampling technique. The minimum sample size was calculated using the sample size 2.0 application which obtained 78.88 (rounded to 80) subjects needed. In this study, the Z score at the 1- /2 confidence interval of two-tailed hypothesis testing was 1.96 with a minimal error of 0.1 for a health study. The proportion of respiratory tract disorders (lung capacity function) was taken from the previous study on the risk analysis of respiratory tract disorders among bus drivers in Palembang City, which was 0.389.6,7

In consideration of conditions in the field to avoid any loss to follow up or sample drop out, the sample size was increased by at least 20% or 16 subjects. Therefore, the minimum sample size required in this study was 96 subjects, hence the sample size we accepted was 100 subjects. Proportional random sampling was applied as the sample collection method, which divided the number of samples proportionally in each terminal. Of nine bus stations in Palembang City, four bus stations were selected as study sites, which were Jakabaring Bus

Table 1. Levels of NO2, SO2, TSP, and PM10 at Bus Stations in Palembang City

Bus Station	Level of NO2 (mg/m3)	Level of SO2 (mg/m3)	Level of TSP (mg/m3)	Level of PM10 (mg/m3)
Jakabaring Bus Station	0.4277	0.84742	4.810	2.385
7 Ulu Bus Station	0.41445	0.8326	6.8	2.650
Ampera Bus Station	0.40915	0.91367	8.099	2.840
Plaju Bus Station	0.37437	0.8658	4.652	2.315
Mean	0.416	0.848	5.559	2.543

Notes: NO2= Nitrogen Dioxide, CO= Carbon Monoxide, SO2= Sulfur Dioxide, TSP= Total Suspended Particulate, PM10= Particulate Matter

Table 2. Distribution of Inhalation Intake of NO2, SO2, TSP, and PM10 at the Bus Station in Palembang City

Description	NO2 Intake (mg/kg/day)	SO2 Intake (mg/kg/day)	TSP Intake (mg/kg/day)	PM10 Intake (mg/kg/day)
Mean	0.037	0.077	0.504	0.230
Median	0.037	0.075	0.476	0.256
Minimum	0.022	0.064	0.284	0.091
Maximum	0.055	0.087	0.828	0.373

Notes: NO2= Nitrogen Dioxide, CO= Carbon Monoxide, SO2= Sulfur Dioxide, TSP= Total Suspended Particulate, PM10= Particulate Matter

Station, 7 Ulu Bus Station, Ampera Bus Station, and Plaju Bus Station. The number of respondents that have been calculated proportionally was taken from each bus station. Measurements of TSP and PM10 concentrations were performed at 4-point measurements. The determination of the measurement point was based on SNI 19-7119.9-2005 using Haz-Dust EPAM-5000. OdaLog 7000 was used for the measurement of NO2 and SO2 concentrations was used. This study used univariate, bivariate, and multivariate data analysis. Univariate analysis was used to describe variables, bivariate analysis was used to see the relationship and significance between two variables, and multivariate analysis knew the dominant risk factors of lung capacity disorders and made a risk model of a non-cancer control.

Results

The mean levels of NO2, SO2, TSP, and PM10 at Palembang City Bus Station were 0.416 mg/m3 for NO2; 0.848 mg/m3 for SO2; 5.559 mg/m3 for TSP, and 2.543 mg/m3 for PM10.

The most critical very high-risk air pollutant is TSP (5.559 mg/m3) since every year the TSP HI increases. The air pollutant with a low risk to pulmonary function is NO2 (0.416 mg/m3). Exposure assessment was used to calculate the dose or the number of risk agents (pollutants or toxic substances) received individually and expressed as “intake”. Further exposure pattern assessment was determined by the frequency of exposure, length of exposure, and route or path of exposure. The assessment of exposure frequency, duration/time of exposure, and duration of exposure in this study were obtained from the calculation of data directly. The exposure route of NO2, SO2, TSP, and PM10 in this study was through inhalation. The mean exposure time was 8 hours/day, the minimum value of exposure frequency was 142 days/year, the duration of exposure was at least two years, and the mean weight of subjects was 58.19 kg. The inhalation rate in this study was based on the standard from the U.S. Environmental Protection Agency (EPA) by taking the value of the inhalation rate on a long-term exposure level 31–41 years. The recommended inhalation rate obtained was 16 m3/day. After unit conversion, the rate of inhalation per hour was 0.66 m3/hour. The exposure analysis to determine the value of the inhalation intake was calculated using the following formula:

I =

Distribution of Inhalation intake of NO2, SO2, TSP, and PM10 for each subject can be seen in Table 2. The lowest inhalation intake of NO2 was 0.022 mg/kg/day, and the highest intake was 0.056 mg/kg/day. The lowest SO2 inhalation intake was 0.066 mg/kg/day, and the highest intake was 0.089 mg/kg/day. The lowest TSP inhalation intake was 0.288 mg/kg/day, and the highest intake was 0.842 mg/kg/day. The lowest inhalation intake of PM10 was 0.092 mg/kg/day, and the highest intake was 0.379 mg/kg/day.

Table 3. Model of Multivariate Analysis

Variable	β	p value	OR	95% CI
Non-cancer risk PM10	0.156	0.026	1.168	1.018–1.341
Smoking habit	2.529	0.001	12.542	2.940–53.500
Exposure duration	1.453	0.006	4.275	1.529–11.951
Records of the disease	1.393	0.028	4.026	1.160–13.967
Constant	–9.326			

Notes: β= Beta, p value = probability value, OR = Odds Ratio, 95%CI= 95% confidence level

Risk characteristics were derived from two parts of the assessment, exposure assessment and dose-response assessment. The value of HI for real-time exposure using the mean values as described previously was 1.85 for NO2; 2.92 for SO2; 7.09 for TSP; and 11.7 for PM10 (HI value 1).[8]

Therefore, it can be concluded that exposure of bus drivers to NO2, SO2, TSP, and PM10 in Palembang City is already considered hazardous to the health of drivers without cancer, so control is needed.

The result of the multivariate analysis shows that the smoking habit variable is the most dominant variable related to respiratory disorders in bus drivers, with an odds ratio (OR) = 12.542 means that a bus driver who has a smoking habit is 12.542 times more likely to suffer from a respiratory disorder compared with a bus driver who has no smoking habit (Table 3).

Discussion

The risk analysis showed that the demand for risk management was greater if HI > 1. The results of this study indicated that risk management was needed to control the health effects caused by NO2, SO2, TSP, and PM10 exposure. Control was done in various ways, which could be formulated quantitatively by modifying the standard or quality standard. HI values >1 could be controlled by controlling the intake value of NO2 inhalation because the RFC value was derived from experimental data that could not be modified (because it was a reference). Therefore, the value that had to be lowered was I to make it harmless. The mean value of I was 0.038 with 0.056 being the highest. The same equation from the non-cancer risk analysis equation to decrease the value of I to the acceptable RFC level of 0.02. However, the RFC values of SO2, TSP, and PM10 were taken from previous studies because they were not yet available in the EPA's Integrated Risk Information System list or the Minimum Risk Level ATSDR table.

When subjects were enrolled at age 16 years old, then they would have about two years more of exposure to NO2, SO2, TSP, and PM10 assuming that they did not quit or move their jobs. Then, there would be an increase in risk according to the scenario with a non-cancer risk control simulation framework of NO2, SO2, TSP, and PM10. At Palembang City bus stations, it was assumed that there was no interaction between existing risks when considering the mean concentrations of NO2 (0.038 mg/m3), SO2 (0.078 mg/m3), TSP (0.512 mg/m3), and PM10 (0.234 mg/m3), respectively. These concentrations increase every year as the rate of vehicles increases, which has been 5% per year (considering the trend of the growth rate of vehicle data from the Central Statistics Agency 1987–2013). The total exposure was considered constant based on a mean value of 8 hours/day. The inhalation rate, using the default value of 0.66 m3/hr, and the frequency of working days was 142 days/year, and the mean body weight at the time of the study was 58.19 kg. The simulation model 1 for exposure started from the second year to the sixth year.[9]

The results of the risk analysis showed that HI >1. Based on the EPA, this indicated that risk management was needed to control the health effects due to exposure to NO2, SO2, TSP, and PM10. The risk control simulation framework also showed that there was another contributing source of exposure besides NO2, SO2, TSP, and PM10 in Palembang City bus station, which was cigarette smoke that exposed subjects. For the primary source of exposure (NO2, SO2, TSP, and PM10) in bus stations, the control was done in various ways, but the aim was to reduce the exposure risk by formulating the recommended standard value quantitatively to modify the standard or quality standard.

The study from Zhengzhou City, China showed that the data from six monitoring stations in Zhengzhou City analyzed the changing trend in concentrations of SO2, NOx/NO2, and TSP/PM10 in 1996–2008, based on the non-parametric Mann-Kendall test and Sen's slope estimator. The overall air pollution level was evaluated by the Multi-Pollutant Index. It was found that the concentration of each pollutant exceeded the WHO guideline value by an apparent amount, but the changing trend varied: SO2 and NO2 significantly increased mainly due to an increase in coal consumption and vehicle number, while NOx, TSP, and PM10 decreased. The air pollution was serious, and differed markedly among the three functional regions: it is the most severe in the Industrial and Residential Area, followed by the Transportation Hub and Business District, and then the High-tech, Cultural and Educational Area.[10] The same study on lung function showed that work period, the use of Personal Protective Equipment (PPE), and the total dust level were factors which affect pulmonary function impairment in workers.[11]

The decrease in lung function over time was associated with both smoking habits and duration of occupational dust exposure. Specifically, occupational quartz exposure negatively influenced annual lung function parameters. Implementation of stricter occupational limit values for dust exposure resulted in a highly significant deceleration of the annual decrease in respiratory function.[12] Cough-related symptoms were associated with incident obstructive lung physiology and emphysema, whereas shortness of breath was associated with restrictive lung physiology. When placed in a clinical context, these are not surprising. Cough or phlegm and episodes of bronchitis may be more “exposure-driven” (including exposure beyond merely cigarette smoking, such as dusty work environments or air pollution) and indicate susceptibility.[13]

The study of smokers in the Netherlands showed that a total of 255 participants were followed up (49%). The point prevalence rate of nonsmoking at follow up was 18% (N Z 47), and 9%, assuming that all non-respondents were smokers. This rate was not lower than the expected rate of quitting in the Dutch population (8%–9%), and primary “care as usual” in smokers screened with abnormal lung function (10%; p >.05 for all comparisons). The average decline in post-bronchodilator Forced Expiratory Volume (FEV1) was 26 ml/year, which was unrelated to smoking status at follow up. In contrast, non-smokers showed a clinically meaningful and statistically significant reduction in post-bronchodilator FEV1 (p <.001).[14]

Factory workers had lower spirometric functions, especially those with high dust exposure. There was a dose-response relation between the duration of dust exposure and FEV1 and Forced Vital Capacity (FVC), the adjusted effect of 21 years of exposure on FEV1 being - 240 ml (−100 to −380 ml) and on FVC −300 ml (−140 to −460 ml). The adverse effect of dust on lung function was more substantial in current smokers and suggested a synergism between smoking and tile dust exposure.[15]

The lung capacity disorders most bus drivers in Palembang City had were caused by smoking habits with exposure to NO2, SO2, TSP, and PM10 with an average length of exposure of 13 hours/day. Dust is among the strong risk factors for pulmonary dysfunction depending on both the level and duration of exposure. In public transportation drivers, workers are in high levels of pollutants for a long time. This prolonged exposure will cause a build up of pollutants with small particles in the alveoli, resulting in changes in lung function. The longer the bus driver works in the terminal area, the longer the exposure to the pollutants is, then the occurrence of lung function disorders will also be greater. However, it also depends on the concentration of pollutants and the mechanism of clearance of each individual.

Conclusion

Most bus drivers who have lung capacity disorders are caused by smoking habits with exposure to NO2, SO2, TSP, and PM10 with an average length of exposure of 13 hours/day. The highest risk air pollutant is TSP since every year the TSP HI increases. Smoking habit variable was the most dominant variable, which influences respiratory disorders.

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