health risk of nitrogen dioxide exposure among primary school children in ogan ilir south sumatera indonesia effect on lung function

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Submission date: 22-Jun-2020 01:56PM (UTC+0700)
Submission ID: 1347905016
File name: JIKM_2020_4.pdf (565.23K)
Word count: 4743
Character count: 24125

p-ISSN 2086-6380
e-ISSN 2548-7949

Jurnal Ilmu Kesehatan Masyarakat, Mar 2020, 11(1):31-42
DOI: https://doi.org/10.26553/jikm.2020.11.1.31-42
Available online at http://ejournal.fkm.unsri.ac.id/index.php/jikm

HEALTH RISKS OF NITROGEN DIOXIDE EXPOSURE AMONG PRIMARY SCHOOL CHILDREN IN OGAN ILIR, SOUTH SUMATRA, INDONESIA: EFFECT ON LUNG FUNCTION

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ABSTRACT

Nitrogen dioxide (NO_2) is one of the most dangerous air pollutants as regards human health. Increased traffic volumes on the east-lane roadside of South Sumatra have led to increased NO_2 concentrations. In terms of age and NO_2, children are the greatest risk group. The aim of this research was to estimate health risks of NO_2 and analyze the correlation between exposure and lung capacity. This was an analytical study, with a cross-sectional design and risk analysis. The study group consisted of 100 children of primary school age. The results showed that the noncancer hazard index (HI)for NO_2 exposure based on real-time data was 1.138. In the study population, as shown by the noncancer HI, 22% of students in OganIlir were classified as not at risk (HI < 1), whereas 78% were classified as at risk (HI ≥ 1). According to the results of simple linear regression, FEV1 (Pearson's test: 0.0001) and FVC (Pearson's test: 0.0001) showed a significant correlation with noncancer NO_2 risk. The results of simulations suggested that a value of 0.176 mg/m^3 can be used as a quality standard recommendation (health advisory) for NO_2 exposure in roadside schools, especially schools abutting inter-provincial roads in South Sumatra.

Keywords: *Nitrogen dioxide exposure, lung function, primary school studen, Ogan Ilir*

ABSTRAK

Nitrogen dioksida (NO2) adalah salah satu polutan udara paling berbahaya dalam hal kesehatan manusia. Volume lalu lintas yang meningkat di sisi timur-jalur jalan Sumatera Selatan telah menyebabkan peningkatan konsentrasi NO2. Dalam hal usia dan NO2, anak-anak adalah kelompok risiko terbesar. Tujuan dari penelitian ini adalah untuk memperkirakan risiko kesehatan NO2 dan menganalisis korelasi antara paparan dan kapasitas paru-paru. Penelitian ini menggunakan studi analiti, dengan desain cross-sectional dan analisis risiko. Kelompok studi terdiri dari 100 anak usia sekolah dasar. Hasil penelitian menunjukkan bahwa indeks bahaya non-kanker (HI) untuk paparan NO2 berdasarkan data real-time adalah 1,138. Dalam populasi penelitian, seperti yang ditunjukkan oleh noncancer HI, 22% siswa di Ogan Ilir diklasifikasikan sebagai tidak berisiko (HI <1), sedangkan 78% diklasifikasikan sebagai berisiko (HI ≥ 1). Menurut hasil regresi linier sederhana, FEV1 (uji Pearson: 0,0001) dan FVC (uji Pearson: 0,0001) menunjukkan korelasi yang signifikan dengan risiko NO2 yang bukan kanker. Hasil simulasi menunjukkan bahwa nilai 0,176 mg / m3 dapat digunakan sebagai rekomendasi standar kualitas (penasehat kesehatan) untuk paparan NO2 di sekolah pinggir jalan, terutama sekolah berbatasan dengan jalan antar provinsi di Sumatera Selatan.

Kata kunci: Paparan nitrogen dioksida, fungsi paru-paru, siswa sekolah dasar, Ogan Ilir

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Received : January 20, 2020 Accepted : February 12, 2020 Published: April, 30, 2020

INTRODUCTION

The growth rate in the number of vehicles on Indonesian roads has increased significantly in recent years, rising throughout 2009, 2010, and 2011 to 67,290,816 units, 77,170,306 units, and 85,601,351 units, respectively. By 2012, the number of motor vehicles in Indonesia was almost 50% greater than that in 2008.[1]

The increase in the number of vehicles has knock-on effects on vehicle exhaust emissions levels. According to the U.S. EPA, the six most common types of air pollutants are ozone, particulate matter, carbon monoxide, nitrogen oxide (NO_x), sulfur dioxide (SO_2), and Plumbum (Pb)[2]. Approximately 50% of NO_x emissions are generated by vehicles.[2] Exposure to air pollution can result in chronic or acute conditions. In the short term, air pollutant gases (Pb, nitrogen dioxide [NO_2], SO_2, TSP, and dust) can cause respiratory disorders, such as bronchopneumonia, pulmonary edema, cyanosis, and methemoglobinemia, resulting inweakness, coughing, and shortness of breath.[3]

Air pollution not only has serious consequences for large cities in developing countries but also for suburban areas in close proximity to cities and provincial traffic routes.[4] Schools located on the edge of the road cross country and provinces have a greater risk than schools on the roadside, with good school facilities.[3] The aim of this study was to predict the health effects of exposure to NO_2 by calculating noncancer hazard index (HI) scores, the prevalence of lung function disorders, and the correlation between these parameters in primary school students in OganIlir, South Sumatra.[5] The aim of this research was to estimate health risks of NO_2 and analyze the correlation between exposure and lung capacity.

METHOD

We conducted a risk analysis to predict the level of health risks from exposure to NO_2 among at-risk populations. The respondents were primary school students attending roadside schools in south-eastern Sumatra. The risk characteristics of noncancer were expressed by the noncancer hazard index (HI), which was based on reference concentration (RfC) values forNO_2 exposure, anthropometric data (inhalation rate and weight), and patterns of exposure (time, frequency, and duration of exposure NO_2).[6] The HI score was based on a comparison of intake with RfC where the intake was the result of the calculation of exposure assessment. This study used a cross-sectional design to test the correlation of health risk prediction scores with NO_2 status, lung capacity, and respiratory disorders.[7]

The study was conducted in four stages. The first stage consisted of a preliminary survey and observations in the study population for the data of risk assessment. The second stage comprised spirometry measurements and air sample data collection. The third stage consisted of a laboratory analysis and spirometry analysis. The fourth stage involved characterization of the health risks, modeling of health risk factors, and simulating risk control models.

The location of this research was OganIlir, South Sumatra Province, Indonesia. We examined NO_2 air quality in 10 primary schools (n = 568 schoolchildren) located at roadsides, including a population at risk located at the edge of East Cross Street, OganIlir, South Sumatra. Sampling was done by the proportionate stratified random sampling method. The sampling unit was a primary school located on the east side of the road (< 5 m).

The minimum sample size in this study was calculated using the application named sample size 2.0. Based on the population size in the study (n = 568), the minimum sample size was calculated as 78.88, rounded to 80 respondents. However, to avoid loss to follow-up or drop outs from the samples, a minimum sample size will be added as much as 20% (i.e., 16 respondents). Thus, the minimum total sample required in this study was n = 96. Therefore, the field of samples to be taken was completed, so the total sample was 100 respondents.

In this study, the districts were selected as a subpopulation. There are 298 primary schools in 15 districts of OganIlir. Ten of these schools were selected, and the required sample size was determined proportionally.

In this study, the score of confidence interval z $1\text{-}\alpha/2$ hypothesis test two-way (two-tailed) was 1.96, with minimal error for health research 0.1. The proportion of the incidence of respiratory disorders (lung capacity function) was based on research[8,9] on respiratory disorders in primary schoolchildren in Palembang was 0.389.

In each school, NO_2 was measured once for 1 h at 12:00 h. The measurements were obtained using a spectrometer (SNI 19-7119.2-2005 Saltman Griess)[9]. The following materials and tools were used in the analysis of the concentration of NO_2: a spectrophotometer, absorb NO_2, NO_2 standard solution, and Aqua Bidest. The spectrophotometric analysis of NO_2 was conducted in the laboratory of Hiperkes, Plaju, Palembang, South Sumatra.[10]

RESULTS

NO_2 concentration levels among primary school students ranged from 0.182 mg/m^3 to 0.222 mg/m^3, with an average of 0.2004 mg/m^3. The distribution of NO_2 concentrations in the different primary schools is shown in table 1.

Table 1. NO_2 concentration in the School

Schools	NO_2 concentration (mg/m^3)
SD N 05 Indralaya	0.2005
SD N 02 Indralaya	0.2215
SD N 06 Indralaya	0.2220
SD N 25 TalangBalaiBaru	0.1925
SD N 2 Srijabo	0.1925
SD N 02 Indralaya Utara	0.2015
SD N 20 Tanjung Raja	0.1922
SD N 06 Tanjung Raja	0.2012
SD N 01 Tanjung Raja	0.2015
SD N 11 Tanjung Raja	0.1820

Risk characteristics were determined based on an exposure assessment and dose–response assessment. The exposure analysis determined the value of inhalation intake. To determine the data needed dose intake of the risk agent, exposure pathway, exposure frequency, and duration of exposure. NO_2 exposure in this study through inhalation. The exposure time (h/day) of each student was obtained by calculating the difference of school time after leaving school. The average exposure time was 5.53 h/day, with a minimum exposure time of 4.7 h/day. The longest exposure time was 6 h/day. The frequency of exposure (days/year) was obtained by calculating the difference between the number of days per year and number of days in the academic calendar of primary schools in OganIlir. The frequency of exposure was 264 days/year. Then, the duration of exposure for 3 years to grade IV. The following anthropometry data were obtained: student's body weight and inhalation rate. The results of weight measurements of the students are presented in Table 2.

Table 2. Weight Distribution (Wb) and Inhalation Rate (R) of Students in Primary School Ogan Ilir

Information	Weight (Kg)	Inhalasion rate (m^3/h)
Mean	25.11	0.516
Median	23	
NOAEL	57	
LOAEL	17	

The average weight of the respondents was 25.11 kg, with a lowest weight of 17 kg and highest weight of 57 kg. The rate of inhalation was calculated according to U.S. Environmental Protection Agency (EPA) standards for long-term exposure among those aged 6–11 years. The recommended rate of inhalation was 12.4 m^3/day. After converting, the inhalation rate per hour was 0.516 m^3/hour and used in this study. In the exposure analysis, inhalation intake (I) was calculated using the following formula:

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

To calculate real-time NO_2 intake of students attending primary schools on the east side of the road, average exposure data were used, as below:

Data exposure pattern

NO_2 Concentration	= 0.2004 mg/m^3
Inhalation Rate (R)	= 0.516 m^3/hour
Duration of Exposure (hours/day)	= 5.53 hours/day
Frequency (days/year)	= 264 days/year
Duration (years)	= 3 years
Weight (W_b)	= 25.11 kg
Mean Period (t_{avg})	= 3x264 days = 792 days

$$\textbf{Intake (I)} = \frac{0{,}2004 \times 0{,}516 \times 5{,}53 \times 264 \times 3}{25{,}11 \times 792}$$

$$= 0.023 \text{ mg/kg.day}$$

Table 3 presents the distribution of NO_2 inhalation intake for each of the respondents. The lowest inhalation intake was 0.01 mg/kg.hari, and the highest intake was 0.04 mg/kg.hari.

Table 3. Inhalation Intake Distribution NO_2 of Students in Primary School OganIlir

Information	Inkate NO_2 (mg/kg.hari)
Mean	0.0241
Median	0.0246
LOAEL	0.01
NOAEL	0.04

The quantitative values required for the toxicity risk characteristics were NOAEL or LOAEL derived from bioassay testing and epidemiological studies. In this study, the reference concentration (RfC) value for NO_2 was the U.S. EPA standard of 0.02 mg/kg/day.[11]

Risk characteristics were obtained from an assessment of exposure and dose–response assessment. The average HI for real-time exposure was 1.138 (≥ 1).[12]

Hazard Index (HI) = *Intake* NO_2/R*f*C NO_2
= 0.023/0.02 = 1.138

Table 4. Calculation of Risk Non Cancer (HI) *Realtime*NO_2 of Students in Primary School OganIlir

Information	Non Cancer Risk			
	HI < 1		H ≥ 1	
	n	%	n	%
Male	10	45,5	43	55,1
Female	12	54,5	35	44,9
Total	22	100	78	100

As shown by the HI calculations for each respondent, most of the students had a HI value ≥ 1: 78% group of boys with 43 respondents and 35% of girls.[13] It can be concluded that NO_2exposure among primary school students attending roadside schools represents a noncancer health risk. Thus, NO_2 exposure needs to be controlled.

Table 5. Correlation of FEV1 with noncancer NO_2 risk

Variable	Correlation of FEV1 with noncancer NO_2 risk		
	Normalitas test (p>0,05)	Pearsons test (p<0,05)	Linear regretion (fit all model)
FEV1	0,200	0,0001	0,0001 (parsial)
HI	0,092	0,0001	0,0001 (parsial)
Pers.	Nilai FEV1 = 1,869 – 0,543 HI		

The relationship of FEV1 value with the estimated non-cancer risk of NO_2 will be tested using Pearson correlation and simple linear regression. The results of the analysis of the relationship between the value of the lung capacity of FEV1 and the estimated non-cancer risk of NO2 showed that there was a significant relationship (p <0.05) between the lung capacity of FEV1 and the estimated risk of non-cancerous NO2

Table 6. Correlation of FVC with noncancer NO_2 risk

Variable	Correlation of FVC with noncancer NO_2 risk		
	Normalitas test (p>0,05)	Pearsons test (p<0,05)	Linear regretion (fit all model)
FVC	0,175	0,0001	0,0001 (parsial)
HI	0,092	0,0001	0,0001 (parsial)
Pers.	Nilai FEV1 = 2,268 – 0,619 HI		

The results of the analysis of the relationship between the value of FVC lung capacity with estimated non-cancer risk of NO_2 showed that there was a significant relationship (p <0.05) between FVC lung capacity and estimated non-cancer risk of NO_2.

Table 7. Relationship between Lung Function Disorders and Respiratory Complaints

Respiratory Tract Complaints		Obstruction Status (%FEV1/FVC)				Odds Ratio (95% CI)	Sign.
		Yes(<75)	No(≥75)	n	%		
Dry cough	Yes	20	50	70	70	0,909 (0,348-2,377)	P>0,05
	No	8	22	30	30		
Cough with phlegm	Yes	17	42	59	59	0,906 (0,371-2,209)	P>0,05
	No	11	30	41	41		
Wheezing	Yes	5	9	14	14	0,657 (0,199-2,166)	P>0,05
	No	23	63	86	86		
Shortness of breath	Yes	7	17	24	24	0,927 (0,336-2,555)	P>0,05
	No	21	55	76	76		
Respiratory Tract Complaints		**Restriction Status (%FVC/FVCPredict)**				**Odds Ratio (95% CI)**	**Sign.**
		Yes (<80)	**No(≥80)**	**n**	**%**		
Dry cough	Yes	4	66	70	70	5,022 (1,346-18,74)	P<0,05
	No	7	23	30	30		
Cough with phlegm	Yes	5	54	59	59	1,851 (0,525-6,532)	P>0,05
	No	6	35	41	41		
Wheezing	Yes	1	13	14	14	1,711 (0,202-14,512)	P>0,05
	No	10	76	86	86		
Shortness of breath	Yes	3	21	24	24	0,824 (0,200-3,387)	P>0,05
	No	8	68	76	76		

Complaints of respiratory distress felt by elementary school students who are on the edge of the eastern crossing highway in the past month is a dry cough, cough with phlegm, wheezing, and shortness of breath. There are two types of lung function disorders analyzed with respiratory complaints, namely obstruction status (% FEV1/FVC) and restriction status (% FVC/FVC Predict). Someone said to have pulmonary obstruction if the percentage value of the FEV1 to FVC ratio is less than 75%. And someone is said to have pulmonary restriction if the percentage value of FVC to FVC prediction is less than 80%. From the results of the analysis using the Chi-square test it was found that there was a significant relationship ($p < 0.05$) between restriction status with complaints of dry cough where the oddsratiowas 5.002.

$$C = \frac{I.W_{b.t_{avg}}}{R.t_e.f_e.D_t} = \frac{0{,}020\ x\ 25{,}11\ x\ 264\ x\ 3}{0{,}516\ x\ 5{,}53\ x\ 264{,}3\ x\ 3} = 0{,}176$$

The results of the calculation of 0.176 mg/m3 can be used as a standard quality recommendation (health advisory) for the roadside school environment, especially cross-provincial roads. If you see the results of measurements of concentration in 10 elementary schools that have been carried out then all elementary schools require control because all NO2 concentrations in the school environment are above the recommended concentration (> 0.176 mg / m3). Only SD 20 Tanjung Raja and SD N 11 Tanjung Raja are approaching. This could be due to the orientation of the building of SD N 20 not facing the east (back) road and SD N 11 Tanjung Raja having a beautiful environment full of green trees.

DISCUSSION

The risk analysis showed that the need for risk management was greater in the presence of a HI value > 1. The results indicate that risk management is required in the study area to control health-related effects of NO_2. Such control can be achieved by modifying standards or quality standards.[14,15] The RfC value is a reference value derived from experimental data and therefore cannot be modified. The HI value > 1 can be controlled by controlling the intake value (I) of NO_2 inhalation.The value has to be lowered to I to make it harmless. In the present study, the mean intake value was 0.0236, and the highest value was 0.04. To decrease the intake value to an acceptable RfC level (i.e., 0.02), we can use the noncancer risk analysis equation. If at this time, the respondents in 4th grade are more or less than 3 years, the respondents exposed NO_2 with the assumption for 3 did not change school. The present study assumed that there were no interventions to existing risks. Based on a mean concentration of NO_2 of 0.2004 mg/m^3 in primary schools in OganIlir and an annual rise in this concentration according to a 5% increase in the rate of vehicular traffic (considering trends in growth rates based on data from the Central Statistics Agency 1987–2013) total exposure is considered constant at an mean value of 5.53 h/day. The inhalation rate using a default value of 0.516 m^3/h, frequency of school days of 264 days, and mean weight of subjects of 25.11 kg. Table 4 shows the results of the first simulation model of exposure among 3rd to 6th year students.[16-18]

Table 8. Estimated Hazard Index and Lung Capacity

	Hazard Index Projection (Subchronic)			
	3rd Year	**4th Year**	**5th Year**	**6th Year**
Concentration NO_2	0.2004	0.21042	0.220941	0.231988
R	0.516	0.516	0.516	0.516
tE	5.53	5.53	5.53	5.53
f	264	264	264	264
D	3	4	5	6
Wb	25.11	25.11	25.11	25.11
I	0.023	0.0239	0.0251	0.02636
RfC	0.02	0.02	0.02	0.02
HI	1.138	1.195	1.255	1.318

NO_2 appears to affect the lung layer by directly causing inflammation and indirectly damaging the immune defense mechanism. People with asthma, respiratory diseases, and chronic inflammation, such as chronic bronchitis, are susceptible, especially children.[13] A study conducted in New Zealand reported an association between indoor NO_2 and lung function (FEV1) of children with asthma, with lung function decreased in the presence of increased NO_2 levels indoors in mornings and afternoons during the wintertime[19]. Research conducted in Bandung, Indonesia revealed a significant relationship (0.001) between the distances of houses from roadsides and NO_2 concentrations inside the house, with houses at greater distances from roadsides having reduced NO_2 values.[14] The mean NO_2 value at the roadside over a 1-week period was 0.432 mg/m^3. The findings of the study in Bandung were similar to those of a study of 39 primary schools in Barcelona, Spain.[20] In the study, the average NO_2 concentration in a school environment (outdoor) was 0.41 mg/m^3. A cohort study of 4th-, 7th-, and 10th-grade children in southern California revealed a significant relationship between decreased lung capacity (FEV1, FVC, maximal midexpiratory flow, and FEF75) and exposure to PM_{10}, $PM_{2.5}$, PM_{10}-$PM_{2.5}$, NO_2, and inorganic acid gases ($P< 0.05$) in both healthy children and those with a history of asthma.[21]

Environmental factors, including the locations of houses, affect a person's lung capacity and exacerbate the effects of NO_2. People living close to pollution sources (e.g., industrial estates and roadsides) are more susceptible to decreased lung capacity than those living in areas far from pollution sources. A study of lung capacity function in a roadside population in Jalgaon City, India reported a decrease in lung capacity in store owners exposed to traffic pollution[22]. In the study, decreases in FEV1 and PEFR in the exposed group was more significant than those in a control group. The lung capacity of the FEV1/FVC group of controls was better than that of the cases, showing that the lung capacity of individuals not exposed to pollution was better than that of those exposed to pollution.

According to data from the Agency for Toxic Substances and Disease Registry, households that burned a large amount of wood or used kerosene heaters and gas stoves had higher NO_2 levels inside their homes as compared with those without wood or kerosene heater use.[23] NO_2, a by-product of combustion produced by indoor gas appliances, such as cooking stoves, was associated with respiratory symptoms in individuals with obstructive airway disease.[24] Home inspection and NO_2 monitoring were conducted 1 week prior to interventions (i.e., stove replacement, air purifier installation, or ventilation hood installation) and 1 week and 3 months after the interventions. Stove replacement resulted in a 51% and 42% decrease in median NO_2 concentrations 3 months post-intervention in kitchens and bedrooms, respectively ($P = 0.01$, $P = 0.01$). Air purifier placement resulted in an immediate decrease in median NO_2 concentrations in kitchens (27%, $P< 0.01$) and bedrooms (22%, $P = 0.02$). However, 3 months post-intervention, a significant reduction in NO_2 concentrations was found only in kitchens (20%, $P = 0.05$). NO_2 concentrations in kitchens and bedrooms did not significantly change following ventilation hood installation. The study concluded that replacing unvented gas stoves with electric stoves or the placement of air purifiers with HEPA and carbon filters can decrease indoor NO_2 concentrations in urban homes.

CONCLUSIONS

The exposure HI using real-time data was 1.138, with 78% of the study population at risk (HI ≥ 1) and 22% not at risk (HI < 1). The model prediction FEV1 by HI predictor NO_2, and the FEV1 value was 1.869 to 0.543 HI. Thus, the value of the parameter FEV1 lung capacity can be predicted using the HI, where any increase in the value of 1 in the HI will be followed by a decline in FEV1 of 0.543 L. Model FVC values were predicted by the predictor HI NO_2, and the FVC value was 2.268 to 0.619 HI. Thus, lung capacity FVC values can be predicted using the HI, where any increase in the value of 1 in the HI will be followed by a decline of 0.619 L in the FVC value. The present study revealed a significant relationship ($P< 0.05$) between the restriction status and complaints of a dry cough (odds ratio of 5.002). The most common complaints were a cough (70%). Other respiratory complaints were not statistically significant, either on the status of obstruction or restriction status. The results suggested that a value of 0.176 mg/m^3 can be used as a quality standard recommendation (health advisory) for NO_2 exposure in roadside schools, especially schools abutting inter-provincial roads.

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health risk of nitrogen dioxide exposure among primary school children in ogan ilir south sumatera indonesia effect on lung function

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