International Journal of Applied Chemistry. ISSN 0973-1792 Volume 12, Number 1 (2016) pp. 34-38

Association between Air Pollutants with FeNO among Primary School Children at Petrochemical Industries

Ahmad Fahmi Yusoff, Juliana Jalaludin and Nur Faseeha Suhaimi
Department of Environmental and Occupational Health
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia, MALAYSIA

Abstract— Children's increased risk of respiratory diseases is possibly due to air pollutants exposure. This study aims to determine the association between air pollutants and respiratory inflammation among school children at petrochemical industries in Kemaman, Terengganu. A cross-sectional comparative study was conducted among selected healthy school children from primary schools in Kemaman. Questionnaires were used to determine reported respiratory symptoms. Indoor exposure to $PM_{2.5}$ in classrooms was measured using DustTrak DRX Aerosol Monitor; VOCs using PbbRAE, while NO_2 and SO_2 using LaMotte Air Sampler. Fractional exhaled Nitric Oxide (FeNO) was measured by instructing respondents to exhale directly into the NIOX MINO device. The median and interquartile range of concentration of $PM_{2.5}$, VOCs, NO_2 and SO_2 in classrooms and homes of studied group was higher than the values in comparative group at $p<0.001$. FeNO shows a significant difference between studied and comparative group at $p<0.001$. NO_2 and SO_2 were found to be significantly associated with FeNO at $p<0.05$. Exposure to NO_2 and SO_2 is associated with FeNO in petrochemical industries area suggesting that greater exposure may influence children's respiratory health**.**

Keywords—FeNO, $PM_{2.5}$, SO_2, NO_2, VOCs

Introduction

People who are often most susceptible to the adverse effects of pollution, for instance children, older adults, people with cardiovascular or respiratory diseases tend to spend even more time indoors. Health effects that have been associated with indoor air pollutants include irritation of the eyes, nose, and throat, headaches, dizziness, fatigue, respiratory diseases, heart disease, and cancer [1, 2].

The exposure of industrial air pollutants in developing countries is usually higher than in developed countries. As a developing country, Malaysia is not exceptional to the air pollution problems for developed countries were said to be stricter about controlling air pollution. Petrochemical industries have been identified as important sources of emissions of chemical substances, and adverse health effects have been reported by residents who live nearby [3, 4].

The purpose of this study is to determine association between $PM_{2.5}$, NO_2, SO_2 and VOCs with airway inflammation among primary school children at petrochemical industries area in Kemaman, Terengganu for some reasons of significant findings of association between indoor air pollutants with prevalence of respiratory health symptoms by previous studies [5, 3].

As the best medicine is always prevention rather than cure, even though this study will provide a data which still cannot be generalized to all Malaysians, the outcome is expected to support limited local studies that had been done before to associate between the indoor air pollutant with the health impacts of primary school children in Malaysia who reside near petrochemical industries area.

Materials and Methods

Study Design

The cross sectional comparative study was carried out among male and female Malay primary school children with the aim to determine the airway inflammation among primary school children in primary schools located near petrochemical industries under the exposures of Particulate Matter less than 2.5 micrometers ($PM_{2.5}$), Sulphur Dioxide (SO_2), Volatile Organic Compounds (VOCs) and Nitrogen Dioxide (NO_2).

Study Location

The study location was the schools located within zone of impact of 5 km radius [6] from centre of petrochemical industries area in Kertih, Terengganu. For the comparative group, schools located outside 5 km radius from centre of petrochemical industries area were chosen.

Sampling Technique

120 Malay male and female primary school children aged 11 years old were randomly selected from schools in Kemaman, Terengganu. Random sampling method was used to select the respondents with inclusion criteria of; healthy from asthma and any upper respiratory illness, Malay ethnicity, and did not take meal or doing exercise at least 1 hour before take part in FeNO measurement.

Funded by Ministry of Education Malaysia

Instruments and Procedures
The standard established questionnaire adapted from American Thoracic Society, "Questionnaire ATS-DLD-C WHO" for children [7] were used in order to determine the socio-demographic, respiratory health symptoms and history of exposure. Period of 5 hours sampling time during school session were used to measure the concentration of the air pollutants in selected school and houses. Air quality monitoring instruments used in this study includes TSI8520 DustTrak Airborne Particles Monitor for $PM_{2.5}$, PbbRAE Portable VOC Monitor (PbbRAE 3000) for VOCs, Q-TrakPlus Model 8554 Monitor for CO_2, CO, Relative Humidity and Temperature, TSI VelociCalc Plus Model 8386 for air velocity, and LaMotte Portable Air Sampling Pump for NO_2, and SO_2. All the instruments were placed at the back of the classroom at a height of 1.0 m above the floor [8], approximately to the children breathing zone level. The measurement of air velocity, temperature and humidity were taken periodically and spread throughout many points within the classrooms to ensure even distribution. The measurement of air pollutants at homes was carried out on voluntary basis. The principle of sampling method was the same as the measurement in school.

Children recruited underwent single-breath FeNO analysis after they were selected. FeNO was determined with an online method by using NIOX MINO (Aerocrine, Stockholm, Sweden) analyser. After comfortably seated, children made an inspiration of exhaled NO via a connected mouthpiece immediately followed by full exhalation at a constant rate of 50mL/sec for at least 6 seconds according to ATS/ERS. However no repetition of analysis was made among children. The measured value of 20 ppb or more were considered elevated values in children, according to ATS/ERS. The measurements were carried out one hour after heavy physical activity (if any) while consumption of nitrate-rich food and caffeine among respondents was discouraged.

Statistical analysis
The p-value of less than 0.05 was considered statistically significant and all analyses were carried out using Statistical Package of Social Sciences (SPSS) version 20.

Results

Sociodemographic of the Respondents
More boys participated in the study. For studied group, there were 33 boys (55.0%) and 27 girls (45.0%), whereas for comparative group, there were 31 boys (51.7%) and 29 girls (48.3%). 100% respondents in studied group live within 5km from petrochemical industries. For comparative group, 100% respondents live more than 5 km from petrochemical industries. Descriptive analysis and Chi-square test were conducted for both variables, and only housing location distance from petrochemical industries shows significant difference for both studied and comparative group at $p<0.001$.

Comparison of Air Pollutants at Schools and Homes
Mann-Whitney U Test was performed to compare the concentration of $PM_{2.5}$, VOCs, NO_2, SO_2 in classrooms and homes for both groups. For classrooms measurements, results in Table 1 show that the median and interquartile range of concentration of $PM_{2.5}$, VOCs, NO_2 and SO_2 of studied group was higher than comparative group at $p<0.001$. For homes measurements, results in Table 2 show that the median and interquartile range of concentration of $PM_{2.5}$, VOCs, NO_2 and SO_2 of studied group was higher than comparative group at $p<0.001$.

Comparison of Airway Inflammation between Groups
Mann-Whitney U test was used. Table 3 shows that there were significant differences in airway inflammation among both groups for the median (interquartile range) of airway inflammation in studied group were higher than comparative group at $p<0.001$.

Table 1: Concentration of Air Pollutants in Schools

Variables	Studied (n= 60) Median (IQR)	Comparative (n=60) Median (IQR)	z	p
$PM_{2.5}$ ($\mu g/m^3$)	35.070 (11.23)	27.00 (7.46)	-3.743	**<0.001***
VOCs (ppm)	0.250 (0.531)	0.074 (0.32)	-3.168	**<0.001***
NO_2 (ppm)	0.140 (0.14)	0.080 (0.08)	-9.459	**<0.001***
SO_2 (ppm)	0.160 (0.28)	0.027 (0.03)	11.687	**<0.001***

N = 120, Significant at p<0.001

Table 2: Concentration of Air Pollutants in Homes

Variables	Studied (n= 33) Median (IQR)	Comparative (n=40) Median (IQR)	z	p
$PM_{2.5}$ ($\mu g/m^3$)	34.93 (26.27)	18.87 (4.50)	-3.212	**0.001***
VOCs (ppm)	0.710 (4.21)	0.040 (0.58)	-3.840	**0.001***
NO_2 (ppm)	0.350 (0.21)	0.140 (0.02)	-3.363	**0.001***
SO_2 (ppm)	0.050 (0.03)	0.000 (0.02)	-4.895	**0.001***

N = 73, Significant at p<0.001

Table 3: Comparison Airway Inflammation

Variables	Studied (n= 60)	Comparative (n=60)	p	PR	95%CI
	Median (IQR)	Median (IQR)			
Present (≥20ppb)	43(95.6)	2 (22.7)	**0.001***	1.41	0.04-1.86
Unlikely (<20ppb)	17 (4.4)	58 (77.3)			

N = 120, Significant at p<0.001

Association between Sources of Home Air Pollutants with Airway Inflammation

FeNO values were categorized based on median value (20ppb). The values higher than or equal to median (≥20ppb) were categorized as high, while the values lower than the median were categorized as low. The home air pollutant sources included were pets, fuel use for cooking and indoor smoking. Chi-square test shows that there were no significant association between home air pollutant sources with airway inflammation.

Association between Air Pollutants at Schools with Airway Inflammation

Table 4 shows that the Pearson's chi-square statistics is 0.320 and 0.593 for $PM_{2.5}$ and VOCs respectively where statistical data shows that there was no significant association between airway inflammation with indoor $PM_{2.5}$ and VOCs. However, the Pearson's chi-square statistics is 36.78 and 44.86 for SO_2 and NO_2 respectively, where statistical data shows that there were significant associations between airway inflammation and indoor SO_2 and NO_2.

Factors that Influenced the Airway Inflammation among Study Respondents after Controlling All the Confounders

Multiple logistic regressions were used to determine the factors that had influenced the airway inflammation the most. The results as shown in Table 5 show that there were significant regressions between the indoor SO_2 (p=0.009, PR=18.09, 95%CI=1.27-5.28) and indoor NO_2 (p<0.001, PR=11.43, 95%CI=1.12-4.28) with airway inflammation among respondents for both studied and comparative group. Multiple logistic regression (forward LR) shows the logistic equation can be written as $Z = -4.453 + 2.982(SO_2) + 2.364(NO_2)$. For SO_2, PR=19.734, 95%CI=3.27-164.28. Thus for every unit increase in SO_2, the odd of airway inflammation is expected to increase by 19.734. For NO_2, PR=10.633, 95%CI=3.12-36.28.

Table 4: Association between Air Pollutants at Schools with Airway Inflammation

Variables	Present (≥20ppb)	Unlikely (<20ppb)	χ^2	p	PR	95% CI
	Total (%)	Total (%)				
High $PM_{2.5}$ (≥28.30 μg/m^3)**	28 (77.7)	8 (22.3)	-	0.572	1.24	1.08-4.18
Low $PM_{2.5}$ (<28.30 μg/m^3)**	21 (87.5)	3 (12.5)				
High VOCs (≥0.084 ppm)	20 (71.5)	8 (28.5)	0.593	0.441	1.35	0.63-2.89
Low VOCs (<0.084 ppm)	18 (56.3)	14 (43.7)				
High NO_2 (≥0.140 ppm)**	13 (54.2)	11 (45.8)	-	**<0.001***	2.36	1.40-8.72
Low NO_2 (<0.140 ppm)**	2 (5.6)	34 (94.4)				
High SO_2 (≥0.05 ppm)**	11(30.6)	25(69.4)	-	**<0.001***	1.12	1.73-4.52
Low SO_2 (<0.05 ppm)**	1(4.2)	23(95.8)				

N = 120, *Significant at p<0.001
Fisher's Exact Test for value <5

Table 5: Factors Influenced Airway Inflammation after Controlling All Confounders

Variables	B	SE	p	PR	95% CI
$PM_{2.5}$	0.131	0.554	**0.813**	1.14	0.39-3.38
SO_2	2.895	1.108	**0.009***	8.09	1.27-5.28
NO_2	2.437	0.684	**0.001***	6.43	1.12-4.28
VOCs	0.504	0.542	0.352	1.66	0.57-4.59

N=120, Nagelkerke R Square=0.560
95% CI=95% Confident Interval; B=Regression Coefficient; S.E=Standard Error
*Significant at p<0.05

Discussion

Comparison of Concentration of Air Pollutants for Both Groups

There was a significant difference in $PM_{2.5}$, VOCs, NO_2, and SO_2 inside the different classrooms of selected schools of studied and comparative group, suggested that the secondary schools' location might had influenced or contributed to the concentration of the particulates and gases.

Measured data of median $PM_{2.5}$ concentration at schools in studied group was higher than schools at comparative group. $PM_{2.5}$ was referred to the international standard set by the US Environmental Protection Agency (2012) for 24-hours (35 μg/m^3) and annual (12 μg/m^3) [9]. The exposure of the studied group towards the $PM_{2.5}$ concentration was higher as compared to comparative and standards mentioned above.

The concentration of SO_2 was significantly higher as compared to the measured data in comparative group. According to national standard of Malaysian Air Quality Guidelines for 1-hour exposure (0.13 ppm) [9], the studied group was exposed to higher concentration of SO_2 as compared to comparative group and Malaysian Air Quality Guidelines.

It was found that the studied group was significantly exposed to high concentration of NO_2 as compared to comparative group. However, when referred to the Malaysian Air Quality Guidelines for exposure to concentration of NO_2 for 1-hour (0.170 ppm) [10], both studied and comparative group were exposed to the concentration of NO_2 below the standards mentioned above.

The measured data of VOCs concentration shows significantly higher concentration in studied group as compared to comparative group. Those statistical data reported above suggested $PM_{2.5}$, SO_2, NO_2, and VOCs were significantly higher in school of studied group which was located near petrochemical industries area as compared to school of comparative group.

As to support the measured data concentration of $PM_{2.5}$, SO_2, NO_2, and VOCs at the schools in both groups, the data concentration of $PM_{2.5}$, SO_2, NO_2, and VOCs was also measured in selected houses of studied and comparative groups. From the data measured, it was found that all the parameters measured were significantly different and higher in comparative group as compared to comparative group.

High $PM_{2.5}$ with median (IQR) concentration of 80.00 (17.00) $\mu g/m^3$ at preschools located in industrial area as compared to rural area was also found in a recent local study conducted by Mohd Nor Rawi et al., (2014) [11]. A study done by Ayuni et al., (2014) [3] found out that the concentration of $PM_{2.5}$ and NO_2 in primary schools located in industrial area (79.00 $\mu g/m^3$ and 3.730 ppm respectively) were higher than comparative area (49.00 $\mu g/m^3$ and 0.140 ppm respectively).

Comparison of Airway Inflammation among Respondents

Based on the statistical data of FeNO value, there were significant differences in FeNO value (ppb) among primary school children of studied and comparative group at $p<0.001$, suggested that the location of the primary schools might have influenced the FeNO levels among study respondents. The median (IQR) reading for fractional nitric oxide (FeNO) among respondents in studied group was higher (21.50 (7.50) ppb) than in comparative group (12.50 (5.70) ppb). This significant difference of airway inflammation between studied and comparative group could be due to the exposure experienced by the respondents.

A study by Aziz et al. (2014) found that there was a significant difference of FeNO value among preschool children in urban area as compared to rural area [12]. Another recent study by Noor Hisyam and Juliana also reported that there was a significant difference in median FeNO level of studied group in industrial area (11.3 ppb) as compared to comparative group in rural area (8.0 ppb) [5]. These could be due to higher degree of exposure experienced by those in the studied area as compared to comparative area [3]. Those studies mentioned above are consistent with the findings of this study that there were significant differences of airway inflammation among studied and comparative group.

Association between Air Pollutant Sources at Homes with Airway Inflammation

There was no significant association between exposures to air pollutant sources at homes with airway inflammation. Air pollutant sources at homes assessed were pets (p-value=1.919), fuel for cooking (p-value=0.599), and home smoking (p-value=0.304). This finding indicates that air pollutant sources at homes did not have significant association with airway inflammation. The findings of this study are supported by the study by Noor Hisyam and Juliana that there were no significant association between exposures to air pollutant sources at homes with airway inflammation among preschoolers [5].

Association between Air Pollutants at Schools with Airway Inflammation among Respondents

For airway inflammation, fractional nitric oxide measurement had been categorised as unlikely or present (Unlikely = reading of FeNO less than 20ppb, Present = reading of FeNO equal or more than 20ppb). According to American Thoracic Guidelines [10], FeNO value greater than 35ppb in children indicates that airway inflammation is significant in symptomatic patient, 20ppb – 35ppb is said to be intermediate with present airway inflammation should be interpreted with reference to the clinical context, whereas below than 20ppb is considered as unlikely of airway inflammation. Statistically, there was a significant association between NO_2 and SO_2 with airway inflammation, suggesting that the air pollutant of NO_2 and SO_2 might have influenced or contributed to the airway inflammation among respondents. However, $PM_{2.5}$ and VOCs shows no significant association. This might be due to low $PM_{2.5}$ and VOCs reading as well as lack in variability of the data.

A local study by Aziz et al. (2014) found that there was a significant association between NO_2 and airway inflammation among study respondents [12]. In addition, a recent study by Noor Hisyam and Juliana (2014) is also in consistent with the findings of this study that there was an association between pollutants NO_2 with airway inflammation [5].

Factors that Influence Airway Inflammation among Respondents after Controlling All the Confounders

Multiple Logistic Regression was performed to assess the contributing factors of airway inflammation among study respondents, and statistically it was found that there were an association between NO_2 and SO_2 with airway inflammation among respondents. The model contained 4 main variables of $PM_{2.5}$, NO_2, SO_2, and VOCs. The confounders of the study were also included, which were total income, air cooling system, and indoor smoking. These were run simultaneously with the study variables. The model as a whole explained between 41% (Cox & Snell R Square) and 56% (Nagelkerke R Square) of the variance in airway inflammation among study respondents.

The strongest predictor of airway inflammation among respondents was SO_2, with prevalence ratio of 18.09. This indicates that respondents who were more exposed to sulphur dioxide were 18.09 times more likely to have an airway inflammation than those who were less exposed to sulphur dioxide, after controlling for all other factors in the model. The prevalence ratio of 11.43 for NO_2 indicates that for every significant exposure to NO_2, the respondents were 11.43 times more likely to experience airway inflammation than those who were less exposed to NO_2, after controlling for other factors in the model. A study in Netherland found that changes in NO_2 concentration were associated with evidences of acute airway inflammation (FeNO Value) and impaired lung function [13]. This finding is consistent with findings of Noor Hisyam and Juliana (2014) [5], whereby NO_2 was found to have stronger associations with FeNO level than $PM_{2.5}$. However, the findings of this study found that SO_2 was slightly above NO_2 as a contributor to airway inflammation.

Conclusion

The study found that children near petrochemical industries in Kemaman were exposed to high concentration of $PM_{2.5}$, NO_2, SO_2, and VOCs as compared to those children in comparative group. The airway inflammation was significantly higher among those in studied group than those in the comparative group. Indoor NO_2 and SO_2 show a significant association with airway inflammation.

Acknowledgment

The authors would like to express our deepest appreciation to the respondents, their parents and guardians, management of the schools, staffs of FMHS UPM, and Ir. Dr. Mohd. Habir Ibrahim from TATIUC for providing supportive valuable information to successfully conduct this study. This article was written in part for a research project funded by Ministry of Education, Malaysia (project code: 04-01-14-1449FR).

References

[1] C.P. Choo and J. Jalaludin, "An overview of indoor air quality and its impact on respiratory health among Malaysian school-aged children," *Reviews on Environmental Health*, vol. 30, no. 1, pp. 9-18, 2015.

[2] N.F. Suhaimi and J. Jalaludin, "Biomarker as a research tool in linking exposure to air particles and respiratory health," BioMed Research International, vol. 2015, article ID 962853, 2015.

[3] N.A. Ayuni, J. Juliana, M.H. Ibrahim, "Exposure to PM_{10} and NO_2 and association with respiratory health among primary school children living near petrochemical industry area at Kertih, Terengganu," *Journal of Medical and Bioengineering*, vol. 3, no. 4, pp. 282-7, 2014.

[4] M.H. Ibrahim, A.M. Abdullah, N.M. Adam et al., "Optimization of remote meteorological parameters in predicting the air pollutant (no_2) distribution by petrochemical industry along coastal zone at east coast of Peninsular Malaysia," *International Journal of Engineering and Technology*, vol. 11, no. 4, pp. 58-67, 2011.

[5] N.H. Noor Hisyam and J. Juliana, "Association between indoor PM_{10}, $PM_{2.5}$ and NO_2 with airway inflammation among Preschool Children at Industrial and Sub-Urban Areas," *Advances in Environmental Biology*, vol. 8, no.15, pp. 149-59, 2014.

[6] Department of Environment Malaysia, "Guidance document on health impact assessment (HIA) in environmental impact assessment (EIA)," *Ministry of Natural Resources and Environment*, pp. 16, Visual Print, Kuala Lumpur, Malaysia, 2009.

[7] R.A. Sweik, P.B. Boggs, S.C. Erzurum et al., "An official ATS clinical practice guideline: interpretation of exhaled nitric oxide levels (FENO) for clinical applications," *American Journal of Respiratory and Critical Care Medicine*, vol. 184, no. 5, pp. 602-15, 2011.

[8] I. Colbeck, Z.A. Nasir, Z. Ali, "Characteristics of indoor/outdoor particulate pollution in urban and rural residential environment of Pakistan," *Indoor Air*, vol. 20, no. 1, pp. 40-51, 2010.

[9] USEPA, "revised air quality standards for particle pollution and updates to the air quality index (AQI)," *The National Ambient Air Quality Standards for Particle Pollution*, 2012, retrieved from http://www.epa.gov/ airquality/particlepollution/2012/decfsstandards.pdf on July 23, 2015.

[10] Department of Environment Malaysia, "Malaysian ambient air quality guidelines," *Ministry of Natural Resources and Environment*, retrieved from http://apims.doe.gov.my/apims/General%20Info%20of%20Air%20Pollutant%20Index.pdf on July 23, 2015.

[11] N.A. Mohd Nor Rawi, J. Jalaludin, P.C. Chua, "Indoor air quality and Respiratory Health among Malay Preschool Children in Selangor," *BioMed Research International*, vol. 2015, Article ID 248178, 2014.

[12] A. Aziz, J. Jalaludin, S.A. Bakar, "indoor air pollutants exposure and the respiratory inflammation (feno) among preschool children in Hulu Langat, Selangor," *Advances in Environmental Biology*, vol. 8, no. 15, pp. 164-70, 2014.

[13] M. Strak, N.A.H. Janssen, K.J. Godri et al., "Respiratory Health Effects of Airborne Particulate Matter: The Role of Particle Size, Composition, and Oxidative Potential - The RAPTES Project," *Environmental Health Perspectives*, vol. 120, no. 8, 2012.