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Potential Pollutants Emitted From a Petrochemical Plant in Malaysia

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Abstract—Malaysia is one of the country that having industrial revolution involving petrochemical activity. With the advantage of petroleum crude oil and natural gas availability and capacity, Malaysia transformed from an importing country to an exporting country dealing with petrochemical arena. It is undeniable that with the growth of industrial areas such as the petrochemical plant will cause increased environmental pollution which subsequently impacting health of nearby community. Exploration of fundamental information pertaining to the issue is very important in order to mitigate the consequences.

Index Terms— Air modelling, benzene, carbon dioxide, hazard quotient, hydrogen sulfide, life cancer risk, nitrogen dioxide, petrochemical, total suspended particulate.

1 Introduction

MALAYSIA has given more focus and effort on industrial development compared to previous years. According to the Global Enabling Trade Report by the World Economic Forum, Malaysia is one of the world's 20 largest trading nations and ranked 30th out of 150 countries (MGCC 2012). This is one of the targets need to be achieved before transforming into a developed country. Petrochemical industry is considered one of the top contributors dealing with industrial sector today. With the advantage of petroleum crude oil and natural gas availability and capacity, Malaysia transformed from an importing country to an exporting country dealing with petrochemical arena. Main petrochemical plants in Malaysia are located in Terengganu, Pahang, Johor, and Sarawak. It is undeniable that with the growth of industrial areas such as the petrochemical plant will cause increased environmental pollution (Herva et al. 2011). With this unsatisfactory quality of environment, the health of nearby community will be subsequently affected (Hänninen et al. 2011). Malaysia is still lacking of sufficient information pertaining to this environmental health related issue up till this moment.

The aim of this study is to identify the possible pollutants emitted from the stack and to determine potential health-related consequences based on results obtained from an air dispersion modelling done for one petrochemical plant in country. The results were divided into two groups, normal operation and abnormal operation.

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2 Methods

This comparison study is based on the air dispersion modeling done for a new proposed petrochemical plant and comparing results of two groups namely normal operation and abnormal operation. Normal operation is basically taking the emission level with installation of the control measures, while abnormal operation is taking the emission level without installation of control measures. The prediction was based on United States Environmental Protection Agency (USEPA) AERMOD and Gaussian Dispersion Model. AERMOD was focusing on aerial or atmospheric dispersion, while Gaussian Dispersion Model used to access the pollutants dispersion distance. The main purpose of having this modeling is actually to estimate chronic exposures and characterizes the health risks.

The critical parameters included in the modelling are Total Suspended Particulate (TSP), Nitrogen Dioxides (NO_2), Sulphur Dioxides (SO_2), Carbon Dioxides (CO_2), Hydrogen Sulfide (H_2S), and Volatile Organic Compounds (VOC). Most of TSP consist of respirable particulate matter with size of less than 10µm (PM_{10}) and VOCs are mainly hexane and benzene. Mentioned parameter were categorized into two groups, based on their carcinogenicity (NRC 2014). Group one is carcinogenic substance and the second group is non-carcinogenic substance. For the purpose of risk characterization, hazard quotient (HQ) was used for non-carcinogenic substance, while lifetime cancer risk (LCR) used for carcinogenic substance. Both HQ and LCR calculation were based on USEPA (2009) guideline, where global acceptance is when HQ should be less than one and LCR should be less than 10^{-4} (USEPA 2001).

3 Results

Pollutants potentially released from a petrochemical plant were from both groups, carcinogenic and non-carcinogenic (Table 1). Non-carcinogenic group consist of TSP (PM_{10}), NO_2, SO_2, CO_2, H_2S, and VOC (hexane), whereby carcinogenic group consist of VOC (benzene). Basically, benzene is one of the main products of two processes in a petrochemical plant namely BTX extraction and transalkylation unit.

During normal operation of the petrochemical plant, the study found that parameters or released pollutants were not exceeding acceptable guideline values of both Recommended Malaysian Ambient Air Quality Guideline (RMAAQG) and Arizona Ambient Air Quality Guidelines (AAAQG). The proportion of predicted maximum ambient of TSP, NO_2, SO_2 and H_2S compared to the guidelines were 13.5%, 71.1%, 26.3% and 0.4% respectively.

As for abnormal operation, only TSP and H_2S within the acceptable range, whereby NO_2 and SO_2 exceeded the guideline values. The proportion of predicted maximum ambient of TSP, NO_2, SO_2 and H_2S compared to the guidelines were 67%, 254.3%, 101.3% and 42.9% respectively.

The guideline value for VOC in both RMAAQG and AAAQG was not available. The incremental proportion could not be calculated. Anywhere, it is important to note that the existing baseline and for VOC was 0.3µg/m^3. Maximum ambient incremental during normal and abnormal operation was 14.3µg/m^3 and 46.8µg/m^3 respectively.

For the HQ, the only pollutants which can be calculated were H_2S and VOC as benzene. In the normal operation, the quotients were less than one (Table 2). The figures showed that the non-carcinogenic risks for human exposures to both air pollutants are deemed as acceptable.

VOC as benzene showed the LCR of 5.5×10^{-5} for normal operation, and it was within acceptable cancer risk range of 10^{-6} to 10^{-4} (Table 3). Therefore, the LCR is taken as acceptable. Among the community which exposed to both normal and abnormal operation, the number of cancer cases will not exceed the prediction. However, the compliancy of this prediction was depending on the mitigation measures and their effectiveness.

4 Discussion

According to literatures, the main groups of pollutants released by petrochemical plants are VOCs, particulate matter and greenhouse gases (Ragothaman & Anderson 2017). This study had shown that all the pollutants are within the safe limit during normal operation. However, NO_2 is predicted to exceed the safe limit during the abnormal operation. All pollutants involved in this study are from those common groups and the highest was NO_2. The finding was supported by other previous studies which associated the increment of atmospheric NO_2 level with industrialization (Cyrys et al. 2012). Previous study had proved that every 10 µg/m^3 increase of NO_2 concentration, will increase the risks of myocardial infarction, cardiovascular deaths and COPDs by 0.36%, 0.2% and 0.38%, respectively (Zallaghi et al. 2015). Apart from that, pregnant woman whom exposed to NO_2 in early pregnancy is associated with reduced fetal growth (Iñiguez et al., 2016).

In this study, both non-carcinogenic and carcinogenic health risk indicators (HQ and LCR) were not exceeded the acceptable range during normal operation of the plant. However, no documented readings of estimation for abnormal operation. Higher readings could be expected in a scenario where the petrochemical plant is functioning abnormally (Jaafar, 2016). The only carcinogenic pollutant involved in this study was benzene (VOC). Based on previous studies done, areas proximate to industrial area will have lower air quality due to the combination effect of traffic emissions and industrial emissions. Baltrenas and friends found that at mospheric level of benzene in urban region exceeded the rural region by 0.63µg/m^3 (Baltrenas et al. 2011).

5 Conclusion

The petrochemical plant can be considered as safe for both normal and abnormal operations. However, regular air quality monitoring and all required mitigation have to be in place in order to prevent the serious consequences especially health-related of the pollutants.

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Table 1. Potential pollutants from a petrochemical plant during normal and abnormal operation

Pollutants	Concentrations (μg/m³)		RMAAQ Limit (μg/m³)
	Normal operation	Abnormal operation	
TSP (24-hour average)	98.3	127.7	260 *
Nitrogen dioxide (24-hour average)	35.5	96.8	75 *
Sulfur dioxide (24-hour average)	20.7	61.3	105 *
Hydrogen sulfide (8-hour average)	0.19	19.1	110 [#, a]
Volatile organic compounds (8-hour average)	13.8	26.1	NA

RMAAQ: Recommended Malaysian Ambient Air Quality Guidelines
* Recommended Malaysian Ambient Air Quality Guidelines
[#] Arizona Ambient Air Quality Guideline 1999
[a] 24- hour averaging time
NA: Not available

Table 2. Hazard quotient of pollutants for normal and abnormal operation

Pollutants	Hazard Quotient	
	Normal Operation	Abnormal Operation
Hydrogen sulfide	0.10	NA
Volatile organic compounds as benzene	0.46	

NA: Not available

Table 3. Lifetime cancer risk for normal and abnormal operation

Pollutants	Lifetime cancer risk	
	Normal Operation	Abnormal Operation
Volatile organic compounds as benzene	5.5×10^{-5}	NA

NA: Not available