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Assessment of health effects due to incremental PM_{10}, NO_2 and SO_2 exposure

Law Puong Ling and Ngu Lock Hei

Department of Civil Engineering, Faculty of Engineering
University Malaysia Sarawak

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Abstract

This study looks into the impact of incremental particulate matters (PM_{10}), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) on nearby population as a result of the operation of a coal-fired power plant at Sejingkat, Kuching, Malaysia. This study focuses on the estimates of incremental health effects due to incremental daily PM_{10}, NO_2, and SO_2 exposures by estimating the increases in (i) daily mortality rate, (ii) hospital visits due to respiratory problems, (iii) exacerbation of asthma, and (iv) respiratory symptom reports. It is predicted that increase in daily mortality rate would be in the range of 0.67% to 2.28%, hospital visits for respiratory cases 0.54% to 0.67%, exacerbation of asthma 1.27% to 2.28%, respiratory symptom reports 0.47% to 2.01%, and decrease in lung function 0.05% to 0.10%. It is concluded that the predicted morbidity and mortality risks are negligible, with the highest percentage increase of 2.28% in both respiratory deaths and emergency department visits due to exacerbation of asthma.

Keywords: particulate matters, nitrogen dioxide, sulfur dioxide, daily mortality rate, respiratory, exacerbation, asthma

1. Introduction

Environmental health impact assessment primarily involves mathematical modeling in an attempt to predict human exposure and body absorption of toxicants through respiratory, oral, and dermal routes (Kolluru et al. 1996). Environmental health impacts are predominantly secondary impacts on the nearby populations that emanate from primary impacts on the physical, biological and social environments (Law et al. 2003). Health impacts resulting from human exposure to air pollutants that are released through point, area and volume sources of an industrial facility are matters of significant concern.

In the context of the operation of a coal-fired power plant, literature review shows that the major health risks are mostly due to air pollutants emitted as a result of the combustion of pulverized coal (Levy et al., 1988). The major air pollutants of concern from bituminous and sub- bituminous coal combustions are particulate matters (PM), sulfur oxides (SO_x), and nitrogen oxides (NO_x) (USEPA 1996). Small amount of other air pollutants are also released such as carbon monoxide (CO), volatile organic compounds (VOCs), semi-volatile organic compounds, polycyclic organic matter (POM), polynuclear aromatic hydrocarbons (PAH), formaldehyde and trace elements like cadmium and arsenic (USEPA 1996).

Effects of sulfur dioxide effects are intensified by the presence of other pollutants, especially particulates. In Donora, Pennsylvania in 1948, in London in 1952, and in other well-known air pollution episodes, both SO_2 and particulates were present in high concentrations simultaneously (Law et al. 2003). Particulate sulfates or inert particles with adsorbed SO_2 can penetrate deep into the lungs and induce severe effects (Levy, et al. 1988). Health effects and dose response for sulfur dioxide and particulate matter published by the National Council Research (1979) are illustrated in Table 1 (NRC, 1979).

Table 1
Health effects and dose response for SO_2 and particulate matters

Location	Particles $\mu g/m^3$	SO_2 $\mu g/m^3$	Measurement Average Time	Effect
London	2000	1040	24 hr	Mortality
	750	710	24 hr	Mortality
	500	500	24 hr	Exacerbation of bronchitis
New York City	145	286	24 hr	Increased prevalence of respiratory symptoms
Birmingham, AL	200	26	24 hr	Increased prevalence of respiratory symptoms
London	200	400	1 week	Increased incidence of respiratory illness
Britain	200	200	6 months	Bronchitis, sickness, absence from work
Britain	70	90	1 year	Lower respiratory infections

Source: National Research Council (NRC), 1979

2. Methodology

In this study, the health impacts emanating from human exposure to air pollutants that would be released through point, area and volume sources of the proposed the proposed coal-fired power plant at Sejingkat, Kuching (Figure 1). The results of air quality dispersion modeling and morbidity statistics serve as input data for this study. Industrial Source Complex Short-Term (ISCST) air quality dispersion model developed by USEPA was used for exposure assessment purpose by estimating the impact of nearby population exposed to particulate matters (PM_{10}), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2)

(Anderson, et al., 1983). Main inputs of the model inputs are 1) emissions, 2) meteorology, and 3) receptor information (USEPA 1995). Emissions data consist of both the physical aspects of the source and mass emission rates. Meteorological data include wind direction, wind speed, atmospheric stability, temperature, and mixing height. Receptor information consists of location using a coordinate scheme that may include ground level as well as elevations (USEPA 1986).

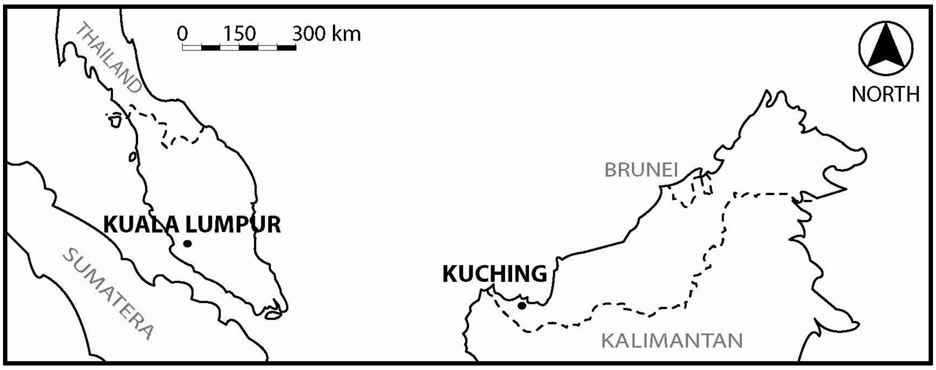

Fig. 1. Locality of proposed coal-fired power plant at Sejingkat, Kuching, Malaysia.

Table 2
Maximum incremental concentrations of selected air pollutants under Scenarios A, B, B1 and C for exposure assessment of nearby communities

Air pollutant	Maximum incremental concentrations ($\mu g/m^3$)			
	Scenario A	Scenario B	Scenario B1	Scenario C
Respiratory particulate or PM_{10} (24 hrs)	4.2	16.1	6.7	-----
Respiratory particulate or PM_{10} (long term)	0.8	3.0	1.2	-----
Sulfur dioxide (1-hr)	70.4	433.2	162.7	257.0
Sulfur dioxide (24-hr)	14.7	91.2	34.1	57.0
Nitrogen dioxide (1-hr)	21.0	121.7	15.0	-----

Table 2 shows the air quality parameters as well as their concentrations that were used for predicting nearby population exposure assessment to air pollutants. A total of four different scenarios were simulated:

1. Scenario A: Based on designed parameters of the furnace and published emission factors for trace elements;
2. Scenario B: Based on peak emission values measured at Phase I existing stack;
3. Scenario B1: Based on average emission values measured at the existing stack; and
4. Scenario C: Based on sulfur content in the coal dust (for sulfur dioxide emission only).

Predicted increase in asthma attacks were calculated using a model developed by Zailina and Badri (1997) on the effects of haze on asthmatic children in Kuala Lumpur during 1994 haze period. It is a statistical model relating frequency of asthmatic attack to the concentrations of three air pollutants, i.e., PM_{10}, NO_2, and SO_2. The model could be summarized as follows:

$$\% \text{ Asthma attacks} = -10.67 + 0.21\ (PM_{10}\ \mu g/m^3) + 0.06\ (NO_2\ ppm) + 0.71\ (SO_2\ ppm) \quad (1)$$

The impact of health effects of the nearby population was estimated by observing the degree of percentage increase in daily mortality, increase in hospital visits (respiratory cases), increase in respiratory symptom reports, and decrease in lung function. Health effect estimates of daily respirable particulate matters (PM_{10}) exposure expressed in terms of percentage change per 10 $\mu g/m^3$ increase in PM_{10} were determined using the methodology recommended by Dockery et al. (1994). As outlined in Table 3, % change of the individual health effect endpoints would be interpolated from the baseline % change per 10$\mu g/m^3$ increase in PM_{10} (Dockery et al. 1994).

Table 3
Health effect estimates of daily respirable particulate matter (PM_{10}) exposure

Health effects	% change per 10 ug/m^3 increase in PM_{10}
Increase in daily mortality	
Total deaths	1.0
Respiratory deaths	3.4
Cardiovascular deaths	1.4
Increase in hospital visits (respiratory cases)	
Admissions	0.8
Emergency department visits	1.0
Exacerbation of asthma	
Asthmatic attacks	3.0
Bronchodilator use	2.9
Emergency department visits	3.4
Hospital admissions	1.9
Increase in respiratory symptom reports	
Lower respiratory	3.0
Upper respiratory	0.7
Cough	1.2
Decrease in lung function	
Forced expiratory volume (FEV)	0.15
Peak expiratory flow (PEF)	0.08

Source: Dockery et al. (1994)

3. Results and discussions

Using the values in Table 3 as guidelines, the health impacts or risks associated with the average incremental for respirable particulate matters (PM_{10}) were predicted as illustrated in Table43. The PM_{10} incremental used was 6.7 $\mu g/m^3$ under the Scenario B1 based on average values of emission measurements made at the existing stack. As shown in Table 4, the increments of the individual diseases are very small. The predicted increase in daily mortality are in the range of 0.67% and 2.28%, hospital visits for respiratory cases 0.54% and 0.67%, exacerbation of asthma 1.27% and 2.28%, respiratory symptom reports 0.47% and 2.01%, and decrease in lung function 0.05% and 0.10%. It is concluded that the predicted morbidity and mortality risks are very small with the highest percentage change of 2.28% for both respiratory deaths and emergency department visits (due to exacerbation of asthma).

Table 4
Incremental health effect estimates due to incremental daily respirable particulates (PM_{10}) exposures

Health effects	% Change per 6.7 ug/m^3 increase in PM_{10}
Increase in daily mortality	
Total deaths	0.67
Respiratory deaths	2.28
Cardiovascular deaths	0.94
Increase in hospital visits (respiratory cases)	
Admissions	0.54
Emergency department visits	0.67
Exacerbation of asthma	
Asthmatic attacks	2.01
Bronchodilator use	1.94
Emergency department visits	2.28
Hospital admissions	1.27
Increase in respiratory symptom reports	
Lower respiratory	2.01
Upper respiratory	0.47
Cough	0.80
Decrease in lung function	
Forced expiratory volume (FEV)	0.10
Peak expiratory flow (PEF)	0.05

Based on a study conducted by Zailina and Badri (1997) on the effects of haze on asthmatic children in Kuala Lumpur, the predicted/modeled values (Table 3) and measured air quality data from various sources were used as inputs to this model. The results (% asthma attack rates) are illustrated in Tables 5, 6 and 7. In each case, the highest increment values (worse case) were used. For instance, in Scenario A, PM_{10} = 4.2 $\mu g/m^3$, NO_2=21 ppm and SO_2=70.4 ppm were used as inputs to Equation 1 above. In Scenario B, PM_{10} = 16.1 $\mu g/m^3$, NO_2=121.7 ppm and SO_2=433.2 ppm, whilst in Scenario B1, PM_{10} = 6.7 $\mu g/m^3$, NO_2=15 ppm and SO_2=162.7 ppm were used as inputs to Equation 1. Scenario C is not applicable because the simulation was based on sulfur content for sulfur dioxide only, and PM_{10} and NO_2 could not be simulated.

Scenario A was simulated using the designed parameters of the furnace and published emission factors for trace elements, The predicted results indicate that daily asthmatic attack rate due to the project will increase by 0.9%, from a pre-project rate of 0.13% to a

Table 5
Daily asthmatic attack rate among children associated with various air quality conditions based on model developed by Zailina and Badri (based on Scenario A)

Air quality conditions	% daily asthma attack rate
1994 haze period PM_{10} = 83.87 μg/m^3 NO_2 = 0.026 ppm SO_2 = 0.005 ppm Source: Zailina and Badri (1997)	6.95
Pre-project ambient air quality PM_{10} = 51.39 μg/m^3 NO_2 = 0.0038 ppm SO_2 = 0.0024 ppm Source: CTTC, UNIMAS, Scheduled Waste Transfer Station at SJFIZ	0.13
Post-project air quality PM_{10} = 55.59 μg/m^3 NO_2 = 0.015 ppm SO_2 = 0.0294 ppm	1.03

Table 6
Daily asthmatic attack rate among children associated with various air quality conditions based on model developed by Zailina and Badri (based on Scenario B)

Air quality conditions	% daily asthma attack rate
1994 haze period PM_{10} = 83.87 μg/m^3 NO_2 = 0.026 ppm SO_2 = 0.005 ppm Source: Zailina and Badri (1997)	6.95
Pre-project ambient air quality PM_{10} = 51.39 μg/m^3 NO_2 = 0.0038 ppm SO_2 = 0.0024 ppm Source: CTTC, UNIMAS, Scheduled Waste Transfer Station at SJFIZ	0.13
Post-project air quality PM_{10} = 64.49 μg/m^3 NO_2 = 0.066 ppm SO_2 = 0.167 ppm	2.99

post-project rate of 1.03%. Scenario B was simulated using the peak values collected from existing stack, and it is indicated that daily asthmatic attack rate due to the project will increase by 2.86%, from a pre-project rate of 0.13% to a post-project rate of 2.99%. A relatively higher increase in Scenario B (0.13% to 2.99% = 2.86% increase) in asthma attacks is mainly due to the fact that peak values were used, which are approximately four times higher than average values. Scenario B1 was simulated by using the average values, and the simulated results show that daily asthmatic attack rate due to the project will increase by 1.45%, from a pre-project rate of 0.13% to a post-project rate of 1.58 %. The increase in percentage in daily asthmatic attacks for all the three scenarios is in the range of 1.45% to 2.86% and are almost negligible as compared to the daily asthmatic attack rate of 6.95%, which was seen during the1994 haze period.

Table 7
Daily asthmatic attack rate among children associated with various air quality conditions based on model developed by Zailina and Badri (based on Scenario B1)

Air quality conditions	% daily asthma attack rate
1994 haze period PM_{10} = 83.87 μg/m^3 NO_2 = 0.026 ppm SO_2 = 0.005 ppm Source: Zailina and Badri (1997)	6.95
Pre-project ambient air quality PM_{10} = 51.39 μg/m^3 NO_2 = 0.0038 ppm SO_2 = 0.0024 ppm Source: CTTC, UNIMAS, Scheduled Waste Transfer Station at SJFIZ	0.13
Post-project air quality PM_{10} = 58.09 μg/m^3 NO_2 = 0.080 ppm SO_2 = 0.064 ppm	1.58

4. Conclusions

From this study, it is found that PM_{10} concentrations in the nearby areas are very low for all scenarios and there will be no significant increase in associated morbidity and mortality rates during the operational phase of the proposed coal-fired power station. It is also concluded that the predicted morbidity and mortality risks due to incremental PM_{10} levels are very small with the highest percentage change of approximately 2.28% for both the respiratory deaths and emergency department visits due to exacerbation of asthma. The increase in percentage in daily asthmatic attacks due to incremental PM_{10}, NO_2, and SO_2 for all the three scenarios is in the range of 1.45% and 2.86% and are almost negligible as compared to the daily asthmatic attack rate of 6.95% which was seen during the1994 haze period.

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