POINT SOURCE MODELING OF NITROGEN DIOXIDE AND PARTICULATE MATTER CONCENTRATION SURROUNDING MELAWA POWER STATION, KOTA KINABALU

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I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a bachelor degree in any university; and that to the best of my knowledge and it does not contain any material previously published or written by another person where due reference has not made in the text.

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ABSTRACT

A study was carried out to model the dispersion of NO_2 and PM_{10} concentration from point source at Melawa Power Station, Kota Kinabalu using ISC-AERMOD View dispersion model. 10 locations were defined within the 1000 m x 1000 m area to serve as sensitive receptors. The dispersion contour showed a similar trend of a fan-like shaped at the west of the power station due to the dominance of eastern wind. The main contributor of emission within the Melawa Power Station Complex is the SESB stack caused by building downwash which the height of the stack is lower than the building. The maximum 1-hr averaging concentration of NO_2 is 123.33 $\mu g/m^3$ and the maximum 24-hr averaging concentration of PM_{10} is 84.75 $\mu g/m^3$ at distance of 0.15 km to the west of the Melawa Power Station Complex. The model was validated by comparing the model output and existing air quality data with 95% of the accumulative frequency distribution by a factor of less than 1.5. Analysis between predicted concentrations with measured data of NO_2 and PM_{10} showed a strong correlation with r-value of 0.926 and 0.932. The highest ground level concentrations predicted at SESB Staff Quarters (R5) is 123 $\mu g/m^3$ of NO_2 and 83 $\mu g/m^3$ of PM_{10}. Results of the study revealed that the air pollutants from Melawa Power Station were well within the adequate exposure limit to human health and compliance limit of the Malaysian Ambient Air Quality Guideline.

PEMODELAN TITIK PUNCA BAGI KEPEKATAN NITROGEN DIOKSIDA DAN ZARAHAN TERAMPAI MENGELILINGI STESEN JANAKUASA MELAWA, KOTA KINABALU

ABSTRAK

Kajian telah dijalankan untuk memodel serakan kepekatan NO_2 dan PM_{10} dari titik punca di Stesen Janakuasa Melawa, Kota Kinabalu dengan menggunakan model serakan ISC-AERMOD View. Sepuluh lokasi dalam lingkungan kawasan 1000 m x 1000 m ditakrifkan sebagai penerima sensitif. Kontur serakan menunjukkan tren yang menyerupai bentuk kipas pada bahagian barat stesen janakuasa disebabkan oleh dominasi angin timur. Penyumbang utama kepada pencemaran dalam lingkungan Kompleks Stesen Janakuasa Melawa adalah cerobong SESB disebabkan oleh "downwash" bangunan di mana cerobong tersebut lebih rendah daripada bangunan. Purata kepekatan NO_2 dalam 1 jam yang tertinggi ialah 123.33 $\mu g/m^3$ dan purata kepekatan PM_{10} dalam 24 jam yang tertinggi ialah 84.75 $\mu g/m^3$ iaitu pada jarak 0.15 km ke barat stesen jakankuasa tersebut. Model tersebut ditentusahkan dengan membandingkan output permodelan dengan data kualiti udara yang diukur dengan 95% daripadanya mempunyai kekerapan terkumpul pada faktor kurang daripada 1.5. Analisis di antara ramalan kepekatan dengan data yang diukur bagi NO_2 dan PM_{10} menunjukkan korelasi yang kuat dengan nilai $r = 0.926$ dan 0.932. Ramalan kepekatan paras tanah yang tertinggi di kalangan reseptor adalah rumah penginapan pekerja SESB (R5) dengan kepekatan NO_2 (123 $\mu g/m^3$) dan kepekatan PM_{10} (83 $\mu g/m^3$). Keputusan kajian ini juga menunjukkan pelepasan bahan pencemar dari Stesen Janakuasa Melawa masih dalam lingkungan had pendedahan kesihatan manusia yang berpatutan dan mematuhi Garis Panduan Kualiti Udara Ambien Malaysia.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

%	percent
°C/km	Celsius over kilometer
g/s	gram per second
K	Kelvin
km	kilometer
kPa	kilo Pascal
m	meter
m/s	meter per second
nm	nanometer
ppm	parts per million
s	second
μm	micrometer
μm^{-3}	micrometer with the power of -3
$\mu g m^{-3}$	microgram per meter cube
x, y, z	Cartesian coordinate
C	condition
H	effective stack height
h_s	physical stack height portion
ΔH	plume rise portion
2D	two-dimensional
3D	three-dimensional
AERMET	AMS/EPA Meteorological Preprocessor
AERMAP	AMS/EPA Map Terrain Preprocessor
API	Air Pollution Index
AQM	Air Quality Modeling
ARL	ARL Tenaga Sdn. Bhd.
BPIP	Building Profile Input Program
CFC	chlorofluorocarbon
CIT	Caltech Institute of Technology
CO	carbon monoxide
CO_2	carbon monoxide

COPD	chronic obstructive pulmonary disease
CTDMPLUS	Complex Terrain Dispersion Model-Plus
H_2	hydrogen
HCN	hydrogen dichromate
ISC-AERMOD	Industrial Short Complex – AMS/EPA Regulatory Model
ISC-PRIME	Industrial Source Complex - Plume Rise Model Enhancements dispersion model
ISCST3	Industrial Source Complex - Short Term regulatory air dispersion model
KSP	Kinematic-Simulation-Particle
MW	megawatt
N_2	nitrogen
NO	nitric oxide
NO_2	nitrogen dioxide
NO_3^{2-}	ion nitrite
NO_x	nitrogen oxides
O_2	oxygen
PDF	probability distribution function
PM_{10}	particulate matter
PPSS	Perth Photochemical Smog Study
RAMMET	Regional Atmospheric Modeling of Meteorological
RMG	Recommended Malaysia Air Quality Guidelines
SESB	Sabah Electric Sdn. Bhd.
SHLE	Swedish Hygienic Limits Exposure
SO_2	sulfur dioxide
SPSS	Statistical Package for Social Sciences software
WHO	World Health Organization
U. K.	United Kingdom
U.S.EPA	United Stated Environmental Protection Agency

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In this modern century today, everything seems to be satisfactory. There is house to live in, jobs to work on and vehicles to travel with. But behind all this, is something what most of us cannot see, trying to fulfill our comforts and needs. Industries like power plants running day and night to generate electric to light up our house, to spin our fan, to heat our food and to supply power to our computer to work with. More over, there are predictions suggesting that almost half of the world's population will be living in cities by the new millennium (Brimblecombe & Maynard, 2001). Those industries emit tones of pollutants into our atmosphere and without knowing when, air pollution is starting to spread out, polluting our atmosphere.

Our world's blanket, the atmosphere, consists of several layers. There is approximately 99% of air within the troposphere layer which distance 0-7 miles (0-12 km) from the earth surface (Surtahman & Abd Ghafar, 1997). The atmosphere is composed of gas molecules held close to the Earth's surface by a balance between gravitation and thermal movement of air molecules.

The composition of air in our atmosphere without any pollutants is shown in Table 1.1. Other than major gases like nitrogen and oxygen, it also contains trace amounts of numerous elements and compounds, including methane, ozone, hydrogen sulfide, carbon monoxide, oxides of nitrogen and sulfur, hydrocarbons, chlorofluorocarbons (CFCs), and various particulates or aerosols (Botkin & Keller, 2000).

Table 1.1 Clean air composition

Types of components	Spatial percentage	Concentration (ppm)
Nitrogen (N_2)	78.09	780 900
Oxygen (O_2)	20.09	209 400
Hydrogen (H_2)	0.00005	0.5
Carbon dioxide (CO_2)	0.0318	318
Carbon monoxide (CO)	0.00001	0.1
Nitrogen dioxide (NO_2)	0.0000001	0.0001
Nitrous oxide (NO_x)	0.000025	0.25
Sulfur dioxide (SO_2)	0.00000002	0.0002

(Source: Adapted from Surtahman & Abd Ghafar, 1997).

Moving along with development, the increasing air pollution has spread across the globe. The matter worsen when come to think that there are thousand of industries, rapid population growth and the consequential growth in energy consumption in developing country like Malaysia (Roger, 2002). Cities are often the focus of many environmental problems, given their density of energy use and occupation. Therefore, pollutants are emitted into the atmosphere everyday in our daily lives without anyone concerns of it. The declining environmental quality also linked to the unplanned growth in many developing countries (Brimblecombe & Maynard, 2001).

The present of emitted pollutants in atmosphere do not only causes air pollution. Where else, if the emitted pollutants come in contact and interact with the meteorological and topographical factor, it will become more concentrated. Nevertheless, without any actions to curb the problem, it will deeply affect our health and will soon bring down our nature together with the qualities of life (Chatwal *et al.*, 1989).

Concerns about the effects of air pollutants on health had rose to a peak and, in some countries, measures were introduced to control emissions. Increasing weight of legislation require information from monitoring of air pollution emission into the atmosphere from industrial processes (Andrew, 1998). Therefore, air quality modeling is an essential tool for most air pollution studies. It grants us the ability to evaluate future air quality by predicting the level of air pollution generated by present and planned source emission (Seinfeld, 1986).

1.2 OBJECTIVE

This research is carried out to accomplish the following objectives:-

- To model the dispersion of NO_2 and PM_{10} concentration from point sources at Melawa power station, Kota Kinabalu.
- To identify the main source of emission of NO_2 and PM_{10} within the Melawa Power Station Complex.
- To assess the receptors exposure on NO_2 and PM_{10} pollutants and evaluate the compliance of the predicted level of pollutants with the Malaysian Ambient Air Quality Guideline.

CHAPTER 2

LITERATURE REVIEW

2.1 AIR POLLUTION

The evolution of the study of air pollution in the last few decades has been characterized by several trends. The movement of interest from local problems to regional, continental and global issues has made the human to expand their knowledge. Air pollution has spread around the world until the worst air pollution problems are often found in the developing countries compared to few decades ago where only industrialized countries were polluted (Zannetti *et al.*, 1993).

Now, environmental laws and regulation have become a determining factor in the evolution of atmospheric sciences. Therefore, many definitions of air pollution have been proposed to clearly understand the definition of air pollution. One of the definitions for air pollution is the presence in the outdoor atmosphere of one or more contaminants in quantities and duration that can injure human, plant or animal life. Furthermore, these continuously interfere with the enjoyment of life or the conduct of business (Liu & Liptak, 2000).

A major cause of air pollution is combustion and yet, combustion is essential to life. When perfect or theoretical combustion occurs, the hydrogen and carbon in the fuel will combine with oxygen from the air to produce heat, light, carbon dioxide and water vapor. However, the impurities in the fuels, poor fuel-to-air ratio, or too high or too low combustion temperatures cause the formation of such side products such as carbon monoxide, sulfur dioxide, nitrogen oxides, fly ash and unburned hydrocarbons – all air pollutants (Wark *et al.*, 1998).

2.2 AIR POLLUTANTS

Air pollution is basically caused by the presence of airborne matter in the atmosphere. This airborne matter is present in all three phases that is gas, liquid and solid. Besides classifying it according to physical state, it can also be classified according to its chemical state (Carslaw & Beevers, 2002).

Many air pollutants are gaseous, such as nitrogen dioxide, carbon monoxide and chlorofluorocarbons. These gases can remain airborne for long times and also can contribute to the atmospheric chemical reaction. Where else in condensed phases, pollutants are usually found as small particles called particulate matter and roughly less than 10 m in diameter. Examples of particulate matter emission are like smoke, dust and haze (Seinfeld, 1986).

As for classification according to chemical state, basically almost every element in the periodic table can be found in the atmosphere. However, just a handful of major groupings like nitrogen-containing compounds and particulate matter that proved to be informative in discussing the air pollution (Wark *et al.*, 1998).

Pollutants can also be divided to either primary pollutants or secondary pollutants. Primary pollutants are pollutants that stay in same form in the atmosphere as in the sources emission. Examples of primary pollutants are carbon monoxide, sulfur dioxide, particulate matter and total suspended particulates (Seinfeld, 1986).

Secondary pollutants such as sulfuric acid and ozone are formed in the atmosphere through chemical reactions of primary pollutants with other substances present. These chemical reactions include hydrolysis, oxidation and also photochemical oxidation (Kenneth, 1990).

2.2.1 Nitrogen Dioxide, NO_2

In the 1990s, nitrogen dioxide has replaced smoke as the prime indicator of poor urban air quality. Nitric oxide (NO) and nitrogen dioxide (NO_2) are collectively referred to as NO_x which generally the most important nitrogen compounds in urban location. Around 90% of the emissions form combustion sources are of NO rather than NO_2; however, since the NO can all potentially be converted to NO_2, it is usual to express all of the NO_x as NO_2 when making mass emission estimates (Colls, 2002).

NO_2 is a reddish brown gas and is quite visible in sufficient amount. It is a secondary pollutant which forms from oxidation of NO in the atmosphere (Stedman *et al.*, 2001). A NO_2 concentration of 1 ppm can be detected by the eye. The potential of

NO reacting to form NO_2 is dependent on the ability to form radicals and the length of NO_2 that is formed (Clapp & Jenkin, 2001).

Among all the oxides of nitrogen present in the atmosphere, NO_2 is present in the highest concentration in the ambient air and it has been shown to accelerate damage to materials (Wark *et al.,* 1998). It can react with moisture to form nitric acid, which can cause considerable corrosion to metal surfaces. NO_2 is capable of absorbing visible light and at the concentration of 0.25 ppm, it will cause appreciable reduction in visibility.

2.2.2 Particulate Matter, PM_{10}

Particulate matter is a term employed to describe the dispersed airborne solid and liquid particles larger than single molecules. These particles consist of various shapes and sizes, starting from aerodynamic diameter of few hundred micrometers to less than 0.01 μm. Its size, chemical composition, atmospheric sustainability and effects of particles are strictly depending on the formation processes (Braccy, 1997).

Particles in the atmosphere are a mix of inorganic substances and complexes organic that range of different sizes between less than 10 nm to 100 μm (Maroni *et al.,* 1995). Therefore, these particles are usually divided into few classes. The small particles are with the aerodynamic size of less than 2.5 μm, rough particles are larger than 2.5 μm, mist is with aerodynamic diameter of 0.001-1 μm and fog is 0.1-10 μm (Wark *et al.*, 1998)

PM_{10} are referring to the particles substances with the aerodynamic diameter of less of equals to 10 μm. It is usually categorized as rough particles due to its large size. Therefore, it has lower sustainability in the air compared to other smaller particles. The particles emitted from the source can be sustainable in the air for the duration of few minutes to few hours (Rao, 1991).

There are two types of mobilization for particles dispersion which is global scale mobilization and area scale mobilization. Global scale mobilization is those particles that can travel the distance of few thousand kilometers while area scale mobilization is those that can travel the distance of few kilometers (Kouimtzis & Samara, 1995).

2.3 SOURCE OF POLLUTANTS

Once selected substances have been carefully studied and determined to be air pollutants base to the evidence available, it is of immediate interest to ascertain the major sources of these substances. Air pollutant sources can be categorized according to the type of source, their number and spatial distribution, and the type of emissions.

2.3.1 Types of Source

Categorization by type of source includes natural and man-made or anthropogenic sources. Natural air pollutants sources include plant pollens, yeast, molds, fungi, virus and bacteria. Dust is the most usual pollutant that is present in the atmosphere.

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