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POINT SOURCE SO_2 DISPERSION MODELING UNDER VARIOUS STACK HEIGHTS AND METEOROLOGICAL CONDITIONS

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Abstract

This paper presents the results of the SO_2 dispersion modeling from an oil fired power plant. The Industrial Source Complex (ISC) air dispersion model was used in the study. The ISC requires input on the source emission, physical stack parameters, and meteorological data. Results on the predicted maximum ground level SO_2 concentration and the distance where it occurs under various stack heights (i. e 20 to 150m) and seasonal meteorological conditions for a given oil fired power plant which consumes 1000 tons/day of fuel containing 3% sulfur were studied using the model.

Introduction

In Malaysia, the electricity demand is increasing at a phenomenal rate due to its rapid growth in the industrial, commercial and domestic sectors. In 1994, the growth was reported to be at an average rate of 13.7% and the projected demand is expected to remain high in excess of 10% per annum. Similarly, the amount of fuel oil burned for a power plant locally remains high. Hence, it is of utmost important to ensure that power plant operates as efficient as possible in manner that it will not adversely affect the environment.

Particles and gaseous emissions (such as SOx and NOx) are the major air pollutants emitted by oil fired power plants. These pollutants are known to give serious implication to the environment as well as to human health. As for an example, a long range transport of SOx and NOx emissions from a point source would result in acid rain problems distributed over a wider area. Thus, the effect of air pollution is of special in that it does not recognized any boundaries.

Coastal sites constitute an important field of air pollution study owing to their varying meteorological conditions. The difference in thermal capacities of the earth and sea surface creates an alternate heating and cooling effect during the diurnal cycle, producing a temperature difference in land and water which influence atmospheric dispersion. Thus, in

this regard, a study on the dispersion of SO_2 emission from a power plant located near the coastal region of Peninsular Malaysia was performed. The power plant is located in one of the important industrial estates in the country.

Emission Characteristics of the Power Plant

The power plant generates 500MW of electricity and consumes a total of 1000 tons/day of fuel oil which contains 3%wt sulfur. It is estimated that 630g/s of SO_2 (assuming 100% conversion of sulfur to sulfur dioxide) will be emitted by the plant. The exit stack gas velocity is 15 m/s and with a stack gas temperature of 527K. The top diameter of the stack is 1.3 m. These parameters were used as inputs to estimate the dispersion of SO_2 emitted by the plant under various stack heights (i.e 20 to 150 m) and prevailing meteorological conditions at the site.

Meteorological Data

Meteorology influences the dispersion of pollutant once it is emitted into the atmosphere. Four prevailing seasons were selected for the exercise and their respective wind rose patterns are presented in Figure 1(a-d). Briefly,

Figure 1a, represents the southwest monsoon season (May to September); with prevailing wind from south.

Figure1b, represent the southeast monsoon season (November to March); prevailing wind direction from the north.

Figure1c, represent the inter-monsoon period (April); with the prevailing wind from the northeast quadrant.

Figure1d, represent the inter-monsoon period (October); prevailing wind is from the southeast quadrant.

These figures represent the frequency of wind directions and wind speeds for a given season. The meteorological data was obtained from the nearest meteorological station. An average ambient temperature of 30°C and mixing height of 500 m with Pasquill's stability Class A, B, and C were selected for the simulation exercise.

The ISC Model

The ISC model is based on a Gaussian plume model and its basic equation is in the form of

$$C(x,y,z,H) = \frac{Q}{\sigma_y \sigma_z u \pi} \exp(-y^2/2\sigma_y^2)\exp(-H^2/2\sigma_z^2)$$

Where,

(x,y,z,H) = short term concentration of pollutant at (x,y,0) in (g/m3 from a continuous point source with effective height, H

z = 0

x = downwind distance (m)

y = lateral distance from plume centerline (m)

H = hs + h; effective stack height (m)

hs = physical stack height

h = plume rise above stack (m)

Q = source strength (g/s)

u = wind speed (m/s)

σy = lateral dispersion parameters (m)

σz = vertical dispersion parameters (m).

The model is useful for estimating concentration of relatively non-reactive pollutants. The calculations were performed based on the hourly meteorological data input of wind direction, wind speed, temperature, stability class, and mixing height. The stack and emission parameters required as inputs were source coordinate and its emission rate, physical stack height, stack diameter, stack gas exit velocity and stack gas temperature. The hourly predicted ground level SO_2 concentration estimates were calculated by the model. In this exercise, the predicted ground level 1-hr averaged SO_2 concentrations surrounding the plant area was studied.

Results and Discussion

Figures 2a - 5a present the predicted hourly averaged SO_2 concentration plotted against the downwind distance under different stack heights and meteorological seasonal variations. In addition, the predicted SO_2 concentration contours are presented in Figures 2b - 5b.

Generally, the results showed that the predicted SO_2 concentrations were higher than the Malaysia Ambient Air Quality Guidelines limit of 350 $\mu g/m^3$ (for 1-hr averaging period). The predicted maximum SO_2 concentrations under various meteorological and stack heights conditions were between 300 and 1400 $\mu g/m^3$ with the downwind distance of between 400 and 800 meters away from the power plant. As expected, the higher the stack height, the lower the SO_2 concentration predicted and the further the distance where the maximum concentration would occur. The results of the modeling exercise are briefly discussed below:

Southwest Monsoon Season (May to September)
The wind direction is mainly from the south during this season. Thus, the pollutant is expected to be dispersed towards the north of the plant (Figure 2b). The highest predicted SO_2 concentration was 1200 ug/m^3 (stack height = 20 m) occurring 600 m away towards the north of the plant (Figure 2a). The highest SO_2 concentration decreases to 600-800 ug/m^3 as the stack heights were increased from 100 to 150 m.

Northeast Monsoon Season (November to March)
In this season, the wind direction is predominantly from the north and thus, the pollutant is dispersed towards the south of the plant (Figure 3b). The highest predicted SO_2 concentration decreases from 1400 ug/m^3 to 700 ug/m^3 as the stack was increased from 20 to 150m high (Figure 3a). It was found that the highest concentration occurs between 600 and 800 m towards a non-populated area to the south of the plant

Inter-monsoon Season (April)
Predominant wind direction is from the northern sector (NNW-NNE), and the pollutant dispersion happens towards the southern part of the plant (Figure 4b). The highest concentration decreases from 600 to 300 ug/m^3 as the stack height was increased 20 to 150 m. The highest concentration occurs between 600 and 800 m south of the plant (Figure 4a).

Inter-monsoon Season (October)
Since the predominant wind direction is from the west to south quadrant and pollutant is dispersed towards the northeast of the point source. The highest concentration occurs at the distance of 400 to 600 m downwind of the plume (Figure 5a). The highest predicted SO_2 concentration was between 700 and 450 ug/m^3 varying the stack height from 20 to 150 m. Since the major population centers are located within 200 to 500 m towards the northeast of the source, then, potential SO_2 exposure to the populace is possible.

The results of the modeling exercise seemed to show that the predicted SO_2 concentrations were higher than the Malaysian guidelines limit of 350 ug/m^3 (1-hr averaging time) even if the stack height was raised to 150 m. The only exception was during the inter-monsoon period (April), where the maximum SO_2 concentration was predicted to be 300 ug/m^3. One important conclusion that can be derived from this modeling exercise is that increasing the stack height and at the same time changing to a less sulfur content fuel oil, will help to reduce the downwind ground level SO_2 concentration to an acceptable level.

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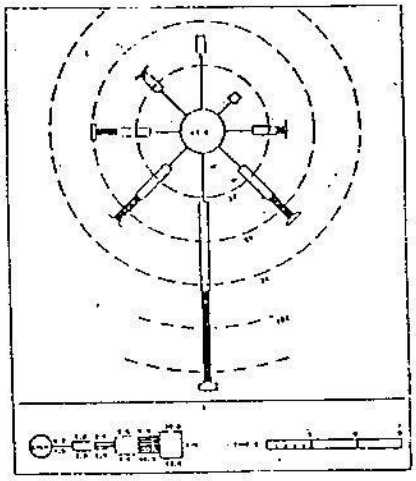

Figure 1a: Wind Rose for May-Sept

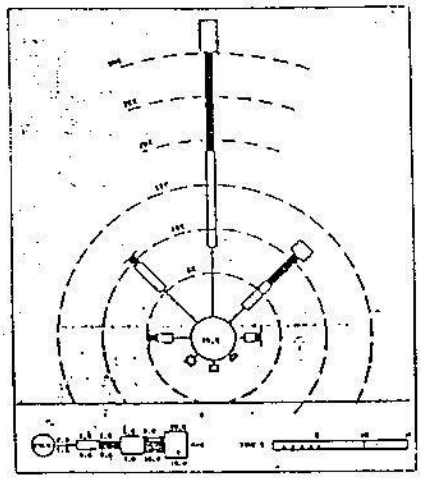

Figure 1b: Wind Rose for Nov-Mac

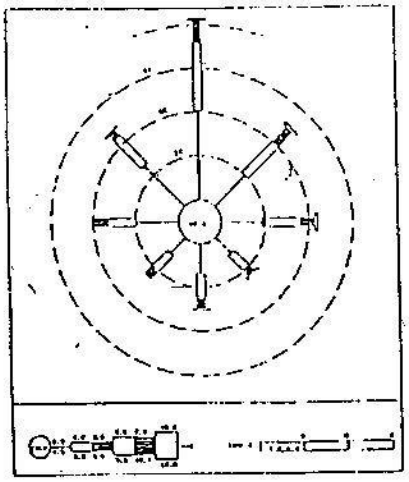

Figure 1c: Wind Rose for April

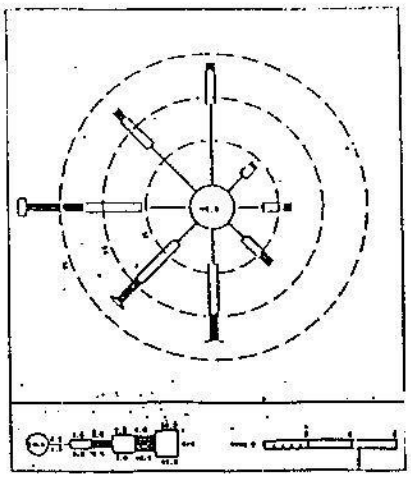

Figure 1d: Wind Rose for October

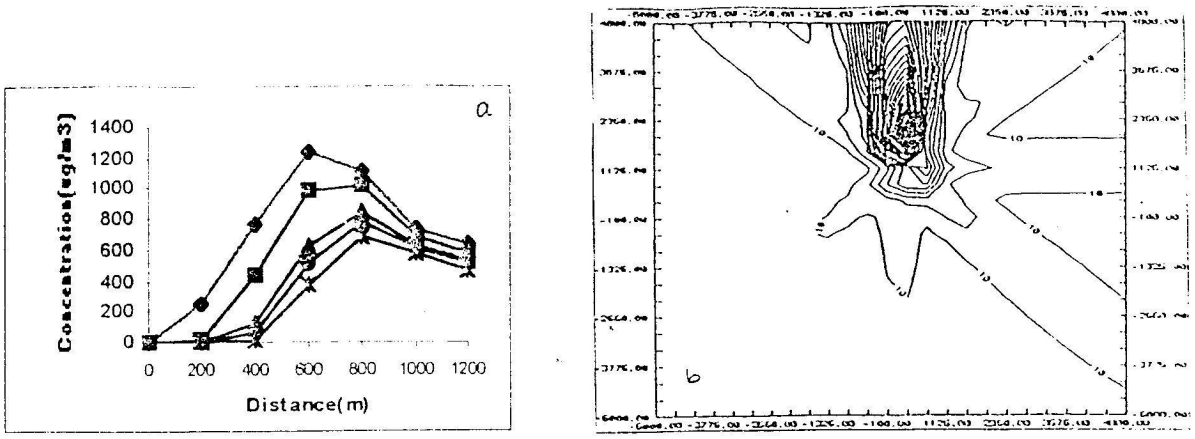

Figure 2 a,b : Estimated ground level concentration and dispersion of SO_2 in $\mu g/m^3$ for the month of May to September

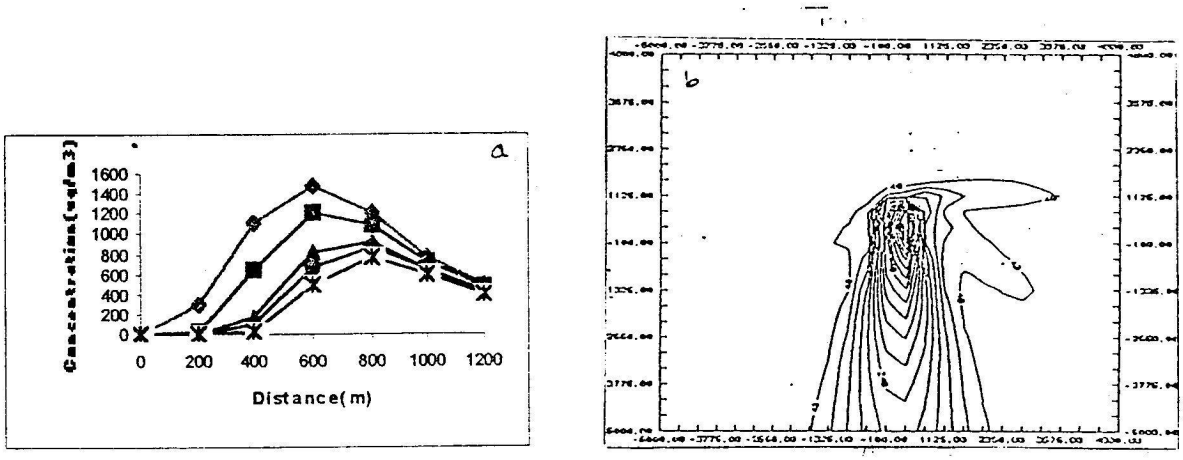

Figure 3 a,b: Estimated ground level concentration and dispersion of SO_2 in $\mu g/m^3$ for the month of November to March

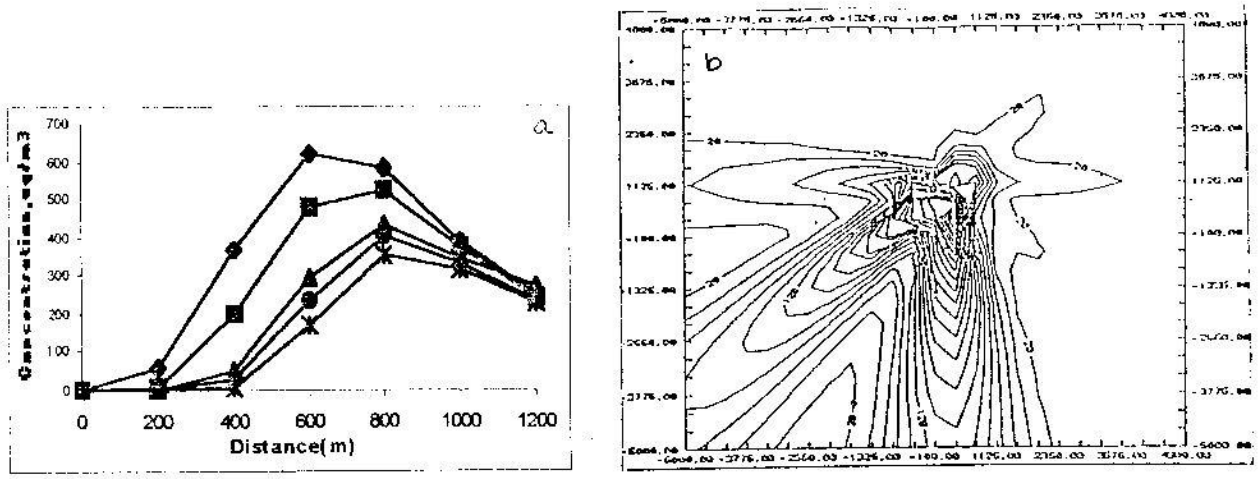

Figure 4 a,b: Estimated ground level concentration and dispersion of SO_2 in $\mu g/m^3$ for the month of April

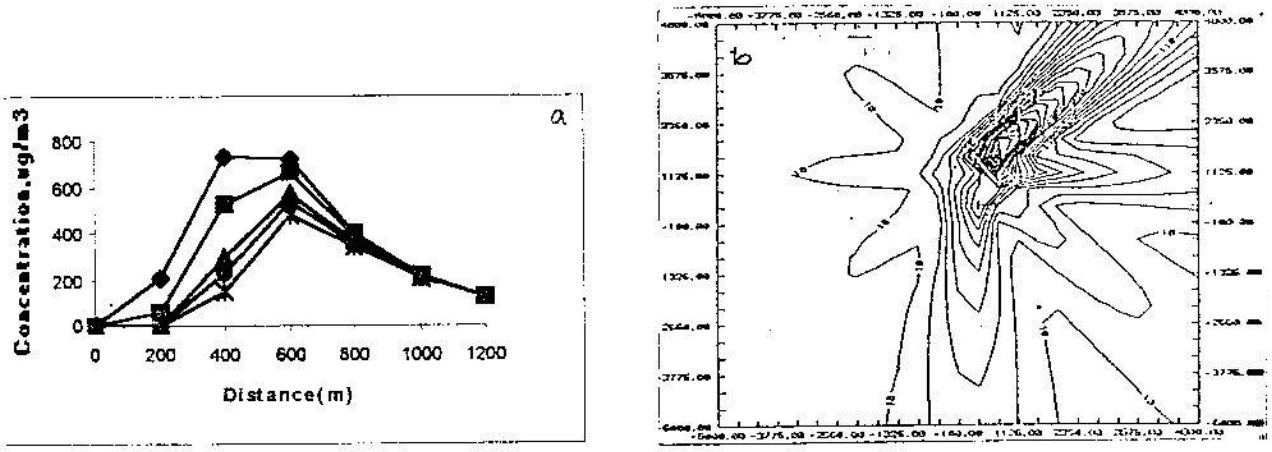

Figure 5 a,b: Estimated ground level concentration and dispersion of SO_2 in $\mu g/m^3$ for the month of October

Stack height

◆ = 20meter ● = 120meter

■ = 50meter ✳ = 150meter

▲ = 100meter