Air Assimilative Capacity for Sulfur Dioxide and Nitrogen Dioxide: Case Study the Eastern Region of Thailand

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Abstract—The assimilative capacity of the Eastern region, Thailand is estimated by using ventilation coefficient data and air quality model. Box model is used to predict the spatial and temporal distribution of two pollutants namely SO₂ and NO₂. Meteorological characteristic of the study area in the year 2010 was selected in the analysis. The results indicated that Tha-Takiap, Chachaengsao was the highest assimilative capacity of SO₂ and NO₂. Temporal variation of assimilative capacity of air pollution in the study area in which the highest carrying capacity was in November.

Index Terms—Air assimilative capacity, air quality model, ventilation coefficient.

I. INTRODUCTION

Development of industry significantly contributes to regional economic growth. However, Industrial development is one of the important causes of environmental problems which can be minimized if industrial development planning is done keeping in view the environmental considerations. At present, Industrial siting is being mainly planned keeping in view the raw material availability, access to the market, transport facilities and other related economic considerations without paying enough attention to environmental aspects, which are normally accepted as one of the significant criteria for siting of new industries. Improper siting of industries can seriously affect the environmental quality. Site selection based on environmental criteria with the purpose of minimizing adverse environmental impacts is a vital prerequisite. This is especially important when the proposed industry is air pollution in nature [1].

The Eastern region of Thailand is the most industrially developed region especially chemical industry and power plant which is important air pollution sources such as sulfur dioxide (SO₂) and nitrogen dioxide (NO₂) [2]. Pollution control focus on emission loads from the source that can be released will not exceed emission standard. The main point of pollution control management, although emission of all factories does not exceed the standard, the pollution emitted into the atmosphere excess air quality standards or not. (The area also has the atmospheric assimilation potential or not.)

The assimilative capacity of atmosphere is estimated through dispersion models in terms of concentration of pollutants. Box Model, dispersion models for area sources, is used to predict the spatial and temporal distribution of two pollutants namely SO₂ and NO₂. Details of this approach are presented through a case study carried out for the Eastern

region of Thailand. The air assimilative capacity environment is defined as the maximum amount of pollution load that can be discharged without violating the best designated use of the air emission resource in the planning region [3]. In this study, ventilation coefficient (mixing height and wind speed) is used as major meteorological input in the analysis.

II. RESEARCH DESIGN

This research aimed to estimate atmospheric assimilation potential in a district level for Eastern region of Thailand by using ventilation coefficient data and air quality model. Meteorological characteristic of the study area in the year 2010 was selected in the analysis. Carrying capacity of SO₂ and NO₂ were evaluated by using box model analysis.

III. DATA COLLECTION

A. Study Area

The study domain covered the Eastern region of Thailand (about 34,475 km²). The Eastern region consists of the 7 provinces as follows:

- 1) Chonburi
- 2) Rayong
- 3) Chanthaburi
- 4) Trat
- 5) Chachaengsao
- 6) Prachinburi
- 7) Sa Kaeo

Fig. 1. The geographical boundary of the study area.

Spatial data on a district level from each province were collected and used in the analysis. These data were achieved from GIS data, obtained from the Department of Provincial Administration, Ministry of Interior. The data used in the

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analysis were total area of the district and the length of district as measured in the northeast-southwest direction. The geographical boundary of the study area is as shown in Fig. 1.

B. Air pollutants Concentration Data

Air pollution is the presence of undesirable material in air, in quantities large enough to produce harmful effects. The undesirable materials may damage human health, vegetation, human property, or the global environment as well as create aesthetic insults in the form of brown or hazy air or unpleasant smells [7].

Most industry of the Eastern region of Thailand is chemical industry and power plant which is important air pollution sources especially SO₂ and NO₂. Therefore, the two air pollutants were studied in this research.

SO₂ and NO₂ ambient concentration measured in the year 2010-2012 from air quality monitoring station located in the Eastern region of Thailand were used in this study. These data were obtained from Pollution Control Department, Ministry of Natural Resources and Environment.

C. Meteorological Data

Wind speed and mixing height data which were used to calculated for ventilation coefficient were derived from a project carried out by Thepanondh in the year 2013 [4]. These data were predicted by using the WRF model. The spatial resolution of each grid cell was 50x50 km² covering the entire area of study domain as show in Fig. 2.

Fig. 2. WRF study domain of Eastern region.

Wind speed and mixing height from WRF Model were used to calculate for ventilation coefficient by using equation (1)

$$VC (m^2/s) = \text{Wind speed (m/s)} \times \text{Mixing height (m)} \quad (1)$$

Spatial analysis of ventilation coefficient was carried out by using the Geographical Information System (GIS). This data were further used to calculate for assimilative capacity of air pollution of the study area in this study.

IV. BOX MODEL

Box model has been used in environmental research. For example, carbon monoxide concentrations were monitored in a deep street canyon and were modelled using a two-box model [5]. Another research applies a fixed box model to

calculate the temporal variance of the concentration of PM10 in Thanh Xuan District, Hanoi [6].

The box model computes the air pollution concentration using general mass balance analysis principle. The model was used to estimate maximum emission load of area [7], by using this equation (2)

$$c = b + \frac{qL}{uH} \quad (2)$$

where

c = Pollutant concentration (g/m³)

b = Background pollutant concentration (g/m³)

q = Emission load (g/s m²)

L = Length of area (m)

u = Wind speed (m/s)

H = Mixing height (m)

The pollutant concentration (c) was set equal to 1 hour ambient air quality standard. Therefore, SO₂ was set as 780 ug/m³. As for NO₂ concentration; this value was set as 320 ug/m³.

Background concentrations (b) of SO₂ and NO₂ were set as ninety-five percentile of the measured concentration of this parameter in the area. Data used in analysis were from 2010 to 2012. SO₂ was set as 26.07 ug/m³. As for NO₂ concentration; this value was set as 50.59 ug/m³.

The ventilation coefficient which was calculated by multiplying wind speed and mixing height data were similar with the value, used in the box model equation (u and H). Therefore an emission load of pollutant could be calculated when background concentration, pollutant concentration and the length of area were known.

V. RESULTS AND DISCUSSIONS

A. SO₂ Emission Load

Results from the box model analysis indicated that there were spatial and temporal variations of carrying capacity of SO₂ emission in the study area.

Fig. 3. SO₂ Emission load of Chonburi.

In general, it was found that Chachaengsao province has the highest assimilative capacity of SO₂ as compared with other provinces. Temporal variation of the highest assimilative capacity was occurred in November. Details were as shown in Fig. 3- Fig. 9.

Fig. 4. SO₂ Emission load of Rayong.

Fig. 5. SO₂ Emission load of Chanthaburi.

Fig. 6. SO₂ Emission load of Trat.

Fig. 7. SO₂ Emission load of Chachoengsao.

Fig. 8. SO₂ Emission load of Prachinburi

Fig. 9. SO₂ Emission load of Sa Kaeo.

B. NO₂ Emission load

Results from the box model analysis indicated that there were spatial and temporal variations of carrying capacity of NO₂ emission in the study area.

Fig. 10. NO₂ Emission load of Chonburi.

Fig. 11. NO₂ Emission load of Rayong.

In general, it was found that Chachoengsao province has

the highest assimilative capacity of NO_2 as compared with other provinces. Temporal variation of the highest assimilative capacity was occurred in November. Details were as displayed in Fig. 10-16.

Fig. 12. NO_2 Emission load of Chanthaburi.

Fig. 13. NO_2 Emission load of Trat.

Fig. 14. NO_2 Emission load of Chachoengsao.

Fig. 15. NO_2 Emission load of Prachinburi.

Fig. 16. NO_2 Emission load of Sa Kaeo.

VI. CONCLUSIONS

The assimilation potential in terms of the emission load was been estimated for the Eastern region of Thailand using box model. The results indicated that the assimilation potential of the atmosphere is directly proportional to the ventilation coefficient and has been computed using meteorological parameters for each month of the years 2010.

Spatial analysis of these data displayed that the highest assimilative capacity of SO_2 and NO_2 was at Tha-Takiap, Chachaengsao. This area is high atmospheric dilution ability because there are large area and high ventilation coefficient.

The results showed that temporal variation of assimilative capacity of air pollution in the study area in which the highest carrying capacity was in November. This is due to the influence of the northeast monsoon resulting in high dilution ability of atmosphere during this time.

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