An Inventory of Primary Gaseous Emissions from Thailand with Spatial and Temporal Allocation Profile

CHATCHAWAN VONGMAHADLEK*, 1 PHAM THI BICH THAO1, BOONSONG SATAYOPAS2, NARISARA THONGBOONCHU3

1 The Joint Graduate School of Energy and Environment (JGSEE) 
King Mongkut’s University of Technology Thonburi (KMUTT) 
Bangkok 10140, THAILAND

2 Department of Civil Engineering 
Faculty of Engineering, Chiang Mai University (CMU) 
Muang, Chiang Mai, THAILAND

3 Department of Chemical Engineering 
Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang (KMITL) 
Ladkrabang, Bangkok, THAILAND

Abstract: - Thailand contains numerous anthropogenic and natural emission sources that can potentially cause air quality problem. It is important to develop representative emissions-related information for emissions abatement strategies. In this study, emissions inventory was developed, covering the key anthropogenic and natural sources in Thailand. Bottom-up approach and local specific information were applied to estimate the amount of emissions. Annual emissions were found as follows: 790.3 Gg of NO\textsubscript{x}, 886.0 Gg of SO\textsubscript{2}, 9,465.9 Gg of CO, 2,583.1 Gg of NMVOC, 439.2 Gg of NH\textsubscript{3}. To investigate emissions variation, spatial (i.e., 1 km x 1 km) and temporal (i.e., monthly, weekly, and diurnal) allocation profiles were developed. Results of this study are expected to be useful for emissions control strategies and thus, air quality management.

Key-Words: - Thailand; Emissions Inventory; Spatial allocation profile, Temporal allocation profile

1 Introduction

The rapid development in Thailand recently leads to air quality problem [1]. Such problem produces the harmful effect to not only environment but also human health [2]. Thus, it is important to have a good system of emissions on which air quality related workers as well as policy makers could base their assessment. In addition, Emissions Inventory (EI) in a proper format and detail is useful for use as input in air quality modeling and effective tool to simulate the distribution of air pollutants [3].

For large scale, several well-known EIs is included Thailand. They are Emission Database for Global Atmospheric Research (EDGAR) [4], Global EI Activity (GEIA) [5], TRAnsport and Chemical Evolution over the Pacific (TRACE-P) [6], and Regional Emission inventory in ASia (REAS) [7]. For local scale, EI has been developed through governmental projects or academic researches. For example, they are technical reports from the Pollutant Control Department, Thailand (PCD) [8], Department of Alternative Energy Development and Efficiency, Thailand (DEDE) [9], Department of Environmental Quality Promotion, Thailand (DEQP) [10] as well as academic thesis [11-14]. These developments have differently used according to purposes and methods of the development. However, those studies contain limitation in terms of adequate of species, domain, and the details needed, which are required as inputs in air quality model.

In this study, an up-to-date EI was developed for Thailand, which tends to take advantage information from local and site-specific sources. The work includes multiple gaseous species, which are NO\textsubscript{x}, SO\textsubscript{2}, CO, NMVOC, and NH\textsubscript{3}. Spatial and temporal allocation profiles are also investigated so that emissions would be prepared in the forms ready to input in the air quality modeling. The results of this work are expected to be useful for assessment and implication of multiple-specie problems (such as
photochemistry or acid deposition) or understand the emission contributions of single specie.

2 Methodology

Emissions of particular species can be calculated by using US EPA method [3] 1) products of the activity rates, the uncontrolled Emission Factors (EFs), and the removal efficiency of applied emission abatement technology or 2) products of the activity rate and controlled EFs only (Eq. 1)

\[ E = EF_{woc} \times A \times (1 - ER) = EF_{wc} \times A \]  

(1)

where,

- \( E \) : Emission rate,
- \( E_{woc} \) : EF without control technology,
- \( E_{wc} \) : EF with control technology,
- \( A \) : Activity rate, and
- \( ER \) : Emission reduction efficiency (%).

Information related to activity rate \( (A) \) was obtained from governmental departments and independent studies of Thailand [9, 11, 15-19]. Most of them are publicized in technical reports, database files, or websites. Emission factors (EF) were taken from either local site specific [12, 14, 20-22] or foreign studies [3, 19, 23, 24]. Emission reduction (ER) was applied for some type of known emission sources (i.e., power plant and large industries).

In this study, emission sources were classified into two types, i.e., anthropogenic and natural sources. The summary of emission sources are listed in Fig.1. Anthropogenic emissions, defined as emissions caused by human activities, include three main types following by the characteristics of emission source: industrial stationary, mobile, and non-industrial stationary sources. Beside anthropogenic source, natural emissions are an important source for determining the composition in the atmosphere. In this study, the major component consists of the contribution from vegetation, lightning, and soil.

Spatial Allocation Profiles (SAPs) are important in which emissions are allocated according to their sources. As an input to air quality modeling, grid maps of emission distribution are required. Thus, emission sources were rearranged into two types: mobile sources as line and the rest as area sources. Geographical Information System (GIS) and spreadsheet application were used to estimate the amount of emission and perform emission merging and aggregating of grid-based EI.

Temporal Allocation Profiles (TAPs) are also important to present the variation of emissions by time (i.e., year, month, day, and hour). TAPs can be calculated using the activity rates of relevant emission sources per fraction of total time. In this study, TAPs of industrial sources were merged profiles from industrial facilities and power plants. TAPs for line sources were derived from on-road emissions only and those for area source were resulted from single biomass burning source.

3 Results and discussion

An annual emission for the year 2005 was estimated as follows: 790.3 Gg of \( \mathrm{NO}_x \); 886.0 Gg of \( \mathrm{SO}_2 \); 9,465.9 Gg of \( \mathrm{CO} \); 2,584.3 Gg of NMVOC; 439.2 Gg of \( \mathrm{NH}_3 \), which anthropogenic sources account for ~92.5%-99.9% of total. Natural sources are significantly large amount for NMVOC (53.5%) and \( \mathrm{NO}_x \) (7.5%). Fig. 2 provides GIS coverage of emissions. As seen, \( \mathrm{NO}_x \), \( \mathrm{SO}_2 \), \( \mathrm{CO} \), and emissions were high in urban area, especially in the location of industrial estates, power plants, and on-road network (i.e., Central and Eastern regions). \( \mathrm{NH}_3 \) is high in the agricultural and farming areas (i.e., Eastern and Western regions). NMVOC is found to be high in the area of forests and fields (i.e., Northern and Western regions).

Figs. 3 show the result of TAPs in monthly, weekly, and diurnal profile classified by point, mobile, and area sources. For monthly industrial stationary emissions peaked on Mar. (8.9%) and Oct. (8.6%) for preparation product before summer and winter time. April shows the lowest fraction due to a long holiday (7.8%) in this month. Mobile emissions are peaked during Mar.-May (8.8% in average) and Jul.-Sep. (8.7% in average). Area emissions are peaked on Feb.-Mar. (8.7% in average) due to the preparation activity before season of planting crops. For weekly, both industrial and mobile emissions have large differences between weekday and weekend, which are 4.1% and 6.2%, respectively. On the other hand, area emissions are higher in weekend (with the peak of 15.7% on Sat.) due to the presence of burning activity at this time. For diurnal, due to the lack of data, only trends of industrial and mobile emissions were considered. For industrial sources, emissions were high during 8:00-11:00 (8.3% in average) and 13:00-16:00 (6.6% in average), similar to the industrial working patterns. For mobile sources, emissions were high during rush hour, i.e., 8:00-10:00 (6.1% in average) and 16:00-18:00 (5.5% in average). It is noted that traffic during rush hour is
always dense and driving pattern with low speed, which release high amount of emissions.

4 Conclusion and recommendation
EI of NO$_x$, SO$_2$, CO, NMVOC, and NH$_3$ from anthropogenic and natural sources of entire Thailand were estimate and presented. The developed EI is intended to assist air quality workers and researchers to have a more complete image of emissions with respect to emission species, emission loading, spatial distribution, and temporal distribution to support air quality management as well as modeling for criteria air pollutants in Thailand in a more integrated manner. In a most direct way, the results found here provide the basis of background emissions for local and regional air quality studies in Thailand. A high-resolution 1 km x 1 km was chosen for emission mapping. A number of temporal allocation profiles were developed to account for the temporal characteristics of emissions. Emissions found in this work and reported in some past studies were also compared, showing that the results found here have fair agreements with those of the past studies for many species considered.

Some limitations of this work are (1) Lack of local EFs, EFs used in this work are mostly from foreign sources (2) Fugitive NMVOC is not included due to the lack of data. Recommendation for future improvement are given as follows: (1) Seek for domestic EFs better representative of various emission sources in Thailand, (2) Enhance the estimation process of activity rates to reflect more realistic nature or conditions of emissions. (3) Develop aerosol species (i.e., PM$_{10}$, PM$_{2.5}$, OC, and BC).

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Figure 1. Emissions Source and its Development
Figure 2. 1 km x 1 km of spatial distribution of gaseous pollutants over Thailand for the year 2005
Figure 3. Temporal profiles classified by average source types for the entire Thailand.