Carbon Monoxide Emission and Concentration Models for Chiang Mai Urban Area

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(Received 9 January 2006; revised 13 June 2006)

ABSTRACT

An emission inventory containing emissions from traffic and other sources was compiled. Based on the analysis, Carbon Monoxide (CO) emissions from traffic play a very important role in CO levels in Chiang Mai area. Analysis showed that CO emissions from traffic during rush hours contributed approximately 90\% of total CO emissions. Regional Atmospheric Modeling System (RAMS) was applied to simulate wind fields and temperatures in the Chiang Mai area, and eight cases were selected to study annual variations in wind fields and temperatures. Model results can reflect major features of wind fields and diurnal variations in temperatures. For evaluating the model performance, model results were compared with observed wind speed, wind direction and temperature, which were monitored at a meteorological tower. Comparison showed that model results are in good agreement with observations, and the model captured many of the observed features. H\textsuperscript{Y}brid Particle And Concentration Transport model (HYPACT) was used to simulate CO concentration in the Chiang Mai area. Model results generally agree well with observed CO concentrations at the air quality monitoring stations, and can explain observed CO diurnal variations.

Key words: carbon monoxide, emission, concentration, Chiang Mai, RAMS, HYPACT


1. Introduction

Carbon Monoxide (CO) is a highly toxic gas, which is considered a dangerous asphyxiant. Combined with haemoglobin of the blood it reduces the blood’s ability to carry oxygen to cell tissues; high CO mixing ratio can directly affect human health. The oxidation of CO initiates photochemical reactions, which result in Ozone (O\textsubscript{3}) production on a regional scale (Novelli et al., 1998). In cities, almost all of the CO is anthropogenic due to vehicle emission and fossil fuel combustion. Natural sources, such as forest fire and biomass burning, also produce huge quantities of CO. Pochanart (2003) studied surface CO variations from measurements during 1997–2000 in rural Thailand. The CO mixing ratios in Thailand show a strong seasonal variation with a maximum in the late dry season (February–March) and a minimum in the mid-wet season (July–August). In this study CO emission and dispersion on a local scale in Chiang Mai (18°78N, 98°38E, 312 meters above sea level) are studied. Chiang Mai is an important city for the regional administration, business, education, medical and is well known as a tourist and cultural city. Due to economic growth, Chiang Mai is facing environmental problems, especially the air pollution problem. Because of traffic congestion most vehicles emit many types of toxic gases. Pollutants from the internal combustion process consist of Carbon Monoxide, Sulfur Dioxide, Nitrogen Dioxide, Hydrocarbons, and Lead etc. This study concentrated on CO which was emitted from traffic, industrial processes, airport, railway station, forest fire, fuel consumption and open burning. There are only 2 ambient air pollution monitoring stations, one in an urban area and the other in a suburban area, which do not cover the whole study area.

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The CO concentration at particular locations and particular times can be known by measurement. But to understand the air pollutant behavior in the environment, it requires the air pollution model for predicting the concentration of CO, which is important for making the environmental abatement regulation.

Up to now there have been many scientists (Schatzke, 1991; Hao et al., 2000; August et al., 1995; Bogo et al., 2001; Goyal and Rama Krishna, 1998) that have estimated the pollutants from vehicular traffic, such as CO and NO\textsubscript{2}. Tang (2002) used the MM5 and the regional Eulerian chemical transport model to simulate the pollutant emission at urban sites and power plants in Nashville, Middle Tennessee. Boybeyi and Raman (1995) constructed a three-dimensional mesoscale meteorological model based on coupling a mesoscale meteorological model with a Monte Carlo (Lagrangian particle dispersion model) plus embedding an Eulerian dispersion model into the mesoscale meteorological model, which applied to the Tennessee Plume field experiment. Sauto et al. (2001) compared the results of a Lagrangian Particle Model (LPM), and an adaptive Puff Model (APM) coupled to the same meteorological model to study the dispersion of pollutant (SO\textsubscript{2}) from coal-fired As Pontes Power Plant in Spain.

This paper consists of a CO emission inventory study from various sources relevant to the Chiang Mai city in 2002, including wind fields study by using the Regional Atmospheric Modeling System (RAMS), and time spatial distribution of CO concentration over Chiang Mai city by using HYbrid Particle And Concentration Transport model (HYPACT).

2. CO emission inventory

Most CO in urban areas is generally emitted from the traffic activities in the transportation network. Therefore, this study focused on the emitted CO from the traffic source.

2.1 CO from traffic

The magnitude of vehicle emission rate is estimated by using emission factors, which vary by vehicle class, traffic volume and traffic speed in specific areas. This study adopted the Mobile-THAI model, which is based on the US EPA Mobile4 for predicting the vehicular emission factor. The traffic flow can be measured in various ways. The most accurate way is to count the number and detect the speed of vehicles passing a specific location mechanically or manually but is labor intensive and costly. Nevertheless, it is not realistic to count traffic volume on all roadways; therefore, TRANSPORT PLANNing model, TRANPLAN, was adopted for estimating the traffic flow in this study. For a road link, the total CO emission rate can be computed by multiplying the emission rate with the traffic volume. The traffic emission rate can be estimated by using the formula:

$$ Q = EV $$

where $Q$ is traffic emission rate, $E$ is emission factor, $V$ is traffic volume.

2.2 CO from other sources

The other sources emission rates were determined by the US EPA emission factors.

3. Model used

In this study the Regional Atmospheric Modeling System (RAMS) was used to calculate the meteorological data set, which includes temperature, and wind fields covering the domain 18.3°N to 19.7°N and 98.4°E to 99.5°E, with the resolution 2000 m x 2000 m in the horizontal and 50 layers in the vertical up to 1000 m. For calculation of the CO concentration and dispersion the Hybrid Particle And Concentration Transport model (HYPACT) was used.

4. Model test

The meteorological data set for input into RAMS are taken from the European Center for Medium range Weather Forecasts (ECMWF), which 8 cases, i.e., May 2002–August 2002 were selected as the case study to represent the local wet season and February 2002–April 2002 and December 2002 were selected as the case study to represent the local dry season. The HYPACT calculated CO concentration and distribution by using meteorological data set from RAMS and CO emission rates from emission inventory results.

5. Results

5.1 Emission inventory

5.1.1 CO emission rate from traffic

The output from TRANPLAN showed that in the urban area, especially the areas that generate and attract trips, the traffic volumes were higher than the other areas. But the traffic speeds were lower than the other areas. The forecasted traffic volumes and traffic speeds from the TRANPLAN model were combined with the emission factors from the Mobile-THAI; the results of this methodology are the CO emission rates from traffic. In order to conveniently incorporate data into the HYPACT, the CO emission rates from traffic were transformed into spatial grids. The Chiang Mai urban area was divided to 100 grids of 1 km x 1 km in each grid. Consequently, the CO emission rates in each