Health Risk Assessment of Industrial Emissions in Map Ta Phut, Thailand using AERMOD modeling

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Abstract. Health risk assessment of air emissions from Map Ta Phut industrial complex in Thailand was carried out. Two gaseous pollutants, NO_2 and SO_2 were assessed for non-carcinogenic health risk by Hazard Quotient (HQ) and Hazard Index (HI). Both short-term and long-term health effects were evaluated. Air dispersion modeling (AERMOD) was used to predict the ground level concentration within 5 km radius of the emission sources. The risk areas were identified by HI and the impact sites were illustrated by Geographic Information System (GIS).Resultingfrom GIS –based map, the impact areas were different between wet and dry season.In the long term annual average, both NO_2 and SO_2 significantly have health impact in the studied areas, HI > 1.

Introduction

The Map Ta Phut Industrial Estate (MTPIE) in eastern seaboard region of Thailand is the largest industrial complex in Thailand, located at 12°30'N and 101°35'E, in, Map Ta Phut Municipality, Rayong Province. It was established in 1989 and initially consisted of four major categories of industry namely gas separation plants, petrochemical plants, fertilizer plants and soda ash plants. The industrial area covers more than 10 square kilometers with 52 large-scale industrial plants and, out of them, 32 factories are petroleum-related industry [1]. Map Ta Phut Municipality, total area of 165.575 km^2 was comprised of 38 communities around the MTPIE and has a registered population of 53,901 [2].There were several reports on air pollution exposure and health effects in Map Ta Phut[3,4,5]. The epidemiologic studies showed statistical associations between levels of air pollution and respiratory disorders of residents in petrochemical complex areas. Living near the MTPIE was associated with an increased risk of wheezing and upper respiratory symptoms [3,4].

The health impact of air pollution from industrial emission has been increasing concerned, particularly among the residents living near sources. The industrial combustion has been known to emit various pollutants such as SOx, NOx, CO_2 , dioxins, acid vapor and heavy metal [6]. This work, we focused on two primary pollutants, NO_2 and SO_2 because of their potential health effects [7]. NOx is emitted from combustion processes in which both mobile and point sources are major emission sources [6]. Most atmospheric NO_2 is initially emitted as NO, which is rapidly oxidized to NO_2. Regular exposure to NO_2 might cause an increased incidenceof acute respiratory illness in children and other sensitive groups [7].The current WHO guideline value of 40 $\mu g/m^3$(annualmean) and 400 $\mu g/m^3$ (1 hr mean) were set to protect the public from the health effects ofgaseous NO_2. The short term exposure to SO_2 can effect to lung function and resipirtory system including the reductions in the mean forced expiratory volume over one second (FEV1), increases in specific airway resistance, and symptomssuch as wheezing or shortness of breath. WHO guideline value for SO_2 was 125 $\mu g/m^3$ for an averaging 24 hours and 50 $\mu g/m^3$ as an annual mean[7].

In this study, AERMOD was used as a tool to predict ground level concentrations of NO_2 and SO_2 for Health Risk Assessment (HRA) in an industrial complex. This aimed to identify the hazard risk areas among receptor sites near industrial sources. Both short-term and long-term health effects were expressed as Hazard Quotient (HQ) and Hazard Index (HI).The risk areas were identified by different HI and the impact sites were illustrated by Geographic Information System (GIS) based maps.

Methodology

Study sites

The study was conducted in three districts in Rayong province, Banchang, Huaipong and Map ta phut. The areas covered 243 stacks MTPIE emission sources and eight impact communities (R1-R8) within 5 km around industrial complex. R1-R8 risk areas are school temple hospital and government office, namely, R1 Wat Nong Fapschool, R2 Map chalut temple, R3 Field crops research center, R4 Muang Mai Map ta phut, R5 Chumchon Islam, R6 Health Promotion hospital, R7 Ban Takuan Public health center and R8Takuan temple. The details of studied sites were shown in Fig. 1.

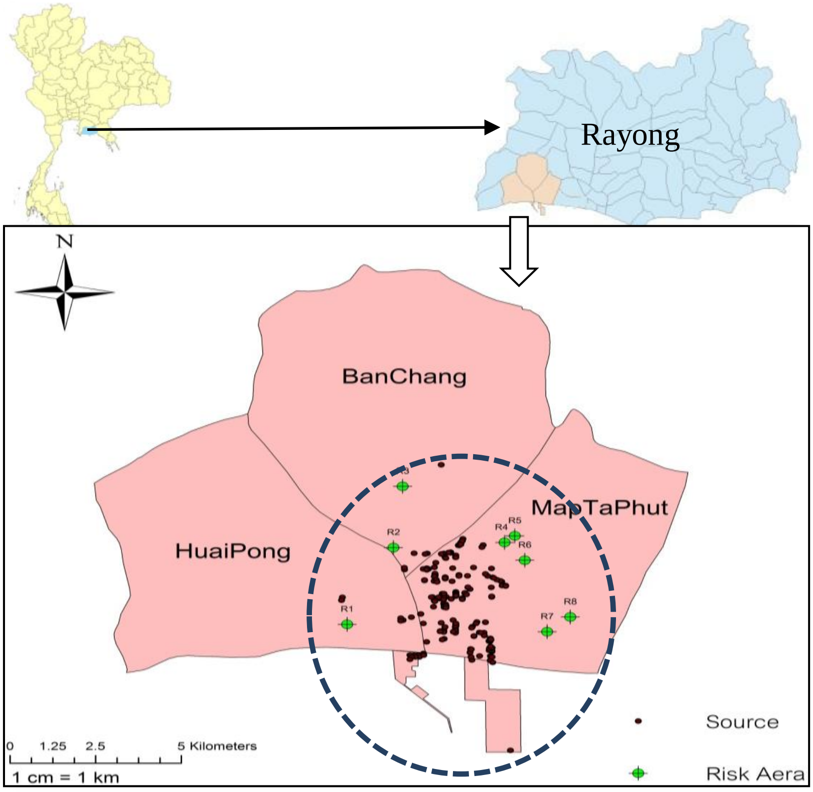

Figure1.The studied area showing eight impact communities R1-R8 ● , stack emission sources ●

Air dispersion modeling

The American MeteorologySociety-Environmental Protection Agency Regulatory Model (AERMOD) modeling system used in this study was run with a commercial interface,AERMOD View (Version 8.8.9) (Lakes Environmental Software). The steps involved in AERMOD modeling are shown in Fig. 2. The required meteorology data for AERMOD including wind direction, wind speed, ceiling height, total cloud cover, direct normal radiation, relative humidity, etc. this data was also purchased from Lakes Environmental Software.The input data, emission inventory from 243 stacks in MTPIE were provided by the Office of Natural Resources and Environmental Policyand Planning (ONEP), the Ministry of Natural Resourcesand Environment of Thailand.

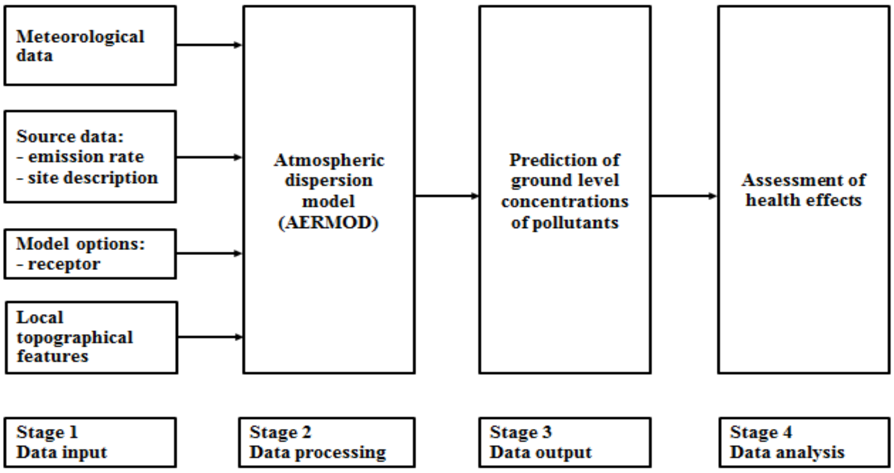

Figure 2. Flow in AERMOD modeling system

AERMOD is based on the steady state Gaussian dispersion equation. If the ground is taken to be the reference height (*z=0*), with the *x* axis of the co-ordinate system aligned along the wind direction at the source, empirical evidence indicates that the time averaged (typically one hour) concentration field can be described in terms of the Gaussian distribution. In this study, the pollutants ground level concentrations were generated from AERMOD by equation 1.

$$C(x,y,z) = \frac{Q}{u} P_y\{y;x\} P_z\{z;x\} \quad (1)$$

Where: Q is the source emission rate, u is the effective wind speed, Py and Pz are the probability density function (pdf) for the lateral and vertical concentration distributions, respectively.

Health risk assessment (HRA)

Inhalation Exposure concentration (EC_{inh}) is quantified as described in equation 2.

$$EC_{inh} = C \times ET \times EF \times ED / AT \qquad (2)$$

Where: C: concentration of each pollutants: NO_2 and SO_2 ($\mu g/m^3$) were predicted from AERMOD; ET: exposure time (24 hours/day); EF: exposure frequency (350 day/year); ED: exposure duration (30 years); AT: average time (for non-carcinogens, AT = ED in years × 365 days × 24 hours/day; for carcinogens, AT= 70 years × 365 days × 24 hours/day).

For non-carcinogenic health riskdue to inhalation, risk characterization is performed by quantifying the hazard using Hazard Quotient (HQ) equation (3) which is definedas followsUSEPA method [8];

$$HQ = EC / RfC \qquad (3)$$

$$HI = \sum HQ \qquad (4)$$

Where: EC = exposure air concentration ($\mu g/m^3$); RfC = referenceconcentration ($\mu g/m^3$)

HQ of less than one (HQ < 1) indicates that pollutant con-centration is below the reference concentration (RfC) value,whereby, the potential risk is within acceptable level withno action required to reduce the pollutant's level. Therefore,HQ < 1 is considered safe. Nevertheless, it should be noted that HQ > 1 does not necessarily suggest a likelihood of adverse effects [9].According to

EPA's Integrated Risk Information System report, RfC of NO_2 and SO_2 are not available [10] so we used WHO guideline values [7] to calculate HQ by equation (3). To define the risk areas of NO_2 and SO_2, hazard index (HI) is calculated from the sum of HQ, equation (4). It is used to assess the overall potential for non-carcinogenic defects posed by more than one chemical. HI <1 indicates that there is no significant risk of non-carcinogenic effects. Conversely, HI >1 indicates the chance of non-carcinogenic effects occurring, with a probability of increasing health risk [9].

Results and discussion

The modeling results

Predicted ground level concentrationsfrom AERMOD were validated against measurement values in 2013 elsewhere [11]. Both NO_2 and SO_2 predicted values were found Index of agreement, 0.99, compared with measured data. The maximum concentrations were found lower than the ambient air quality standard and WHO guideline values as summarized in Table 1. The short term seasonal variation of HQ, the predicted concentrations in February was selected as a dry season exposure and the concentrations in July were represented for wet season.

Table 1.Predicted maximum ground level concentration compared with WHO guideline values and The National Ambient Air Quality limit.

Pollutant	Short – term concentration (µg/m^3)		Short – term concentration WHO Guideline (µg/m^3)	Long – term concentration (µg/m^3)	Long – term concentration WHO Guideline (µg/m^3)	Annual ambient air quality limit (µg/m^3)
	Dry season	Wet season				
SO_2	49.65	46.34	125	38.88	50	100
NO_2	22.85	54.66	400	31.89	40	57

The Map Ta Phut area is influenced by the sea wind, which sweeps from southwest to northeast with a wind speed typically below 6 m/s, Fig. 5d. However, there is some changing with occasional wind from the north into the area from October to December and the wind direction comes from the south to the area in February-April. In wet season, the wind blows from southwest into the area in community and MTPIE from June to September. Fig. 3a, 3b showed SO_2 dispersion on 1-h and annual average and Fig. 4a, 4b showed NO_2 dispersion on 1-h and annual average. For short term 1 hour average, SO_2 Fig. 3a and NO_2 Fig. 4a in area R1, R2 and R3 were found exceeded WHO guidelines. For annual average concentration, both SO_2 and NO_2 in all sites were lower than annual WHO guidelines.

Health Risk Assessment

The HQs of NO_2 and SO_2 are computed to determine the short-term (1-h) and long-term (annual) non-carcinogenic health risks. All sites have HQ < 1 which could mean no potential adverse health effects exist during short term dispersion. The long term annual results are within acceptable level of pollutant concentration with HQ less than one. However, high HQs in three sitesR4, R5 and R6 were found in both short term and long term cases.

The hazard index (HI) of short term were lower than 1 but for the annual long term R4, R5 and R6 in Maptaphut district were more than one, 1.51, 1.27 and 1.25 respectively. A potential for adverse health effects exists during longterm dispersion of NO_2 and SO_2. The risk areas were identified by different HI and the impact sites were illustrated by GIS-based maps in Fig. 5. The impact sites were different between wet and dry season. This could due to the wind speed and direction changed.

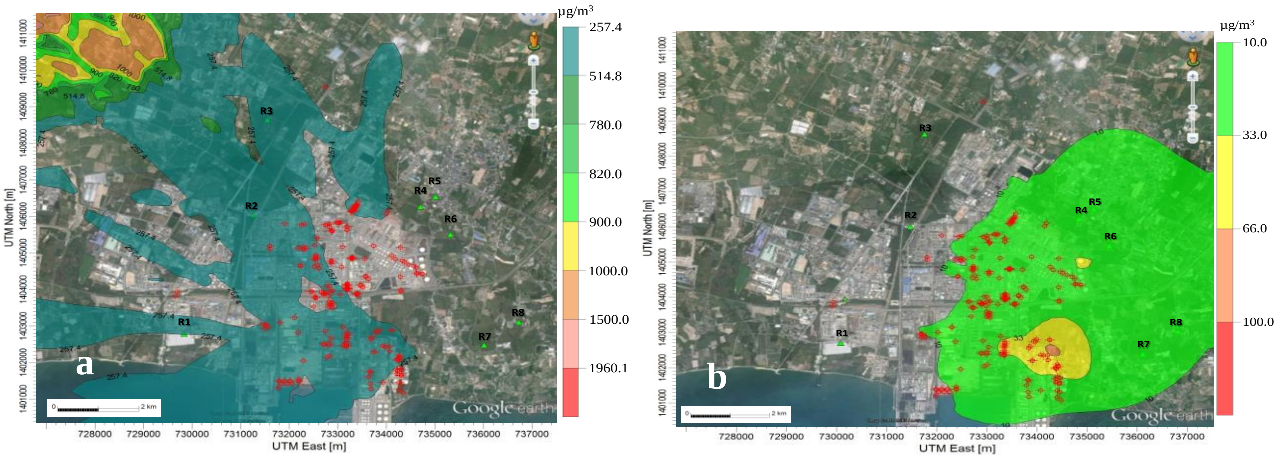

Figure 3 Dispersion of SO_2over MTPIE and 5 km vicinity areas
a. 1 hour average SO_2 b. Annual average SO_2

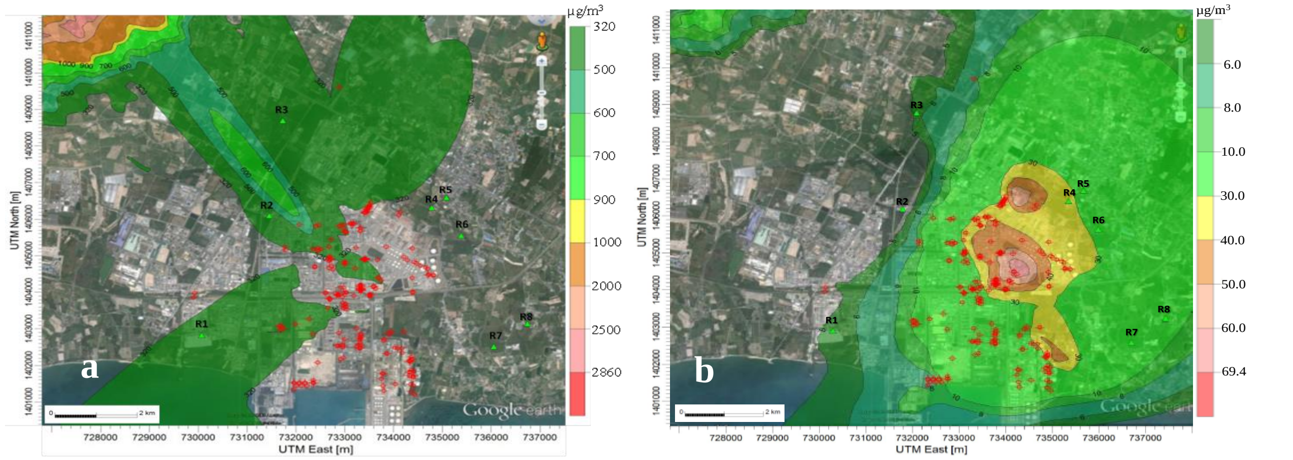

Figure 4 Dispersion of NO_2 over MTPIE and 5 km vicinity areas
a.1 hour average NO_2 b. Annual average NO_2

Summary

Health Risk Assessment was conducted in an industrial site complex. With a wide area and a number of stak emission, air dispersion modeling is suitable for these tasks. Although the short term, HQ and HI were found less than 1 but in the area near sources at Map Ta Phut district could be further monitored. In the long term from annual average, both NO_2 and SO_2 significantly have health impact in three studied areas R4, R5, R6. The risk areas were identified by different HI and the impact sites were illustrated by Geographic Information System. The GIS-based map can be appliedd in decesion making process in environmental mangement policy.

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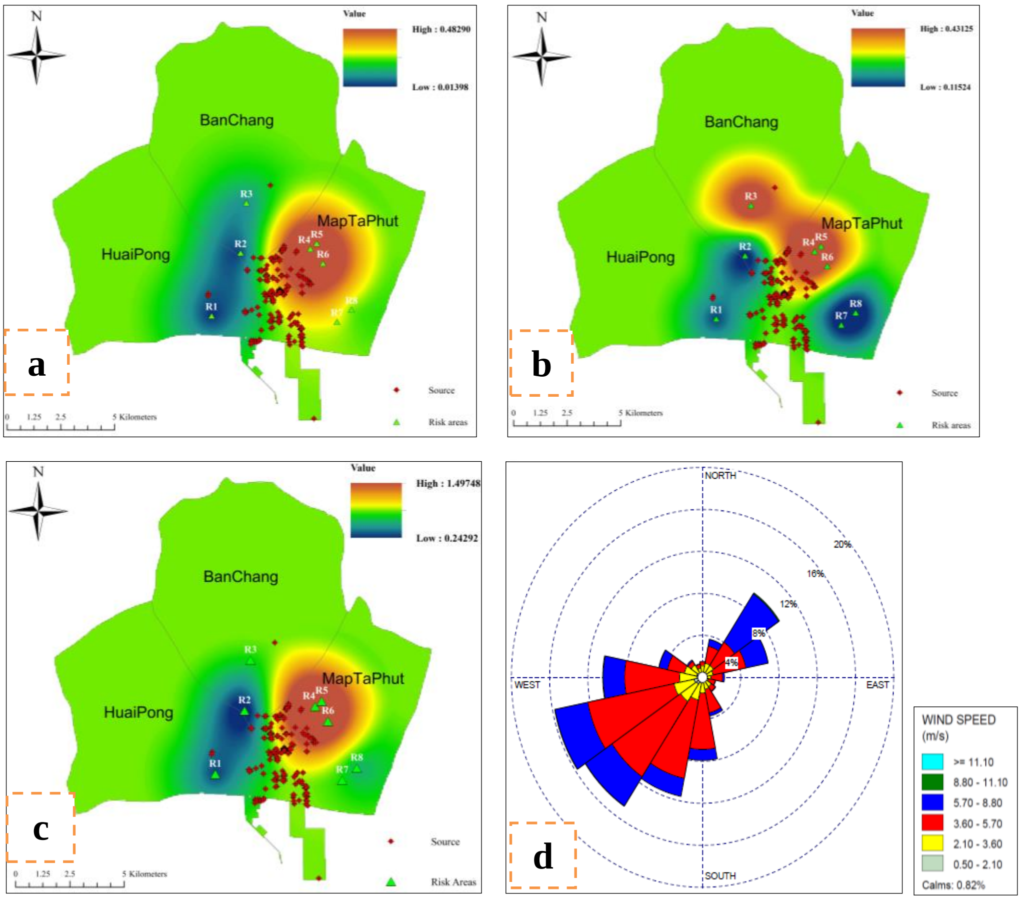

Figure 5 Site Distribution of HI and windrose: a. short term wet season, b. short term dry season, c. long term annual d. annual average windrose

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