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Executive Summary Report

Study of Air Pollution Management for Sustainable Development in Map Ta Phut Industrial Area

September 2020

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Study of Air Pollution Management for Sustainable Development in Map Ta Phut Industrial Area

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Study of Air Pollution Management for Sustainable Development in Map Ta Phut Industrial Area

The Eastern Economic Corridor (EEC) Office has assigned United Analyst and Engineering Consultant Co., Ltd. (the Company) as the Consultant for the Study of Air Pollution Management for Sustainable Development in Map Ta Phut Industrial Area (Contract Number EEC043/2019 dated 30 September 2019). The descriptions and summary are as below.

1 Background

The National Environment Board (NEB) resolved at the meeting number 6/2007 on 6 April 2007 to approve the Environmental Impact Assessment Report for new projects or expansion of production capacity in Map Ta Phut Sub-district and Huai Pong Sub-district, Mueang Rayong District, and Ban Chang Sub-district (only in Asia Industrial Estate), Ban Chang District, Rayong Province. This effort aimed to be used as the guideline for considering the environmental impact assessment report for industrial and energy projects. Under such a principle, new projects or expansion of production capacity will be permitted with allowable emission rates of Nitrogen Oxide (NO_x) and Sulfur Dioxide (SO_2) not more than 80% of the pollutant volume eased by the principle for easing the pollution emission ratio of 80:20. Based on this principle, the current pollution emission rate (January 2018) from the industrial and energy sources in Map Ta Phut was lower than in 2007 (the year in which the easing principle of 80:20 was adopted in this area). More precisely, the emission rate of NO_x dropped by 18% (around 447 g/s) from 2007 to 2018, with the emission rates of 2,480 and 2,033 g/s, respectively, and that of SO_2 was dropped by 27% (around 660 g/s) from 2007 to 2018, with the emission rates of 2,398 and 1,737 g/s, respectively.

Based on the above data, the air pollution emission rate in Map Ta Phut today has dropped so significantly that it might be able to expand the industrial area in Map Ta Phut. However, this 80:20 principle may require a reduction of the pollution emission of the existing projects before expanding the production capacity or launching new projects. This could be done by applying the emission offset of the existing projects or the emission trading of other projects to expand production capacity or launching new projects. Business operators who have several projects in the area might have no problem doing the latter in practice, but new players who do not have any project in the area might not be able to use the emission offset or even the emission trading method; there might not be other business operators to offer the trade. This limitation is the obstacle for new business operators to establish new projects in the area. Therefore, it is important for EEC Office, in collaboration with The Office of Natural Resources and Environmental Policy and Planning (ONEP), to examine the current pollution emission rate, review the principle and the method for pollution emission management, as well as revise the policy so that Map Ta Phut has a clearer and more sustainable industrial development for its unique context.

1.1 Objectives

2.1 To investigate, collect data, and make a database of emission and reduction of air pollutants NO_x and SO_2 according to the principle of 80:20 and the database of Volatile Organic Compounds (VOCs) (particularly Benzene, 1,3-Butadiene) from factory sources in Map Ta Phut or pollution-control area that applies the pollution emission reduction rate of 80:20

2.2 To analyze the strength, weakness, opportunity, and threat for using the 80:20 principle in practice in the past and the capacity for industrial expansion in the area and new suitable industries for Map Ta Phut Area, and propose the policy (e.g., principle for choosing air pollution emission management) for a suitable reform in terms of profitability and sustainability of the area

2.3 To educate government personnel on how to use air modeling systems such as AERMOD properly and have AERMOD in their office.

1.2 Implementation period

The Company has 270 days to complete this task, starting from 1 October 2019 to 26 June 2020. However, the pandemic of Coronavirus Disease 2019 (COVID-19) is a force majeure that makes the Company unable to complete the activities as planned. Therefore, the implementation and AERMOD workshop training has been expanded for another 90 days until 24 September 2020.

1.3 Scope of the study area

The scope of the study area is within Map Ta Phut pollution control zone in Rayong Province as per the notification of the NEB No. 32 (2009) re: determining the entire area of Map Ta Phut Sub-district, Hua Pong Sub-district, Noen Phra Sub-district, and Thap Ma Sub-district of Mueang Rayong District, Map Kha Sub-district of Phanat Nikhom District, Ban Chang Sub-district of Ban Chang District, Rayong Province, along with the seashore in these administrations as pollution control areas dated 30 April 2009. The land use was determined as per the notification of the EEC Board of Committee re: the map of land use and map of utilities and infrastructure in the EEC 2009 announced in the Government

Gazette on 9 December 2009 as shown in **Figure 1.** The data were derived from compilation of pollution sources in Map Ta Phut pollution control area by relevant government agencies and state enterprises, including the environmental impact assessment report (EIA), the environmental impact mitigation measures and monitoring measures (EIA monitoring report) from ONEP, the Initial Environmental Examination Report (IEE) by the Industrial Estate Authority of Thailand (IEAT), and the results of measuring relevant environmental indicators by the Pollution Control Department.

Map Ta Phut pollution control area in Rayong has a total area of 416.70 square kilometers (114.3 sq.km. in the sea and 302.4 sq.km. in land). There are five industrial estates in this area, including Map Ta Phut Industrial Estate, WHA Eastern Seaboard Industrial Estate (Map Ta Phut), Pha Daeng Industrial Estate, Asia Industrial Estate, and RIL Industrial Estate, and one industrial port known as Map Ta Phut Industrial Port. Most factories in the industrial estates operate petrochemical and chemical factories, followed by industrial gas production, and basic metal industries, respectively. There are 344 industrial factories located outside of the industrial estates but in Map Ta Phut pollution control area. The industries vary, and most of them are small and medium-size, including metal products, metal for construction, auto repair, and plastic factories.

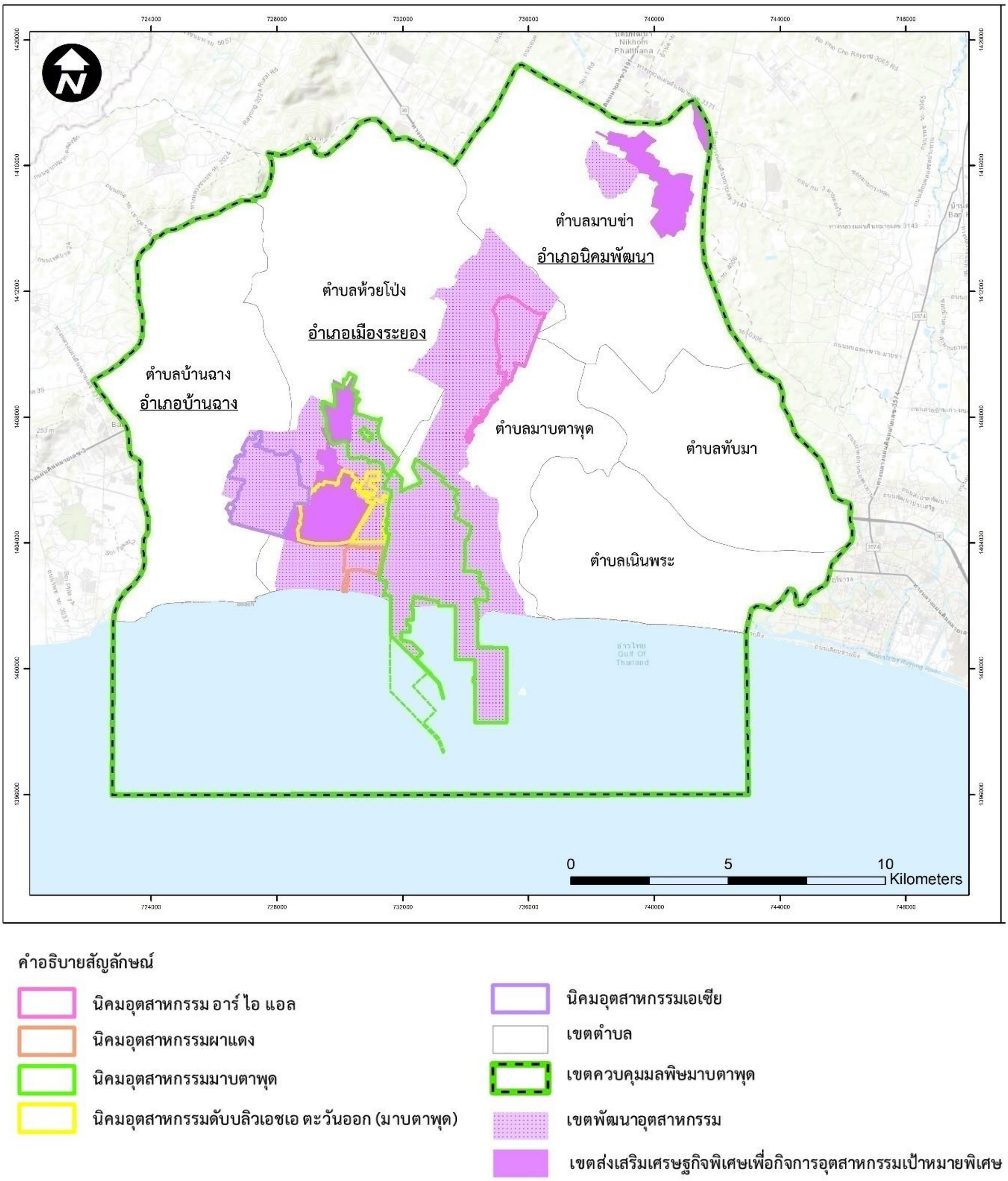


Figure 1 The map of the study area of the project

1.4 Implementation approach

The Company has made an action plan to systematically prioritize the activities in the scope of the study so that the Project becomes successful and reaches its objectives and goals within 270 days. However, with the pandemic of COVID-19, the implementation has been extended for another 90 days. The implementation comprises main and minor activities as follows:

1) Make a detailed implementation plan and study methodology

2) The study of NO_x and SO_2

   2.1) Collect the data of NO_x and SO_2 (emission and concentration) from the sources specified in the environmental impact assessment report (EIA), which are considered the control value and actual emission value as presented in the environmental impact implementation report of each project (actual results from the stack).

   2.2) Make a database sorted by project name, by type of project, by owner of project, by industrial estate in Map Ta Phut or the pollution control area in Rayong Province by indicating where the 80:20 principle and significant impact level (SIL) principle are used, listing the equipment or systems used for treating, reducing, or controlling the emission of each project and overall.

   2.3) Air quality assessment from the emissions of NO_x and SO_2 according to the control value in the EIA and the actual results from the stack, the comparison using AERMOD, and the comparison with the air quality monitoring stations (AQMS) in the study area

   2.4) Perform the SWOT analysis of the 80:20 principle in the past and analyze the capacity of industrial expansion in the area and introducing new industries suitable for the pollution control area in Rayong according to the current carrying capacity of Map Ta Phut.

   2.5) The workshop training on AERMOD for government personnel at the ONEP, the IEAT, the Pollution Control Department (PCD), The Department of Environmental Quality Promotion, staff of the approving authorities, and other relevant agencies as deemed appropriate. The minimum number of workshop participants is 50 people. There shall be at least 1 trainer from other countries. Procure AERMOD equipment in the environmental analysis division permanently so that the staff uses it to assess the impact continuously.

3) The study of volatile organic compounds (VOCs)

3.1) Make a database of VOCs emission from the report submitted to the approving/authorizing agencies (IEAT and Department of Industrial Works (DIW)), which represents the actual values in the report (no control values as per EIA and no actual monitoring results)

3.2) Assessment of ambient air quality based on VOCs emission from the reports submitted to the authorizing agencies using AERMOD and comparison with the actual results of the air quality monitoring stations in the study area

3.3) Study the obstacles, recommendation, and needs for reducing VOCs from the previous operations of each project and make a summary of policy proposal in the local and central levels for VOCs management in the study area

4) Public hearing meeting

4.1) Organize the board meetings to provide academic supervision for the project to hear academic opinion and recommendations toward the study results for at least 3 times.

4.2) Organize public meetings by inviting stakeholders of air pollution management for at least 2 times to hear the opinion toward the study approach and study results. Each meeting shall have at least 80 participants.

5) Documentation include

5.1) The database of NO_x, SO_2 and VOCs emission in the hard copy and in the computer system

5.2) Make the study report, including the inception report, the interim report, the draft final report, the final report, and the executive summary report both in Thai and English version

5.3) Distribute the simplified information about AERMOD to the public (in Thai) and the guideline for assessing VOCs from industrial factories

5.4) The report of air pollution carrying capacity of Map Ta Phut Industrial Area and the industrial expansion according to the air pollution carrying capacity of the area, and policy recommendations for sustainable industrial development

6) Develop a webpage that includes the project descriptions, related knowledge, database, and assessment of pollution dispersion in ambient air using the model and link the webpage with the website of ONEP and EEC

2 Results

2.1 The study of NO_x and SO_2

2.1.1 The data of NO_x and SO_2 emission from factories in the pollution control area

The study of NO_x and SO_2 of factories in the pollution control area is divided into 2 parts.

1. The control values in EIA report, which is the current version of each factory (in September 2019), herein referred to as **“Control values in the EIA report”** (or the accounting allowable value).

According to the data, currently (as of September 2009), the control values in the EIA report from the industrial sources in Map Ta Phut pollution control area dropped from 2007 (the first year to introduce the 80:20 principle). More precisely, the emission rate of NO_x dropped by 13% (around 314 g/s) from 2007 to 2019, with the emission rates of 2,430.20 and 2,116.44 g/s, respectively, and that of SO_2 dropped by 20% (around 439 g/s) from 2007 to 2018, with the emission rates of 2,177.27 and 1,738.21 g/s, respectively).

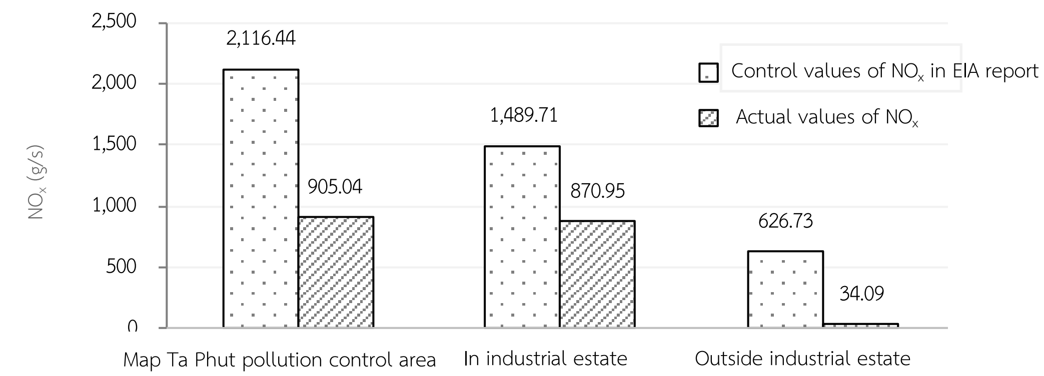
2. The emission values in the EIA and EIA monitoring report, herein referred to as “**Actual results**”. These values were recently reported for 2 periods (July – December 2018 and January – June 2019).

According to the data, the actual value of NO_x was 905.04 g/s or 47.76% of the control value in the EIA report and that the actual value of SO_2 was 784.93 g/s or 45.16% of the control value in the EIA report (as shown in **Figure 2** and **Figure** 3). There are certain stacks that has the control value in the EIA report, but currently there are no NO_x and SO_2 emissions. The total emission values are 683.43 and 290.99 g/s, respectively. The current status of the stacks is divided into 3 scenarios (**Table 1**) as described below.

(1) There are no measuring results (because the stacks are not used anymore, have not been constructed, are under construction, are not used as in the report, the monitoring measures do not require the measurement). In the future, there might be additional emissions. The control values in the EIA report for NO_x and SO_2 are 233.81 and 200.56 g/s, respectively.

(2) The factories have stopped operation or have no production with the total control values in the EIA report for NO_x and SO_2 of 447.44 and 84.67 g/s, respectively.

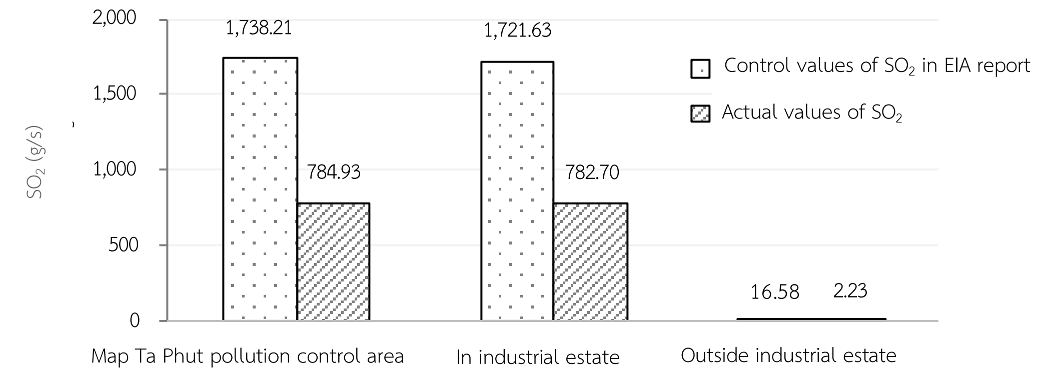
(3) The stacks that the emission status is not known with the control values in the EIA report for NO_x and SO_2 are 2.19 and 5.76 g/s, respectively.



Remark: including the spare stacks

Source: data collected by the United Analyst and Engineering Consultant Co., Ltd. (UAE), 2020

Figure 2 Comparison between control values in the EIA report and actual values of NO_x



Remark: including the spare stacks

Source: data collected by the United Analyst and Engineering Consultant Co., Ltd. (UAE), 2020

Figure 3 Comparison between control values in the EIA report and actual values of SO_2

Table 1 Summary of the stacks without actual values of NO_x and SO_2

Industrial estate	Data of stacks that have control values in the EIA report, but no actual values			
	No. of stacks	NO_x (g/s)	No. of stacks	SO_2 (g/s)
1) No measurement* (total)	**79**	**233.81**	**44**	**200.56**
in industrial estate	67	140.06	38	198.44
outside industrial estate	12	93.75	6	2.12
2) Stopped operation or have no production (total)	**20**	**447.44**	**24**	**84.67**
in industrial estate	7	3.38	14	82.95
outside industrial estate	13	444.06	10	1.72
3) Unknown status (total)	**2**	**2.19**	**2**	**5.76**
in industrial estate	2	2.19	2	5.76
outside industrial estate	0	0	0	0
Total of stacks that have control values in the EIA report, but no actual values 1)+2)+3)	**101**	**683.43**	**70**	**290.99**

Remark: * Including the cases where the stacks are not used anymore, have not been constructed, are under construction, are not used as in the report, the monitoring measures do not require the measurement) and in the future, there might be additional emissions.

- including the spare stacks

Source: data collected by the United Analyst and Engineering Consultant Co., Ltd. (UAE), 2020

2.1.2 Measuring results of NO_2 and SO_2 in ambient air in the pollution control area

According to the measuring results of Nitrogen Dioxide (NO_2) and Sulfur Dioxide (SO_2) in ambient air from seven Air Quality Monitoring Stations (AQMS) in Map Ta Phut pollution control area from 2007 – 2019 by the Industrial Estate Authority of Thailand and Pollution Control Department, the concentration average of NO_2 and SO_2 passed the standard every year. There are 4 AQMSs of the Industrial Estate Authority of Thailand, namely Nong Faep Station, Mueang Mai Station (Nong Suea Kueak), Ban Ta Kuan Station, and Krok Yai Cha Station. The annual concentration averages of NO_2 and SO_2 ranged from 3.74-36.05 and 2.36-40.31 µg/m^3, respectively. There are 3 AQMSs of the Pollution Control Department, namely Map Ta Phut Sub-district Health Promotion Hospital Station, Rayong Crops

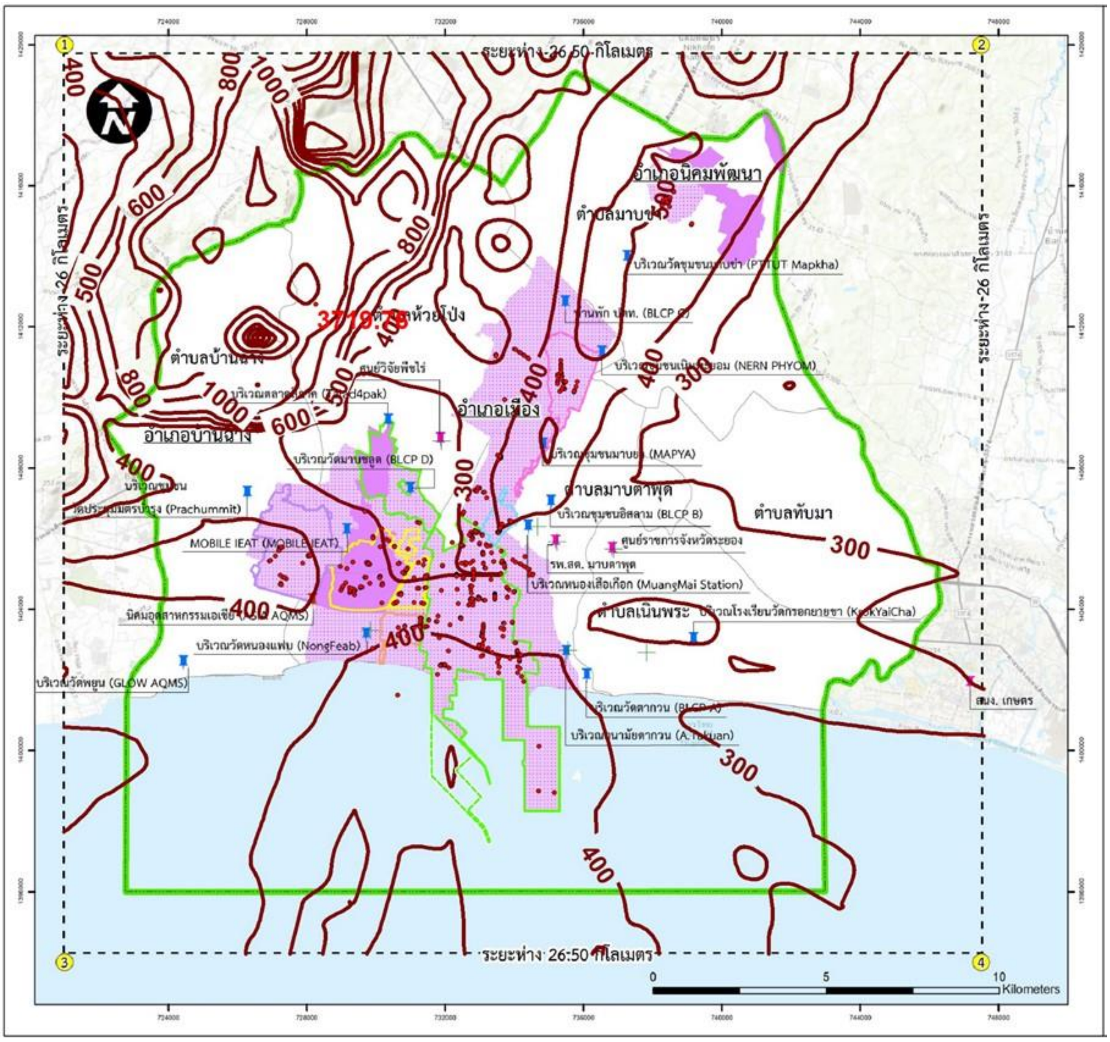
Research Station, Rayong Government Complex Station. The annual concentration averages of NO_2 and SO_2 ranged from 15.04-31.96 and 5.24-21.0 μg/m^3, respectively. (The standards of Nitrogen Dioxide and Sulfur Dioxide in ambient air in one year shall not be more than 57 and 100 μg/m^3, respectively).

2.1.3 Air quality assessment using AERMOD

Based on the air quality assessment using AERMOD with the two sets of data, the study results in the "Control values in the EIA Report" of nitrogen dioxide indicated that the maximum 1-hr concentration at the highest concentration point and 7 additional observation points (the same point as the AQMS) exceeded the standard of air quality for nitrogen dioxide of not more than 320 for the 1-hr concentration, and the maximum 1-hr concentration of Sulfur Dioxide at the highest concentration exceeded the standard of 1-hr Sulfur Dioxide of not more than 780 μg/m^3 for the 1-hr concentration. On the other hand, all the "Actual results" of nitrogen dioxide were lower than the standard of 1-hr Nitrogen Dioxide of not more than 320 μg/m^3, except for the highest concentration point (the example of the contour line of maximum 1-hr concentration of NOx as "control values in the EIA report" and "actual results" were shown in **Figure 4** and **Figure 5**, respectively). The ratio of NO_x:NO_2 was around 50-60%. It could be said that the 1-hr concentration was close to the standard of ambient air quality for nitrogen dioxide of not more than 320 μg/m^3. Regarding Sulfur Dioxide, the results of 1-hr maximum, the 24-hr maximum, and 1-year average were below the standard of ambient air quality for Sulfur Dioxide of not more than 780, 300, and 100 μg/m^3, respectively.

By comparing the assessment with AERMOD with the NO_2 and SO_2 concentration in ambient air from the actual results in 2 scenarios (Scattering plot and Q-Q plot), the Scattering plot (for the same period and position) showed the R^2 in the range of 0.0111–0.7188 and the slope in the range of 0.0135-6.1814. The Map Ta Phut Sub-district Health Promotion Hospital Station showed the best R^2, ranging from 0.2496-0.7188 and slope from 0.0956-0.9097. For the assessment of all stations, the mathematical model did not accurately estimate the position and time of the concentration. More precisely, the R^2 ranged only from 0.0615-0.2036 and slope 0.0856-0.1777. For the Q-Q plot in the same position indicated that the R^2 ranged from 0.4522-0.9858 and slope from 0.0861-100.2700. The Map Ta Phut Sub-district Health Promotion Hospital Station showed the best R^2, ranging from 0.9252-0.9858 and slope 0.2020-0.8917. For overall stations, the mathematical model showed accurate air pollution concentration assessment results in term of data distribution and chance to find the data, with the R^2 ranging from 0.9284-0.9825 and slope 0.2354-0.5064. In conclusion, by using both methods, it was found that The Map Ta Phut Sub-district Health Promotion Hospital Station should be the most suitable station to monitor NO_2 and SO_2 generated from factories in Map Ta Phut Industrial Estate.

It can be concluded that when considering the emission as “control value in the EIA report” that all projects in the area possess, it still exceeds the pollution capacity. That is to say, the study area does neither have the accounting capacity for additional emission nor the hypothetical carrying capacity. It is worth noting that the NO_x and SO_2 dispersion with the AERMOD with the “actual results” showed the NO_x ratio of NO_x:NO_2 around 50-60% was relatively close to the standards of 1-hr average and lower than the 1-year average. However, these factories are able to fully emit the pollutants. Therefore, it is impossible to apply the hypothetical carrying capacity. Therefore, it is recommended to continue using the 80:20 principle until we can control the control value in the EIA report of all projects in the area to be the same as the actual results, which are around 900 – 1,000 g/s for NO_2 to not cause the impact and not exceed the current standard. Government agencies should also conduct the same assessment as this study every 2-3 years to observe the increasing trend of pollution from the said measure and use the Map Ta Phut Sub-district Health Promotion Hospital Station to monitor NO_2 and SO_2 generated from factories in Map Ta Phut pollution control area.



คำอธิบายสัญลักษณ์

สถานีตรวจวัดคุณภาพอากาศ

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- นิคมอุตสาหกรรมมาบตาพุด
- นิคมอุตสาหกรรมเอเซีย

ขอบเขตพื้นที่

- นิคมอุตสาหกรรม อาร์ ไอ แอล
- นิคมอุตสาหกรรมผาแดง
- นิคมอุตสาหกรรมมาบตาพุด
- นิคมอุตสาหกรรมดับบลิวเอชเอ ตะวันออก (มาบตาพุด)
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- เขตตำบล
- เขตควบคุมมลพิษมาบตาพุด
- เขตพัฒนาอุตสาหกรรม
- เขตส่งเสริมเศรษฐกิจพิเศษเพื่อกิจการอุตสาหกรรมเป้าหมายพิเศษ

ลำดับ	ระบบพิกัด UTM WGS 84 Zone 47	
	X	Y
1	721000	1420000
2	747500	1420000
3	721000	1394000
4	747500	1394000

Figure 4 The contour line of maximum 1-hr concentration of NO_2 (ug/m^3) as "control values in the EIA report"

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Figure 5 The contour line of maximum 1-hr concentration of NO_2 (ug/m^3) as "Actual results"

2.1.4 SWOT analysis of the 80:20 principle

The 80:20 principle for handling air pollution in the study area has been adopted since 2007 by the NEB in the Meeting No. 6/2007 on 9 April 2007. The meeting resolved to approve the principle for considering the environmental impact analysis, the measures in the environmental impact analysis report for industrial and energy projects in Map Ta Phut, Rayong province by ONEP. Consequently, The IEAT was studying the carrying capacity of air pollution in Map Ta Phut, particularly NO_2, SO_2 and TSP by updating the data and inputting the parameters into the mathematical model to examine the air pollution carrying capacity of Map Ta Phut, Rayong Province to be more reliable. The study suggested that the CALPUFF model and AERMOD model used by IEAT to forecast the Maximum Ground Level Concentration (Max. GLC) of NO_2 and SO_2 exceeded the standard of ambient air up to 8 times and 4 times, respectively. Therefore, the NEB set up a sub-committee or a working team under supervision of the Pollution Control Department to investigate the application of more acceptable model, including AERMOD to use as the tool for the agency in charge of environmental planning. These tools are aimed to be used concurrently with other measures such as the environmental monitoring system, the control of key sources, reducing the 80:20 principle in the area, and the EIA reported by the projects. It was found that, since the adoption of the 80:20 principle, the NO_x and SO_2 emissions in Map Ta Phut dropped from 2007 – 2012, based on the pollution sources of factories in Map Ta Phut area in Mueang Rayong District, Rayong Province, by ONEP. Therefore, the guideline for assessing air quality with mathematical model in the environmental impact analysis report for other industrial and energy projects in Map Ta Phut and other areas was approved by the National Environment Board in the Meeting of 6/2013 on 29 August 2013 as described below.

1) Pollution Emission Rate Determination in pollution control area in Rayong is based on the air quality screening assessment principle of U.S. EPA as the principle for classifying the control level of NO_x and SO_2 emission from new sources and/or additional emission by comparing with the maximum ground level concentration with the Significant Impact Level (SIL), which is used as the screening standard as explained below.

(1) When the maximum concentration does not exceed the SIL, use the emission rate inputted into the model if the concentration from the monitoring is lower than 80% of the standard of ambient air quality.

(2) If the maximum concentration from the model exceeds the SIL or the concentration from the monitoring results of ambient air in the study area reaches 80% of the standard of ambient air quality, use the 80:20 principle. That is to say, reduce the emission rate from the maximum actual

emission of the existing project (emission offset) or that of other projects (emission trading), as the case may be, in order to trade the emission rate to the new sources and/or additional emission of the new project or the project with production expansion or the project description revision by not more than 80% of the reduced pollution emission rate.

(3) In case the project is located in an industrial estate or the project has similar nature as the industrial estate, use the emission rate allocated for the area.

(4) If the industrial estate project or the project has the same nature as the industrial estate, use the combination between the concentration difference of 80% of the ambient air quality for the pollutant with the highest background concentration to calculate the suitable emission rate for the stacks with the height of 10, 20, 30, 40, 50 and 60 meters, respectively.

(5) The determination of emission rate of a project shall be based on the system of the Best Available Control Technology; BACT) and/or conform to the best practices in air pollution control. In any case, ONEP shall consider based on the principle of U.S. EPA on a case-by-case basis.

2) Emission Rate Determination in other areas: If the results of ambient air quality for NO_x and SO_2 in the study area reach 80% of the standard of ambient air quality, use the 80:20 principles. To clarify, reduce the maximum actual emission of the existing project (emission offset) or of other projects (emission trading), as the case may be, in order to trade the emission rate to the new source and/or increase the emission rate of the new project or production expansion or revised project description by not more than 80% of the reduced emission rate. In this case, the project needs to assess the concentration of accumulated pollution which indicates the total impact in order to compare with the standard of ambient air quality as described below.

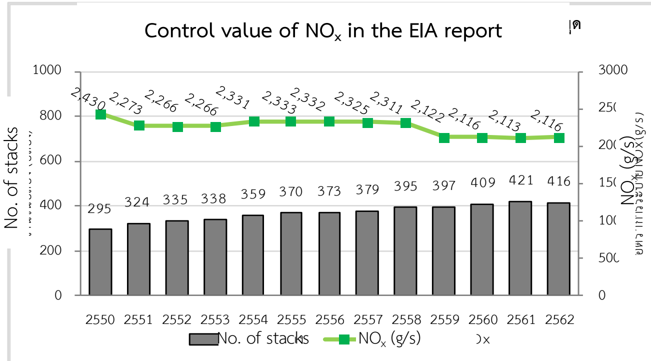
(1) Use the highest concentration derived from the assessment, which has been adjusted to the standard condition (1 bar and 25 ^{0}C) and combined with the baseline concentration in ambient air before the project establishment.

(2) In case the new source and/or additional emission results in the exceedance of the total impact, the project needs to reduce the emission rate until the assessment pass the standard of ambient air quality.

(3) In case VOCs results in the study area exceed the standard of ambient air quality, affecting the total impact, it must be proven that the project will not change the existing class of risk.

To examine and analyze the strength, weakness, opportunity, and threat (SWOT analysis) of the 80:20 from the previous operation, the Company has collected the study results of control value in the EIA report of all factories in Map Ta Phut pollution control area. From 2007 – 2019, there are 295 stacks in the EIA Report that emit NO_x and tend to increase to 416 stacks whereas the emission rate tends to decline from 2,430.20 g/s to 2,116.44 g/s. Similarly, SO_2 increased from 179 to 222 stacks and the emission rate lowered from 2,177.27 g/s to 1,738.21 g/s as shown in **Figure 6.**

(a) Control value of NO_x in the EIA report



(b) Control value of SO_2 in the EIA report

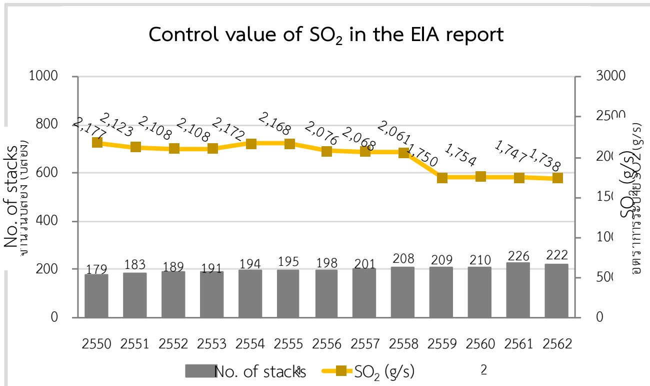


Figure 6 Control values of NO_x and SO_2 in the EIA report of factories in Map Ta Phut pollution control area

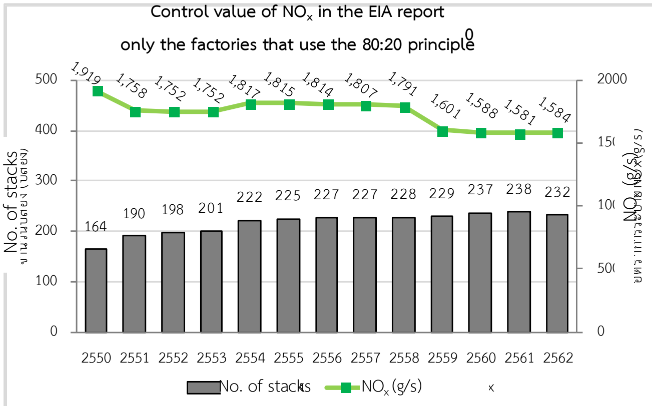
There are 3 factors that cause the change of pollution emission in Map Ta Phut pollution control area.

1) The 80:20 principle is a primary reason for lower pollution emission. By this principle, new projects or the expansion of production or revised project description in the area has to adopt the 80:20 principle. As a result, the emission rate of NO_x dropped by 17% (to around 335 g/s, particularly in 2007 and 2019 with the emission values of 1,919.19 and 1,583.97 g/s, respectively). Similarly, the emission rate of SO_2 dropped by 24% (or around 450 g/s, particularly in 2007 and 2019 when the emission values were 1,840.32 and 1,390.76 g/s, respectively) as shown in **Figure 7.**

The Project decided to use the air pollution management and control methods such as changing the fuel, reducing sulfur in fuel, and choosing suitable technology to control or treat the pollution. For NO_x control, the projects opted to use Low NOx Burner, Dry Low NOx Burner, Ultra Low

NOx Burner, Steam Injection, Selective Catalytic Reduction (SCR), Selective Non Catalytic Reduction (SNCR), Water injection system, Direct Fired Thermal Oxidizer (DFTO), and for SO_2 control, for example, SOx Reduction Additive Injection, Tail Gas Treating Unit (TGTU), Seawater Flue Gas Desulphurization (SW-FGD), and SO_2 Scrubber.

(a) Control value of NO_x in the EIA report only the factories that use the 80:20 principle



(b) Control value of SO_2 in the EIA report only the factories that use the 80:20 principle

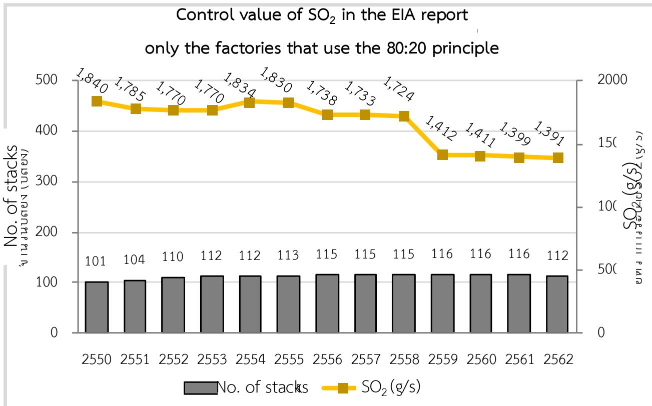
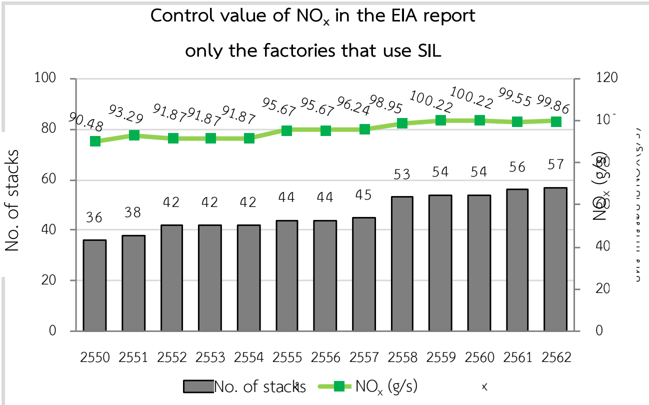


Figure 7 Control values of NO_x and SO_2 in the EIA report only the factories that use the 80:20 principle

2) Adoption of SIL: The emission values of NO_x and SO_2 increased slightly and the increase occurred only in the industrial area from 2013 – 2019 as shown in **Figure 8**, because the new projects, the production expansion, or revised project description applied the SIL values according to the air quality assessment with a mathematical model in the environmental impact analysis for industrial and energy projects in Map Ta Phut and other areas approved by the National Environment Board in the Meeting 6/2013 on 29 August 2013. That is to say, "if the maximum concentration from the model does not exceed the SIL value, use the pollution emission rate inputted in the model in the case that the pollution concentration measured in the area is lower than 80% of the standard of ambient air quality."

3) Other methods reduce the emission rate of NO_x and SO_2 such as using the Max Actual, changing the fuel type (from engine oil to natural gas), revision of the project description, and reassessment of the emission rate for improved accuracy.

(a) Control value of NO_x in the EIA report only the factories that use SIL



(b) Control value of SO_2 in the EIA report only the factories that use SIL

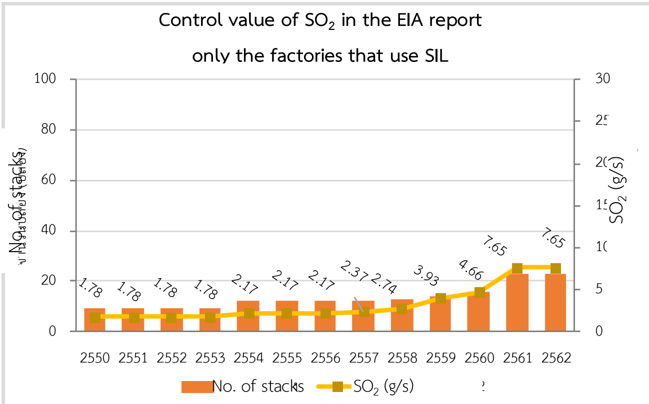


Figure 8 Control values of NO_x and SO_2 in the EIA report only the factories that use SIL

This study opened to receive public opinion from representatives of business operators in the area and those of central and regional government agencies to analyze the strength, weakness, opportunity and threat (SWOT) and the recommendations for management of NO_x and SO_2 emission by using the 80:20 principle. The opinions and recommendations can be summarized into 4 factors, namely 1) political and law, 2) economics, 3) technology, 4) environmental and social as shown in **Table 2.** It was found that these policies are effective to manage pollution and the public have trust on these concrete measures. However, the measures can be obstacle for new investors. Also, there are not enough data for planning the investment and the body of knowledge of government agencies might not be enough. There should be a central agency to collect the data for analysis and main in charge of promoting the balance of NO_x and SO_2 management.

Table 2 The summary of SWOT analysis for NO_x and SO_2 emission management using the 80:20 principle

Topic	Political and law	Social	Economic	Technology
Strength	- The current regulations are already strictly enforced. - There are clear mechanisms for using the 80:20 principle that is measurable with a scientific method. - Government sector can easily supervise and monitor. - Same standard for relevant factories (factories required to make EIA/EHIA reports) - Results in the allocation of emission between existing factories and new factories - Equality in competition between existing factories and new factories - Determine the policy for EEC to develop target industries, resulting in stricter enforcement	- Effective to reduce air pollutants, especially NO_x ,making the environment better. - Reduce the impact on the community, reduce the complaint, and increase trust for the community. - Improve health for local people and decrease diseases, especially respiratory diseases - Establish trust in air pollution among the public - Create a more positive image for factories adopting the 80:20 principle	- Have good management system and business operators can adapt within the changed time frame or situation. - There are more investments from the same business operators in the area	- Have the effective and accurate technology for assessing air quality - Have the effective and modern technology to minimize environmental impact

Table 3 The summary of SWOT analysis for NO_x and SO_2 emission management using the 80:20 principle (continued)

Topic	Political and law	Social	Economic	Technology
	- It is a good tool to control air pollution. - It is the measure that creates trust for society and community and minimize environmental impact.			
Weakness	- There is no plan for monitoring the measures and presenting the monitoring measures. The measures are not implemented continuously. - It is not enacted as a law, but as condition or order for specific factors applicable to the requirement of making the EIA or EHIA report, and it has not covered all the areas. - The timeline and criteria are not clear enough. - There is no monitoring and revision of the quota	- Government agencies in charge of environmental matter for factories outside of industrial estate have not adopted the 80:20 principle such as Department of Industrial Works and the Provincial Natural Resources and Environment, and the Provincial Industrial Office. - Information is not distributed to local administrations such as provincial public health office, district public health office so that they can	- There is a risk to develop the area that uses the 80:20 principle, especially the petrochemical industry (in Map Ta Phut pollution control area). - There is a risk of value for money in investment because businesses have to invest more such as pollution-reduction technology during construction and operation and specialists. - There is no economic and	- Domestic technology is inadequate and not modern enough to control and minimize air pollution.

Table 3 The summary of SWOT analysis for NO_x and SO_2 emission management using the 80:20 principle (continued)

Topic	Political and law	Social	Economic	Technology
	for NO_x and SO_2 emission for factories that are allowed to emit but have not started operation. - The monitoring results of NO_x and SO_2 are not reliable because it is just sampling	make use of the data such as health impact assessment for local people.	environmental mechanism for overall management. - There has not been a central agency to manage the marketing mechanism and the quota for pollution emission as per the 80:20 principle. - Determination of emission using the max actual with the factories that use good technology might be obstacle for expanding the business in the future. - There will be slowdown in investment because businesses have to consider many investment aspects such as technology for	

Table 3 The summary of SWOT analysis for NO_x and SO_2 emission management using the 80:20 principle (continued)

Topic	Political and law	Social	Economic	Technology
			management pollution.	
Opportunity	- The establishment of EEC is the opportunity to review the capacity or potential to carry air pollution of the area.	- Collaboration between EEC and relevant agencies in promoting effective implementation.	- There is the opportunity for managing emission such as emission trading. - It is a chance for reviewing technology and engineering for environmental management. - There are example studies for considering adopting the emission trading such as CDM and carbon trading.	- Promotion, invention, and development of new technology, including the management method for air pollution control and reduction. - Technological advancement or new technology introduction from overseas. - Development of domestic knowledge e.g. universities have to improve their instruction to educate students about new technology and development for domestic use. - Personnel development

Table 3 The summary of SWOT analysis for NO_x and SO_2 emission management using the 80:20 principle (continued)

Topic	Political and law	Social	Economic	Technology
Threat	- Enforcement of the government sector does not cover all the area and is not strict for all factories. - Foreign executives do not understand the important of this policy. - Stakeholders do not have clear understanding regarding law, and they lack technical knowledge.	- Communities have limited knowledge about the measures and principles.	- Less employment and more unemployment.	- Modern and effective technology application to control pollution may require more money, which is against the principle of investment. - Lack development and invention of new technology in the country. - Lack sharing of technology data - Lack personnel for using technology

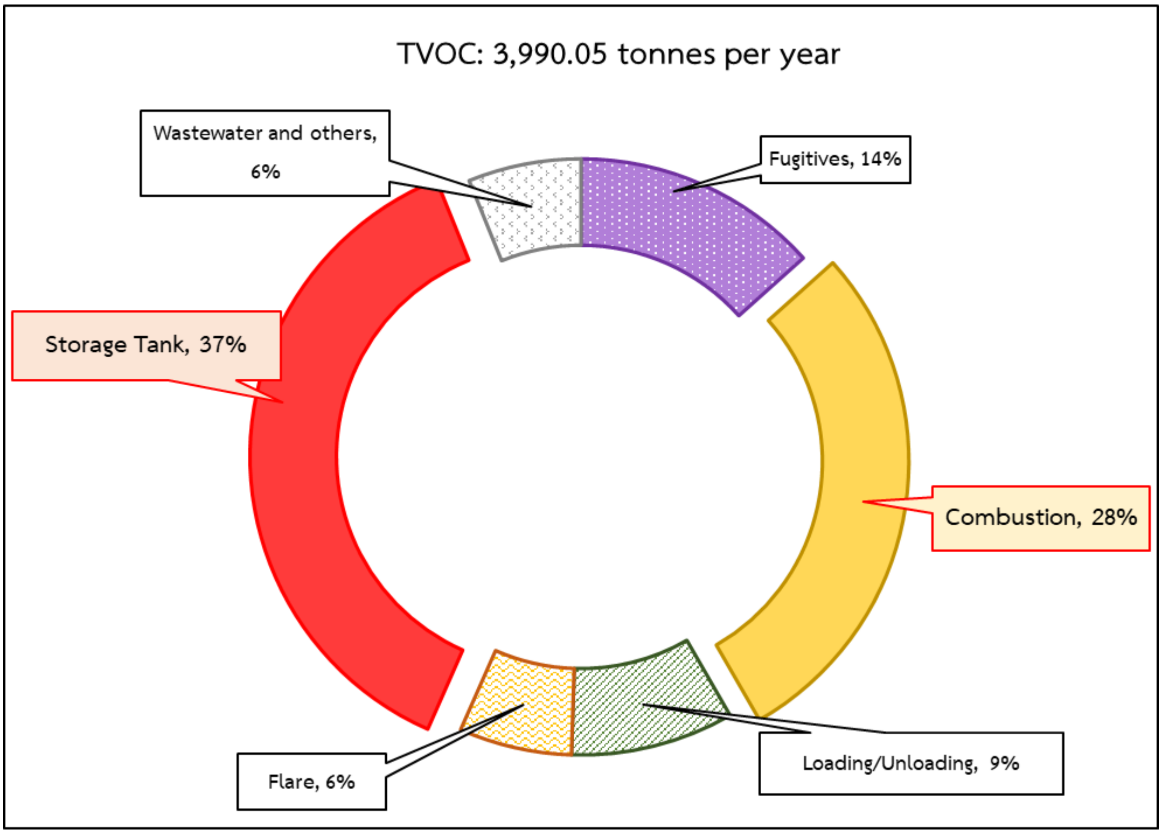
2.2 The study of Volatile Organic Compounds (VOCs)

2.2.1 Emission of VOCs from factories in the pollution control area

According to the data of VOCs from projects in Map Ta Phut pollution control area reported in the database of the Industrial Estate Authority of Thailand as of the round 2/2019 and the monitoring results of VOCs from monitoring report and environmental impact mitigation measures round 2/2019, there are 74 projects with VOCs emission. VOCs emission is in the form of TVOC from all activities totaling 3,990.05 tons/year. Most of the VOCs emission is from the storage tank (1,486.58 tons/year or 37.3% of the total emission), followed by combustion (1,129.43 tons/year or 28.3%), and fugitives (533.64 tons/year or 13.4%) as shown in **Figure 9**

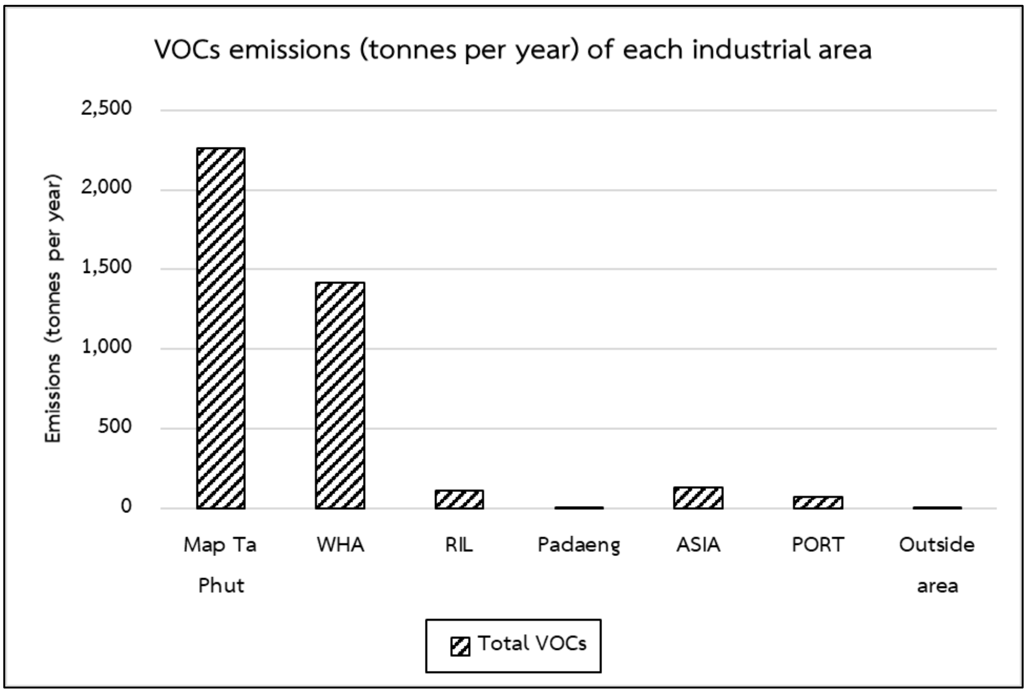
Sorted by area, Map Ta Phut Industrial Estate accounts for the most TVOC emission (2,263.16 tons/year or 56.7% of the total emission), followed by WHA Eastern Seaboard Industrial Estate (Map Ta Phut) (1,415.04 tons/year or 35.5%). The two industrial estates above combined account for more than 90% of the total emission. The lowest emission is from Pha Daeng Industrial Estate and factories outside of any industrial estate (0.57 and 0.27 tons/year, respectively, or 0.01%) as shown in **Figure 10**

Considering the industrial estates and activities with the most TVOC emission, it was found that TVOC emission from combustion, transfer, and incineration comes mainly from Map Ta Phut Industrial Estate. On the other hand, fugitives, storage tank, and wastewater treatment are the main causes of TVOC emission from WHA Eastern Seaboard Industrial Estate (Map Ta Phut). Considering the types industry and sources of VOCs, there are 65 petrochemical projects with the most TVOC emission up to 3,666.95 tons/year or 91.9% of the total emission, followed by oil refineries (303.47 tons/year) whereas the lowest emission is from gas production plant (0.39 tons/year).



Source: data collected by the United Analyst and Engineering Consultant Co., Ltd. (UAE), 2020

Figure 9 Total VOCs emission in all area sorted by sources



Source: data collected by the United Analyst and Engineering Consultant Co., Ltd. (UAE), 2020

Figure 10 VOCs emission sorted by areas

2.2.2 Results of VOCs in ambient air

The results of VOCs in ambient air sorted into 3 substances, namely Benzene, 1,3-Butadiene, and 1,2-Dichloroethane from 2007-2019 are based on the monitoring results at monitoring stations by Pollution Control Department. It was found that most results of Benzene in ambient air showed a stable trend. The results at nearly all stations exceeded the standard. However, from 2018 – 2019, the 1-year averages of Benzene of all stations in 2019 were evidently lower than those of 2018. The results exceeding the standard at Map Ta Phut Sub-district Health Promotion Hospital Monitoring Station, Mueang Mai Map Ta Phut Monitoring Station, and Ban Phlong Community Monitoring Station exceeded the standard every year. The results of 1,3-Butadiene in ambient air from 2007-2019 showed a stable trend. Since 2013, the results at Map Ta Phut Sub-district Health Promotion Hospital Monitoring Station and Mueang Mai Map Ta Phut Monitoring Station showed significantly higher values than other monitoring stations. However, from 2018 – 2019, the 1-year averages of 1,3-Butadiene at some stations in 2019 were lower than 2018 such as at Wat Nong Faep School Monitoring Station, Map Ta Phut Sub-district Health Promotion Hospital Monitoring Station, Mueang Mai Map Ta Phut Monitoring Station, and Nopphaket Village Monitoring Station. The stations with exceeding values are Map Ta Phut Sub-district Health Promotion Hospital Monitoring Station, Ban Ta Kuan Public Health Center Monitoring Station, and Mueang Mai Map Ta Phut Monitoring Station. The results of 1,2-Dichloroethane in ambient air from 2007-2019 showed a stable trend. However, the results at Mueang Mai Map Ta Phut Monitoring

Station were significantly higher than other stations and those at Mueang Mai Map Ta Phut Monitoring Station exceeded the standard every year. Considering only 2019, there are 2 stations with 1-year average of 1,2-Dichloroethane exceeding the standard, namely Map Chalut Monitoring Station and Mueang Mai Map Ta Phut Monitoring Station. It is worth noting that since 2016, the results of 1,2-Dichloroethane at Map Chalut Monitoring Station showed a constantly increasing trend.

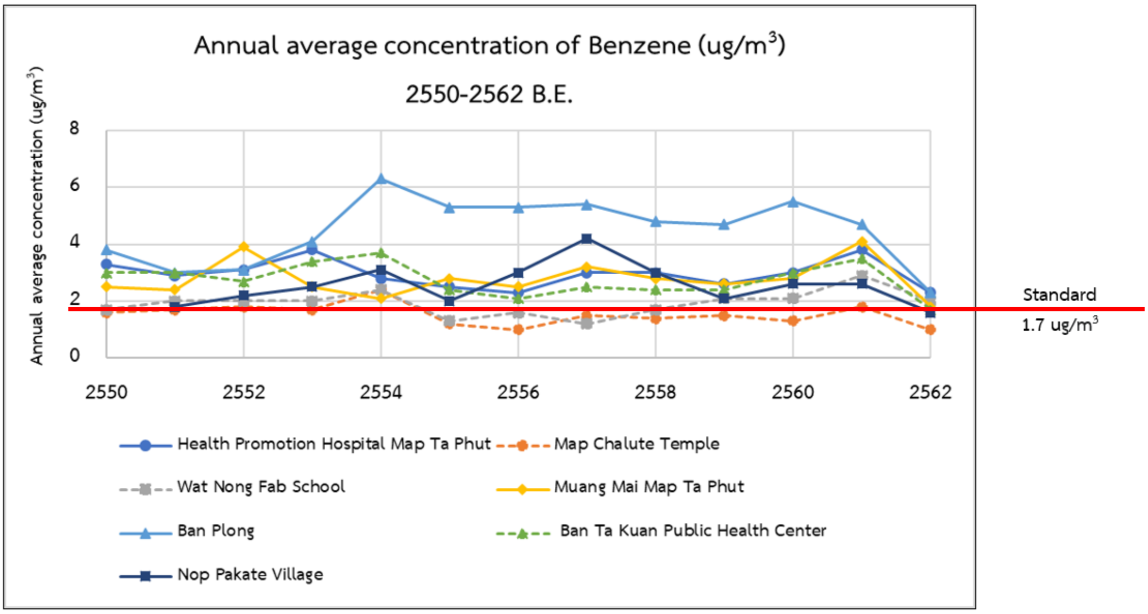


Figure 11 Results of Benzene at monitoring stations of Pollution Control Department

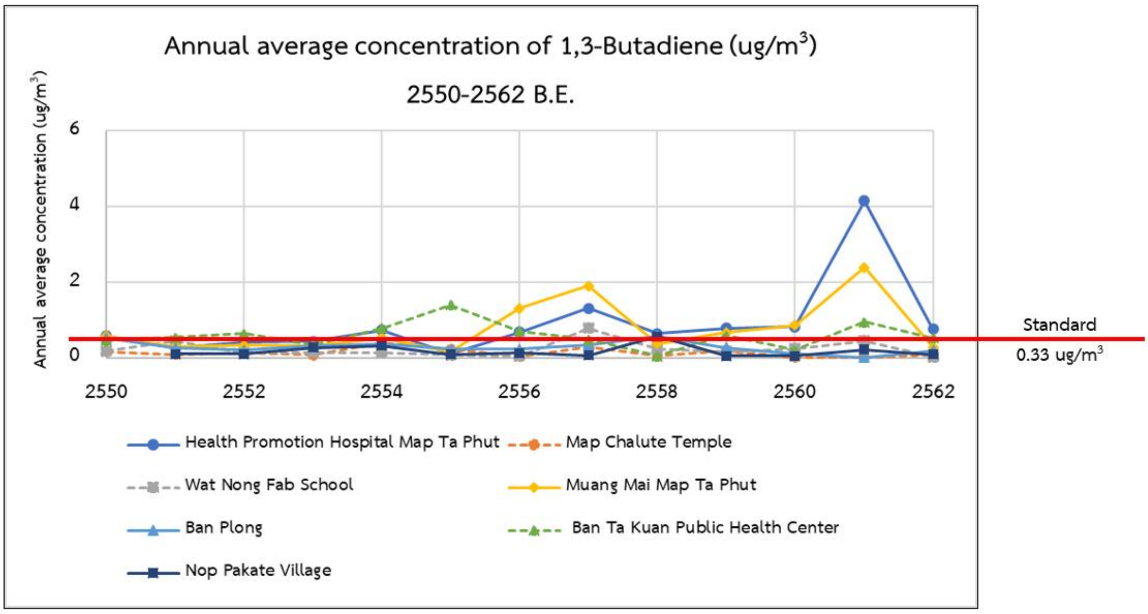


Figure 12 Results of 1,3-Butadiene at monitoring stations of Pollution Control Department

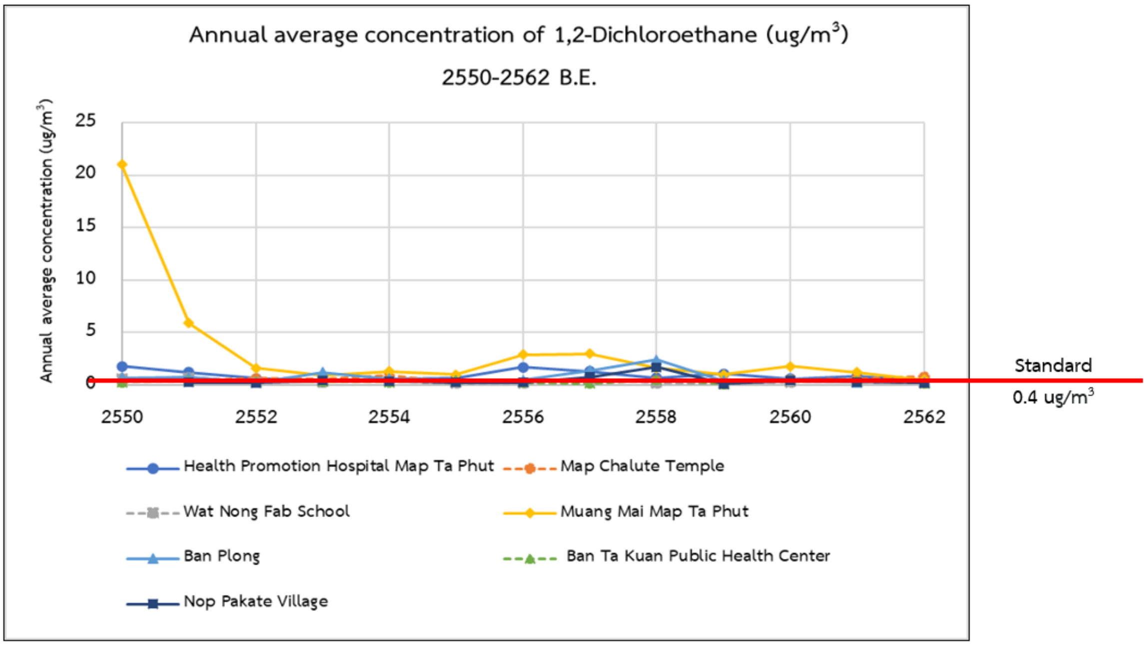


Figure 13 Results of 1,2-Dichloroethane at monitoring stations of Pollution Control Department

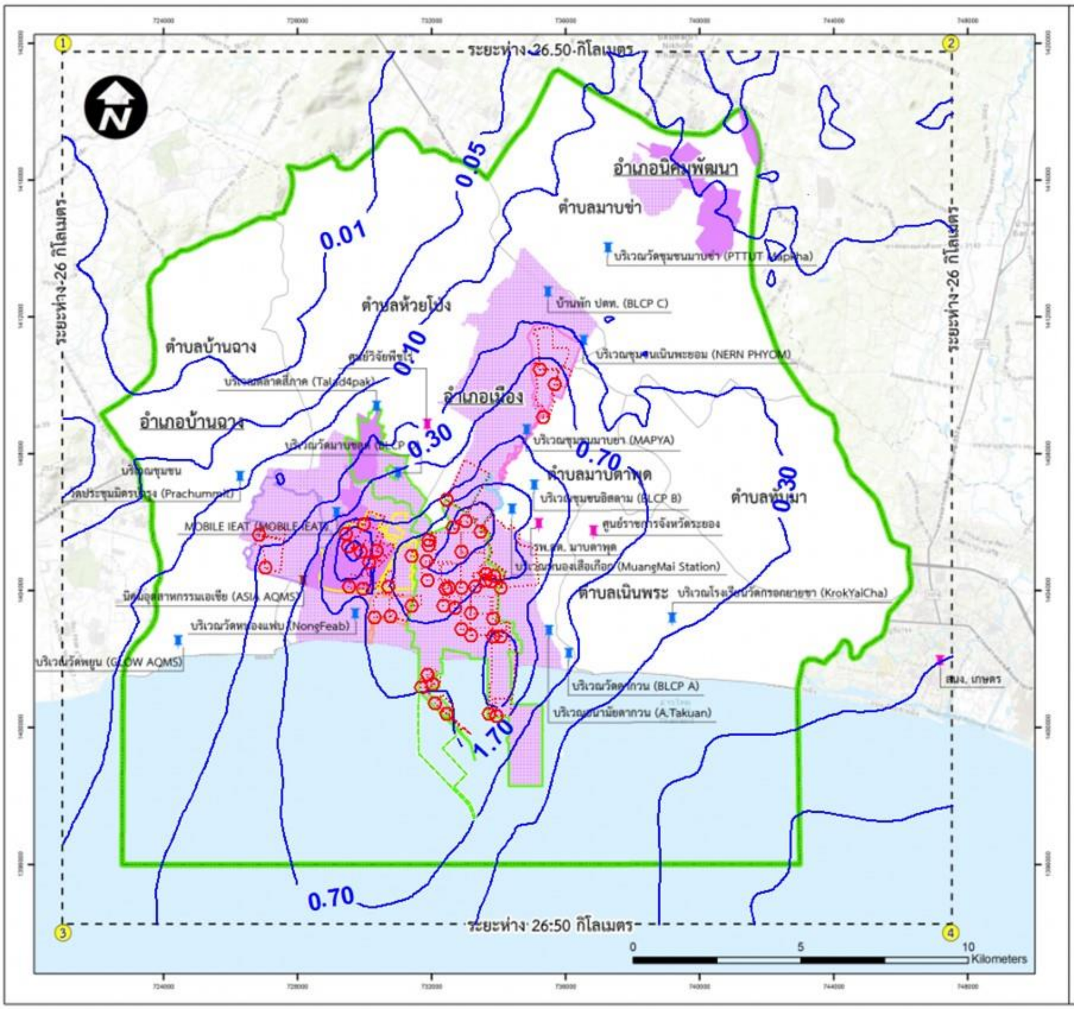
The yearly average of VOCs in ambient air at monitoring stations of IEAT from 2013-2019 showed that most annual averages of Benzene exceeded the standard, particularly on I-4(1) Road, with significantly higher Benzene than other area and constantly increasing trend. The areas with the results exceeding the standard were mostly in industrial estates. There is only one area with the results not exceeding the standard, namely I-1 Road (PTT Chemical). The results of 1,3-Butadiene in ambient air at I-4(1) Road and I-2 Road were significantly higher than other areas. Considering only 2018 – 2019, the area of I-1 Road (PTT Chemical) had the 1-year average 1,3-Butadiene not exceeding the standard. Besides, the results of 1,2-Dichloroethane in many areas showed a decreasing trend, especially at Map Ta Phut Industrial Estate Office and I-3 Road and I4 Road Intersection with significantly lower results compared to 2013. However, early 2017, three stations showed the results of 1,2-Dichloroethane exceeding the standard, but not a decreasing trend, namely I-10 Road Check Post Monitoring Station, Fence line of I6 Road Monitoring Station, and Upstream Canal Quality Monitoring Station. It should be noted that most values exceeding the standard were found along the north and southwest fence lines of Map Ta Phut Industrial Estate.

2.2.3 Assessment of VOCs carrying capacity of the area using AERMOD

The VOCs emission values of 74 projects were inputted into the AERMOD, particularly 3 substances, namely Benzene, 1,3-Butadiene and 1,2-Dichloroethane. The numbers of projects with the three VOCs emission are 47, 41, and 16, respectively. The amounts of each substance emission in the study area are 79.79, 23.28 and 460.69 tons/year, respectively (2.00%, 0.58%, and 11.55% of the total TVOCs emission, respectively.) By using AERMOD, it was found that the maximum 24-hr concentration of Benzene, 1,3-Butadiene ,and 1,2-Dichloroethane in the study area exceeded the standard of monitoring levels of 24-hr VOCs concentration in ambient air, which shall not be higher than 7.6, 5.3 and 48.0 μg/m^3, respectively. Similarly, the maximum 1-year average of Benzene, 1,3-Butadiene and 1,2-Dichloroethane in the study area exceeded the standard of monitoring levels of 1-year VOCs concentration in ambient air, which shall not be higher than 1.7, 0.33, and 0.4 μg/m^3, respectively.

The AERMOD assessment results are compared with the actual results of VOCs concentration in ambient air in two scenarios: the Scattering plot and the Q-Q plot. It was found that the Scattering plot method results in the assessment accuracy by only 2.75%, 1.14%, and 4.19% for Benzene, 1,3-Butadiene ,and 1,2-Dichloroethane, respectively. With the Q-Q plot, the accuracy levels compared to the actual results for Benzene, 1,3-Butadiene ,and 1,2-Dichloroethane were 89.80%, 74.17%, and 96.20%, respectively. Considering the confidence level of 95%, AERMOD model cannot explain the distribution of Benzene and 1,3-Butadiene well enough although it can explain the distribution of 1,2-Dichloroethane more than 95%. However, the assessment results and the actual results, especially the maximum results, were found to be much different.

Therefore, it is concluded that AERMOD still has limitations and it is important to use other measures to manage the three substances of VOCs in the study area.



คำอธิบายสัญลักษณ์

สถานีตรวจวัดคุณภาพอากาศ

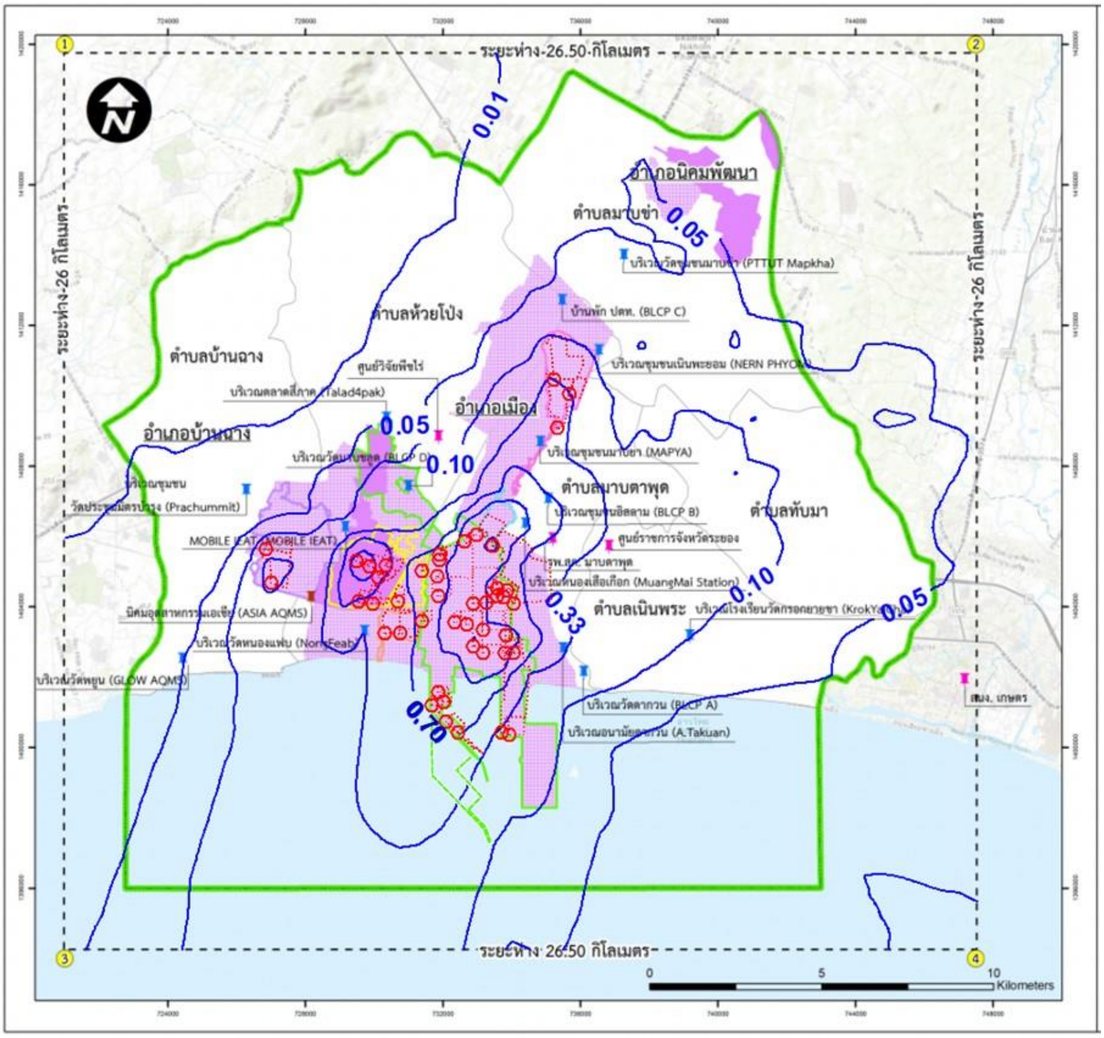
- กรมควบคุมมลพิษ
- นิคมอุตสาหกรรมมาบตาพุด
- นิคมอุตสาหกรรมเอเซีย

ลำดับ	ระบบพิกัด UTM WGS 84 Zone 47	
	X	Y
1	721000	1420000
2	747500	1420000
3	721000	1394000
4	747500	1394000

ขอบเขตพื้นที่

- นิคมอุตสาหกรรม อาร์ ไอ แอล
- นิคมอุตสาหกรรมผาแดง
- นิคมอุตสาหกรรมมาบตาพุด
- นิคมอุตสาหกรรมดับบลิวเอชเอ ตะวันออก (มาบตาพุด)
- นิคมอุตสาหกรรมเอเซีย
- เขตตำบล
- เขตควบคุมมลพิษมาบตาพุด
- เขตพัฒนาอุตสาหกรรม
- เขตส่งเสริมเศรษฐกิจพิเศษเพื่อกิจการอุตสาหกรรมเป้าหมายพิเศษ

Figure 14 The contour line of 1-year average of Benzene (μg/m^3)



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3	721000	1394000
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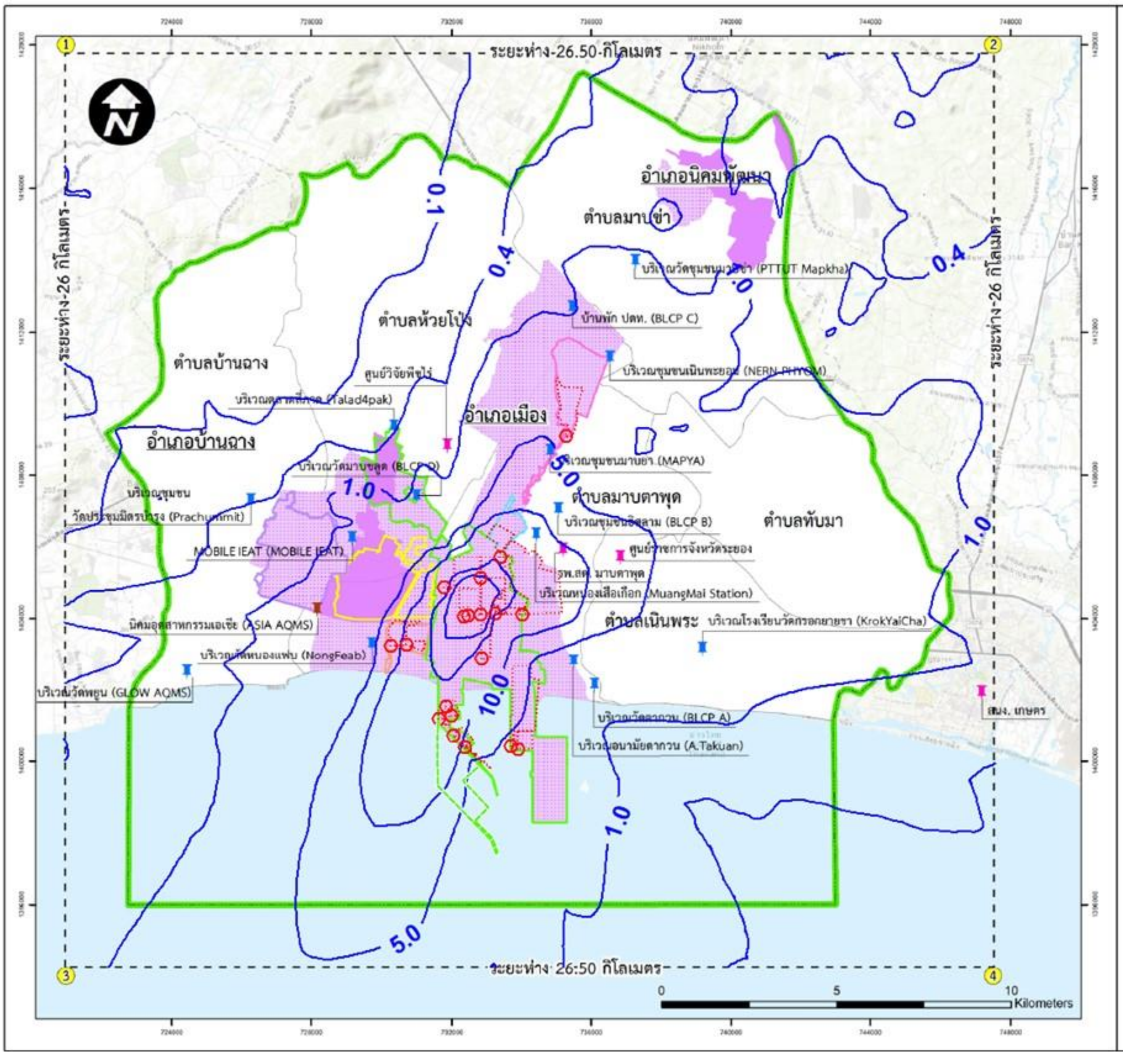
ขอบเขตพื้นที่

- นิคมอุตสาหกรรม อาร์ ไอ แอล
- นิคมอุตสาหกรรมผาแดง
- นิคมอุตสาหกรรมมาบตาพุด
- นิคมอุตสาหกรรมดับบลิวเอชเอ ตะวันออก (มาบตาพุด)
- นิคมอุตสาหกรรมเอเชีย
- เขตตำบล
- เขตควบคุมมลพิษมาบตาพุด
- เขตพัฒนาอุตสาหกรรม
- เขตส่งเสริมเศรษฐกิจพิเศษเพื่อกิจการอุตสาหกรรมเป้าหมายพิเศษ

Figure 15 The contour line of 1-year average of 1,3-Butadiene ($\mu g/m^3$)



คำอธิบายสัญลักษณ์

สถานีตรวจวัดคุณภาพอากาศ

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- นิคมอุตสาหกรรมเอเซีย

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- นิคมอุตสาหกรรมดับบลิวเอชเอ ตะวันออก (มาบตาพุด)
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- เขตควบคุมมลพิษมาบตาพุด
- เขตพัฒนาอุตสาหกรรม
- เขตส่งเสริมเศรษฐกิจพิเศษเพื่อกิจการอุตสาหกรรมเป้าหมายพิเศษ

ลำดับ	ระบบพิกัด UTM WGS 84 Zone 47	
	X	Y
1	721000	1420000
2	747500	1420000
3	721000	1394000
4	747500	1394000

Figure 16 The contour line of 1-year average of 1,2-Dichloroethane ($\mu g/m^3$)

2.2.4 VOCs management problems

Based on the situation of VOCs emission from projects in Map Ta Phut pollution control area, the results of VOCs in ambient air, and the assessment results of VOCs carrying capacity of the area, the problems for VOCs management were collected by interviewing business operators in the area regarding VOCs and holding meetings with representatives from government, private, and public sectors. In these meetings, the brainstormed results were divided into 4 groups, namely 1) Political and Law, 2) Economics, 3) Technology, and 4) Environmental and Social. It can be summarized as below.

Table 4 Summary of VOCs management problems

Topics	Problems
Political and Law	• Lack a shared big data system among different agencies • Government sectors do not take environmental problems of factories to perform VOCs in-depth analysis • The PRTR Project is only voluntary. It lacks training for factories and clear results how it can be used policy-wise. • The study of VOCs sources in the area is not yet comprehensive, particularly absence of vehicle source. • The standard of 1-year average VOCs in ambient air is too strict. • Legal consistency among different agencies and much diversity of laws make it difficult to manage. • The methods for acquiring VOCs emission data are varied (coefficient calculation method). It lacks one single standard method. • Some laws or measures are enacted without public hearing or notification in advance to the public. • Factories have to submit the report to several agencies, each requiring different scopes, wasting time to make and submit several reports.
Economics	• Factories invest a lot for emission control e.g. pollution control technology, pollution treatment system, monitoring equipment, and specialists. These are the investment obstacles. • There is no economic – environmental analysis for VOCs management. • It lacks investment incentive measures e.g. machine tax reduction and pollution reduction technology support.

Table 4 Summary of VOCs management problemsSummary of VOCs management problems (continued)

Topics	Problems
Technology	• Current technology is limited in the capacity to reduce VOCs. Most monitoring equipment and test kits are expensive. Some have short lifespan. • Factories in the area are using suitable technology to control VOCs, but the results at the fence line still exceed the standard because many other factories are also using VOCs at a high rate. • The target for reducing VOCs emission continuously every year is impossible in practice due to technological limitations. • It is difficult to identify types of fugitives.
	• Some technology can reduce VOCs, but generate other pollutions such as NO_x • It takes labor and time to monitor VOCs e.g. leak check at factories that have many sources.
Environmental and Social	• There is no information available to the public about how each type of VOCs affect health or whether a certain health issue is caused by VOCs. • The public lacks understanding of VOCs control using the current standard. • Factories and government agencies lack communication with the public about VOCs management used in the area.

2.3 AERMOD workshop training

The AERMOD workshop training aims to educate personnel how to use AERMOD. The participants include 50 representatives from ONEP, IEAT, DIW, the Department of Energy Business, the Department of Environmental Quality Promotion, Regional Environment Office 13 (Chon Buri), the Energy Regulatory Commission, representatives from universities. A total of 47 participants who attended 80% of the workshop session received a training certificate from Mr. Michael Hammer, CCM. The expert from Lakes Environmental Software Co., Ltd. from Canada led the online training for 3 days from 5 – 7 August 2020 from 08.30 – 12.30 hr. (Due to the pandemic of COVID-19, the Consultant requested to change the implementation method of the project. Originally, the expert would travel from Canada to lead the training in Thailand for one day. However, it was changed to online training and extended to 3-day session (due to time zone different, schedule from 08.30-12.30 hr. Thai time). Therefore, the expert did not have to travel to Thailand. The Consultant prepared the computer and TV screens for the training).

2.4 Public hearing meetings

For the study to be comprehensive and serve the objectives, public hearing meetings were organized and divided into 2 sessions:

2.4.1 The project academic committee meetings

A set of academic committees was assigned to give opinion toward the scope of the study, the methodology, and results. There are three academic committee meetings: the first one on 11 November 2019, the second on 20 February 2020, and the third on 1 September 2020.

2.4.2 The public hearing meetings

The public hearing meetings aim at receiving the opinion and recommendations for the project. The meetings were held two times. The first one aims to gather the opinion toward the study approach, held on 23 June 2020 at the Golden City Hotel Rayong, with 93 participants. The second meeting aim to gather the opinion toward the study result, held on 16 September 2020 at the Golden City Hotel Rayong, with 97 participants.

2.5 Documentation

Several documents were made for this Project, including the following:

1. A database of NO_x, SO_2 and VOCs emission in the hard copy and in the computer system (external hard disk) (4 sets).

2. The final report (50 copies)

3. Executive Summary Report in Thai and English (50 copies each)

4.The report of air pollution carrying capacity of Map Ta Phut Industrial Area and the industrial expansion according to the air pollution carrying capacity of the area, and policy recommendations for sustainable industrial development (100 copies with CD-ROM)

5. Simplified information about AERMOD for the public and the guideline for VOCs assessment from industrial factories (100 copies with CD-ROM)

The cover of relevant reports and documents have QR code for PDF download.

2.6 Webpage

The content on the webpage includes the project description, relevant knowledge, database, and the assessment results of pollution distribution in ambient air using mathematical model so that the public have access to and are able to perform the basic assessment. The webpage shall be linked with the website of ONEP and EEC Office (http://eec-mtp.onep.go.th/)

Figure 17 Main page of the webpage

3 Recommendations

3.1 Policy recommendations for NO_x and SO_2 management

Based on the assessment results of air quality using the mathematical model to analyze the carrying capacity of NO_x and SO_2 in the area and the public opinion hearing with the stakeholders, the Consultant has compiled the policy recommendations for NO_x and SO_2 management in order to achieve sustainable and suitable industrial development in Map Ta Phut pollution control area.

3.1.1 Policy recommendations for assessing air quality with AERMOD

1) For Nitrogen Dioxide and Sulfur Dioxide management, AERMOD can be used quite effectively, based on the accuracy of the Q-Q plot method. In addition, the three sets of data, namely the sources, meteorological data, and topographical data (elevation) were collected in the forms that can be used without any obstacle. However, regarding the principle and objective of management for Nitrogen Dioxide, there are only standards value for 1-hr average and 1-year average. Therefore, it is important to determine the standard for 24-hr average to monitor NOx during a 24-hr period because some areas may have an average measurement value of 1-hr beyond the standard, to improve air pollution management, and to be useful for assessing air quality with AERMOD. For Sulfur Dioxide, the complete criteria are already available, including the 1-hr average, 24-hr average, and 1-year average.

2) Based on the study of air pollution carrying capacity with AERMOD, it was found that the "Control values in the EIA report" Nitrogen Dioxide and Sulfur Dioxide already exceeded the carrying capacity. However, considering the "Actual results", it was found that the emission rate of the actual production has not exceed the standard. Therefore, the 80:20 principle should continue to be used (There are projects that are not operated or projects that have closed but still possess the emission quota). The purpose is to reduce the pollution reduction in the "Control values in the EIA report" or the accounting value to be close to the current "Actual results". To be specific, the values of Nitrogen Dioxide dropped from 2,116.44 g/s to 905.04 g/s or around 57% and Sulfur Dioxide dropped from 1,738.21 g/s to 784.93 g/s or 55%.

3) Currently, the air quality impact assessment criteria are based on the following principle.

Air quality when the project is established

= **maximum concentration caused by the project** (the estimate by AERMOD) + **background concentration + maximum concentration from projects that have been approved by ONEP** (projects that required to make EIA reports) **which is not emitted into the atmosphere**

However, by using Q-Q Plot, it was found that Nitrogen Dioxide usually shows negative intercept, meaning there might be the concentration of other sources in ambient air and the values of each station are not the same. Therefore, the background concentration from the previous year should be concluded by government agencies and the same background value should be used as the standard for environmental impact assessment for Map Ta Phut.

3.1.2 Policy recommendation for NO_x and SO_2 management

1) Data management

Government agencies should establish a local center for environmental administration and a central database system. They should also promote academic knowledge, provide consultation, and share opinions among government and private sectors' personnel (including the managerial and operational staff), as well as the public sector to cover all the aspects of pollution control and to create the network and encourage participation.

Relevant agencies should integrate the data for the economic, social, and environmental benefits. For example, they study of health impact from industrial sector can be integrated with public health agencies in order to analyze environmental data and the effect of the 80:20 principles with the public health data.

2) Data preparation for air quality assessment with mathematical model

- Government agencies should prepare the background concentration and use the same background value as the standard for local environmental impact assessment. Map Ta Phut Sub-district Health Promotion Monitoring Station should be used to monitor Nitrogen Dioxide (NO_2) and Sulfur Dioxide (SO_2) generated by industrial sector in Map Ta Phut pollution control area. Moreover, the results of atmospheric air quality measurements for each station in industrial area should be provided to set as the average value for new projects owner, production expansion, or revised project.
- For assessing air quality with AERMOD, If sensitive receptors such as schools and temples on the mountains are affected, there should be a more detailed grid receptor than on the plain to make sure if the maximum concentration (Cmax) falls on the mountain area.

3) Review the scope of using the 80:20 principle

A central agency should be in charge of administering and developing industrial area in Map Ta Phut pollution control area (both in and outside of the industrial estate), review the pollution emission rate based on the 80:20 principle, and review the carrying capacity of the area.

Relevant agencies should review and determine the use of the 80:20 principle with the industry that affects the air quality impact. This is because this measure is not put to effect as a law, but only an administrative order as the condition for specific factories which are applicable to perform the EIA, EHIA, or IEE.

The authorizing agencies should monitor the effect of the 80:20 principles of the authorized project based on the actual emission values of the Project. The Consultant would like to suggest the practice guideline for the factories that are already operating and do not change the project description after the approval of EIA, EHIA, or IEE within the period of 10 years (or as determined otherwise) in two cases.

Case 1: Review the report of EIA/EHIA/IEE and report of actual emission in the past and submit to the authorizing agencies and/or ONEP.

Case 2: Make the project development plan for the next 10 years (or as determined) and the report of actual emission in the past and submit to the authorizing agencies and/or ONEP.

4) Development and promotion of Economic mechanisms for environmental protection

Increase or review the policy and measure to promote environmental management for industry such as emission trading via participation process. There should be a central agency and a clear and fair emission trade mechanism. Implementations are divided into 2 cases.

Case 1: For factories that are already operating and have spare emission value, these factories can stock the emission spare in the future and trade as they wish.

Case 2: For factories that have not been constructed and the emission quota has been allocated, these factories need to be established within 5 years (or as determined). Failure to do so will force them to return the emission quote by 20% per year (or as determined) until the construction is complete. If a factory does not have enough emission quota, the factory needs to trade more with the central agency.

The above cases will allow the quota of emission and introduce the modern air pollution control technology in the production process.

The money earned from emission trading should be returned to local communities for sustainable development. The community and relevant sectors should participate and have a voice in how the money will be spent.

5) Knowledge promotion of area-based pollution management

Knowledge promotion of area-based pollution management is important for the present and the future so that government officials from the central and regional area, as well as private sectors (including managerial and operational level), and the public. Media and documents should be suitable for audience at different levels. The effectiveness of this measure should be monitored and assessed. There should be a channel for sharing opinion from stakeholders for the sake of continuous improvement. There should be research and development to improve and update knowledge by coordinating with universities, developing lessons to educate students about environmental management, air pollution control or treatment technology, and improvement of technology for domestic use in the future.

3.2 Policy recommendations for VOCs management

Considering the study results, which are about the assessment of VOCs emission based on the area sources, there are limitations in VOCs management. It can be concluded that AERMOD as the VOCs management tools for the 3 pollutants in the study area is not enough. There should be more measures. The Company, therefore, offers recommendations from the study results for VOCs management in the future.

3.2.1 Policy recommendations for air quality assessment for factories

- **VOCs management with factory sources:** Suitable measures for each factory are:
  - **Using LDAR Program:** VOCs should be monitored and control. VOCs from fugitive sources can be controlled by using leak detection and repair program known as LDAR program. This method will require the factory operators to survey VOCs and take corrective action within specific time frame if leak is detected. The implementation outcome can reduce VOCs emission effectively. Usually, VOCs emission reduction will be more effective if the survey is conducted more often.
  - **Fence line monitoring measure** is developed to monitor potential impact from VOCs emission. The method can be referenced from US. EPA Method 325A and 325B. The implementation results will be calculated to find the difference in

concentration. For example, if the 1-year Benzene concentration average and the difference is more than 9 μg/m^3, the factory need to find corrective measures.

- **VOCs Inventory** is an accounting process to quantify VOCs by benchmarking with the result of good practice.

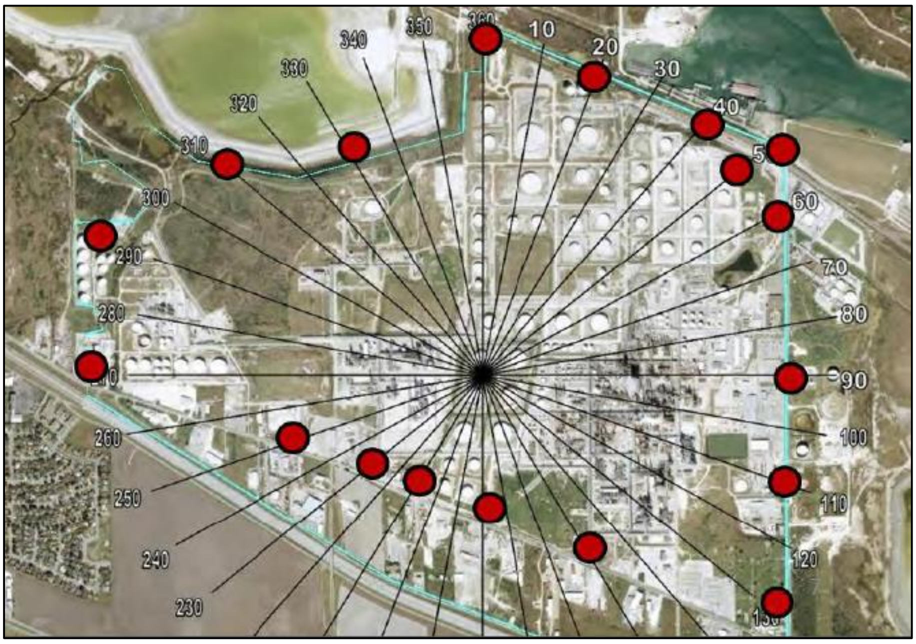
○ 

Figure 18 Example of pinning VOCs monitoring stations around the factory (fence line monitoring) (Source: US.EPA (2015))

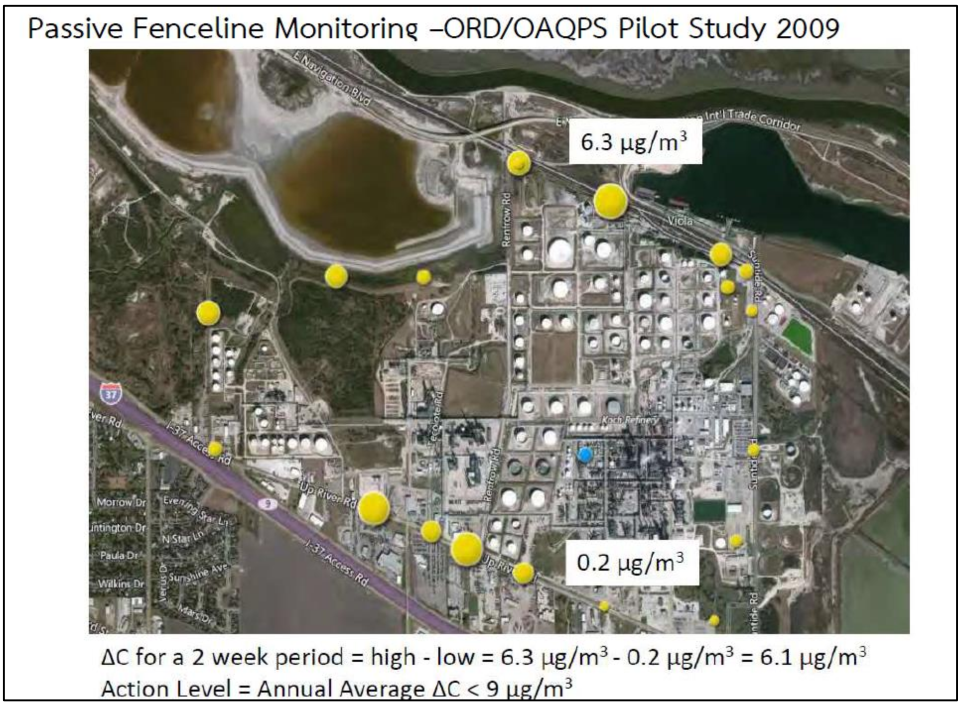


Figure 19 Example of VOCs monitoring around the factory (fence line monitoring) (Source: US.EPA (2015))

3.2.2 Policy recommendations for VOCs management with legal measures

- **Control and management of Benzene, 1,3-Butadiene, and 1,2-Dichloroethane continuously.** The results of ambient air quality by Pollution Control Department and IEAT in 2019 of the three types of VOCs still exceeded the standard in some areas.

- **Review the standard of legal measure for 1-year VOCs in ambient air to suit the current condition of the area.** Compared to the standard of Benzene in ambient air of other countries (1-year concentration <1.7 µg/m^3), Thailand's standard is stricter than many countries such as Japan, South Korea, Canada, New Zealand, South Africa, the United Kingdom, the European Union. For 1,3-Butadiene, Thailand standard (1-year concentration <0.33 µg/m^3) is stricter than than New Zealand and the United Kingdom (**Table 5**). Therefore, it is difficult to reduce VOCs in the industrial sector based on the current standard. The enforcement of the same standard in the industrial area and the community area also is a problem for communities. Relevant agencies should review the standard and control values to be more suitable. The criteria for standard value of the EU determines that 1) standards should come from observation or survey with a scientific method or considered from the health or environmental impact of a certain substance. It may not cover technological or economic aspect to control or minimize the impact from such a substance. 2) The standard should be universal for every area, with an exception for conservation area. 3) The standard should be practical. If factories cannot follow the standard within a short time, there should be timescales of compliance with legal measures by years.

- **Pass the VOCs control law to be clear, comprehensive for all sources and factories, non-redundant with existing law, and equally enforceable.** The current control of VOCs from industrial sources focus on fugitive and stacks. Other sources were only the guideline and recommendation instead of a clear law. The enforcement is voluntary or cooperative. Therefore, the control of VOCs is not complete. Currently, there are laws under investigation and pending for enactment such as the (draft) measure for volatile organic compounds from factories (year...), the (draft) notification for the report of incinerators (year....), and the (draft) control measure for volatile organic compound emission from storage tanks (year...). To pass a new law, it is important to hear opinions of all stakeholders and should not be redundant with existing law. The new law should be equally applicable to all factories. For example, factories located outside of industrial estate as significant sources should take the measures or be audited by agencies as strictly as factories in the industrial estate.
- **Review or revise laws about monitoring and reporting VOCs data to minimize redundancy.** Currently, factories, especially those in industrial estates, need to monitor VOCs and submit the report to several agencies. These agencies have different report formats and submission interval. The inconsistency cost time and labor for making each report. The databases of each agency are also inconsistent. In addition, it is advised to compromise for factories that revised the project description, which does not increase production capacity or pollution emission significantly. These factories should be exempted from making another EIA report, but only add the project descriptions and pollution assessment into the existing report.

Table 5 Standard of VOCs in ambient air of other countries

State / Country / Region	Control Value	Unit
1. Benzene		
European Union [1]	5	µg/m^3 (1 year)
United Kingdom [2]	3.6	µg/m^3 (1 year)
Arizona, USA [3]	630	µg/m^3 (1 hr)
	51	µg/m^3 (24 hr)
	0.14	µg/m^3 (1 year)
Japan [4]	3	µg/m^3 (1 year)
South Korea [5]	5	µg/m^3 (1 year)
Alberta, Canada [6]	30	µg/m^3 (1 hr)
	3	µg/m^3 (1 year)
Ontario, Canada [7]	5	µg/m^3 (24 hr)
New Zealand [8]	3.6	µg/m^3 (1 year)
South Africa [9]	5	µg/m^3 (1 year)
2. 1,3-Butadiene		
United Kingdom [2]	2.4	µg/m^3 (1 year)
New Zealand [8]	2.4	µg/m^3 (1 year)

Sources:

[1] European Union (2000), Directive 2000/69/EC of the European Parliament and of the Council of 16 November 2000 relating to limit values for benzene and carbon monoxide in ambient air.

[2] UK, 2007 No. 64 Environmental Protection: The Air Quality Standards Regulations 2007.

[3,7] PCD (2009), The Development of Environmental and Emission Standards of Volatile Organic Compounds (VOCs) in Thailand: Table 9 Internationally available of ambient VOCs guideline.

[4] Masanori Kida, Deputy Director, Air Quality Management Division, Environmental Bureau, Ministry of the Environment, Japan

[5] Wen-Tien Tsai (2016), Toxic Volatile Organic Compounds (VOCs) in the Atmospheric Environment: Regulatory Aspects and Monitoring in Japan and Korea.

[6] Government of Alberta (2015), Ambient Air Monitoring Performance Specification Standards – Continuous Analyzers.

[8] Ministry for the Environment, New Zealand (2002), Ambient Air Quality Guidelines 2002 Update

[9] Minister of Water and Environmental Affairs, South Africa (2009), National Environmental Management: Air Quality Act (2004)

3.2.3 Policy recommendations for VOCs control by administration

- **The Central Database System should contain all data about VOCs management** to monitor the environmental impact solution. The data should be stored in the central database system, including the data of overall VOCs inventory of the area, the ambient air quality, the standard of management in the industrial estate and factories operated in the area. The data should be systematically stored and traceable from the past to the present. All stakeholder agencies and private sector should participate in the process of making the central database. A central unit shall take the lead in supervising all Map Ta Phut pollution control area and adjacent area in and outside of the industrial estate. It is important to seek collaboration from Pollution Control Department, Department of Industrial Works, EEC Office, provincial industrial office, provincial office of natural resources and environment, local administrative organizations. Also, it is advised to review and revise the role or authority of the existing agency, which usually have issues of incomprehensiveness and redundancy with other agencies.
- **Review the location of VOCs monitoring station.** The VOCs monitoring stations, especially in the community area, have been in charge of the Pollution Control Department for many years. However, the land use of Map Ta Phut pollution control area has changed a lot, with more community density and land transportation. The monitoring stations at the ground level might be affected by VOCs emitted from vehicles.
- **Increase or review the policy or measures to promote environmental management for industry,** particularly equipment or technology for the sources that produce and/or use Benzene, 1,3-Butadiene, 1,2-Dichloroethane, oil refineries, oil warehouse, high-traffic industrial ports. The new policy and measure should cover the existing factories and the new ones, such as the income tax reduction, tax reduction for the import of pollution control machine, and promoting the reuse technology of VOCs. These will reduce the cost and amount of VOCs emission to the atmosphere. Some incentives might be attractive for investors who wish to expand the factories or build new factories without emitting additional pollution. There should be incentives for the factories that can reduce pollution emission significantly from the past or use the best available technology or best practice. All these depend on the potential of each factory. For instance, factories with limited budget might have problems of funding to change the costly technologies.

- **There should be a system to report the carrying capacity of Map Ta Phut pollution control area** by studying the VOCs carrying capacity continuously e.g. every 2-3 years. The system should determine whether the area can still have carrying capacity. This will help government agencies assess whether the VOCs reduction measures are effective or not and help them make more informed decisions about investing in expanding in or building new factories of private sectors.

- **Promote the study of VOCs emission and distribution from other sources than industrial sources.** To effectively reduce VOCs emission, it is important to handle with all relevant sources. Therefore, there should be a study to collect the data and assess VOCs emission from other sources than industrial ones, particularly vehicle. The project owner should take the leader role to supervise Map Ta Phut pollution control area and adjacent area.

- **There should be a system to promote academic knowledge, consultation, opinion sharing for staff of government agencies, private sectors (managerial and operational levels alike), and the public to cover al aspects of VOCs management.** The scope covers the policy, laws, measures, good practice, technology for VOCs control, and the current pollution status so that these stakeholders understand the policy, law, and measures for VOCs control more accurately. It is also a chance for sharing attitudes toward policies and measures into practice. Managers of factories should join this process of making the environmental policies and provide financial support to reduce VOCs. It is also important to educate staff about relevant laws and method for monitoring and calculating VOCs by using the same standard to avoid confusion. This will result in more credible data in the VOCs inventory. The training could be in the form of the guideline or manual.

- **Promote networking between central government, local government, private sector (business operators), and local communities** to effectively manage and reduce VOCs and update knowledge and understanding among themselves.

- **Communicate more about environmental monitoring result and the VOCs management method to local agencies and communities continuously** using local mechanisms such as the industrial office, local factories, local administrative organizations such as provincial public health, municipality, sub-district administrative organization office. The communication of these data will allow all stakeholders to make use of the data to assess health impact on local people and increase trust for nearby communities.

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