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Application of Modelling Tools for Air Quality Management in Giao Long Industrial Zone, Ben Tre Province, Vietnam

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Abstract

The Giao Long industrial zone (IZ) is one of the important IZs in the socio-economic development of Ben Tre Province, Vietnam. Air quality management in Giao Long IZ has yet to achieve high efficiency. This study developed data on air pollution emissions from the production activities of enterprises and applied model system, The Air Pollution Model (TAPM) - The AMS/EPA Regulatory Model (AERMOD), to simulate the distribution of air pollution from the IZ to its surroundings. Research results show the following: (i) the emission load from coal combustion is significantly higher than that of other commonly used fuels, with 75% NO_2, 77% CO, 100% SO_2 and 99% TSP; (ii) simulation results show that the average 1-hour and 24-hour highest and annual concentrations of NO_2, CO and TSP are lower than the National Technical Regulation on Air Quality in Vietnam - QCVN 05:2013/BTNMT; in particular, for SO_2, the average 1-hour and 24-hour highest concentrations were 1.6-fold and 1.2-fold higher than QCVN 05:2013/BTNMT; and (iii) based on the results of the simulation and assessment of the impact of air pollution on the surrounding areas, the study proposed some solutions to improve efficiency in air quality management at Giao Long IZ. In addition, the study developed scenarios to reduce SO_2 emissions by enhancing SO_2 treatment efficiency in enterprise emissions. in addressing water-related problems and for sustainable water resource management.

Keywords: Air pollution; Giao Long industrial zone; TAPM-AERMOD model system

1. Introduction

Industrial production activities are significant sources of air pollution in urban areas. Studies on air pollution management in industrial zones (IZs) have been carried out all over the world. These studies were based on air quality monitoring results and assessed the influence of air pollutants from IZs on human health (Al-Hasnawi *et al.,* 2016; Perrino C. *et al.,* 2020; Neha Parveen *et al.,* 2021). In addition, studies have been conducted using air quality models to assess the impact of industrial activities on surrounding areas (Shuang-Hua Yang *et al.,* 2022; Wanting Hei *et al.,* 2022; Gengyu Gao *et al.,* 2021; Pravitra Oyjinda *et al.,* 2019; K Katika *et al.,* 2018; Sunil Gulia *et al.,* 2015; H. Moradi *et al.,* 2013; R. Sivacoumar *et al.,* 2001) or using deep learning models (Qingtian Zeng *et al.,* 2021), as well as other models. In Vietnam, environmental protection in IZs has been gradually given attention and focus by agencies, departments and enterprises dealing with IZ infrastructure. To evaluate the limitations in the environmental management of IZs, Le Thi Kim Tuyen *et al.* (2012) analysed the limiting factors in environmental management (Tuyen, 2012). Tran Van Minh *et al.* (2020) assessed the current situation to propose solutions to improve the efficiency of environmental management in IZs (Tran Van Minh *et al.,* 2020). In addition, Pham Xuan Truong *et al.* (2017) conducted a similar study in the Northwest Dong Hoi IZ, Quang Binh Province (Truong, 2017). Nguyen Thi Thu Thuy *et al.* (2018) assessed the state management of IZ development in Hai Phong City as a premise for developing solutions to improve the sustainable development of IZs there (Thuy, 2018). Nguyen Phuong Binh (2014) also used the AMS/EPA Regulatory Model (AERMOD) model to assess the possibility of air pollution transmission in Tam Thang IZ and proposed solutions to improve efficiency in environmental management in the IZ (Phuong, 2014).

An emission inventory study for point sources is an essential step in air quality management in IZs. The three main methods commonly used to calculate point source air emissions are monitoring, material balance and emission factor. In general, the monitoring method at source is considered the best method to access the actual emission quality; however, it is too costly in terms of both money and effort. Meanwhile, the material balance method is less accurate, in general. Therefore, this study applies the emission factor method to calculate air emissions in IZ (Ho Quoc Bang and Ho Minh Dung, 2021).

In addition, the air quality model is one of the most commonly used tools in air quality management today. This tool allows the simulation of air pollution distribution and can forecast air quality according to different scenarios of emission sources. Currently, several models can be used to simulate air quality at different scales, such as the Community Multiscale Air Quality Model (CMAQ) (Jorge E. Pachón *et al.,* 2018; Haotian Zheng *et al.,* 2019), the Transport and Photochemistry Mesoscale Model (TAPOM) (Zarate, E *et al.,* 2007; Brulfert G. *et al.,* 2004), the AMS/EPA Regulatory Model (AERMOD) (Hang, 2020; Nguyen Thanh Ngan *et al.,* 2017; Ba Quoc Tran, 2020; Maryam Idris *et al.,* 2019; Yara S Tadano *et al.,* 2014; Noorpoor A *et al.,* 2015; N. Jittra *et al.,* 2015), the Chemistry Transport Model (CTM) (Ho Quoc Bang *et al.,* 2019; Stephen Vander Hoorn *et al.,* 2022) and the California Puff Model (CALPUFF) (Quoc Bang Ho *et al.,* 2019; Nattawut Jittra *et al.,* 2015). In addition, there are some meteorological models to simulate meteorological data as input data for air quality models, such as the Mesoscale Model (MM5) (Curci Gabriele *et al.,* 2000; Nguyen Thanh Ngan, 2015), the Weather Research & Forecasting Model (WRF) (Tran Tan Tien *et al.,* 2018; Kumar *et al.,* 2014), the Finite Volume Model (FVM) (Minh Dung Ho *et al.,* 2009) and the Air Pollution Model (TAMP) (Mai Xuan Khang, 2021; Vu Hoang Ngoc Khue *et al.,* 2018). Based on the above studies, each model has its advantages and disadvantages. Depending on the size of the simulation area and emission sources, it is possible to choose the appropriate model system for each study. In this study, the authors chose TAPM-AERMOD model system because it is suitable for the simulation of point sources and provides accurate simulation results.

This study aims to evaluate the impact of air quality in Giao Long IZ on the surrounding areas using the AERMOD model and then proposes appropriate mitigation measures to combat the air pollution problem in this IZ.

2. Materials and methods

2.1 Study area

Giao Long IZ is located in Chau Thanh District, Ben Tre Province (Figure 1), with a total area of 164.22 hectares and an occupancy rate of 93.5%. Until 2020, Giao Long IZ has 27 investment companies and is officially operating. Enterprises in Giao Long IZ include industries such as garment, production of coconut products, paper production, packaging production, synthetic leather production, handbag processing, leather products, cocoa production, equipment, car components, textiles, energy and coal production. In addition, the enterprises in Giao Long IZ use several types of fuel (coal, firewood/rice husk, diesel oil, etc.) in high volume in their procedures that can cause air pollution; thus, the authors chose this IZ for the present study. The selected air pollutants in this study were NO_2, CO, SO_2 and TSP, mainly emitted from manufacturing activities and fuel use in Giao Long IZ.

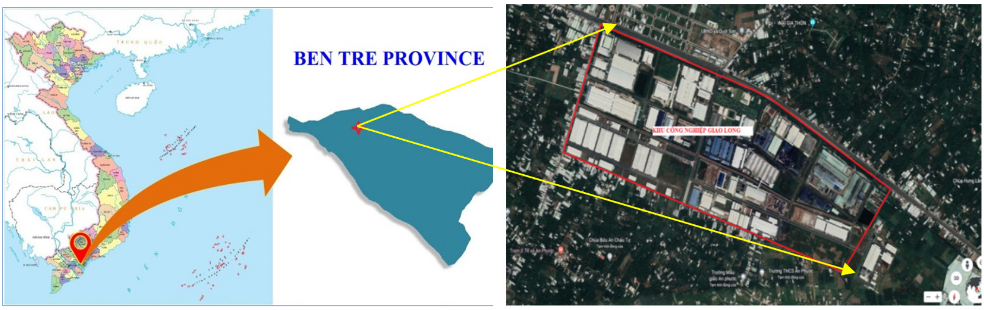

Figure 1. Location of Giao Long IZ (Source: Google Earth)

2.2 Research contents

The specific research contents of this study are as follows: (i) assessing the current status of air environment management in Giao Long IZ, including surveying the current situation in Giao Long IZ to obtain more specific information about the environmental issues there, finding out the current status of air quality in Giao Long IZ and the enterprises there (boiler, fuel used, exhaust gas treatment systems, etc.) and calculating air emissions from enterprises in Giao Long IZ; (ii) applying the TAPM-AERMOD model to simulate the possibility of air pollution distribution from the activities in the IZ to neighbouring areas, including assessing air pollution dispersion from activities in the IZs to surrounding areas; and (iii) from the results of the simulation, the distribution of air pollutants in the environment and the assessment of the influences and limitations in air environment management, this study proposes solutions to improve the efficiency of air quality management in Giao Long IZ.

2.3 Methodology

2.3.1 Field survey

The general statistical method synthesizes all secondary data to analyze the actual situation of environmental management in Giao Long IZ. The data processing method is used to process all input data, and the emission sources of enterprises are used to help prepare input data for the AERMOD model. The method of investigation and field survey helps provide more information to supplement the input data of the model, such as production capacity, amount of fuel used, number of stacks, stack height, exhaust gas temperature, type/amounts of fuels used, volume, combustion time and exhaust gas treatment system. To obtain sufficient data for the research, the authors collected and surveyed all 27 enterprises in Giao Long IZ.

2.3.2 Estimation of emission

The emission load calculation method is based on the emission factor. According to Official Letter No. 3051/BTNMT-TCMT, the Ministry of Natural Resources and Environment recommended using emission factors to calculate a load of air pollutants in different emission sources. Therefore, the authors chose the method of calculating emission load by emission factor in this study. The load emission of each air pollutant from each source is calculated using the following formula:

$$E = A \times EF \times [1-(ER/100)]$$

where E is the emission level (g/year), EF is the emission factor (g/ton of fuel or product), A is the operating rate (tons of fuel use or tons of product/year) and ER is the efficiency of the pollution treatment system (%). The calculation of the emission load involves two sources, namely, fuel combustion and production processes. The emission factors are referenced in the EMEP/CORINAIR emissions inventory manual (European Environment Agency, 2016).

2.3.3 Air quality model

The TAPM meteorological simulation model developed recently at The Commonwealth Scientific and Industrial

Research Organisation (CSIRO) can simulate air quality in three dimensions. In the TAPM V4 version, this function is also improved when integrated with surface and profile meteorological file formats. Therefore, the TAPM model can also be considered a meteorological support tool for pollutant dispersion models, especially as input meteorological files for air quality models, which include the AERMOD model (Peter Hurley, 2008). The AERMOD (AMS/EPA Regulatory) air pollution model consists of three main parts (Figure 2): 1) AERMOD (AERMIC dispersion module); 2) AERMAP (terrain module) and 3) AERMET (meteorological module). The AERMOD model is the best support tool for simulating pollutant dispersion in the study area. The input data for the model include the emission data for each plant (area and point source), surface, upper meteorological data and terrain data.

For the calibration and validation of the model, the meteorological monitoring data of the Hydrometeorological Center of Ben Tre Province (coordinates: 10.242573°N, 106.364551°E) during the period 1–31 January 2020 was used to verify the TAPM model by the correlation coefficient R. For calibration and validation the AERMOD model, the formula for calculating the simulation error S was used (periodic monitoring results of Giao Long IZ in 2020 for model calibration and verification). If S ≤ 15%; R ≥ 0.6, the simulation results are close to the actual conditions (Vu Hoang Ngoc Khue *et al.,* 2018).

$$R = \frac{\sum(P_i-\overline{P_l})*(O_i-\overline{O_l})}{\sqrt{\sum(P_i-\overline{P_l})^2*\sum(O_i-\overline{O_l})^2}} \quad ; \quad S = \frac{100*|P_i-O_i|}{O_i}$$

where P_i is the simulated value, $\overline{P_l}$ is the average of the simulated values, O_i is the observed value, $\overline{O_l}$ is the average of the observed values and i is the value at time i.

2.4 Preparation model input data

2.4.1 TAPM model

The input data for the TAPM model are the global meteorological observations for different world regions. The data include global topographic elevation grid data, soil type data, water data, vegetation data, leaf area index, global scale meteorological data and information about the simulation area, such as coordinates, location, topography, average annual temperature, wind speed and precipitation. The TAPM model will simulate detailed meteorology using nested grid cells. In this study, three simulation domains are selected according to size, namely, from large to small. This number of domains ensures the detailed simulation size for the area of Giao Long IZ. Domain 1 has dimensions of 300 km × 300 km with 30 × 30 grid cells (grid size, 10 km × 10 km); Domain 2 has dimensions of 150 km × 150 km, with 30 × 30 grid cells (5 km × 5 km grid size); and Domain 3 has dimensions of 30 km × 30 km, with 30 × 30 grid cells (grid size 1 km × 1 km). The output meteorological file includes the surface meteorological and upper meteorological data.

2.4.2 AERMOD model

(I) Simulation scope: For the AERMOD model to simulate the dispersion of air pollutants, it is necessary to determine the terrain and research scope (Figures 3 and 4). In general, the terrain in the simulation area is relatively flat.

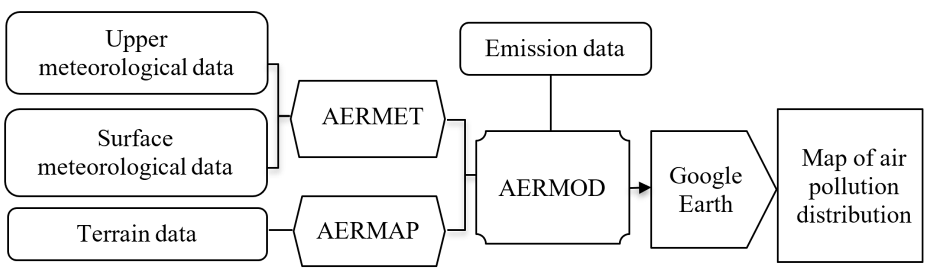

Figure 2. Simulation steps according to the AERMOD model

(II) Set up and run the AERMOD model: First, it is necessary to determine the centre of the study area and the radius of the simulation area. The centre coordinates in the UTM coordinate system are X = 6534470 m and Y = 1138774 m, and the simulation radius is 30 km, covering the simulation area. Input the emission source data (including coordinates of emission sources according to the UTM system, emission loads, height and diameter of stacks, topographic elevations calculated according to sea level, velocity and temperature of exhaust gases). Set up the grid and simulation area. Declare the two meteorological files obtained from the TAPM model. Process the terrain of the study area and then run the AERMOD model.

3. Results and discussion

3.1 Assessment of the current status of environmental management in Giao Long IZ

Until 2020, Giao Long IZ has 27 investment and operation companies. Given that Giao Long IZ focuses on different types of industries, the current environmental management in the IZ still needs to improve. Currently, air quality management at the enterprises there is based mainly on the results of periodic environmental monitoring. However, these monitoring results are mostly for reference only; the data do not reflect the reality that would enable the authority to assess the ability and efficiency of waste gas treatment at the enterprises. The enterprises have installed exhaust gas treatment systems with key technologies, such as cyclone, filter, absorption tower, dry filter tower and wet filter tower. Generally, the enterprises' exhaust gas treatment technologies only partially meet the treatment of common pollutants TSP, SO_2, CO and NOx. In addition, the enterprises have not fully implemented the periodic maintenance and cleaning of environmental treatment systems.

The current air quality status around Giao Long IZ in 2020 was assessed by the Industrial Zones Authority of Ben Tre Province based on environmental monitoring results in the IZ, showing that the concentrations of SO_2, NO_2, CO and TSP reached QCVN 05:2013/BTNMT (MONRE, 2013). Moreover, based on the enterprises' environmental monitoring reports, the quality of the exhaust gas met the standards of QCVN 19:2009/BTNMT. However, the above results do not accurately reflect the actual air quality in Giao Long IZ.

3.2 Emission calculation results

According to the survey results of the 27 enterprises operating in Giao Long IZ, only seven have a stage of burning fuel for production. The remaining enterprises do not have a set of burning fuel or buying steam. Table 1 shows the calculation results of emissions from fuel-burning plants. Based on Table 1, we can see that the air emission load from Thanh Cong Energy Services Joint Stock Company (JSC) is the highest. Depending on the nature of the company's industry, its

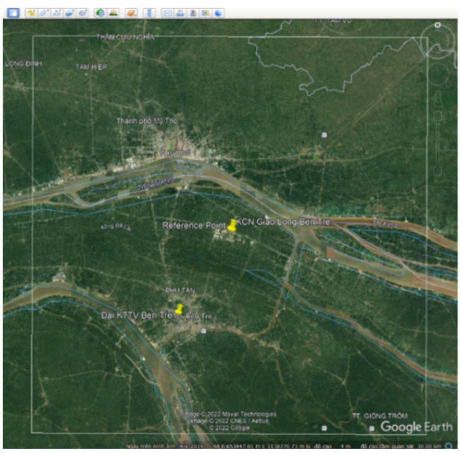

Figure 3. Map of the simulation area

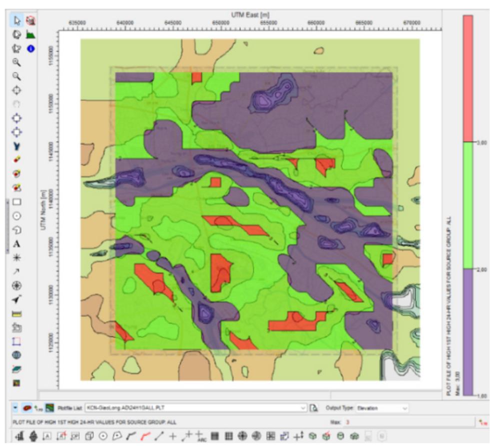

Figure 4. Terrain map of the study area

demand for fuel (coal and rice husk) is quite high to provide steam for enterprises in the IZ. Therefore, the level of emissions of Thanh Cong Energy Services JSC is much higher than that of other companies.

To assess the emission load arising from different kinds of fuel, the authors synthesised the emission loads from four main types of fuel, namely, coal, firewood/rice husk, DO and LPG, in 2020 (Figure 5). The results show that in Giao Long IZ, coal and firewood/rice husks are commonly used as fuels in factories. The use of coal and firewood/rice husk is mainly due to the fact that they are cheaper than other fuels (DO, LPG). The calculation results of the pollutant load of fuels show that coal fuel is the main source of emissions in the IZ; the rate is nearly 100% for SO_2 and TSP, 77% for CO and 75% for NO_2. This is followed by firewood/rice husk at the rate of 16% for NO_2 emission and 22% for CO emission. Meanwhile, due to the small amount used by the enterprises, DO and LPG account for a negligible proportion of the air emission pollution in Giao Long IZ.

Table 1. Point source air emission load at the enterprises

No.	Enterprises	Emission load (tons/year)			
		NO_2	CO	SO_2	TSP
1	Viet Thanh Garment Company	4.3	4.3	0.073	0.001
2	Viet World Company	2.6	10.8	26.2	0.745
3	Minwie Co., Ltd	10.6	52.7	100.5	3.3
4	Jacobi Carbons Vietnam Co., Ltd	62.8	325.1	590.2	28.2
5	Branch of Kien Giang Canned Food JSC in Ben Tre	1.43	6.9	0.14	0.002
6	Coronet Vietnam Co., Ltd	35.4	13.86	0.360	0.360
7	Thanh Cong Energy Service JSC	296.2	1702	3477	19.522

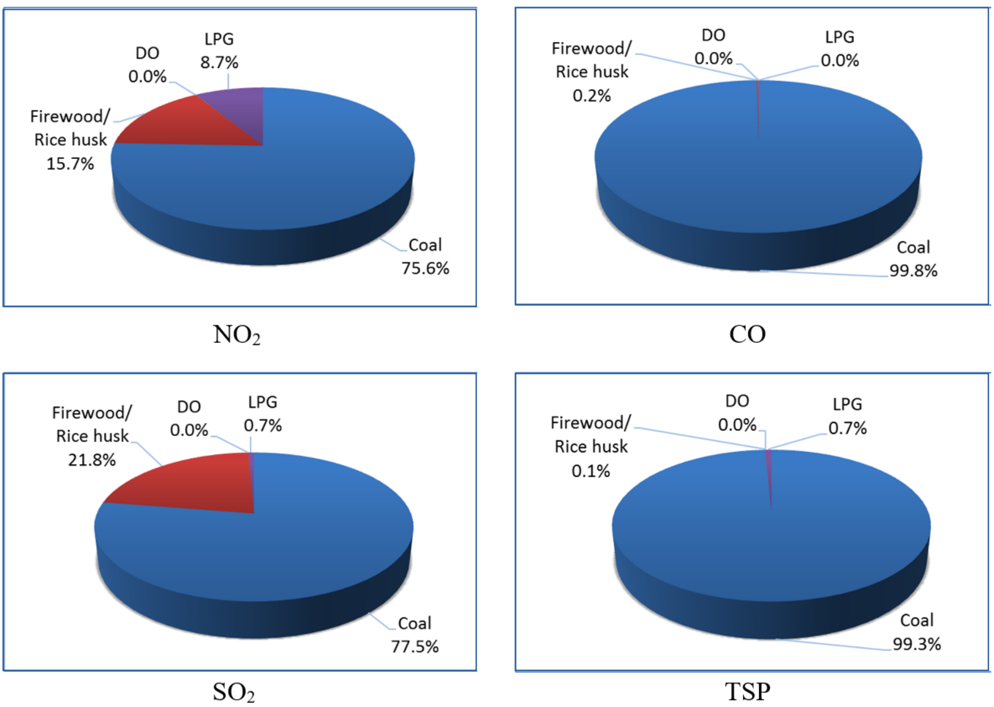

Figure 5. Emission load ratio of NO_2, CO, SO_2 and TSP of different kinds of fuel

3.3 Air quality simulation

3.3.1 Calibration and validation of the model

TAPM model: Surface temperatures and wind speeds are selected to validate the TAPM meteorological model. The test results show that the simulated temperature values through the TAPM meteorological model are close to the observed values with the coefficient R^2 = 0.76 (Figure 6). Thus, it can be used as input data for the AERMOD model.

AERMOD model: The air quality simulation results from the AERMOD model are calibrated and verified with periodic monitoring data of Giao Long IZ at two locations outside of Giao Long IZ: A1 - located outside the above IP National Highway 57B (550 m from gate D3 towards Highway 60); A2 - located outside the IZ on Highway 57B (630 m away from D3 gate towards Binh Dai). In the calculation results, the error between the simulated and observed values range from 6.24 to 13.3%, within ± 15%. Therefore, the AERMOD model is capable of simulating pollution transmission for this study.

3.3.2 Meteorological simulation

Based on the rise of wind simulated in 2020 by the TAPM model, the dominant wind direction of the year is the southeast, with the highest wind speed reaching 3.6 – 5.7 m/s.

3.3.3 Air quality simulation

The simulation results of the current air quality situation are summarised in Table 2.

NO_2: The highest average 1-hour concentration of NO_2 was 86.1 μg/m^3 (Figure 7), which reached QCVN 05:2013/BTNMT. The simulation results show that the dispersion of NO_2 is mainly to the west of Giao Long IZ, within a radius of 6 km. The concentration ranged from 60 – 80 μg/m^3, affecting a part of Chau Thanh District and Ben Tre City. The highest average 24-hour concentration of NO_2 was 23.1 μg/m^3, which reached QCVN 05:2013/BTNMT. The simulation results show that NO_2 disperses mainly to the northwest of the IZ. Within a radius of 4 km, the concentrations of NO_2 ranged from 10 to 20 μg/m^3, affecting a part of Chau Thanh District and My Tho City, Tien Giang Province. The annual average concentration of NO_2 was 11 μg/m^3, which reached QCVN 05:2013/BTNMT. The simulation results show that the concentration of NO_2 does not significantly affect the ambient air quality in the surrounding area of Giao Long IZ.

SO_2: The highest average 1-hour concentration of SO_2 was 566 μg/m^3 (Figure 8), which is 1.6 times higher than QCVN 05:2013/BTNMT. Within a radius of 1 km from the centre of the IZ, the concentration exceeded QCVN 05:2013/BTNMT. The highest average concentration in 24 hours of SO_2 was 149 μg/m^3, which is 1.19 times higher than QCVN 05:2013/BTNMT. This result shows that the pollutants tended to disperse towards the north of the IZ and move towards the resettlement area of Giao Long IZ, with concentrations ranging from 80 – 100 μg/m^3 within a radius of about 1 – 2 km. The annual average concentration of SO_2 was 42.32 μg/m^3, which is lower than QCVN 05:2013/BTNMT. The simulation results

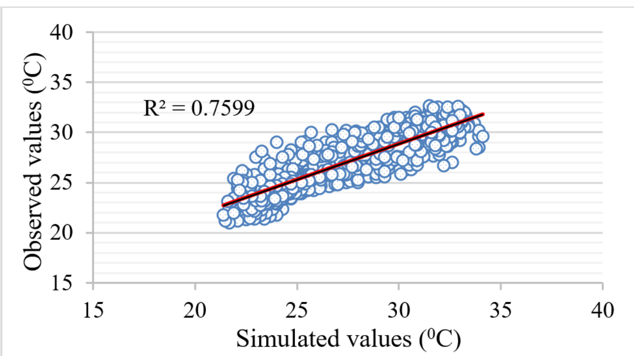

Figure 6. Result of temperature parameter testing of the TAPM model

also showed the direction of air pollutants spreading from East to West of the IZ. The annual average concentration of SO_2 was 20 – 40 g/m^3 and tended to spread to the northwest of the IZ, partially affecting Phu An Hoa commune, Chau Thanh District.

CO: The highest concentration in 1 hour of CO was 328.16 µg/m^3 (Figure 9) at the site opposite the main gate of the IZ and met QCVN 05:2013/BTNMT. The pollutants tended to disperse through My Tho City, Tien Giang Province, which is the influence of sea breezes going inland. The CO concentration was about 100 – 300 µg/m^3, accounting for the majority, which tended to spread from Giao Long IZ to the neighboring areas with a radius of 5 – 10 km from the point with the highest concentration. The highest average concentration of CO in 8 hours was 199.6 µg/m^3 at the site opposite the IZ and reached QCVN 05:2013/BTNMT. Within a radius of 4 km, the concentration ranged from 10 to 20 µg/m^3, affecting a part of Chau Thanh District and spreading to My Tho City, Tien Giang Province.

TSP: The highest average 1-hour TSP concentration was 191 µg/m^3 (Figure 10), which met QCVN 05:2013/BTNMT. The simulation results also show that TSP was dispersed around Giao Long IZ, with concentrations in the range of 100 – 200 µg/m^3, concentrated mainly in the northwest of the IZ, bordering Phu An Hoa commune, with a radius from the centre of about 1 – 2 km. The highest 24-hour average TSP concentration was 21.11 µg/m^3, meeting QCVN 05:2013/BTNMT. In addition, the range of TSP concentration was from 10 to 20 µg/m^3, mainly concentrated in the northwest of the IZ, and with a radius of about 2 – 3 km. The average annual concentration of TSP was 4.52 µg/m^3, which reached QCVN 05:2013/BTNMT. However, the TSP emission of the enterprises in Giao Long IZ was not significant for the ambient air quality in the area.

Table 2. Simulation results of the state of air quality in Giao Long IZ in 2020

No.	Parameters		Modelling result (µg/m^3)	QCVN 05:2013/ BTNMT (µg/m^3)
1	SO_2	Highest 1-hour average	566	350
		Highest 24-hour average	149	125
		Year average	42.34	50
2	CO	Highest 1-hour average	328.16	30,000
		Highest 8-hour average	199.6	10,000
3	NO_2	Highest 1-hour average	86.14	200
		Highest 24-hour average	23	100
		Year average	11	40
4	TSP	Highest 1-hour average	191	300
		Highest 24-hour average	21.11	200
		Year average	4.52	100

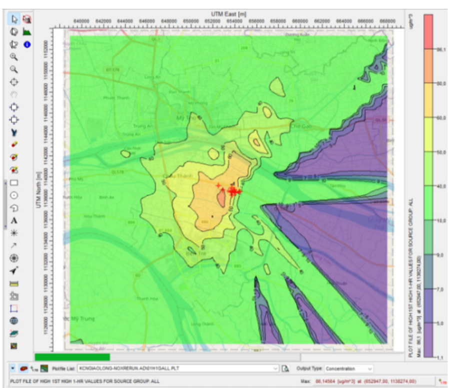

Figure 7. Simulation result of the highest average 1-hour concentration of NO_2

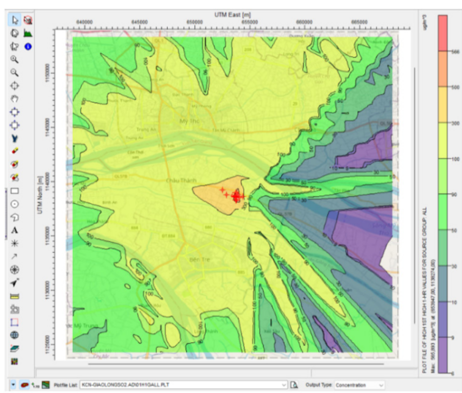

Figure 8. Simulation result of the highest average 1-hour concentration of SO_2

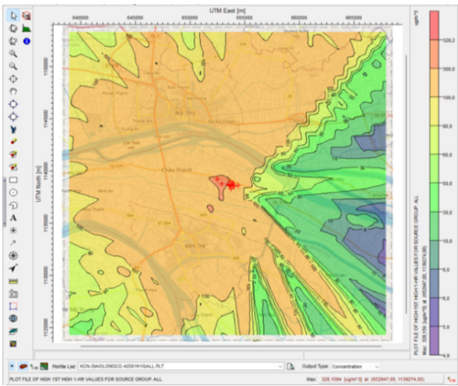

Figure 9. Simulation result of the highest 1-hour average concentration of CO

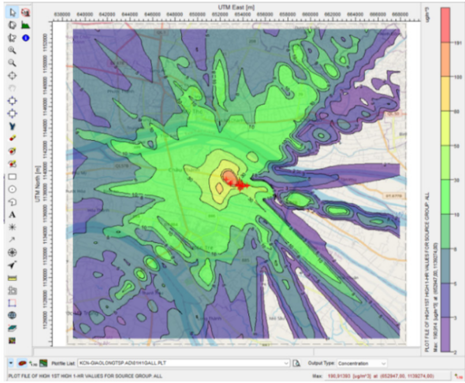

Figure 10. Simulation result of the highest average 1-hour concentration of TSP

Thus, the simulation results show that the NO_2, CO and TSP concentrations all met the QCVN 05:2013/BTNMT, which means the impacts of these air pollutants do not significantly affect the air quality of the surrounding area of Giao Long IZ. However, the highest 1-hour average concentration of SO_2 exceeded QCVN 05:2013/BTNMT, prompting the need to re-evaluate the exhaust gas sources and the quality and type of fuels used, especially the efficiency treatment of SO_2 at the treatment exhaust gas systems.

3.4 Proposed solutions to improve air quality management in Giao Long IZ

3.4.1 Policy and management solutions

Air quality management in Giao Long IZ is beset with many difficulties, especially in inspecting and handling business violations on air pollution issues. To overcome these difficulties, the following solutions are proposed:

(i) Assigning the right of full-time inspection to the Industrial Zones Authority to inspect and coordinate with agencies to handle violations in the environmental field;

(ii) Applying information technology in environmental management, building an information network between agencies and companies, such as the Industrial Park Authority, Infrastructure Development Company, departments, and enterprise data systems, as well as timely information update support in business management;

(iii) Strengthening the inspection and examination of environmental protection activities, especially at enterprises that pose a high risk of causing environmental pollution; the environmental inspection agency must coordinate with the Industrial Zone Authority to conduct an unscheduled inspection of operating enterprises;

(iv) Requiring enterprises with high pollution potential to install automatic exhaust gas monitoring stations and to send results directly to the management agency so they can directly monitor the exhaust gas quality of these enterprises;

(v) Imposing strict punishments for enterprises that do not fully implement environmental protection; the application of cleaner production solutions and circular economy must be promoted to improve production efficiency and reduce pollution;

(vi) Advocating for businesses with high pollution risk to conduct emission inventories, practice cleaner production and improve new treatment technology to reduce air emissions; enterprises should be advised to use the correct fuel as registered or clean fuel/clean energy and limit the use of fossil fuel sources; and

(vii) Governing units need to regularly propagate and organise training courses on environmental law or environmental protection activities at the enterprises located within the IZ to raise awareness on environmental protection in their production activities.

3.4.2 Technical solutions

Regular maintenance and use of appropriate chemicals are necessary for effective exhaust gas treatment systems. The above air quality simulation results show that the highest average 1-hour and 24-hour concentrations of SO_2 exceeded QCVN 05:2013/BTNMT. Given that SO_2 removal efficiency is highly dependent on the chemical used, two scenarios were proposed. In Scenario 1, the chemical quantities (NaOH/CaO) are sufficient for SO_2 treatment efficiency of about 40 – 60%, while in Scenario 2, more chemicals are used to achieve 70 – 80% SO_2 treatment efficiency. The simulation results show that in Scenario 1 (Figure 11), the highest concentration of 24 hours and the annual average of SO_2 was 94 $\mu g/m^3$ and 28.8 $\mu g/m^3$, respectively, which met QCVN 05:2013/BTNMT. However, the highest average 1-hour concentration of SO_2 was 368 $\mu g/m^3$, which is 1.05 times higher than QCVN 05:2013/BTNMT. In Scenario 2 (Figure 12), the highest average SO_2 concentration of 1 hour, 24 hours and the annual average were 170 $\mu g/m^3$, 51.9 $\mu g/m^3$ and 17.4 $\mu g/m^3$, respectively, which met QCVN 05:2013/BTNMT. Thus, if the treatment efficiency is increased to 70 – 80% using chemicals with higher doses, the deleterious effect of environmental pollution on the health of people in the area will be mitigated. Therefore, to minimise SO_2 pollution, enterprises must follow the operating procedures for exhaust gas treatment by using the correct absorbent chemicals, such as NaOH/CaO solution, in the exhaust gas treatment process. Notably, the reduction or lack of chemical treatment to reduce operating costs is one of the causes of the current state of air pollution in IZs.

4. Conclusion

The air quality management in Giao Long IZ needs to be enhanced and made more effective. This research calculated the emission of air pollution load in enterprises and applied the TAMP-AERMOD model system to simulate air pollution dispersion in Giao Long IZ. The simulation results show that the highest average values of 1 hour, 24 hours and average annual NO_2, TSP and CO reached QCVN 05:2013/BTNMT standards. The highest 1-hour and 24-hour average concentrations of SO_2 were 1.6-fold and 1.19-fold higher than QCVN 05:2013/BTNMT. From the simulation results, the study proposed appropriate solutions to improve the efficiency of air quality management in Giao Long IZ, Ben Tre Province, such as adjusting

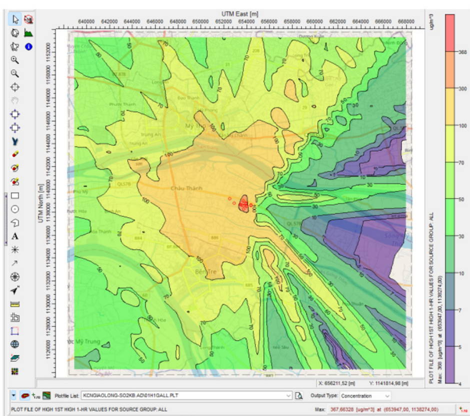

Figure 11. Simulation result of the highest 1-hour average concentration of SO_2 in Scenario 1

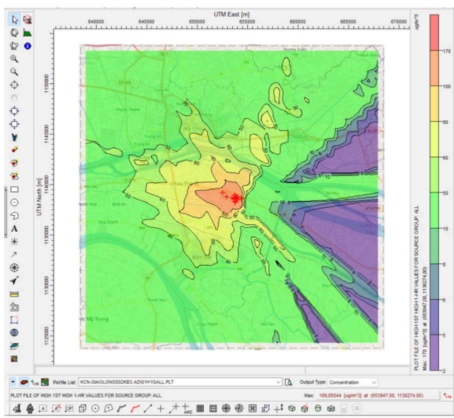

Figure 11. Simulation result of the highest 1-hour average concentration of SO_2 in Scenario 1

certain policies to confirm the role and responsibility of the Ben Tre Industrial Zones Authority in environmental management in Giao Long IZ. The enterprises, agencies and departments need to work together in inspecting and sanctioning cases affecting the air quality in the IZ. Management agencies should cooperate with specialised agencies to re-evaluate the effectiveness of the exhaust gas treatment systems in all enterprises in the IZ. In addition, it is necessary to organise training sessions on environmental management to raise awareness of environmental protection in the enterprises within the IZ. The study also proposed two scenarios to improve the efficiency of SO_2 treatment in exhaust gas treatment systems to reduce SO_2 emissions when enterprises use fuel. This study only calculated emissions and simulated air quality at Giao Long IZ for the current emission status at the enterprises and did not consider other emission scenarios for using different fuels. In addition, due to time and budget constraints, the study only assessed common air pollutants, such as SO_2, NO_2, CO and TSP, and not greenhouse gases and other gases.

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