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PART II: SELECTED FULL PAPERS

Researching the Potential Impact of Industrial Stacks of the Bright International Vietnam Company on the Ambient Environment

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Abstract

Air pollution due to stacks emission is the biggest problem threatening the sustainable development of Bac Ninh province. As one of the economic development centers of the country, Bac Ninh has many industrial zones and major factories, causing air pollution to become more and more serious. In this study, the AERMOD model was used to evaluate the impact of the stack emission from 72 industrial stacks of the Bright International Vietnam factory. Hourly monitored emission data for five consecutive days is fed in the AERMOD model with the hourly meteorological data taken from the ERA5 dataset from 1/1/2018 to 31/12/2020. The maximum 1-HR, 24-HR, 99th percentile, and annual average concentrations of TSP, SO2, and NO2 were simulated within the 20km x 20km domain of 100m x 100m grid resolution. Air dispersion simulation is performed on the observed background gas concentration of the everyday environment. The simulated spatial distribution of gases indicates the strong fluence of the mountainous topography on the dispersion of stack emission. Results also revealed that the emission potentially causes serious TSP pollution over the region if the exhausted gases are not properly treated.

1. Introduction

Air pollution is a worldwide problem and Vietnam is no exception. According to The Environmental Performance Index (EPI) annual report conducted by the US Environment Organization, Vietnam is one of the top 10 air polluting countries in Asia, especially dust pollution. Humans are victims of environmental pollution, but humans are also the main culprit of environmental pollution. Many daily human activities contribute to the increase of air pollution. Among these activities, industrial production is the main cause of air pollution, not only in Vietnam but also in many developing countries. Smoke and dust from the exhaust stacks of factories and factories in industrial zones darkened the sky. They emit CO_2, CO, SO_2, NO_x and a number of other organic substances, with extremely high concentrations.

Bac Ninh province is one of the most polluted cities in the country. As one of the economic development centers of the country, Bac Ninh has many industrial zones and major factories, causing air pollution to become more and more serious. Environmental management and pollution reduction are a top priority in Bac Ninh, especially towards factories that are newly built or increase capacity. Bright Vietnam International Co., Ltd. is a 100% Taiwan - China owned company belonging to Brico Group, specializing in the production of high quality enameled metal utensils for the kitchen. The main company production include pots and pans, furnace bar and mainly for exportation to European and American markets. In 2014, the company has capacity production of 12.000 tons of products per year. In the coming time, the Company will invest in expanding, increasing the project capacity to 48.000 tons of products per year. Increasing three times the original capacity is inevitably increases the pressure on the environment and affects the feasibility of the project. This research focus on researching the potential pollution to the air environment due to the company's production activities. The AERMOD model has been adopted in this study. AERMOD is a short-range emission model specified by US/EPA in air pollution management. This is the state-of-the-science, steady-state Gaussian air dispersion model based on planetary boundary layer theory.

2. Study area and Data

2.1. Study area

This study was conducted for Bright International Vietnam factory in Thuan Thanh II Industrial Park, Bac Ninh province. The scope of the study area is determined within a radius of 10km from the center of the industrial stacks. The factory has a total of 72 industrial stacks that emit many different types of emissions, especially fossil fuel combustion emissions including SO_2, NO_x and total suspended solids (TSP).

2.2. AERMOD model

AERMOD, a steady-state dispersion model, includes the effects on dispersion from vertical variations in the planetary boundary layer (PBL). In the SBL the concentration distribution is Gaussian, both vertically and horizontally, as is the horizontal distribution in the convective boundary layer (CBL). However, the CBL's vertical concentration distribution is described with a bi-Gaussian PDF, as demonstrated by Willis and Deardorff (1981). Buoyant plume mass that penetrates the elevated stable layer is tracked by AERMOD and allowed to reenter the mixed layer at some distance downwind. AERMOD has been widely used for environmental management purposes (Silverman et al 2007; Suadee 2008; Huertas et al 2012). The AERMOD model is recommended for short-range dispersion modelling at a distance up to 50km from the emission source (Seangkiatiyuth et al., 2011; Krzyzanowski, 2011).

2.3. Data and materials

a. In-situ data

Hourly emission data from the 72 stacks of the Bright International Vietnam factory was obtained from periodic environmental monitoring reports that took place twice a year. For each monitoring period, emissions from the stacks are examined for 5 consecutive days for flow velocity and gas volume. At the same time, exhausted gases are sampled and analysed for pollutants concentration including TSP, NO_x and SO_2. Since the factory plans to increase its capacity up to three times higher, the projected emission for future scenarios is calculated in proportion to the current emission volume.

Considering the ambient atmospheric quality in the modeling process, hourly average air quality data were collected at 3 locations for consecutive five days from 20-Jul 2021 to 24 Jul 2021. TSP, NO_x, and SO_2 were considered in this study.

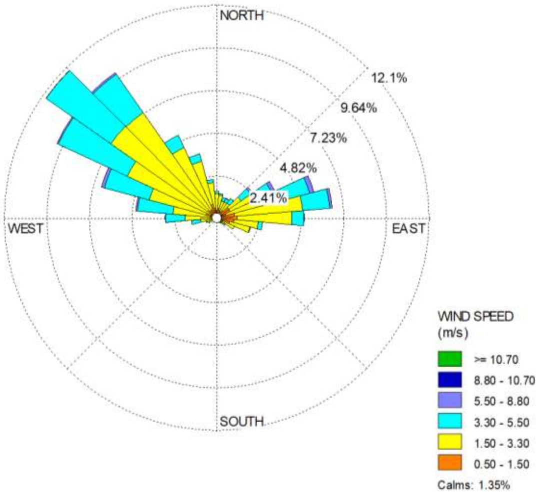

Figure 1. Wind-rose from 1/1/2018 to 31/12/2020 of Bac Ninh province

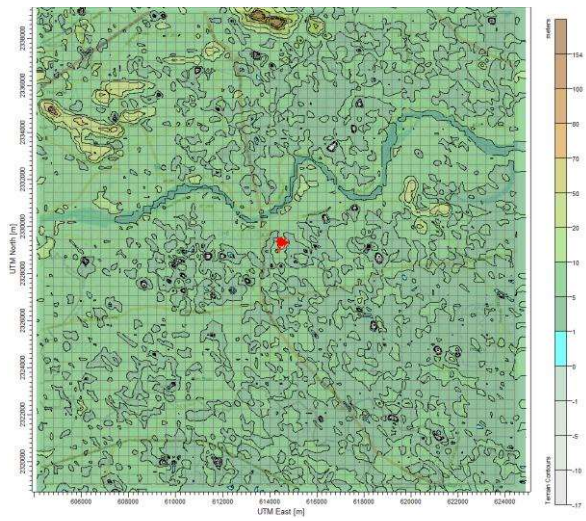

Figure 2. Topography map of the study area and the location of the stacks (red crosses)

c. Meteorology data

We used the ERA5 atmospheric, land, and oceanic climate variables for surface meteorological data. ERA5 data cover the Earth on a 10km grid and resolve the atmosphere from the ground up to 80 km height using 137 vertical levels. Wind direction, wind speed, temperature, precipitation, heat flux, solar radiation, and albedo at hourly resolution were extracted for the research region for the period span from 1st January 2018 to 31st December 2020. The corresponding upper air meteorological condition of the same time period, i.e. wind speed (Figure 1), was taken from the hourly recorded radiosonde data at Noibai International Airport.

d. Topography and surface data

The digital elevation model data used in AERMOD was extracted from 1 arc-second resolution SRTM (Shutter Radar Topography Mission) topographic data (~30m resolution) produced by NASA (National Aeronautics and Space Administration) in collaboration with NGA (Geospatial-Intelligence Agency) (Figure 2). The elevation data on the computed domain is bilinear interpolation to match the spatial resolution to the receptors grid using AERMAP.

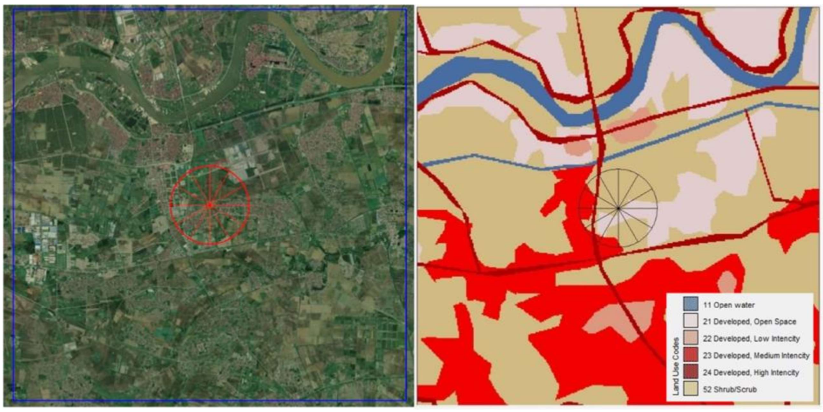

Figure 3. Land cover map prepared at 30m resolution

Surface land cover data at 30m resolution was prepared using the combination with 100m resolution Global Land Cover (GLC) land cover data and Google Maps satellite image data (Figure

3). The Global Land Cover Map is a data product developed by Copernicus' Land Monitoring Core Service (LMCS) - Europe's leading program for Earth observation.

2.3. Model setup

Simulation for the dispersion of stack-born pollutants of the Bright International Vietnam factory is conducted for the period from 1 Jan 2018 to 31 Dec 2020, a total of 26.403 hours. The simulation domain was configured for a 20km x 20 km region centred by the factory and covered by the Cartesian receptor grid made up of 20.201 nodes of 100m x 100m resolution. In this study, future scenarios are assumed using two cases including (1) the exhaust gases treatment system has a problem which leads to the highest environmental impacts on the social and the environment and (2) the factory operates stably and the environmental treatment systems perform as designed. The spatial and temporal impacts of stack emissions on the environment are examined with the following experiments (Table 1).

Table 1. Experiments on the dispersion of stack emissions

No.	Experiments
1	Highest emission averaged for 1 hour, 24 hours
2	Annual averaged concentration
3	Emission averaged for 1 and 24 hours at 50^{th} and 99^{th} percentiles

3. Results and discussion

3.1. Ambient air quality

The results of the ambient air quality surrounding the study area are illustrated in Table 2, where the concentration of the major pollutants from the stack is compared with the national standard (QCVN 05:2013/BTNMT). It can be clearly seen that the current ambient air quality is quite good since the concentration of TSP (59 – 78 µg/m^3), SO_2 (32 – 46 µg/m^3), and NO_2 (29 – 35 µg/m^3) is noticeable lower than the limitations. The research results show that the study area is not affected by the surrounding industrial plants and currently the factory's exhaust gas treatment system is operating effectively.

Table 2. Current status of environmental quality in the study area

No.	Pollutants	Unit	Concentration				QCVN 05:2013/ BTNMT[b]
			K01[a]	K02	K03	K04	
1	TSP	*µg/m^3*	78	74	68	59	*300*
2	SO_2	*µg/m^3*	38	32	46	37	*350*
3	NO_2	*µg/m^3*	31	35	32	29	*200*

Note:
[a]K01-04 are the locations sampling the ambient quality surrounding the factory
[b]National Technical Regulation on Ambient Air Quality

3.2. Potential environmental impacts due to stack emission under exhausted gases treatment system malfunction scenario *a. Highest pollution cases*

The simulation results for the case of the largest possible contaminant concentration with meteorological data from T1/2018 to 12/2020 for an average of 1 hour and an average of 24 hours are shown in Figure 3. The average 1h TSP concentration in the largest case (rank 1) is 14,085 µg/m3 which is 47 times higher than the maximum 1-hour average required threshold of 300 µg/m3. The radius of the polluted area is distributed in a very wide range around the factory area, from 400 - 500m. Outside the 500m radius, the concentration of TSP fluctuates around 5,000 – 7,000 µg/m^3, 17 - 24 times higher than the maximum threshold. Within 10,000m from the factory, the dust concentration in the air is still up to 1,000 – 1,500µg/m3 which still threatens the safety of the environment. The simulation results show that if the exhaust gas treatment system fails, the impact on the environment from the project is pollution on a very wide scale and a high level of harm to the environment and people. This largest 1-h average TSP instance represents the maximum impact level across more than 26,000 time slides. With the average 24h continuous TSP experiment, the highest level of TSP was over 4,900 µg/m3, this index is nearly 25 times higher than the threshold of 24h average maximum concentration of TSP of 200 µg/m3. In all scenarios, the peak concentrations of TSP were well above the norm and distributed over a very wide range. When the exhaust gas treatment system fails to function properly, the emissions will negatively affect the environment, especially within a radius of 500-1000m around the factory.

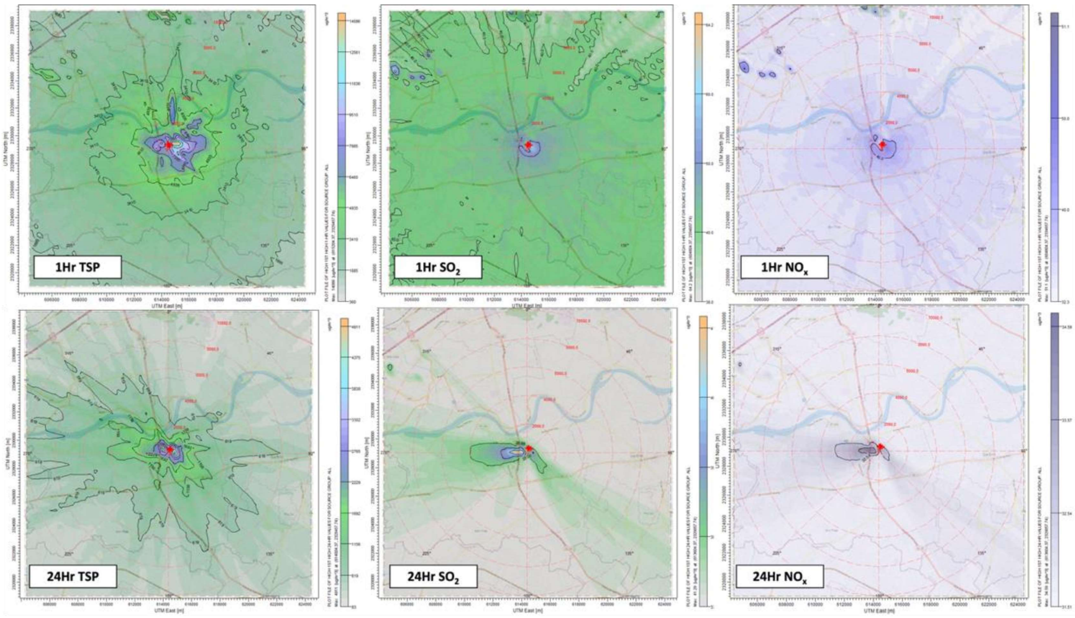

Figure 4. Averaged 1-hour and 24-hour extreme emission cases

The concentration of SO_2 dispersed from the stacks to the environment is also shown in Figure 3. The simulation results show that the average maximum SO_2 concentration in 1h is 64.2 g/m^3 and the average 24h is 41.21 µg/m^3 which is lower than the regulated thresholds of 350 µg/m^3 (average 1 hour) and 125 µg/m^3 (24h averaged), respectively. The results at the 99th percentile threshold are not much lower than the maximum. With a background threshold concentration of 37 µg/m^3, the impact of SO_2 on the environment is negligible. Simulated SO_2 concentration for each season also shows the similarity between times of the year, SO_2 concentration is always at a safe level for the environment.

Simulation results show the largest concentration of NO_2 in the natural environment under the influence of stack is very small, with an average of 51.1 µg/m^3 for 1 hour and 34.59 µg/m^3 for an average of 24 hours which is safe within the regulation of QCVN 05/2013/BTNMT. It is possible to conclude that the NO_2 concentration from the stack does not have a negative impact on the natural environment.

b. Potential environmental impact of extreme emission cases

Since the highest pollution cases reflect the very "rare" occurrence of the pollution among 3 years of simulation, it is sometimes too arbitrary and might be caused by extreme climate events. The extreme emission cases shown by the 99th percentile region, reflect the rare occurrence of 1% possible might be more suitable to examine the potential impact of stack-born pollution. Figure 4 compares the 50th percentile and the 99th percentile emission for TSP which show the difference between normal emission and extreme cases.

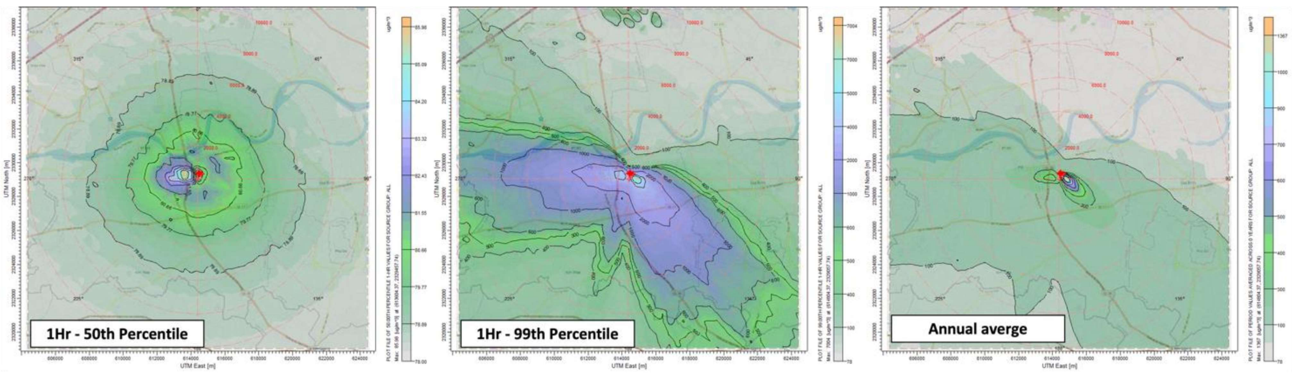

Figure 5. Emission of TSP from the stacks

Simulation result for 1h average TSP at the 50th percentile shows that the most common and most typical concentration level of the project is around 86 g/m^3, close to the regulated threshold 100 µg/m^3. Thus, the common impact level of the stack in any time period is close to the pollution level, potentially causing harm to the environment. The result for 99th percentile emission – the concentration representing 1% probability highest at 7,000 µg/m^3, very high above the norm, above the threshold of 70 times. This finding indicates the high possibility of environmental pollution due to the stack emission in case of treatment system failure.

c. Spatial distribution of air pollution

The annual distribution of pollutants reflects the most affected areas by stack emission. Annual distribution of TSP (Figure 5) is similar to other pollutants showing that the vast areas from the west to the south-east of the factory are strongly influenced by the emission. The negatively affected distance is roughly 5,000m far from the sources.

3.3. Potential environmental impacts under the normal working condition of the gas treatment system

Simulation results (result not shown) for the dispersion of all pollutants at the normal working condition of the gas treatment system show that emissions from the stacks will not cause harm to the environment. For example, the average distribution of TSP at 1h rank 1 is the largest at 188 µg/m3, is still safe within the permissible limit of 300 µg/m^3. With the average 24h TSP distribution results, rank 1 also gave the same results as the average 1h, the TSP concentration was always well controlled and lower than the maximum allowable threshold.

4. Conclusion

Environmental pollution from stack emissions is one of the top concerns of the authorities in Bac Ninh province. In this study, the AERMOD model was used to evaluate the influence of stack-born pollutants from the Bright International Vietnam factory on the ambient air environment, namely TSP, NO2, and SO2 gases. The observed 5-day hourly observation data for ambient air quality and stack emission was used to validate the model. In this study, air dispersion simulation using the AERMOD model with 2018 to 2020 meteorological data has shown the high risk of air pollution if pollutants are not properly treated. The TSP emission is potentially dangerous to the environment, the concentration of untreated TSP has a negative influence radius far beyond the 10km radius. The area with the greatest negative impact is within the 400-1000m radius from the factory. The most negatively affected residential areas are located in the west to the southeast stack location. SO_2 and NO_2 have a very low level of environmental impact, not likely to cause harm to the surrounding environment. The emission source of the above gases is only generated from the medium-frequency induction furnace, the volume of generated exhaust gas is negligible.

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