Public Health of Indonesia
Jayadipraja EA et al. Public Health of Indonesia. 2016 March;2(1): 20-27
http://stikbar.org/ycabpublisher/index.php/PHI/index
ISSN: 2477-1570

Original Research

APPLYING SPATIAL ANALYSIS TOOLS IN PUBLIC HEALTH: THE USE OF AERMOD IN MODELING THE EMISSION DISPERSION OF SO2 AND NO2 TO IDENTIFY AREA EXPOSED TO HEALTH RISKS

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Accepted: 18 March 2016

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ABSTRACT

Background: The cement industry is one of the main contributors of pollutant gasses in the environment through stack emissions.
Aim: This study aims to model the dispersion of SO_2 and NO_2 gasses and to determine the area of the dispersion by *American Meteorological Society – Environmental Protection Agency Regulation Model* or AERMOD has been utilized by PT. Semen Tonasa (Tonasa Cement, Ltd.).
Methods: Meteorological data from AERMENT was collected from reanalysis of MM5 data. While topographical data was extracted from SRTM30 satellite data. The model was carried out for a year, to cover both the dry and rainy season.
Results: The result of the modeling showed that the peak value of the concentration of SO_2 and NO_2 pollutants for one hour are 135 µg/m^3 and 160 µg/m^3 respectively (quality standards of SO_2 and NO_2 are 900 µg/Nm^3 and 400 µg/Nm^3). The area of dispersion tends to be in the eastern area, such as District Minasatene (Sub-district Bontoa, Kalabbirang, Minasatene dan Biraeng), District Bungoro (Sub-district Biringere, Sapanang, Mangilu, Bulu Tellue) and District Labakkang (Sub-district Taraweang).

Key words: Spatial analysis, AERMOD, cement factory, exposed area, SO_2 and NO_2

INTRODUCTION

ASEAN Economic Community (AEC) is the result of a realization of economic integration among countries of ASEAN to increase their stability of the economy. As an outcome, goods from any country can *freely* enter others within ASEAN. Indonesia, as one of the prominent cement producer in the world, faces a lot of demands in the world market, which has increased because of AEC. Thus, cement industries in Indonesia, including PT. Semen Tonasa in Pangkep, will increase their production to fulfill those demands.[1,2,3,4] PT. Semen Tonasa is among one of the eight biggest cement industries in Indonesia. It has been producing and selling cement for the national and international market since 1968. The area of limestone mining for the company is in Maros and Pangkep, South Sulawesi, which is one of the biggest karst areas in the country. The karst cluster in this area, including some parts of Bantimutung Bulusaraung National Park, covers 43.750 ha. The company itself has a right to manage the area of 750 ha. in Desa Biringere, District of Bungoro, Regency of Pangkep, Indonesia. Around 5,980,000 tons of cement can be produced by the company since it is supported by four factory units; Tonasa Factory Unit II, III, IV and V. By using dry processes, 0.59 million tons of cements are produced by Unit II and III, and 2.3 and 2.5 million tons of cements are produced by Unit III and IV respectively.[5] In its production process, the company will use more fossil fuel as a result of the large production. A cement factory has quite a big role in creating air pollution.[6] Nitrogen oxide, or NO_2, and sulphur dioxide, or SO_2, are the primary gases resulting from the cement burning.[7] Epidemiologic study shows the strong relation between air pollution dispersion and cardiovascular or respiratory disease found among people living in areas near the factory.[6]

Every industry is supposed to prevent any pollution before it creates more problems. One method of prevention in the study of public health is by using a spatial study to identify people living in the area with high dispersion pollution. U.S. EPA (*Environmental Protection Agency*) collaborated with *American Meteorological Society* (AMS) and formed a committee called AMS/EPA Regulatory Model Improvement Committee, AERMIC, which consists of scientists from AMS and EPA. This committee further created *American Meteorology Society/Environmental Protection Agency Regulatory Model* or shortened AERMOD. It is a model to predict the pattern of dispersive pollutants by estimating the concentration in several areas through simulating the atmosphere and meteorological condition. This model can be used for several sources and receptors as exposed area.[8] This article described the use of AERMOD as an assessment tool of Gaussian dispersion theory in evaluating the effect of emission gasses from the stacks of a cement factory. The model has not been very popular in Indonesia but has been utilized in some countries.[9,10,11,12]

METHODS

A. AERMOD Model

AERMOD is a short reach Gaussian model (less than 50 km) to simulate the dispersion of stack emissions from industrial activities.[13] The model has been calibrated and adopted by the U.S. EPA since 2005, replacing the ISC3 model.[14,15,16] AERMOD uses *Planetary Boundary Layer* or PBL similarity theory to calculate dispersion affected by the heating, surface, and friction.[17] The model needs some information related to the surface, such as the lengths of roughness, humidity and reflexivity. Moreover, complete information about the upper atmosphere is also needed to determine the depth of the mixing height and to create partial plume penetration above it.[18]

The AERMOD model consists of AERMOD as the primary model, AERMET as the meteorology processor, and AERMAP as the geomorphology processor.[13] The AERMET model is employed to provide meteorological data, such as wind velocity and direction, temperature, cloud cover, and data related to the surface, such as albedo, surface roughness and Bowen ratio. All of this data is processed by AERMET to calculate the surface parameter of PBL, such as friction velocity, Monin-Obukov length, convective velocity scale, temperature scale, the mixing height, and surface heat. Additionally, the parameter of PBL upper air is also calculated, such as the vertical profile of wind velocity, the lateral and vertical profile of turbulent fluctuation, gradient, and potential temperature. Further, AERMAP will provide topographical data of grid data chosen from data from *Digital Elevation Model* or DEM, and the receptor position counted from the mean sea level or MSL[13,19].

B. Meteorological and Topographical Data Collection

The level of accuracy of the input of meteorological data in AERMOD is very essential for an accurate prediction. A vertical meteorological profile conducted hourly is needed to simulate the wind field and mixing height. Unfortunately, this kind of data is not available in Indonesia. Thus, satellite data or data from the prediction of a regional atmosphere model such as MM5 or WRF is needed. This prognostic data will further be downscaled, where one degree is valued to 12 x 12 km. Predictions using this data will give a better result.[20]

Prognostic meteorological data taken hourly during 2013 is obtained from *Mesoscale* model MM5.[21] This output is then formatted to acquire meteorological data of surface and upper air that is suitable to AERMET input. The grid center is set at a coordinate of 4.787917 S and 119.616722 E with the width of cell 12 x 12 km coincided with the main stack. The height of the anemometer and its basic elevation are 15 meters and 149 meters above sea level respectively. DEM data is extracted from SRTM30 satellite imagery while land use is determined through visual observation.

C. Data of Stack Emission

The data from stack emission is obtained from annual average emission in 2014, as shown in Table-1. This raw data uses a mg/l unit which then be converted with a g/s unit based on the characteristics of each stack. The national ambient quality standard is used to analyze the effect of stack emission; the tolerable concentration of SO_2 and NO_2 for one hour, 24 hours and one year is 900 µg/Nm^3, 365 µg/Nm^3, 60 µg/Nm^3 for SO_2 and 400 µg/Nm^3, 150 µg/Nm^3, 100 µg/Nm^3 for NO_2.

Tabel 1. Monitoring of emission stack of SO_2 and NO_2 from PT. Semen Tonasa in 2014

COMPONENT	Factory Unit II Limestone Dryer	Factory Unit II Kiln	Factory Unit III Kiln	Factory Unit IV Kiln	Factory Unit V Kiln	Factory Unit IV Grate Cooler	Factory Unit V Grate Cooler
Coordinate S	04°47’02.9”	04°47’08.5”	04°47’15.2”	04°47’08.5”	04°47’32.5”	04°47’06.2”	04°47’06.2”
Coordinate E	119°37’12.6”	119°37’05.7”	119°37’02.6”	119°37’05.7”	119°36’51.3”	119°37’00.2”	119°37’00.2”
Stack Gas Exit Temperature (Celcius)	31.2	30.9	30,5	31,2	31,5	32,1	31,5
Stack Temperature (Celcius)	158	121	134,2	129	208	157	218
Stack Gas Exit (m/s)	8.74	7.31	7.45	7.42	8.68	8.71	8.79
Stack Height (m)	61.37	50.00	47.00	59.31	105.60	37.78	39.70
Stack Inside Diameter (m)	2.24	2.80	3.20	5.48	5.30	3.37	2.65
Emission Rate							
SO_2 (mg/Nm3)	25.325	11.238	21.323	25.162	12.812	23.142	18.228
NO_2 (mg/Nm3)	19.281	8.561	19.185	22.116	11.747	19.224	14.834

RESULTS

A. Analysis of Meteorological Data

Meteorological data analyzed here consist of data about the surface and the profile. The result of wind rose analysis on the surface and the profile wind shows that the wind blows from East to West with average velocity of 4.25 m/s and a calm frequency of 4.25%. Both wind roses show almost similar characteristics. To test the validity of model data, wind rose from the measurement of radiosonde of Sultan Hasanuddin Airport is utilized. All these wind roses exhibit similar results. This means that the data of wind from modeling and the results of field measurement are alike.

Figure 1. Surface Wind Profile and Upper Wind Profile

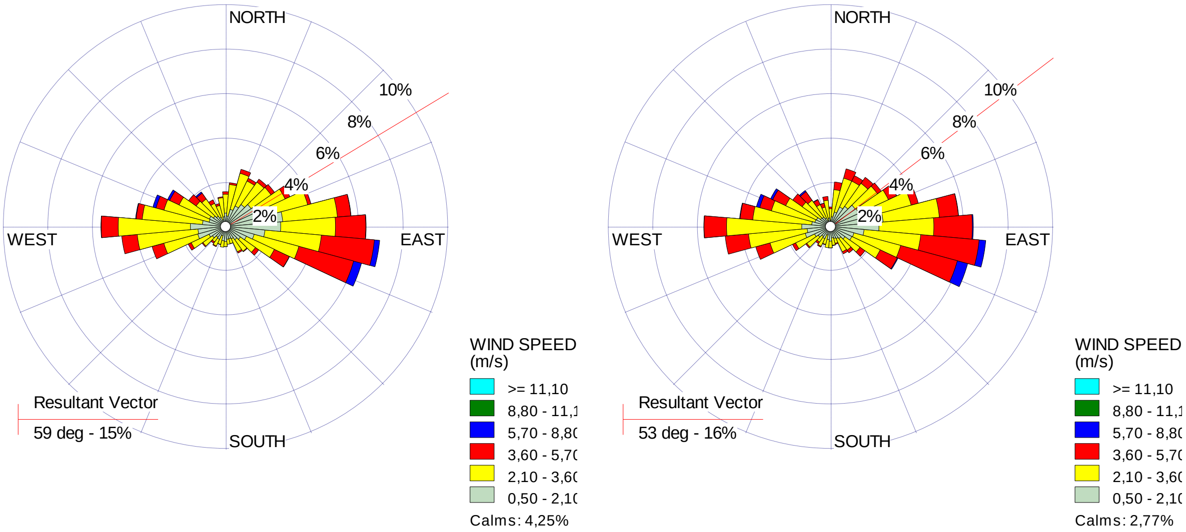


Figure 2. Radiosonde Wind Profile

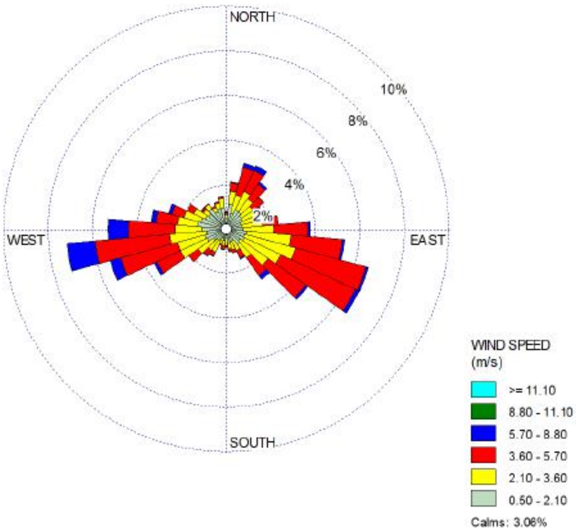


Figure 3. Dispersion Pattern of SO_2: Highest Hourly Average

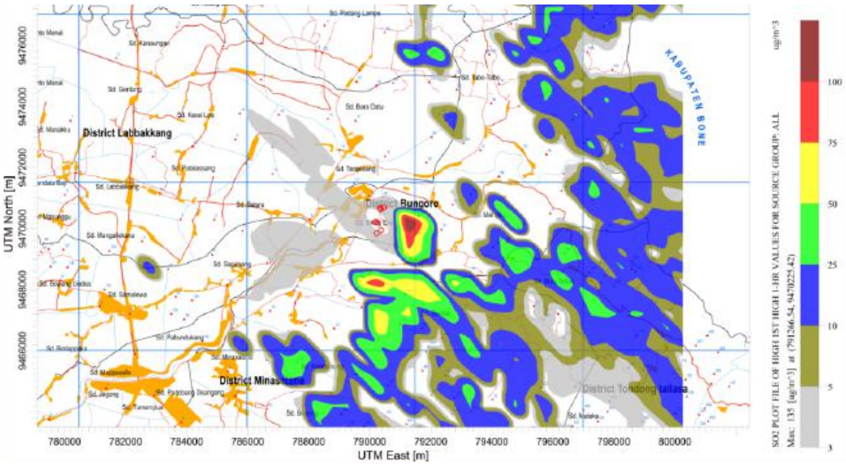


Figure 4. Dispersion Pattern of SO_2: Highest Annual Average

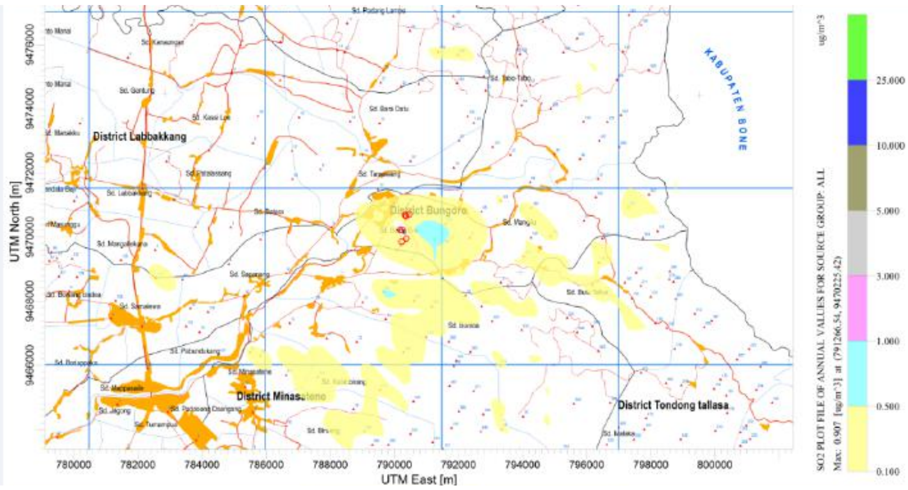


Figure 5. Dispersion Pattern of NO_2: Highest Hourly Average

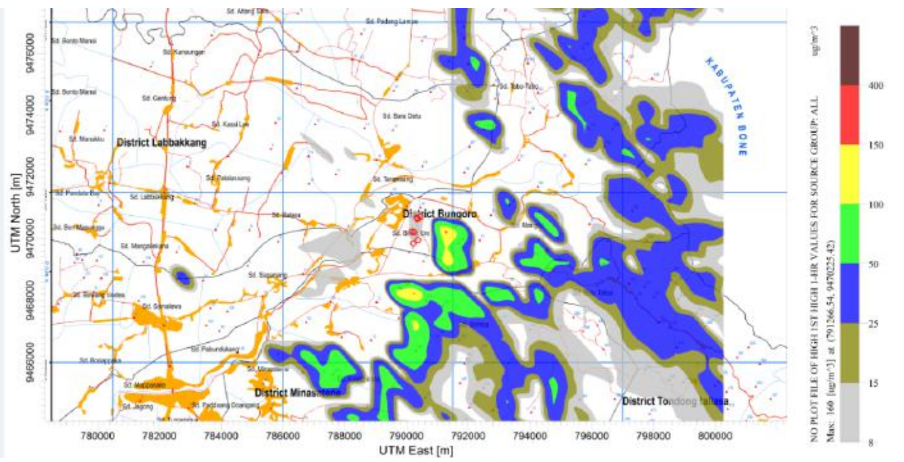
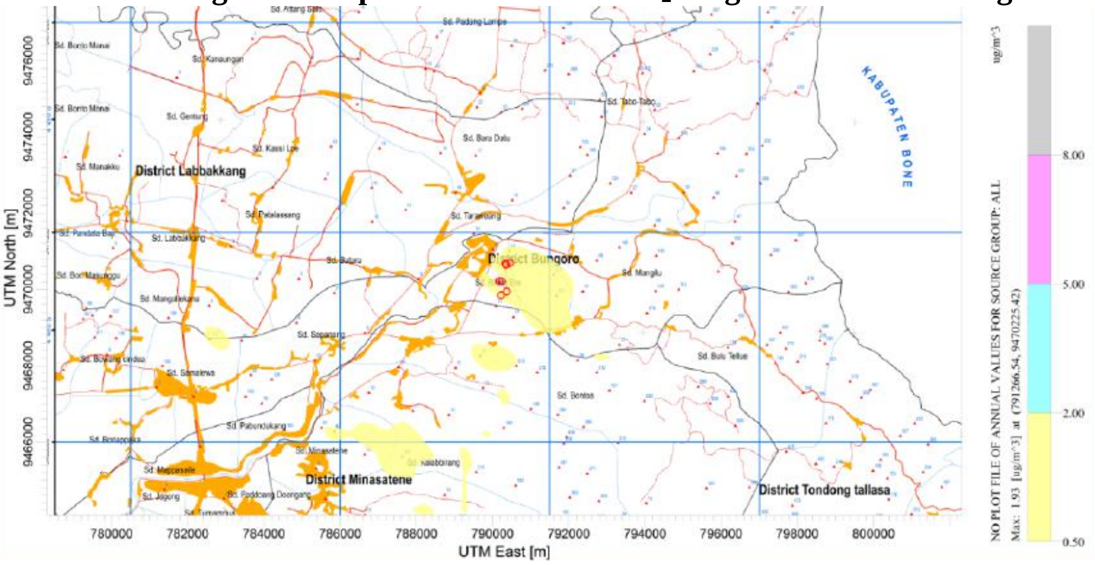


Figure 6. Dispersion Pattern of NO_2: Highest Annual Average



B. Modeling of SO_2 and NO_2 Dispersion

Based on the inputs about stack emissions, topography and model wind data, AERMOD has been utilized for one year. The modeling result of SO_2 and NO_2 dispersion for the average of one hour, three hours, 24 hours, and one year shows that this dispersion is far below the standards of quality. The peak value for one hour is 135 $\mu g/m^3$ for SO_2 and 160 $\mu g/m^3$ for NO_2. Furthermore, the peak value for one year is 0.907 $\mu g/m^3$ for SO_2 and 1.93 $\mu g/m^3$ for NO_2. The direction of emission dispersion is in accordance to the wind direction, which is East-West. The highest average concentration in one hour does not exceed the quality standard. However, the dispersion pattern in the figure tells us which areas have a greater risk of being affected by cement industry emission stacks.

DISCUSSIONS

Stack emissions from PT. Semen Tonasa tend to go to East. The result is based on the analysis of meteorological data (Figure 1 and 2) and topographical data (satellite imagery of SRTM30), and further analyzed using the AERMOD model. The wind from West to East has more effect on the emission dispersion since it does not confront any obstacle. Furthermore, the wind from the other way gets obstructed, due to the height of the mountains. The mountains disintegrate and diffract the wind from East. The average velocity of the wind is 4.26 m/s with calm frequency of 4.25%.

The AERMOD model can give detailed information about exposed areas by stack emission from PT. Semen Tonasa. Picture 3 and 4 show areas at greater risk of SO_2 and NO_2; they are District Minasatene (Sub-district Bontoa, Kalabbirang, Minasatene and Biraeng), District Bungoro (Sub-district Biringere, Sapanang, Mangilu, Bulu Tellue) and District Labakkang (Sub-district Taraweang). The peak value in one hour is 135 $\mu g/m^3$ for SO_2 and 160 $\mu g/m^3$ for NO_2, below the quality standard of 900 $\mu g/m^3$ for SO_2 and 400 $\mu g/m^3$ for NO_2. The peak value in one year also shows the same trend, being below the quality standard of SO_2:60 $\mu g/m^3$ and NO_2 100 $\mu g/m^3$. The value for this period is 0.907 $\mu g/m^3$ for SO_2 and 1.93 $\mu g/m^3$ for NO_2. The quality standard here is based on Indonesia's government regulation of PP RI No. 41 1999 on air pollution control.

From this information, it can be seen that the riskiest air pollution caused by emissions from cement industry happened in District Minasatene (Sub-district Bontoa). Though concentration of the stack emission is below the quality standard, continual exposure over a long period can pollute the environment and risk the health of the people. The pollution does not only affect the air and global climate change,[22] but it also causes respiratory disease.[23,24,25] By using this AERMOD model, exposed areas with emission from the cement industry can be revealed in order to find out efforts for taking care of the environment. Through this, morbidity rate can be prevented, especially diseases related to the respiratory system caused by emission exposure over a long period.

CONCLUSION

Emissions of SO_2 and NO_2 from stacks of PT. Semen Tonasa factory tend to go East, in accordance to wind direction and topographical conditions. Concentration in one peak hour is 135 $\mu g/m^3$ for SO_2 and 160 $\mu g/m^3$ for NO_2, below the quality standard. Areas with higher risk of this emission are District Minasatene (Sub-district Bontoa, kalabbirang, minasatene and biraeng), District Bungoro (Sub-district Biringere, Sapanang, Mangilu, Bulu Tellue) and District Labakkang (Sub-district Taraweang). In the end, efforts are needed to save the environment, especially in those areas.

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Cite this article as: Jayadipraja EA, Daud A, Assegaf AH, Maming. Applying Spatial Analysis Tools in Public Health: The Use of AERMOD in Modeling the Emission Dispersion of SO_2 and NO_2 to Identify Exposed Area to Health Risks. Public Health of Indonesia 2016;2(1): 20-27