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Research Article

The application of the AERMOD model in the environmental health to identify the dispersion area of total suspended particulate from cement industry stacks

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ABSTRACT

Background: The emission from the stacks of a cement industry produces some particles that harm the quality of the air, such as total suspended particulate (TSP). Cement dust causes lung function impairment, chronic obstructive lung disease, restrictive lung disease, pneumoconiosis and carcinoma of the lungs, stomach and colon.
Methods: The research methods used American Meteorological Society – Environmental Protection Agency Regulation Model or AERMOD as spatial analysis tools to show the TSP dispersion. AERMOD requires meteorological and topographical data. The meteorological data processed by AERMEDT is taken from the reanalysis of MM5 data while the topographical data is extracted from SRTM30 satellite data. The model is carried out for a year, to cover both dry and rainy seasons.
Results: The result shows that the TSP peak concentration in one hour is 314μg/m^3 (in which the quality standard of TSP is 90μg/Nm^3). The area of dispersion tends to head east of the stacks, including District Minasatene (Sub-district Bontoa, Kalabbirang, and Minasatene), District Bungoro (Sub-district Biringere, Sapanang, Mangilu, Bulu Tellue and Tabo-tabo) and District Labakkang (Sub-district Taraweang), Indonesia.
Conclusions: AERMOD model can show potential exposure area from cement industry. It needs serious efforts to prevent and minimize the impact to public health.

Keywords: Total suspended particulate, AERMOD, Spatial study, Cement industry, Dispersion area, Health

INTRODUCTION

The beginning of 2016 is marked by the enactment of ASEAN Economic Community or AEC in Southeast Asia, including Indonesia. There are ten countries that contribute in AEC whose purposes are to increase the economic growth and development among the countries. However, there will be some impacts of this enactment, such as increasing production to meet the demands of goods among ASEAN countries. As one of the biggest cement producing countries in the world, Indonesia will face high demand for cement to support the development of these countries. This high demand will also affect to the rising waste gas from the production of cement.[1-4] PT. Semen Tonasa is one of the biggest cement industries in Indonesia, located in Desa Biringere, District of

Bungoro, Regency of Pangkep, South Sulawesi Province. This industry can produce as much as 5.98 million tons of cement a year. In its production process, the industry is supported by four factory units; they are Pabrik Tonasa II, Pabrik Tonasa III, Pabrik Tonasa IV and Pabrik Tonasa V.[5]

The increasing production of this industry leads to the increase of the exploration of its primary and supporting material such as limestone, clays, silica and iron sand, and gypsum. This exploration will create air pollution and cause the raising amount of total suspended particulate (TSP) in the air.[6-8]

Epidemiologic study shows the relation between pollution dispersion and cardiovascular or respiratory disease of the people who live in the area near the cement factories.[9,10] To manage and prevent negative impacts, a model to see the emission dispersion needs to be applied.[11-13]

One of the models that have been applied in other countries is the American Meteorology Society/Environmental Protection Agency Regulatory Model (AERMOD). However, this model which can predict the dispersion area is rarely used in Indonesia.

This model is developed by the U.S.EPA (Environmental Protection Agency) in corporation with the American Meteorological Society (AMS). Scientists from both organizations started a committee called AMS/EPA Regulatory Model Improvement Committee, AERMIC. The model that this committee created, AERMOD, is used to predict the dispersion area of pollutants by estimating its concentration in the specific area and simulating the condition of atmosphere and meteorology. AERMOD can be used for some varieties of sources and receptors.[14-17]

This paper will describe the use of AERMOD as the assessment tool of Gaussian theory in making dispersion patterns of TSP emission from the stacks of the cement industry. Then this model would determine the area exposed by emission in which a health assessment would be undertaken.[17-19]

METHODS

Model AERMOD

AERMOD is a Gaussian model for less than a 50 km reach to simulate the dispersion of stack emissions of industrial activities.[20] This model has been calibrated and adopted by US.EPA since 2005 to replace the ISC3 model.[21-23] AERMOD uses similarity theory of Planetary Boundary Layer or PBL to count the dispersion affected by the surface heating and friction.

The model needs information related to the surface such as roughness length, humidity and reflexivity. Moreover, it also needs comprehensive information about upper atmosphere to determine the mixing height and to construct partial plume penetration along the upper part of the mixing height.[24]

An AERMOD model is composed by a primary model or AERMOD, a meteorological processor or AERMET and a geomorphological processor or AERMAP.[20]

The AERMET is used to provide meteorological data, such as wind velocity and direction, temperature, cloud covering and to present surface data, such as albedo, surface roughness and Bowen ratio. All of this data is processed by AERMET to count the PBL surface parameters, such as friction velocity, Monin-Obukov length, convective velocity scale, temperature scale, mixing height, and surface heat.

Additionally, PBL upper air parameters are also counted; they are vertical profile of wind velocity, lateral and vertical profile of turbulent fluctuation, gradient and potential temperature. On the other hand, the AERMAP will provide topographic data of grid data chosen from Digital Elevation Model or DEM data. It also presents receptor position calculated from mean sea level or MSL.[11,20,25]

Meteorological and topographical data collection

Accuracy of meteorological data input to AERMOD is an important factor in getting an accurate prediction result. An hourly vertical meteorological profile is needed to simulate the wind field and mixing height. However, this data cannot be provided in Indonesia, thus a substitution is needed.

The former data can be substituted with satellite data or data of the prediction of regional atmosphere, such as MM5 or WRF. This prognostic data will be downscaled from one degree to 12 x 12 km. The prediction using such data will be satisfactory.[11,26]

Mesoscale MM5 provides hourly prognostic meteorological data for the period of 2013.[27] This output is reformatted to generate meteorological data of surface and upper air that is suitable for AERMET input format. The grid center is set at a coordinate point of 4.787917 S and 119.616722 E with a cell area of 12 x 12 km coinciding with the main stack. The anemometer height and base elevation are 15 m and 149 m above sea level. Furthermore, DEM data is extracted from SRTM30 satellite imagery while land use is determined through visual observation.[11]

Data of stack emission

The data of stack emission is derived from the mean emission in 2014 as shown in Table 1. The raw data has a unit of mg/l which will be converted to a unit of g/s according to the characteristics of each stack. To analyze the impact of stack emission, a national quality standard of air ambience is needed. According to this standard, the tolerable maximum concentration of TSP for one hour and 24 hours is 90µg/Nm^3 and 230µg/Nm^3 respectively.

Table 1: The monitoring of TSP from stack emission of 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 (^{0}C)	31.2	30.9	30,5	31,2	31,5	32,1	31,5
Stack Temperature (^{0}C)	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
TSP Emission (mg/Nm^3)	1.249	0.727	1.701	8.333	6.161	2.228	1.460

Source: PT. Semen Tonasa 2015

RESULTS

Analysis of meteorological data

The meteorological data analyzed in this paper consists of the surface and profile data. The analysis result of wind roses of the surface and profile wind shows that the wind tends to head from the East to the West with a mean velocity of 4.26 m/s and a calm frequency of 4.25%.

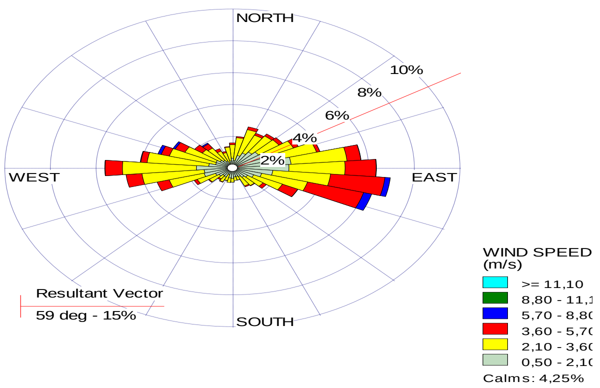

Figure 1: Wind rose of surface and profile wind.

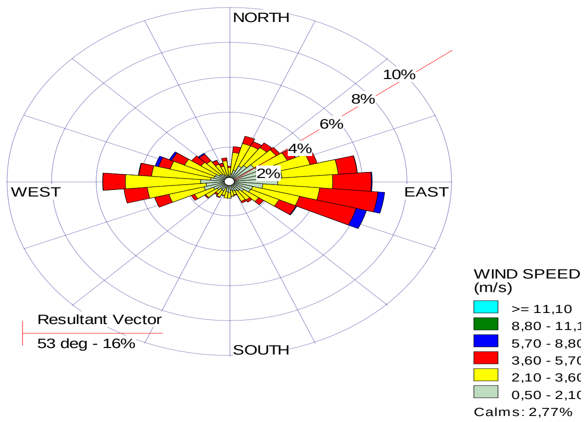

Figure 2: Wind Rose of Sonde Radio Measurement Result.

Both wind roses have nearly similar characteristics. To test the validity of model data, the wind rose of sonde radio measurement is also needed. This data was taken at Sultan Hasanuddin Makassar airport. The wind roses of profile wind and sonde radio results are almost similar. This means that wind data of the modelling has similar characteristics with field measurement results.[11]

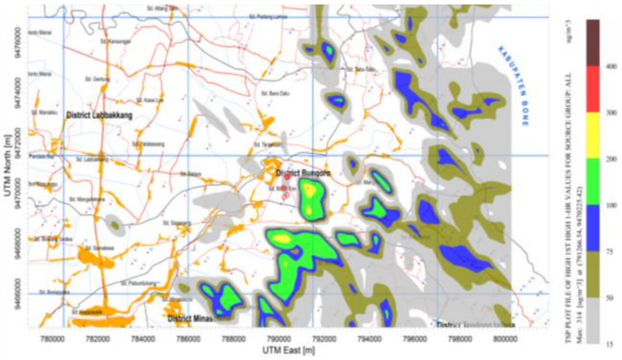

Figure 3: Dispersion pattern of TSP during the one hour peak.

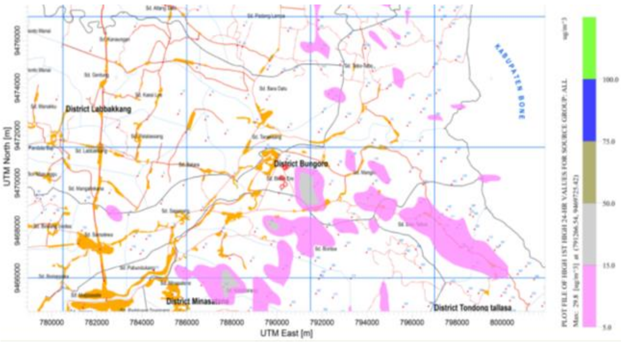

Figure 4: Dispersion pattern of TSP during the 24 hour peak.

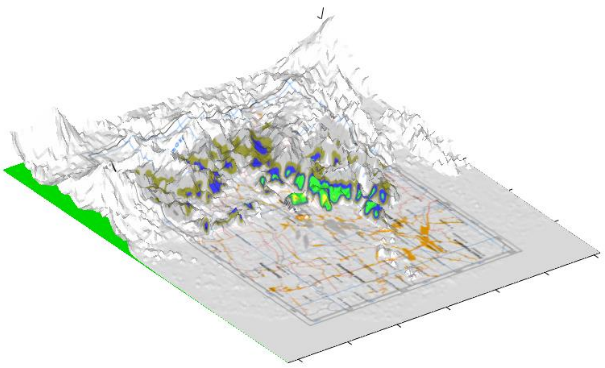

Figure 5: 3D Dispersion Pattern of TSP Concentration.

TSP dispersion model

Based on the input of stack emission, topography data and model wind data, the AERMOD program is carried out for a year. The modelling result of TSP dispersion for the average of one hour and 24 hours shows that TSP dispersion is far below the quality standard. The peak value of the one hour peak is 314µg/m^3 while the 24 hour peak is 29.8 µg/m^3. The direction of the emission dispersion is in accordance with the wind direction, which is from the East to the West. The average concentration during the one hour peak shows that it does not surpass the quality standard. However, by discovering the dispersion pattern of cement industry emissions, the area with increasing amounts of emmision risk can be identified in order to find a solution for managing the environment and preventing people from getting diseases.

DISCUSSION

According to the analysis of meteorological and topographical data (SRTM30 satellite imagery), the movement of wind direction, as seen in Picture 2 and 3, goes from the East to the West with an average wind velocity of 4.26m/s and with a calm frequency of 4.2%. However, the result analysis using AERMOD shows that the direction of TSP movement from stack emission goes toward the East (as shown in Figure 3 and 4). The wind movement from the West to the East has more impact than the other way. Topographical variation also contributes to the wind condition.[28] In the research location, there are karst hills on the eastern side of the source of stack emission which affect wind movement.

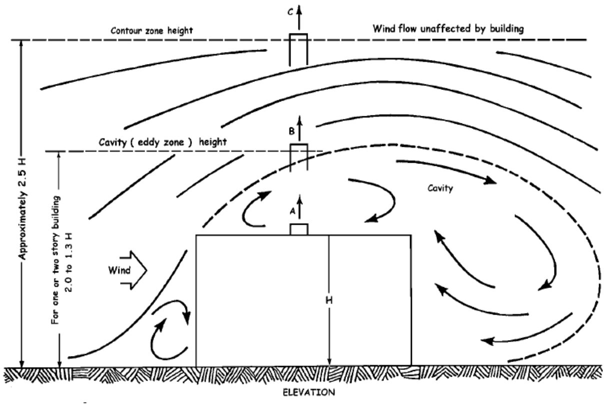

Figure 6: Gambar 8 Cavity Model.[29]

The wind around the hills will go in circular path which increases the TSP concentration moving from the West to the East. By using the AERMOD model, it will be easy to identify the area at risk of TSP dispersion emission. As can be seen in Picture 3, the pattern of TSP dispersion is found bigger around District Minasatene (Sub-district Bontoa, Kalabbirang, and Minasatene), District Bungoro (Sub-district Biringere, Sapanang, Mangilu, Bulu Tellue and Tabo-tabo) and District Labakkang (Sub-district Taraweang). The peak value during one hour and 24 hours is 314µg/m^3 and 29.8µg/m^3, in which the TSP quality standards for both durations are 90µg/Nm^3 and 230 µg/Nm^3 respectively. The quality standard used is from Indonesian Government Act No. 41 Year of 1999 about air pollution control management.

The concentration of emission dispersion from cement industry stacks in this research is surprisingly below the quality standard. However, continuing exposure of this emission has negative impact on the environment and health. Air pollution caused by emission can lead to global climate change.[6] Furthermore, continuing TSP and

<10 micron particles exposure can harm respiratory system or even lead to death due to several diseases, such as cardiopulmonary, lung cancer, and ischemic heart disease.[30-32]

The AERMOD model will supply information about areas affected by TSP exposure from cement industry emmisions. This, efforts related to environmental management can be undertaken. These efforts are to prevent morbidity numbers, like respiratory disease.

CONCLUSIONS

According to the AERMOD model, TSP emission from stacks of the Semen Tonasa industry tends to move toward the East. Peak concentration during one hour is 314µg/m^3, which is below the quality standard. Areas with higher risk of exposure to TSP emission are District Minasatene (Sub-district Bontoa, Kalabbirang, and Minasatene), District Bungoro (Sub-district Biringere, Sapanang, Mangilu, Bulu Tellue and Tabo-tabo) and District Labakkang (Sub-district Taraweang). It is hoped that the cement industry and people who live around the area can make some serious efforts to prevent and minimize the impact of this emission.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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