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***RESEARCH ARTICLE***

# COMPUTATIONAL POLLUTANT OF $SO_2$/$NO_2$ IN THE ENVIRONMENT USING AERMOD IN SEMI-URBAN AREA, STUDI CASE IN TUBAN, EAST JAVA

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## Abstract

Air pollution is a problem that often occurs in Indonesia, especially in cities where the industry is growing rapidly, such as Tuban City. This is due to the low level of environmental management planning, including air quality management. Many models can be used to predict pollutant concentrations in ambient air. Currently, the model often used is Meteorological Forecast Models, one of which is AERMOD. The effort made here is to evaluate the performance of the AERMOD (AERMOD + Background concentration) model. The AERMOD model was used to predict ambient air quality in Tuban, East Java, and evaluated using ratio-to-observer, MAPE, and relative mean bias values. Air quality modeling was carried out in the rainy and dry seasons in 2018 and 2019. The modeling results using the AERMOD model resulted in an acceptable model. The results of the $NO_2$ parameter modeling result in an overpredicted model trend, and changes in grid size affect the MAPE value and the resulting relative means bias. Meanwhile, the $SO_2$ parameter modeling results produce a model that tends to be underpredicted, and the change in grid size does not have a significant effect. The performance evaluation of the model is expected to be useful for air quality management and further development of this model.



## Introduction:-

Tuban City is one of the cities in Indonesia whose industry is growing. In addition, the city of Tuban is not the capital of the province, so the city still does not have air quality management that can accommodate changes in the number of pollutants in the future. Industrial development is usually also followed by an increase in the mobility of people, goods, or other supply chains. This will be a problem that will be faced in the future.

The cement factory is one of the industries that impact the existing air quality in the city of Tuban. The cement production process produces air pollutant parameters in the form of CO, oxides of nitrogen (NOx), sulfur dioxide ($SO_2$), and hydrocarbons from combustion activities in clinker and other activities [10]. In addition, cement factories increase the number of mobilized vehicles used in supply chain activities. Air pollutants released from a point source and line source activities have a negative impact on the environment and health. So we need tools for assessment in determining the form of air quality management. However, model validation plays an important role before being used in different geographic and climatic areas where the AERMOD model is developed

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## Methodology:-

### Studi area

The study area is around the factory about 14 km west of Tuban City, East Java (Figure 1). The area is an area that is mostly farm and residential area. In addition, in the study area, there are factories that are sources of emissions. The study area has a height of about 6 – 124 meters above sea level, whereas the southern area has a reasonably high area. The elevation maps are derived from the National DEM's Digital Elevation Model (DEM) data.

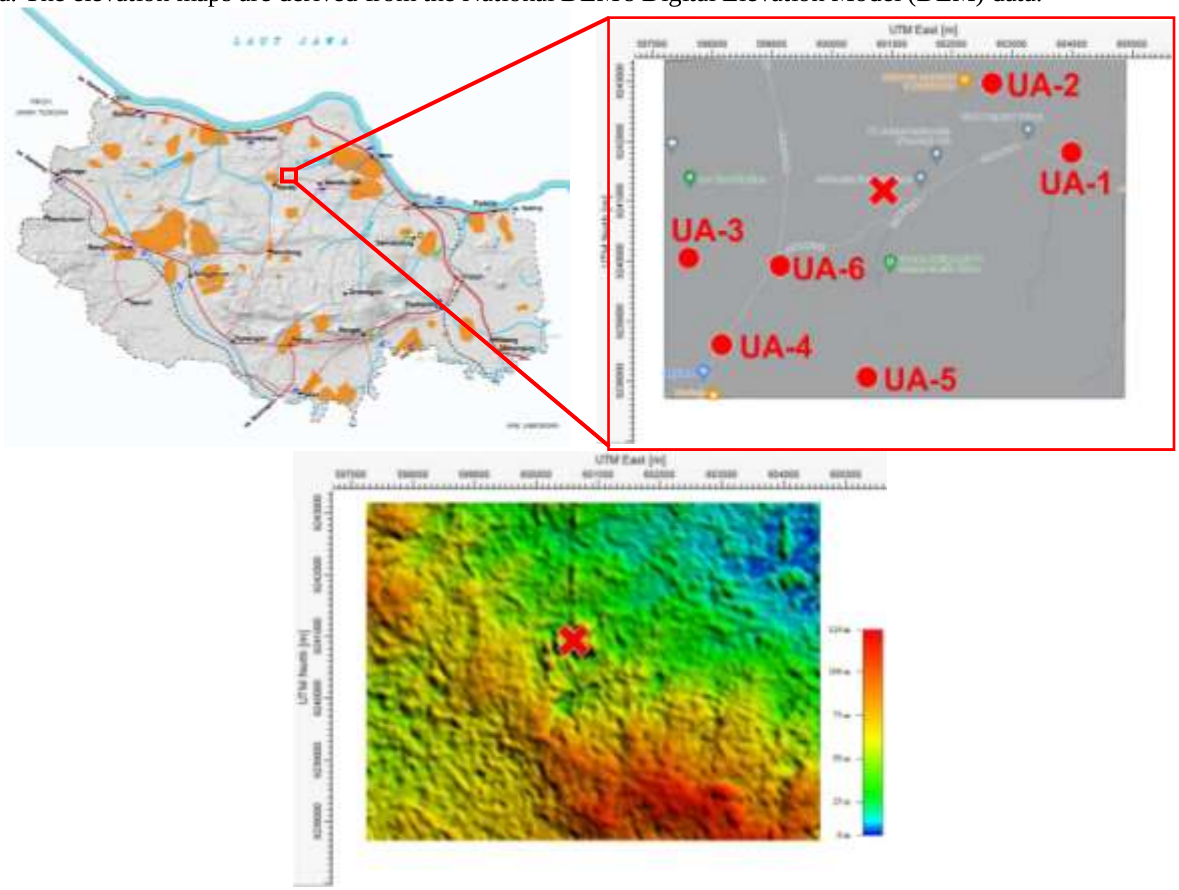



**Figure 1:-** The location of the study area in the city of Tuban, East Java, Indonesia.

### Emission source

The emission source data used in this study consists of point sources and line sources. The point source emission source comes from the measurement of company chimney emissions in the study area. The emission measurement data used is the average emission data for 2018 – 2019 (Table 1). Emission measurements are carried out every three months by companies in the study area.

**Tabel 1:-** Technical data for the chimneys.

| | Stack EP Raw Mill Tuban 1 | Stack EP Raw Mill Tuban 2 | Stack EP Raw Mill Tuban 3 | Stack EP Raw Mill Tuban 4 |
|---|---|---|---|---|
| Stack Gas Exit Temperature (Celcius) | 115 | 121 | 88 | 55 |
| Stack Gas Exit (m/s) | 12.30 | 11.78 | 12.87 | 10.42 |
| Stack Height (m) | 68.5 | 68.5 | 68.5 | 116.2 |
| Stack Inside Diameter (m) | 5.7 | 5.7 | 5.7 | 5.3 |
| Emission $SO_2$ (g/s) | 0.029 | 0.023 | 0.012 | 0.019 |
| Emission $NO_2$ (g/s) | 1.632 | 1.437 | 1.094 | 0.269 |

In addition to point source emissions, this study also uses line source emission sources based on the volume of vehicles in the study area. The line source emission source uses a calculation approach based on traffic volume using the emission factor approach published by the government. The calculation of emission sources is presented in Table 2.

**Tabel 2:-** Line source emission in the study area.

| | Street 1 | Street 2 | Street 3 | Street 4 | Street 5 | Street 6 |
|---|---|---|---|---|---|---|
| Distance (km) | 7231 | 1774 | 1143 | 1539 | 5760 | 4046 |
| Emission$SO_2$(g/s) | 0.074 | 0.051 | 0.010 | 0.008 | 0.007 | 0.008 |
| Emission$NO_2$(g/s) | 1.220 | 0.906 | 0.200 | 0.154 | 0.107 | 0.102 |

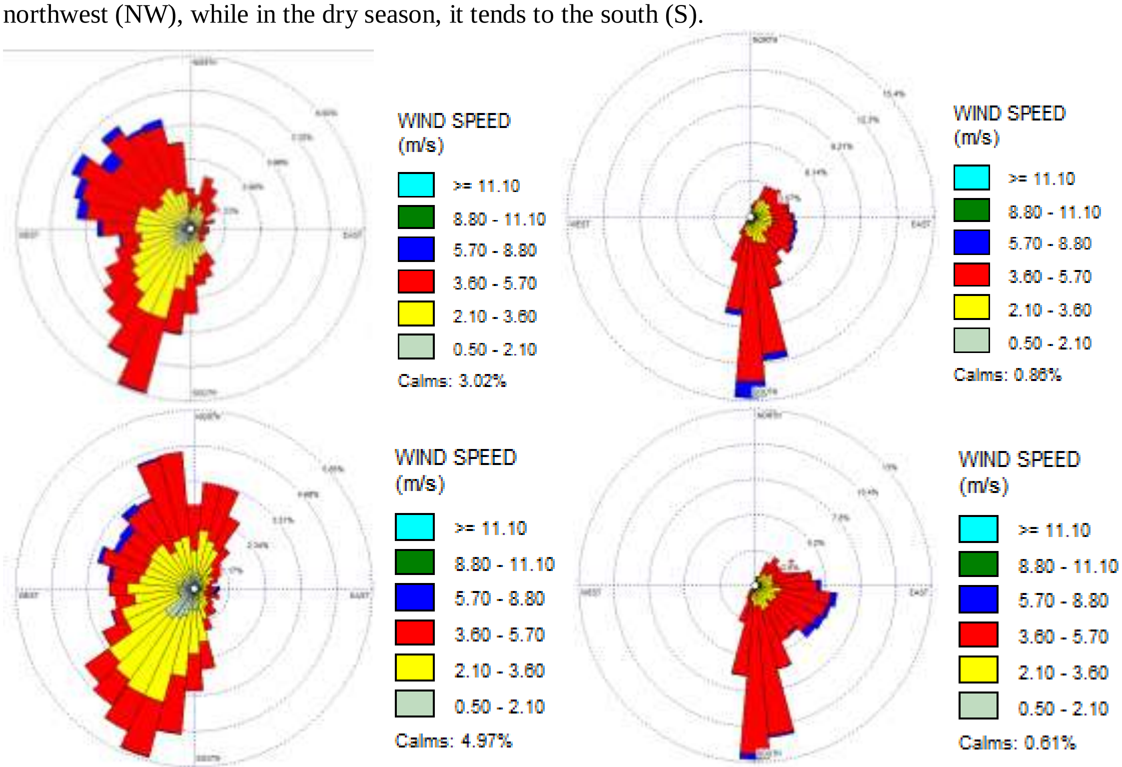
Note :
Street1 :street in kerek sub-district - margomulyo village
Street2 :streetinKasiman village
Street3 :streetinSumberarum village
Street4 :streetinKaranglo village
Street5 :streetinMerakuraksub-distric–Temadang village
Street6 :streetinMargomulyovillage

**Ambient Air monitoring data**

Ambient air quality measurement data is monitoring data carried out by companies in the study area. Measurements are carried out by the company every three months. Measurements were carried out at six measurement points for ambient air quality (Figure 1). The ambient air measurement locations were identified as UA-6, UA-2, UA-3, UA-4, UA-5, and UA-6. No ambient air quality measurement result exceeds the national quality standard.

**Meteorological Data**

Meteorological data used in this study were collected from January 1, 2018, to December 31, 2019. The meteorological data used is MM5-ready data from Lakes Environmental. Wind measurement at the station at a base altitude of 89 meters above sea level (AMSL). Meteorological data was processed using WRPLOT to determine the windrose in the study location. Windrose is used to determine meteorological characteristics in each season, both 2018 – 2019. Windrose shows the tendency of the wind direction in the rainy season towards the southwest (SW) – northwest (NW), while in the dry season, it tends to the south (S).



**Air dispersion model**
AERMOD is a steady-state plume model. In the stable boundary layer (SBL), AERMOD assumes a concentration distribution according to the Gaussian model both vertically and horizontally (crosswind and downwind). In the convective boundary layer (CBL), the horizontal distribution is assumed to follow the Gaussian model distribution, but the vertical distribution follows the bi-Gaussian - probability density function. The distribution of concentrations in CBL has been demonstrated by Willis and Deardorff (1981) and Briggs (1993) [4,11]. Air quality dispersion is carried out every season, both rainy and dry. Modeling is carried out to determine the daily average value (24h) on the date of air quality monitoring. The air dispersion modeling report uses a grid variation between 100 – 1 km. The grid resolution sizes often used in AERMOD modeling are 100 m, 200 m, and 500 m [3,7,8,9]. This grid variation is used in this study to determine the performance of the AERMOD model results.

Based on EPA's Appendix W Final Rule (2017), background concentration is needed in developing a good air quality model. Background concentration is strongly influenced by the surrounding conditions at the study site[5]. In this study, the background concentration that will be used uses field measurement data carried out. The selected field data is the location of the point where at the time of measurement is not the receptor area of the emission source.

The criteria for assessing the model's accuracy are quite diverse, where one method is to compare it with historical field measurement data [2]. This validation method compares the results of field measurements with model predictions (ratio to observer). In addition, the value of the mean absolute percentage error (MAPE) and relative mean bias is one indicator for evaluating the model's performance.

## Result and Discussion:-

The concentration of air quality dispersion results in the rainy season tends towards all cardinal directions. The dispersion results show that the biggest emission contributor is emission from a line source. In contrast to the concentration of air quality dispersion in the rainy season, the dispersion in the dry season tends towards the north, as shown in Figure 2.

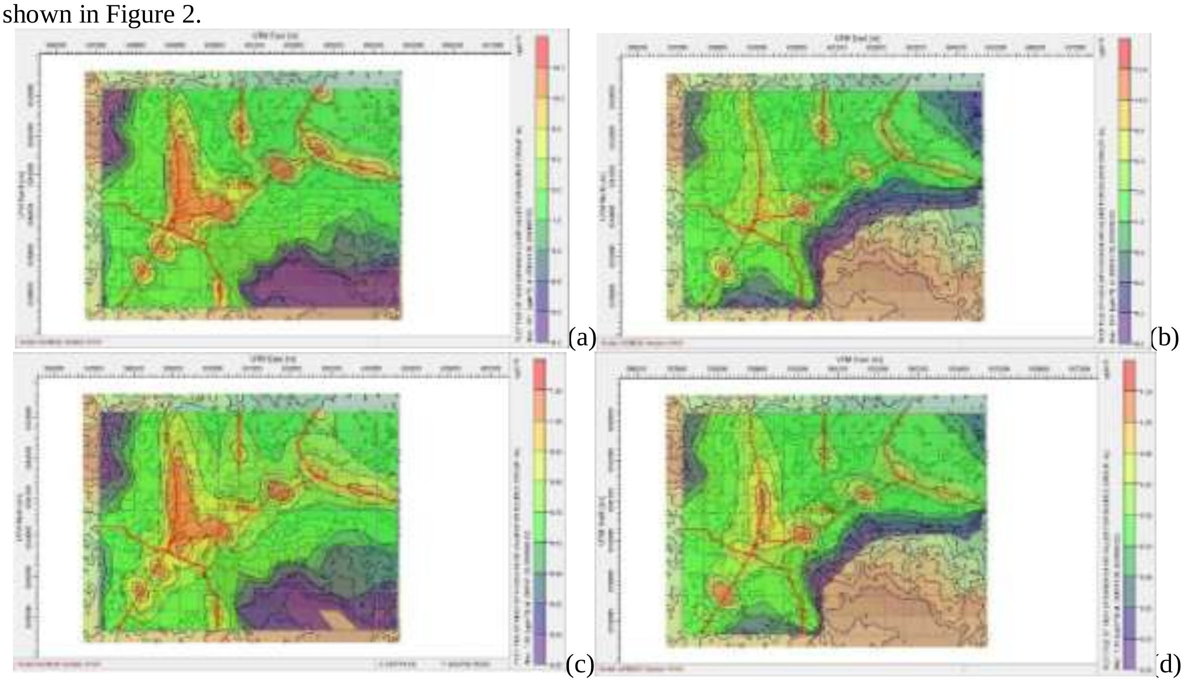


**Figure 2:-** Dispersion of air quality in the study area (a) $NO_2$ in rainy season (b) $NO_2$ in dry season (c) $SO_2$ in rainy season and (d) $SO_2$ in dry season.

The results of ambient air concentration based on field observation data were compared with the estimated emission data using the AERMOD (AERMOD + Background concentration) model. In this study, the data used as background concentration is field measurement data that has not become a receptor area (downwind) from the emission source. The area that is not a receptor (downwind) is determined based on windrose data at measurement.

Each field observation location that becomes a downwind at the time of measurement is compared with the model (ratio to observer).

**Tabel 3:-** Comparison of Modeling Prediction Results (24h) with Field Observation Data.

| | Parameter $NO_2$ | | Parameter $SO_2$ | |
|---|---|---|---|---|
| Season / Grid | Range Ratio to Observed | Average Ratio to Observed | Range Ratio to Observed | Average Ratio to Observed |
| Rainy / 100 m x 100 m | 0.67 – 1.90 | 1.04 | 0.82 – 1.17 | 0.97 |
| Rainy / 200 m x 200 m | 0.67 – 1.90 | 1.03 | 0.82 – 1.17 | 0.97 |
| Rainy / 500 m x 500 m | 0.68 – 1.44 | 1.00 | 0.82 – 1.07 | 0.96 |
| Dry / 100 m x 100 m | 0.84 – 1.42 | 1.05 | 0.62 – 1.08 | 0.93 |
| Dry / 200 m x 200 m | 0.83 – 2.28 | 1.12 | 0.62 – 1.12 | 0.95 |
| Dry / 500 m x 500 m | 0.81 – 1.21 | 0.94 | 0.62 – 1.08 | 0.94 |

The results of the ratio observed show that the AERMOD + background concentration model has an average value close to 1. The results of the $SO_2$ parameter modeling have an average ratio to observer value below 1.0, which indicates an underpredicted model. This tendency to underpredict the $SO_2$ parameter has the same results reported by Dreser and Huizer (2011) [2]. The results of the $NO_2$ parameter model have a tendency to overpredict which has a value above 1.0.

Based on Chang et al. (2004) report, a good model is a model with a prediction error rate below 50% of the observed and a relative mean bias of ±30%[5]. The statement reinforces this by Hatasuhut (2014), where the mean absolute percent error (MAPE) of the modeling results is below 50%, so the model is declared suitable for use [1]. The modeling results with AERMOD for the $SO_2$parameter have the highest relative mean bias error of -7.5%, while the highest MAPE is 9.2%. Modeling for the $NO_2$ parameter also has quite good results where the error rate value is below 50%, with the highest error rate value of 27.6% and the relative mean bias of -14.9%. These results indicate the modeling with AERMOD (AERMOD + Background concentration) is a good model.

**Tabel 4:-** MAPE and Relative Mean Bias of Model Prediction.

| | Parameter $NO_2$ | | Parameter $SO_2$ | |
|---|---|---|---|---|
| Season / Grid | MAPE(%) | Relative Mean Bias (%) | MAPE(%) | Relative Mean Bias (%) |
| Rainy / 100 m x 100 m | 25.8 | 0.0 | 7.2 | -3.2 |
| Rainy / 200 m x 200 m | 27.6 | -1.0 | 7.4 | -3.5 |
| Rainy / 500 m x 500 m | 25.0 | -17.0 | 6.9 | -4.5 |
| Dry / 100 m x 100 m | 22.9 | -0.6 | 8.7 | -6.0 |
| Dry / 200 m x 200 m | 18.6 | -10.5 | 8.1 | -6.9 |
| Dry / 500 m x 500 m | 7.1 | -14.9 | 9.2 | -7.5 |

In the rainy season, the $NO_2$modeling results tend to have a MAPE almost the same for each grid size, but the relative mean bias of the modeling results increases with the increase in the grid size used in the modeling. The results of modeling the $NO_2$ parameter in the dry season give a different trend. The increase in grid size gives modeling results with the MAPE value getting smaller but the relative mean bias getting bigger. On the $NO_2$ parameter in the rainy season, a grid size of 100 m gives the best modeling results where the MAPE value is almost the same as the grid size of 200 and 500 but gives a very small relative mean bias value.

The result of modeling with the $SO_2$ parameter gives a different tendency with the $NO_2$ parameter, where the MAPE value and relative mean bias are almost the same in all grid sizes. The MAPE value and the relative mean bias of the modeling results for all grids give a value below 10%. Changes in grid size that do not affect the model are possible because the emission source from the $SO_2$ pollutant load is very small, so it does not have a significant impact on the modeling results.

## Conclusion:-

The performance of the AERMOD model in predicting air dispersion (24h) for $NO_2$ and $SO_2$ parameters in a semi-urban area (Tuban city) gives good results. The modeling results for the $NO_2$ parameter tend to give overpredicted results, while the $SO_2$ model results tend to give the underpredicted results. Changes in grid size affect the $NO_2$ parameter, while the $SO_2$ parameter has little effect.

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