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Regression Equation of PM₁₀ Dispersion of Gypsum Industry Emissions by AERMOD Model (Case Study: Zarch, Iran)

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ABSTRACT

Background: Gypsum industry is one of industries which is known as an environment pollutant. In this study distribution and prediction of emitted PM₁₀ from Gypsum factory is studied by modeling. The main goal of this study is to create a regression equation to demonstrate the Zarch factory PM₁₀ dispersion by the AERMOD model.

Methods: In this study distribution and concentration of emitted particulate matter (PM₁₀) is estimated by AERMOD model. The regression equation of emission is resulted by AERMOD estimation and excel software, finally the results of AERMOD model and regression equation was compared to each other.

Results: In this study the regression equation is $c = 14.6 \times (-1.045)$ and by this regression equation the particulate matter's concentration could be estimated around the factory. Comparison of regression equation and AERMOD model represented that 69% of total results are similar in models.

Conclusion: The results of this study represented that by AERMOD outputs, a regression equation could be created which is able to estimate particulate matter's concentration around the emission sources according to sources properties, meteorological parameters, site topography and etc.

1. Introduction

Environmental pollution is undoubtedly one of the problems of the present world and the harmful effects of air pollution on human health and the environment are not hidden from anyone. Particulate matter less than 10 microns is one of the most important critical pollutants and is introduced as the main indicator of airborne particles. According to studies, particulate matter is more hazardous to health than sulfur oxides and nitrogen oxides [1].

Researches represent that there is a direct relation between

daily concentrations of suspended particles in the atmosphere and the daily death rate in adults [2].

In addition to death, particulate matter, can cause chronic bronchitis, asthma, and shortening working days and other problems, resulting in significant financial damage [3].

The AERMOD model is a permanent state dispersion model that can be used to determine the concentration of various pollutants in urban and rural areas, smooth and rugged, surface emissions and high altitudes sources, consist of point sources, linear, volumetric, and various types of

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surface sources which is recommended to simulate the dispersion of pollutants in the range up to 50 kilometers.

In this model, it is assumed that the particulate matter dispersion in the stable boundary layer (SBL) in the both vertical and horizontal directions is Gaussian similar to the distribution of the concentration in the horizontal direction in the CBL [4].

In addition to the AERMOD's primary processor, this model consists of a meteorological preprocessor named AERMET and a geological preprocessor named AERMAP. The AERMET preprocessor, processes the meteorological data and estimates proper boundary layer parameters of the atmosphere for the model and the AERMAP preprocessor analyzes the region's topographic information. Finally, the model uses the results of these two preprocessors and the complementary information of the sources, grid and the receivers to calculate and provide the results [5, 6].

The term regression means return and indicates that value of one variable returns to another variable. This term was first used by Francis Galton in 1877 [7].

Regression analysis or variance analysis is a statistical technique to examine and model the relationship between variables. In researches using regression analysis, the goal is usually to predict one or more criterion variable from one or more predicting variables. If the objective of a criterion predicting variable consists of several predicting variables, multiple regression model is used. If the objective is predicting simultaneous several criteria variables of predicting variables or sub variables of it, multi-variable regression model is used. In the multi-variable regression, the objective is to find predicting variables which predicts the criteria varieties [8].

Recently, various studies have been done in this field, for example Michanowics et al. (2016), the AERMOD prediction of PM_{2.5} in LUR model from ambient particles [9].

Lee et al. (2017), has done researches on Regression land use pollution in Hong Kong have done researches on dispersion of air pollution emission of several industrial sources by AERMOD model [10-16].

In this research, the regression equation of PM₁₀ dispersion of gypsum industry by AERMOD model results is introduced.

2. Materials and Methods

2.1. Research Zone

The research zone is Zarch gypsum industry in Yazd province. This factory is the only active gypsum factory in Yazd province and the gypsum production is about 200 tons per day. For some reasons, currently the production is 800 tons per day. The geographical position of factory in UTM system is 40s 240148.79 Easting and 3543795.85 Northing, the altitude is 1236 meters. The Figure 1 represents the aerial image of factory position to Yazd city. The factory location to Yazd city center is about 14 kilometers.

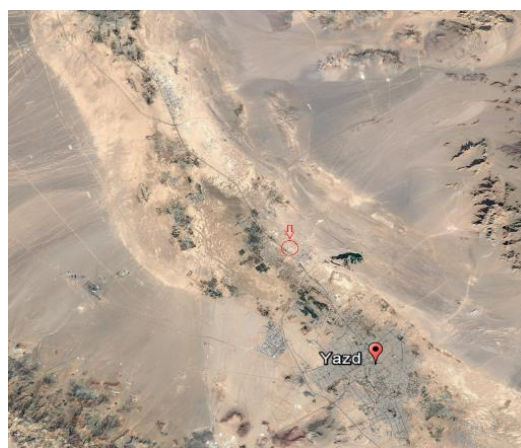


Figure 1: Aerial image of gypsum factory location to Yazd city

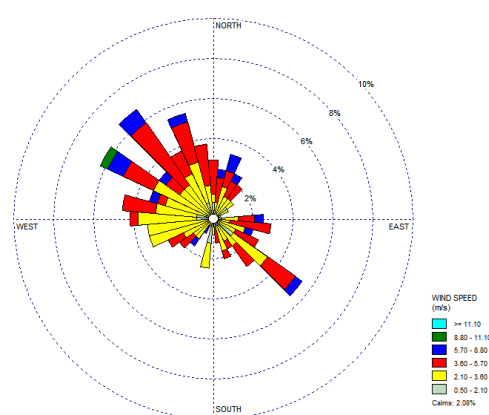


Figure 2: Wind rose of Zarch city, July 2017

According to Figure 2, the prevailing wind blows from north west to south east, and the second prevailing wind is from south east to north east. The wind rose of Zarch represent different winds from several sides and there is not a specific prevailing wind. The highest wind direction during this period is 10 meters per second in 300 degrees.

2.2. Methods

The area hourly meteorological data consisting of wind speed and direction, temperature, relative humidity and cloud cover in the year 2017 and the ground cover data was prepared for meteorology input. The specifications of emission sources, such as stacks' locations, emission mass flow rate, stacks' height, outflow temperature and diameter of stacks in average of the year for the industry was gathered. This data was prepared to the proper information for AERMOD and announced to the model. After preparation of input data, this model ran for the 50 kilometers grid by topography data and the output results declare as high 24 hour values (according to ambient standard limits) inside and around the factory. Also the schematic Figure 3 of highest concentrations (critical situations) is represented by ArcGIS software and is located by Google Earth in the layout. In the following, the results of AERMOD model dispersion and site sampling results would be compared in order to evaluate the results.

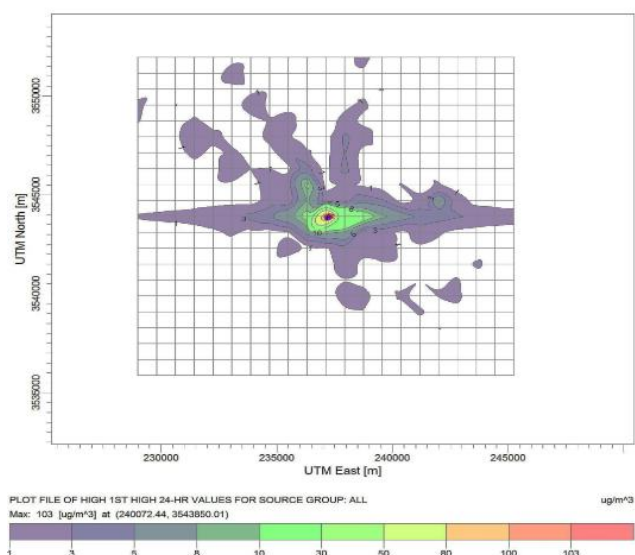


Figure 3: PM₁₀ highest 24-hour concentration around Zarc factory

Table 1: AERMOD input sources

Source Type	Source Name	X	Y
Point	Stack	240180	3543840
Linear	Conveyor 1	240235	3543832
		240192	3543808
Linear	Conveyor 2	240188	3543818
		240179	3543838
Point	Crusher 1	240256	3543832
Point	Crusher 2	240178	3543825
Area	Depot	240180	3544007
		240130	3543889
		240280	3543835
		240145	3543956
Point	Dryer	240190	3543813

3. Results and Discussion

Particulate matter's Regression and effective parameters in air pollution dispersion by the linear regression of highest 24 hour concentrations is done in order to calculate an equation to represent a predicting equation of concentration and concentration's relationship.

Therefore, AERMOD highest 24 hour results is assumed as the main function and the data variations in several distances from source (Zarch gypsum factory) is analyzed. The Figure 3 represents highest 24 hour concentrations around gypsum factory. In order to analyze the data variations against the distance to source, concentration variation chart in east and west direction of country is represented in Figures 4 and 5.

According to Figures 4 and 5, in the center of the factory because of area, linear and point sources the PM₁₀ concentration is highest and in destinations from factory reduces, and tend to zero. In order to find a relation between varieties of concentration and destination from source, functions obtained from data curves' trend line, and consist of exponential, linear, logarithmic, polynomial and power function from results of AERMOD model in east and west of factory.

The regression multiplier and equation was allocated to each function and finally the curve with highest regression multiplier in east and west direction was chosen, and the power function had the highest regression multiplier. The Figure 6, represents the AERMOD concentrations results chart of power function in the west of factory.

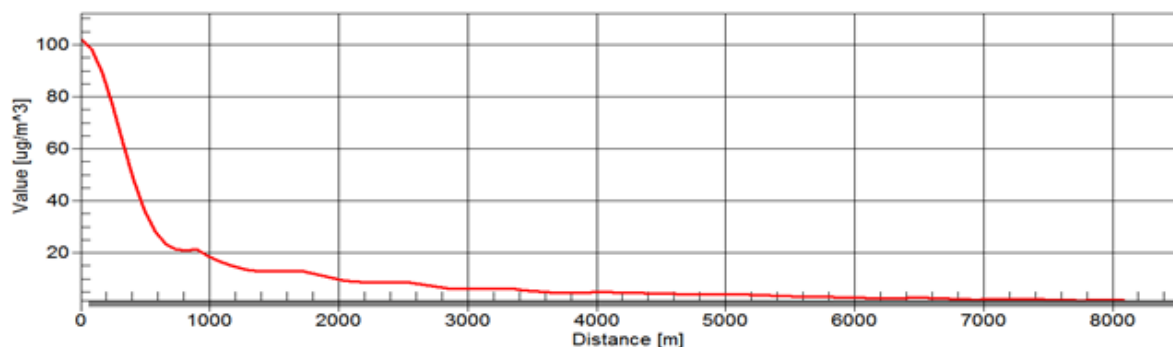


Figure 4: PM₁₀ highest 24 hour concentrations by distances from factory in east direction

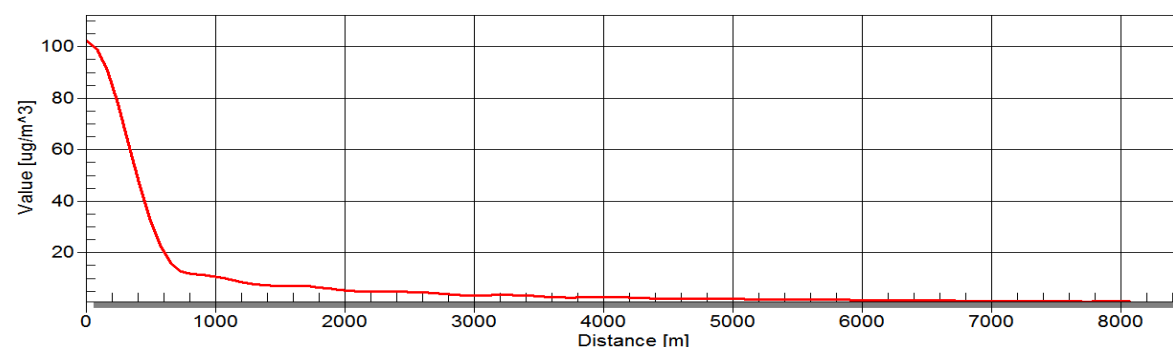


Figure 5: PM₁₀ highest 24 hour concentrations by distances from factory in west direction

This chart's regression multiplier is 98% and the function is:

$$Y = 11.726 x^{-1.108}$$

The above chart indicates that the relation of concentration variates to the distance from source could be converted to the power function bellow:

$$C = aX^{-b}$$

The parameters "a" and "b" depend on several factors such as stack's height, meteorological conditions and topography which "a" is 11.72 and "b" is -1.10 in the west of the factory.

The bellow Figure 7 is power function of AERMOD PM₁₀ results in the east of factory. This chart's regression multiplier is 97% and function is:

$$y = 17.67 x^{-0.997}$$

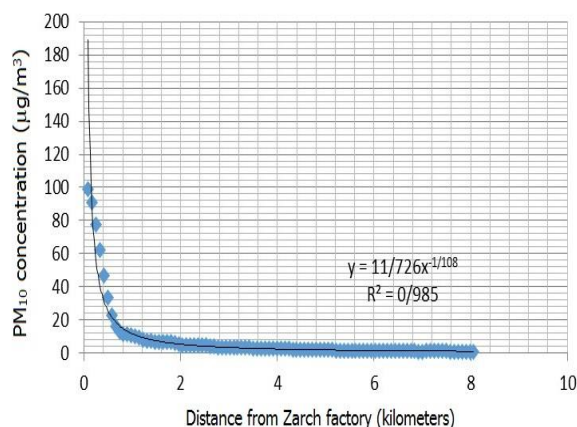


Figure 6: AERMOD PM₁₀ concentration results chart by power function in west direction

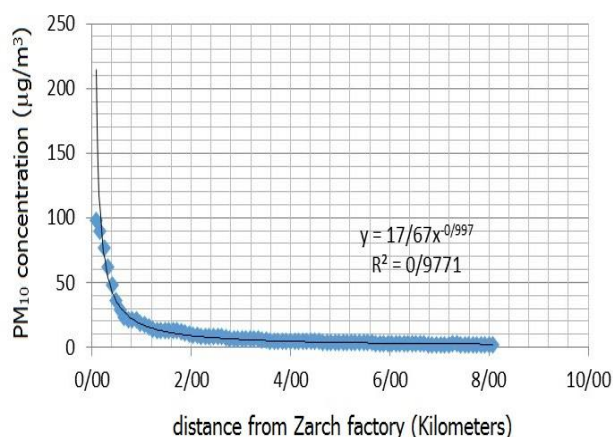


Figure 7: AERMOD PM₁₀ concentration results chart by power function in east direction

4. Conclusion

The air pollution producing industrial activities in recent years, causes significant environment effects in Iran country. Studies declare the reason, sources, activities and particulate matters dispersion, environment effects and also presents methods and suggestion to solve such problems.

The main goal of this study is to create a regression equation to demonstrate the Zarch factory PM₁₀ dispersion by the AERMOD model which is an accepted model by EPA [17].

In this study the AERMOD model is ran in a real situation for Zarch gypsum factory. The PM₁₀ 24 hour resulted concentrations compared to sampling results. The results indicate appropriate similarity between sampling and modeling data that $R^2 = 87\%$ and $= 1/05$. The modeling results represent the correlation of metrological and topography parameters to particulates matter dispersion and confirms the dispersion of particulate matters is in their direction.

Also the variations are correct in other directions and according to the Gaussian equation, by increasing distance from the source, the concentration decreased.

The AERMOD model output results declare that the effective radius is about 8 kilometers and the particulate matter emitted from gypsum factory is more than standard limit in several locations.

According to regression functions based on AERMOD model in west and east direction of the factory which has the highest PM₁₀ dispersion, the power function regression equation was calculated. The power regression equation is which the multipliers are average of multipliers in west and east directions. This equation is used to predict the concentration of points on the grids of 8 kilometers from factory. Comparison of the particulate matters modeled by AERMOD model and Regression equation indicates 69% of accuracy. The most accuracy is in points between 4 to 8 kilometers. In order to estimate particulate matters in other industries such as cement factories, modeling by AERMOD and regression model in several years, statistic comparison, to calculate average results by use of this research method is suggested.

Authors' Contributions

M.M., conceptualized the study, collected the data, worked on the methods and data analysis. N.M., Supervisor and Corresponding Author. A.V., Supervisor. M.H.B., and S.A.M., Advisor.

Conflict of Interest

The authors report no conflict of interest.

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