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Original

Comparison of Application of AERMOD and ISCST3 Models for Simulating the Dispersion of Emitted Pollutant from the Stack of an Industrial Plant in Different Time Scales

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Abstract

Background: One of the main parts of air quality management is known as modeling of atmospheric pollutants. In this regards, simultaneous application of several models in a project and comparing the results obtained from these models could have been a considerable contribution to air quality managers for taking a more efficient decision. **Methods:** In this study, the stack of an industrial plant in the southwest of Isfahan was selected as the emission source and the total suspended particles emitted from this stack was simulated by applying AERMOD and ISCST3 view models (version 8.2). In this vein, the modeling process was conducted using MM5 meteorological data in a 50×50 km extent with 2000 m network distance for each of the models in 1-h, 24-h term averages (short term averages) and monthly and annual periods (long term averages) at ground level concentrations (GLC). **Results:** Results indicated that the highest simulated concentration for both models occurred in a 2000 meters' distance in the east of the stack. Moreover, the highest simulated concentration applying AERMOD was lower than that of applying ISCST3 in all term averages which is due to existing differences between applied algorithms in these two models. **Conclusion:** Consequently, applying AERMOD due to the use of more advanced and up-to-date algorithms have priority over ISCST3 model. Applying ISCST3 can also be useful for small projects that require less input data compared to the AERMOD.

Key words: AERMOD; ISCST3; Modeling; Concentration

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Introduction

Since the problems regarding air quality considered as being on constant growth, the need to find manners for understanding and simplifying this complexity is of utmost importance,[1] Planning on pollution strategies depends significantly on authentic information about air quality and operational scenarios that may occur in the future. Air quality modeling as a convenient tool is capable of providing this information in an understandable and applicable form and is becoming an integral part in

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comprehensive environmental assessments.[2] In this regard, by applying mathematical algorithms known as numerical models; physiochemical process affecting concentration, reaction and dispersion of pollutants in atmosphere are simulated by receiving a variety of input data, including meteorological data, emission rate, topography and etc.[3,4] Predicting spatial-temporal concentrations of pollutants resulted from different sources is an important issue.[2] Assessing the dispersion of atmospheric pollutant emitted from dangerous industrial sources and the relevant risks for the population is of great importance as well.[5] The Gaussian air dispersion models, as the most common and most recognized ones in the field of air dispersion modeling in past decades, can still be applied to accomplish this goal.[6-8] In such models, in addition to the manner that pollutant is dispersed in the air, the concentration of emitted pollutant released from a source can be determined in different time and space intervals.[9]

AERMOD is an advanced and highly applied plume dispersion model which has been updating on constant basis. This model jointly developed by American meteorological society and EPA was replaced by ISTCST3 in 1991. After 15 years, in 2006, it was introduced as the preferred regulatory model by EPA.[9-12] Although AERMOD is considered as the latest model of EPA, application of ISCST3 due to its simplicity, low requirement of various input data and its good results in comparison with other air dispersion models could still be beneficial.[13] The objective of this study is to apply both the AERMOD and ISCST3 for simulating the total suspended particles emitted from stack of an industrial plant in Isfahan and comparing the obtained results of these models.

Methods

Study area

In this study, the flue-gas stack of a steel plant located in the south of Isfahan was chosen for the modeling process Figure 1. This plant with 3000 tons capacity per year was launched in 1995 and is located in the km 55 of the road Isfahan to Mobarakeh. Manufactured products of this plant, after going through different processes in various units, are used in many industries including oil, gas, petrochemical, power plants, automotive, and etc. Topographical and meteorological features of the area calculated as 1670 from mean sea level, Figure 2, the average temperature of 12 ° C and wind speed of 2.5 m/s.

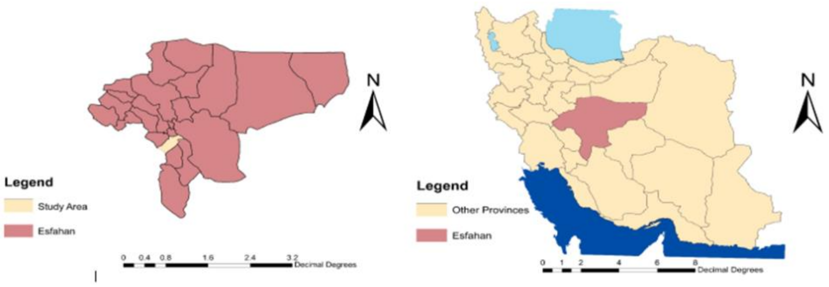

Figure 1. Geographical location of the study area

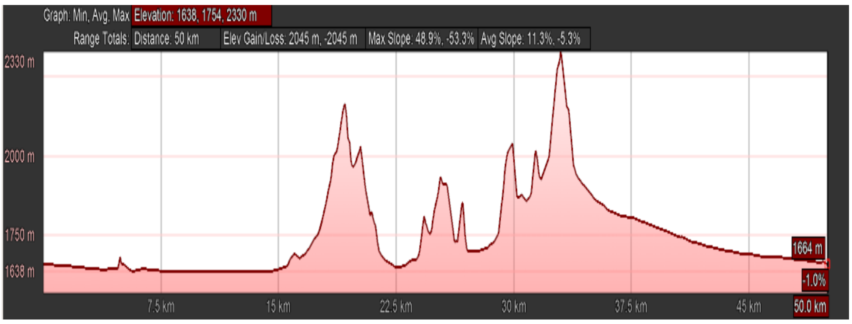

Figure 2. Elevation changes in 50 km radius

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Adopting the AERMOD model

In order to run AERMOD model, required meteorological data of MM5 type were purchased from Lake Environmental Company in Canada (https://www.weblakes.com/services/met_data.html). Hourly data were completed with SAMSON and TD6201 formats for March 21st, 2014 to March 21st, 2015 and 32•35' N and 51•61' E geographical coordinates were directly imported to AERMET preprocessor without any modification. Produced wind rose containing common meteorological data between two models was calculated by the frequency that the wind blows from a particular direction per unit of time,[14] Figure 3. Afterwards the three parameters of Bowen ratio, Albedo and surface roughness according to type of the land use around the steel plant were divided to four sectors of cultivated land, desert shrub land, urban and cultivated land where each of the three mentioned parameters were determined on an annual basis with respect to, Table 1.

After being done with AERMET preprocessor, in order to determine the receptors size, a uniform Cartesian grid with 50×50 km extent and 2000 meters network distance was defined and having determined the emission coefficients of the TSP for flue-dust stack which was obtained by Durag F-701-20 portable device for the same time period, was set at center of this network. It should be mentioned that, this stack was the only emission source of the study. Finally, to assess the terrain effects on pollutant dispersion, a global SRTM3 90 m was imported to AERMAP preprocessor.

Adopting the ISCST3

In order to run ISCST3 model, only the meteorological preprocessor of this model (PCRAMMET) was applied and other common parameters between this model and AERMOD were accepted with no change. In this respect, only the SAMSON file of the MM5 meteorological data was applied as the surface data and to estimate the mixing height parameter which is one of the required parameters in this preprocessor (PCRAMMET), anemometer height of 13m, Albedo of 0.3275, Bowen ratio of 4.75 and surface roughness of 0.2625 were determined. At the end, after running this preprocessor, the ISCST3 model was run completely.

Table 1. Surface parameters used in AERMET preprocessor

Sector	Start	End	Land use type	Albedo	Bowen ratio	Surface roughness
1	0	50	Cultivated land	0.28	0.75	0.07
2	50	250	Desert shrub land	0.33	4.75	0.26
3	250	320	Urban	0.21	1.62	1.00
4	320	0	Cultivated Land	0.28	0.75	0.07

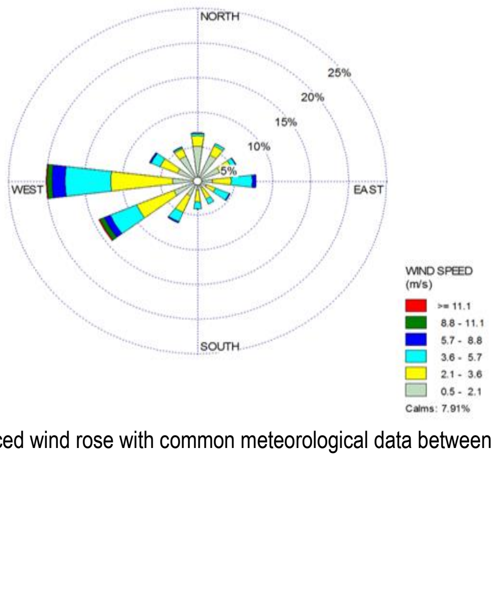

Figure 3. Produced wind rose with common meteorological data between two models

Results

The wind rose plot produced by using MM5 meteorological data, considered as input meteorological data for both models, is shown in Figure 3. After running both models in full, the obtained results of highest simulated values of these models were determined in contour plot files for short and long term averages, Figure 4 to 11.

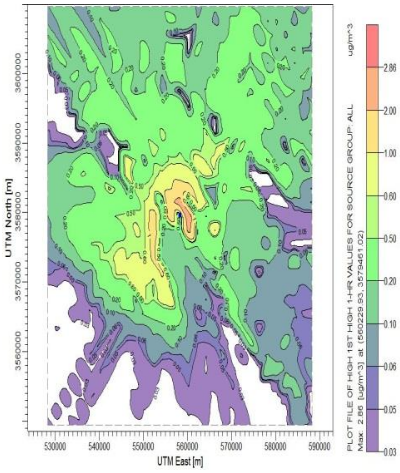

Figure 5. 1 hour average concentrations Using AERMOD

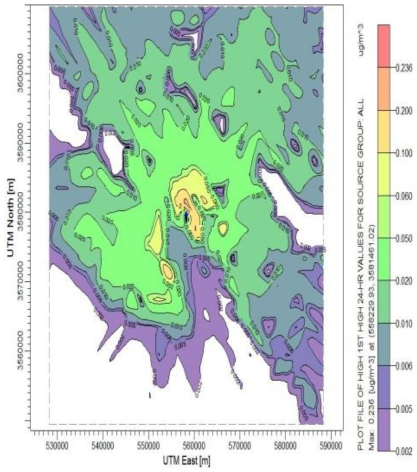

Figure 4. 24 hour average concentrations Using AERMOD

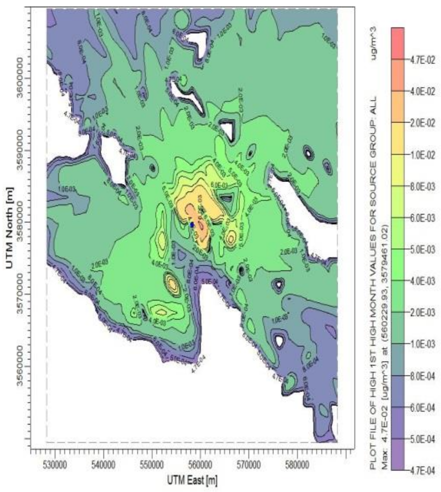

Figure 7 . Monthly average concentrations Using AERMOD

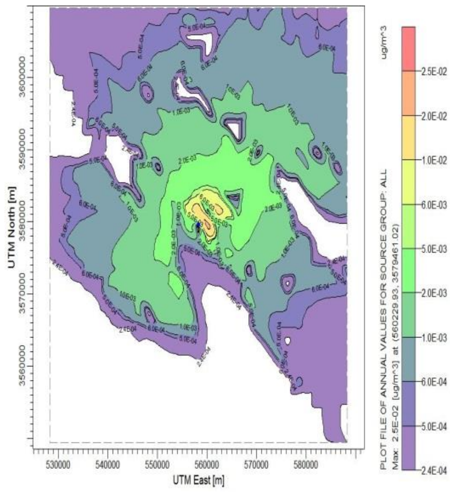

Figure 6. Annual average concentrations using AERMOD

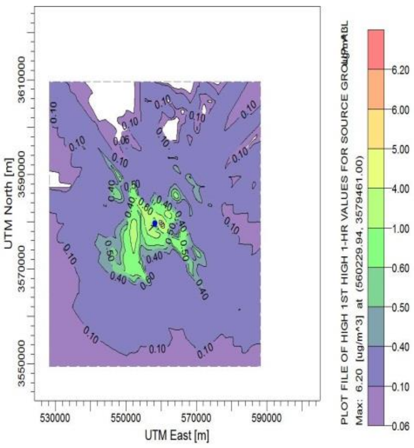

Figure 9. 1 hour average concentrations Using ISCST3

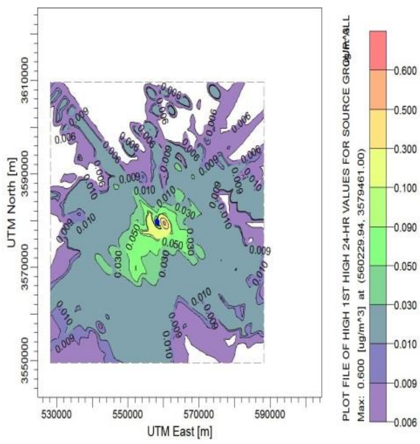

Figure 8. 24 hour average concentrations using ISCST3

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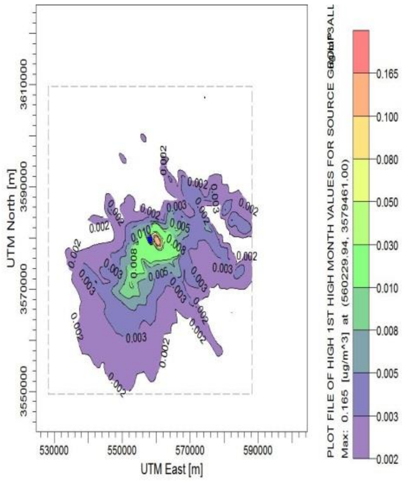

Figure 11. Monthly average concentrations Using ISCST3

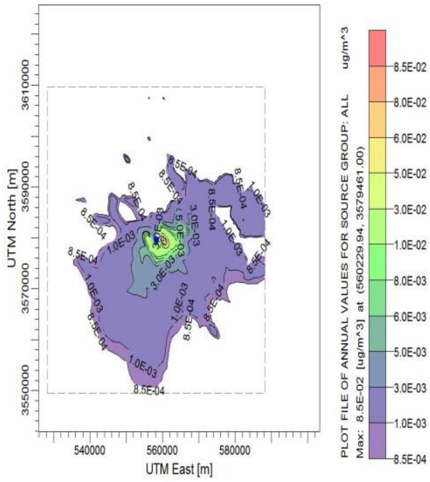

Figure 10. Annual average concentrations using ISCST3

Comparing the highest simulated concentrations obtained through both models

According to Figure 4-11, with respect to direction and distance of highest concentrations as expressed in Tables 2 and 3, the highest simulated concentrations for both models in all term averages have occurred in 2000 meters distance from the stack in the east, which is in line with west-east prevailing wind in this region, Figure 2. However, the most obvious difference between the obtained results is recognized in the amount of concentrations indicating that the simulated concentrations by AERMOD in all term averages are less than that of the ISCST3. The main reason for this is in the difference between employed algorithms in these two models, Figure 12.

Table 2. The maximum simulated concentration by AERMOD

Direction	Distance from electric arc furnace stack (km)	Coordinate Y(UTM)	Coordinate X(UTM)	Concentration µg/m³	term average
East	2	3579461/02	560229/93	2/86	1h
East	2	3579461/02	560229/93	0/24	24h
East	2	3579461/02	560229/93	0/05	Monthly
East	2	3579461/02	560229/93	0/02	Annual

Table 3. The maximum simulated concentration by ISCST3

Direction	Distance from electric arc furnace stack (km)	Coordinate Y (UTM)	Coordinate X (UTM)	Concentration µg/m³	Time average
East	2	3579461	560229/94	6/20	1h
East	2	3579461	560229/94	0/60	24h
East	2	3579461	560229/94	0/16	Monthly
East	2	3579461	560229/94	0/08	Annual

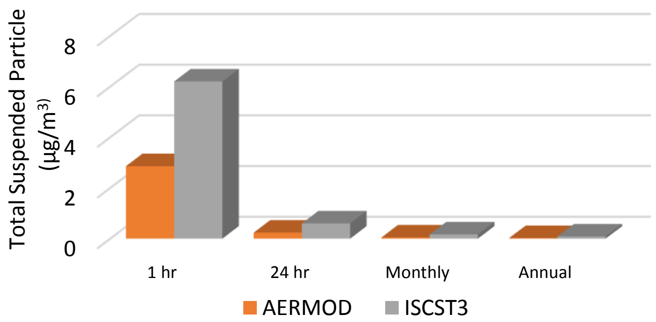

Figure 12. Comparison of simulated concentrations with AERMOD and ISCST3

Conclusion

In this study, in order to simulate the dispersion of emitted pollutant from the stack of an industrial plant in the south of Isfahan, AERMOD and ISCST3 were used as the two dispersion model. According to the obtained results, the highest simulated concentrations for both models predicted at the 2000 meters distance from the stack in the east which is in the direction of prevailing wind in the region. Moreover, due to the differences and applications of more advanced algorithms in AERMOD, the highest simulated concentrations are recognized as lower than the ones found by ISCST3 in all term averages. In fact, applying AERMOD leads to under prediction while applying ISCST3 leads to over prediction of concentrations in this study. This observation is consistent with[15,16] and[17] studies as well. However, it is of significant importance to note that, applying different sets of data and parameters for both models could result in different observations. For instance, AERMOD is more sensitive to parameters like changes in albedo, surface roughness, wind speed, temperature, and cloud cover while taking into consideration ISCST3, solar radiation (as it affects stability class) and mixing heights below 160 m have more impact on sensitivity.[18] In addition to this fact, in some scenarios AERMOD could have larger maximum concentrations. For instance, in the annual concentration estimated for the rural setting, tall and squat building with a 100–meter-stack (both nearby to the building and separated from the building). Such results can only be attributed to variations in the dispersion algorithms within the two models.[19]

Finally, it should be mentioned that, in the field of air quality modeling, no model can be considered as the most complete one due to the variety in the model types, their functionality and restrictions. It is realized that the applying large number of input data and complex algorithms does not necessarily mean that given model is known as completely perfect, while increasing input data can increase the amount of uncertainty in a model. In general, a modeler should select a model with a complete understanding of various types of models and consider the priorities and required parameters of a project.

Conflict of interest

The authors did not report any contradiction of interests.

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