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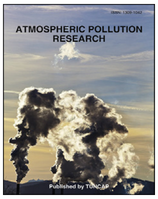

Comparison of AERMOD, ADMS and ISC3 for incomplete upper air meteorological data (case study: Steel plant)

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ABSTRACT

In this paper three well known Gaussian dispersion models have been evaluated for a case study of a steel plant using complete and incomplete upper air meteorological data.

In developing countries, the availability of surface and upper air meteorological data is limited. AMS/EPA Regulatory Model (AERMOD), Advanced Dispersion Modeling System (ADMS) and Industrial Source Complex Model (ISC3) have been evaluated for both real and estimated upper meteorological data and the results have been compared with field measurements both in the horizontal and vertical directions.

The results show significant differences in predicted concentrations when modeling with real (actual) and estimated upper meteorological data. The differences ranged from 100% to 450%. Comparison of model performance suggests that AERMOD and ADMS with real meteorological data produce consistent results in the horizontal direction while ISC3 output over-predicts in general. In AERMOD and ISC3 the predicted concentrations have a similar trend of variation in the vertical direction but in ADMS the concentration variation in the vertical direction exhibited different trends. In general, the ADMS predicted concentrations under-estimated field observations.

The paper suggests that upper data must be used for modeling and the default values must be used with care. In absence of upper meteorological data, users could estimate upper meteorological data by different available algorithm rather than only default option of models.

1. Introduction

Gaussian dispersion models have been used widely for concentration prediction, sampling network design, EIA (Environmental Impact Assessment) and environmental management scenarios (EPA, 2015). The relative simplicity of use, quick setup, acceptable accuracy and wide applicability in different atmospheric condition are the advantages of these models (EPA, 2015). In developing countries, the using of these models has several constraints in both source emission determination and availability of meteorological data. In these countries accurate and sequential meteorological data are not available (especially upper meteorological data). Another problem is the location of industries. Most plants and industrial facilities have been constructed outside of large cities where meteorological sites are not available for modeling (Carbonell et al., 2010). In this paper three different models (i.e., ADMS, AERMOD, and ISC3) have been evaluated.

1.1. AERMOD (AMS/EPA Regulatory Model)

AERMOD is the Gaussian air dispersion model which incorporates building downwash algorithms, advanced depositional parameters, local terrain effects, and advanced meteorological turbulence calculations. AERMOD could be implemented with both real and estimated upper meteorological data (EPA, 2004). The minimum surface meteorological data for running AERMOD are (EPA, 2004):

1. Year, Month, Day, Hour
2. Wind Speed
3. Wind Direction
4. Dry Bulb Temperature

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5. Cloud Cover (tenths)

1.2. *Advanced Dispersion Modeling System (ADMS)*

ADMS is a Gaussian air dispersion model used to evaluate industrial impacts on air quality. ADMS incorporates building effects, complex terrain, coastlines and variations in surface roughness; dry and wet deposition; chemistry schemes; short-term releases (puffs); calculation of fluctuations of concentration on short timescales, odors and condensed plume visibility; and allowance for radioactive decay including γ-ray dose. One can use default values for upper air data or use a file includes vertical meteorological in format of _prf (CERC, 1998). The minimum ADMS meteorological data inputs (CERC, 1998):

1. Year, Month, Day, Hour
2. Wind speed,
3. Wind direction
4. One of the following: the reciprocal of the Monin-Obukhov length, the surface heat flux, or the cloud cover

1.3. *Industrial Source Complex Model version 3 (ISC3)*

ISC3 is another Gaussian plume model which can be used to predict pollutant concentrations from industrial facilities. ISC3 had been the US-EPA preferred air dispersion model for regulatory purposes until December 2006 when it was replaced by AERMOD. The major advantage of AERMOD and ADMS over ISC3 is related to the state of art algorithm of turbulent dispersion (EPA, 1995). The minimum ISC3 meteorological data are (EPA, 1995):

1. Wind speed
2. Wind direction
3. A stability class determination
4. Mixing depth

In this paper, these models have been evaluated for complete and incomplete upper meteorological data and all of them have been verified with measurements.

2. Area of study

The case study is the MOBARAKEH steel complex located at 539733.79 m E and 3567898.85 m N zone 39 S. It is the largest steel maker of MENA[1] region. This facility made 52 percent of all the steel produced in Iran. Its products consist of hot and cold rolled sheets and coils, pickled coils, narrow strip coil, tinplate sheet and coil galvanized coil, pre-painted coil and slab (MSC, 2015).

There are plenty of buoyant and non-buoyant sources in the facility include point, line and area sources. The site included point sources (like.e.g., stacks), line sources (e.g., conveyor and roads), area sources (e.g., piles and wind erosion from surrounding areas). The main pollutant from the facility is PM_{10} which was evaluated in this paper. The emissions from piles were evaluated by using Fluent CFD modeling (in conjunction with AP-42) and wind erosion fluxes have been estimated. Gambit model has been used to generate iron ore piles and the wind profile is calculated by Fluent (EPA, 2006; Torano et al., 2006; Ashrafi et al., 2015). The method of estimating emission rates of sources follows these steps sequentially:

1. Direct measurement
2. Indirect measurement (using measurement results in other same companies)
3. The use of modeling tools like CFD
4. The use of ap42 emission rates

Table 1
PM_{10} emission rates for MOBARAKEH steel facility.

Process and unit	Method of emission calculation	Contribution	g/s[a]
Pellet making	measurement and emission factor	29%	118.32
Direct reduction	measurement and emission factor	12%	48.96
Steel making	measurement and emission factor	46%	187.68[b]
Wind erosion	CFD-Fluent[c]	8.4%	34.272
Miscellaneous	measurement and emission factor	4.6%	18.768
Total			408

[a] The value of total emissions from point, area and line sources for each process units has been converted to g/s.

[b] High value of emission in steel making unit is due to uncontrolled dust emission from roof of units and above EAF.

[c] The Fluent CFD Model was used for PBL and the default coefficient of the model for turbulence and surface roughness and wall function has been modified before use (Torano et al., 2006; Ashrafi et al., 2015).

There are about 400 miscellaneous sources of PM_{10} in this facility. The sources and emissions are mentioned in Table 1.

The modeling area has a radius of 7.5 km around the facility and the topographical conditions include flat and elevated terrain. The modeling area of was determined to be urban based on Gimson et al. (2007). The models were ran for the 2014–2015 meteorological period. Maximum wind speeds at a 10 m anemometer tower was 35 m/s for 2014–2015 period. The wind rose of the area is shown in Fig. 1.

3. Methodology

The performance of the models was evaluated using different meteorological inputs. AERMOD was evaluated for the following three meteorological cases:

1. AERMOD_REAL: AERMOD modeling with real upper meteorological data.

In this case, hourly surface and upper data has been used for modeling. These data measurements from the nearby airport meteorological station.

2. AERMOD_ESTIMATOR: AERMOD modeling with default upper meteorological estimator of AERMOD.

In this case, hourly surface data was used but upper data has been estimated with AERMOD default option estimator (The et al., 2001).

3. AERMOD_ALGORITHM: AERMOD modeling with upper meteorological data based on the algorithms proposed by Batchvarova and Gryning (1991).

In this case, hourly surface data has been used but upper data has been estimated with Batchvarova and Gryning algorithm. For details of this algorithm and implementation please refer to (Carbonell et al., 2010; Gill, 1982; Thomson, 2000).

The ADMS model was evaluated for the following cases:

1. ADMS_PRF: ADMS modeling for real vertical profile meteorological data (_prf)

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[1] Middle East & Northern Africa.

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