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AIR DISPERSION MODELING IN ORDER TO ASSESS IMPACT OF POWER AND INDUSTRIAL PLANTS

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ABSTRACT

Dispersion modeling uses mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by a source. Based on emissions and meteorological inputs, a dispersion model can be used to predict concentrations at selected downwind receptor locations. University of Belgrade Faculty of Mechanical Engineering Department of Process Engineering possess dispersion modeling package AERMOD View. Previous modeling has shown that the biggest issue is the lack of appropriate meteorological data for the Republic of Serbia. In this study are presented some of results for coal power plant and cement plant. Results obtained by models justified the use of dispersion modeling in order to assess the impact of emission sources on air quality in area of model domain.

Key words: *dispersion, modeling, emission, air quality, AERMOD.*

INTRODUCTION

In order to create the possibility to take adequate preventive, spatial planning and environmental protection measures against excessive air pollution it is necessary to provide a system for air quality monitoring in order to get a precise picture of air pollution on the territory of the observed area. In cases where there are no data of air quality measurements from the field (in the design phase of new industrial facilities), access to mathematical modeling, i.e. simulation of atmospheric processes with the help of mathematical models.

Dispersion modeling is a mathematical simulation of emissions as they are transported throughout the atmosphere. Dispersion models replicate atmospheric conditions, (which includes wind speed and direction, air temperature and mixing height), and provide an estimate of the concentration of pollutants as they travel away from an emission source. These models can also generate estimates of secondary formation of pollution by incorporating atmospheric chemistry into the model. Dispersion models can be used to determine whether a new source will adversely impact an area or to predict whether the control of an individual source will have a beneficial effect. Dispersion models are used when a prediction of ambient concentrations is necessary, such as in a new source review or evaluating emissions reduction plans. The available dispersion models vary in their complexity. At a minimum, most of the models require meteorological data, emissions data, and details about the facilities in question (such as stack height, gas exit velocity, etc). Some of the more complex models require topography information, individual chemical characteristics and land use data. The output from this type of model is a prediction of the concentration of the pollutant in question throughout the appropriate region (which depends on the model chosen).

The models are more reliable for assessing the average concentration of long periods than shorter, for a specific location. They have acceptable reliability in estimating the value of the highest concentrations occurring somewhere within the observed area. Typical accuracy of the results obtained by modeling are in the range of 10 to 40 per cent in the assessment of the maximum concentration.

Modeling generally need three types of information: the source of emissions, meteorology of the observed area and terrain features and receptors.

University of Belgrade Faculty of Mechanical Engineering Department of Process Engineering use Gaussian Plume Air Dispersion Model *AERMOD View* for teaching purposes and preparation of environmental impact assessment studies. Over the past few years numerous studies have been carried out for industrial and power plants.

The present study aims to present some results as well as conclusions and issues that have been encountered.

AERMOD

AERMOD includes a wide range of possibilities for modeling the effects of pollutants on air pollution. This model provides the possibility of modeling a number of sources of pollution, including point, line, surface and volume. The model contains algorithms for the analysis of the aerodynamic flow in the vicinity and around buildings (building downwash). Values of pollutants from the source can be treated as constants during the period of analysis, and may vary within the month, the period, or an optional hour time change.

AERMOD is a steady-state plume model. In the stable boundary layer (SBL), the concentration distribution is assumed to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL), the horizontal distribution is assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (p.d.f.). This behavior of the concentration distributions in the CBL was demonstrated by (Willis, and Deardorff, 1981) and (Briggs, 1993). Additionally, in the CBL, AERMOD treats “plume lofting,” whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. AERMOD also tracks any plume mass that penetrates into elevated stable layer, and then allows it to re-enter the boundary layer when and if appropriate.

Figure 1. shows the flow and processing of information in AERMOD. The modeling system consists of one main program (AERMOD) and two pre-processors (AERMET and AERMAP).

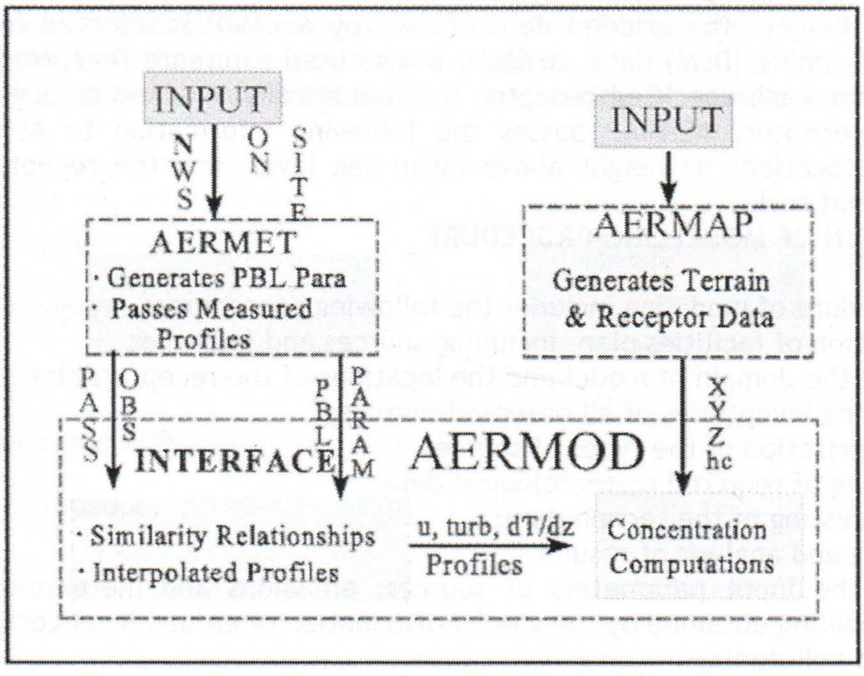


Figure 1. Data Flow in the AERMOD Modeling System

Meteorological Preprocessor (AERMET)

The basic purpose of AERMET is to use meteorological measurements, representative of the modeling domain, to compute certain boundary layer parameters used to estimate profiles of wind, turbulence and temperature. The surface parameters provided by AERMET are the Monin-Obukhov Length, surface friction velocity, surface roughness length, surface heat flux, and the convective scaling velocity. AERMET also provides estimates of the convective and mechanical mixed layer heights. Although AERMOD is capable of estimating meteorological profiles with data in from as little as one measurement height, it will use as much data as the user can provide for defining the vertical structure of the boundary layer. In addition to planetary boundary layer (PBL) parameters, AERMET passes all measurements of wind, temperature, and turbulence in a form AERMOD needs.

Terrain Preprocessor (AERMAP)

Since it is particularly difficult to both represent actual complex terrain as a collection of idealized terrain features and associate each receptor with a unique hill, AERMAP (the terrain preprocessor for AERMOD), operating from a receptor's point of view, samples the landscape around each receptor to objectively specify a representative "hill" height associated with that receptor.
AERMAP uses gridded terrain data to calculate a representative terrain-influence height, also referred to as the terrain height scale. The terrain height scale, which is uniquely defined for each receptor location, is used to calculate the c dividing streamline height. The gridded data needed by AERMAP is selected from Digital Elevation Mapping (DEM) data. AERMAP is also used to create receptor grids. The elevation for each specified receptor is automatically assigned through AERMAP. For each receptor, AERMAP passes the following information to AERMOD: the receptor's location, its height above mean sea level, and the receptor specific terrain height scale.

DESCRIPTION OF MODELLING PROCEDURE

Each procedure of modeling includes the following procedures:

1. Preparation of facilities plan, including sources and facilities;
2. Defining the domain of model and the locations of the receptors;
3. Developing inventories of all observed sources;
4. Characterization of the types of sources;
5. Processing of required meteorological data;
7. The processing of the terrain data;
8. Modeling and analysis of results.

Based on the input parameters of sources, emissions and meteorological data values, modeling obtained by the spatial distribution of ground level concentrations of selected pollutants.

In order to obtain a clear picture of the polluters for each source of emissions is necessary to define the following information:

- the type of pollutants,
- physical stack height,
- geographic coordinates of stack,
- diameter of the stack,
- the flow of flue gases through the stack,
- the temperature of flue gases in the stack,
- emission values of the pollutants.

Digital Elevation Model (DEM) data are entered into AERMOD, which were assigned elevation of receptors, sources and buildings. AERMOD gives possibility to use different types of digital maps of terrain, but because of its availability we use SRTM3 - Shuttle Radar Topography Mission (resolution: ~ 90m, 3 arc-sec). In addition to the elevation terrain, it is necessary to define the location and the intervals between the receptor and the plant based on the Universal Transverse Mercator - UTM coordinate system. Receptor network covers a large area, while the individual receptors can be defined as areas of special interest (e.g., schools, hospitals or the nearest adjacent property). Receptors can be represented as a point on the ground or as an item at a specific height.

Meteorological data for the model are entered through the data on the parameters of the surface boundary layer and profile data variable meteorological parameters which include wind speed, wind direction and turbulence parameters. These two types of meteorological parameters need for AERMOD model generate meteorological preprocessor called AERMET. Since upper air data is not available, AERMET Upper Air Estimator is used for our projects.

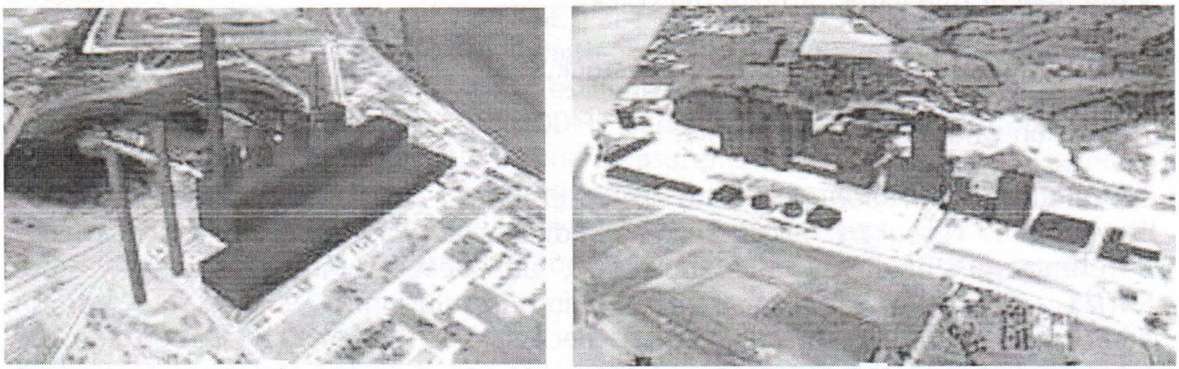
Meteorological data that we used for the preparation of models include hourly values of:

- wind speed,
- wind direction,
- ambient temperature,
- relative humidity,
- atmospheric pressure,
- cloud cover-opaque.

RESULTS AND DISCUSSION

In this study are shown results of using AERMOD to evaluate impacts of coal power plant and cement plant in Serbia. Both models are done within the official environmental impact assessment studies.

Following, described, modeling procedures all necessary facilities data are obtained by the contracting authority. As buildings could radically influence the dispersion of pollutants there is need for building downwash analysis. Figure 2. shows 3D models with all sources (red stacks) of a) coal power plant and b) cement plant. Both models are designed by AERMOD in order to evaluate downwash effects.



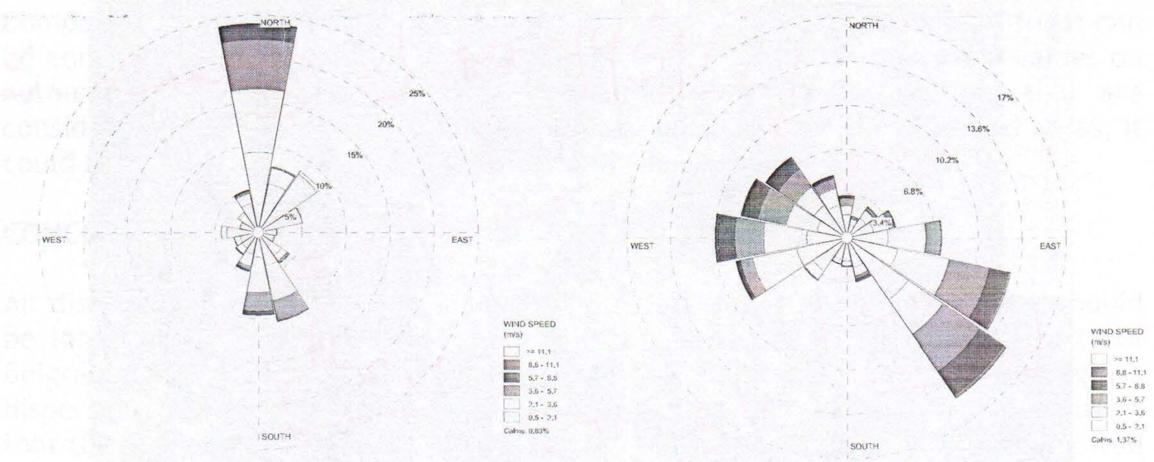
a) b)

Figure 2. 3D models with all sources (red stacks) of a) coal power plant and b) cement plant.

Modeling for the present studies included model domain of 50 km x 50 km, with facilities in its center, or an area of 2500 km^2. Cartesian coordinate system with the distance of 400m between adjacent points (receptors) is used, which means that the models processed 15876 points (receptors).

Republic Hydrometeorological Service of Serbia is in charge for the collection and keeping of meteorological data. According to the Law on Ministries, adopted on March 11th, 2011, air quality monitoring within the national network of air quality stations was entrusted to the Serbian Environmental Protection Agency (SEPA) at the Ministry of Energy, Development and Environmental Protection, so meteorological data are collected as well within 28 automatic stations for monitoring air quality. Despite these state institutions that collect and dispose of meteorological data, is still very hard to provide quality data to match the needs of the modeling software. Besides meteorological measurement data, it is possible to be ordered modeled meteorological data for defined time and area, but such information should be used only in case if the field data are not available.

Figure 3. shows wind roses plots and frequency analysis for location of a) coal power plant and b) cement plant for 2010. Wind roses are generated by AERMET using meteorological data of Republic Hydrometeorological Service of Serbia and Serbian Environmental Protection Agency (SEPA).



a) b)

Figure 3. wind roses plots and frequency analysis for location of a) coal power plant and b) cement plant in 2010.

Dispersion of SO_2, NO_2, CO and PM10 in 2010 are evaluated for these two facilities. Modeling results are presented on 2D and 3D plots in adequate percentile for hourly and daily means as well as annual means. Figures 4. and 5. show, respectively, 2D plot of 2010 SO_2 99.73 percentile of hourly means and 3D plot of 2010 SO_2 of annual mean, for coal power plant. Figure 6. shows 2D plot of 2010 CO of annual mean, for cement plant.

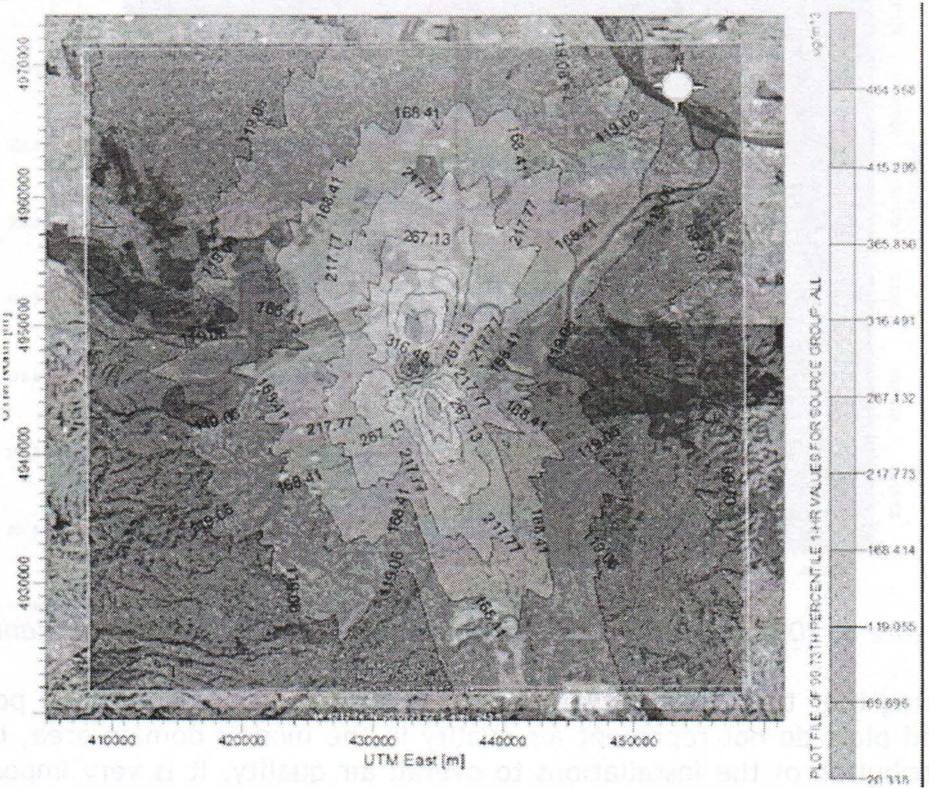


Figure 4. 2D plot of 2010 SO_2 99.73 percentile of hourly means, $\mu g\ m^{-3}$, for coal power plant.

Figure 5. 3D plot of 2010 SO_2 of annual mean, µg m^{-3}, for coal power plant.

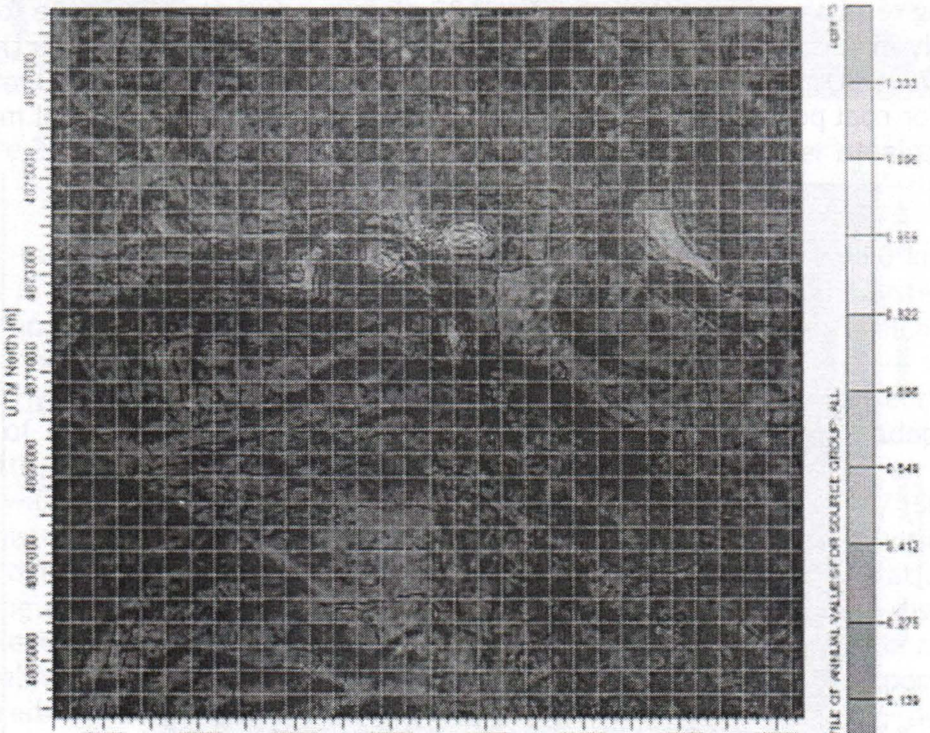


Figure 6. 2D plot of 2010 CO of annual mean, µg m^{-3}, for cement plant.

Considering that these models are not taken into account background pollution, presented plots do not represent air quality in the models domain area, but only the contribution of the installations to overall air quality. It is very important to note that these models represent the worst case scenarios, consider that all pollutant sources emit maximum emission rate 24 hours a day, 365 days a year, which is certainly not the case.

Comparing modeling results with official air quality reports of SEPA in 2010, it can be concluded that models give the results which are close to measured values on automatic stations for monitoring air quality. Since the installations that are considered in these models are dominant emission sources of the observed areas, it could be considered that model verification is done.

CONCLUSIONS

Air dispersion modeling presents complex, but very important procedure and should be integral part of each environmental impact assessment studies. University of Belgrade Faculty of Mechanical Engineering Department of Process Engineering use dispersion modeling package AERMOD View and previous work led to the conclusion that the biggest issue is the quality and appropriate meteorological data. Presented air modeling results for coal power plant and cement plant are just example, but they shows possibilities of modeling package. Although results obtained by AERMOD are very good, better meteorological and terrain data would give even better results and enable the use of more complex models, which would provide more accurate results.