DISPERSION REGULATORY MODEL FOR DESIGNING NEW INDUSTRIAL STACKS - SOFTWARE PLUME

Nelly Gromkova, Kostadin Ganev, Dimiter Yordanov, Emilia Georgieva, Reneta Dimitrova, Nikolay Miloshev
Geophysical Institute, Bulgarian Academy of Sciences, Sofia , BULGARIA

INTRODUCTION

The product *PLUME* is a tool for environmental impact assessments in the vicinity of industrial stacks. The method and the corresponding software have been approved as a national regulatory standard for designing new industrial stacks, so that the pollution from them does not exceed the environmental standard concentration values as well as for evaluating the air pollution and calculating the maximum preceding pollution from the existing stacks' configuration**-** *Bulletin "Construction and Architecture"* (1998).

PHYSICAL BACKGROUND

The product is based on a conventional Gaussian plume dispersion model from continuous elevated point sources – *Hanna S.* (1982). The processes considered in the model are: plume rise; horizontal advection; vertical and cross-wind turbulent diffusion and gravitational deposition. As the model aims at the pollution calculations in the close surroundings of the industrial sources, the horizontal heterogeneity of the meteorological fields, the chemical transformations and dry deposition of the pollutants are not taken into account. An advantage of the program is that it is designed to use the surface routine meteorological input information, provided by the national station network.

The wind profile is reconstructed by the power law, where the power exponent depends on the Pasquill stability class and the underlying surface characteristics - urban or rural conditions. The rural and urban crosswind and vertical dispersion parameters are a function of the downwind distance and Pasquill stability classes - *User's Guide ISC2* (1992).

PROGRAM ARHITECTURE

The software package has been coded in Visual Basic and works under *WINDOWS' 9X or NT*. Its structure provides an easy way across the tasks, the users had to carry out. The input information is user-friendly, well-provided-to warning messages of missing or restrictions on supplied data.

There are three branches of dispersion models, determining:

- The Physical Design Height of a New Stack;
- The Expected Ground-Level Concentrations;
- The Maximum Preceding Pollution from Existing Stack Configuration.

After picking out one of the options above, the logic of these kinds of programs require stimulating information. Here, it is sorted out as model, meteorological and source input for each task. The last two have no need of any pre-processing.

Physical design height of a new stack

The scope of the module is to determine the optimal physical parameters of a planned new stack, so that the pollution from it (the sum of absolute maximum and background level concentrations) does not exceed the single Limit Admissible Concentration (LAM) for any emitted admixture.

Meteorological input:
The dispersion calculations in this branch of the program, make a loop over combinations of meteorological parameters (Table 1), representative for a wide range of wind speeds and the respective stability class. The ambient temperature is set to 25 °C. The procedure is coded in the algorithm.

Table 1. The Combination of Wind Speeds and Respective Stability Class, Coded in Algorithm.

Wind Speed [m/s] (at 10 m)	1	2.5	4	5.5	7
Stability Class	A , B	B , C , E	B , C , D	C , D	D

Source input:
The optimal physical stack height is searched between two fixed values - the minimum and the maximum possible ones, with a view to technological considerations. The source input is the following: temperature of released gases [°C]; volumetric flow [m3/s]; gravitational settling velocity [m/s]; emission rate [g/s]; minimum project height [m]; maximum project height [m]; inner radius [m].

Model input:
The calculations here are made along the direction of plume axis. The model input required is: number of steps and distance between them in meters; rural or urban conditions; single limit admissible concentration (LAC) [mg/m^3] (by national standard) for pollutant considered in calculations; background concentration [mg/m^3] for this pollutant. If it is not available, the user could calculate its level by running the third branch of the product for functioning stacks.

Expected ground-level concentration
For a particular pollutant the program makes statistical or episodic simulation of the exped concentrations. The necessary input parameters are the following:

Model input:
These inputs supply the program run with the spatial field, where the disperse calculations will be done as well as the local characteristics of the site:receptor grid - number of steps and distance between them (in meters) in West-East and South-North direction of the concentration field; rural or urban conditions; latitude and longitude of the site (default parameters for Bulgaria) - obligatory, when sequential hourly records of meteorological variables are used; name of output file - The button *Select File Name* , creates an ASCII format file, that will storage the concentration values in field points, convenient for visual post-processing, after the program ended.

Meteorological input:
This menu consists of three items, calling individual input-forms for :

- Concrete Meteorological Situation : wind speed [m/s]; wind direction (degree from the North); ambient emperature [°C] at the anemometer height and stability class (by Pasquill).
- Wind Rose:ambient temperature [°C]; wind speed [m/s] and frequency [%] for wind rose; stability class. (Here, *apriori* a neutral stratification D is set.)

Hourly Meteorological Records require as input information a file that contains sequential hourly records of meteorological variables, representative of a given region. Each row consists of two groups of records as follows :

- *Identification group* -Year (YY) ;Month (MM);Day (DD);Hour(HH) and

- *Meteorological group* -wind direction (WD) [deg]; wind speed (WS) [m/s]; temperature (Tmp) [K] at the anemometer height (10 m); stability category (Stb) or cloud cover (Cld) in oktas.

Source input:
number of sources - not more than 10 sources. The restriction is automatically controlled in the program code and brings out an warning message. Depending on this, a grid with the same number of rows is appeared, where the respective information about a particular chimney is provided in the columns: x- and y-coordinates [m]; height [m]; inner radius [m]; temperature of released gases [°C]; volumetric flow [m3/s]; gravitational settling velocity [m/s]; emission rate [g/s].

This form visualizes the receptor points in scaling examining field and the respective stacks position. The user could change the position if any wrong x- or y-coordinates have been put.

Maximum preceding pollution from existing Stack configuration
This dispersion module calculates both the maximum preceding pollution and the background level concentration of functioning stacks for particular a pollutant.

Model input: as for the Expected ground-level concentration module.

Meteorological settings:
This meteorological block is coded in the algorithm. The wind speed and the stability class are varied according to *Table 1* and the wind direction is taken every 45 degree, starting from the North.

Source input: as for the Expected ground-level concentration module.

SOME EXAMPLES
Calculation of the ground-level concentration for sulphur dioxide (SO_2), nitrogen dioxide (NO_2) carbon oxide (CO) and dust (PM) from the Maritza-Iztok Ltd. power plant stacks is given below as an example of some of the method and software abilities. The meteorological data file, representative for this region, contains sequential hourly records of meteorological variables, from October 1995 to September 1996.

The analysis of the meteorological conditions showed that the dominating winds are from the west (W) - 22.24%, southwest (SW) - 17.22%, west-southwest (WSW) - 11.07% and south-southwest (SSW) - 7.95%. This means, that the areas of higher concentration of the pollutant should be expected in the northeastern quadrant with respect to the sources' configuration, depending on their emissions. The wind speeds are between 0 and 1 m/s in 64.07% of the cases. The highest observed speed is 5 m/s. The average speed values of the wind do not exceed 2 m/s.

The stability class analysis showed that in the predominant wind's directions - first quadrant of the rose, the stratification is mostly stable - D, E and F classes, i.e. in these directions the concentration will be spread over a longer distance. The situation in the second and in the beginning of the third quadrant is similar - in most cases the stratification is stable. In the rest third and fourth quadrant the stratification is unstable - A, B and C classes, i.e. the diffusion of the pollutants will be achieved very fast and the higher concentration can found close to the sources. Therefore, the southeastern area of coalmine Maritza-Iztok I, II, и III should be expected to be cleaner than the northwestern one. A detailed statistical processing of the stratification rose showed that for this period the predominant stability class is **E**, i.e. the average stratification is stable.

Table 2. The input stack parameters for Maritza-Iztok power plants.

Stack ID	Stack Height [m]	Stack Diameter [m]	Exhaust Gas Temperature [°C]	Exhaust Gas Flow Rate [m3/s]	Pollutant	Actual Emission [t/yr]
MIz-I-1	150	6	190	575.6	***SO2***	98639.7832
	150	6	190	575.6	***NO2***	3567.8486
	150	6	190	575.6	***CO***	165.3349
	150	6	190	575.6	***PM***	5801.3645
MIz-I-2	120	5	60	433.3	***SO2***	13296.3488
	120	5	60	433.3	***NO2***	276.3144
	120	5	60	433.3	***CO***	22.1048
	120	5	60	433.3	***PM***	14688.8269
MIz-I-3	120	5	60	288.9	***SO2***	7998.9952
	120	5	60	288.9	***NO2***	166.2482
	120	5	60	288.9	***CO***	13.2996
	120	5	60	288.9	***PM***	8836.4640
MIz-II-1	325	12	120	2325.6	***SO2***	386322.5152
	325	12	120	2325.5	***NO2***	15924.1794
	325	12	120	2325.6	***CO***	736.7524
	325	12	120	2325.6	***PM***	18218.7074
MIz-II-2	325	10	120	493.9	***SO2***	84451.2634
	325	10	120	493.9	***NO2***	3475.8177
	325	10	120	493.9	***CO***	160.51408
	325	10	120	493.9	***PM***	5860.0502
MIz-III-1	325	12.4	140	1960.0	***SO2***	519344.8087
	325	12.4	140	1960.0	***NO2***	13580.3780
	325	12.4	140	1960.0	***CO***	627.7799
	325	12.4	140	1960.0	***PM***	9016.2032

The ground-level concentrations of SO_2, NO_2, CO and PM averaged for the entire period are shown in Figure 1.

The black points mark the position of the six Maritza-Iztok power plant stacks. It can be seen that the obtained ground-level concentration averaged for the selected period do not exceed the annual LAM. However, the transient concentration values can exceed the instantaneous LAM, so the maximal concentration value for all stacks at more disadvantageous meteorological conditions is also evaluated - Table 3. As is seen, only sulphur dioxide (SO_2) maximal concentration is 3.68 times higher than the single LAC's one at stability class A and wind velocity 1 m/s. That's easy to explain, because the emission of sulphur dioxide is the highest - see Table 2.

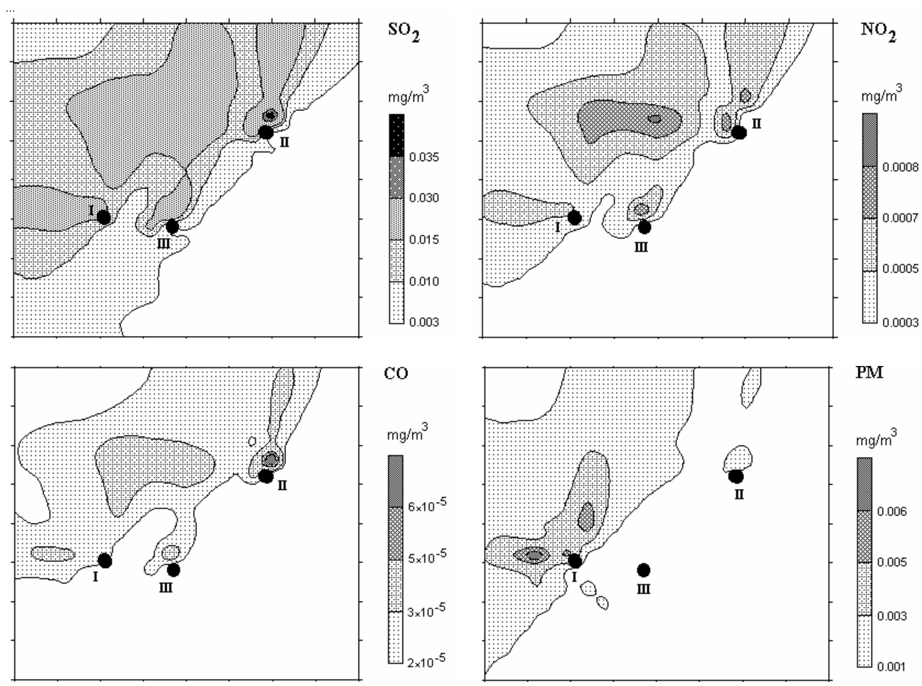

Figure 1. Averaged for entire period ground-level concentration for SO_2, NO_2, CO and PM

Table 3. Maximal Concentrations for Maritza-Iztok coal-mine stacks.

Admixture	Max concentration [mg/m^3]	Single LAC [mg/m^3]	Distance [км]	Stability class	Wind Speed [m/s]
SO_2	1.8381	0.5	2.4	**A**	1.0
NO_2	0.0620	0.2	18.1	**A**	1.0
CO	0.0029	60.0	18.1	**A**	1.0
PM	0.3099	0.5	2.0	**B**	2.5

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