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MODELING AND SIMULATION OF POLLUTANT DUST WAVE FROM A FOUNDRY

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ABSTRACT. In this paper a model was developed for pollutant dust wave dispersion from a foundry. The chemical composition of the foundry dust is 88.02 % SiO_2, 4.62 % Fe, 7.36 % others (Al, Cu, Pb, Ca, Cr, Zn etc.). The Gaussian Dispersion Model – local model dispersion for point shape sources with continuous or accidentally emission was used. The dispersion of a pollutant dust wave in the environment is influenced mainly by the wind velocity, atmospheric stability class and sources characteristics. Matlab was used to create this simple model and together with the simulation program that provides information about the dispersion area of the pollutant dust wave. The model can be used and help in promptly acting to prevent or to solve the pollutant accidents.

INTRODUCTION

The pollution is a phenomenon that cannot take in account the countries physical borders (ex. acid rains, polluted rivers) and for this, we all are responsible and we have to try to prevent pollution.

Economical-industry evolution of our country in the last decades made serious environment pollution problems. Therefore, researchers are trying to develop the most efficient methods to catch and purify the residual gases before their evacuation in the atmosphere and also, to redesign the equipments or entire technology.

The basics for mathematical modeling of pollutant dispersion are represented by three important equations that describe mass balance, energy balance and momentum balance. This kind of equations must be written for each pollutant.

Generally, for one receiver, it could be made an estimation of one source substance concentration by using the dispersion equation. For the models accepted by EPA (European Pollution Administration) the necessary

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data about the emission that took place are: source coordinates, internal diameter of the chimney top side, exit velocity of emission and temperature on the top of the chimney. Also, it's necessary to know hourly meteorological parameters (stability class of the atmosphere, wind direction, wind velocity, air temperature, etc.). The results of this kind of models are the hourly concentrations that are evacuated by each pollutant source [4].

The model in this research was made for a pollutant dust wave from a foundry. The chemical composition of the foundry dust is 88.02 % SiO_2, 4.62 % Fe, 7.36 % others (Al, Cu, Pb, Ca, Cr, Zn etc.). Because of the presence of the SiO_2 in dust, the most of the employees have a disease called silicosis.

DISPERSION MODEL'S DESCRIPTION

For this research was used the Gaussian Dispersion Model – local model dispersion for isolated sources with continuous or accidentally emission [3]. The Gaussian dispersion model is used especially to obtain static parameters of concentrations (average values, passing frequencies of sanitary limits, etc.). To estimate the concentration value, the distribution frequencies of meteorological parameters obtained by measurements is used. Dispersion coefficients used in this model were experimentally developed for long distances between 10 km and 30 km and the Gaussian model provides reliable predictions for this distances. For distances between 20 km and 100 km the model can be used only to obtain qualitative information about pollutants concentration [3].

Gaussian model uses the following equations to evaluate pollutant concentration:

a. if the mixing height (h_s) is infinite, there is no thermal inversion or weather is stable, is used Gaussian solution for a point shape source with continuous release:

$$\overline{C}(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z\overline{u}}\exp\left(-\frac{y^2}{\sigma_y{}^2}\right)\cdot g(z,H) \tag{1}$$

$$g(z,H) = \exp\left[-\frac{1}{2}\left(\frac{(z-H)^2}{\sigma_z{}^2}\right)\right] + \exp\left[-\frac{1}{2}\left(\frac{(z+H)^2}{\sigma_z{}^2}\right)\right] \tag{2}$$

b. if the value of dispersion parameter is $\sigma_z > 1,6h_s$ and the weather is instable or neutral:

$$\overline{C}(x,y,z)=\frac{Q}{\sqrt{2\pi}\sigma_y h_s}\exp\left(-\frac{y^2}{2\sigma_y{}^2}\right) \tag{3}$$

In this situation the pollutant is mixed uniformly in boundary layer and the concentration doesn't depend on hight z.

c. if the weather is instable or neutral and the dispersion parameter value is $\sigma_z < 1{,}6h_s$:

$$\overline{C}(x,y,z)=\frac{Q}{2\pi\sigma_y\sigma_z\overline{u}}\exp\left(-\frac{y^2}{2\sigma_y{}^2}\right)\cdot g(h_s) \tag{4}$$

$$g(h_s)=\sum_{k=-4}^{k=+4}\left\{\exp\left[-\frac{1}{2}\left(\frac{(z-H+2kh_s)^2}{\sigma_z{}^2}\right)\right]+\exp\left[-\frac{1}{2}\left(\frac{(z+H+2kh_s)^2}{\sigma_z{}^2}\right)\right]\right\} \tag{5}$$

In case of thermal inversions, the pollutants can't be dispersed vertically because the inversion surface behaves like a mirror surface.

The values for meteorological parameters for each stability class are presented in [3].

RESULTS AND DISCUSSION

Dispersion of a pollutant dust wave in the environment is influenced mainly by the wind velocity, atmospheric stability class and sources characteristics. The maximal admissible value of the dust in atmosphere is 0.5 g/m^3.

Pollutant concentration in atmosphere is kept high for a long area if wind velocities are low and the maximal admitted concentration is over passed for a distance of 5000-6000 m (Fig. 1).

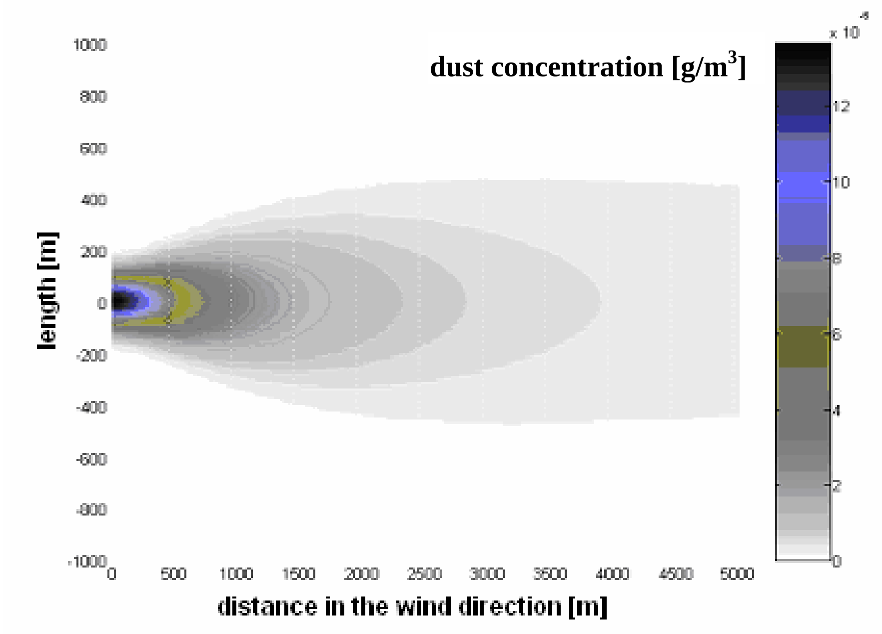

Fig. 1. Pollutant dust wave dispersion area in case of atmospherically calm conditions at z=20 m

If the wind velocity grows, the pollutant spread distance, with concentrations higher than 0.5 μg/m^3, decreases from 5000-6000 m to 1000-1500 m because of the faster spread of the pollutant particles in the atmosphere. If the wind velocity is higher than the evacuation velocity of the air mixed with dust, appears a phenomenon called downwash (flowing of the pollutant downward the chimney out-wall, Fig. 2).

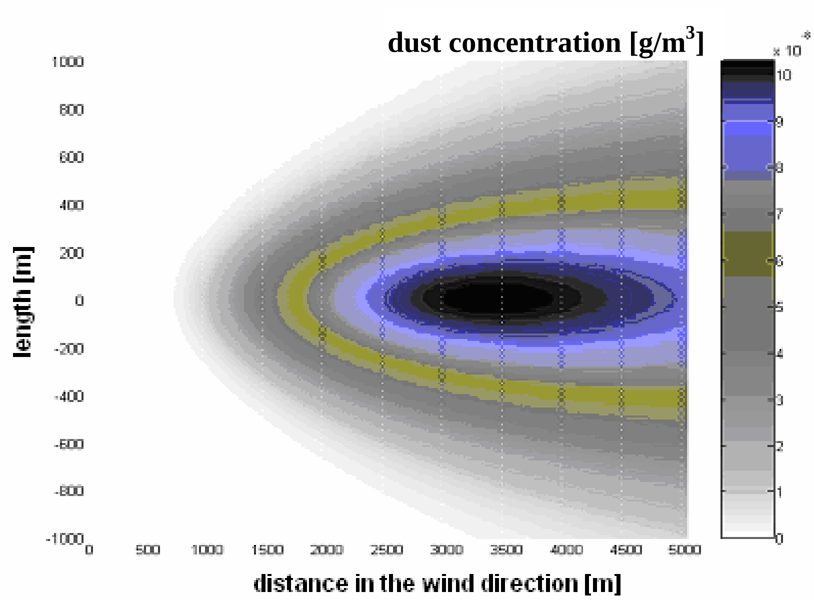

Fig. 2. Downwash effect (footprint of the dust concentration at z=20 m).

In the foundry, there are 5 pollutant sources (5 cyclone dust separators that don't work properly or don't work at all) that are different by the exit flow and the diameter of the evacuation chimney (Table.1).

Table 1.

Sources inventory [6]

Source No.	Chimney diameter [m]	Exit flow [m³/h]	Dust quantity in exit flow [g/h]
1	0.4	30000	2100
2	0.6	24000	1560
3	0.35	16000	768
4	0.9	28000	1820
5	0.25	2000	140

When all 5 sources work simultaneously, the dust concentration evacuated in atmosphere is the highest and the dispersion area becomes larger (Fig. 3). The pollutant dust wave becomes more dangerous for the environment and for the people. In this conditions dust concentration in the atmosphere is about $2 \cdot 10^{-5}$ g/m³.

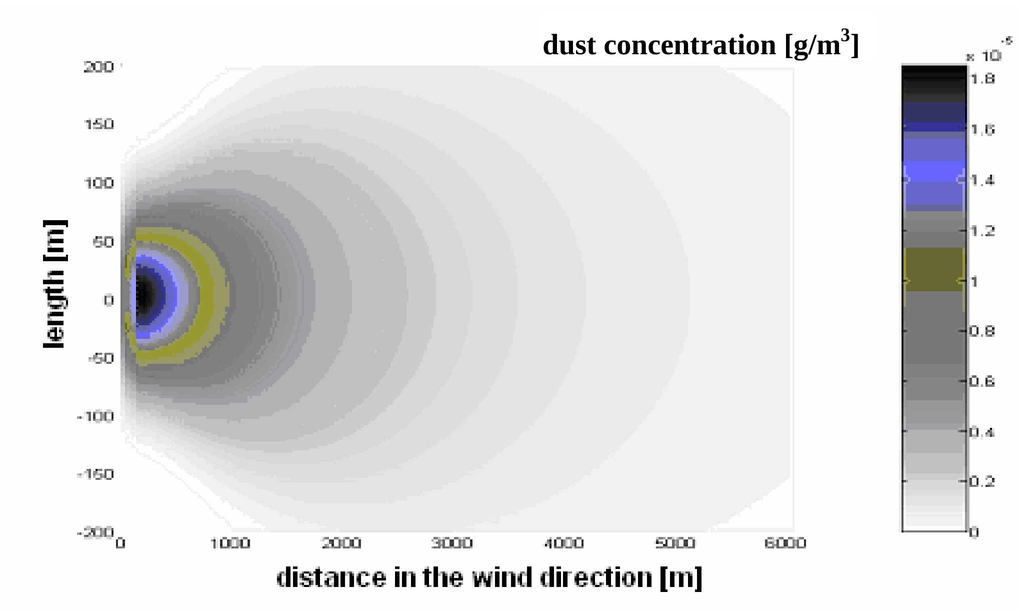

Fig. 3. Pollutant dust wave from all five sources in the wind direction (footprint of the dust concentration at z=20 m)

If the cyclone dust separators are replaced with bag filters (94 % efficiency), pollutant dust concentrations are reduced under the maximal limit of 0.5 μg/m³ (Fig. 4). For the conditions of source no. 1 (30000 m³/h evacuated air, 1200 g/h dust) the filter evacuates in atmosphere only 126 g/h dust in 30000 m³/h air.

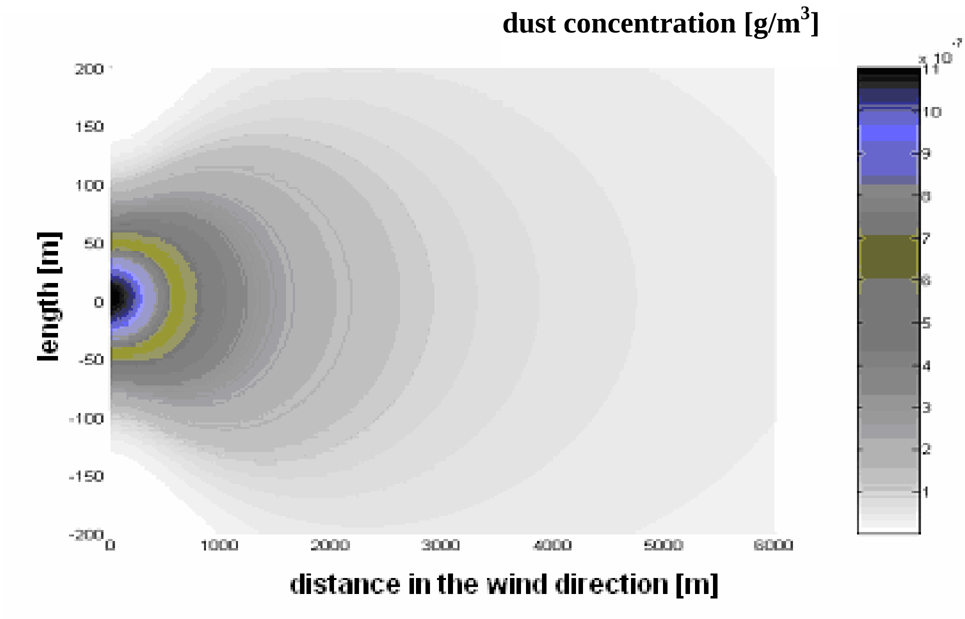

Fig. 4. Pollutant dust area for a filter bag in the condition of source 1 (footprint of the dust concentration at z=20 m)

CONCLUSIONS

Gaussian model used for modeling and simulation of the pollutant dust dispersion in the environment is only a simplified model that helps to estimate the values of dust concentration evacuated in atmosphere (prediction and post evaluation). The simulations can help to estimate accidental emissions and, if the pollution already occurred, provides the opportunity to know how far the dust extends and how large is the area that the environmental agents have to clean or to evacuate.

Matlab was used to create this simple model and to simulate the process that gives information about the dispersion area of the pollutant dust wave. This software can be easily used and help to promptly act to prevent or to solve the pollutant accidents. It can be easily used for other substances because the Gaussian model needs only the released mass of the pollutant in atmosphere and it's not necessary to know the chemical and physical characteristics of the pollutant substances.

The pollution becomes more serious when the pollutant wave contains toxic or lethal substances that affect not only the vegetation and animals but also the people.

List of symbols

x – down-wind horizontal coordinate, m

y – cross-wind horizontal coordinate, m

z – vertical coordinate, m

$\overline{C}(x, y, z)$ *- concentration as a function of the terms between the brackets, g/m*^{3}

Q – released mass, g

σ_y, σ_z *– cross-wind and vertical dispersion parameters of cloud, m*

u – down-wind velocity of dispersing material, m/s

H – height of cloud centre-line, m

h_s *– mixing height, m*

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