POLLUTANT VARIATION ESTIMATION ACCORDING TO THE WIND SPEED AND THE MASS FLOW OF THE POLLUTANT FOR PAROSENI THERMAL POWER STATION

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Abstract: The paper deals with the determination of the variation of the concentration of pollutant considering the wind speed and the mass flow of the pollutant based on the determination of the matrix of the concentration of pollutant. The diagrams representing the dependence of the concentration of pollutant on the wind speed and the mass flow of the pollutant have therefore been created for Paroșeni Thermal Power Station.

Key words: concentration of pollutant, pollutant mass flow, modelling

1. INTRODUCTION

Solid fuels are compounds which are composed of flammable elements, non-flammable elements as well as water and different non-flammable mineral compounds.

After having burnt in the steam generator, the by-products are exhausted into the environment which they pollute. The main problem of environmental pollution is closely related to the transport and diffusion of impurities into the atmosphere [3].

Therefore, the starting point should be the reactions developed by O.G. Sutton, reactions which in time suffered changes and amendments carried out by other researchers such as: Bosanquet, Pearson, Freidlander, Joustone, Davies. Rondic, Hay, Pasquill, Fikina. Starting from the Sutton's first symmetric equation [1], on which the turbulent diffusion phenomenon is based, ensured by the empirically determined parameters, the researchers have later developed a series of mathematical formulas,

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more or less approximate, used especially for the study of pollution produced by a single point source.

Improving Sutton's relation by other researchers developing other formulas they are mathematically dealt with using G.I. Taylor's classic diffusion theory [2] on the diffusion in low atmosphere regarding the statistic correlation of the turbulence.

2. CASE STUDY OF THE CONCENTRATION OF POLLUTANT FROM PAROŞENI THERMAL POWER STATION

In order to determine the dispersion of pollution into the environment, the speciality literature uses several models. The study carried out for the Paroseni Thermal Power Station is based on the following parameters for the exhaustion into the environment of combustion by-products:

- The physical height of the chimney H = 160 m;
- The interior diameter of the base D_b = 7 m;
- The interior diameter of the top D_v = 6.2 m;

The calculation model used is a Gaussian-Cartesian model which allows the long and short-term determination of emissions from industrial plants, automobile traffic as well as from diffused sources.

The Gaussian model is considered to have the form of the following equation (1):

$$c(x,y,z)=\frac{\dot{m}}{2\pi\cdot u\cdot\sigma_y\sigma_z}\cdot e^{-0.5\left(\frac{y}{\sigma_y}\right)^2\cdot\left[e^{-0.5\frac{(z-H)^2}{\sigma_z}}+e^{-0.5\frac{(z+H)^2}{\sigma_z}}\right]} \quad (1)$$

with the following simplification hypotheses: stationary conditions; Gaussian profiles on both y and z directions; the wind speed u(m/s) which has a constant module and direction; pollutant flow $\dot{m}$ (kg/s) continuous and stable; the dispersion on the direction of the wind x may be neglected compared to the one transported; the pollutant is a stable gas or aerosol which does not react chemically; the equation which describes the range of concentrations results from a single chimney.

In order to carry out the determination the following need parameters are required:

- the pollutant mass flow $\dot{m}$ (kg/s);
- the dispersion coefficient σ_y and σ_z, both rural Pasquill as well as urban Briggs;
- the height at which the dispersion starts $H(m)=H_e=H_c+H_r$ and implicitly the lifting height of the blade, H_r [m]. H_c from the previous expression is the built height of the chimney for the dispersion of sulphur dioxide without any desulphurisation installation as is the case for Paroseni Thermal Power Station;

- the wind speed, *u* (m), for the height of the chimney;
- the balancing class, for choosing the set of dispersion coefficients;
- the type of area, i.e. rural or urban.

The determination of the dispersion of the pollutants around the polluting source is determined using relation (1): where: *x* is the distance from the ground in the direction of the wind (*x* = 0-3000 m); *z* – is the perpendicular distance from the ground in the direction of the wind; *z* – is the vertical distance from the ground.

The value of the height of the chimney is *H* = 160 m.

The standard derivations are analytically expressed as:

$$\sigma_y = A \cdot x^a; \quad \sigma_z = B \cdot x^b \tag{2}$$

where σ_x is the distance from the source expressed in m;

A,a - B,b – constancies determined from the Pasquill-Gifford diagonals depending on the balance and the distance between the source and the receiver.

In 1975 Briggs determined the coefficients σ_y and σ_z using the following relations:

$$\begin{aligned} \sigma_y &= a_1 \cdot x^{b_1} \left(1 + C_1 \cdot x\right)^{d_1} \\ \sigma_z &= a_2 \cdot x^{b_2} \left(1 + C_2 \cdot x\right)^{d_2} \end{aligned} \tag{3}$$

where the coefficients for the stable regime represents the following values:

a_1 = 0.11; b_1 = 1; C_1= 0.0004; d_1 = -0.5

a_2 = 0.08; b_2 = 1; C_2= 0.00015; d_2 = -0.5

The density of the gases in the area considers the pressure and the temperature, thus for ρ_{gN} = 1.234 kg/m^3 the accepted value for the gases, the Clapeyron-Mendeleev equation is obtained:

$$\rho = \rho_{gN} \frac{p}{p_N} \frac{T_N}{T} = 1.234 \cdot \frac{714}{760} \cdot \frac{273}{273 + 143.3} = 0.76\ kg / m^3$$

The values of the dispersion coefficients are obtained replacing the corresponding values in relation (4):

$$\sigma_z = 0.11 \cdot 50 (1 + 0.0004 \cdot 50)^{-0.5} = 5.446$$

$$\sigma_z = 0.08 \cdot 50 (1 + 0.00015 \cdot 50)^{-0.5} = 3.985$$

The values of the wind speed were also measured with a cup anemometer, the obtained values being comprised within the range *u* = 2 - 6 m/s with a pace of 0.5. The pollutant mass flow considering the real conditions on site was determined using an ultrasonic Fluxus ADM 6125 flowmeter. The values of the hourly mass flow were then multiplied by ρ and divided by 3600; the values of the mass flow were therefore obtained, i.e. $\dot{m} = 100.97; 131.236; 167.437; 178.961\ kg/s$.

Considering the value *y* = 4 m and *z* = 2 m, this being the area which is most affected for humans, using expression (1), the value matrix of the concentration of pollutant c was determined:

$$c = \begin{pmatrix} 0.37 & 0.481 & 0.614 & 0.656 \\ 0.296 & 0.385 & 0.491 & 0.525 \\ 0.247 & 0.321 & 0.409 & 0.437 \\ 0.212 & 0.275 & 0.351 & 0.375 \\ 0.165 & 0.214 & 0.273 & 0.292 \\ 0.148 & 0.192 & 0.246 & 0.262 \\ 0.135 & 0.175 & 0.223 & 0.239 \\ 0.123 & 0.16 & 0.205 & 0.219 \end{pmatrix} \quad \frac{mg}{m^3}$$

Fig. 1. The value matrix of the pollutant concentration for Paroseni Thermal Power Station

For a more suggestive graphical visualisation of the value matrix of the pollutant concentration presented in Figure 1, the following 3D representation has been developed, presented in Figure 2:

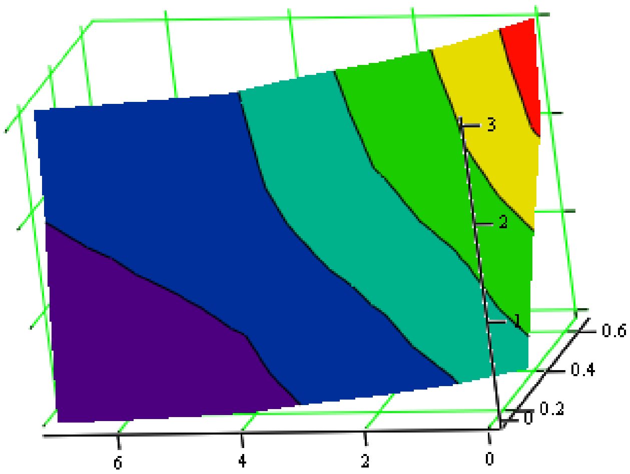

Fig. 2. 3D representation of the matrix concentration of pollutant

The study also proposes to determine the variation of the concentration of pollutant according to wind speed and the mass flow of pollutant. The variation of the concentration of pollutant considering the two variables is presented in Figures 3 and 4.

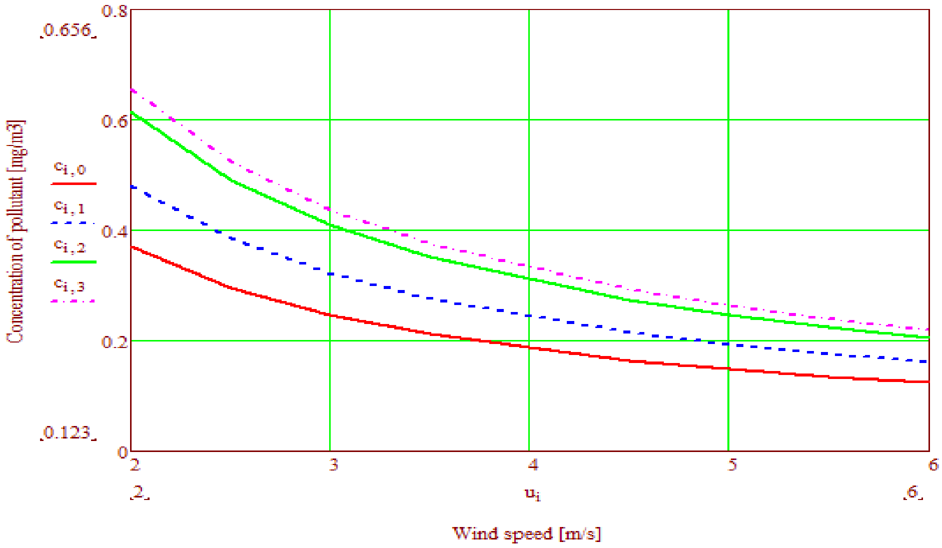

Fig. 3. Function $c = f(u, \dot{m})$, considering the values of the variable wind speed and the constant mass flow

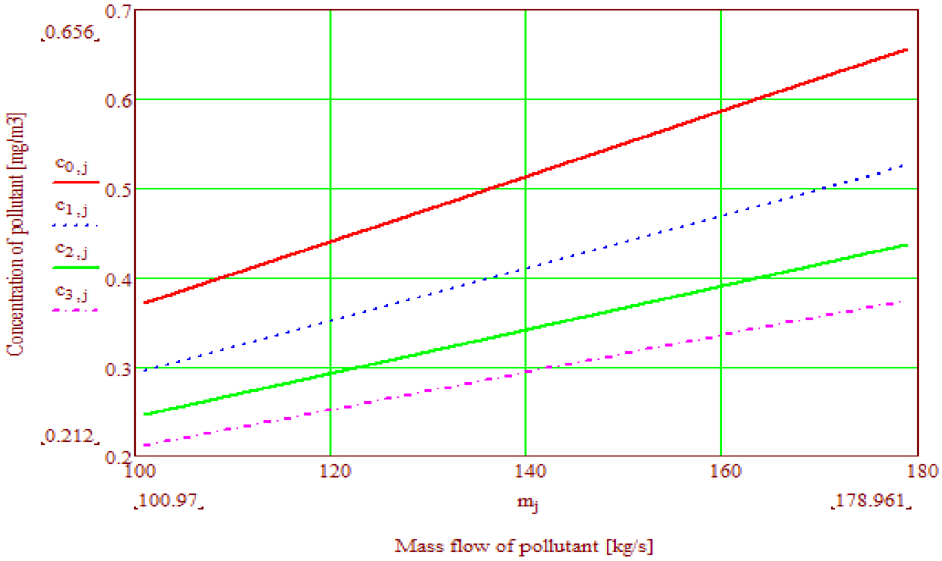

Fig. 4. Function $c = f(u, \dot{m})$, considering the values of a constant wind speed and a variable mass flow

3. CONCLUSIONS

Analysing the diagrams in Figures 3 and 4, the following conclusions may be drawn:

The variation of the concentration of pollutant was determined depending on the wind speed and the mass flow based on the determination of the matrix of the concentration of pollutant.

The diagrams in figures 3 and 4 highlight the following aspects:

- The concentration of pollutant considering the wind speed presents itself with a decrease of the constant value of the pollutant mass flow;
- The concentration of pollutant considering the mass flow increases for constant values of the wind speed.

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