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[1.]Mihaela FLORI, [2.]Lucia VÎLCEANU

PREDICTION OF GASEOUS POLLUTANTS DISPERSION IN AIR

[1-2.]University Politehnica Timisoara, Faculty of Engineering Hunedoara, Hunedoara, ROMANIA

Abstract: Estimation of gaseous pollutants concentrations at ground level after 1 hour of continuous emission by a point source is determined by use of Screen View software. The software uses Gaussian air dispersion model and calculates concentration (in μg/m^3) versus distance from source (in m) in function of pollutant source type, weather conditions and pollutant characteristics.
Keywords: air pollution, point source, Gaussian dispersion model, Screen View software

1. GAUSSIAN MODEL OF POLLUTANTS DISPERSION IN ATMOSPHERE

Among environment factors, thermo-energetic industry pollutes mainly the atmosphere and the soil [1]. Emissions consisting of gases, vapors and/or very small solid particles that remain in suspension are released at high altitude, transported at certain distances after which it settles on the ground [1]. As monitoring pollution over large area is difficult to achieve, several mathematical models were developed (see list in reference [2]), which predicts air dispersion of pollutants and concentration over a certain distance at ground level.

Screen View software uses Gaussian model of air dispersion [3-5]. Figure 1 presents a schematic representation of the Gaussian model parameters of the pollutant plume air dispersion [6].

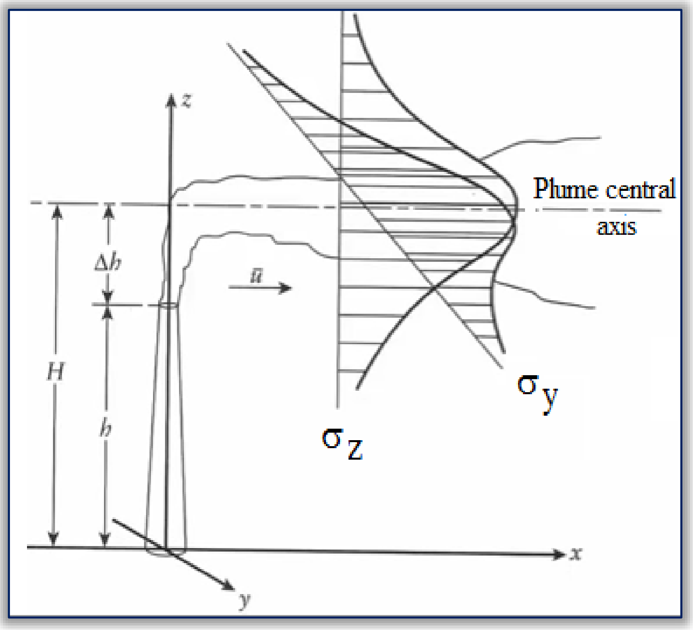

Figure 1 – Gaussian model parameters of pollutant plume dispersion in air [6]

In figure 1 it was noted the stack effective height [6, 7]:

$$H = h + \Delta h \text{ [m]} \quad (1)$$

where h [m] is the construction height and Δh [m] is the rinse of the plume above the stack which may be calculated with the equation [7]:

$$\Delta h = \frac{v \cdot d}{u}\left(1{,}5 + 0{,}268 \cdot p \cdot d \cdot \frac{T - T_a}{T}\right) \ [m] \quad (2)$$

where: v[m/s] – is gas velocity at exiting the stack, d[m] – diameter at the stack top, u[m/s] – wind velocity, p[kPa] – atmospheric pressure, T[K] – gas temperature at stack exit, T_a[K] – air temperature.
Also, σ_z [m] and σ_y [m] are the dispersion coefficients or standard deviations which are a measure of the plume spread in vertical and lateral directions, respectively [6].
If the pollution source is in a rural area, the dispersion coefficients in the z and y directions may be calculated with relations [4, 5]:

$$\sigma_z = a \cdot x^b \ [m] \quad (3)$$

$$\sigma_y = 465{,}11628 \cdot (x) \cdot tg(TH) \ [m] \quad (4)$$

$$TH = 0{,}017453293 \cdot [c - d \cdot \ln(x)] \quad (5)$$

where: a, c and d are coefficients that depend on the atmosphere stability classes (Pasquill stability categories, A-F) and the distance from the source of pollution, x[km].
Table 1 gives the parameters a and b for the atmospheric stability class D, and Table 2 gives parameters c and d [4].

Table 1 - Parameters a and b for calculating dispersion coefficients σz (rural areas)[4]

Atmospheric stability class	x [m]	a	b
D	<0.30	34.459	0.86974
	0.31 – 1.00	32.093	0.81066
	1.01 – 3.00	32.093	0.64403
	3.01 – 10.00	33.504	0.60486
	10.01 – 30.00	36.650	0.56589
	>30.00	44.053	0.51179

Table 2 - Parameters c and d for calculating dispersion coefficients σy (rural areas)[4]

Atmospheric stability class	c	d
A	24.1670	2.5334
B	18.3330	1.8096
C	12.5000	1.0857
D	8.3330	0.72382
E	6.2500	0.54287
F	4.1667	0.36191

At distance *x* from source, under plume centerline (y = 0) at ground level (z = 0), the concentration of the pollutant is calculated with the equation [3, 4]:

$$C(x,0,0) = \frac{Q}{\pi \cdot \sigma_y \cdot \sigma_y \cdot \bar{u}} \cdot \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \left[\frac{g}{m^3}\right] \quad (6)$$

where: Q [g/s] – is the pollutant emission rate.
For any space point it may be assumed that the concentration of pollutant C(x, y, z) depends directly proportional to the pollutant emission rate (Q) and inversely proportional to the wind speed (u) and respectively with the standard deviations (σ_z and σ_y) [6].

2. CASE STUDY

The objective of this case study is to estimate gaseous pollutant concentration emitted continuously by a point source (chimney stack). The predicted values are obtained considering ground level, under plume centerline, in function of distance from source.
Also, the effluent (namely, plume) consists of a mixture of the following gases: sulfur dioxide (SO_2), nitrogen oxide (NO_x), carbon monoxide (CO) and ash dust in suspension. These pollutants are known to be emitted by electric power plants functioning with solid fuel [1, 8].
Simulations were done with SCREEN View software for one pollutant at a time and the obtained results were expressed in μg/m³ of pollutant settled at ground level, after 1 hour of emission.
To express real conditions of atmospheric dispersion phenomenon, as emission conditions, considered input data for simulations, were taken the following experimentally measured parameters at an electric power plant and presented in reference [8]:

- emission rate, Q in [g/s]:

SO_2 [g/s]	NO_x [g/s]	CO [g/s]	Ash [g/s]
1030.6	143.2	9.8	172.9

- stack height: H = 250 m;
- diameter at the stack top: d = 8 m;
- pollutant velocity at stack exit: v = 16,4 m/s;
- pollutant temperature at stack exit: T = 410 K;
- air temperature: T_a = 293 K;
- maximum distance from the source: 5 km.

For the determination of dispersion coefficients, the source of pollution is considered to be in a rural area.

As the emission conditions listed above were considered the same for all pollutants, except the emission rates, results in terms of concentration variation versus distance from source, gave the same curve shape as the one presented in figure 2 for SO_2. Differences consist in concentration values.

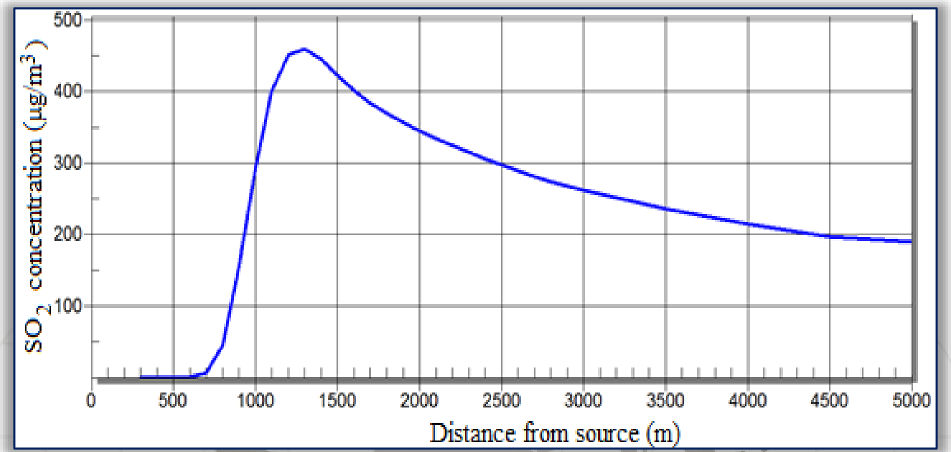

Figure 2 – Variation of SO_2 concentration vs. distance from the source

So, for all considered pollutants it was observed that starting with 300 m distance from the source, it begin to settle at ground level, obtained concentration values being given in Table 3.

Table 3 - Pollutant concentration at 300 m distance from the source

SO_2 [μg/m³]	NO_x [μg/m³]	CO [μg/m³]	Ash [μg/m³]
$0.1476 \cdot 10^{-9}$	$0.2051 \cdot 10^{-10}$	$0.1404 \cdot 10^{-11}$	$0.2476 \cdot 10^{-10}$

Also, the pollutants concentrations settled on the ground are continuously increasing up to a maximum value estimated at distance of 1274 m from the pollution source.

For analyzed pollutants, maximum 1 hour concentration values are given in Table 4. Further, pollutant concentrations decreases with distance from source (see figure 2).

Table 4 - Maximum pollutant concentration settled at ground level

SO_2 [μg/m³]	NO_x [μg/m³]	CO [μg/m³]	Ash [μg/m³]
459.8	63.89	4.373	77.14

Under the presented conditions, over the entire considered range (up to 5 km away from source), the concentration values do not exceed the short-term limit value required by the Romanian legislation. For comparison, in table 5 are given the pollutants maximum admissible concentrations values required by Romanian standard no. 12574-87 „Air from polluted areas-quality conditions" [9].

Table 5 - Pollutants maximum admissible concentrations [9]

Pollutant	Average admissible concentrations [μg/m³]		
	Short-term (30 min.)	24 hours	Annual
SO_2	750	250	10
NO_x (NO_2)	300	100	10
CO	6000	2000	-
Particulate matter in suspension	500	150	75

3. CONCLUSIONS

This study shows results of modelling air dispersion of four types of gaseous pollutants (SO_2, NO_x, CO and ash dust) which may be emitted by an electric power plant which functions on solid fuel combustion. With Screen View software was estimated the ground level concentration of these pollutants on a distance of 5 km from the point source (250 m height stack).

Also it was determined the maximum pollutants concentration and compared with the admissible values required by the Romanian legislation.

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