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ATMOSPHERIC DISPERSION MODEL APPLIED TO FLUE GASES

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Introduction

The atmospheric dispersion model (ADM) is the mathematical simulation of how pollutants are released into the atmosphere. ADMs are used to estimate the concentration of air pollutants emitted by industrial activity or car traffic in the wind direction. ADM was applied to the flue gases discharged on the chimney of a technological furnace from the diesel hydrofining plant in an oil refinery.

Materials and methods

The calculation of the maximum concentrations at ground, for two possible pollutant components present in the flue gases was performed: NOx (assimilated with NO2) - nitrogen oxides and CO - carbon monoxide. These two components were identified by flue gases analysis from the technological furnace in the hydrofining plant.

According to the Technical Guide for Air Quality Control (TA Luft), the field for the evaluation of immissions, resulting from the technological processes in the hydrofining plant, is the surface that is completely inside the circle around the chimney, which is 50 times higher than the actual height of the chimney and where the additional pollution has more than 3.0% of the value of long-term pollutant concentrations.

The actual height of the furnace chimney in the installation is 100 m, so the evaluation range is within a radius of 5 km around the chimney.

The stationary conditions are considered as simplifying hypotheses, in which the dispersion in the x-wind direction is negligible compared to the transported one (diffusion and convection) and the pollutant is a stable gas or aerosol that does not react chemically and does not interact with other chimneys.

The general Gauss dispersion equation, for a continuous point source of pollutants as a cloud of smoke resulting from the chimney of evacuated pollutants in the atmosphere, is calculated with the relation:

$$c_{(x,y,z)} = \frac{q}{2\cdot\pi\cdot u\cdot\sigma_y\cdot\sigma_z}\cdot e^{-0,5\cdot\left(\frac{y}{\sigma_y}\right)^2}\cdot\left(e^{-0,5\cdot\left(\frac{z-H}{\sigma_z}\right)^2}+e^{-0,5\cdot\left(\frac{z+H}{\sigma_z}\right)^2}\right)$$

where, C is the emission concentration [g/m3], q – emission source rate [g/s], u – horizontal wind velocity, y – lateral distance from the plume centre, z – the effective plume height above the ground [m], H – receiver height [m], σz – standard deviation of the vertical distribution emission [m], σy – standard deviation of the horizontal distribution emission [m].

The highest concentration that occurs at ground level is located in the centre of the plume for z = 0 and y = 0.

In order to calculate the pollutant concentration, the effective height from which the dispersion takes place must be known, this involves calculating the height of the smoke plume, H.

Calculations were made for stability classes for atmospheric air A (instability) and F (stability).

Table 1. Data required for the calculation of pollutant concentrations

Source	Pollutant	Mass flow q,[g/s]	Chimney height [m]	Inner diameter of chimney peak [m]	Exhaust temperature [K]	Wind velocity at height chimney, u, m/s	Flue gases velocity at exhaust [m/s]
Emission chimney	NO_2 CO	8.63 3.5	100	3.8	373	2	4

To verify the results obtained with the classical algorithm according to the guide, the Screen View 4.0.1 program was used, a calculation and simulation program that uses the Gaussian model of atmospheric dispersion to estimate the concentration of gaseous pollutants at ground level.

Screen View is based on the ISC3 (Industrial Source Complex) complex program for determining pollutant emissions from different types of sources.

Results and conclusions

Low concentrations of pollutants are favoured by weak winds and stable conditions in the lower structure of the atmosphere compared to high concentrations that are supported by dense and persistent fog, unstable conditions or thermal inversion.

Table 2. Maximum concentrations of pollutants for stability classes A and F, at distances x=500 m and x = 2500m (according to TA Luft guide algorithm)

Stability class	Distance from source, m	Height of pollutant plume, m	σ_y	σ_z	Pollutant	Concentration, µg/Nm^3
A	500	238.6	146.06	146.97	NO_2	**17.1**
					CO	**6.95**
F	2500	180.6	194.45	91.77	NO_2	**11.1**
					CO	**4.5**

Table 3. Maximum concentrations of pollutants depending on distance and stability class (Screen View 4.0.1 simulation program)

Class stability	Pollutant	Distance from source [m]				
		200	**500**	1000	**2500**	5000
		Maximum concentration of pollutant (smoke plume centre) [µg/m^3]				
A	NO_2	0.472	**18.29**	8.94	3.27	2.06
	CO	0.192	**7.42**	3.63	1.36	0.836
F	NO_2	0.111E-09	0.308E-01	3.11	**11.28**	9.05
	CO	0.451E-10	0.125E-01	1.26	**4.55**	3.7