UDC 519.6

EXPERT SYSTEM TO PREDICT THE ATMOSPHERE POLLUTION IN THE CASE OF THE ACCIDENT AT THE SOLID ROCKET PROPELLANT STORAGE

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Introduction. Nowadays the solid rocket propellant t of RS-22 missile is stored at Pavlograd Chemical Plant. It is a very dangerous source of the atmosphere chemical pollution in the case of the possible accident (Fig.1, 2). Worthy of note that tis storage is situated near the residential districts of Pavlograd city (Fig.1).

Fig.1. Pavlograd Chemical Plant: 1- storage with rocket propellant; 2 – territory of the plant; 3-residential districts

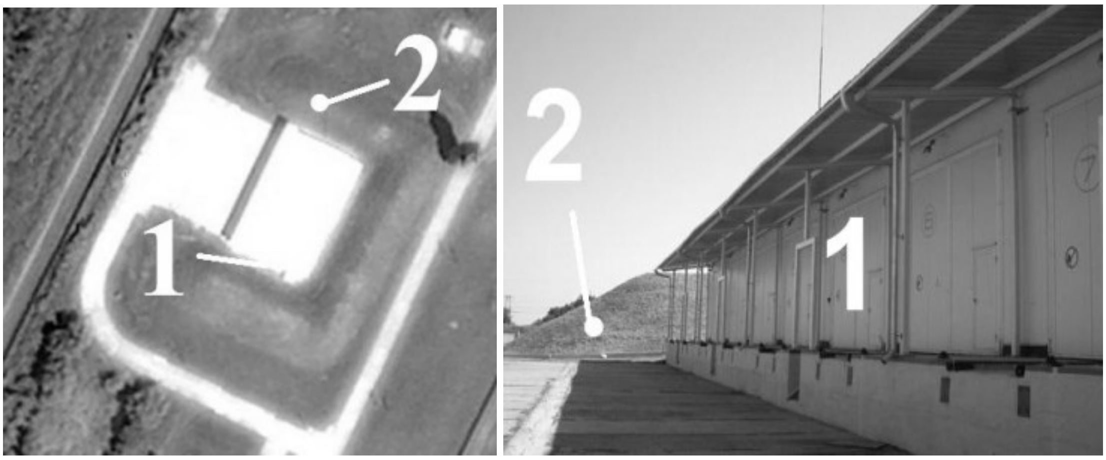

Fig. 2. Storage of rocket propellant: 1 – storage with rocket propellant; 2- receptor (building at the territory of the plant)

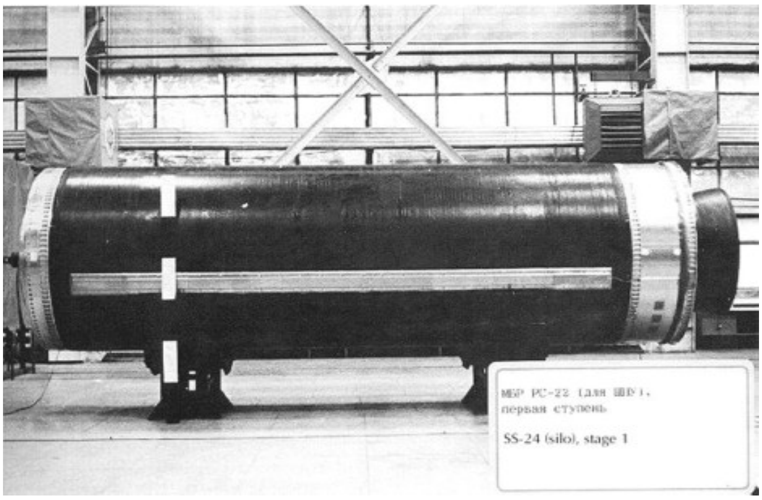

Fig.3. First stage of the solid propellant engine

That is why the prediction of the atmosphere pollution in the case of the accident at the storage is of great interest.

Literature review. Nowadays to predict the dimensions of the hitting area in the case of outdoor toxic chemical release the special standard model is used in Ukraine [1, 5, 7]. This model is formed on the basis of some empirical models and it has a lot of lacks and is, without doubt, unrealistic. The model doesn't take into account the influence of the wind velocity and the atmosphere diffusion on the concentration dispersion in the atmosphere. The main lack of this model is that the standard model cannot calculate the change of toxic chemical concentration in the atmosphere after the accident.

Objective of the work. The main objective of this work is the development of the numerical models to predict the atmosphere pollution which is more effective than the standard model and application of this model to predict the atmosphere pollution at the territory of the Pavlograd Chemical Plant. These models form the basis of the developed expert system to predict the level of the atmosphere pollution in the case of the possible accident at the storage with the rocket propellant. The description of the mathematical models is discussed below.

1."<u>Microsale level</u>".

To compute the toxic chemical (product of propellant burning) dispersion the Navier-Stokes equations and equation of mass transfer are used [6]:

$$\frac{\partial \omega}{\partial t}+\frac{\partial u\omega}{\partial x}+\frac{\partial v\omega}{\partial y}=\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 \omega}{\partial x^2}+\frac{\partial^2 \omega}{\partial y^2}\right), \quad (1)$$

$$\frac{\partial^2 \psi}{\partial x^2}+\frac{\partial^2 \psi}{\partial y^2}=-\omega\,, \quad (2)$$

$$\frac{\partial C}{\partial t}+\frac{\partial uC}{\partial x}+\frac{\partial vC}{\partial y}+\sigma C=div(\mu gradC)+\sum_{i=1}^{N}Q_i(t)\delta(x-x_i)\delta(y-y_i), \quad (3)$$

where

ψ – is flow function*;*

$\omega = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$ – is vorticity, $u = \frac{\partial \psi}{\partial y}$, $v = \frac{\partial \psi}{\partial x}$;

C – is concentration;

u, v – are velocity components;

$\mu = (\mu_x, \mu_y)$ – are the coefficients of turbulent diffusion;

σ – is the coefficient which takes into account the chemical transformation;

Q_i – is intensity of emission;

$\delta(x - x_i), \delta(y - y_i)$ – is Delta function.

This model is used to predict the air pollution near the storages with solid rocket propellant (Fig.2, 3).

2.“Local level”.

To simulate the process of toxic chemical dispersion in the atmosphere (for the distance about 2-3 km) the transport equation is used [1, 4, 6]:

$$\frac{\partial C}{\partial t} + \frac{\partial uC}{\partial x} + \frac{\partial vC}{\partial y} + \frac{\partial wC}{\partial z} + \sigma C = \frac{\partial}{\partial x}\left(\mu_x \frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(\mu_y \frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(\mu_z \frac{\partial C}{\partial z}\right) + \sum Q_i(t)\delta(x - x_i)\delta(y - y_i)\delta(z - z_i), \quad (4)$$

where

u, v, w – are the velocity components in x, y and z direction respectively;

C – is the concentration of toxic chemical;

σ – is the parameter taking into account the process of toxic gas decay or rain wash out;

μ_x, μ_y, μ_z – are the coefficients of turbulent diffusion in x, y and z direction respectively;

x_i, y_i, z_i – are the coordinates of point source of emission;

Qi(t) – is the intensity of pollutant emission;

$\delta(x - x_i)\delta(y - y_i)\delta(z - z_i)$ – is Dirac delta-function.

In the developed numerical model, the following profile of velocity component u and coefficient of diffusion μ_z is used [3]:

$$u = u_1\left(\frac{z}{z_1}\right)^n, \quad \mu_z = k_1\left(\frac{z}{z_1}\right)^m,$$

where

u_1 – is the velocity at height z_1;

k_1=0,2; n=0,16; m≈1.

The following models to calculate the other diffusive coefficients are used

$$\mu_y = \mu_x, \quad \mu_y = \kappa_0 u,$$

where

κ_0 – is the empirical parameter.

The height of the plume which is formed during the propellant firing was calculated using the following empirical model [7]

$$h = 4{,}71 \cdot \frac{Q^{0{,}444}}{u^{0{,}694}},$$

where

u – is wind speed;

Q – is the intensity of the heat emission ($Q=4*10^3$ kJ/kg).

This vertical plume is simulated as the set of vertical point sources using Delta function.

3.“Urban level”.

To simulate the process of toxic chemical dispersion in the atmosphere (for the distance about 8-12 km) the 2-D transport equation is used [2, 4, 6]:

$$\frac{\partial C}{\partial t} + \frac{\partial uC}{\partial x} + \frac{\partial vC}{\partial y} + \sigma C = div(\mu gradC) + \sum_{i=1}^{N} Q_i(t)\delta(x - x_i)\delta(y - y_i),$$

The boundary conditions for the governing equations are discussed in [2, 4]:

Numerical integration. To solve the governing equations the implicit difference schemes were used [6].

Results. On the base of the developed numerical models the special codes were developed. Some results of their application are shown in Fig.4, Fig.5.

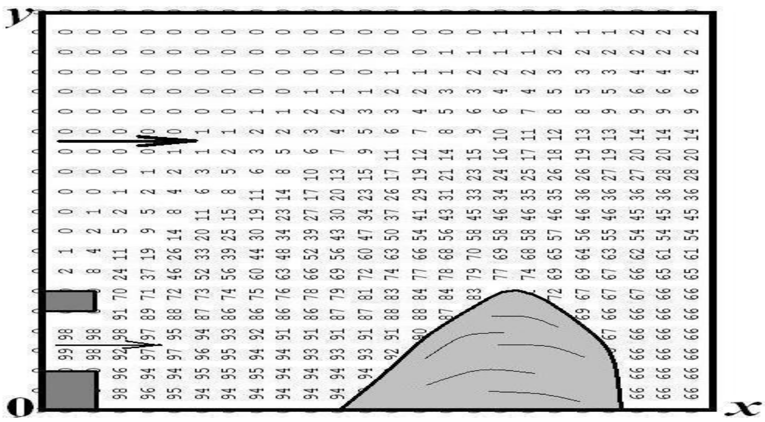

Fig. 4. Concentration of toxic chemical near the storage t=52 c

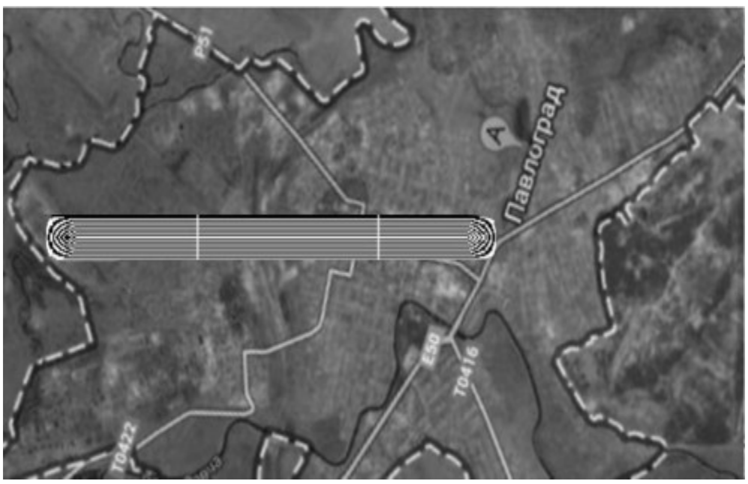

Fig. 5. Area of death hitting $t = 25{,}5$ *min*

One can see from Fig.5 that the accident at the storage will result in mass hitting of people in Pavlograd city.

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