Possibility of estimating radioactive fallout by modelling atmospheric processes

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The paper suggests methods and means for solving problems of determining contamination by radioactive waste, appearing as precipitation when moving radioactive particles in the atmosphere. The model for predicting and evaluating radioactive fallout is developed. Meteorological conditions determine the conditions for turbulent diffusion of pollution on a regional and global scale.

The deposition of radioactive wastes like precipitation is formed as a result of the settling of long-lived explosion products from the atmosphere. If the parameters of the explosion (intensity, geometry, type of explosion and etc.) form a qualitative composition of radioactive products, then the effect of the meteorological influence are finally reduced to transport and change of the concentration of radioactive contamination.

Scattering of radioactive impurities is determined by stratification, turbulence and other parameters of the atmosphere, the direction and speed of their spatial distribution - the parameters of the direction and speed of the wind. Particles with sizes less than 10-12 microns moving at a speed identical to that of vertical movements (≈1cm /s) precipitate on the Earth's surface either in the turbulent motion of air masses (dry deposition), or by washing out sediments (wet and wet sediments) [1].

Assuming, in accordance with the idea of Taylor and Schmidt [2], that the process of turbulent diffusion is equivalent to the process of molecular diffusion, one can obtain the next formula for the vertical turbulent heat flux in the surface layer of air

$$P = \rho C_p D(\theta_w - \theta) \qquad (1)$$

where ρ is the air density (typical value is around 1.23×10^{-3} g/cm^3), Cp is the heat capacity of air at constant pressure (normally depends very strongly on physical conditions at which the air exists, and equal to 1,007 kJ/kg·K at 300K and dry weather), θ_w is the temperature of the active Earth's surface, θ is the air temperature at a certain height, (measured in m), D is the integral characteristic of the conditions of vertical turbulent transport between the underlying surface and the atmosphere (cm^2/sec) which is called by M.I. Budyko [3] as the coefficient of external diffusion and is expressed in the form

$$D = \frac{1}{\int_0^z \frac{dz}{k}} \qquad (2)$$

herein z is the air level at temperature θ (for example, if $\theta_{200\ cm}$, then $z_{200\ см}$), k is the coefficient of turbulent exchange expressed in cm^2/sec.

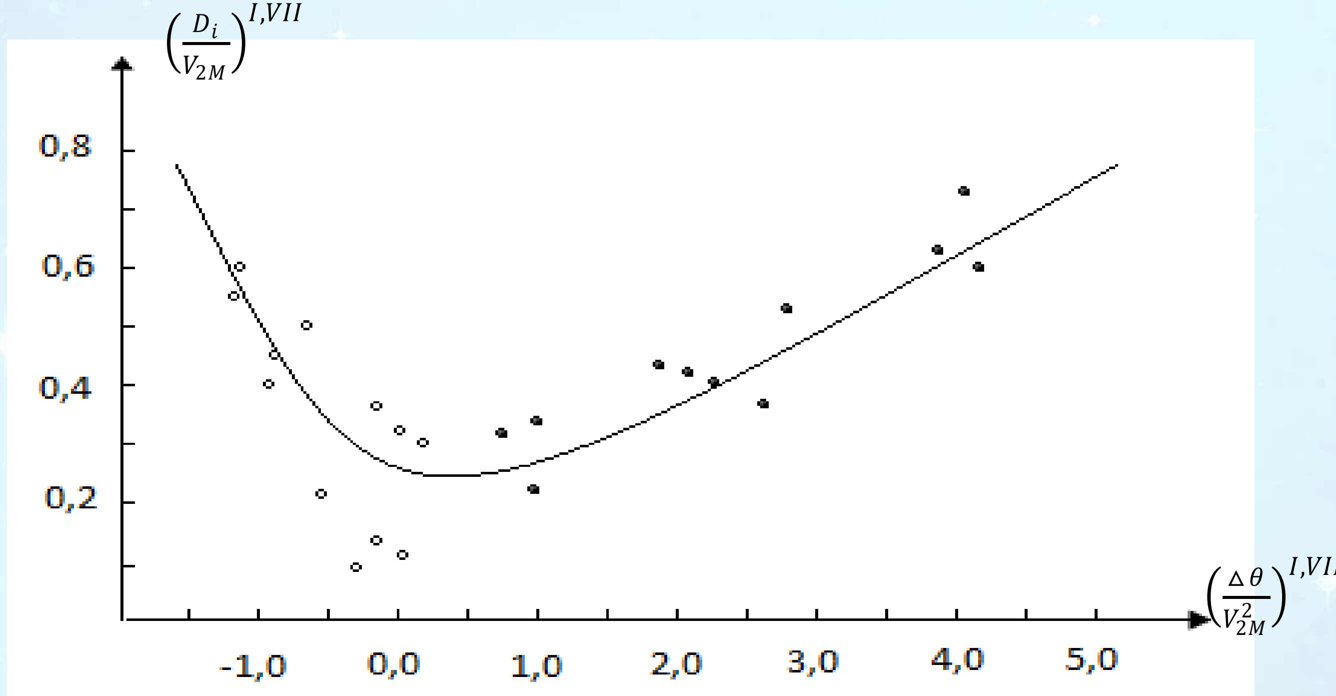

Fig. 1. Graph of the relationship between the climatic parameters of the stability parameter and the ratio of the integral turbulent exchange rate coefficient to the wind speed for the Transcaucasus region (black dots for July, bright for January) [3].

Crucial point herein is the character of the relationship between the integral coefficient of intensity of heat and moisture exchange (D) and the coefficient of turbulent exchange (k). In accordance with equation (2), we can write

$$\int_0^z \frac{dz}{k} = D^{-1} \quad (3)$$

Due to varying the value D between 0.5 and 1.3 in dependence on the climatic and landscape conditions, the average monthly values for climatological calculations will also have different and specific values which obey the same pattern [3].

Radioactive contamination of the terrain, among other things, depends on the speed of movement of radioactive particles in the atmosphere under the influence of wind. If we assume that the process of moving radioactive particles in the atmosphere is described by the diffusion equation, then for an excess concentration of particles marked as Δn (excess over the atmosphere, which is also radioactive), we have

$$v_z \frac{d(\Delta n)}{dz} = \lambda \frac{d^2(\Delta n)}{dz^2} - \alpha(\Delta n - \Delta n_0) \quad (4)$$

The following symbols are introduced into the equation (4): v_z is the speed of the forced motion of radionuclides (in terms of the diffusion equation, this is the speed of the convection), and λ is the coefficient of molecular diffusion of radionuclides in the layer under consideration.

More preferable looks the option when the wind speed is different by altitude thereto the lower the altitude, the lower the wind speed. In this case, the zone of contamination of the terrain with heavy radionuclides will not be so wide, since heavy RF will fall down in areas near the source of pollution is located.

As a result of pollution of the RF on a regional and global scale, it is necessary to use ground-based and remote methods and means of observation. The most effective use of radar remote sensing systems (RSS) in conjunction with optoelectronic equipment [5,6]. The most benefit of radar RSS is the absence of weather and time (day/night) restrictions [7] for getting information.

Radar means for detecting radioactive meteorological formation of anthropogenic nature are very different (active and passive radar). Monitoring principles of nuclear cycle enterprises is based on the appearance of anthropogenic release in the lower layers of the atmosphere which leads to a change in the physical parameters of the propagation medium, which creates a radar contrast and makes it possible to detect atmospheric inhomogeneity.

Experimental values of specific effective scattering area (abbreviated as ESR) of radioactive emissions are due to:

a) turbulent inhomogeneity of the air zone close to the exhaust pipe of NPP;

b) increased density of particulates (water droplets, aerosols, clusters and so on) so that radioactivity contributes to the formation of clusters which, consequently, affect the growth of large drops;

c) climatic and weather conditions, etc.

The analysis of the literature shows that for making studies targeted to creation of the satellite systems for the radar monitoring of radioactive releases it is necessary:

1. Creation of specialized multifrequency active and passive radars with increased energy potential;
2. Map of climatic and weather features of the area under study;
3. Data from meteorological satellites for comprehensive research;
4. Development of special algorithms for processing reflected radar signals [8].

Conclusion

In this paper the main factors of formation of radioactive wastes in the form of precipitation are revealed. On the basis of turbulent diffusion, a method has been demonstrated for the transport of contaminants, both regionally and globally.

A model for moving radionuclides in several parallel (altitudes) atmospheric layers is proposed. The model takes into account the meteorological parameters determining the intensity of radioactive waste deposition. The model can be applied to any territory and predict radioactive pollution of the territory; it’s necessary just include into the model meteo – and terrain/landscape specifications of the territory under research.

Thank you for attention!