The STADIUM and MM models

A set of physical and mathematical diffusion models of different scales (local, mesoscale, and global) developed in the Federal Environmental Emergency Response Center (FEERC of Roshydromet), forming part of the Federal State Budgetary Institution Research and Production Association Typhoon (RPA Typhoon) , and which is used for operational forecasting of contamination of air and underlying surface in accidental anthropogenic and natural air pollution emissions, includes two ranges models:

- Lagrangian model STADIUM and
- Eulerian model MM.

All models of the set are built in developed in FEERC of Roshydromet RECASS NT system for information support of decision making in case of anthropogenic and natural emergencies at production facilities (including chemical- and radiation-dangerous facilities).

In the statistical model of transport and turbulent atmospheric dispersion of pollutants STADIUM transport is taken into account by regular wind field, while dispersion is simulated by random walks of particles as a continuous Markov process.

In numerical Monte Carlo model, which is used as a statistical technique, Lagrangian tracking of movement of a large number of particles emitted from a source is applied.

Accordingly, concentration field description is carried out using the positions of particles in space.

Model STADIUM generates a field of average and integrated concentrations of pollutants in the atmosphere in several layers in the vertical. In the Eulerian model MM transport and turbulent dispersion of impurities is taken into account by solving the three-dimensional non-stationary semi-empirical equation of turbulent diffusion by method of moments.

Conceptually, in the model MM a plume of pollutants released from a source in accordance with the scenario of an accident or standard operating procedures is transferred in the non-stationary wind field, and its mass (activity), the geometric dimensions (dispersion) and spatial location (coordinates of the centroid) in each horizontal layer of the plume are determined by solution of the diffusion equation.

In the method of moments the system of equations for the moments is obtained by horizontal integration of diffusion equation. As a closure for the system of equations serves the hypothesis of the Gaussian distribution of pollutants in each horizontal layer that allows you to get in each horizontal layer the system of six equations: one for mass (activity) of pollutant, two for the coordinates of the centroid and three for the components of the dispersion tensor.

As boundary conditions for the diffusion equation in MM model the condition of total reflection of quite remote upper boundary (up to 15 km) and condition of partial reflection (absorption) of impurities on the underlying surface are used.

Both models (MM and STADIUM) describe the transport of pollutants in the range of scales, from the near zone to the global scale, necessary for the assessment of transboundary effects. The vertical scales, which are taken into account by the models, include a range of altitudes up to the lower stratosphere. Time interval (3 - 5 days) used in forecast mode of the models for pollutant transfer is determined by the capabilities of global forecasting of the Hydrometeorological Centre of Russia, preparing these meteorological fields. In diagnosis mode the time interval is limited only by the amount of archived meteorological data and capacities of computational tools used. The models take into account non-stationarity and spatial heterogeneity of meteorological parameters that determine transport of pollutants (wind field, boundary layer depth, atmospheric stability, and precipitation). The models are able to describe the propagation of pollutants from multiple sources with arbitrary geometric dimensions, release rates, time mode of action and dispersion characteristics of pollutants emitted. A set of physical processes taken into account in the models is quite wide, it includes atmospheric transport, turbulent dispersion, interaction with non-homogeneous underlying surface, sedimentation, dry and wet deposition and radioactive decay of pollutants.

Experience gained by FEERC of Roshydromet when working with the European system of regional forecast COSMO allowed to develop successful algorithm for assimilation of mesoscale meteorological data of the Japan Meteorological Agency (JMA MESO) for the time interval of active phase of the accident at the plant in Fukushima Daiichi (11.03.2011 - 31.03.2011) and use this algorithm to adapt the JMA MESO data for meteoprocessor of RECASS NT system and then use this information to calculate transport, dispersion and deposition of radioactive products of Daiichi nuclear power plant emissions. The main parameters used to determine the levels of radioactive contamination of the environment were sedimentation velocity V_R, dry deposition velocity V_d, parameter of washing-out of pollutants from the atmosphere λ, proportional to rainfall rate I. Proportionality coefficient is the product of the parameters $\gamma 0$ and $\gamma 1$, where $\gamma 0$ - wash-out ability of rain with the rate I = 1 mm/h, and $\gamma 1$ - relative wash-out ability of precipitation of various types. As provided for in RECASS NT system parameter $\gamma 1$ varies from 1 (for light rain) to 3 (for snow). Recommended default values of parameters V_R, V_d, γ_0 for the types of radionuclides used in the calculations in RECASS NT system are given in Table 1

Table 1. The values of the physical constants for the gravitational settling, deposition and wash-out for some radionuclides

Radionuclide	V_R, m/s	V_d, m/s	γ_0, h/(mm.s)
Elementary Iodine, I_2	0	$2 \cdot 10^{-2}$	$4 \cdot 10^{-5}$
Organic Iodine compounds, CH_3I etc.	0	$1 \cdot 10^{-4}$	$4 \cdot 10^{-7}$
Aerosol	$7 \cdot 10^{-3}$	$8 \cdot 10^{-3}$	10^{-5}
IRG (inert radioactive gases, noble gases)	0	0	0
Tritium, ^3H	0	$5 \cdot 10^{-4}$	10^{-5}
Carbon, ^{14}C	0	$6 \cdot 10^{-4}$	10^{-5}

These values of parameters for Cs-137 aerosol were used in calculations by models MM and STADIUM to generate fields of concentration and deposition of particles of Cs-137 aerosol in the Daiichi nuclear power plant accident in the area of 28 ° - 48 ° North and 125 ° - 155 ° East on the grid with a step 0.05 ° x 0.05 °.