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Numerical estimation of distribution scales Cs^{137} in the Kara Sea at a possible runoff from the river Ob

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Abstract. The results of numerical experiments by definition of propagation zones Cs^{137} in the Kara Sea in case of a radiological contamination offset from the estuary Ob are tendered. The stationary source of a radioactivity dumping was set in surface layer of river and seawaters mixing zone in the Ob Bay. The modeling was carried out on the basis of a numerical solution of the three-dimensional equation of passive impurity transport with turbulent diffusion and with allowance for of processes of a half-decay and sedimentation on suspension. The equation was considered concerning total concentration of a radioactive impurity in seawater (in dissolved state and suspended matter). The assumptions of a stationarity of concentrations Cs^{137} ratio in different states and constant suspended matter distribution in water column were done. The part of radionuclides content in suspension from total radionuclide content was set in particular coefficient p on the basis of nature measurements. As a result simulation we obtained the predominant transfer Cs^{137} in northern and north-east direction from an estuary Ob and the sufficiently strong dependence of the scales of propagation on the coefficient p.

1. INTRODUCTION

The radiochemical plants, located in basin of the river Ob, represent potential threat to an ecosystem of the Kara Sea. The prognosis of migration of long-lived anthropogenic radionuclides, in case of emergency dumping at these plants, with helping of a numerical modeling is an actual problem.

The most general approach to modeling of propagation and transformation of the pollution in dissolved state and suspended matter is joint solution of transport equations for both states of radioactive contamination in sea water with the use of kinetic transfer coefficients of one state into another [1]. Sorption and desorption of radionuclides on the suspension can be described also with the aid of the equilibrium distribution factors with the forecast for a prolonged time [2]. With conducting of our model experiments on the simulation of propagation Cs^{137} in the Kara Sea, we considered evolution of total concentration Cs^{137} (in dissolved state and suspended matter) and assumed a stationarity of Cs^{137} concentrations ratio in different states and constant suspended matter distribution in water column. Obtained by us results of evaluating the consequences of an offset of radiological contamination from an estuary Ob are represented in this work.

2. MATERIALS AND METHODS

The modeling was carried out on the basis of a numerical solution of the three-dimensional equation of passive impurity transport with turbulent diffusion and with allowance for of processes of a half-decay and sedimentation on suspension.

View of model equation in Cartesian coordinate system x, y, z is following:

$$\frac{\partial c}{\partial t} + \frac{\partial (uc)}{\partial x} + \frac{\partial (uc)}{\partial y} + \frac{\partial \left(\left(w + pw_s\right) c\right)}{\partial z} + \sigma c = \mu \left(\frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2}\right) + \nu \frac{\partial^2 c}{\partial z^2} + f \qquad (1)$$

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Here c – total concentration of radionuclide; u, v, w – components of current velocity; w_s – speed of suspended matter sedimentation; p – part of radionuclide content in suspension from a total radionuclide content; μ – factor of horizontal turbulent diffusion; ν – factor of vertical turbulent diffusion; $\sigma = \ln 2/\tau$, τ – period of half-decay of considered radionuclide, f (x, y, z) – source of pollution.

The condition of the absence of impurity stream was assigned on the rigid lateral boundaries. On liquid lateral boundaries the offset of an impurity abroad was allowed only. The numerical plan of model is the explicit difference scheme, "the second scheme with differences against a flow" for advective terms and central differences for diffusive terms.

Three-dimensional arrays of monthly average velocities of the Kara Sea currents with horizontal grid step 7, 5 nm obtained in Arctic and Antarctic Research Institute (AARI), St.Peterburg, Russia and correspondent to velocities fields an array of depths AARI [3] were utilized with the calculations.

The stationary source of a radioactivity dumping was set in surface layer of river and seawaters mixing zone in the Ob Bay and equal to $100\,\mathrm{Bq/m^3}$. The factors of horizontal and vertical turbulent viscosity were equal 10^5 and $1\,\mathrm{sm^2/sec}$, accordingly. Speed of suspended matter sedimentation was equal to 0.001sm/sec. The value p was taken according to the natural data obtained on cruises RV "Akademik Boris Petrov" (1999–2003) within framework of the German-Russian project SIRRO [4]. The calculations were carried out for two different ways of setting of factor p: parameter p was equal to 0.1 in all of calculations points and parameter p was equal to 0.2 in estuaries of the rivers and 0.02 in remaining points.

3. RESULTS AND CONCLUSIONS

Obtained distributions Cs^{137} on a surface of the Kara Sea for space uniform parameter p and for different parameter p in estuaries of the rivers and open part of the sea after three years of model integration are represented on Figure 1 and Figure 2, accordingly.

Figure 1. Surface concentration Cs^{137} ($\mathrm{Bq/m^3}$) at constant dump in Ob Bay after three years modeling time. The parameter p is equal 0.1 in all points of calculating area.

From resulted figures, prevailing transport of Cs^{137} in northern and northeast direction from an estuary Ob is visible. In the Ob Bay and Yenisei Bay strong currents interfere with penetration of the polluted waters upstream. Comparison of modeling results for various definitions of parameter p**,** shows, as a whole, similar behavior of an isoline 1 $\mathrm{Bq/m^3}$ in both cases. However, in case of spatially homogeneous parameter p (Figure 1), isolines of major concentrations envelop a major water area in

Figure 2. Surface concentration Cs^{137} (Bq/m^3) at constant dump in Ob Bay after three years modeling time. The parameter p is equal 0.2 in estuaries of the rivers and 0.02 in remaining points.

comparison with use of spatially changeable factor p (Figure 2). It is connected with more intensive process of Cs^{137}sedimentation in estuaries of Ob and Yenisei in the case of spatial not uniform setting factor p, because of that p in the given areas is much greater than in an open part of the sea.

At integration on time of model, the accumulation deposited at the bottom content Cs^{137} for each point of a computation grid was carried out. The distributions of the summary Cs^{137} concentration at the bottom after three model years for space uniform p are shown on Figure 3.

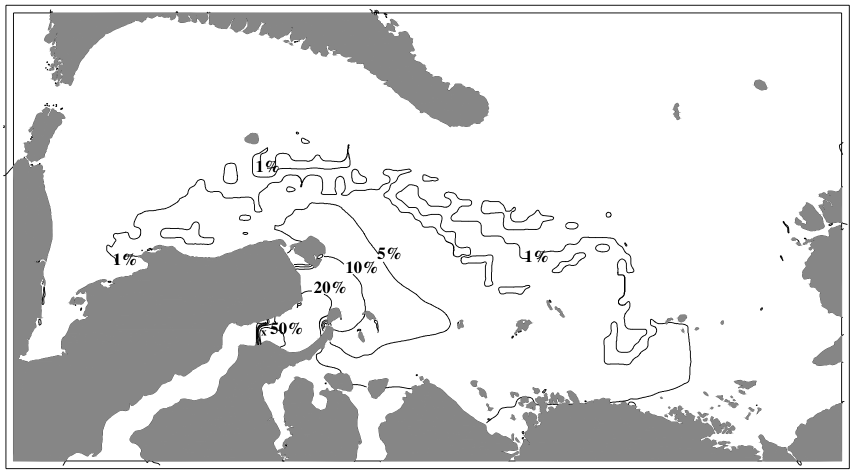

Figure 3. Distribution of Cs^{137} at bottom after three model years at constant dump in Ob Bay. The parameter p is equal 0.1 in all points of calculating area.

The concentration on Figure 3 is represented in the percent ratio from the maximum value, which corresponds to the point of the bottom under the place of a constant discharge of radioactivity. The picture of the distribution of sedimentated on the bottom Cs^{137} corresponds well to surface transfer. In the case of anisotropy p practically entire content of precipitated Cs^{137} allocated inside the region, where value p was equal to 0.2 (estuaries of Ob and Yenisei) (Figure 4).

Figure 4. Distribution of Cs^{137} at bottom after three model years at constant dump in Ob Bay. The parameter p is equal 0.2 in estuaries of the rivers and 0.02 in remaining points.

On the basis obtained distributions Cs^{137} it is possible to make a conclusion about the fitness for work of the numerical realization of the sedimentation process in the model. The sufficiently strong dependence of the obtained results on the definition of coefficient p speaks about the importance of an adequate parameterization of a sedimentation process Cs^{137} on suspended matter.

As a whole, the obtained by us tendencies of the propagation Cs^{137} with the possible constant runoff in the Ob Bay, with different numerical realizations of the process of sedimentation, coincide with the known ideas about the extension of substance from the river Ob into the basin of the Kara Sea [3, 5, 6]. This tells about the availability of our approach for the preliminary forecasts of the radio-ecological situation in the Kara Sea.

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