Multi-step algorithm for solving the optimization problem of the mean pollution concentration in Moscow region

Environmental pollution is one of the current interest ecology problems. Propagation of pollutants from pipes of industrial enterprises and public transport contributes to overall pollution of various regions. During the summer period (or periods of drought) forest and peat fires of significant intensities may also arise (e.g. summer 2010 in the European part of Russia). Amount of public resources needed to eliminate pollution, to secure people health and to provide safety of different ecosystems depend on effectiveness and timing of solving the problem.

In the previous works of the author (Novikov, 2013, 2015) the optimization problem of a mean pollution concentration in region from local sources (viz. regions of industrial pipes or fires) was considered and one-step algorithm for solving the problem was proposed. As a mathematical model of pollution propagation the three-dimensional non-stationary convection-diffusion equation was used. Tikhonov regularization (Tikhonov et al., 1979) was applied to solve the studied problem as it is ill-posed. The algorithm of solution was built on the basis of "dual" representation of residual functional (Marchuk et al., 1982), adjoint equations methods (Marchuk, 2000) and optimal control methods (Agoshkov, 2003).

However, in the previous papers an initial mean pollution concentration (i.e. mean concentration calculated without "controls") or initial economic damage may be reduced insignificantly (for example, only fourfold). Examples of graphics of pollution concentration in region before and after "controls" (the laws, utilizing which it is necessary to reduce intensities of local sources) are shown in fig. 1-2, and examples of "controls" are shown in fig. 3-4. Attempt to reduce the initial concentration more significant may lead to nonphysical solution of the problem (for example to negative pollution concentration, Novikov, 2013). In the cited work the initial mean concentration was reduced tenfold, but the concentration of impurities (the solution of pollution spread problem) was negative in some areas of the region of interest, see e.g. fig. 5. Such the effects took place because the "controls" was calculated in one step by using the explicit formula. Application of multi-step algorithm proposed in this work yields decrease in the initial mean pollution concentration up to level determined by sanitary standards, i.e. a tenfold reduction or more. "Controls" are repeatedly evaluated and refined in the method. Moreover, the algorithm does not lead to nonphysical solutions of the problem. Results of numerical experiments (in Moscow region as an example) illustrating theoretical statements of the studied problem and effectiveness of the proposed algorithm are also demonstrated.

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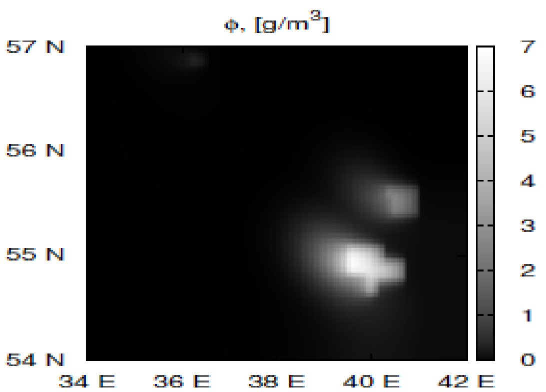


Fig.1. Pollution concentration in region before "controls"

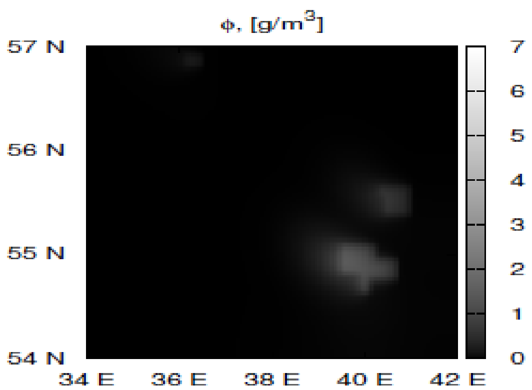
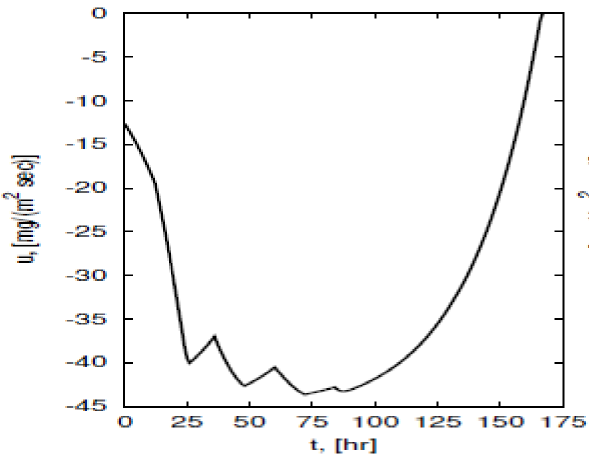


Fig. 2. Pollution concentration in region after "controls". (initial mean pollution concentration was reduced fourfold).



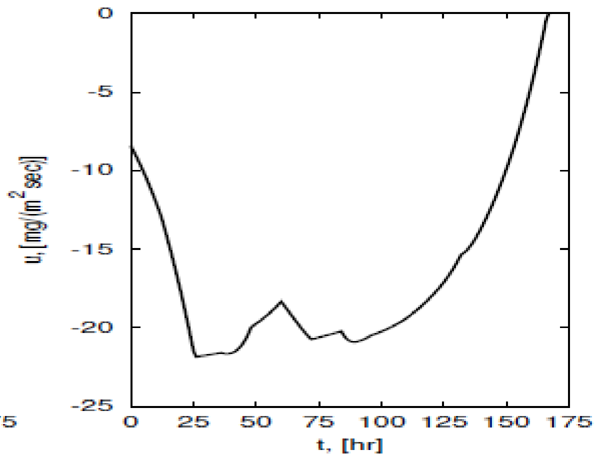


Fig.3."Control" in region with coordinate $(40^{o}E, 55^{o}N)$. Fig.4."Control" in region with coordinate $(41^{o}E, 55^{o}30'N)$.

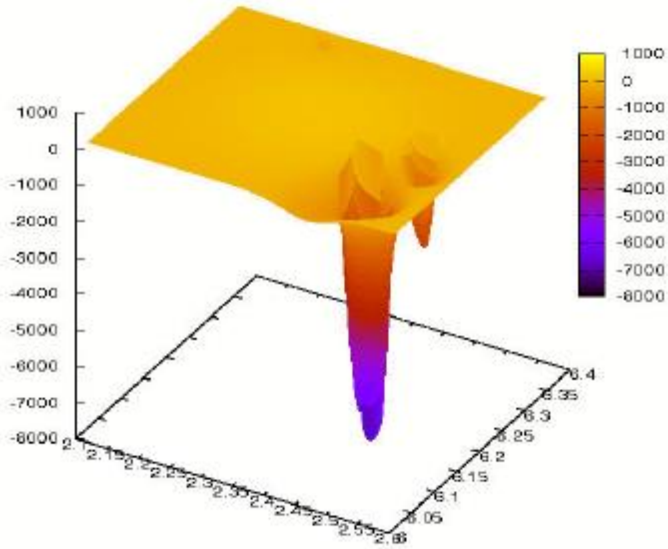


Fig.5. Pollution concentration in region after "controls"
(the result of attempt to reduce initial mean pollution concentration tenfold).