Model “PROLOG” for Countermeasures Efficacy Assessment and its Calculation Algorithm Verification on the Base of the Chazhma Bay Accident Data

S. Bogatov, Nuclear Safety Institute of Russian Academy of Science, Moscow, Russia
A. Kiselev, B. Nuclear Safety Institute of Russian Academy of Science, Moscow, Russia

ABSTRACT

Methodical approaches are presented that is used in computational model “PROLOG”. This model is intended to assess radiological situation and counter measures efficacy after short term releases. Basic local Gaussian dispersion algorithm is supplemented with modules for plume rise, dry deposition velocities, building and complex terrain influence etc. The modules are intended to provide a compromise between simplicity, shortage of initial data and adequacy of the model in case of real accident. Approaches to dose and countermeasures efficiency assessments are presented as well. Plume rise, complex terrain and pollutant polydispersity modeling approaches were tested on the base of comparison of calculation and experimental results of doze rate and Co-60 surface contamination measured after Chazhma bay accident in 1985.

Keywords: Complex Terrain, Counter Measures Efficacy, Gaussian Dispersion Algorithm, Plume Rise, Radiological Contamination

INTRODUCTION

One of the most important problems of the emergency response is fast estimation of the radiation situation, expected irradiation and counter measures efficacy. Such evaluations require correct estimation of atmospheric dispersion and particle deposition. Most of existing models, that are capable to carry out such calculations, demand a lot of specific parameters that is usually not available for short time in emergency situation.

DOI: 10.4018/jiscrm.2013040105
«PROLOG» is intended for short term releases estimation (Bogatov, Kiselev, & Shvedov, 2011). Code «PROLOG» is based on the Gaussian model for atmospheric dispersion that we supplemented with modules for aerodynamic shadow of single building, complex terrain influence, pollutant polydispersity, plume rise and its depletion due to dry and wet deposition.

The model contains radionuclide data base with appropriate dose coefficients that makes it possible to assess radiological accident consequences such as the radionuclide concentrations in environment as well as expected personnel or public irradiation, to define areas where protective measures are necessary and to assess their efficacy in prevented dose units.

Intrinsic feature of the development is testing and verification of the model approaches on real accidents or experiments. This article is one of the examples of the tests - the comparison of calculated and measured results of dose rate and surface fallout after the nuclear submarine accident. The accident took place at Chazhma Bay (Far East) on August 10, 1985, and it may be considered as one of a few real events where pollutant dispersion was influenced by the release polydispersity, complex terrain and atmospheric precipitation.

CHAZHMA BAY ACCIDENT

Nuclear submarine refueling at shipyard in Chazhma bay has been completed on August 2, 1985. Pressure test revealed that bow reactor top cover was mounted untight due to the fragment of welding rod that was clenched between reactor top cover and copper pad on the reactor vessel. This circumstance required reactor cover removal and copper pad substitution. During the reactor cover lift on August 10, accidental clench and withdrawal of reactivity compensation lattice occurred that was followed by spontaneous chain reaction (SCR). As a result of energy burst internal reactor structures were destroyed and partially thrown out together with overheated steam-air mix, fire started onboard. Accident occurred with “fresh” nuclear fuel in the active core and radionuclide composition of the release contained short lived fission products (krypton, xenon, iodine) and activation products (mainly $^{60}$Co).

Some SCR features were assessed in Bogatov, Kiselev, and Shvedov (2011). Indirect assessments on the base of observable consequences of explosion made it possible to assess energy release about 100 kg of trinitrotoluene equivalent, fuel amount that formed critical mass was evaluated as several dozen of kilograms, about $10^{19}$ nuclear fission (energy equivalent $Q \approx 3 \times 10^8$ J) occurred. This value of specific energy release (~ 1000 cal/g(U)) is enough for fuel melting and dispersion into fine particles, corresponding temperature of steam generation was taken as 1800°C.

Assuming steam thermal capacity at this temperature $C_p = 2.8 \times 10^3$ J/kg/grad, specific steam generation heat $r = 2.3 \times 10^6$ J/kg, mass of evaporated water $M$ at the overheat temperature $\Delta T=1500^\circ$K can be roughly assessed as:

$$M = \frac{Q}{r + C_p \cdot \Delta T} \approx 46 \text{ kg}$$

Energy burst was fast, and main part of the release was contained in overheated steam-air mix. At the time of accident there was south-eastern wind with velocity of 5 m/s, periodical drizzling rain, atmospheric stability class D by Pasquill (Sivintsev et al., 2005).

COMPUTATIONAL MODEL “PROLOG”

“PROLOG” Gauss Model Features

Atmospheric diffusion model “PROLOG” is intended to assess air concentration and fallout density at distance up to 30 km from the release point. Gaussian atmospheric diffusion model is used according to recommendations of Shershakov, Klepikova, Troyanova, Freimundt, Stogova, and Zharova (2009). Differences between “PROLOG” and work (Shershakov,
Related Content

Evaluate Alternatives for Disaster Recovery Plan Development
(2000). A Primer for Disaster Recovery Planning in an IT Environment (pp. 50-52).
www.igi-global.com/chapter/evaluate-alternatives-disaster-recovery-plan/119790?camid=4v1a

Social Media and Disasters: Applying a New Conceptual Framework to the Case of Storm Desmond
Briony J. Gray, Mark J. Weal and David Martin (2016). International Journal of Information Systems for Crisis Response and Management (pp. 41-55).
www.igi-global.com/article/social-media-and-disasters/185639?camid=4v1a
Developing a Public Online Learning Environment for Crisis Awareness, Preparation, and Response

Use Team Building to Make the Most of Your Public-Private Partnerships
[www.igi-global.com/chapter/use-team-building-to-make-the-most-of-your-public-private-partnerships/124654?camid=4v1a](www.igi-global.com/chapter/use-team-building-to-make-the-most-of-your-public-private-partnerships/124654?camid=4v1a)