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Application of the Bulgarian Emergency Response System in Case of Nuclear Accident in Environmental Assessment Study

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ABSTRACT

The development of the Bulgarian Emergency Response System (BERS) for short term forecast in case of accidental radioactive releases to the atmosphere has been started in the mid 1990's [1]. BERS comprises of two main parts - operational and accidental, for two regions "Europe" and "Northern Hemisphere". The operational part runs automatically since 2001 using the 72 hours meteorological forecast from DWD Global model, resolution in space of 1.5° and in time - 12 hours. For specified Nuclear power plants (NPPs), 3 days trajectories are calculated and presented on NIMH's specialized Web-site (http://info.meteo.bg/ews/). The accidental part is applied when radioactive releases are reported or in case of emergency exercises. BERS is based on numerical weather forecast information and long-range dispersion model accounting for the transport, dispersion, and radioactive transformations of pollutants. The core of the accidental part of the system is the Eulerian 3D dispersion model EMAP calculating concentration and deposition fields [2].

The system is upgraded with a "dose calculation module" for estimation of the prognostic dose fields of 31 important radioactive gaseous and aerosol pollutants. The prognostic doses significant for the early stage of a nuclear accident are calculated as follows: the effective doses from external irradiation (air submersion + ground shinning); effective dose from inhalation; summarized effective dose and absorbed thyroid dose [3]. The output is given as 12, 24, 36, 48, 60 and 72 hours prognostic dose fields according the updated meteorology.

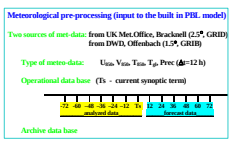
The BERS was upgraded to simulate the dispersion of nuclear materials from Fukushima NPP [4], and results were presented in NIMH web-site. In addition BERS took part in the respective ENSEMBLE exercises to model ^{131}I and ^{137}Cs in Fukushima source term. In case of governmental request for expertise BERS was applied for environmental impact assessment of hypothetical accidental transboundary radioactive pollution. The consequences were estimated based on the worst emission scenario for the existing basic reactor type, selection of real meteorological forecast conditions, favoring the direct transport of the contaminated air masses to the territory of the country in consideration. In the present work BERS is used to estimate the worst case accidental scenario impact from a possible new unit of Paks Nuclear Power Plant, Hungary over the territory of Bulgaria.

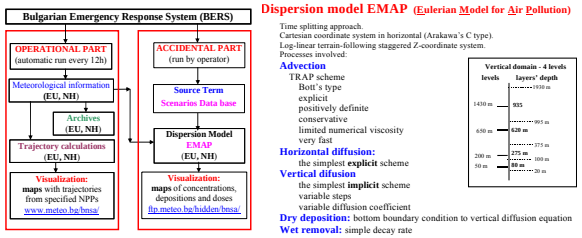
BERS Description

BERS comprises of 2 parts - operational and accidental, for two regions "Europe" and "Northern Hemisphere". Eulerian 3D dispersion model EMAP is the core of the accidental part of BERS.

Trajectory calculations

$$\boldsymbol{X}(t+\Delta t) = \boldsymbol{X}(t) + \boldsymbol{V}(t).\Delta t$$





Dispersion model EMAP (Eulerian Model for Air Pollution)

Time splitting approach.
Cartesian coordinate system in horizontal (Arakawa's C type).
Log-linear terrain-following staggered Z-coordinate system.
Processes involved:

Advection
TRAP scheme
Bott's type
explicit
positively definite
conservative
limited numerical viscosity
very fast

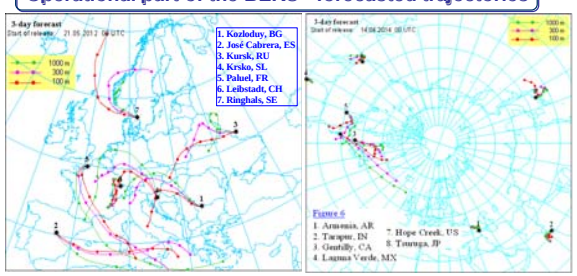
Horizontal diffusion:
the simplest **explicit** scheme

Vertical difusion
the simplest **implicit** scheme
variable steps
variable diffusion coefficient

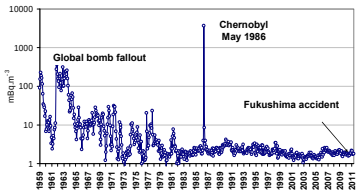
Dry deposition: bottom boundary condition to vertical diffusion equation

Wet removal: simple decay rate

Operational part of the BERS - forecasted trajectories



http://info.meteo.bg/ews/EWS/



Monthly long lived airborne total beta activity (measured 120h after sampling) at NIMH, Sofia, 1959-2011.

Accidents with off-site releases of radionuclides to the environment and atmosphere. RNG,^{131}I и ^{137}Cs are given in PBq (1.10^{15} Bq)

Accident	Data	Released radionuclides in PBq			Others
		RNG	I-131	Cs-137	
Chelyabinsk-40 plutonium plant, Kyshtym, USSR*	September 1957			3.6 E-03	100 PBq medium and long-lived 5.4 PBq ^{90}Sr+^{90}Y
Windscale accident, Northern England *	October 1957	14 ^{133}Xe	0.74-1.2	0.046	0.2 TBq ^{90}Sr 1.6 TBq ^{239}Pu
SL-1 Reactor, Idaho falls, USA *	January 1961		2.6E-03		
Rocky Flats plant, Denver, USA	1969				0.22 TBq Pu
Three Mile Island, Unit 2, USA	March 1979	77.7	5.55E-04		
Chernobyl NPP accident, former USSR	26-April 1986	6533 ^{133}Xe+^{85}Kr	1760	86	
Tokaimura nuclear fuel processing plant, Japan	30.09. 1999				~200 persons up to 21 mGy or n, γ
Fukushima, Dai -ichi NPP, Japan	March 2011	11000 ^{133}Xe	160	15	

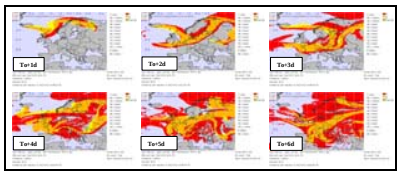
There were altogether 543 tests in the atmosphere. Global release of ^{131}I and ^{137}Cs from atmospheric nuclear weapon testing is 675 000 PBq and 948 PBq respectively (UNSCEAR, 2000, UNSCEAR 2008)

BERS validation - ETEX, RTMOD, ENSEMBLE

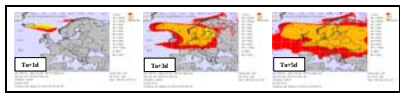
ENSEMBLE Volcano Exercise

BERS simulations *vrs.* ensemble ones

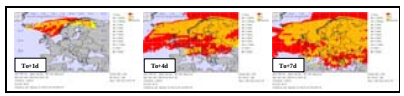
A. Concentration fields at height 6 km



B. Accumulated Dry Deposition fields (earth surface)



C. Accumulated Wet Deposition fields (earth surface)



ENSEMBLE: Web-based decision support system to collect atmospheric dispersion forecasts produced by various participants. The ENSEMBLE system allows users to perform on line ensemble analysis.

ENSEMBLE consortium run Volcano&Fukushima exercises, 2011.

Volcano Results: BERS is ranked as 5th of the participated 11 models in percentage of overlapping.

BERS development

UPGRADES of BERS

2001 – putting of BERS into operation

2007 – multi-nuclide treatment, exposure doses calculations

2010 – for ENSEMBLE Volcano exercise:
- **new vertical structure – up to 12 km, exercise specific levels**
- **vertical diffusion coefficients aloft – 10% of PBL ones**
- **NCEP meteorology added over 2 km (to the DWD data)**
- **continuous source long term calculations**

2011 – for ENSEMBLE Fukushima exercise:
- **increase the space resolution of NH from 300 to 25 km**
- **respective upgrade of meteorological pre-processing**
- **respective upgrade of EMAP and visualizing software**
- **new Figures 7, 8 added to BERS web-site containing the results from every day hypothetical release simulations (animated).**

Selected test cases with real meteorology for simulations with BERS of hypothetical accidental releases from Paks NPP, Hungary

	Case 1	Case 2	Case 3	Case 4	Case 5
Date	03.02.2013	07.02.2013	03.03.2013	04.01.2013	12.05.2012
Start of release (UTC)	08:00	15:00	00:00	09:00	06:00
Release height (m)	100	100	100	100	100
Release duration (hours)	2.00	2.00	2.00	2.00	2.00
Release activity (Bq)	0.89.10^{19}	0.89.10^{19}	0.89.10^{19}	0.89.10^{19}	0.89.10^{19}

BERS upgrade with dose assessment block

Radionuclides selection and grouping for simulation of the early stage of nuclear accident

In the present version of BERS **31 radioactive isotopes in gaseous and aerosol form** are modeled and grouped **in 8 "lump pollutants" groups** :

- **Group 1** (***long lived RNG***): *Kr-85, Xe-133, Xe-133m;*
- **Group 2** (***RNG with medium T1/2***): *Xe-135, Kr-85m, Kr-88+Rb-88;*
- **Group 3** (***short lived RNG***): *Kr-87, Xe-135m, Xe-138;*
- **Group 4** (***gaseous iodine***): *I-131 as I2;*
- **Group 5**: ***Carbon-14, tritium***; (not of major significance)
- **Group 6** (***long lived aerosols***): *Cs-137/Ba-137m, Sr-90/Y-90, Pu-239, Co-60, Cs-134, Ru-106;*
- **Group7** (***aerosols with medium T1/2***): *Zr-95, Sr-89, Ru-103, Nb-95, Ce-141, Cs-136, Ba-140/La-140, I-131;*
- **Group 8** (***short live aerosols***): *Te-132, I-133, I-135, I-132, Cs-138;*

The radionuclides are modeled as 4 basic groups according to dispersion:
Radioactive noble gases (RNG);
Iodine (^{131}I, ^{132}I, ^{133}I and in some cases ^{134}I and ^{135}I) in different chemical and physical forms;
Aerosols. Volatile tellurium and alkaline metals are expected to be released as aerosols, as well as iodine isotopes, attached to the aerosols;
Others - ^{3}*H* and ^{14}*C*.

The most important doses during the early stages of accident calculated from BERS:

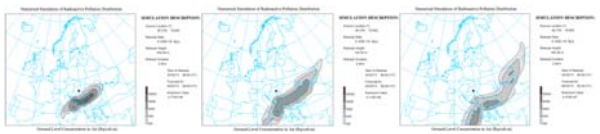
a) Absorbed dose in thyroid gland denoted as D_{thyr};

b) Effective dose by inhalation of radioactive substances, excluding RNG (E_{inh});

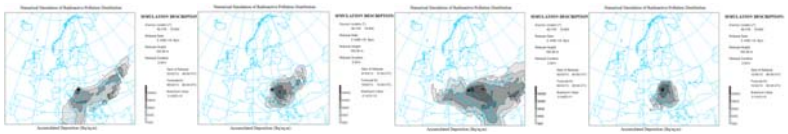
c) Effective dose by external exposure to the radioactive plume (air submersion), and ground shinning - E_{cl} and E_{gr}.

Accidental scenario – test cases with BERS

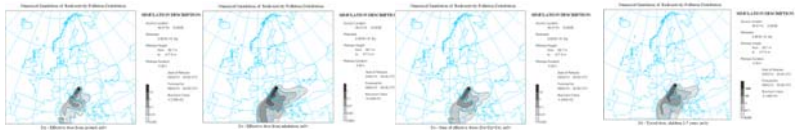
The scenario for accidental release of mixture of radionuclides to the atmosphere is based on the severe accident scenario with core melt (BY+CD) for an existing power reactor of Paks (WWER 440). The scenario is one of the typical scenarios of RODOS system. In our case for BERS the 55 radionuclides are reduced to 31 main radiologically important radionuclides incorporated in BERS.



Forecasted ground level radioactivity concentrations 24, 48 and 72 hours after start of hypothetical release.



Forecasted accumulated deposition on the ground 72 hours after start of 2hours hypothetical release, Case 1, 2, 3 and Case 5.



Forecasted dose fields from ground shining, from inhalation, effective dose and absorbed dose in the thyroid gland 72 hours after start of 2hours hypothetical release, worst test scenario - Case 5.

Acknowledgements

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References

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