ASSESSMENT OF EFFECTS FOR A HYPOTHETICALLY RDD EVENT AT CHERNOBYL SITE IN UKRAINE

Alexandru O. PAVELESCU[1], Mărgărit PAVELESCU [2]

Abstract *In the context of the crisis generated by the Russian-Ukrainian conflict, a hypothetical scenario was devised involving a radiological dispersal device emission at Chernobyl premises. A decision support software system for radiological and nuclear emergencies was used, with the main purpose of identifying potential areas of influence on the territory of Romania. The atmospheric dispersion of radioactive materials was evaluated as a result of such RDD explosion also known as "dirty–bomb" with a load of radioactive Cs-137 and an activity of 10 TBq in the Chernobyl exclusion zone using real time meteorology prognosis data.*

Keywords: decision-support systems; situation forecasts; potential areas of radiological risk; total effective dose equivalent (TEDE).

DOI 10.56082/annalsarsciphyschem.2025.1.16

1. Introduction

In the context of the crisis generated by the Russian-Ukrainian conflict, an improbable but possible RDD release event could have occurred at Chernobyl Site in Ukraine which has witnessed several military confrontations. For such case, a decision support software system for radiological and nuclear emergencies was used, with the main purpose of identifying a potential influence on the territory of Romania as a consequence of such radioactivity release.

2. Assessment tool

Decision support systems (DSS), such as dose projection tools, for estimating radiation doses, are essential in preparing and responding to nuclear and radiological emergencies. Users of decision-making systems are the regional, national, and international institutions and organizations responsible for emergency management. The assessments of the possible radiological consequences of the scenarios as described were conducted by running the computer code JRodos – the reference computer code in development under the EC auspices [1]. The European Realtime Online Decision Support System for nuclear emergency management (RODOS) is a synthesis of many innovative methods and

[1] Department of Life and Environmental Sciences, Horia Hulubei" National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Reactorului Str. No. 30, PO-Box: MG-75126, Bucharest-Măgurele, Romania (e-mail: alexandru.pavelescu@nipne.ro).
[2] Chairman of Physics Section, Academy of Romanian Scientists (ARS), Ilfov Street, No. 3, Sector 1, Bucharest, Romania (mpavelescu2002@yahoo.com)

techniques. Forecasting modules predict how contamination would spread following atmospheric and aquatic releases of radiation. A set of models calculate the best estimate of the current and evolving radiological situation in contaminated inhabited and agricultural areas. Dose models predict the dose to individuals and communities for all exposure pathways not related to ingestion, both with and without the application of countermeasures. In the almost three decades that have passed since the beginning, hundreds of scientists and software engineers, emergency managers and stakeholders in many European countries were involved in the multitude of projects like EURANOS [2] and NERIS-TP [3].

In more recent times, a Java-based successor version of RODOS was issued in 2009 under the name JRodos [4]. It operates on modern information technology platforms and shows good performance and operational stability. JRodos simulation models account for atmospheric transport and deposition phenomena and the resulting terrestrial exposure pathways after an accidental release of radioactive material into the environment. The released volumes of air follow the wind flow. With growing distance, the initial nuclide concentration is diluted because uncontaminated air gets mixed in, and the cloud will spread until it reaches an inversion lid. The passing cloud causes external exposure by gamma irradiation and internal exposure by inhalation of radioactive air near ground. Dry and especially wet deposition processes lead to radioactive contamination of surfaces, causing external exposure by gamma irradiation. In addition, material deposited onto natural surfaces can finally end up in the human food chain and lead to internal exposure by ingestion of contaminated food products

Current JRodos world-wide usage implies that it can tackle radioactive releases anywhere on the globe. It cannot not be taken for granted that appropriate national meteorological data would be available for running JRodos.
In the RODOS-Lite data entry interface (Fig. 1), the input parameters are introduced in order to initialize the calculation sequence, accessing the appropriate module for calculating Radiological Dispersal Device (RDD) radionuclide releases.

Fig. 1. JRodos Graphical User Interface, RODOS-Lite.

Input data in JRodos models can be national weather data online from weather towers or numeric data for global weather forecast such as those from the United States National Center for Environmental Predictions (NOAA-NCEP) available through the NOMADS online service [5]. Thus, this data can be downloaded for the desired period as numerical forecast data up to 120 hours (5 days) or as retroactive reanalysis data. The downside is that the spatial resolution is lower disregarding local conditions, although it has been substantially improved in recent years. The models of transport and atmospheric dispersion for the close field (LSMC) on a radius of up to 800 km around the emission point, implemented in JRodos are of several types, namely: models of Gaussian "puff" such as RIMPUFF (developed within Risø, Roskilde) [6].

3. The Radiological Assessment

3.1. Postulated Scenarios

Assessment of situation for Ukraine NPP was made with JRodos system resident at IFIN-HH/DFVM with the purpose of determining the potential areas of influence on the Romanian territory in case of an RDD incident. The narrative of the considered scenarios involved the unintentional detonation of bomb hitting a CS-137 source on the premises of Chernobyl exclusion zone which is still contaminated, followed by the release of radioactive material into the atmosphere. Three scenarios were considered involving a given initial quantity of Cs-137 and three TNT equivalent yields.

Fig. 2. Location of Ukraine's NPP Map [7].

The simulations were carried out considering three possible scenarios for the quantities of propellant explosives of the radioactive material:

1) detonation of the RDD with an explosive quantity of 1 kg TNT equivalent;
2) detonation of the RDD with an explosive quantity of 10 kg TNT equivalent;
3) detonation of the RDD with an explosive quantity of 100 kg TNT equivalent

Input data for all three scenarios are given in Table 1.

Table 1. Input data for all scenarios.

Date and hour of event	27.10.2022; 11:00
Monitoring interval (hours)	8
Event localization	Chernobyl Exclusion Zone
Source emission localization (lat., lon.)	51.27024, 30.21945
Nuclide	Cs-137
Activity (Ci)	10 TBq (270 Ci)
Height emission (m)	2
TNT equivalent (kg)	1, 10, 100
Cloud modification rise factor	0.1
Model range (km)	40, 100, 400
Meteorology data	NOMADS (NOAA-NCEP)

3.2 JRodos Assessment

The JRodos assessments are presented below for the proposed scenario. Hence, the meteorological situation for the 8 h interval (27.10.2022; 11:00h – 27.10.2022; 19:00h) is considered for Chernobyl NPP Site, using numerical prognosis meteorology data from NOMADS Global Service (NOAA). The prognosticated maximum value of the *Total Effective Dose Equivalent* (TEDE) in mSv at the end of the 24 h interval is emphasized near source. Results could be displayed statically in single steps of 1 hour or rendered dynamically for 8 h to study the trajectory and evolution on the map of the contaminant cloud. The calculations were performed using the atmospheric dispersion gaussian model RIMPUFF with 48 calculation timesteps of 60 min and a range of 40-400 km. The RIMPUFF atmospheric dispersion model is a local-scale puff diffusion model developed by Risø DTU National Laboratory for Sustainable Energy of Denmark. It is a model to help emergency management organizations deal with chemical, biological and radiological releases to the atmosphere. It is in operational use in several European national emergency centres for preparedness and prediction of nuclear accidental releases, chemical gas releases, and for airborne virus spread. RIMPUFF uses parameterized formulas for puff diffusion, wet and dry deposition, and gamma dose radiation. Its range of applications covers distances up to ~1000 km from the point of release. RIMPUFF calculates instantaneous atmospheric dispersion considering the local wind variability and the local turbulence levels. The puff sizes represent instantaneous relative diffusion and is calculated from similarity scaling theory. Puff diffusion is parameterized for travel times in the range from a few seconds and up to one day

The situation assessment maps of the assessments for all three scenarios are shown in Fig. 3. 4 and 5.

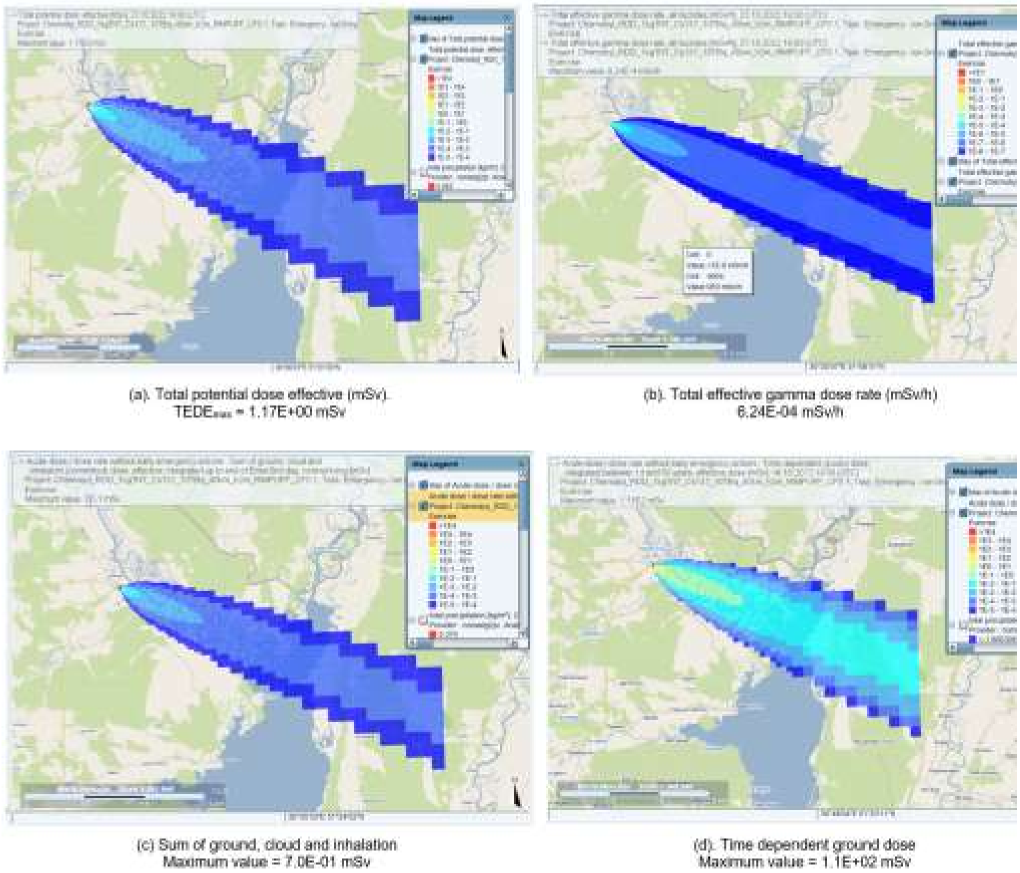
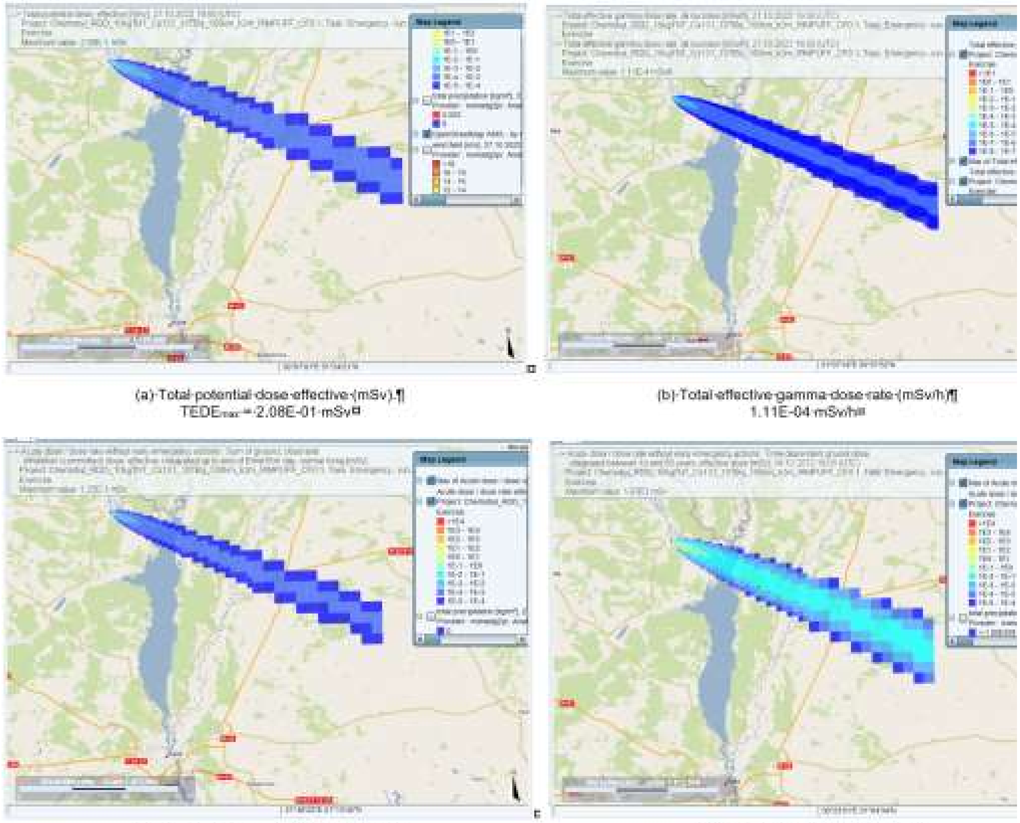


Fig. 3. Situation awareness maps for Scenario 1 (1 kg of TNT equivalent explosible)

Table 2. Dose results (near source) for scenario 1

Doses	**Maximum values**
Total Potential Dose Effective, TEDE (mSv)	1.17E+00
Total Effective Gamma Dose Rate, all nuclides (mSv/h)	6.24E-04
Acute dose without early emergency actions: sum of ground, cloud and inhalation (commited) dose effective integrated up to end of Emersim Day, normal living (mSv)	7.00E-01
Acute dose without early emergency actions: time dependent ground dose, integrated between 1 day and 50 years, effective dose (mSv)	1.11E+02



(a) Total potential dose effective (mSv).
$TEDE_{max}$ = 2.08E-01 mSv

(b) Total effective gamma dose rate (mSv/h)
1.11E-04 mSv/h

(c) Sum of ground, cloud and inhalation
Maximum value = 1.25E-01 mSv

(d) Time dependent ground dose
Maximum value = 1.97E+01 mSv

Fig. 4. Situation awareness maps for Scenario 2 (10) kg of TNT equivalent explosible)

Table 3. Dose results (near source) for scenario 2

Doses	**Maximum Values**
Total Potential Dose Effective, TEDE (mSv)	2.08E-01
Total Effective Gamma Dose Rate, all nuclides (mSv/h)	1.11E-04
Acute dose without early emergency actions: sum of ground, cloud and inhalation (commited) dose effective integrated up to end of Emersim Day, normal living (mSv)	1.25E-01
Acute dose without early emergency actions: time dependent ground dose, integrated between 1 day and 50 years, effective dose (mSv)	1.97E+01

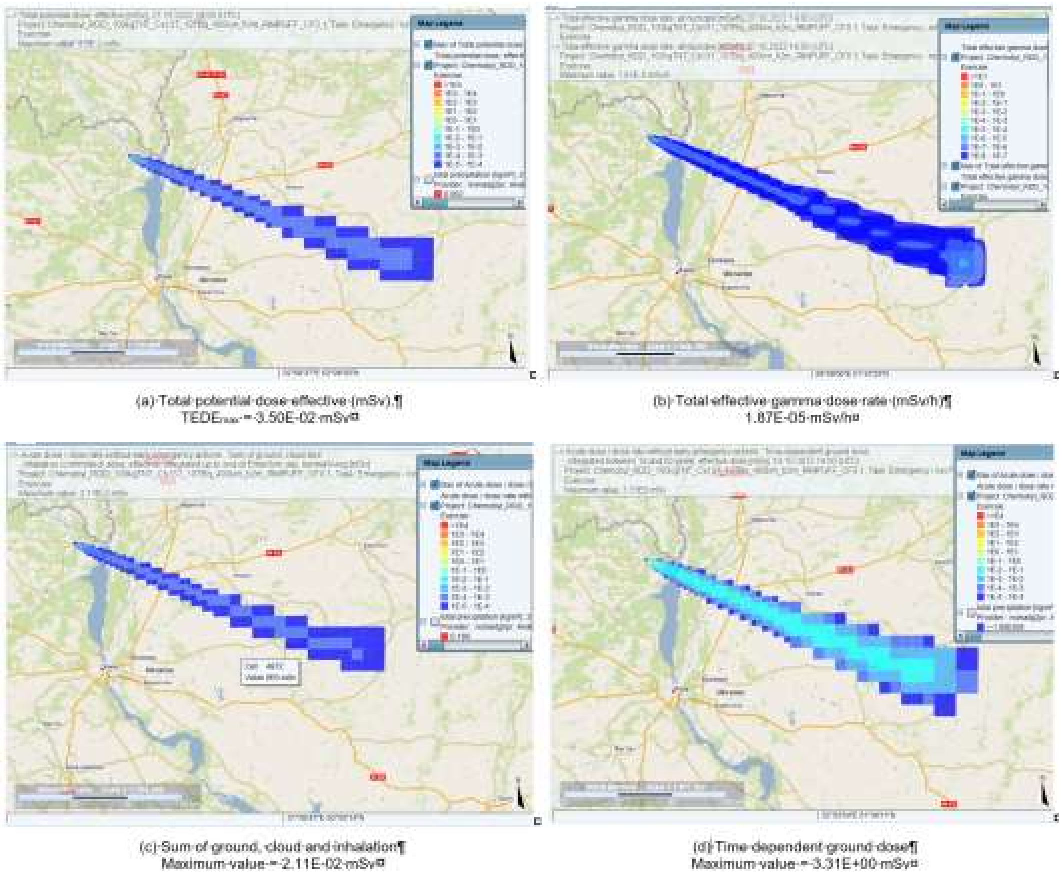


Fig. 5. Situation awareness maps for Scenario 3 (100) kg of TNT equivalent explosible)

Table 4. Dose results (near source) for scenario 3

Doses	**Maximum Values**
Total Potential Dose Effective, TEDE (mSv)	3.50E-02
Total Effective Gamma Dose Rate, all nuclides (mSv/h)	1.87E-05
Acute dose without early emergency actions: sum of ground, cloud and inhalation (commited) dose effective integrated up to end of Emersim Day, normal living (mSv)	2.11E-02
Acute dose without early emergency actions: time dependent ground dose, integrated between 1 day and 50 years, effective dose (mSv)	3.31E+00

We have taken into consideration the dose equivalent values that are considered to be of importance in taking the necessary countermeasures. The assessment dose values for the proposed scenarios are summarized in Tables 2, 3 and 4. We emphasize the fact that in this kind of assessment, the maximum intervention dose level (TEDEmax) is considered of importance by the first responders.

4. Conclusions

Potentially affected areas in Ukraine were assessed with the decision support systems JRodos. The visual and numerical results presented represent the protective quantities (i.e. equivalent and effective doses) oriented towards pre-emptive/immediate intervention: the Total Effective Dose Equivalent (TEDE), Acute Lung, Acute Bone and Thyroid (TTHD) expressed in mSv. Therefore, the situational maps in the paper render the affected area in respect to the projected TEDE from the time integrated concentration over the monitoring time, which is considered the most important dose for protective actions.

After the potential exposure areas have been assessed, we could conclude that the maximum values of TEDE are 1.17 mSv for Scenario 1, 0.21 mSv for Scenario 2 and 0.04 mSv for Scenario 3. We observe that a smaller explosive yield generated higher contamination concentrated on a smaller area than a higher explosive yield which spread the contamination over a larger area.

We can conclude that given the low levels of doses assessed in the potentially affected areas it is reasonable to say that an RDD event in Chernobyl zone will not influence the national territory of Romania. Even using the most unfavourable meteorological data with a wind direction towards Romanian territory, in the expert's best guess source term scenarios, the threat is negligible due to the distance of circa 1000 km between Chernobyl and Romanian border, and therefore poses no risk to both the Romanian public and the environment.

Closer investigating of such an event in the vicinity of the state frontier remains necessary and will constitute the subject of a new more detailed study using models of CBRNE software as well.

R E F E R E N C E S

[1] RODOS: Realtime Online Decision Support System for nuclear emergency management, Last modified: Mar 25, (2015).

[2] EURANOS: European approach to nuclear and radiological emergency management and rehabilitation strategies Research project under the European Commission's 6th Framework Programme, EURATOM Research and Training Programme on Nuclear Energy (2002-2006), contract no. FI6R-CT-2004-508843.

[3] NERIS-TP: Towards a self-sustaining European Technology Platform (NERIS-TP) on Preparedness for Nuclear and Radiological Emergency Response and Recovery. Research project under the European Commission's 7th Framework Programme, EURATOM for Nuclear Research and Training Activities (work programme 2010), Fission-2010-3.3.1, Grand Agreement Number 269718 European Technology Platform (NERIS-TP) on Preparedness for Nuclear and Radiological Emergency Response and Recovery.

[4] JRodos, Java based RODOS version. Real-time On-line DecisiOn Support) system for off-site emergency management after nuclear accidents, Last modified: Dec 20, (2019).

[5] National Oceanic and Atmospheric Administration (NOAA) Operational Model Archive and Distribution System (NOMADS).

[6] Thykier-Nielsen, S., Deme S., Mikkelsen, T., Description of the Atmospheric Dispersion Module RIMPUFF (1999), Risø National Laboratory RODOS(WG2)-TN (98)-02.

[7] Nuclear Newswire. Focus on Ukraine. Feb 18, 2022. https://www.ans.org/news/article-3676/focus-on-ukraine/.