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Atmospheric Dispersion Modelling for a Hypothetical Nuclear Accident

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INTRODUCTION AND MAIN RESULTS

Atmospheric dispersion and dose assessment models were applied to evaluate the behavior of radioactive material released into the air and radiation effects for the hypothetical nuclear accident at Zaporizhzhia. From the simulations, the radioactive plumes transported in the area of European countries near the Zaporizhzhia in early phase of the accident and they moved to the Asian areas by westerlies after one week of the accident.

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Introduction

After the outbreak of the war between Russia and Ukraine in February 2022, the Zaporizhzhia Nuclear Power Plant (NPP) came under Russian control, raising global concerns about its safety amid the ongoing conflict. If the cooling system fails due to power supply disruptions caused by airstrikes or unexpected accidents, a large amount of radioactive material might be released into the environment. The atmospheric dispersion of radioactive materials and the resulting radiation dose were assessed for a hypothetical accident at the Zaporizhzhia NPP in Ukraine.

The evaluation utilized atmospheric dispersion and dose assessment models, both of which are key components of the Radiological Accident Preparedness System in Korea (RAPS-K) developed by the Korea Atomic Energy Research Institute.

Simulation results showed that radioactive plumes initially moved to the western across Europe, and later, some plumes were transported to the Asia due to westerly winds. Dose assessments revealed that effective radiation doses were showed above 1 mSv in certain areas near the Zaporizhzhia plant, while radiation exposure remained below 0.1 mSv across the rest of Europe, Asia, and North America.

Methods

Atmospheric dispersion model named LADAS (Lagrangian Atmospheric Dose Assessment System) was developed to evaluate the dispersion and deposition characteristics of radioactive materials released into the atmosphere.

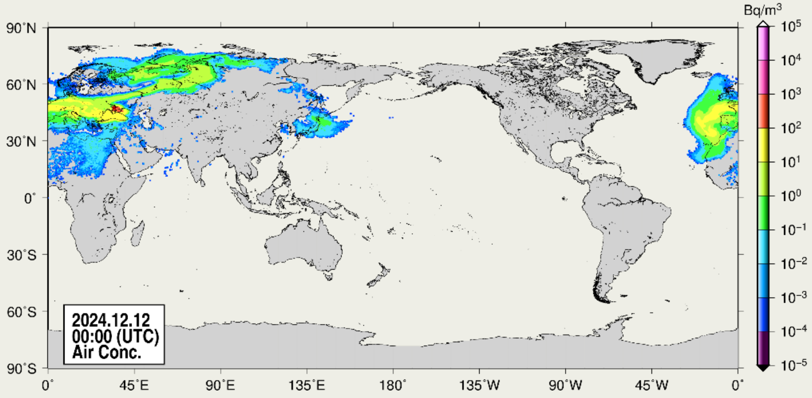
This model calculates air concentrations, dry and wet depositions within a three-dimensional domain. It incorporates removal processes such as dry/wet deposition and radioactive decay. A particle is transported by mean wind velocities and turbulent motion in three-dimensional space. The motion of a particle is presented by a sum of the movements due to advection and dispersion.

Exposure dose assessment model named LARIAS (Land and Aquatic Radiological Impact Assessment System) developed to evaluate exposure doses by considering both internal and external pathways.

This model can calculate effective doses to individuals over short-, intermediate-, and long-term periods from radionuclides released into terrestrial and aquatic environments. It includes five exposure pathways: inhalation, cloudshine, groundshine, resuspension and ingestion.

Results

Simulations were conducted under the assumption that ^{131}I and ^{137}Cs were continuously released into the atmosphere at 1,760 PBq and 73.4 PBq, respectively, over ten days from December 1 to December 11, 2024, and total calculations were performed for four weeks. The simulation period was arbitrarily selected for the hypothetical assessment. Meteorological data which is an important input for the atmospheric dispersion model, was obtained from the global numerical forecast dataset of the Korea Meteorological Administration (KMA).



Calculated air concentration profiles of ^{131}I near surface

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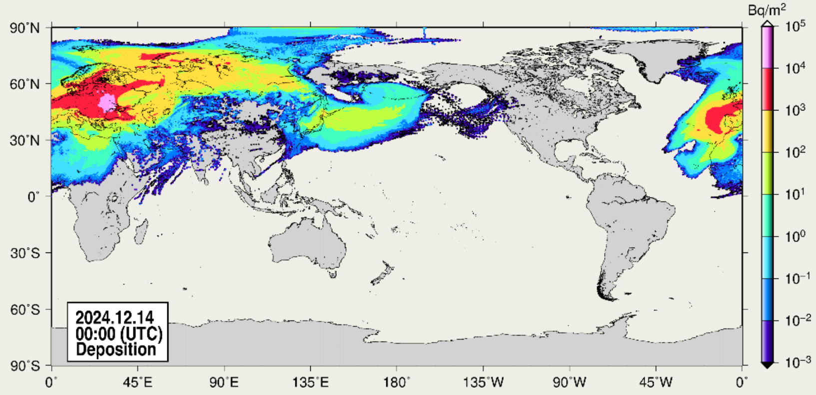
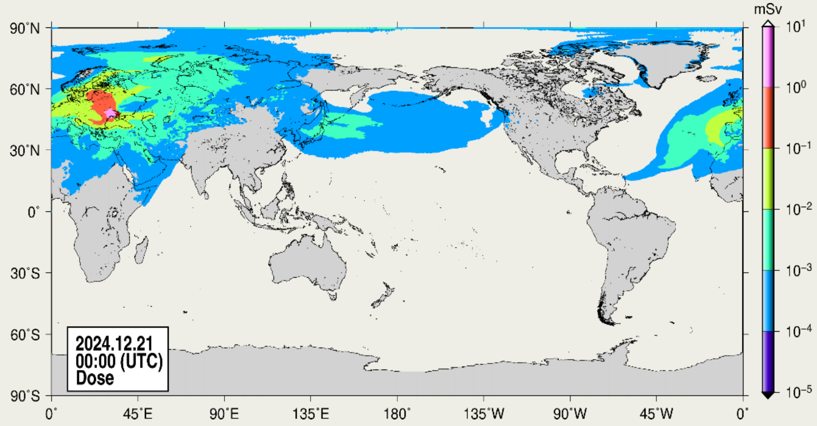
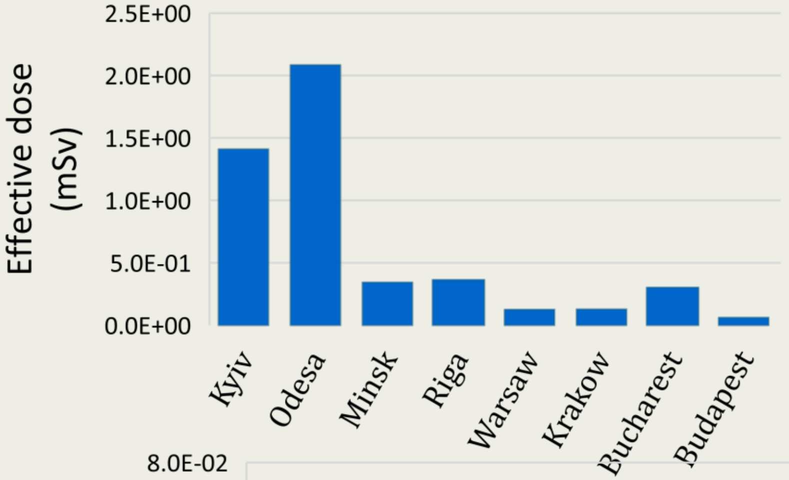
Results

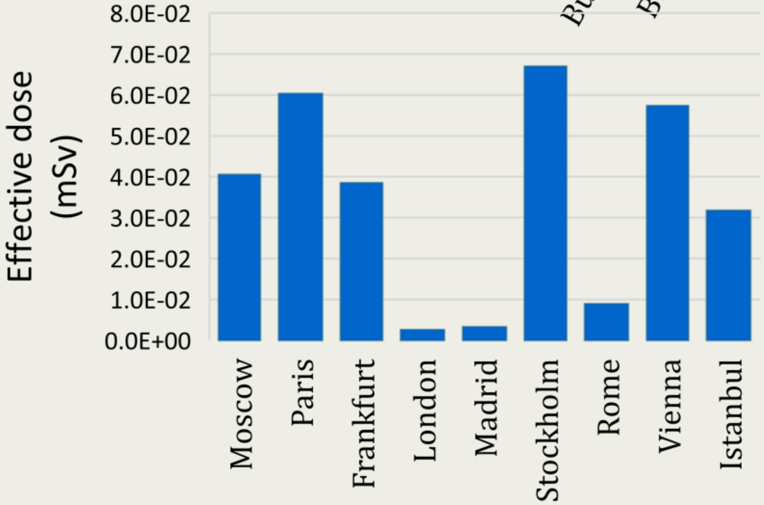


Calculated ground deposition of ^{137}Cs



Effective dose distributions in ten days and three weeks after the accident





Effective dose in four weeks after the release in selected European cities

Simulation results indicated that the radioactive materials initially moved toward Europe due to easterly winds and dispersed across the entire Northern Hemisphere within three weeks.
The dose assessment revealed that radiation exposure was presented above 1 mSv near the Zaporizhzhia NPP.
The effective doses presented the value of 1.4 mSv and 2.1 mSv, respectively in Kyiv and Odessa located west of the affected site, whereas other major European cities remained below 0.1 mSv. Asia and North America remained below 10-4 mSv, therefore radiological impact in these areas showed insignificant from the hypothetical accident at Zaporizhzhia NPP.

Conclusions

Overall, the radiological impact of the hypothetical accident based on the assumptions of this study was found to be insignificant, except in the vicinity of the Zaporizhzhia NPP.
The RAPS-K developed by the KAERI is currently in real-time operation to assess the dispersion of radionuclide and radiological impact for potential nuclear accidents around the world. The system will be operated more efficiently in connection with radiation monitoring.

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