Global risk from the atmospheric dispersion of radionuclides by nuclear power plant accidents

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Outline

NPP Global Atmospheric Risk

Model Simulations

Model Validation: Fukushima NPP Accident

- 8 Emissions
- A Risk Assessment

Global Surface Level Concentration Risk Seasonal Variability Ground Deposition Relative Population Risk

- Our Contract Structures
- Outlook

NPP Global Atmospheric Risk

Estimate global risk from atmospheric dispersion of radionuclides from nuclear power plant (NPP) accidents

Risk Assessment Model: Relative, Climatological - no assumption on time of accident and emission profile:

- Use global atmospheric model (EMAC: ECHAM5/MESSy)
- Emission and transport of aerosol and gas radionucludes
- Constant continuous emissions from each NPP (1000 hPa)
- Removal through decay (gas), dry & wet deposition (aerosol)
- Relative Risk estimate: *Normalized Climatic* average of surface concentrations, cumulative ground depositions



Model simulation

20 yr run (2010–2030) for climatic representability:

- Model boundary conditions (SST) from IPCC A2 scenario
- Concentrate on two radio-isotopes with adverse effects:
- Caesium ¹³⁷Cs:
 - Water-soluble aerosol
 - Long decay half-life (30 yrs) no simulated decay
 - Removed predominantly through precipitation and 5-10% dry deposition & sedimentation
- lodine ¹³¹I:
 - Modeled purely in the gas phase
 - Atmospheric removal through exponential decay (half-life 8 days)



Model Validation: Fukushima Accident

- Model setup validated for Fukushima NPP accident
- Simulated of ¹³⁷Cs, ¹³¹I, ¹³³Xe transport, decay & deposition
- Emission profiles by i) Stohl et al., ii) JAEA
- Meteorology driven by ECMWF ERA-Interim reanalysis
- Model validated against CTBTO global station measurements



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NPP Risk Analysis

Nuclear Power Plants Emission Sources



Surface Level Concentration ¹³¹

Mean 20-yr surface-level concentration of gaseous ¹³¹I



Risk highest in US mid-west, east, Japan continental Europe, maximum in southwestern Germany

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NPP Risk Analysis



Risk Seasonal Variability



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Ground Deposition ¹³⁷Cs

Climatological total global cumulative dry and wet deposition & sedimentation of aerosol $^{137}\mathrm{Cs}$



Enhanced risk over tropics: wet deposition due to heavy precipitation

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National Risk Distribution



Nuclear policy making at the national level: Provide risk estimates for all NPP opearated/planned by each country/nation

Data for all countries available online

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Relative Risk by Country

Relative Risk Index (RRI) = Relative Concentration/Deposition \times Population Exposed



Highest risk index globally by USA, followed by India and France

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NPP Risk Analysis

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Relative Risk Planned & Proposed NPP



Future risk index to become highest in China, followed by India and the USA.



Statistical Uncertainty





Coefficient of variation (σ/μ) :

- Overall within 5%
- Does not exceed 20% locally

Temporal variability appropriately captured

Outlook

Refinements underway:

- Runs at higher resolution $(120 \rightarrow 50 \text{ km})$ for impacts
- Ensemble of IPCC scenarios for systematic uncertainty range

Future Outlook:

- Data available for interfacing with impacts studies (e.g. human health)
- Per country itemized risk analysis possibility available
- Model available and open for collaborations on NPP risk assessment
- Global Climatological Risk Assessment approach complementary to regional/scenario specific studies



References

T Christoudias, Y Proestos, J Lelieveld

Atmospheric Dispersion of Radioactivity from Nuclear Power Plant Accidents: Global Assessment and Case Study for the Eastern Mediterranean and Middle East *Energies* 7 (12), 8338-8354

T Christoudias, Y Proestos, J Lelieveld Global risk from the atmospheric dispersion of radionuclides by nuclear power plant accidents in the coming decades *Atmospheric Chemistry and Physics* 14 (9), 4607-4616

T Christoudias, J Lelieveld Modelling the global atmospheric transport and deposition of radionuclides from the Fukushima Dai-ichi nuclear accident Atmospheric Chemistry and Physics 13 (3), 1425-1438

