



UK Health
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Improved modelling of the radiological consequences and remediation effectiveness after nuclear blast fallout in inhabited areas

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Outline

- Background to the project
- Overview of the ERMIN tool
- Identification of missing radionuclides
- Reconciling ERMIN particle groups to those following nuclear detonation
- Short- and long-term recommendations for ERMIN



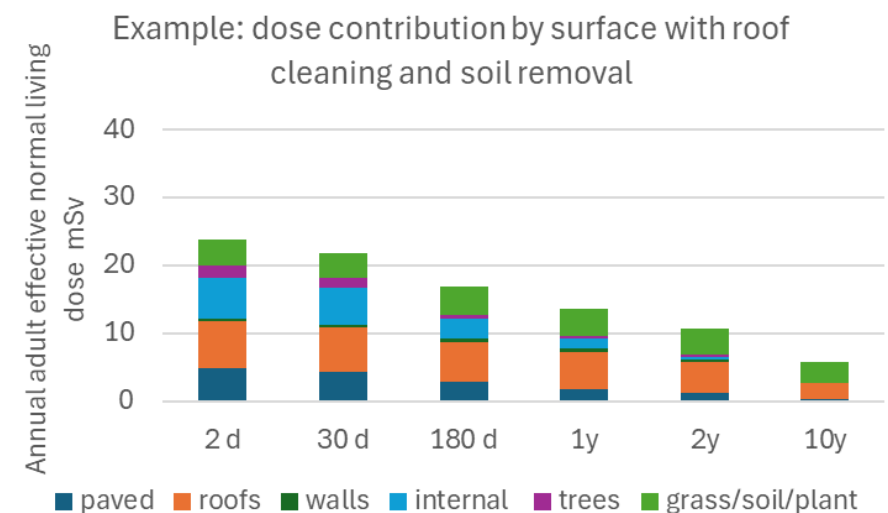
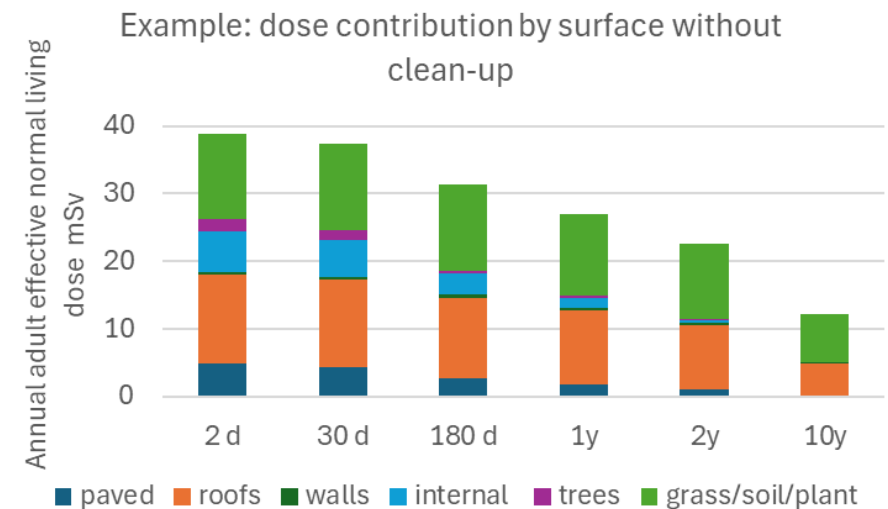
Project background

- A subtask of PREDICT WP 2. 2
- Application of ERMIN to nuclear detonation (ND) scenario - at distances where “normal life” can continue, and the primary challenge is the long-term management of environmental contamination
- Two questions:
 - Which missing radionuclides are significant for ND scenarios and long-term exposures?
 - How current particle group parameters in ERMIN can be used and adapted for ND?
- Recommendations for ERMIN modifications in the short and long term.
- Identify further research requirements

ERMIN overview

ERMIN, the EuROpean Model for INhabited areas, [versions implemented in RODOS and ARGOS].

- Supports remediation following nuclear accidents
 - long-term projected and residual doses
 - duration that doses exceed reference levels
 - impact of remediation strategies
 - resources, cost, and waste amount/activity
- Starts from initial deposition to ground
 - distributes radionuclides across urban surfaces (paved, walls, roofs, trees etc).
 - long-term weathering modelled with empirical retention functions,
 - clean-up represented by redistributing radioactivity from surfaces.
 - indoor/outdoor doses for standard built environments are calculated using a library of unit dose rates derived from Monte Carlo particle transport studies.
- Most ERMIN functions/parameters are empirical, based on Chornobyl
- A nuclear detonation (ND) scenario introduces substantial uncertainty.
- Experimental or observational data for ND events are very limited.



Identification of missing radionuclides

Current radionuclides chosen because expected to be significant in recovery phase of nuclear accident.

Are significant ND recovery radionuclides missing?

Used PREDICT vector – 359 ranked according to contribution to a proxy dose¹

- excluded: half-life < 7days, and not in equilibrium with parent
- excluded: external dose < 0.5% of total in periods 1-30, 30-365 and 365-720
- excluded: inhalation dose <1% of total in periods 30 days, 6 months, 1 year and 5 years

Rank	Nuclide	Half-Life	Relative dose %	Comments
1	¹³¹ I	8.0207 d	3.63	In ERMIN
2	⁹⁵ Zr	64.032 d	3.20	In ERMIN
3	¹⁰³ Ru	39.26 d	3.14	In ERMIN
4	¹⁴⁰ Ba	12.752 d	2.01	In ERMIN
5	⁹⁵ Nb	34.991 d	0.89	In ERMIN
6	¹⁴⁷ Nd	10.98 d	0.54	In ERMIN
7	¹³⁶ Cs	13.16 d	0.49	In ERMIN

Rankings external 1 – 30 days

Rank	Nuclide	Half-Life	Relative dose %	Comments
1	¹⁰⁶ Rh*	29.8 s	28.77	In ERMIN
2	⁹⁵ Nb	34.991 d	26.80	In ERMIN
3	¹²⁵ Sb	2.75856 y	12.34	
4	⁹⁵ Zr	64.032 d	11.90	In ERMIN
5	^{137m} Ba*	2.552 m	10.48	In ERMIN
6	¹⁴⁴ Pr*	17.28 m	6.01	In ERMIN
7	¹⁴⁴ Ce	284.91 d	2.57	In ERMIN
8	¹⁰³ Ru	39.26 d	0.66	In ERMIN

Rankings external 365 – 730 days (* in secular equilibrium)

Most significant radionuclides already in ERMIN,
Recommended to add ¹²⁵Sb and daughter ^{125m}Te

¹ Axelsson, A. and P. Kock (2025). WP9 [D9.29] PREDICT – D1.1 Identification of radionuclides of potential importance for different time phases in fallout from nuclear explosions.

Suitability of particles groups in ERMIN for ND: Current ERMIN scheme

ERMIN “Particle groups” link radionuclides to parameters for distributing across urban surface and for long-term weathering

User picks a scenario to apportion radionuclides to particles groups (or proportion specify directly)

Are current particle groups suitable for ND?

New scenarios for ND?

		Current ERMIN NPP scenarios			
		No fuel particles, no oxidation (default)	Significant fuel particles, no oxidation	No fuel particles, significant oxidation	Significant fuel particles and significant oxidation
Current ERMIN particle groups	Soluble particles < 2 µm	Cs 100% Ru 0%* Pu 0%*	Cs 50% Ru 0% Pu 0%	Cs 50% Ru 95% Pu 0%	Cs 50% Ru 50% Pu 0%
	Fuel particles 2-5 µm	Cs 0% Ru 5%* Pu 5%*	Cs 2.5% Ru 5% Pu 5%	Cs 2.5% Ru 0.25% Pu 5%*	Cs 2.5% 2.5% Pu 5%
	Fuel particles 5-10 µm	Cs 0% Ru 45%* Pu 45%*	Cs 22.5% Ru 45 Pu 45%	Cs 22.5% Ru 2.25% Pu 45%*	Cs 22.5% Ru 2.25% Pu 45%
	Fuel particles 10-20 µm	Cs 0% Ru 50%* Pu 50%*	Cs 25% Ru 50% Pu 50%	Cs 25% Ru 2.5% Pu 50%*	Cs 25% Ru 25% Pu 50%
		* Not expected in this scenario			

Suitability of particles groups in ERMIN for ND: ND particle forming processes

Simple description of particle forming processes:

- Everything vapourised, then temperature decreases rapidly
- At 3000°C formation of liquid drops
 - refractory elements distributed homogenously through drops
 - drops solidify with refractory elements contained – smaller particles known as N1
 - in air burst only N1 particles formed
- Near ground burst incorporates vapourised debris - most of the contaminated mass
- This mass solidifies around 1500°C (≈melting point of soil) – larger particles known as N2
- Relatively volatile elements tend to form on the surface of particles (N1 and N2)
- N2 particles can be relatively very large

Simple classification of elements:

- Volatile: Ba, Cs, I, Rb, Sr, Te, Zn, Ru and ^{141}Ce
- Refractory: All other radionuclides in ERMIN including other isotopes of Ce

Suitability of particles groups in ERMIN for ND simplifying assumptions

Assumed:

- Air burst only N1 particles:
 - refractory elements locked inside, volatile elements on the surface
- Ground burst, N1 and N2 particles:
 - refractory elements in N1, volatile elements on surfaces of N2

Current ERMIN particle groups don't quite fit:

- Refractory elements locked in N1 – urban distribution like '< 2µm soluble' group but lower long-term mobility
- Volatile elements on N2 surface – urban distribution like 'fuel particle' groups but higher long-term mobility
- N2 particles come in a range that extends to sizes larger than 20 µm

Suitability of particles groups in ERMIN for ND: new ERMIN particle groups proposed

4 new ERMIN particle groups proposed

Combining properties from the existing particle groups:

- “N1 interior” – urban distribution of “< 2µm soluble” + low mobility of ‘fuel particles’
- 3 x “N2 surface” groups – urban distribution of 3 x “fuel particles” + high mobility of “< 2µm soluble”

Suitability of particles groups in ERMIN for ND: new proposed scenarios

Air burst scenario

- 100% volatiles assigned to existing “soluble particle”
- 100% refractory assigned to new “N1 interior” group

Ground burst

- 100% refractory assigned to new “N1 interior” group
- Volatiles spread across new “N2 surface” groups – but how to apportion?

Required insight into the mix of sizes deposited at distance (10s-100s km)

Asked PREDICT partners for assistance – i.e. for ADM output of deposition by particle size

Norwegian Meteorological Office and RIVM were able to help

ADM Model Insights

Norwegian Met Office, 3 cases:

- 2 US weapon tests
- 1 hypothetical scenario, at Bergen

50 particle sizes from 0.6-500 μm radius
(c 2-1500 μm AMAD)

Total, wet and dry accumulated deposition, to c3000km

RIVM, 1 case (more to follow):

- US weapon test

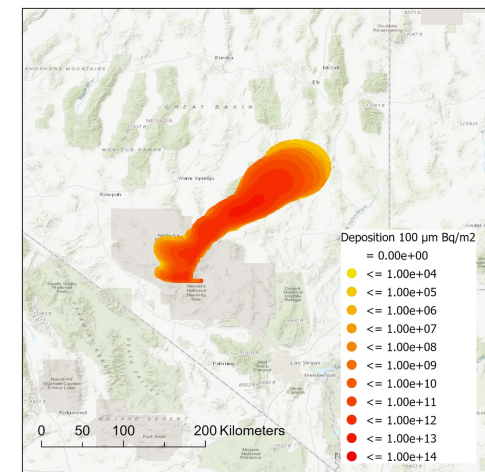
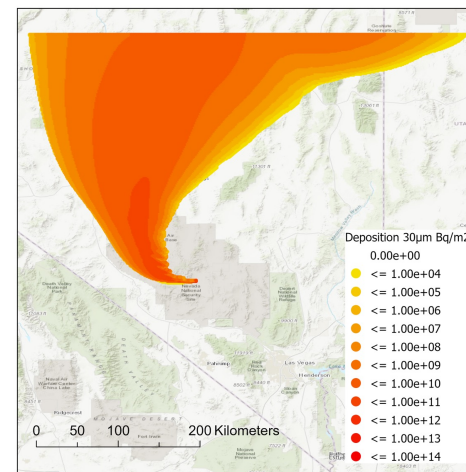
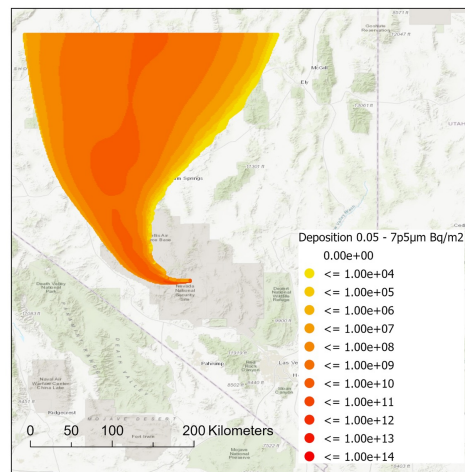
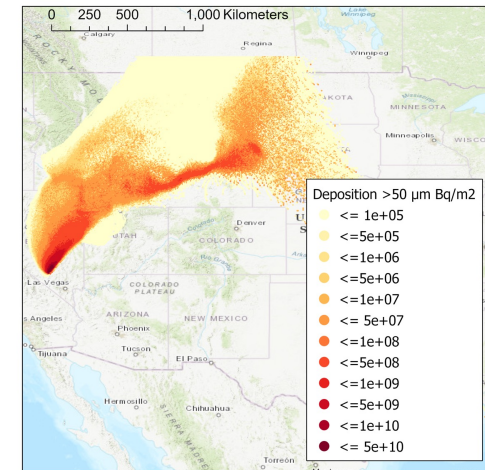
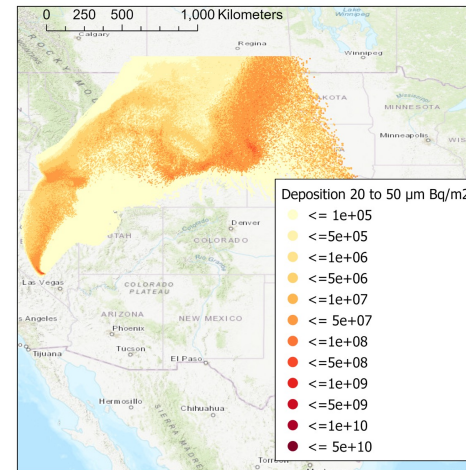
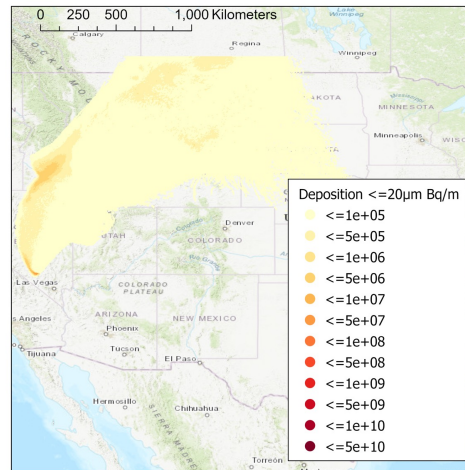
6 particle sizes: 0.05 0.55, 3.0, 7.5, 30, 100 μm AMAD

Total accumulated deposition, to c400km

Both models predict that large and very large particles are significant to far distances, 100s of km.

Sorting by atmospheric processes

‘Nancy’ case



Particle group recommendations

- Three new ERMIN scenarios:
 - Air burst scenario
 - 100% refractory “N1 interior”
 - 100% volatiles “soluble particle”
 - Ground burst default
 - 100% refractory “N1 interior”
 - 100% volatiles “N2 surface > 10 μm ”
 - Ground burst (far)
 - 100% refractory “N1 interior”
 - 50% volatiles “N2 surface 5 -10 μm ”
 - 50% volatiles “N2 surface > 10 μm ”

Source of uncertainty (the small print)

Sources of uncertainty remain:

- Analysis based on a simple story of ND particle formation
- Division into volatile and refractory is simplistic –
 - but probably the best we can do at this stage
- Largest particle size in ERMIN (10-20 μm) < very large particles in ground burst
- Omission of short-lived radionuclide impacts very short period doses.
 - consider projected/residual dose only after 48 hours
- Particle size/distance dependent on model assumptions, especially initial distribution of particle sizes

Long-term recommendations

In the longer term:

- Refine understanding of particle forming processes
- Obtain/derive (somehow) better parameters for ND specific particle groups
- Refine assumptions about particle size and distance travelled, consider other ADM models
- Consider challenges of linking of ERMIN and ADM (mapping ADM particle size to ERMIN particle groups)

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