UK Health Security Agency

PIANOFORTE
EUROPEAN PARTNERSHIP FOR RADIATION PROTECTION RESEARCH

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PREDICT

PREDICT Work Package 2: Preliminary progress with the improvement of atmospheric dispersion and radiological dose assessment models applied to nuclear detonation scenarios

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Determine the current (baseline) modelling capability

Current (baseline) capability of each organisation in respect of modelling & provision of radiological protection advice in the event of a nuclear detonation scenario (were such an incident to happen in early 2024)…

- Includes contributions from: Denmark (DEMA & DTU), Germany (BfS and KIT), Netherlands (RIVM), Norway (DSA and NMBU), Sweden (SSM) and UK (MO and UKHSA).
- Topics covered:
  - Atmospheric dispersion modelling
  - External gamma dose from material deposited on surfaces
  - Food-chain transfer models
- Details:
  - the approach and parameterisations applied, inputs employed and assumptions made.
- Value:
  - facilitate the identification of gaps & aspects for improvement in models
  - a baseline - such that recommended improvements will have context & figure prominently.

Task 2.1: Improvements in atmospheric dispersion modelling following a nuclear detonation

UKMO (lead), DEMA, DSA, DTU, Met No, NMBU, RIVM, SSM

- Improvements will include enhanced model input parameters & advanced modelling approaches.
- Recommendations will be guided by
  - Outcomes of WP1 (source term description)
  - Experience & modelling techniques developed for radiological assessment studies
    - Including planning for accidents and responding to accidents, such as the incidents at the Chernobyl and Fukushima Nuclear Power Plants
  - Knowledge garnered and modelling developed for parallel applications
    - e.g., volcanic ash studies
  - Requirements for dose and food-chain modelling (Tasks 2.2 & 2.3)

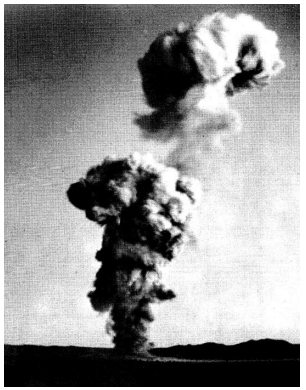


Improvements in atmospheric dispersion modelling

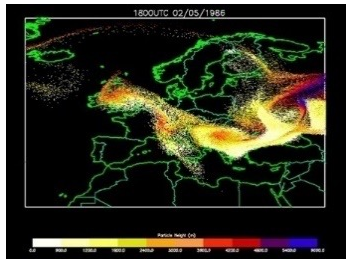
- Improvements to
  - Source term description
    - Radionuclides, particle properties (size distribution, density, shape, sphericity, solubility), activity, source shape, spatial distributions,…
  - Input meteorological data
    - Resolution (temporal & spatial), meteorological fields
  - Atmospheric dispersion model setup and parameterisations
    - Wet & dry deposition, sedimentation, turbulence, convection, radioactive decay,…
  - Output produced
    - Quantities, spatial and temporal resolution, processing (averaging, instantaneous, etc.)



Meteorological Data



Source Data



Dispersion Model

Forecast Output

Atmospheric dispersion modelling reviews



- Baseline modelling capability

2 Description of the baseline modelling capability for a response to a nuclear detonation incident 7

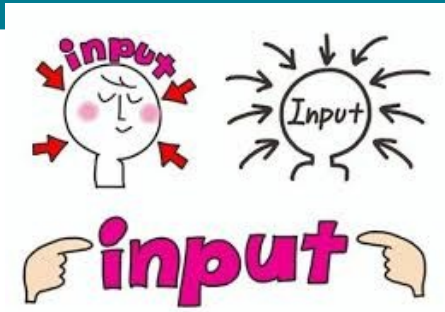
2.1 Denmark / DEMA (and DTU) 7
2.2 Germany / BfS (and KIT) 11
2.3 Netherlands / RIVM 18
2.4 Norway / DSA (and NMBU) 21
2.5 Sweden / SSM 28
2.6 United Kingdom / MO & UKHSA 33

- Literature
  - Nuclear detonations
  - Radiological assessment studies
  - Nuclear power plant incidents
  - Parallel applications

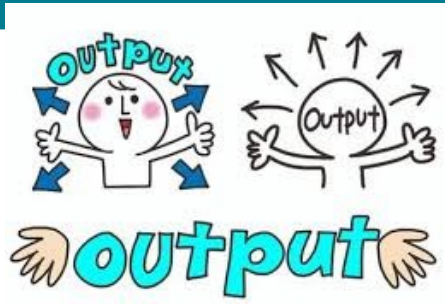
- Identify atmospheric dispersion modelling
  - Commonalities & differences
  - Recommendations
  - Limitations
  - Sensitivities

➢ Review paper?

Interactions with other WPs



- WP1: Characterization of the source term description for the stabilised cloud
  - How to represent the source term accurately for different blast conditions
- WP2 (tasks 2.2 & 2.3):
  - How to produce the optimal atmospheric dispersion output for dose & food-chain modelling

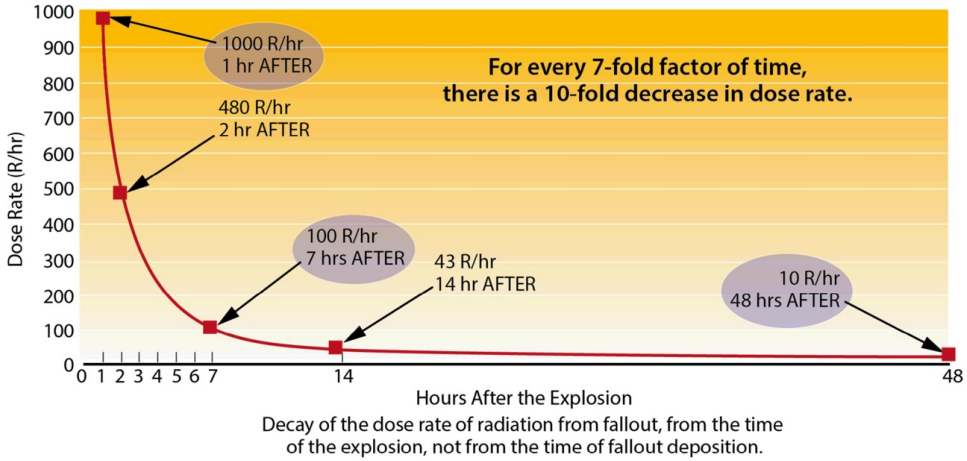


- WP3: Model comparison and validation using historic events & sensitivity analysis
  - Identify atmospheric dispersion modelling improvements
    - Recommended model parameters / parameterizations, set-ups
    - Model parameter distributions / ranges
  - Identify future longer-term improvements

Task 2.2 Improvement in external dose & dose rate modelling in the context of nuclear detonation scenarios

(UKHSA Lead, BfS, DEMA, DSA, DTU, EPA, KIT, NMBU, PDC-ARGOS, RIVM & SSM)

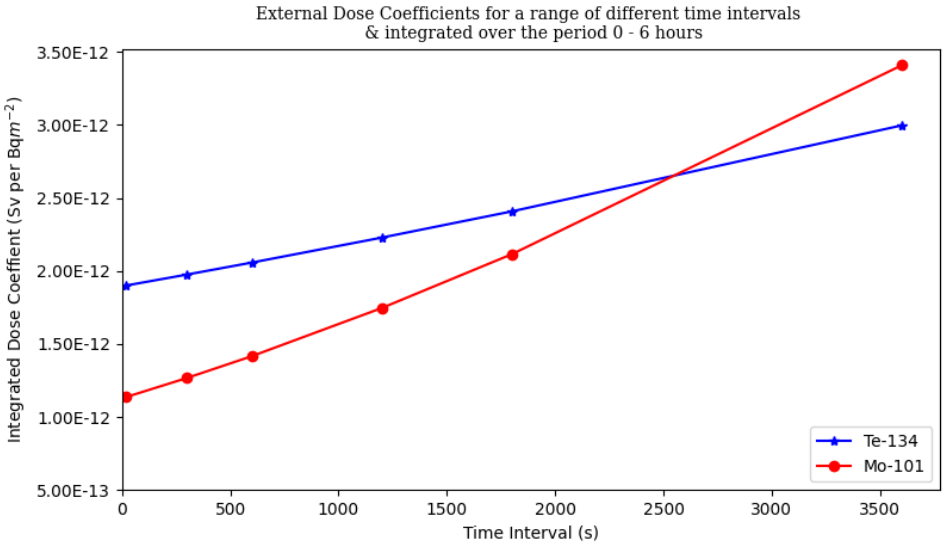
- External irradiation from deposition on surfaces tends to contribute most to dose;
- Model improvements to the assessment of dose from this exposure pathway provide the greatest gains;
- Therefore the external irradiation from deposition on surfaces exposure pathway is the focus for Task 2.2 (and not external irradiation from the plume nor inhalation from the plume).



https://remm.hhs.gov/nuclearfallout.htm

Improve modelling capability in respect of the application of external dose coefficient data

- Deposition Modelling:
  - Some modelling approaches assume all deposition occurs @ time = 0 for an instantaneous or short duration release.
  - Approach not pragmatic for ND scenarios.
  - A suitable approach will be sought & recommended.
- Identify & collate representative & practical external dose coefficients:
  - Use the radionuclide list developed in Task 1.1
  - Use ICRP 144
  - Suitably describe dose rate as function of time
  - Ensure the contribution from daughters is captured.
  - Soil migration (as a function of particle size?)?
- Review novel approaches for assessing the dose from external exposure, for example RIVM's single cocktail dose coefficient approach.



Improve the assessment of deterministic health effects (DHE)

Currently a simplistic & minimal approach is applied in ARGOS & RODOS:

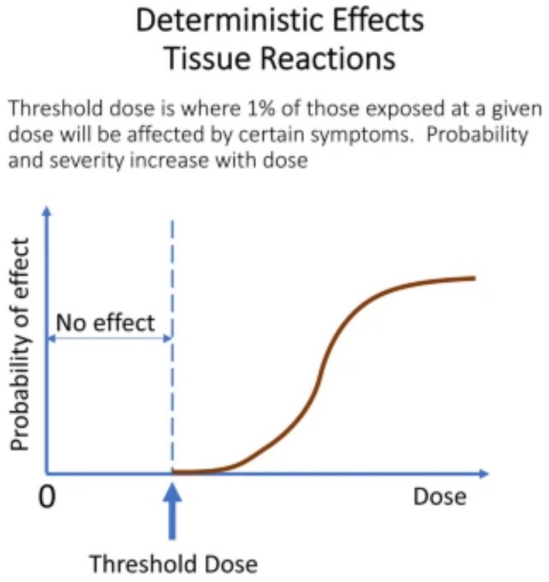
- Total effective dose and one or more equivalent dose to organ(s) for comparison with threshold values.

Dose criteria to the foetus (embryo, foetus brain) in IAEA GSR part 7 is low; the foetus is relatively sensitive compared to adult organs.

Neither ARGOS nor RODOS estimates foetus dose (RODOS infers from uterus dose).

Undertake a review:

- determine the approaches
- recommend one or more method(s) for application in DSS.
- recommend one (or more) model(s) for the foetus.



Review the applicability of currently used location factors to calculate external doses and recommend revisions where necessary in the context of nuclear detonation events

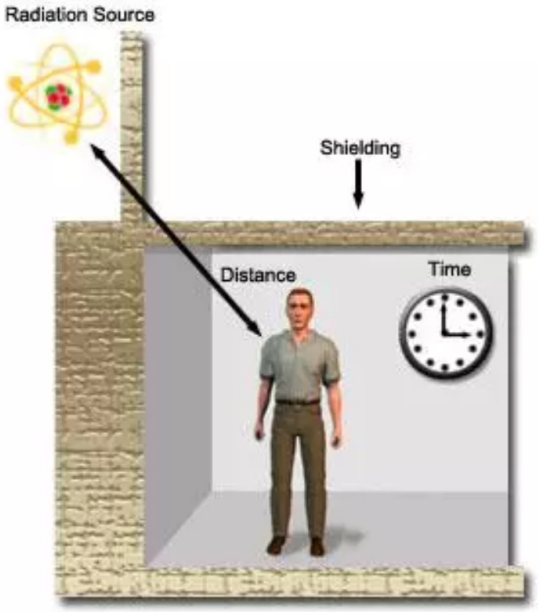
Regional & national analysis of geospatial data:

- Document current DSS approach & its applicability to ND scenarios.
- Explore other means of utilising large scale geospatial data to effectively categorize (urban) buildings & generate location factor mapping:
  - Remote sensing / satellite imagery data
  - GIS datasets

Local analysis of air exchange & indoor deposition rates of housing stock:

- Review (& develop) building ingress modelling.
- Assess air exchange rates & indoor deposition rates.
- Derive location factors e.g. using MCNP.

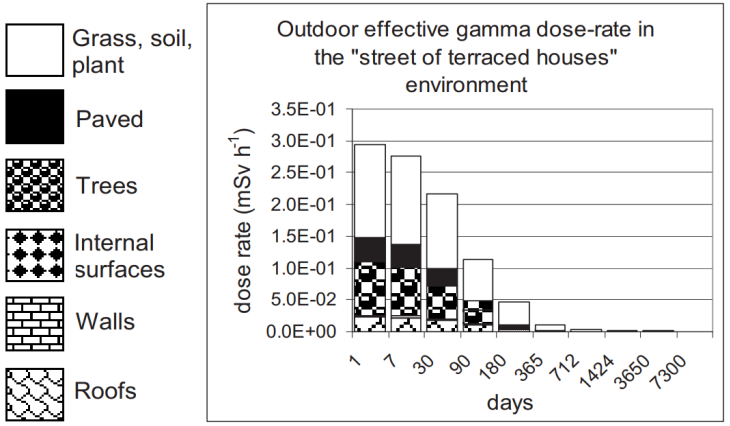
Review location factors for bomb shelters (tilfluktsrom) & comparable protection.



https://www.radiation-therapy-review.com/Radiation_Protection.html

Advances in recovery options following the contamination of an urban environment with radioactive material

- Updates to ERMIN (European Model for Inhabited Areas)
- Identify “new” radionuclides to add to ERMIN (progeny, dose per unit intake values, DCF)
- Determine unit doses for one or more of the environments defined in ERMIN (focus: brick house without basement)
- Create new deposition scenarios in ERMIN (based on chemical & physical form: particle type, size & susceptibility to weathering)
  - assign model parameters eg deposition ratios, retention parameters and countermeasure parameters
- Aspiration to feed into the versions of ERMIN applied in ARGOS and RODOS (for one environment).



Task 2.3 Application of food-chain transfer models following a nuclear detonation

(DSA Lead, BfS, DEMA, DTU, EPA, NMBU, SSM, UKHSA)

- Test applicability of commonly used foodchain models (e.g. FDMT, FARMLAND) to fallout from nuclear detonations by:
  - Investigating whether (particle) size distributions & solubility influence food-chain transfer
  - Considering whether uptake of short-lived radionuclide can be important
  - Revisiting assumptions concerning interception & retention of radionuclides
  - Addressing the issue of 'non-standard' radionuclides where transfer data may be lacking
- The goal will be to determine:
  - The extent to which existing models can be adapted & applied
  - Whether ingestion doses are significant (for selected scenarios)
  - Where model improvements are needed for decision support systems

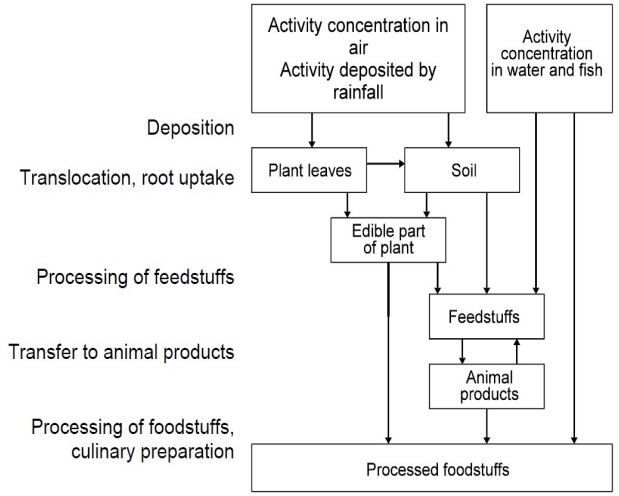


Fig 1.1: Steps of food chain transfer calculations

Which factors/processes may be important for radionuclide food-chain transfer following a detonation & how might these differ from a “standard” application?

Plant	Translocation factor					
Winter wheat	Δt	150	95	55	30	0
	T(Δt)	0	0.005	0.1	0.1	0.075
Spring wheat	Δt	120	80	50	30	0
	T(Δt)	0	0.005	0.1	0.1	0.075
Winter barley	Δt	150	75	50	25	0
	T(Δt)	0	0.01	0.1	0.1	0.075
Spring barley, oats	Δt	110	75	50	25	0
	T(Δt)	0	0.01	0.1	0.1	0.075
Rye	Δt	150	90	65	30	0
	T(Δt)	0	0.01	0.1	0.1	0.075
Corn cobs	Δt	155	115	85	45	0
	T(Δt)	0	0.01	0.1	0.1	0.02
Beet	Δt	174	122	91	0	
	T(Δt)	0	0.02	0.15	0.15	
Potatoes	Δt	128	72	55	0	
	T(Δt)	0	0.15	0.15	0	

Dry deposition

- It is well established that particle size & density affects deposition velocity. Explore how particle size distributions associated with detonations affect this parameter.

Translocation (for plants which are only partly used)

- FDMT uses a mobile-immobile element categorization for translocation factors. Map “new” radionuclides onto the most relevant category.

Root uptake (soil to plant transfer)

- Modelled using concentration ratios based on empirical datasets & (usually) a location distant from detonation sites. Transfer will be affected by the presence of particles; but essentially driven by ‘soil processes’.

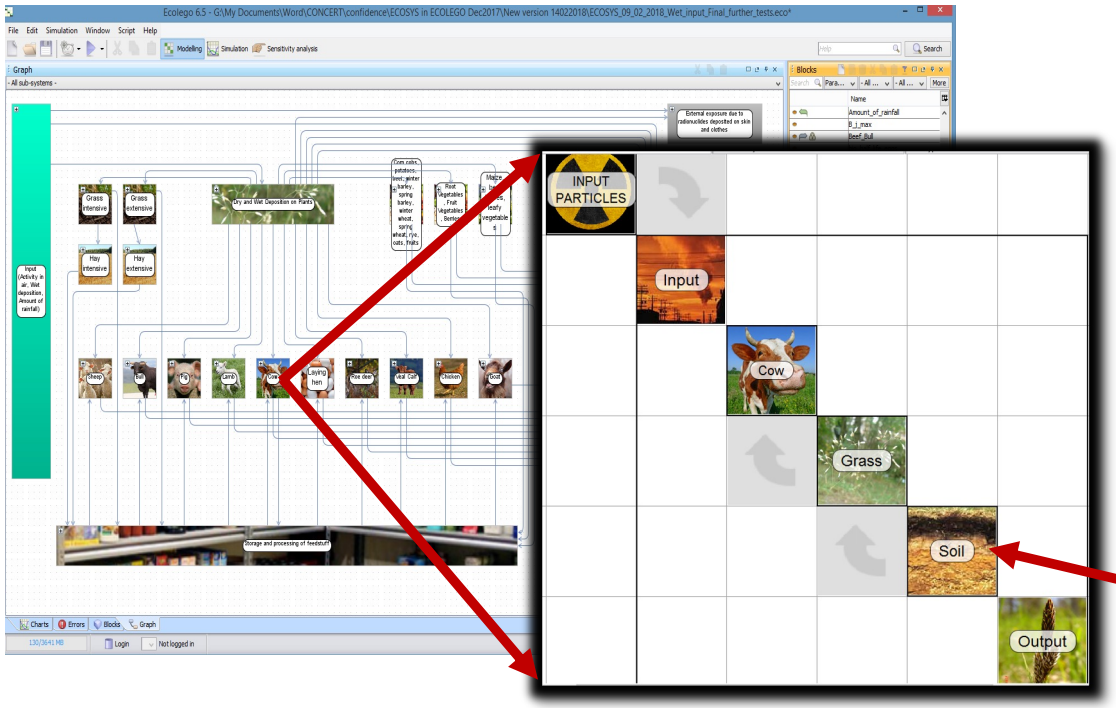
Soil processes

- May recommend a model with a slow release from an (initially) inert pool so that activities in a ‘bioavailable’ compartment increase over time.

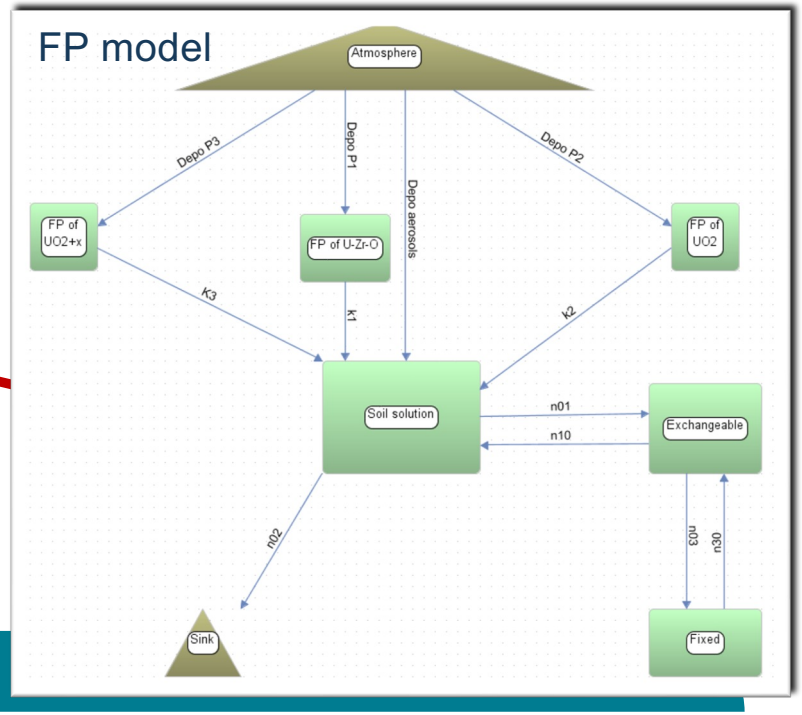
Transfer to animals

- A general (non-quantitative) consideration/review of particle size on transfer to animals is needed. The derivation of (particle-specific) quantitative values for transfer coefficients & biological half-lives may be challenging.

Potential adaptation (further development) of existing models to cover nuclear detonation scenarios



- The original/default FDMT 2 compartment ‘soil process’ adsorption-desorption model can be replaced by a bespoke particle weathering model.



New radionuclides and scenarios

- Addition of new radionuclides
  - Methodology/rationale for selection of radionuclides
    - ➔ List based on fission yields
    - ➔ Rank according to:

      ingestion dose coefficients &

      radioecological parameters

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Decay calculations using DosCalc; only nuclides in original vector retained after decay														
2	Starting vector is PREDICT vector (t=10 min): "Max" vector containing nuclides with > 1 kBq/kt @ 10 min and that have DC for ground dose in ICRP														
3	Nuclide activity at given point in time and product of activity and ICRP 119 DCF for committed dose from ingestion (if it exists)														
4															
5		359			359			359			359			359	
6															
7	10 min (sorted: alphabetical)			10 min (sorted: activity)			1 hour + 10 min (sorted: activity)			24 hours + 10 min (sorted: activity)			7 days + 10 min (sorted: activity)		
8															
9	Ag-108	2,83E+09		Cs-139	5,66E+18	0,00E+00	Cs-138	1,10E+18	1,01E+08	Xe-135	5,92E+16	0,00E+00	Xe-133	8,13E+15	0,00E+00
10	Ag-108m	1,51E+03		Y-95	5,40E+18	2,48E+08	I-134	1,09E+18	1,20E+08	I-133	4,75E+16	2,04E+08	Mo-99	4,18E+15	2,51E+06
11	Ag-109m	2,18E+16		Sr-93	5,34E+18	0,00E+00	Tc-101	8,60E+17	1,63E+07	Nb-97	3,95E+16	2,69E+06	Tc-99m	4,03E+15	8,87E+04
12	Ag-110	2,34E+04		Tc-102	5,24E+18	0,00E+00	Ba-139	7,95E+17	9,54E+07	Zr-97	3,67E+16	7,71E+07	La-140	3,90E+15	7,80E+06
13	Ag-110m	1,04E+06		Mo-102	5,20E+18	0,00E+00	Te-134	6,91E+17	7,60E+07	Y-93	3,21E+16	3,85E+07	Ba-140	3,68E+15	9,57E+06
14	Ag-111	3,14E+14		Tc-105	4,73E+18	0,00E+00	La-142	6,80E+17	1,22E+08	Ce-143	2,81E+16	3,09E+07	I-132	3,67E+15	1,06E+06
15	Ag-111m	5,34E+17		Ba-142	4,61E+18	1,61E+08	Te-131	6,08E+17	5,29E+07	Rh-105	2,75E+16	1,02E+07	I-131	3,63E+15	7,99E+07
16	Ag-112	5,16E+14		Mo-101	4,56E+18	1,87E+08	Sr-92	4,42E+17	1,90E+08	Sr-91	2,72E+16	1,77E+07	Te-132	3,56E+15	1,35E+07
17	Ag-113	2,91E+16		Xe-137	4,34E+18	0,00E+00	Te-133m	4,40E+17	1,23E+08	I-135	1,98E+16	1,84E+07	Pr-143	3,51E+15	4,21E+06
18	Ag-113m	3,32E+17		Xe-138	4,29E+18	0,00E+00	Y-94	4,36E+17	3,53E+07	Mo-99	1,90E+16	1,14E+07	Ce-141	1,78E+15	1,26E+06
19	Ag-114	3,60E+17		Tc-104	4,22E+18	3,38E+08	Tc-104	4,35E+17	3,48E+07	Y-91m	1,73E+16	1,90E+05	Rh-105	1,70E+15	6,29E+05
20	Ag-115	2,44E+17		La-143	4,04E+18	2,26E+08	Ba-141	3,77E+17	2,64E+07	Tc-99m	1,69E+16	3,72E+05	Ru-103	1,63E+15	1,19E+06
21	Ag-116	3,73E+17		Y-94	4,01E+18	3,25E+08	La-141	3,29E+17	1,18E+08	I-132	1,35E+16	3,92E+06	Rh-103m	1,62E+15	6,16E+03
22	Ag-117	1,70E+16		Ba-141	3,67E+18	2,57E+08	Kr-87	3,13E+17	0,00E+00	Te-132	1,30E+16	4,94E+07	Nd-147	1,45E+15	1,60E+06
23	As-74	3,60E+05		Rb-89	3,13E+18	1,47E+08	Sb-131	3,09E+17	3,09E+07	Y-92	1,26E+16	6,17E+06	Ce-143	1,37E+15	1,51E+06
24	As-76	1,31E+10		Te-133	2,63E+18	1,89E+08	Rh-107	3,05E+17	7,32E+06	Pr-145	1,08E+16	4,21E+06	Sb-127	1,22E+15	2,07E+06
25	As-77	1,80E+14		Kr-89	2,44E+18	0,00E+00	Rb-88	2,79E+17	2,51E+07	Xe-133	8,44E+15	0,00E+00	Te-127	1,14E+15	1,94E+05
26	As-78	5,52E+14		Ce-145	2,39E+18	0,00E+00	Kr-88	2,73E+17	0,00E+00	Pd-109	8,27E+15	4,55E+06	Zr-95	1,06E+15	1,01E+06

- <u>Simple</u> scenarios & model-model comparisons
  - Scenario set up (source-radionuclides, time & (generic) location)
  - Model runs (including original defaults)
  - Comparisons – qualitative or statistical? Develop approach

Deliverable

- One deliverable in the form of a report will be produced.
- Aim for a first full draft late 2025 / early 2026.
- WP2 report to be delivered by 30th June 2026.

