Strål säkerhets myndigheten
Swedish Radiation Safety Authority

Analysing radiological consequences from fallout after nuclear explosions with ARGOS

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The Swedish Radiation Safety Authority

- The Swedish Radiation Safety Authority (SSM) has mandates from the Swedish Government within the areas of nuclear safety and security, radiation protection, and nuclear non-proliferation.
- Increased knowledge of the possible radiological consequences of fallout from nuclear explosions constitutes a valuable basis for the development of the Swedish total defence. SSM has found ARGOS to be a useful tool in recent efforts to study such consequences.

ARGOS DSS

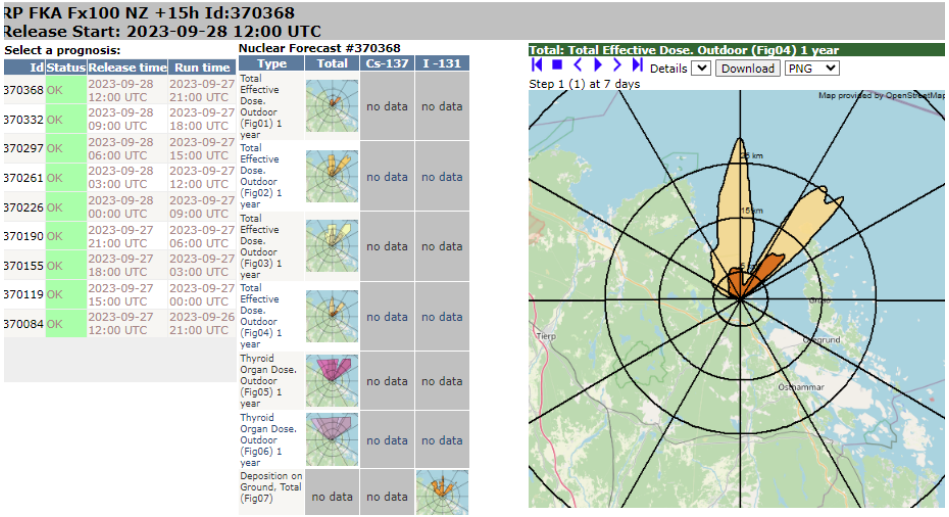
- ARGOS (Accident Reporting and Guidance Operational System) was originally developed in Denmark for DEMA (EPR authority) by PDC (company).
- Used for C(B)RN(E) Emergency Preparedness and Response.
- ARGOS has been a tool in EPR at SSM since 2003
- Prognosis with integrated atmospheric dispersion models (ADM), such as the Gaussian puff-model, Rimpuff, from the Danish Technology University, DTU.
- Prognosis with external long range ADM, such as the Eulerian model MATCH with an initial Lagrangian part from the Swedish Meteorological and Hydrological Institute, SMHI.
- Dose calculations are integrated into ARGOS.

Scheduled runs in ARGOS

Scheduled runs are executed automatically at regular intervals and presented on a web-server based application, ArgosWeb.

Results can be downloaded in raw format, as well as predefined images, in png- or shape format.

A time-saver when producing a Nuclear and radiological assessment report in case of a radiological emergency.



Batch runs in ARGOS

- ArgosWeb is also used as an interface for batch runs, as in the review of the Swedish emergency planning zones and distances (SSM 2017:27e)
- Batch runs consists of many dispersion and dose calculations where the release time is distributed over a time period (randomly or fixed intervals). The runs are analysed based on a set of batch criteria.
- The information on the geographical point for which the criterion was exceeded at the greatest distance from the release/explosion point is recorded and stored in ARGOS.
- One data record per fulfilled batch criterion, with information on coordinates, distance, bearing, calculated value, etc. in csv format can be downloaded from ArgosWeb for further processing.
- Batch runs were used to model fallout after nuclear explosions (SSM 2023:05)

Meteorological data from SMHI

In the nuclear explosion study historical Harmonie-Arome weather was used to simulate the dispersion every 13 hours (January 2021 - January 2022)

6-hourly forecasts per day

Horisontal resolution 2,5 km (0.03 degrees)

Temporal resolution of one hour

65 altitude levels from the ground level up to 10 hPa

ARGOS dispersion and dose calculation in the nuclear explosion study

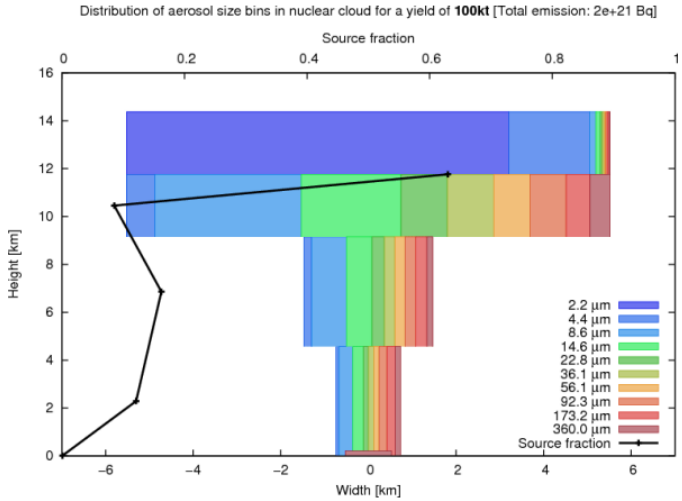
- Representative person for the public near an explosion site in Sweden
- Model limitations close to the explosion – studied 8 km – 300 km
- No direct effects from the explosion are included
- The main scenario for this study is a ground-level explosion with an explosive yield of 100 kilotons and a fusion fraction of 50 %
- Three contributions to total effective dose (cloud, ground, inhalation)
- Equivalent dose to the thyroid gland
- Ground dose vs sheltering
- Early, up to one year consequences (effects on food etc still to be addressed)

Fallout after nuclear explosions - source

Horizontal and vertical distribution of particles in the stabilised cloud depends on a number of different parameters of the explosion (explosive yield, fission fraction, height, etc.)

Source description from US (KDFOC3) implemented by the Swedish Defence Research Agency, FOI

Source together with the nuclide vector is incorporated into the dispersion model MATCH-BOMB from SMHI



Nuclide vector – a selection of dose-contributing radionuclides

A set of fission and activation (ground and weapons components) products

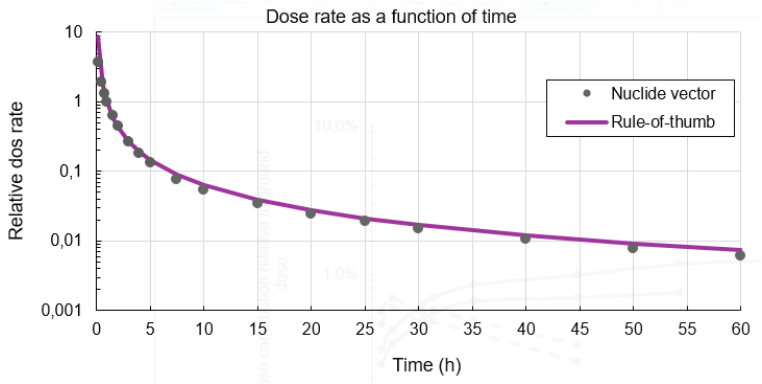
Represents at least 95 % of the effective dose from ground, cloud and inhalation during different time periods

SSM's nuclide vector - 129 nuclides with max activity per nuclide from 3 fission reactions:

^{239}Pu (1 MeV *n*), ^{235}U (1 MeV *n*) or ^{238}U (14 MeV *n*)

Approximation: the same nuclide composition on every particle (no fractionation)

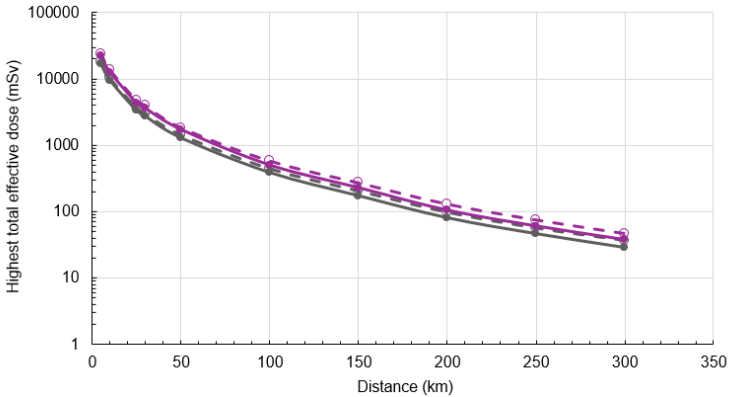
SSM's nuclide vector



The dose rate from the nuclide vector for the main scenario at various times between 10 minutes and 60 hours (points) relative to the dose rate at 60 minutes.

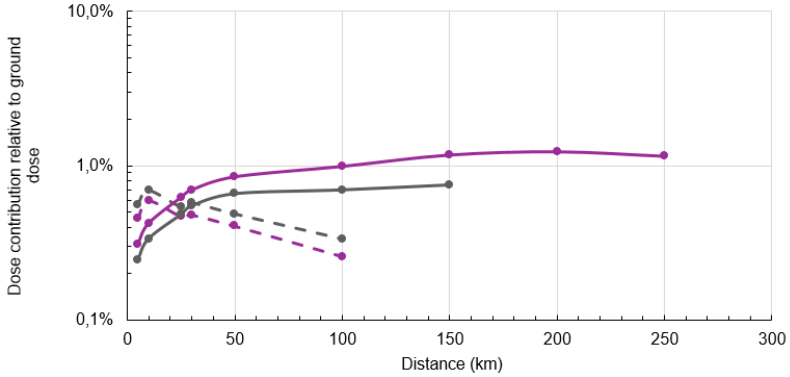
The figure also shows as a solid curve (purple) the dose rate according to $t^{-1.2}$

Dose results and exposure pathways



Highest total effective dose received by an unprotected one-year-old child (purple) and an unprotected adult (grey) at specified distances from the explosion if 90 % of occurring weather scenarios are considered.

Solid lines show the effective dose during the first day after the explosion and dashed lines show the effective dose during the first two days



The highest effective dose from external exposure to the cloud (dashed lines) and the maximum committed effective dose from inhalation (solid lines) of an unprotected one-year-old child (purple) and an unprotected adult (grey) as a proportion of the maximum effective dose from external exposure from the ground during the first 24 hours after the explosion.

At specified distances from the explosion if 90 % of occurring weather scenarios are considered.

Equivalent dose to the thyroid gland

			One-year-old child		
Thyroid dose	Distance*		Effective dose at this distance (first 24 hours)		Contribution of thyroid dose to effective dose
	Outdoors				
50 mSv	110 km		440 mSv		~2.5 mSv
100 mSv	74 km		890 mSv		~5 mSv
500 mSv	9 km		13,000 mSv		~25 mSv
	Indoors in a large building				
50 mSv	9 km		1,300 mSv		~2.5 mSv
100 mSv	< 8 km		> 1,400 mSv		~5 mSv
500 mSv	< 8 km		> 1,400 mSv		~25 mSv

*At specified distances from the explosion if 90 % of occurring weather scenarios are considered.

Some conclusions from SSM 2023:05

- Radiation doses are entirely dominated by effective dose from ground contamination thus good initial shelter is the most important protective action
- Evacuation in connection with the fallout from a nuclear explosion is not effective, it is better to use available time to seek out good shelter
- Relocation may be required in areas out to large distances (over 100 km) from the explosion to limit radiation doses in the long term after good initial sheltering has been terminated. At shorter distances from the explosion (tens of km), there may be areas where evacuation due to ground contamination needs to be carried out urgently.
- Iodine tablets have no practical function in the event of fallout from nuclear explosions
- There is a need for further investigations such as looking at the consequences from food intake

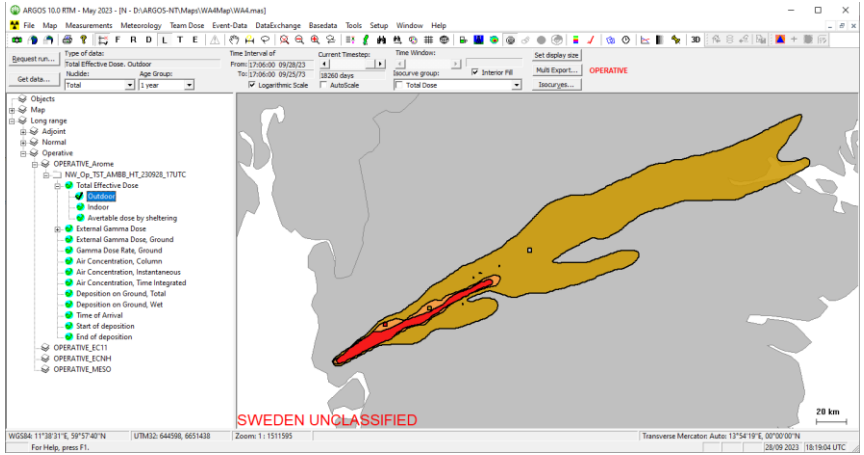
ARGOS operative mode

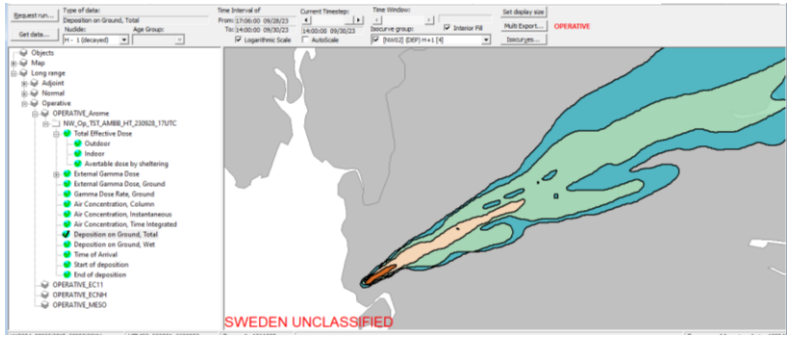
Pseudo-nuclide (H+1) representing the overall activity one hour after detonation.

H+1 is a time-invariant quantity that can be converted to actual activity, in total or for a particular nuclide, with the use of a nuclide vector.

A rapid analysis can also be made in ARGOS with the pseudo-nuclide alone.

To estimate the effective dose from ground in operative mode, the pseudo-nuclide is subject to decay (*e.g.* $t^{-1.2}$) and an overall ground dose factor is applied.





Thank you very much for your attention!

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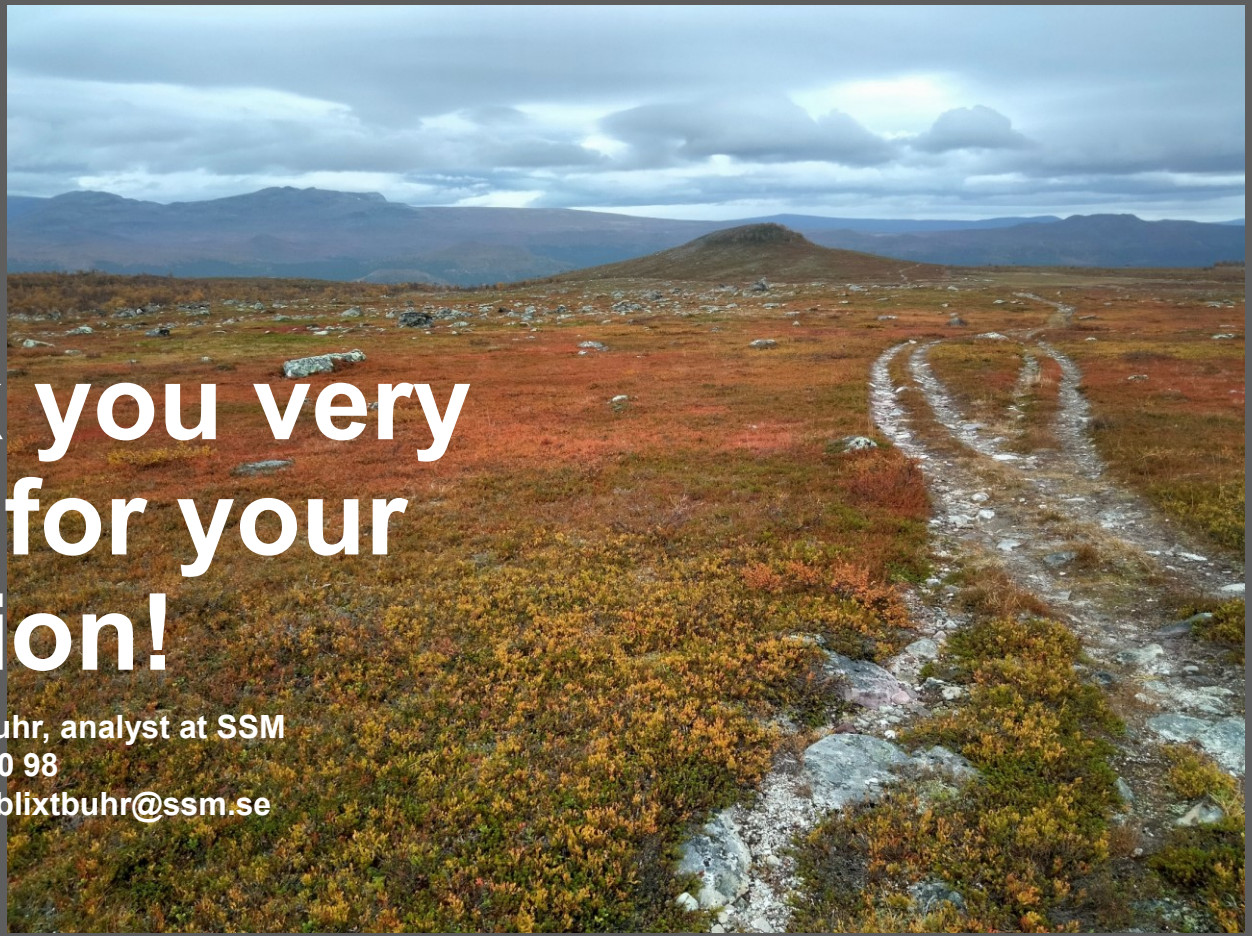

Saltoluokta, Sweden. September 2023