Use of the SCALE-SAS1 code for dose rates calculations in case of a criticality accident

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Context : Since Tokai criticality accident in 1999, French nuclear operators dealing with fissile materials must add to their regulatory files maps of dose rates and doses likely to be received in case of an hypothetical criticality accident, inside and outside of the concerned plant. As a technical support to the French Nuclear Safety Authority (ASN), the Institute for Radiological Protection and Nuclear Safety (IRSN) has developed an expert support tool, allowing to quickly assess the dosimetric consequences in case of a criticality accident, up to 1 km from the location of the accident, and with a precision around 30%.
The purpose of this poster is to present the methodology used to constitute the tool's database from dose rates values behind thick shields and at large distance obtained with the SCALE4.4a-SAS1 code. A few validation results, for some chosen configurations, are also presented.

Tools : existing abacus, empirical or semi-empirical formulas, are without any shielding and not beyond 300m. It was retained to create a database of doses calculations (neutrons and gamma rays) for many representative situations, with a quick access through an interface.
The doses can be calculated using a simulation transport code (advantage: precision, disadvantage: difficulty to converge for long distances and large thicknesses) or a deterministic transport code (advantage: short calculation time, disadvantage: precision unknown beyond 50 cm of ordinary concrete).
The choice: SN deterministic SAS1 module of SCALE4.4a code has been chosen in order to quickly obtain dose rates values. Given the peculiarities of the engaged calculations, and a lack of qualification for studied configurations (thick shieldings and large distances), the SAS1 module has been validated against MCNP5, the stochastic code chosen as a reference.

Configurations : from inventory of many plants dealing with fissile materials in France

Nuclide : ^{239}Pu (dose rates higher than others fissile nuclides), Watt spectrum for prompt neutrons, prompt gammas calculated by the codes; delayed particles ignored

Source

Nature	Density or concentration	Radius [cm]	Volume	Remarks
Metallic ^{239}Pu	19,82	5	0,524 l	Critical mass : non reflected non moderated
	15,80	6,23	1,01 l	
$^{239}PuO_2$ powder	3,5	27,3	85,2 l	
	5,5	17,4	22,1 l	
	11,0	8,7	2,76 l	
$^{239}Pu(NO_3)_3$ solution	10 g/l	40,3	274,2 l	Minimal critical mass non reflected
		62,0	1 m^3	-
		181,4	25 m^3	-
	200 g/l	15,6	15,9 l	Minimal critical mass non reflected
		62,0	1 m^3	-
		181,4	25 m^3	-

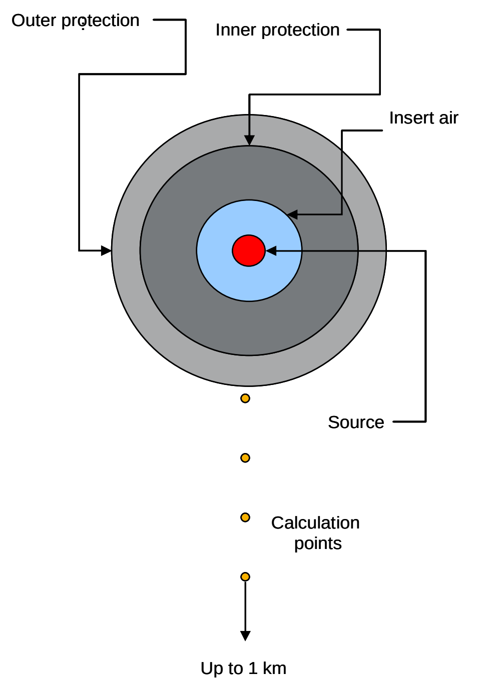
Protections with one layer

Nature	Density	Range of thickness
Ordinary concrete	2,30	10 cm - 3 m
Colemanite concrete	1,88	10 cm - 2 m
Lead	11,34	5 cm - 25 cm
Leaded glass	4,23	10 cm - 1,4 m
316L Steel	7,80	1 cm - 35 cm
Magnetite concrete	3,30	10 cm - 2 m
Barytine concrete	3,30	10 cm - 2 m

Protections with two layers

Inner layer		Outer layer	
Nature	Thicknesses [cm]	Nature	Thicknesses
316L Steel	5, 10, 20, 25, 30, 40	Ordinary concrete	50 cm 1 m 1,5 m 2 m 3 m
Lead	2, 5, 10, 15, 20, 25		
Colemanite concrete	100		
Glass (ordinary glass + leaded glass)	35 cm + 78 cm 22 cm + 66 cm 15,2 cm + 47 cm		
Magnétite concrete	70, 85, 100		

Geometry : 1-D spherical



SAS1 runs :

- fixed source (1 neutron), order of quadrature 32, convergence criteria 10^{-9}
- gamma fluxes with coupled 27n-18g library (ENDF/B-IV)
- neutron fluxes with 238n library (ENDF/B-V)
- mesh size around mean free path of particles, and very fine around distance calculations to avoid spatial averaging.

Points of interest :

- backscatering is considered : geometry up to 2 km
- insert air has non negligible effect on dose rates : from 0 to 10m
- concrete hydrogen content is an important parameter : $\pm$ 5% leads to $\mp$ 10% on total dose rate
- insufficient representation of iron and barium cross section for neutron transport

The CODAC (COnséquence Dosimétrique d'un Accident de Criticité) tool

- library of neutron and gamma fluxes for all sources, natures and thicknesses of protection, insert air thicknesses, and distances up to 1 km (>10,000 configurations)
- extraction of the fluxes for the parameters chosen by the user via a user friendly interface
- calculation of the dose rates (neutron, gamma and total) with the ICRP 74 conversion factors, the number of neutrons per fission and the total number of fissions
- printing of the results in a text file

Additional capabilities of CODAC:

- change of flux to dose conversion factors
- change of number of neutrons per fission
- change of total number of fission of the criticality accident
- automatic generation of SAS1 or MCNP input files for new configurations
- extraction of fluxes from output files and implementation in the library
- implementation of specific correction for specified protections

Qualification of SAS1 by MCNP5 (ENDF/B-VI) :

- on selected configurations :
  - every source
  - every nature of protection (one and two thicknesses)
  - the minimum and the maximum thickness
  - 54 distances calculations, from contact to 1 km
  - 4 insert air thicknesses, from 0 to 10 m
- source and insert air have secondary impact on SAS1-MCNP5 agreement
- Better agreement if MCNP is operated with ENDF/B-V multigroup representation

- SAS1-MCNP5 agreement < 30% in all cases, except for :
  - magnetite concrete with thickness beyond 80 cm
  - barytine concrete with thickness beyond 100 cm

→ specific correction defined, based on SAS1-MCNP5 agreement