RADIOLOGICAL CONSEQUENCES OFA HYPOTHETICAL "ROOF BREAKDOWN" ACCIDENT OF THE CHERNOBYL SARCOPHAGUS

G. PRETZSCH
Gesellschaft für Anlagen- und Reaktorsicherheit (GRS)mbH,
Berlin, Germany

1 Introduction

On behalf of the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety GRS performed investigations with the aim to improve the safety of the Chernobyl Unit 4 shelter in close connection with the Ministry for Environment and Nuclear Safety of the Ukraina from 1992 to1995. One of the tasks of the working programme was concerned with the analysis of hypothetical accidents of the present shelter, which comprises the newly builded Sarcophagus and the remaining ruins of Unit 4. In close collaboration with ukrainian and russian experts the maximum hypothetical accident was defined to be the breakdown of the roof of the Sarcophagus and subsequent release ot the radioactive dust which is mainly located in the destroyed reactor hall and the neighboring rooms.

2 Radioactive dust inside the shelter

The total mass of the radioactive dust, which is mainly located in the destroyed former reactor hall and the neighboring rooms amounts to about 1 t . The dust forms a thin layer of less than 1 mm on the surface of the debris of the destroyed reactor, the walls etc. Although a dust suppression system periodically sprays organic liquid into the reactor hall, an essential part of the dust remains unfixed. Moreover, new dust generation proceeds in the lower rooms due to erosion processes of the lava-like fuel containing material. This dust is partly transported by ventilation into the reactor hall so that the total amount of unfixed dust remains relatively constant over time. The dust distribution was determined by different methods /2/. Regarding the respirable particle fraction in the layer an upper estimation was chosen.

3 Roof construction and accident scenario

The main roof construction consists of two parallel metal griders which are founded in the eastern part on the two remaining ventilation stacks and in the western part on the remaining monolithic western wall. Connection is only due to frictional forces. Perpendicular to the two me-

Tab. I : Relative mass fraction V of radioactive aerosolparticles inside the shelter depending on aerodynamic equivalent diameter AED [μm] as well as the corresponding deposition velocity v_g [m/s] and washout coefficient Λ_0 [1/s]

V	0.35	0.27	0.08	0.05	0.09	0.16
AED	6.5	17	27	30	32	49
v_g	$1.5 \cdot 10^{-3}$	$9 \cdot 10^{-3}$	$2.1 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$	$3 \cdot 10^{-2}$	$7.2 \cdot 10^{-2}$
Λ_0	$1.5 \cdot 10^{-4}$	$3 \cdot 10^{-4}$	$4 \cdot 10^{-4}$	$4 \cdot 10^{-4}$	$4 \cdot 10^{-4}$	$4 \cdot 10^{-4}$

Tab. II : Composition and activity fractions of the nuclides corresponding to a dust mass of 50 kg (by the end of 1994)

Nuclide	Activity [Bq]
Sr 90	$4.9 \cdot 10^{13}$
Y 90	$4.9 \cdot 10^{13}$
Ru 106	$1.1 \cdot 10^{12}$
Rh 106	$1.1 \cdot 10^{12}$
Cs 134	$2.5 \cdot 10^{12}$
Cs 137	$6.0 \cdot 10^{13}$
Ce 144	$6.5 \cdot 10^{11}$
Pr 144	$6.5 \cdot 10^{11}$
Pm 147	$1.5 \cdot 10^{13}$
Pu 238	$2.7 \cdot 10^{12}$
Pu 239	$2.7 \cdot 10^{11}$
Pu 240	$3.1 \cdot 10^{11}$
Am 241	$4.2 \cdot 10^{11}$

tal griders 27 metal tubes of 1.22 m in diameter and with a length of 34.5 m were put on the metal griders. Above the tubes a roof of shaped steel plates and large-size shields was installed. The total mass of the roof construction was estimated to be 1050 t.

After a strong external impact (e.g. earthquake, wind loads etc.) or internal impact (corrosion, erosion etc.), the breakdown of the western wall and/or the roof cannot be excluded. In the present work a hypothetical breakdown of the roof into the former reactor hall which has roughly the dimensions of 42 m x 42 m (square) x 17 m (height) is assumed. After the breakdown of the roof part of the unfixed radioactive dust becomes airborne. Part of this fraction will settle down again after a short time or will be screened by construction materials or walls. The fraction of airborne radioactive aerosols which will be released due to the turbulent air stream as well as due to the upward stream of about 0.5 m/s, which constantly exists inside the shelter, was roughly estimated to be 5.0 % of the total mass, i.e. 50 kg. This fraction is in accordance with estimates of the Kurchatov Institute, Moscow /2/. The influence of the non radioactive dust was also considered.

4 Diffusion model and input data

The potental radiation exposures for adults on the site and up to 2000 m distance in downwind direction were calculated by means of the GRS computer code BEREG developed on the German Incident Calculation Bases /1/.

The considered exposure pathways are inhalation of aerosol particles with AED < 10 μm during the passing of the radioactive cloud (effective dose D [Sv] by Inhalation = 50 year dose) and ground shine due to gamma-radiation caused by all deposited aerosol particles for a period of 30 days.

5 Diffusion conditions

The diffusion factor was calculated applying the GAUSS model, the diffusion parameters are based on experimental data sets. The influence of the building dimension on plume formation was taken into account as well as the reduction of radioactive material in the plume by radioactive decay, dry deposition and washout.

The ukrainian side defined the atmospheric diffusion category C without rain and a wind speed of 4.2 m/s at 100 m height (corresponding to a wind speed of u = 2.53 m/s at 10 m height). Additionally, calculations were performed for u = 1.0 m/s (at 10 m height) without as well as with rain of intensity 1 mm/h, the dry diffusion categories A and F were also considered.

6 Results

Fig. 1 shows the results for the inhalation doses. The radiation exposure for the diffusion category C decreases only slowly from 50 m to about 200 m. For greater distances a more rapid decrease is obtained. For the wind speed of 2.53 m/s at 10 m height the inhalation doses in the vicinity of 50 m amount to about 1 Sv. At distances above 1100 m does the effective dose decrease below the dose limit of 50 mSv/y for occupationally exposed workers. Assuming a wind speed of 1.0 m/s in correspondence with the German Incident Calculation Bases the doses are increasing by a factor of 2.5 . Hence, the radiological consequences become more severe for lower wind speeds.

A comparison of the results for the categories A, C and F is also shown in Fig. 1. In the vicinity up to 100 m the maximum values are obtained for the categories A and F. The most rapid decrease with distance is observed for category A. Rain has no significant influence on the inhalation dose.

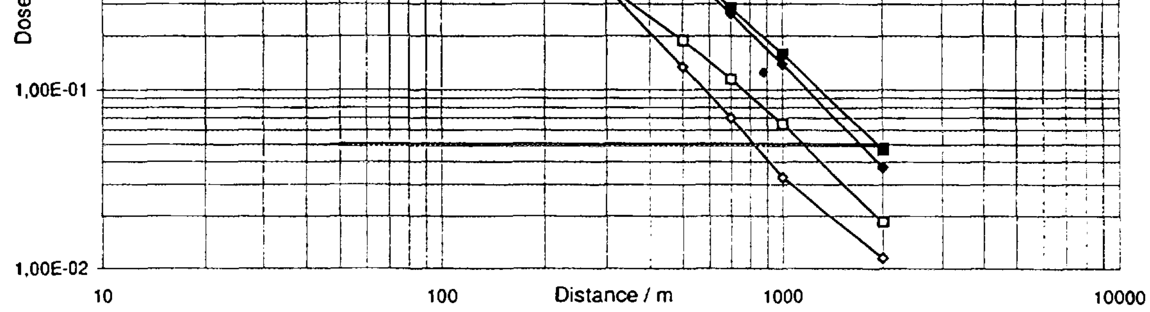

Fig. 1 : Effective Dose by Inhalation

Fig. 2 shows the results for the effective doses due to ground shine for the categories A, C and F. Contrary to inhalation the dose due to ground shine is caused by all aerosol particles, i.e. also in the nonrespirable diameter range. Therefore the dependence of the curves on the distance is slightly changed owing to higher deposition velocities of heavier particles.

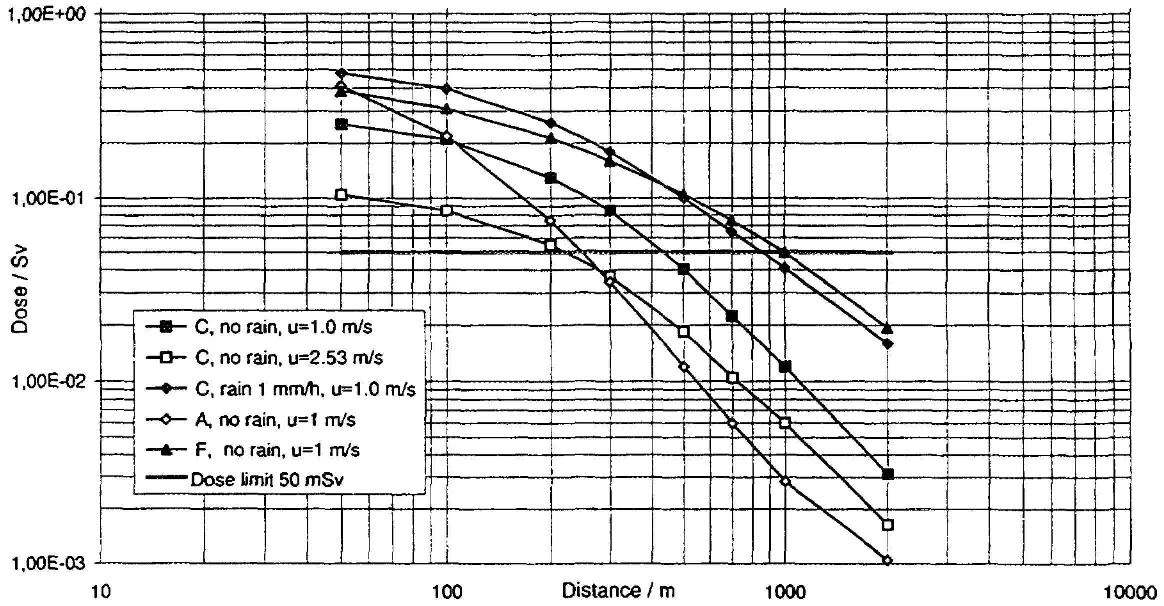

Fig. 2 : Effective Dose by Ground Shine, Exposure 30 Days

In Tables III and IV the contributions of the different nuclides to the inhalation dose and to the ground shine dose are shown.

Tab. III : Fractions of the radiation exposure due to inhalation caused by the different radionuclides

Nuclide	Fraction [%]
Am 241	32.8
Pu 240	24.2
Pu 238	18.5
Pu 239	17.4
Sr 90	6.7

Tab. IV : Fractions of the radiation exposure due to ground shine caused by the different radionuclides

Nuclide	Fraction [%]
Cs 137	89.6
Cs 134	9.7
Ru 106	0.5
Ce 144	0.1

The ground shine dose is approximately linear in time so that shorter exposure periods can easily be scaled down. Only for longer exposure periods of some years the contribution of Cs 137 is more dominant than in Tab. IV.

7 Conclusions

The doses due to inhalation in the vicinity of the shelter up to 200 m are very high predominantly for low wind speeds and exceed the dose limit of occupationally exposed workers.

Except for the stable diffusion category F for all other weather conditions, the inhalation dose decreases below the limit for distances above 2000 m, so that a relevant hazard for longer distances, e.g. for the town of Chernobyl, is not to be expected. The inhalation dose is predominantly caused by long lived transuranium nuclides, hence the choice of the moment of the accident (e.g. end of 1994) does not play any important role.

Compared to the inhalation the effective doses due to ground shine for an exposure period of 30 days are generally lower by about one order of magnitude and show a similar behaviour depending on the distance.

The ground shine dose is primarily caused by long lived nuclides of fission products, e.g. Cs 137, so that again the choice of the moment of the accident does no matter.

Contrary to the inhalation the doses due to ground shine are signifcantly influenced by the duration of exposure and also by the intensity of rain during the accident. Depending on the given weather conditions, it is possible for a person to stay for several days on the NPP site after the accident and not exceed the dose limit.

References

/1/ German Incident Calculation Bases, Bundesanzeiger 46 of 26.11.1994, No. 222a.

/2/ Technical Bases of the Nuclear Safety of the Object "Shelter", Kurchatov-Institute, Moscow 1990.