PROBABILISTIC ASSESSMENT OF ORGAN DOSES AFTER ACCIDENTAL RELEASES FROM NUCLEAR POWER PLANTS

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1. Introduction

Results of risk assessments for facilities of the nuclear fuel cycle are so far nearly exclusively presented in the form of frequency distributions and expectation values of the number of fatalities. These final results are less appropriate when conclusions should be drawn with respect to the planning of emergency actions and medical countermeasures including the evaluation of criteria for these actions. To judge the necessity, effectiveness and feasibility of protective measures and medical care, information about the radiation dose levels to be expected after accidental releases of activity as well as the number of persons exposed should be available.

For this reason a modified version /1/ of the accident offsite consequence model UFOMOD /2/ of the German Risk Study /3/ was developed to calculate the 50 a doses after accidental releases to the organs bone marrow, bone surface, lung, thyroid, gonads and to the whole body. Additionally, acute bone marrow doses (up to 30 days) and 1-year lung doses both relevant for early fatalities (EF) can be assessed. Analysing recalculations were performed employing the release categories established in the German Risk Study (GRS).

2. Results

2.1 Individual Doses

Activity releases result in space-dependent concentrations of radionuclides in the air and on the ground. The variability of the possible meteorological conditions during the dispersion process determines the possible concentrations and thereby the variation in the doses to be expected. Moreover, protective actions considered in the accident consequence model depend on dose levels. This causes further variation in the actual doses to individuals. With the results of accident consequence calculations based on the 4 x 115 different weather sequences of the GRS, frequency distributions of the above-mentioned organ doses were built for each mesh of the radial grid (4 meshes per decade). From these distributions, characteristic quantities like mean values and percentiles can be derived. As an example, Fig. 1 shows the distance dependent 95%-fractiles of the acute bone marrow doses calculated under the assumption of releases due to the categories FK1 to FK8. They can be interpreted as doses to individuals at any azimuthal position, which are not exceeded in 95% of all accident consequence situations. In particular, only 5% of all situations lead to radiation doses greater than 100 rad (threshold dose for EF) at distances beyond about 2 km from the site.

2.2 Population Doses

Dependent on wind direction and site, different population distributions are affected by the dispersed radioactivity. For this

reason, calculations based on the 19 sites considered in the GRS were performed to assess the spectrum of the possible numbers of persons exposed. The results were linked in probability distributions of the number of persons within a given dose interval for each radial grid mesh, release assumed. These 3-dimensional probability distributions for each distance interval, release category and organ are not easy to review, interprete and present completely. A reasonable reduction of information is necessary which has regard to the special application. So e.g. the mean and the maximum number of persons within a given dose range or a given distance could be sufficient information. Typical results are exemplarily shown in Fig. 2 and 3 for the release category FK2 of the GRS.

In Fig. 2 the number of persons with acute bone marrow doses above the dose levels 50 rad, 100 rad (threshold dose for EF) and 500 rad (LD-50 for EF) are given in dependence of the distance from the site. The curves show, that such doses occur at distances up to about 20 km. The total numbers of persons affected with doses of the different ranges are given in Table 1, showing the number of EF calculated with UFOMOD/B3, too. These numbers as well as the corresponding distributions allow to analyse the collective early fatality risk and to make conclusions on the effectiveness and the necessity of administrative and medical countermeasures.

Fig. 3 shows the same distribution type for the 50 a-thyroid doses, whereby the dose ranges are 15 rad (dose limit established in §28(3) of the German Radiation Protection Regulation), 100 rad and 1000 rad (begin of a non-linear dose-risk-relationship for thyroid /4/). Thyroid doses above 15 rad occur at all distances up to 540 km, where the site specific calculations terminate /2,3/. Even the number of persons with high dose values is rather large and non-linear dose risk curves can influence the predictions of the number of late thyroid cancer fatalities shown in Table 1, too.

3. Conclusions

The detailed graphical and numerical presentation of risk assessment results on the basis of radiation doses may provide more insight into the nature of risk from nuclear facilities. This may be helpful in decision-making processes as well as in the discussion of acceptance problems.

/1/ J. Ehrhardt, U. Zöller, "Darstellungsformen für individuelle und kollektive Strahlendosen nach unfallbedingten Aktivitätsfreisetzungen", Report KfK-3562 (1983)

/2/ A. Bayer et al., "The German Risk Study: Accident Consequence Model and Results of the Study", Nucl.Techn. 59, 1982, p.20-50

/3/ "Deutsche Risikostudie Kernkraftwerke", Verlag TÜV, Rheinland, Köln, Hauptband (1979), Fachband 8 (1981)

/4/ E. Oberhausen, "Die Dosis/Wirkungs-Beziehung bei der Strahlenexposition", GRS-Fachgespräch 1982, Report GRS-52 (1983)

	Number of Early Fatalities	Number of Persons with Acute Bone Marrow Doses		
		D>50rad	D>100rad	D>500rad
$\bar{P}$	29,8	1 551	559	25,2
	Number of Late Fatalities by Thyroid Cancer	Number of Persons with Radiation Doses to Thyroid (50a)		
		D>15rad	D>100rad	D>1000rad
$\bar{P}$	1233	3 096 000	243 000	12 780

Tab. 1: Number of Early and Late Fatalities in Correlation with the Number of Persons Exposed to the Corresponding Organ Doses (Release Category FK2)

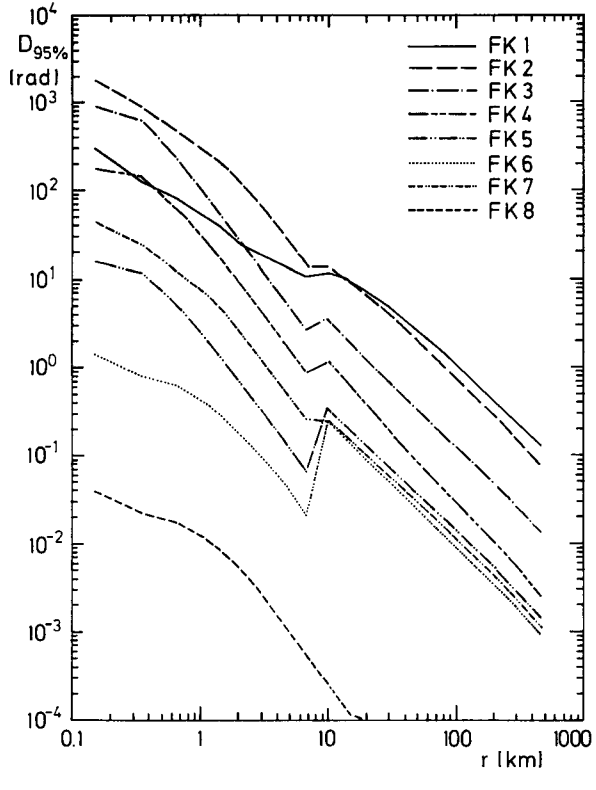

Fig. 1: 95%-Fractiles of the Individual Acute Bone Marrow Dose Distributions

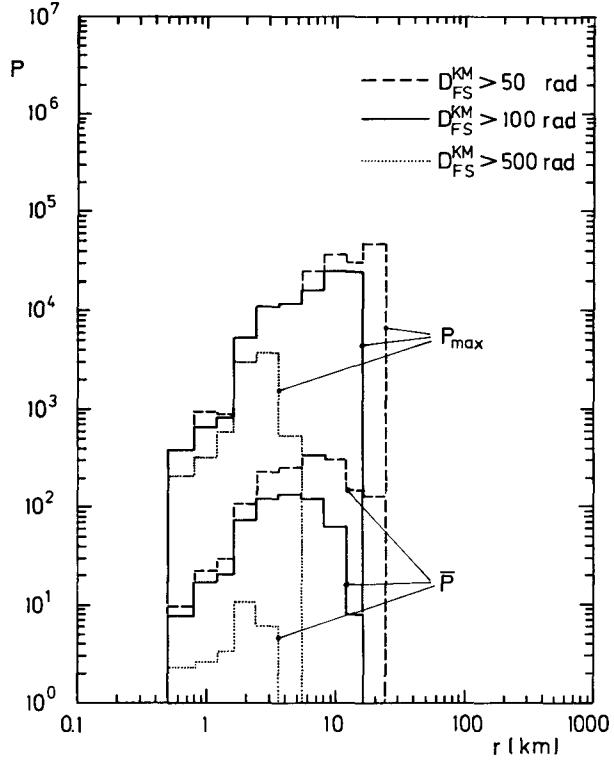

Fig. 2: Mean and Maximum Number of Persons with Acute Bone Marrow Doses for Release Category FK2

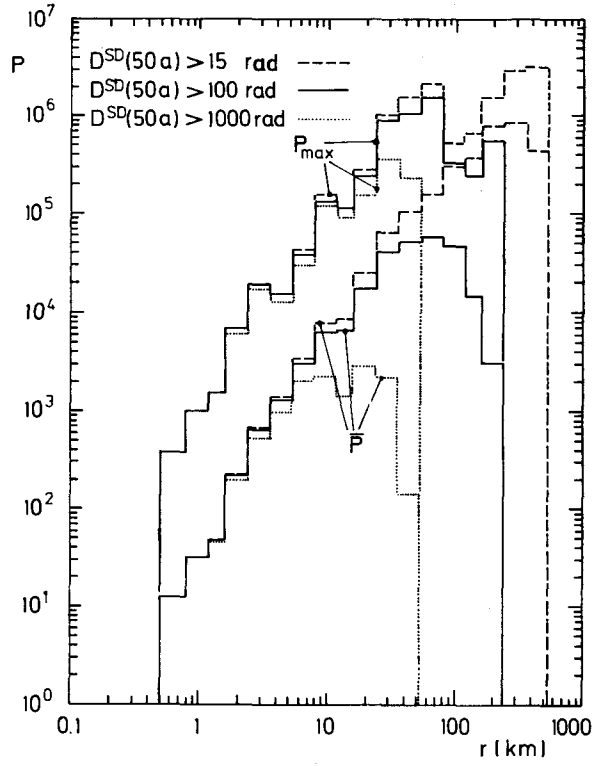

Fig. 3: Mean and Maximum Number of Persons with 50 a-Doses to Thyroid for Release Category FK2