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Uncertainty and Sensitivity Analyses of the Complete Program System UFOMOD and of Selected Submodels

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UNCERTAINTY AND SENSITIVITY ANALYSES OF THE COMPLETE PROGRAM SYSTEM UFOMOD AND OF SELECTED SUBMODELS

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Abstract

Uncertainty and sensitivity studies with the program system UFOMOD have been performed since several years on a submodel basis to get a deeper insight into the propagation of parameter uncertainties through the different modules and to quantify their contribution to the confidence bands of the intermediate and final results of an accident consequence assessment. In a series of investigations with the atmospheric dispersion module, the models describing early protective actions, the models calculating short-term organ doses and the health effects model of the near range subsystem NE of UFOMOD, a great deal of experience has been gained with methods and evaluation techniques for uncertainty and sensitivity analyses. Especially the influence on results of different sampling techniques and sample sizes, parameter distributions and correlations could be quantified and the usefulness of sensitivity measures for the interpretation of results could be demonstrated.

In each submodel investigation, the (5%,95%) - confidence bounds of the complementary cumulative frequency distributions (CCFDs) of various consequence types (activity concentrations of I-131 and Cs-137, individual acute organ doses, individual risks of nonstochastic health effects, and the number of early deaths) were calculated. The corresponding sensitivity analyses for each of these endpoints led to a list of parameters contributing significantly to the variation of mean values and 99% - fractiles. The most important parameters were extracted and combined for the final overall analysis.

The intercomparison of all results obtained from the various investigations provides a clear view of the contributions of the single submodels and their parameters to the overall uncertainties.

Unsicherheits- und Sensitivitätsanalysen für das komplette Programmsystem UFOMOD und ausgewählte Teilmodule

Unsicherheits- und Sensitivitätsstudien für das Programmsystem UFOMOD sind seit einigen Jahren auf der Basis von Teilmodulen erstellt worden. Es ging darum, tiefere Einsicht in die Fortpflanzung der Parameterunsicherheiten durch die verschiedenen Teilmodule zu bekommen und deren Beitrag an den Unsicherheiten der Resulte der Teilmodule bzw. der Endresultate von Unfallfolgenrechnungen zu quantifizieren. In einer Reihe von Untersuchungen zu den Modellen zur atmosphärischen Ausbreitung, zu Schutz- und Gegenmaßnahmen, zur Berechnung von akuten Individualdosen und Frühschäden des Nahbereich - Teilsystems NE von UFOMOD konnten reichhaltige Erfahrungen mit Unsicherheits- und Sensitivitätsmethoden gewonnen werden. Insbesondere der Einfluß verschiedener Stichprobenverfahren und -umfänge, unterschiedlicher Parameter - Verteilungsfunktionen und Parameterkorrelationen wurde quantifiziert und die Nützlichkeit von Sensitivitätsmaßen für die Interpretation der Resultate demonstriert.

Für jeden Teilmodul wurden (5%,95%) - Konfidenzschranken der komplementären kumulativen Häufigkeitsverteilungen (CCFDs) der verschiedenen Konsequenzarten (Aktivitätskonzentrationen für I-131 und Cs-137, akute Individualdosen und -risiken nichtstochastischer Schäden, sowie Frühschäden) ermittelt. Die entsprechenden Sensitivitätsanalysen lieferten eine Rangreihenfolge von Modellparametern, deren Unsicherheiten signifikant zu den Vertrauensbereichen der Erwartungswerte bzw. der 99% - Quantile der Konsequenzarten beitrugen. Die wichtigsten Parameter aus den Teilmodulanalysen wurden jeweils ausgewählt und für die abschließende Gesamtanalyse zusammengefaßt.

Der Vergleich sämtlicher Resultate aus den verschiedenen Analysen lieferten einen klaren Überblick über den Beitrag der einzelnen Teilmodule und deren Parameter zu den Unsicherheiten bei der Gesamtanalyse.

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1. Introduction

Accident consequence assessment (ACA) codes consist of many submodels with varying degrees of complexity, which have a large number of parameters associated with significant uncertainties. It is of considerable importance to understand the nature and magnitude of these uncertainties and their influence on the accuracy of the assessed consequences. This is a prerequisite in decision-making, where knowledge of the inherent uncertainties in the information being evaluated is essential if balanced and well considered judgements are to be made. It is equally important for the identification of modelling weakpoints and thus areas for further improvements and supporting research and development activities.

Appropriate techniques are available for propagating parameter uncertainties through complex models like the program system UFOMOD. Their main task is the generation of a set of parameter vectors for which the ACA codes are run repeatedly. The parameter values of each vector are sampled from the probability distributions describing their variability. A variety of sampling techniques are in use for uncertainty analyses. For the investigations with UFOMOD, the Latin Hypercube Sampling (LHS) program developed at SANDIA has been used together with the corresponding evaluation programs calculating correlation and regression coefficients [24], [25]. A more comprehensive description of the procedures adopted, the results obtained and the conclusions drawn, is given in [12] and [11] and Appendix A.

Some general features which are important in performing uncertainty analyses for the program system UFOMOD are presented in Chapter 2. Before starting the uncertainty and sensitivity analyses, a detailed discussion of the parameter variations in the various modules took place together with experts. It led to lists of parameters given in Chapter 2.1.

The uncertainty investigations for the atmospheric dispersion module (ATM - module) and the module describing early protective actions (CTM - module) are shortly mentioned in Chapter 2.1. The results have been presented in detail in [15] and [14]. Sensitivity tables for these two submodules will be presented once again in Appendix C. The uncertain model parameters for calculating short - term organ doses (DCF - module) and the health effects model (HEM - module) of the UFOMOD subsystem NE are explained in Chapter 2.1.1 and 2.1.2. (The subsystem NE covers the near range up to about some ten kilometers and contains models and data to assess early consequences.) Chapter 2.1.3 provides a list of the uncertain model parameters for the overall (OA or OAL) analysis, which were selected based on the experience gained from the various submodule uncertainty analyses.

The following endpoints of accident consequence assessments are investigated: The variability of the mean values <later called **(M) - evaluation**>[1] and 99% - quantiles <later called **(P) - evaluation**> of activity concentrations for I-131 and Cs-137 on ground surface and in the air near ground, individual acute doses (lung, bone marrow), indidual risks (pulmonary, hematopoietic syndrome) at three distances: D1 (.875 km), D2 (4.9 km) and D3 (8.75 km) and the corresponding number of early fatalities. For the HEM - module the number of health effects from lung function impairment, pulmonary syndrome, hematopoietic syndrome and gastrointestinal syndrome were considered as endpoints in the analysis.

Chapter 3.1 briefly describes the IMAN / CONOVER procedure for Latin hypercube sampling. The estimation of confidence bounds is indicated in Chap 3.2.

The identification of important contributors to variations in consequences is done by the use of a sensitivity measure, the so-called partial (rank) correlation coefficient, PCC or PRCC. Both sensitivity measures, PCC or PRCC, respectively, are measures that quantify the relation between the uncertainty in consequences and those of model parameters. When a nonlinear relationship is involved it is often more revealing to calculate PCCs between parameter *ranks* than between the *actual* values for the parameters. The numerical value of the PRCCs can be used for hypothesis testing to quantify the confidence in the correlation itself, i.e. by statistical reasons one can determine which PRCC values indicate really an importance (significance) of a parameter or which PRCC values are simply due to 'white noise'. This is described in Chapter 3.3 or more explicitely in Appendix A. Moreover, it is possible to calculate the percentage contribution of each uncertain model parameter to uncertainty in consequences by use of so-called *coefficients of determination* (R^2).

The last step in performing uncertainty analyses is to present and interprete the results of the analyses. Chapter 3.4 condenses the information obtained from the uncertainty analysis for some submodules and the overall uncertainty analysis of the program system UFOMOD, subsystem NE, and gives a guideline to understand the detailed figures and tables in the Appendices B and C.

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[1] averaged over 144 weather sequences sampled from synoptic records of the two years 1982/83

2. Models

2.1 General features

The program system UFOMOD [8] is an advanced probabilistic accident consequence assessment (ACA) code. Its structure and modelling is based on the experience gained from applications of the old UFOMOD code during and after the German Risk Study - Phase A [3], the results of scientific investigations performed within Phase B, the CEC - project MARIA[2] [29], and the requirements resulting from the extended use of ACAs to help in decision - making.

The new program system UFOMOD is subdivided into three subsystems, each designed to assess accident consequences occurring in different time periods or distance ranges. The two subsystems **NE** and **NL** covering the near range up to about 50 km contain models and data to assess early and late consequences as indicated in Figure 1. The far range subsystem **FL** is designed mainly for estimating long-term doses and countermeasures and the resulting stochastic health effects in the population up to about 3000 km.

For the UFOMOD uncertainty and sensitivity analyses described in this report only the near range subsystem NE of UFOMOD is used.

Each subsystem of UFOMOD has an almost identical modular structure. It consists of several program units designed to assess sequentially the various types of accident consequences.

Each program unit contains the complete loop structure over weather sequences, grid points, release phases and further module specific arrays. All point results calculated in each module are stored on temporary and/or permanent data files. In addition, special evaluation programs have access to the data sets stored from each module to provide numerical and graphical presentations of the various intermediate and final results and their correlations. This structure has the advantage, that parameter studies, uncertainty and sensitivity analyses of single submodels and selected endpoints can be easily performed without the repetition of calculations in preceding computational steps. Also the reevaluation of the results

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2

CEC : Commission of the European Communities
MARIA: Methods for Assessing the Radiological Impact of Accidents within the CEC Radiation Protection Research Programme

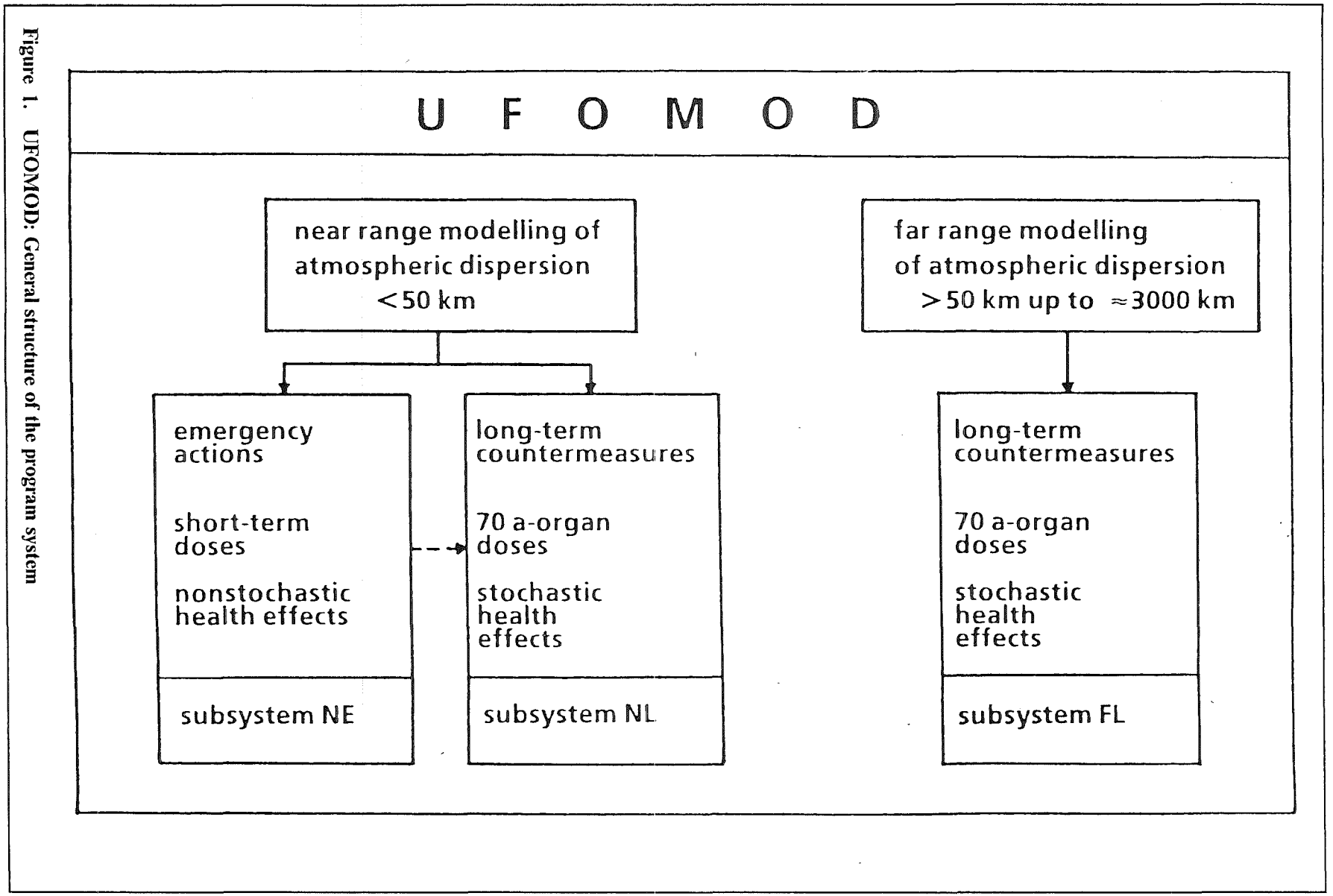

Figure 1. UFOMOD: General structure of the program system

obtained during a complete ACA is possible under changing aspects which may come up during the interpretation period.

Atmospheric dispersion and deposition (ATM - module)

The task of the atmospheric dispersion module is to calculate space-dependent time-integrated air and ground concentrations of radionuclides resulting from an accidental release of radioactive material for a large number of different weather sequences. In the near range, a modified version of the segmented plume model MUSEMET (trajectory model) is applied.

Based on the source term characteristics and the meteorological conditions, the atmospheric dispersion models in UFOMOD calculate normalized time-integrated concentrations patterns in the air near to the ground and on the ground surface. Thereby, the models distinguish between different dry and wet deposition characteristics which depend on the physical and chemical form of the isotopes released. The spatial concentration fields are transferred to subsequent modules of UFOMOD to calculate distribution functions of air concentrations, contaminated areas, organ doses and health effects together with areas and numbers of persons affected by countermeasures which are taken to reduce the exposure and thus the health implications in the population.

In an earlier uncertainty analysis of the UFOMOD ATM - submodule (see [15]) it was shown that variations in deposition velocities and in the mixing height parameters play the most important role in the activity concentration values.

The following parameters were considered as uncertain model parameters:
initial horizontal and vertical plume width in the wake of the reactor building, σ_{y0} and σ_{z0}, mixing heights for different stability classes, h_m , horizontal and vertical plume diffusion for different stability classes, $\sigma_y(S)$ and $\sigma_z(S)$, dry deposition for aerosols and elementary iodine, $v_d(AE)$ and $v_d(IO)$, washout coefficients for aerosols and elementary iodine for different rainfall intensities, Λ_{AE} and Λ_{IO}.
The analysis was limited to pure model parameters; quantities describing the source term (like termal energy) or measured values (like wind speed or wind direction) were not considered. As source term an unit release (1 Ci) of I-131 and Cs-137 in three hourly subsequent phases was chosen. The release height was assumed to be 10 meters.

The conditions of UFOMOD uncertainty analyses described in this report are summarized in Figure 2.

source term: FK2/5

release:	noble gases	100%
	elem. iodine	8%
	Cs-Rb	6%
	Te-Sb	4%

no thermal energy

meteorology: Karlsruhe

no. of weather sequences:	144
sampling scheme:	stratified

population:

5 German sites with highest population density in the near range

Figure 2. Conditions of UFOMOD runs for uncertainty analyses

Countermeasures (CTM - module)

For an uncontrolled release of radionuclides, the exposure of members of the public can only be limited by actions usually termed *protective actions*, *countermeasures*, or simply *measures*. Depending on the type and amount of release, the dispersion conditions, the distance to the source, and time, countermeasures may cover the whole range between minor restrictions, almost without any impact on the average citizen, and disruption of normal living due to evacuation or relocation.

There are several types of countermeasures and each of them may exhibit a large variety of possible features characterized by parameters in the program system UFOMOD. The types of countermeasures implemented in the subsystem NE are sheltering and evacuation against short - term exposure. How the evacuation is simulated in the UFOMOD subsystem NE is shortly described in [9].

The following parameters were considered as uncertain model parameters:
initial delay of actions in area A (keyhole shaped area determined by two radii (r,R) and an angle) or B (area determined by an isodose line), TINA, delay time between end of release and end of sheltering period in area A, TDELA, fraction of population with different behaviour during the sheltering period in area A, PAUFA, intervention dose level for emergency actions in area B, GRWRTB, index of last outer radius of the keyhole shaped area A, IEVA2, angle of keyhole sector in area A, azimuthal shift of the keyhole sector of area A against the wind direction of the first release phase, WGRNZA, driving time to leave area A, TDRA.

2.1.1 Parameters contributing to uncertainty in the DCF - analysis

The exposure pathways considered in the program system UFOMOD are those, which are known as the most important ones. In the subsystem NE, irradiation from cloudshine, groundshine and inhalation is modelled for up to 141 radionuclides.

Due to the threshold nature of nonstochastic effects, only high doses delivered over a relatively short timespan (*"acute exposure"*) can lead to these effects. Such doses are supposed to occur only within a few tens of kilometers around the site and are therefore assessed with the near range model UFOMOD/NE. For acute exposure it is assumed that the doses from ingestion of contaminated food do not contribute to the acute dose since this exposure patheway can - for a brief time - be completely avoided by restricting the distribution of freshly produced foodstuffs. The acute doses from inhalation of resuspended activity are also not taken into account, since for the source terms considered the short term exposure from this pathway is negligible.

The UFOMOD module EARLY (EARLY contains a detailed modelling of fast protective actions) calculates short-time integrated individual organ doses taking into account the patterns of dose mitigating actions determined in the UFOMOD module PROTEC.

The **dose-conversion factors (DCFs)** for external and internal irradiation are read from data sets, which are derived from a large data base provided by the Gesellschaft für Strahlen- und Umweltforschung (GSF) mbH (for details see [8]). It contains age- and time dependent dose - conversion factors for those organs and nuclides considered in UFOMOD. The data sets of the present versions of UFOMOD contain dose - conversion factors for adults only.

In principle, doses are calculated in the following way:

$$DOSIS(organ) = \sum_{i=1}^{3}\left(\sum_{k} CONC(i,k) \cdot DCF(i,k,organ) \cdot AF(i,j) \cdot [ARATIH]\right) \quad [1]$$

where

- i exposure pathway (cloudshine, groundshine, inhalation)
- j type of shielding (houses with low or high shielding, shielding in cellars, shielding in cars, shielding outdoors)
- k type of nuclide
- AF stands for the different shielding factors given below

The following list gives the name and the meaning of the parameters:

DCFxx(t)		dose conversion factors for *xx, where xx* ∈ *(Sr-89, Ru-106, Te-132, I-131,133,135, Cs-134,137, Ba-140)* integrated over the time interval t=1,2,3,4 (organ dependent) of the protracted exposure
ARATIH		breathing rate (inhalation)
AFHAUL(i)	(i=1,2,3)	shielding factor (houses with low shielding) 1. cloudshine 2. groundshine 3. inhalation
AFHAUF(i)	(i=1,2,3)	shielding factor (houses with high shielding) 1. cloudshine 2. groundshine 3. inhalation
AFKELL(i)	(i=1,2,3)	shielding factor (in cellars) 1. cloudshine 2. groundshine 3. inhalation
AFAUTO(i)	(i=1,2)	shielding factor (inside cars) 1. cloudshine 2. groundshine
AFFREI(i)	(i=1,2)	shielding factor (outdoors) 1. cloudshine 2. groundshine

All uncertain parameters have been split into two factors:

$$Par = w \bullet Par_{ref} \qquad [2]$$

the first of them being a random variable w with a suitable frequency distribution, and the second one being the best estimate or reference value.

For example, the original AFHAUL(1) - values used in the UFOMOD code vary within the range of 0.1 and 1.0. This corresponds to Table 2 in the following manner:

$$AFHAUL(1) = w \bullet AFHAUL(1)_{ref} \in [0.1,1.0] \qquad [3]$$

When quantifying uncertainties of dose conversion factors, internal and external exposure pathways have to be considered separately. According to [28], the uncertainties of thyroid dose assessments for short - term inhalation of short - living iodine isotopes are lognormal distributed with a 95% - quantile of 2.2 times the best estimate. For the Cs-137 inhalation the 95% - quantile is higher by a factor of 1.6. After discussions about the variability of dose conversion factors also for other nuclides [19], it was concluded that the assumption of lognormal distributions with 95% - quantiles a factor of 3 times higher than the median values would be an acceptable judgement. The uncertainties are mainly caused by the large variability of the biological half - lives and the body masses of individuals.

Uncertainties of external does conversion factors for cloudshine and groundshine are in the order of magnitude of 10% [26], and thus negligible in comparison to those of the internal dose conversion factors. Therefore, they are not considered in this uncertainty analysis.

The breathing rate for adults strongly depends on the physical activity of the individuals. In [33], the possible range of values is estimated as 5 [l/min] up to 35 [l/min]. A triangular distribution was chosen as representative of the behaviour of the population.

The shielding factors for inhalation depend on the filtering effect of the houses. They may vary between 0.3 and 1.0 (see [5]). Due to lack of knowledge, a rectangular distribution was assumed.

The shielding of and by houses against external irradiation from the cloud and from surfaces strongly depends on the shielding properties of the building materials and structures, and on the residence place of the individual. Therefore, the shielding factors show a large variability. The range of values was assessed on the basis of the results obtained for a variety of residence places and house types documented in [27]. Due to missing informations, rectangular distributions were assumed.

No.	Parameter	Reference value	Distribution	Additional characteristics	Quantiles			Correlation of parameters
					w_{05}	w_{50}	w_{95}	
1	DCFSR	$1.25\ 10^{-9}$	lognormal	*)	0.333	1	3	[1])
	DCFSR(t) t=2,3,4							
2	DCFRU	$5.03\ 10^{-9}$	lognormal	*)	0.333	1	3	[2])
	DCFRU(t) t=2,3,4							
3	DCFTE	$3.67\ 10^{-10}$	lognormal	*)	0.333	1	3	[3])
	DCFTE(t) t=2,3,4							
4	DCFIO	$6.80\ 10^{-10}$	lognormal	*)	0.333	1	3	[4])
	DCFIO(t) t=2,3,4							
5	DCFCS	$6.33\ 10^{-10}$	lognormal	*)	0.333	1	3	[5])
	DCFCS(t) t=2,3,4							
6	DCFBA	$8.74\ 10^{-10}$	lognormal	*)	0.333	1	3	[6])
	DCFBA(t) t=2,3,4							

Note:

*) truncated at 0.1th and 99.9th percentile for t=1,2,3 :

[1]) DCFSR(t) 100% correlated to DCFSR ≡ DCFSR(1)

[2]) DCFRU(t) 100% correlated to DCFRU ≡ DCFRU(1)

[3]) DCFTE(t) 100% correlated to DCFTE ≡ DCFTE(1)

[4]) DCFIO(t) 100% correlated to DCFIO ≡ DCFIO(1)

[5]) DCFCS(t) 100% correlated to DCFCS ≡ DCFCS(1)

[6]) DCFBA(t) 100% correlated to DCFBA ≡ DCFBA(1)

Table 1. Transformed DCF - parameter distribution table

No.	Parameter	Reference value	Distribution	Additional characteristics	Range of variation			Correlation of parameters
					w_1 *)	w_0 *)	w_2 *)	
7	ARATIH	$3.33\ 10^{-4}$ $[m^3/s]$	triangular		0.25	1	1.75	
8	AFHAUL3	1	uniform		0.3		1.0	
9	AFHAUF3	1	uniform		0.3		1.0	
10	AFKELL3	1	uniform		0.3		1.0	
11	AFHAUL1	0.3	uniform		0.33		3.33	(11,16) corr. = 0.5
12	AFHAUF1	0.01	uniform		0.50		10	(12,17) corr. = 0.5
13	AFKELL1	0.05	uniform		$2\ 10^{-3}$		2	(13,18) corr. = 0.5
14	AFAUTO1	1	uniform		0.3		1	(14,19) corr. = 0.5
15	AFFREI1	1	uniform		0.3		1	(15,20) corr. = 0.5
16	AFHAUL2	0.1	uniform		0.6		5	
17	AFHAUF2	0.01	uniform		0.1		6	
18	AFKELL2	0.03	uniform		$3.33\ 10^{-3}$		1.33	
19	AFAUTO2	0.7	uniform		$1.43\ 10^{-1}$		1.43	
20	AFFREI2	1	uniform		0.1		1.5	

Note:
*)
$w_1 = w_{min}$ $w_0 = w_{mod}$ $w_2 = w_{max}$

Table 2. Transformed DCF - parameter distribution table (cont'd)

The following list gives the name and the meaning of the consequence variables:

```
DOSLUD1     individual acute dose (lung)                 at  D1 (0.875 km)
DOSLUD2     individual acute dose (lung)                 at  D2   (4.9 km)
DOSLUD3     individual acute dose (lung)                 at  D3  (8.75 km)
DOSBMD1     individual acute dose (bone marrow)          at  D1 (0.875 km)
DOSBMD2     individual acute dose (bone marrow)          at  D2   (4.9 km)
DOSBMD3     individual acute dose (bone marrow)          at  D3  (8.75 km)
RSKLUD1     individual risk  (pulmonary syndrome)        at  D1 (0.875 km)
RSKBMD1     individual risk  (hematopoietic syndrome)    at  D1 (0.875 km)
POP(LU)     early fatalities (pulmonary syndrome)
POP(BM)     early fatalities (hematopoietic syndrome)
```

2.1.2 Parameters contributing to uncertainty in the HEM - analysis

The assessment of nonstochastic health effects is based on the 'Health Effects Model (HEM) for Nuclear Power Plant Accident Consequence Analysis [10]. The probability r that an individual will exhibit a nonstochastic effect is modelled using hazard functions. Mathematically a hazard function has the form:

$$r = 1 - e^{-H} \qquad [4]$$

The cumulative hazard H is a function of dose. For acute exposure, H is taken to be a Weibull function,

$$H = \ln(2) \cdot \left(\frac{D}{D_{50}} \right)^{S} . \qquad [5]$$

Such functions are characterized by parameters, which are called D_{50} and S: D is the dose in the organ of interest. D_{50} is the median dose at which 50% of the exposed individuals would be expected to exhibit the effect (mortality or clinical symptoms of illness in the case of morbidity). The parameter S characterizes the slope of the dose - risk function.

To account for protracted exposure the approach is made to express the cumulative hazard as sums of the normalized doses received within various time intervals:

$$H = \ln(2) \cdot \left(\sum_{i} \frac{D^i}{D^i_{50}} \right)^{S} , \qquad [6]$$

where D^i is the dose accumulated in some time interval i and the normalization parameter D^i_{50} is the dose at which 50% of the individuals are likely to develop the effect when continually exposed in this time interval. The slope parameter S is assumed to be independent of the dose rate for all effects. To determine the overall mortality risk from exposure of several organs, the cumulative hazard is calculated as the sum of the hazards of each effect.

Mathematically, the risk predicted by a hazard function is positive for any nonzero level of dose. Because of the threshold nature of the nonstochastic effects, it is assumed that acute doses below a certain threshold do not cause any early health risk. The default values for S, D_{50} and the thresholds currently used in UFOMOD/NE are given in [8] or [9]; they all can be changed by the user.

All fatal effects specified in the HEM are also considered in UFOMOD. They comprise the effects following radiation of the bone marrow (hematopoietic syndrome), the lung (pulmonary syndrome) and the GI-tract (gastrointestinal syndrome). Of the possible non-fatal effects only such are taken into account in UFOMOD which will lead to a severe disability

of the affected individual for the rest of her or his life or which require continuous medical treatment and/or social care. The effects considered in UFOMOD are the impaired pulmonary function, hypothyroidism, cataracts and mental retardation after irradiation in utero. For uncertainty analyses only the impaired pulmonary function is taken into account. The models for nonstochastic health effects are implemented in the modules for assessing individual risks of the subsystem NE.

The following list gives the name and the meaning of the parameters:

LGMD50(t)	t=1,2,3,4	the dose that would induce lung function impairment in half the population exposed during time interval t
THRESLGM(t)	t=1,2,3,4	threshold dose for exposure during time interval t (lung function impairment)
LGFD50(t)	t=1,2,3,4	the dose that would induce pulmonary syndrome in half the population exposed during time interval t
THRESLGF(t)	t=1,2,3,4	threshold dose for exposure during time interval t (pulmonary syndrome)
BMFD50(t)	t=1,2,3	the dose that would induce hematopoietic syndrome in half the population exposed during time interval t
THRESBMF(t)	t=1,2,3	threshold dose for exposure during time interval t (hematopoietic syndrome)
GIFD50(t)	t=1,2	the dose that would induce gastroindestinal syndrome in half the population exposed during time interval t
THRESGIF(t)	t=1,2	threshold dose for exposure during time interval t (gastroindestinal syndrome)
LGMSHP		shape parameter (lung function impairment)
LGFSHP		shape parameter (pulmonary syndrome)
BMFSHP		shape parameter (hematopoietic syndrome)
GIFSHP		shape parameter (gastrointestinal syndrome)

For details see [8], p. 56ff.

All uncertain parameters have been split into two factors:

$$Par = w \bullet Par_{ref} \qquad [7]$$

the first of them being a random variable w with a suitable frequency distribution, and the second one being the best estimate or reference value.

For example, the original GIFSHP - values used in the UFOMOD code vary within the range of 5 and 20. This corresponds to Table 3 in the following manner:

$$GIFSHP = w \cdot GIFSHP_{ref} \in [5,20] \qquad [8]$$

The uncertainties of the parameters determining the dose - risk - relationship for non - stochastic health effects were quantified on the basis of the range of values already used in uncertainty analyses of the MACCS - code (see [17], [18]). Due to lack of information the shape parameters and the D_{50} - values were assumed to be uniformly distributed, the correlations between both parameters are -.75 as suggested in [17] and [18]. The dose tresholds are calculated by the relation

$$T = 0.5 \cdot D_{50}. \qquad [9]$$

Therefore, a 100% correlation exists between T and D_{50}. The D_{50} - values of protracted time periods were assumed to show the same variability as those for short - term exposure (100% correlation).

The following list gives the name and the meaning of the consequence variables:

```
RSKLMD1     individual risk (lung function impairment)  at  D1 (0.875 km)
RSKLMD2     individual risk (lung function impairment)  at  D2 (  4.9 km)
RSKLFD1     individual risk  (pulmonary syndrome)       at  D1 (0.875 km)
RSKBMD1     individual risk  (hematopoietic syndrome)   at  D1 (0.875 km)
RSKGID1     individual risk  (gastrointest. syndrome)   at  D1 (0.875 km)
RSKTTD1     individual risk  (mortality: all effects)   at  D1 (0.875 km)
POPLUM      early fatalities (lung function impairment)
POPLUF      early fatalities (pulmonary syndrome)
POP(BM)     early fatalities (hematopoietic syndrome)
POP(GI)     early fatalities (gastrointestinal syndrome)
POPTOT      early fatalities (mortality: all effects)
```

No.	Parameter	Reference value	Distri-bution	Range of variation		Correlation of parameters
				w_1 *)	w_2 *)	
1	LGMD50	4.6	uniform	0.59	1.30	[1])
	LGMD50(t) t=2,3,4					
	THRESLGM(t) t=1,2,3,4					
2	LGFD50	9.3	uniform	0.86	2.58	[2])
	LGFD50(t) t=2,3,4					
	THRESLGF(t) t=1,2,3,4					
3	BMFD50	4.7	uniform	0.60	1.28	[3])
	BMFD50(t) t=2,3					
	THRESBMF(t) t=1,2,3					
4	GIFD50	15.0	uniform	0.67	1.50	[4])
	GIFD50(2)					
	THRESGIF(t) t=1,2					
5	LGMSHP	7.0	uniform	0.36	1.43	(1,5) corr. = -.75
6	LGFSHP	7.0	uniform	0.36	1.43	(2,6) corr. = -.75
7	BMFSHP	6.0	uniform	0.50	2.00	(3,7) corr. = -.75
8	GIFSHP	10.0	uniform	0.50	2.00	(4,8) corr. = -.75

Note:

*) $w_1 = w_{min}$ $w_2 = w_{max}$

[1])

```
LGMD50(t)    100% correlated to LGMD50 ≡ LGMD50(1)   t=2,3,4
THRESLGM(t)  100% correlated to LGMD50(1)            t=1,2,3,4
```

[2])

```
LGFD50(t)    100% correlated to LGFD50 ≡ LGFD50(1)   t=2,3,4
THRESLGF(t)  100% correlated to LGFD50(1)            t=1,2,3,4
```

[3])

```
BMFD50(t)    100% correlated to BMFD50 ≡ BMFD50(1)   t=2,3
THRESBMF(t)  100% correlated to BMFD50(1)            t=1,2,3
```

[4])

```
GIFD50(2)    100% correlated to GIFD50 ≡ GIFD50(1)
THRESGIF(t)  100% correlated to GIFD50(1)            t=1,2
```

Table 3. Transformed HEM - parameter distribution table

2.1.3 Parameters contributing to uncertainty in the OVERALL - analysis

Based on the experiences and conclusions from the submodule uncertainty and sensitivity investigations (for details see Chap. 3.4) 10 out of 20 uncertain model parameters have been chosen from the atmospheric dispersion and deposition submodule, 6 out of 20 from the countermeasures module, 6 out of 20 from the module calculating acute individual organ doses, and 2 out of 8 from the health effects module, i.e. the total number of uncertain model parameters to be considered for the overall analysis is 24.

The following list gives the name and the meaning of the parameters:

h_m	mixing height
$\sigma_z(S)$	horizontal plume diffusion for stability class S (S ∈ {A,B,C,D,E,F})
Λ_{AE}	washout coefficients of aerosols
$v_d(AE)$	dry deposition of aerosols
$v_d(IO)$	dry deposition of elementary iodine
GRWRTB	intervention criteria for evacuation of area B (B is defined by an isodose line)
TDELA	delay time between end of release and end of sheltering period in area A [h], where A is geometrically determined (keyhole - shaped)
IEVA2	index of last outer radius belonging to area A
PAUFA(i)	fraction of population with different behaviour during the sheltering period in area A 1. in cars (spontaneous evacuation) 2. in cellars 3. in buildings with low shielding 4. in buildings with high shielding 5. outside, rural area
TINA	initial delay of actions in area A [h]
DCFxx(t)	dose conversion factors for *xx* *xx* ∈ *(Sr-89, I-131,133,135, Cs-134,137)* integrated over the time interval t=1,2,3,4 (organ dependent) of the protracted exposure
AFHAUL(1)	shielding factor (houses with low shielding) cloudshine
AFFREI(1)	shielding factor (outdoors)

		cloudshine
ARATIH		breathing rate (inhalation)
LGFD50(t)	t=1,2,3,4	the dose that would induce pulmonary syndrome in half the population exposed during time interval t
THRESLGF(t)	t=1,2,3,4	threshold dose for exposure during time interval t (pulmonary syndrome)
BMFD50(t)	t=1,2,3	the dose that would induce hematopoietic syndrome in half the population exposed during time interval t
THRESBMF(t)	t=1,2,3	threshold dose for exposure during time interval t (hematopoietic syndrome)

The following list gives the name and the meaning of the consequence variables:

IODCGD1	concentration of I-131 on ground surface	at	D1 (0.875 km)
IODCGD2	concentration of I-131 on ground surface	at	D2 (4.9 km)
IODCGD3	concentration of I-131 on ground surface	at	D3 (8.750 km)
IODCAD1	concentration of I-131 in air near ground	at	D1 (0.875 km)
IODCAD2	concentration of I-131 in air near ground	at	D2 (4.9 km)
IODCAD3	concentration of I-131 in air near ground	at	D3 (8.750 km)
CAECGD1	concentration of Cs-137 on ground surface	at	D1 (0.875 km)
CAECGD2	concentration of Cs-137 on ground surface	at	D2 (4.9 km)
CAECGD3	concentration of Cs-137 on ground surface	at	D3 (8.750 km)
CAECAD1	concentration of Cs-137 in air near ground	at	D1 (0.875 km)
CAECAD2	concentration of Cs-137 in air near ground	at	D2 (4.9 km)
CAECAD3	concentration of Cs-137 in air near ground	at	D3 (8.750 km)
DOSLUD1	individual acute dose (lung)	at	D1 (0.875 km)
DOSLUD2	individual acute dose (lung)	at	D2 (4.9 km)
DOSLUD3	individual acute dose (lung)	at	D3 (8.75 km)
DOSBMD1	individual acute dose (bone marrow)	at	D1 (0.875 km)
DOSBMD2	individual acute dose (bone marrow)	at	D2 (4.9 km)
DOSBMD3	individual acute dose (bone marrow)	at	D3 (8.75 km)
RSKLUD1	individual risk (pulmonary syndrome)	at	D1 (0.875 km)
RSKBMD1	individual risk (hematopoietic syndrome)	at	D1 (0.875 km)
POP(LU)	early fatalities (pulmonary syndrome)		
POP(BM)	early fatalities (hematopoietic syndrome)		

No.	Parameter	Additional characteristics	Reference value	Distribution	Range of variation			Correlation of parameters
					w_1 +)	w_0 +)	w_2 +)	
1	$h_m(S)$	DC = A	1600 m	triangular	0.5	1	1.5	100% between all stability classes
		DC = B	1200 m					
		DC = C	800 m					
		DC = D	600 m					
		DC = E	300 m					
		DC = F	200 m					
2	$\sigma_z(S)$	DC = A	$\sigma_z(x,S)$ KA-JÜ z = 50m for details see [15] Chap. 2	triangular	0.39	1	2.56	50% between all stability classes
3		DC = B			0.60	1	2.56	
4		DC = C			0.60	1	1.67	
5		DC = D			0.57	1	1.66	
6		DC = E			0.42	1	1.75	
7		DC = F			0.42	1	2.38	
8	Λ_{AE} [1])	0-1 mm	0.34 E-4	lognormal[3])	1/5	1	5	*)
		1-3 mm	1.17 E-4					
		> 3 mm	3.29 E-4					
9	$v_d(AE)$ [2])		0.55 E-3	lognormal[3])	1/5.5	1	5.5	no correlation
10	$v_d(IO)$ [2])		1.00 E-2		1/3	1	3	
11	GRWRTB		0.5	uniform	0.2		1	
12	TDELA		0	triangular	0	2	4	
13	IEVA2	$p_{1,2,3} = \frac{1}{3}$	10	discrete	0.9	1.0	1.1	
14	PAUFA(1)		0.3	triangular	0.333	1	1.666	$\sum_{i=1}^{5} PAUFA(i) = 1$
15	PAUFA(5)		0.1	uniform	0		1	
	PAUFA(2)	$= [1 - (PAUFA(1) + PAUFA(5))]/2$						
	PAUFA(3)	$= [1 - (PAUFA(1) + PAUFA(5))]/4$						
	PAUFA(4)	$= [1 - (PAUFA(1) + PAUFA(5))]/4$						
	PAUFB(t)	t = 1,...,5 PAUFB 100 % correlated to PAUFA						
16	TINA		2	triangular	0.5	1	2.5	TINB 100% correlated to TINA
	TINB							

Note: +) $w_1 = w_{min}$ $w_0 = w_{mod}$ $w_2 = w_{max}$ DC = Diffusion category *) 100% with respect to diff. rain intensities
[1]) Units for Λ_{AE} are [1/s] [2]) Units for $v_d(AE)$, $v_d(IO)$ are [m/s]
[3]) lognormal distribution truncated at 0.1th and 99.9th quantile;
$w_1 = 0.1\%$ quant. $w_0 = 50\%$ quant. $w_2 = 99.9\%$ quant.

Table 4. OVERALL - parameter distribution table

No.	Parameter	Additional characteristics	Reference value	Distribution	Range of variation			Correlation of parameters
					w_1 +)	w_0 +)	w_2 +)	
17	DCFSR	*)	$1.25\ 10^{-9}$	lognormal	0.333	1	3	[1])
	DCFSR(t) t=2,3,4							
18	DCFCS	*)	$6.33\ 10^{-10}$	lognormal	0.333	1	3	[2])
	DCFCS(t) t=2,3,4							
19	DCFIO	*)	$6.80\ 10^{-10}$	lognormal	0.333	1	3	[3])
	DCFIO(t) t=2,3,4							
20	AFHAUL1		0.3	uniform	0.33		3.33	
21	AFFREI1		1	uniform	0.3		1	
22	ARATIH		$3.33\ 10^{-4}$ $[m^3/s]$	triangular	0.25	1	1.75	
23	LGFD50		9.3	uniform	0.86		2.58	[4])
	LGFD50(t) t=2,3,4							
	THRESLGF (t) 1,2,3,4							
24	BMFD50		4.7	uniform	0.60		1.28	[5])
	BMFD50(t) t=2,3							
	THRESBMF (t) 1,2,3							

Note:

+) $w_1 = w_{min}$ $w_0 = w_{mod}$ $w_2 = w_{max}$

*) lognormal distribution truncated at 0.1th and 99.9th percentile
w_1 = 5% quantile w_0 = 50% quantile w_2 = 95% quantile

[1])
DCFSR(t) 100% correlated to DCFSR ≡ DCFSR(1) t=1,2,3

[2])
DCFCS(t) 100% correlated to DCFCS ≡ DCFCS(1) t=1,2,3

[3])
DCFIO(t) 100% correlated to DCFIO ≡ DCFIO(1) t=1,2,3

[4])
LGFD50(t) 100% correlated to LGFD50 ≡ LGFD50(1) t=2,3,4
THRESLGF(t) 100% correlated to LGFD50(1) t=1,2,3,4

[5])
BMFD50(t) 100% correlated to BMFD50 ≡ BMFD50(1) t=2,3
THRESBMF(t) 100% correlated to BMFD50(1) t=1,2,3

Table 5. OVERALL - parameter distribution table (cont'd)

All uncertain parameters (except TDELA) have been split into two factors:

$$Par = w \cdot Par_{ref} \quad \text{and} \quad Par \neq \text{TDELA} \qquad [10]$$

the first of them being a random variable w with a suitable frequency distribution, and the second one being the best estimate or reference value.

For example, the original TINA - values used in the UFOMOD code vary within the range of 1 and 5. This corresponds to Table 4 in the following manner:

$$TINA = w \cdot TINA_{ref} \in [1,5] \qquad [11]$$

But we have to set

$$Par = w + Par_{ref} \quad \text{for} \quad Par = \text{TDELA} \qquad [12]$$

3. Uncertainty Analysis

The preceding chapter described ranges, distributions and correlations of the model parameters, respectively.

The first task to do for uncertainty analyses performed with the program system UFOMOD is to define specific vectors of the uncertain model input parameters to be used in each run of UFOMOD. The selection of these sets of specific parameter values is done by a suitable *sampling scheme*. With *one* parameter set each run produces *one* complementary cumulative distribution function (CCFD). From all runs a family of curves results, which visualizes the variability of the CCFDs of consequences. Confidence bands can be derived together with sensitivity measures, which determine what causes this variability in consequences.

Important questions are, how to construct CCFD curves and confidence bands, how to calculate sensitivity measures and how many UFOMOD-runs are necessary to get reliable uncertainty and sensitivity results?

Uncertainty analysis methods may need much computer runs and time if there are a lot of model parameters and the accident consequence code is long-running. Therefore, on one hand the designer of a sampling scheme should aim at a low number of runs, on the other hand the number of runs should be large enough to get stable and thrustworthy results.

The viewgraphs Figure 3 and Figure 4 show the necessary steps for uncertainty and sensitivity analyses and the objectives of the UFOMOD uncertainty investigations.

As a summarizing overview Figure 5 indicates in a schematic way the steps of uncertainty and sensitivity analyses.

User defined characteristics (ranges, distributions, correlations) of uncertain model parameters serve as input to the Latin hypercube sampling program. The resulting set of sampled parameter values is written to a so-called LHS - design file. The preprocessing input interface prepares the sampled values for the input module EINLES of UFOMOD. For submodule analyses, precalculated results of preceding UFOMOD modules are stored on permanent files. For example, if the countermeasures module is to be investigated, the activity concentration fields of the atmospheric dispersion module have to be read for each UFOMOD run during the uncertainty analysis. The output file contains the complete information to build CCFDs of consequence variables. A graphics program displays CCFDs and corresponding estimated confidence bounds. The PRCSRC program is used to get the most sensitive parameters responsible for variations in consequences.

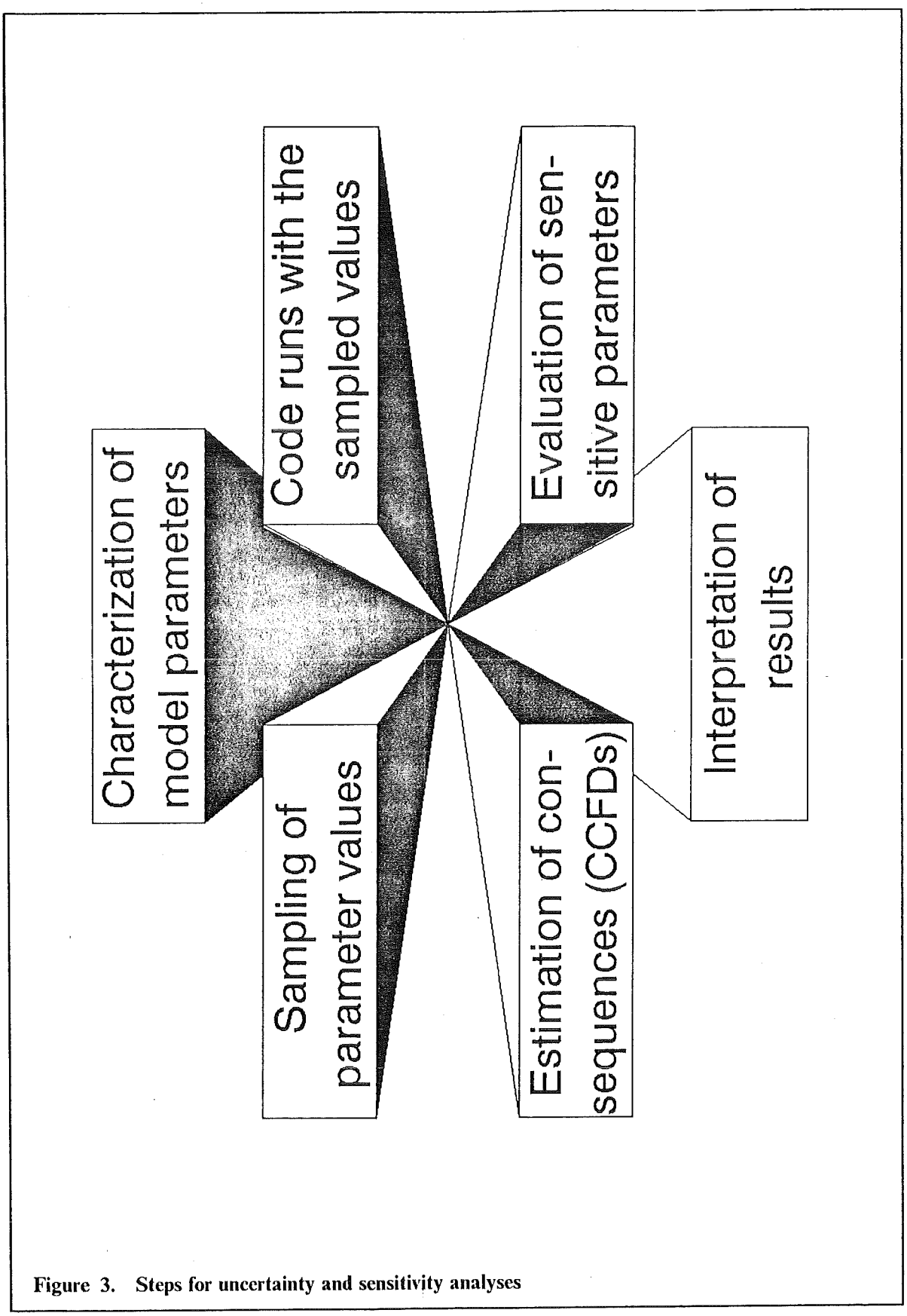

Figure 3. Steps for uncertainty and sensitivity analyses

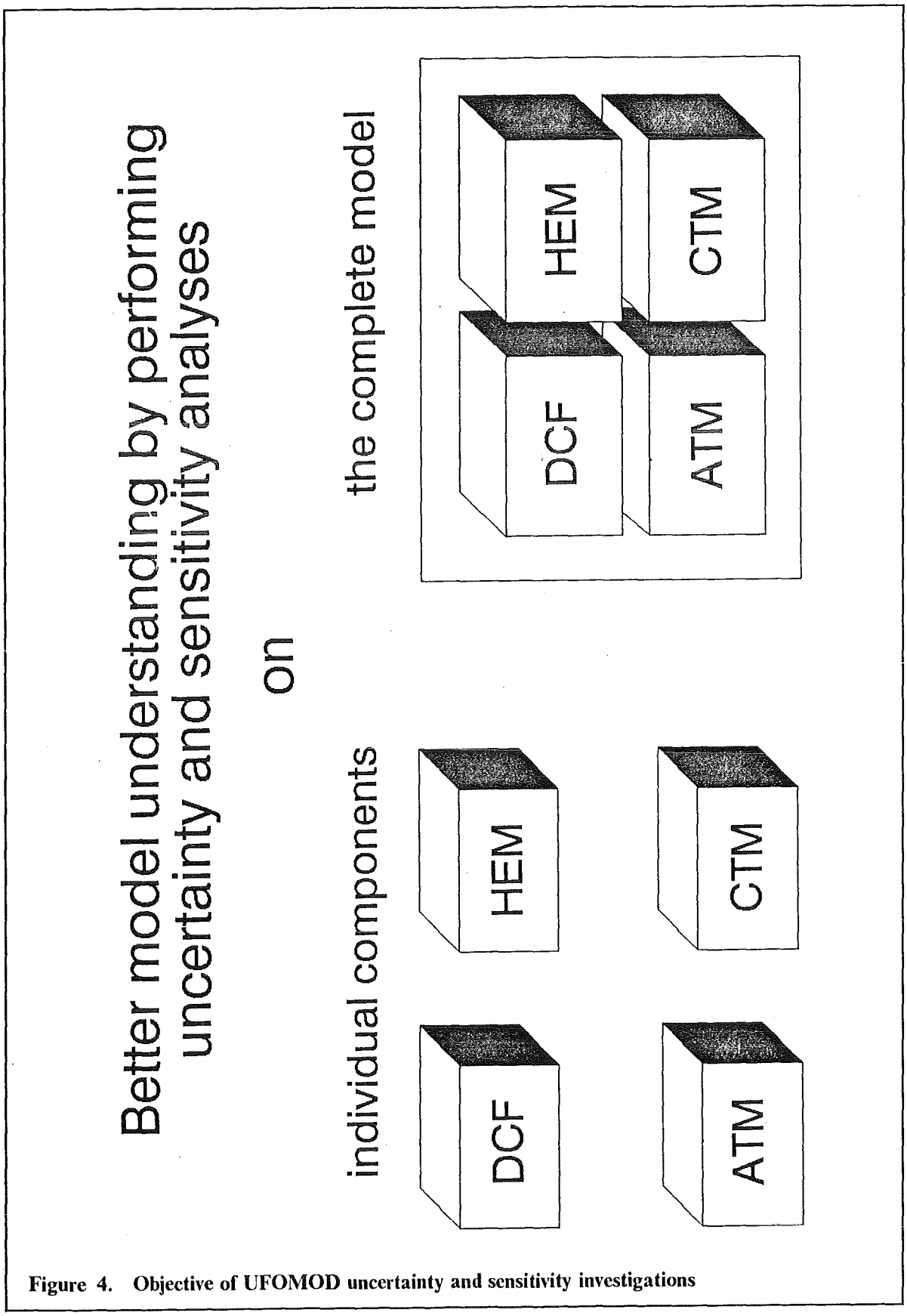

Figure 4. Objective of UFOMOD uncertainty and sensitivity investigations

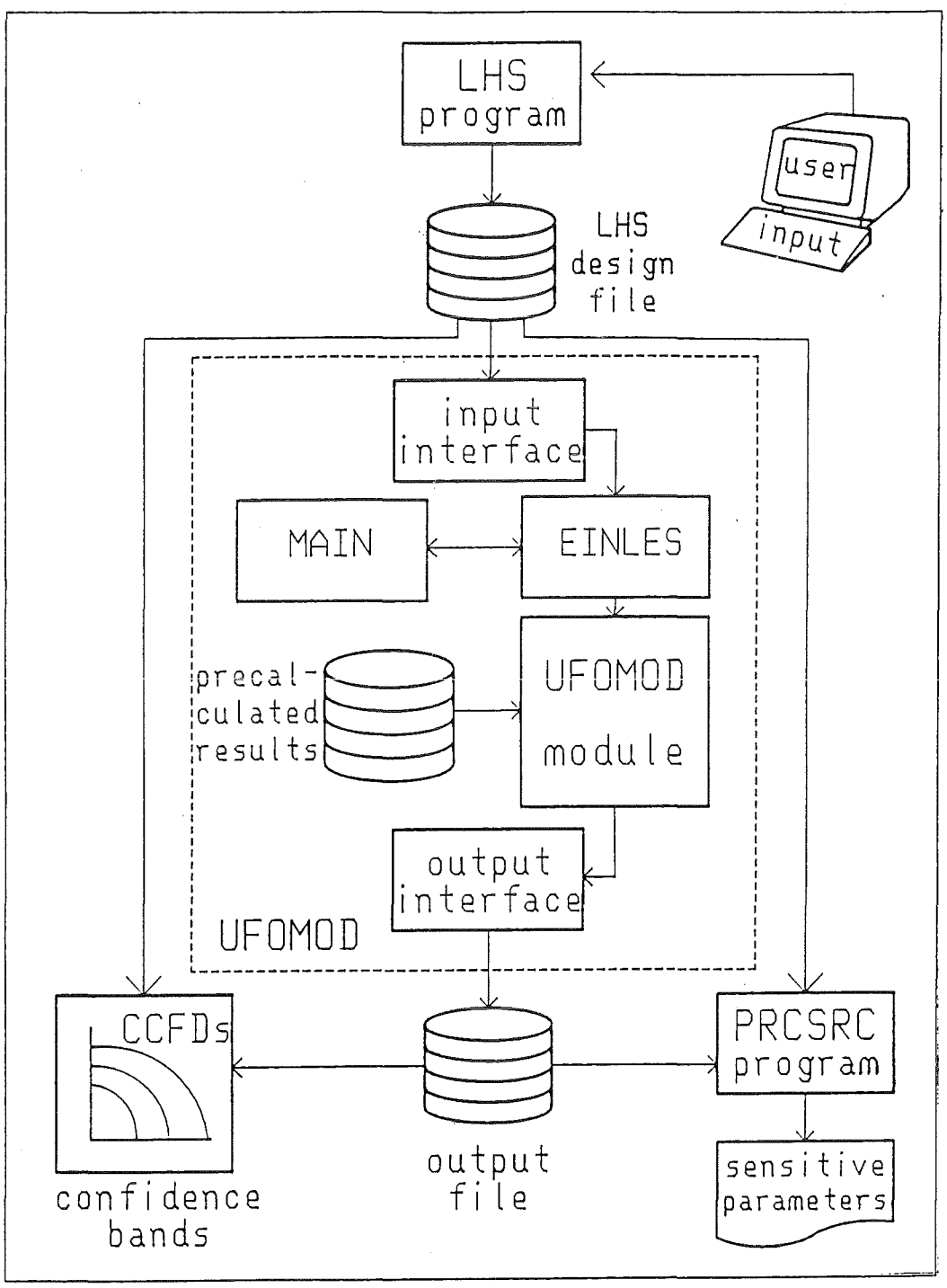

Figure 5. Scheme of UFOMOD - uncertainty and sensitivity analyses

3.1 The sampling scheme

From the various possible sampling strategies the Latin hypercube sampling (LHS) approach was selected. LHS is a modified random sampling with stratified samples and is found to have very good sampling characteristics when compared to other methods (see [23] and [34] (Vol. 3 K-5)).

The sampling procedure forces the value of each model parameter to be spread across its entire range. In random sampling it is possible by chance to choose only a portion of the range of model parameters, leaving out another part of the possible range that could greatly influence the consequence variables. The intent of LHS is to make more efficient use of computer runs than random sampling even for *smaller* sample sizes. For *large* sample sizes there is little difference between the two techniques.

A Latin hypercube sample of size n stratifies the range of each model parameter into "n" nonoverlapping intervals on the basis of equal probability. Randomly a value is selected from each of these intervals. Let X_i (i= 1,...,k) be the model parameters. The n values obtained for X_1 are paired at random with the n values obtained for X_2. These n pairs are combined in a random manner with the n values for X_3 to form n triples. The process is continued until a set of n k-tuples is formed.

There may exist "spurious" correlations between model parameter values within a Latin hypercube sample, due to the random pairing of the model parameter values in the generation of the sample. This is most likely when n is small in relation to k. Such correlations can be avoided by modifying the generation of the sample through use of a technique introduced by R.I. Iman and W.J. Conover [21]. This technique preserves the fundamental nature of LHS, but replaces the random pairing of model parameter values with a pairing that keeps all of the pairwise rank[3] correlations among the k model parameters close to zero.

The Iman/Conover-technique can also be used to induce a desired rank correlation structure among the model parameters. The procedure is distribution free and allows exact marginal distributions to remain intact. This is used for the UFOMOD - LHS - design (The SANDIA LHS program [24] is used.). For some mathematical details see [21] and [13].

---

3 The rank order statistic for a random sample is any set of constants which indicate the order of observations. The actual magnitude of any observation is used only in the determination of its relative position in the sample array and is thereafter ignored in any analysis based on rank order statistics.

3.2 *Estimation of confidence bounds*

The next task is to run the accident consequence code with the sampled input parameter values from the LHS-design.

The following distinctions are necessary:

- There are stochastic variations e.g. in weather conditions or wind directions. Each run of UFOMOD therefore produces one frequency distribution (CCFD) of consequences.
- Due to lack of knowledge about the actual model parameter values there is an uncertainty in these results. This can quantitatively be expressed by confidence intervals of the frequency distribution of consequences.

CCFD curves are generated by considering the probability of equaling or exceeding each consequence level on the x-axis. To construct a CCFD keep in mind 144 weather sequences with different probabilities, say PWET(L) (L = 1,...,144), and 72 azimuthal sectors of 5 ° each, are considered. For each radius (distance) there exist 144 × 72 point values with the probability PWET(L)/72. The 144 × 72 consequence values are sorted into 90 classes (which correspond for instance to nine decades of consequence values on a logarithmic x-scale). Each class has its own probability of occurrence given by summing up the probabilities of the members of the class. Adding the probabilities of the classes stepwise from the right to the left will give the CCFD.

To get confidence curves for each consequence level so-called p-quantiles are calculated from the number n_0 of associated probability values at this consequence level x.

Example:

Suppose $n_0 = 100$ UFOMOD - runs, i.e. there are 100 CCFDs and - corresponding for each consequence level x - 100 probability points. To get a (p %) - confidence the following procedure has been adopted:
For each consequence level x find the (p %) - smallest probability value of n_0 ordered values. For all individual consequence levels these selected probability points are connected to obtain the estimated (p %) - confidence curve.

Particularly for the 5 % (95 %) - confidence curves connect the $p \times n_0$ -th numbers from the bottom in the ordered list of n_0 probability points, i.e. in our example connect the 5-th and the 95-th values from the bottom, respectively. Mean and median curves can be created in a similar manner.
□

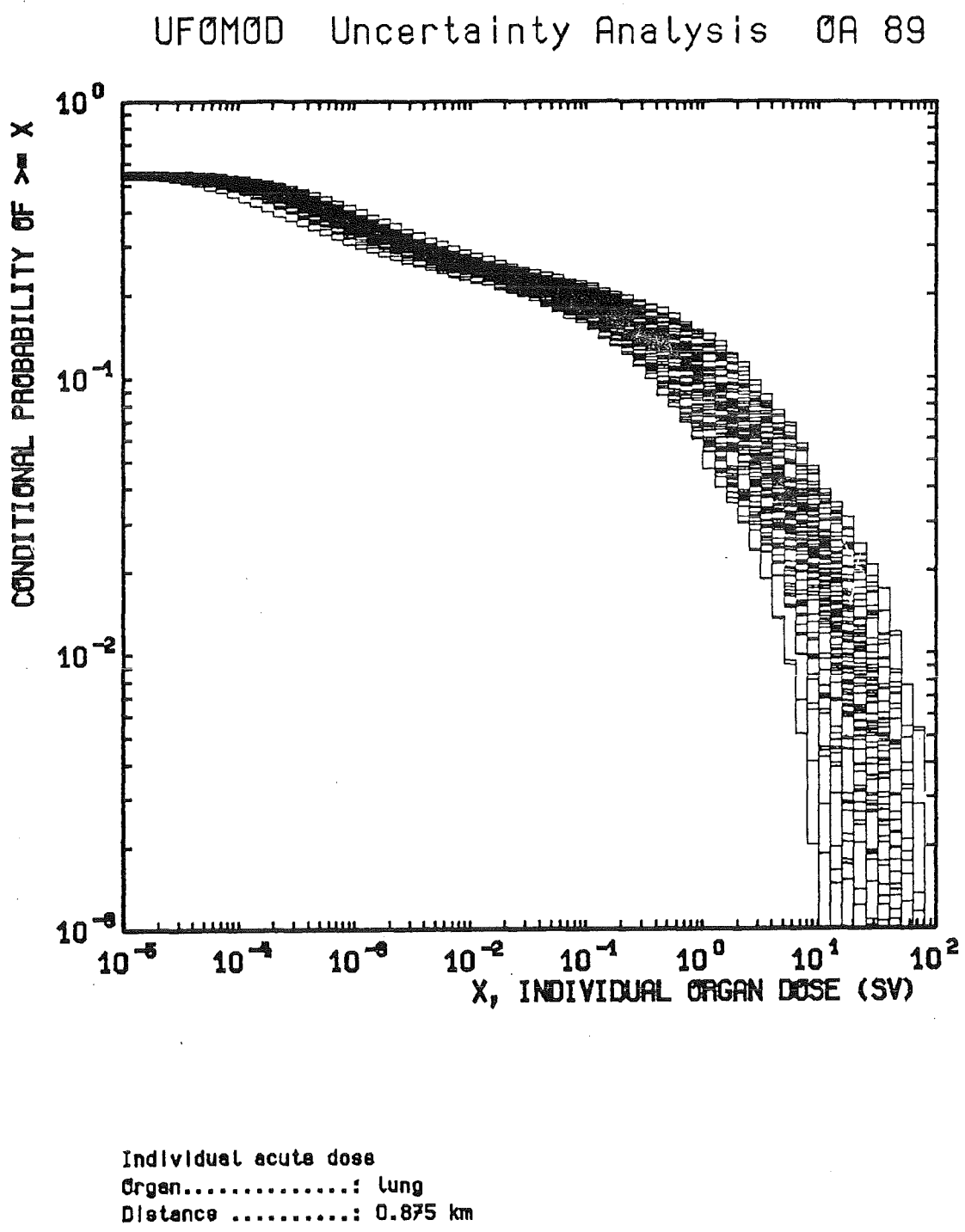

Figure 6. Complementary cumulative frequency distributions (CCFDs) of acute individual lung dose values: Each CCFD (assuming release has occurred) corresponds to one of the 100 runs in a Latin hypercube sample of size 100 in the overall analysis (OAL).

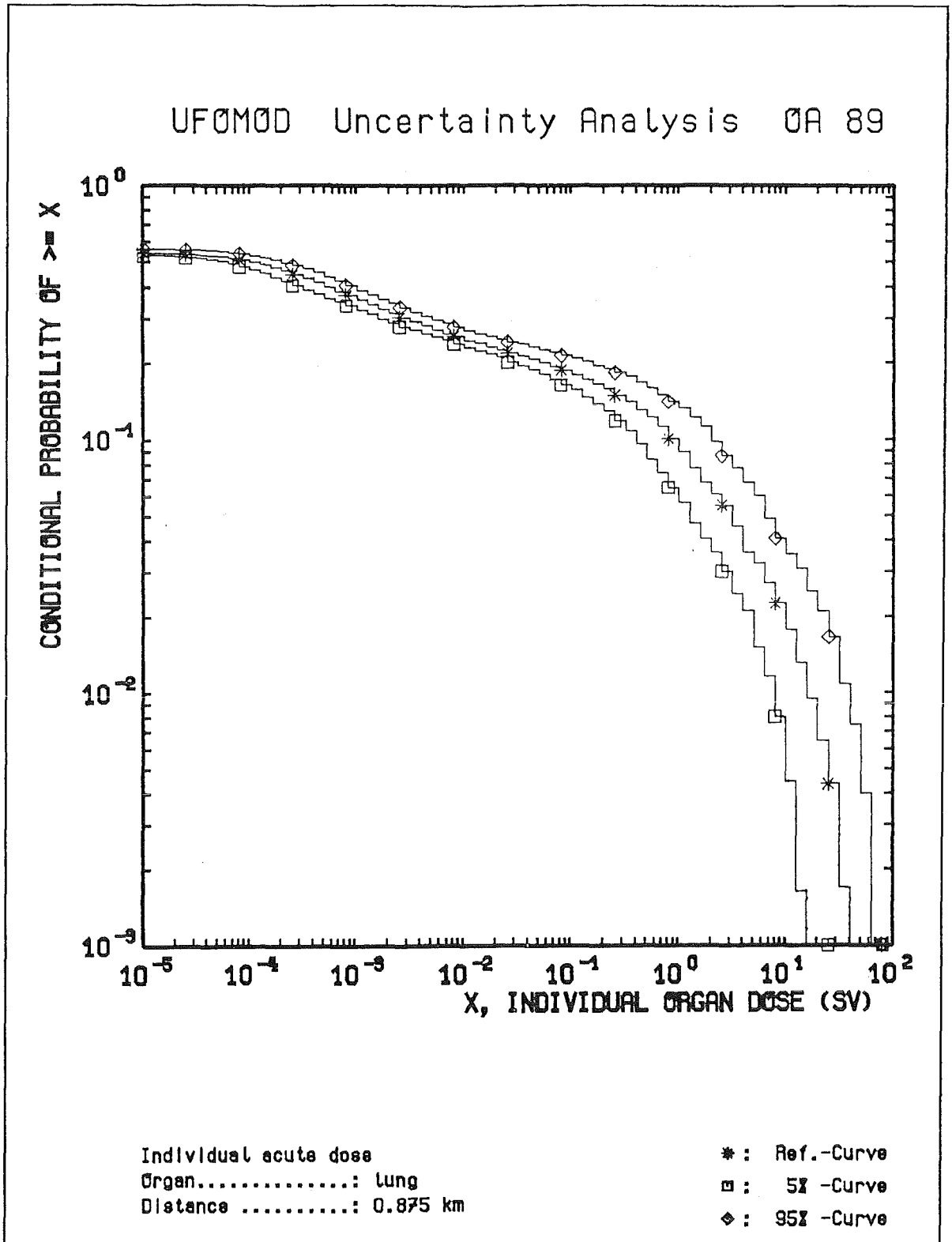

Figure 7. Reference CCFD of acute individual lung dose values: The empirical 5%-,95%-quantiles are given as estimated confidence bounds at discrete points of the x-axis.

It has been tested[4] that different samples for $n \geq 1.5 \cdot$ number of model parameters do not significantly change the 5%-95%-confidence bands. Figure 6 shows 100 estimated complementary cumulative frequency distributions for the acute individual dose values at the distance of .875 km in the overall uncertainty analysis.

Figure 7 shows the corresponding estimated so-called *reference CCFD* (all uncertain input model parameters are at their point value (50%-quantile)) and the empirical 5%-95%-quantiles at each consequence level. The 5%-95%-'confidence curves' were generated by considering the probability of equaling or exceeding each consequence level appearing on the x-axis. For each consequence level the 5% and 95%-quantiles (or other values: mean, median etc.) were calculated from the 100 associated probability values. These probability estimates for individual consequence levels were then connected to obtain the empirical 5%-95%-confidence curves (see [1]).

So, the confidence bounds have to be interpreted as follows:

There is 90%-confidence that the conditional probability for the activity concentrations, x, on ground surface, is

- below the ordinate value at x of the 95%-curve,and
- above the ordinate value at x of the 5%-curve.

The width of the CCFD-confidence band is an indicator of the sensitivity of model predictions with respect to variations in parameters, which are imprecisely known.

3.3 Sensitivity analysis

Now, those uncertain input model parameters have to be identified which are important contributors to variations in consequences. Following [23], there are several methods for quantifying the relative importance of the uncertain model parameters to the output of the accident consequence model. Usually, each of the uncertain model parameters is ranked on the basis of its influence on the consequences. Some methods provide such an overall ranking while others (e.g. stepwise regression) are designed to select subsets consisting of only the most influential parameters.

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4 In [23] is stated, that good results can be obtained even with $n = 4/3$ times the number of uncertain model parameters. For $n < k$ it seems appropriate to use the LHS - technique in a piecewise fashion on subsets of the k model parameters. For details see [21].

- Rankings beyond the first few most important uncertain parameters usually have little or no meaning in an absolute ordering, since only a small number of the total number of uncertain parameters actually turns out to be significant. This will be explained later in more detail.
- Sensitivity analysis in conjunction with any form of sampling or design is easiest to carry out *if a regression model is fitted* between the model consequences and the model parameter values. Such a regression model is inherent in the calculation of correlation coefficients. But, regression techniques are influenced by extreme observations and nonlinearities. Therefore it seems to be appropriate to transform the data.

A method which

- is regression based,
- ranks either all uncertain model parameters or only those within a subset, and additionally
- avoids sophisticated transformations

is the ranking on the basis of *partial rank correlation coefficients.*

Now, *regression analyses* define the mathematical relationship between two (or more) variables, while *correlations* measure the strength of the relationship between two variables.

But do all correlation numbers indicate a significant relationship between variables, i.e. is there an actual relationship or only one by chance ('white noise')? Up to which level (**'white noise'-level, critical value**) the correlation numbers are treated as garbage?

The numerical values of correlation coefficients or partial (rank) correlations coefficients can be used for significance testing of the correlation, or with other words, for hypothesis testing to quantify the confidence in the correlation itself. For details see Appendix A.

But to summarize the main results in advance:

To get **statistically stable results for sensitivity analyses** larger sample sizes than for confidence bounds calculations have to be chosen. The number of uncertain model parameters, which have a sensitivity measure value above the so-called 'white noise level' increase with sample size. For details see Appendix A and the sensitivity tables in Appendix C.

The **partial correlation coefficient (PCC)** is a measure that explains the linear relation between for instance a consequence variable and one or more uncertain model parameters with the possible linear effects of the remaining parameters removed. Following [16], when nonlinear relationships are involved, it is often more revealing to calculate PCCs between variable *ranks* than between the *actual values* for the variables. Such coefficients are known as **partial rank correlation coefficients (PRCCs)**. Specifically, the smallest value of each vari-

able is assigned the rank 1, the largest value is assigned the rank n (n denotes the number of observations). The partial correlations are then calculated on these ranks.

The next step is to pick out the relevant sensitivity information out of the bulk of hidden messages within the CCFDs.

There are various possible ways to condense the extensive data:

- Estimate fractiles, or other characteristics of the n CCFDs *at certain consequence levels.* There will be possibly divergent 'importance rankings' for different consequence values.
- Estimate *one* fractile, *one* estimated mean value etc. for each of the n consequence curves.

The second procedure is used for the UFOMOD - uncertainty and sensitivity analyses. To find the most important contributors to uncertainty in the consequences partial rank correlation coefficients (PRCCs) are used under assistance of the SANDIA PRCC-code (see [25]).

There is a need to compare the variation ranges of each consequence endpoint for each submodule analysis and the overall analysis. The variability of each consequence endpoint investigated was quantified by

- calculating e.g. the (5 %, 95 %) - estimated confidence bands of the n (n = sample size) mean values or the 99 % - quantiles (the horizontal 10^{-2} *'cut'* in the CCFD - (frequency, consequence) - diagram (as an example see Figure 8),
- calculating the PRCCs of the mean values (**M - type evaluation**) and of the 99% - quantiles (**P - type evaluation**),
- presenting the corresponding most sensitive parameters (from the submodule analyses and the final overall inverstigation) and their percentage contribution to the variation in the consequence variables.

The variability of the 99% - quantiles of the consequence endpoints with respect to variations of the uncertain model parameters might be of higher interest than variations of mean values if the results of consequence assessments are used in decision making. The comparison of both evaluations based on mean values (**M - type evaluation**) or based on 99% - quantiles (**P - type evaluation**), respectively, may give an indication whether future analyses can be limited to only one quantity. Therefore, the sensitivity tables of all submodule and the overall model analyses are supplemented by the corresponding M and P columns of PRCC values.

Importance ranking is done by taking *absolute* values of the PRCC values. The model parameter associated with the largest absolute PRCC value is called the **most important** one responsible for uncertainty in consequences and gets **importance rank 1.**

This differs from the definition of *ranks of sample values*, where the smallest values has rank 1, the next smallest has rank 2 and so on.

It is well known how to calculate the percentage contribution of each uncertain model parameter to variations in consequences by so-called 'coefficients of determination', R^2. Keep in mind: All coefficients of determination R^2_s are normalized by R^2_t , i.e.

$$R^2 = \left(\frac{R^2_s}{R^2_t}\right) \times 100 \ , \qquad [13]$$

where R^2_s , R^2_t are calculated by the SANDIA - PRCSRC-code (see [25]) and the R^2_t - values are calculated with *all* (i.e. the complete set of) model parameters.

The (%) - columns in the sensitivity tables contain the *normalized* R^2 corresponding to Eq. [13] ; in all tables an additional row contains the *nontransformed* total R^2_t - values (*all* model parameters are included in the R^2 analysis). This allows to judge up to which extent the uncertainty in consequences can be explained by the variation of model parameters (all model parameters included). Our experience shows that in a lot of cases $R^2_t \geq 95$ % and mostly $R^2_t \geq 90$ % .

In some cases the sum of the R^2 - values in a column is larger than 100%. This is due to rounding errors.

Example:

On the basis of 100 UFOMOD - runs with LHS for the overall analysis, the most important uncertain parameters including their PRCC and *importance rank* for each consequence (e.g.: acute individual lung dose values at the distance of .875 km) are identified. By statistical reasons (as explained before), a parameter is significant with confidence 95%, if the absolute value of the corresponding PRCC is greater than .22 (for n = 100). The absolute value describes the strength of the input-output dependency, while the (+,-)-sign indicates increasing (decreasing) model consequences for increasing uncertain parameter values. The dose conversion factor for iodine, DCFIO, and the breathing rate (inhalation) ARATIH, are the most important sources of variation for the individual acute lung dose values with PRCC-values of from .92 to .94. Increasing DCFIO and ARATIH lead to a strong increase of individual acute lung dose values (see Appendic C).
□

In addition to evaluating the influence of each uncertain model parameter on the model consequences, the calculation of PCCs or PRCCs provide a good indicator of the 'fit of the analysis' to the model behaviour: the **coefficient of determination, R^2**, which is a measure of how well the linear regression model based on PCCs (or the corresponding standardized regression coefficients) can reproduce the actual consequence values. Or, in other words, it

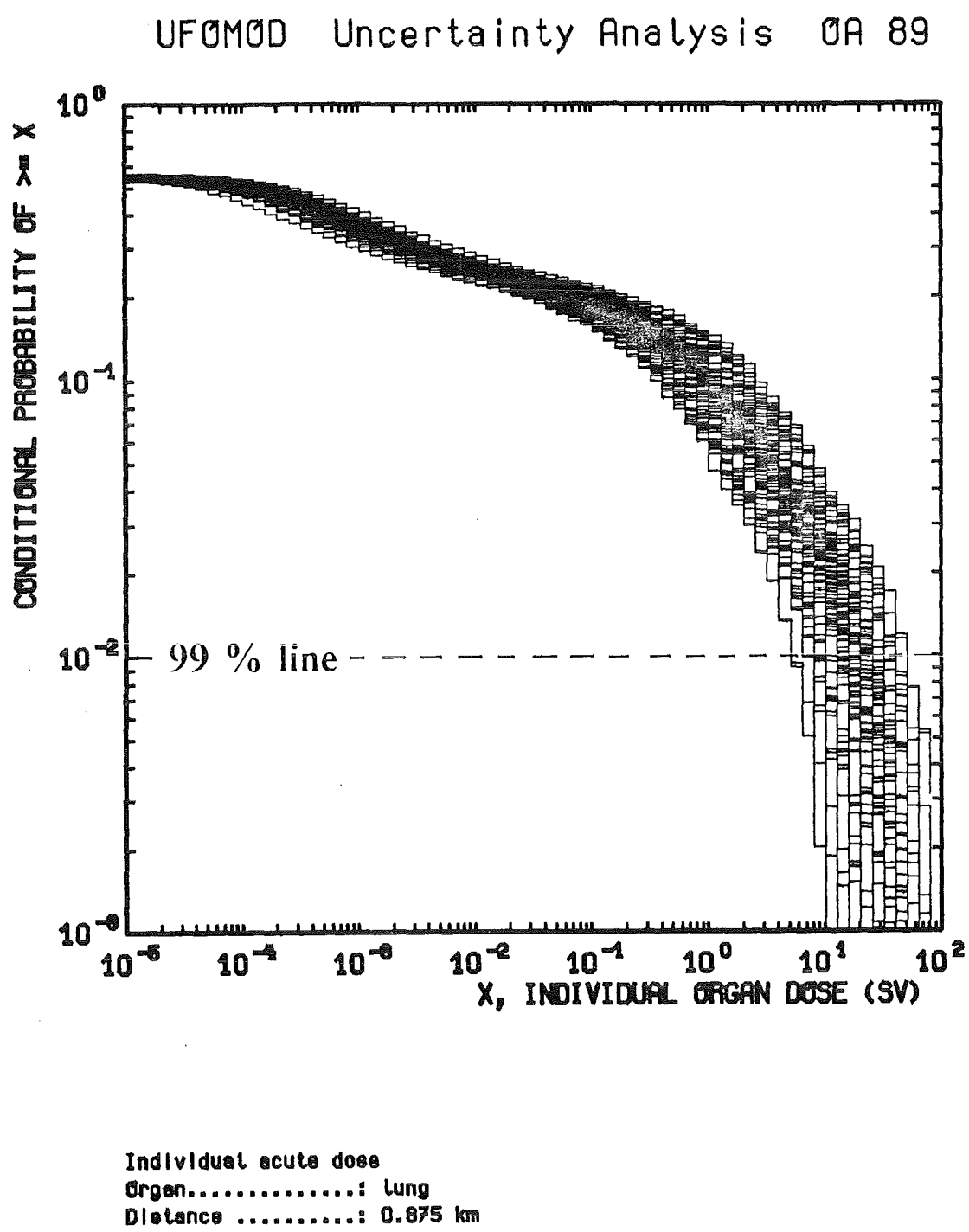

Figure 8. Cutline example for CCFDs of acute individual lung dose values: Each CCFD (assuming release has occurred) corresponds to one of the 100 runs in a Latin hypercube sample of size 100 in the overall analysis (OAL).

reflects the fraction of the variance in model consequences which can be explained by regression, i.e. it is possible to calculate the *percentage contribution* of each uncertain model parameter to variations in consequences. R^2 varies between 0 and 1 and is the square of the corresponding PCC. The closer R^2 is to unit, the better is the model performance.

For instance, the percentage contribution of the model parameters DCFIO and ARATIH to the uncertainty in the acute individual lung dose values at the distance of .875 km is 39 % each if the sensitivity analysis is based on mean consequence values. If 99% - quantile values are the basis for sensitivity calculations then the percentage contribution of ARATIH increases to 45 %, DCFIO contributes to 36%.
□

3.4 *Results*

In two reports (see [15] and [14]) uncertainty and sensitivity studies (based on mean consequence values) were explicated for the atmospheric dispersion module (ATM), and the models describing early protective actions (CTM). This chapter summarizes the main conclusions of these investigations and presents in more detail the uncertainty and sensitivity investigations for

- the models calculating short-term organ doses (DCF),
- the health effects model (HEM), and
- the overall analysis (OAL).

The following endpoints of an accident consequence assessments were investigated:

- air and ground concentrations (I-131 and Cs-137)
- acute individual organ doses
  (lung, bone marrow)
- individual risks
  (pulmonary syndrome, hematopoietic syndrome)
- number of health effects
  (pulmonary syndrome, hematopoietic syndrome, lung function impairment))

considering the variability of the mean[5] (**M - type evaluation**) and the 99% - quantiles (**P - type evaluation**) of their probability distributions (CCFDs).

In Figure 9 the number of the underlying uncertain model parameters for each submodule is given. Additionally, the largest number of UFOMOD runs performed for each submodule is indicated.

A large amount of results emerged from the uncertainty and sensitivity analyses, and there was a need to condense the information in illustrative presentations. Figure 10 to Figure 16 shown in chapter 3.4.1 to 3.4.4 (distance dependent analyses) contain two types of results:

- in the upper part, the (5%, 95%) confidence bands of the 99% - quantiles derived from the CCFDs of consequences (in the **P - type evaluation**) are presented in the form of bars on an absolute logarithmic scale. This allows an easy intercomparison of the uncertainties of consequences with values of different orders of magnitude (e.g. for

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5 (averaged over 144 weather sequences which represent the weather of the two years 1982 / 83)

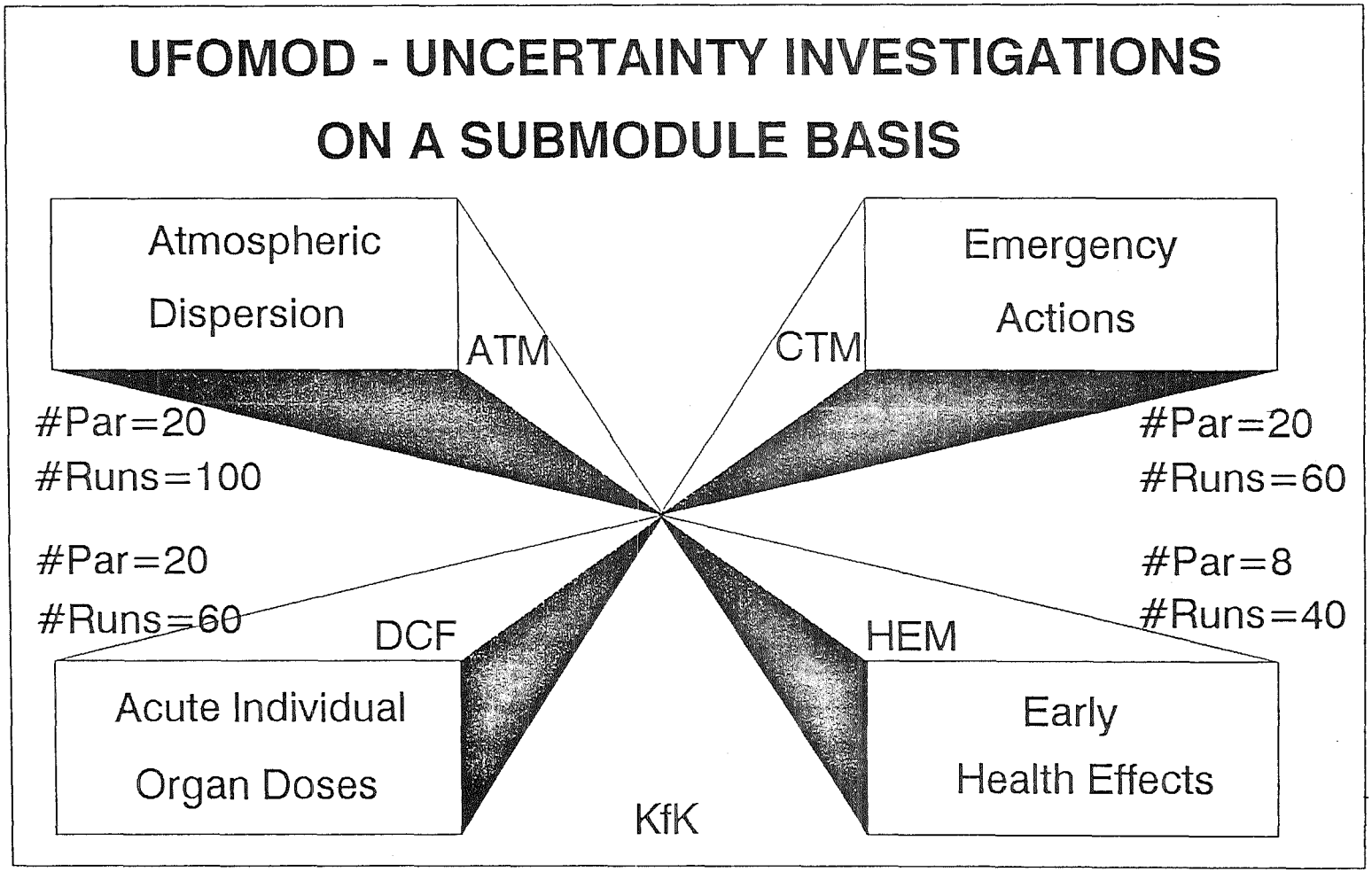

Figure 9. UFOMOD uncertainty investigations on a submodule basis

activity concentrations at three distances D1 (.875 km), D2 (4.9 km) and D3 (8.75 km);

- in the lower part, the percentage contribution of those model parameters mainly causing the uncertainties of consequences are presented as bars for each distance. Thus, changes of the significance of model parameters with increasing distance from the site can easily be seen.

In chapter 3.4.5 the results of the overall analysis (OAL) are discussed. In this context, the contribution of the single submodules to the overall uncertainty are of interest. Therefore, Figure 19 to Figure 28 presented in chapter 3.4.5 again contain two types of results:

- in the upper part, the (5%, 95%) confidence bands of the 99% - quantiles derived from the CCFDs of consequences (in the **P - type evaluation**) from each single uncertainty analysis (ATM, CTM, DCF, HEM) and from the overall analysis (OAL) are presented in the form of bars on an absolute logarithmic scale. Thus, it becomes very clear, which module contributes in which range of values to which extent to the overall uncertainties;
- in the lower part, the most significant model parameters and their percentage contributions to the uncertainties of consequences for each single analysis (ATM, CTM, DCF, HEM) and for the overall analysis (OAL) are listed. In brackets, the sign of the PRCC values is given, indicating a positive or negative correlation between the uncertainties of the model parameter and the consequence type.

A comprehensive presentation of results is provided in either some former reports (ATM, CTM) [15] and [14] or the Appendices B and C (DCF, HEM, OAL).

3.4.1 ATM - Analysis

In Chap. 2 the conditions (restriction to pure model parameters, no source term uncertainties, unit release) and the main results of an earlier submodule analysis for the ATM submodule are described. For more details see [15]. The restriction to pure model parameters and revised uncertainty bands of these parameters led to significantly smaller confidence bands of the consequence endpoints than for the old UFOMOD / B3 code (see for comparison [13]). It was shown that uncertainties in deposition velocities and in the mixing height parameters cause the largest part of the variability of the activity concentration values. [15] contains comprehensive comparison with respect to different sample sizes and different distribution types. The only endpoints considered were activity concentration values.

In the new investigations a non-unit source term was used based on the release category FK2 of the German Risk Study, Phase B, (see Figure 2 in Chap 2). Justified by the results

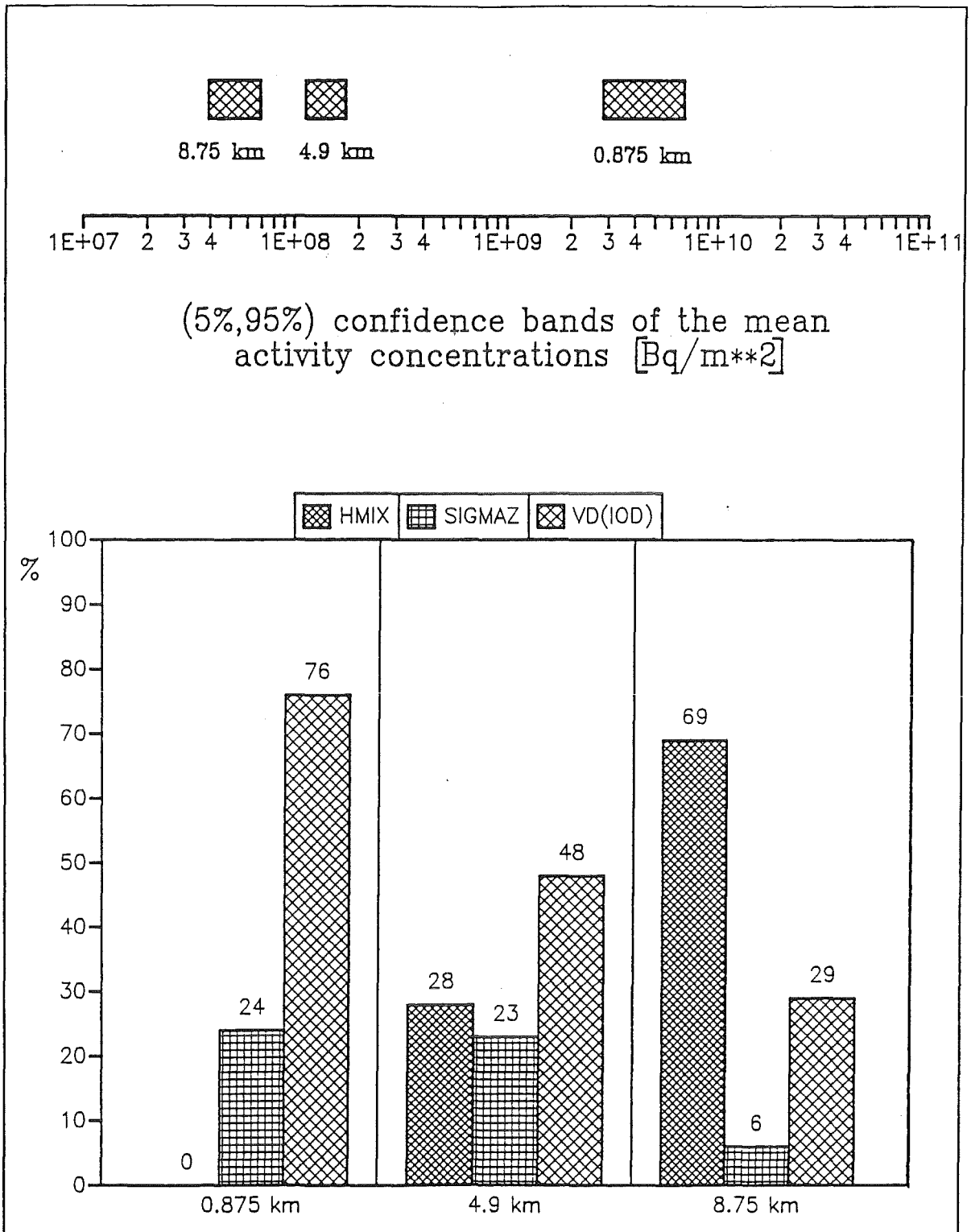

Figure 10. ATM - analysis based on mean values of I-131 concentrations on ground surface: (5%,95%) confidence bands of mean values of activity concentrations and percentage contributions of model parameters

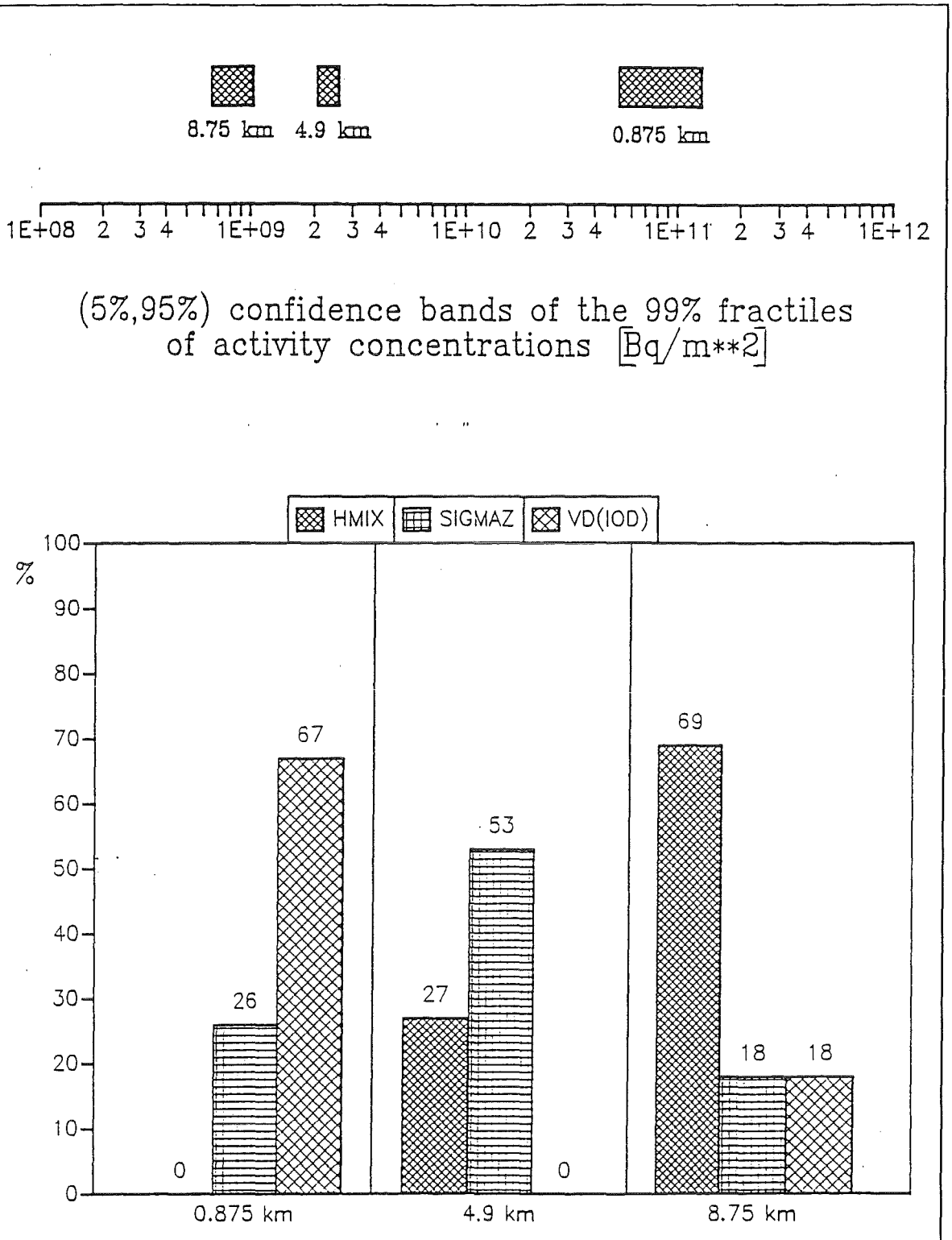

Figure 11. **ATM - analysis based on 99% fractiles of I-131 concentrations on ground surface:** (5%,95%) confidence bands of 99% fractiles of activity concentrations and percentage contributions of model parameters

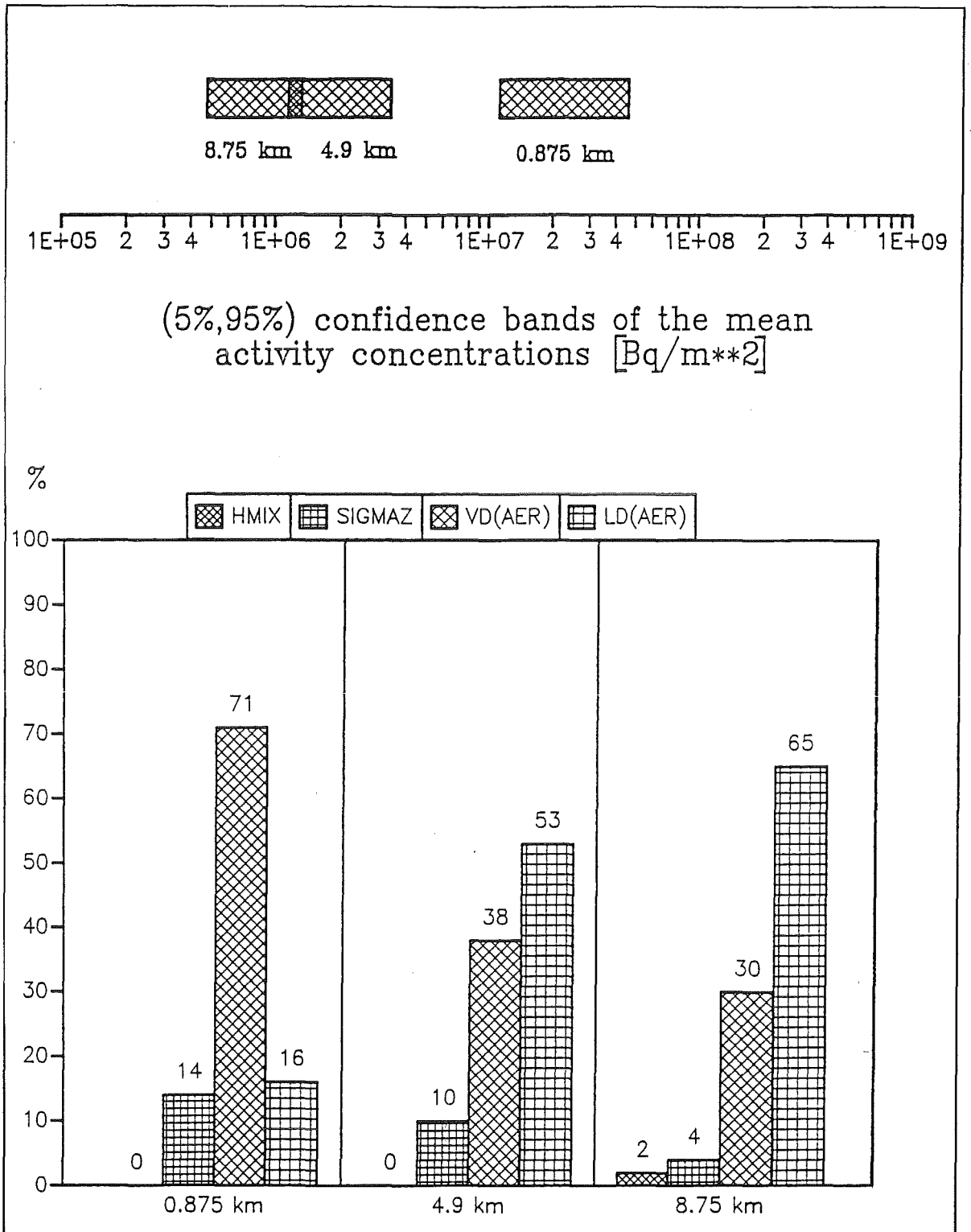

Figure 12. ATM - analysis based on mean values of Cs-137 concentrations on ground surface: (5%,95%) confidence bands of mean values of activity concentrations and percentage contributions of model parameters

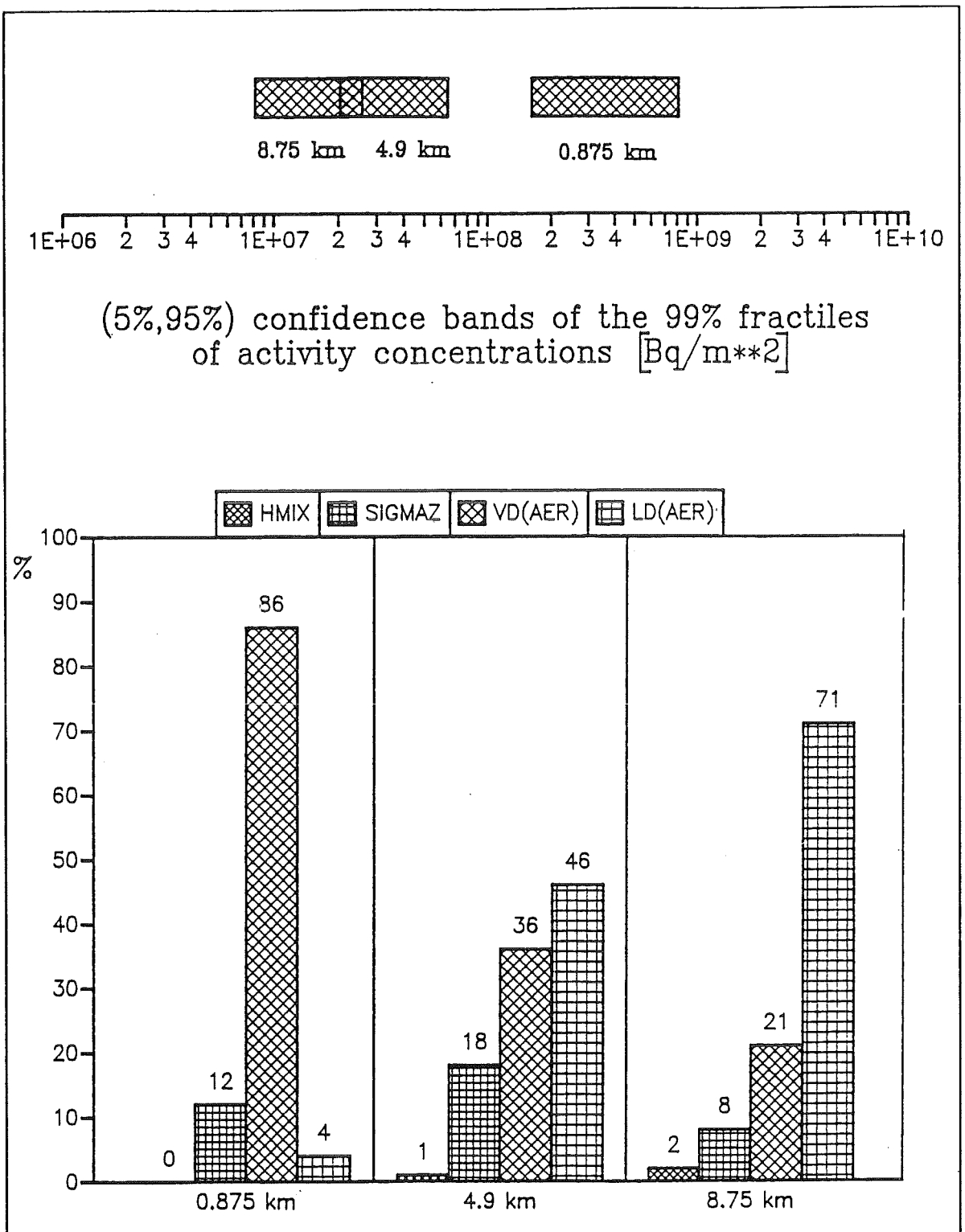

Figure 13. ATM - analysis based on 99% fractiles of Cs-137 concentrations on ground surface:
(5%,95%) confidence bands of 99% fractiles of activity concentrations and percentage contributions of model parameters

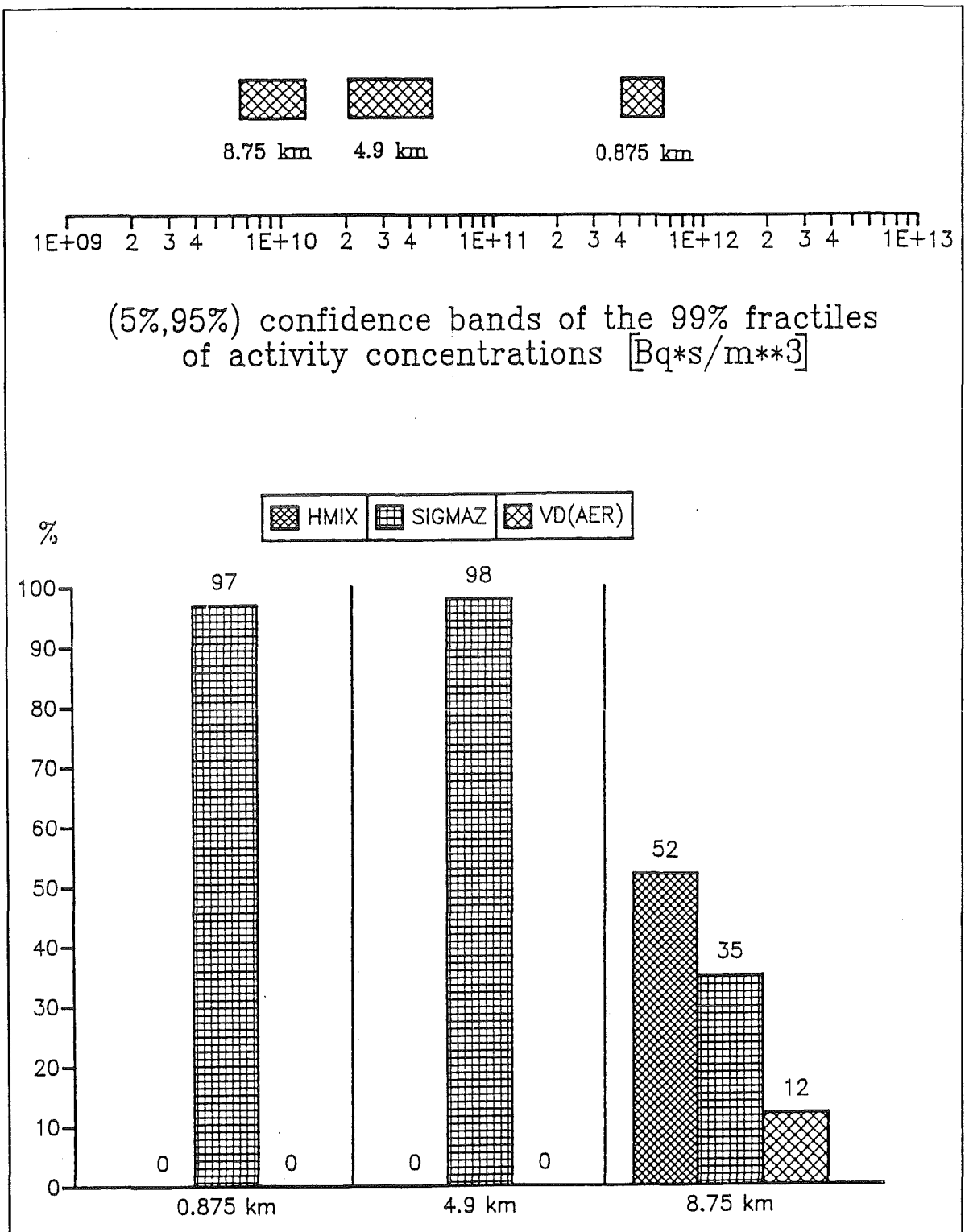

Figure 14. ATM - analysis based on 99% fractiles of Cs-137 concentrations in the air near ground:
(5%,95%) confidence bands of 99% fractiles of activity concentrations and percentage contributions of model parameters

of [15] the number of uncertain model parameters was reduced from twenty to ten. The third distance D3 (27 km) evaluated in the analysis was changed to D3 (8.75 km). Additionally, sensitivity calculations were performed not only for mean values of consequences, but also for their 99% quantiles. To be consistent with later submodule uncertainty investigations there was the need to rerun the ATM submodule and to calculate the different endpoints (concentrations, doses, risks, and early fatalities) considered in the other submodule and overall model analyses. As an example some interpretations to Figure 13 are given. There is a *decreasing* influence of the dry deposition velocity of aerosols, VD(AER), from near to far distances. VD(AER) contributed to 86% (36%, 21%) to the uncertainty in Cs-137 concentrations on ground surface for 0.875 km (4.9 km, 8.75 km). This is due to the fact that VD(AER) is proportional to the concentration in the air near ground which decreases with increasing $\sigma_y(S)$ and $\sigma_z(S)$. There is an *increasing* influence of the wet deposition velocity of aerosols, LD(AER), from near to the far distances. LD(AER) contributed to 4% (46%, 71%) to the uncertainty in Cs-137 concentrations on ground surface for 0.875 km (4.9 km, 8.75 km). This is due to the fact that LD(AER) is proportional to the integral of the air concentration from h = 0 m to h = z_0 m (with z_0 maximum vertical extension of the plume), and thus decreases with $\sigma_y(S)$ only.

There is no significant difference between the **M - type evaluation** (see Figure 12) and the **P - type evaluation** (see Figure 13). The (5%, 95%) bands as well as the percentage contributions of parameters are similar.

In the case of iodine ground concentrations (see Figure 10 and Figure 11), the wet deposition parameters are unimportant because the dry deposition velocities are larger by a factor of about 20. Therefore, the mixing height, which limits the vertical dispersion and determines - besides $\sigma_y(S)$ - the air near ground concentration, becomes the most important parameter at farther distances.

3.4.2 CTM - Analysis

The uncertainty and sensitivity analysis of the countermeasures models included in UFOMOD/NE led to the conclusion, that the most sensitive parameters are the initial delay of emergency actions in a keyhole shaped area A, TDELA, and the fraction of the population evacuating area A spontaneously during the sheltering period, PAUFA1, or staying outdoors, PAUFA5. Under the conditions of the source term used the influence on the overall uncertainty in the consequence variables - individual acute organ doses, individual risks and early fatalities - of driving times, TDRA, to leave the evacuation area was rather small.

[14] showed decreasing dose values from near to far distances and only a small width of confidence bands. No individual risks and therefore no early fatalities were calculated at the second and third distance 4.9 km and 8.75 km. Whilst the individual risks for the pulmonary syndrome showed a small variability only, the risks for the hematopoetic syndrome had a larger width of confidence bands. This was explained by the different contributions of external and internal exposure pathways and the way how individual risks are calculated in UFOMOD (for details see [14]).

The intervention criteria for evacuation of area B, GRWRTB, became important in the second (4.9 km) and third (8.75 km) distance, because it determines the extent of dose reducing emergency actions outside area A.

3.4.3 DCF - Analysis

To illustrate the main conclusions of the uncertainty and sensitivity analysis of the dose models, the consequence variables acute lung doses and acute bone marrow doses are discussed in the following (see also Figure 15 and Figure 16). In both evaluation procedures (**M - type evaluation** and **P - type evaluation**) of the sensitivity analyses, a dominant influence on the confidence bounds of the model parameter breathing rate,ARATIH, was found. Its percentage contribution to the uncertainties of the consequence variables DOSLUD1 (DOSLUD2, DOSLUD3) (i.e. individual acute lung dose at .875, (4.9, 8.75) km distance) increases from 56% (.875 km) to 69% (8.75 km). The second most important model parameter is the dose conversion factor, DCFIO. It varies[6] from

[(M): 35% in .875 km; (P): 36% in .875 km]
to
[(M): 27% in 8.75 km; (P): 22% in 8.75 km].

The other dose conversion factors and the shielding factors are unimportant in comparison to ARATIH and DCFIO (see definition in Chap. 2.1.1). The uncertainty bands reduce slightly from the near range to farther distances.

The main reasons for this behaviour are:

- The significance of the exposure pathway 'inhalation' is reduced from about 90% at 0.875 km to about 75% at 8.75 km. This causes smaller uncertainty bands, because breathing rate and dose - conversion factors are not distance dependent.

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6 (M) means sensitivity analyses based on mean values,
(P) means sensitivity analyses based on 99% - values

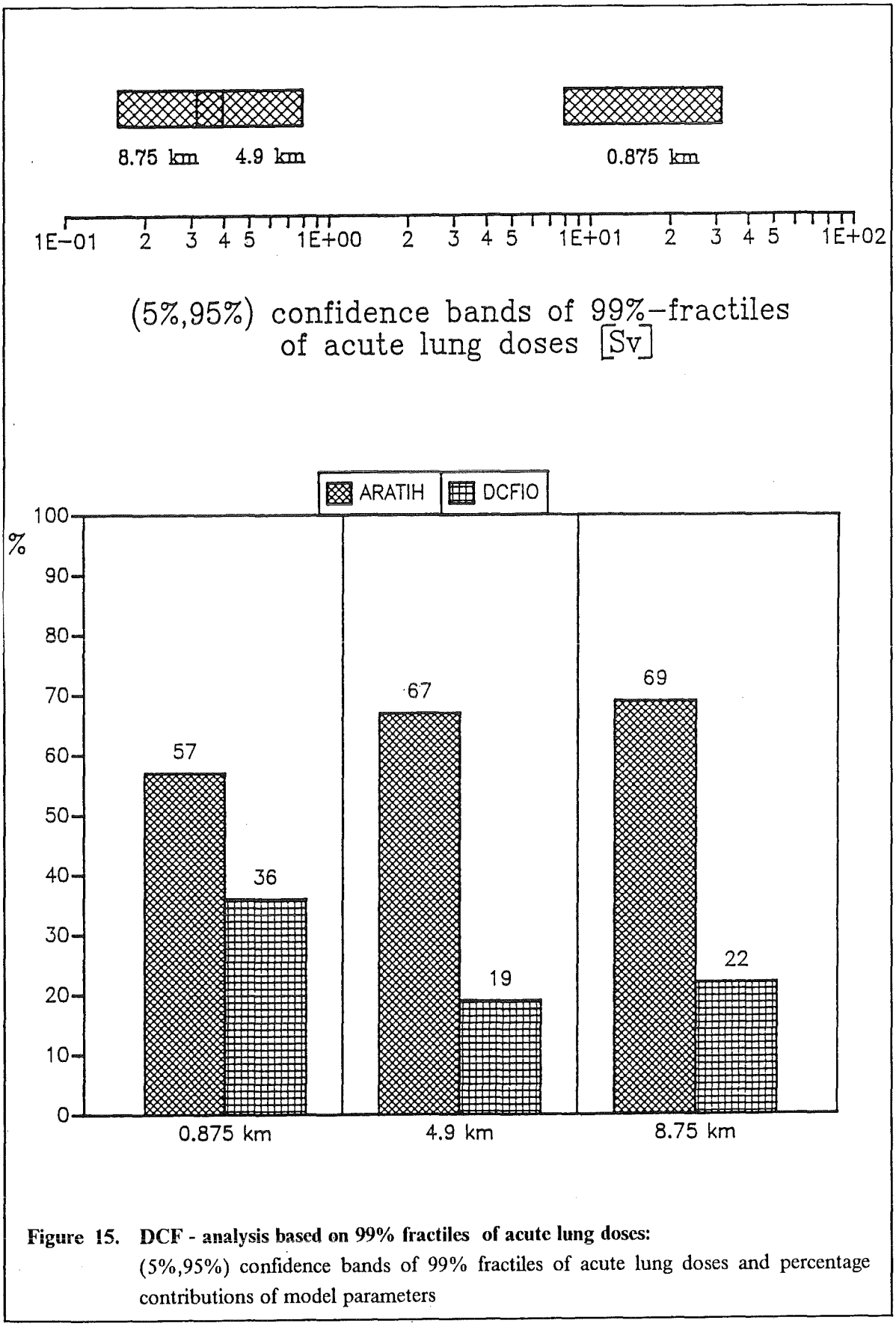


Figure 15. DCF - analysis based on 99% fractiles of acute lung doses:
(5%,95%) confidence bands of 99% fractiles of acute lung doses and percentage contributions of model parameters

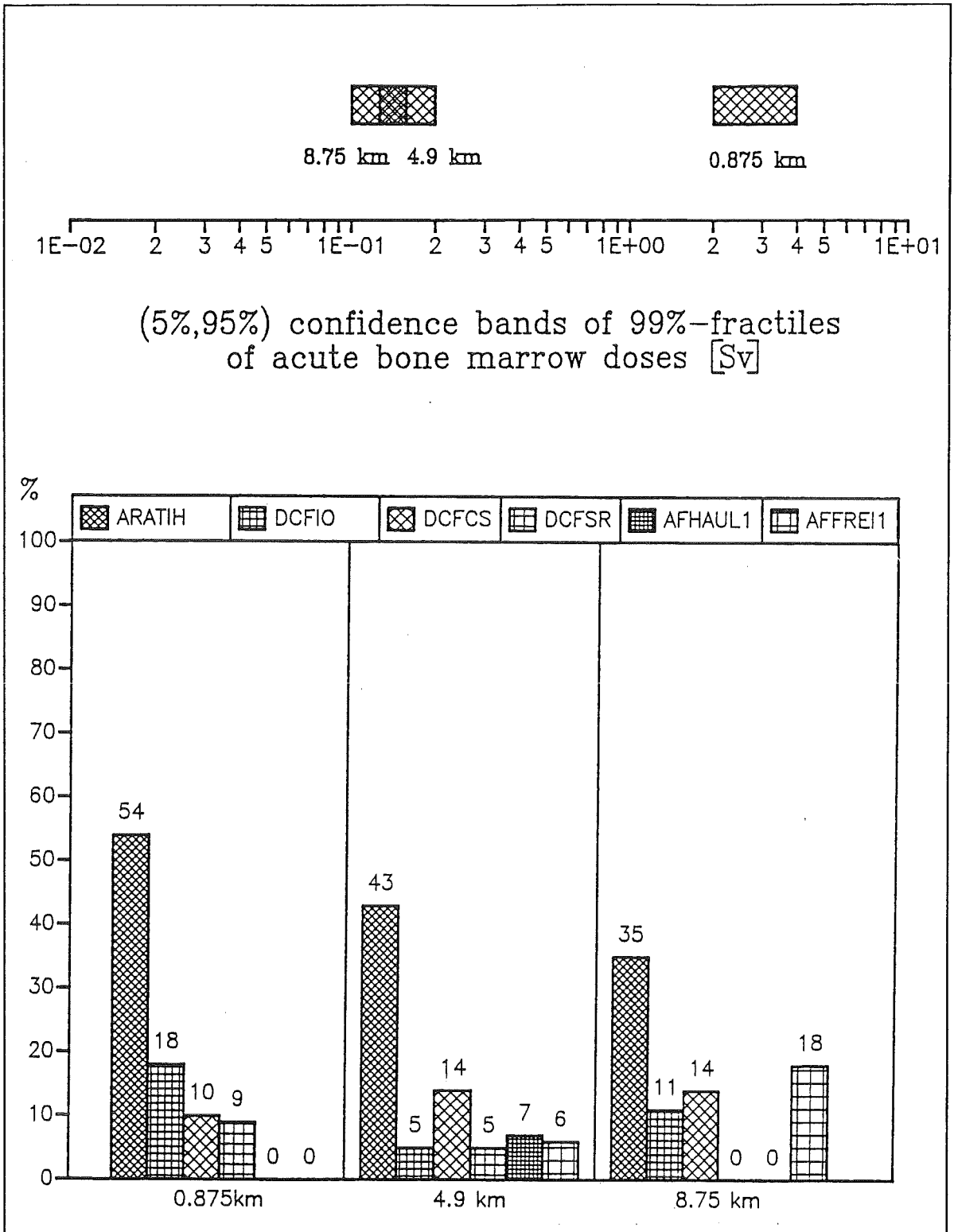


Figure 16. DCF - analysis based on 99% fractiles of acute bone marrow doses: (5%,95%) confidence bands of 99% fractiles of acute bone marrow doses and percentage contributions of model parameters

- The contributions of the iodine isotopes to lung dose caused by inhalation changes from about 51% at 0.875 km to about 36% at 8.75 km. This reduces the percentage contribution of DCFIO to the confidence bounds.

The confidence bounds of the acute bone marrow doses also show a slight decrease with growing distance. There is a contribution from 53% to 61% of ARATIH in the case of **M - type evaluation** and from 54% to 35% for **P - type evaluation.** The dose conversion factors for iodine, caesium and strontium (see definition in Chap. 2.1.1), DCFIO, DCFCS and DCFSR, follow as next most important contributors. Increasing or decreasing percentage contributions from near to far distances are not so clearly expressed as in the case of acute lung dose values. In the case, DOSBML3 (**P - type evaluation**), i.e. the bone bone marrow dose values for the third distance, there is an exception: The total coefficient of determination, R^2_t , is only about 57%. For details see the tables in APPENDIX C.

The main reasons for the distance dependent behaviour of the uncertainty and sensitivity analysis results for the acute bone marrow doses are as follows:

- The contribution of exposure pathways changes from the near range (cloudshine: 38%, groundshine: 7%, inhalation: 55% at 0.875 km) to farther distances (cloudshine: 27%, groundshine: 49%, inhalation: 24% at 8.75 km). This explains the decreasing importance of ARATIH and the growing influence of parameters from external dose models, such as AFFREH.
- Directly coupled with the changing importance of exposure pathways is the distance dependent contribution of other radionuclides to the confidence bounds of the bone marrow doses, such as DCFCS and DCFSR.

No individual risks are calculated at the second and third distance 4.9 km and 8.75 km (see Table 7). Therefore, the number of early fatalities (see Table 8), mainly result from an area close to the site, and the contribution of model parameters to the confidence bounds of both consequence types are about those discussed above for acute does at 0.875 km distance.

DISTANCE [*km*]	DOSLU [*Sv*]		DOSBM [*Sv*]	
	5 % value	95 % value	5 % value	95 % value
0.875	$7.94\ 10^{0}$	$3.16\ 10^{+1}$	$2.00\ 10^{0}$	$3.98\ 10^{0}$
4.9	$3.16\ 10^{-1}$	$7.94\ 10^{-1}$	$1.00\ 10^{-1}$	$2.00\ 10^{-1}$
8.75	$1.58\ 10^{-1}$	$3.98\ 10^{-1}$	$1.26\ 10^{-1}$	$1.58\ 10^{-1}$

Note:
*) sample size n=60 ; calculations based on 99% fractiles

DOSLU, DOSBM = acute individual doses (lung, bone marrow)

Table 6. (5 %, 95 %) values of DCF - consequence variables (acute individual doses)

DISTANCE [km]	RSKLU		RSKBM	
	5 % value	95 % value	5 % value	95 % value
0.875	$1.26\ 10^{-1}$	$1.00\ 10^{0}$	$2.00\ 10^{-3}$	$1.00\ 10^{-1}$
4.9	0	0	0	0
8.75	0	0	0	0

Note:
*) sample size n=60 ; calculations based on 99% fractiles

RSKLU, RSKBM = indivudual risks (pulm. syndrome, hemat. syndrome)

Table 7. (5 %, 95 %) values of DCF - consequence variables (individual risks)

DISTANCE [km]	POP(LU)		POP(BM)	
	5 % value	95 % value	5 % value	95 % value
	$8.13\ 10^{+1}$	$5.13\ 10^{+2}$	$1.29\ 10^{+1}$	$6.46\ 10^{+1}$

Note:
*) sample size n=60 ; calculations based on 99% fractiles

POP(LU); POP(BM) = early fatalities (pulm. syndrome, hemat. syndrome)

Table 8. (5 %, 95 %) values of DCF - consequence variables (early fatalities)

3.4.4 HEM - Analysis

Two parameters of the dose - risk realtionships for each non - stochastic health effects were varied in the uncertainty and sensitivity analyses: the shape parameter and the D_{50} - value. The M -type and P - type evaluation of the CCFDs of the individual risks and the number of early health effects showed that the only model parameters significantly contributing to the confidence bounds of both consequence types are the D_{50} - values (nearly 100%), the dose that would induce the health effect in half the population.

An increase of the D_{50} - value for lung function impairment, LGMD50, leads to a strong decrease of the corresponding individual risk consequence variable, RSKLM. An increase of the D_{50} for pulmonary syndrome causes the RSKLM variable to increase. This is due to the fact, that a reduced individual risk of mortality enlarges the individual risk of morbidity. With respect to the total individual fatality risk, RSKTT (all effects included) the dominant

model parameter is LGFD50, because of the high risk of pulmonary syndrome in comparison to the fatal effects.

CONSEQUENCE	5 % value	95 % value
RSKLMD1	$5.01\ 10^{-1}$	$1.00\ 10^{0}$
RSKLFD1	$7.94\ 10^{-2}$	$7.94\ 10^{-1}$
RSKBMD1	$3.98\ 10^{-2}$	$1.26\ 10^{-1}$
RSKTTD1	$1.58\ 10^{-1}$	$7.94\ 10^{-1}$
POPLUM	$4.07\ 10^{+2}$	$1.29\ 10^{+3}$
POPLUF	$8.13\ 10^{+1}$	$2.57\ 10^{+2}$
POP(BM)	$3.24\ 10^{+1}$	$8.13\ 10^{+1}$
POPTOT	$8.13\ 10^{+1}$	$2.57\ 10^{+2}$

Note:
*) sample size n=40 ; calculations based on 99% fractiles ;
D1 = distance 0.875 km

RSKLM, RSKLF = indivudual risks (lung function impairment, pulmo. syndrome)
RSKBM, RSKTT = indivudual risks (hematopoietic syndrome,
mortality: all effects)
POPLUM, POPLUF = early fatalities (lung function impairment, pulmo. syndrome)
POP(BM),POPTOT = early fatalities (hematopoietic syndrome,
mortality: all effects)

Table 9. (5 %, 95 %) values of HEM - consequence variables

The same conclusions are valid for the number of early health effects.

An increase of the D_{50} - value, LGMD50, leads to a strong decrease of the number of non - fatal health effects POPLUM. An increase of the D_{50} - value for pulmonary syndrome, LGFD50, causes the POPLUM variable to increase. The dominating sensitive parameter for the total number of early fatalities, POPTOT, is the D_{50} - value for the pulmonary syndrome, LGFD50.

In Table 9 an overview of the (5%,95%) values of the HEM - consequence variables is given.

3.4.5 OVERALL - Analysis

In the uncertainty and sensitivity analyses of the submodules of UFOMOD/NE described in the previous chapters, those model parameters contributing most to the confidence bounds of the various consequence endpoints were identified. Figure 17 summarizes once again the number of model parameters considered, the number of runs performed with UFOMOD/NE, and the number of different endpoint CCFDs evaluated in each analysis. As already described in Chapter 2.1.3, 24 uncertain model parameters were identified for the overall analysis (see Figure 18). They were varied with the LHS - design and 100 computer runs with UFOMOD/NE were performed for this final analysis. The number of endpoint CCFDs evaluated in the OAL analysis are shown in Figure 17.

The (5%, 95%) - confidence bounds of all these endpoints are listed in Table 10 to Table 13. Some of them are presented as bars in Figure 19 to Figure 28 and compared with the results of the submodule investigations.

The atmospheric dispersion model is the first in the sequence of modules. Therefore, the endpoints 'activity concentrations of Cs-137 and I-131 in air and on ground surface' should show the same uncertainties in the overall as in the submodule analysis. This is confirmed by the results, e.g. when comparing the (5%, 95%) confidence bands of the 99% - quantiles of the CCFDs presented in Figure 11 and Figure 13 with the value listed in Table 10 and Table 11. This fact also clearly shows the stability of the results with respect to different samples of the LHS -design. This is valid also for the results of sensitivity analyses: the parameters contributing most to the uncertainties of activity concentrations did not change when using a smaller number of model parameters and different samples (see Figure 10 and the IODCGD1 (100M) - column in the Appendix C.5 (OAL Part 1 of 8)).

Individual organ doses are the first consequence endpoints, whose uncertainties are caused by the combined influence of model parameters of submodules. These are the ATM, CTM and DCF modules, and Figure 19 to Figure 21 (Figure 22 to Figure 24) show the results of the overall analysis for acute lung doses (and acute bone marrow doses) for the three distances considered.

It is obvious from the results that besides the uncertainty bands (see also Table 12), also the contributions of the submodules and their parameters to the confidence bounds of doses are strongly distance dependent. For the lung doses, the breathing rate ARATIH is the most important parameter. It contributes with 45% at 0.875 km up to 57% at 8.75 km. For the other parameters the situation is less clear: at the inner radius, the iodine dose conversion factor DCFIO (36%) and the vertical dispersion parameters for stability categories (E, F) (14%) are important. At the outer radius, DCFIO (13%), HMIX (10%) and the intervention level GRWRTB for evacuation of area B (10%) are significant. It is also interesting

subject of uncertainty analysis		no. of paramters	no. of runs	CCFDs with (5%, 95%) confidence bounds			
				activity concentrations	radiation doses	individual risks	no. of early effects
atmospheric dispersion	ATM	20	$\leq$100	12	6	2	2
early protective actions	CTM	20	60	-	6	2	2
dose model	DCF	20	60	-	6	2	2
health effects	HEM	8	40	-	-	6	5
overall model	OAL	24	100	12	6	2	2

Figure 17. Overview of uncertainty analyses with UFOMOD / NE

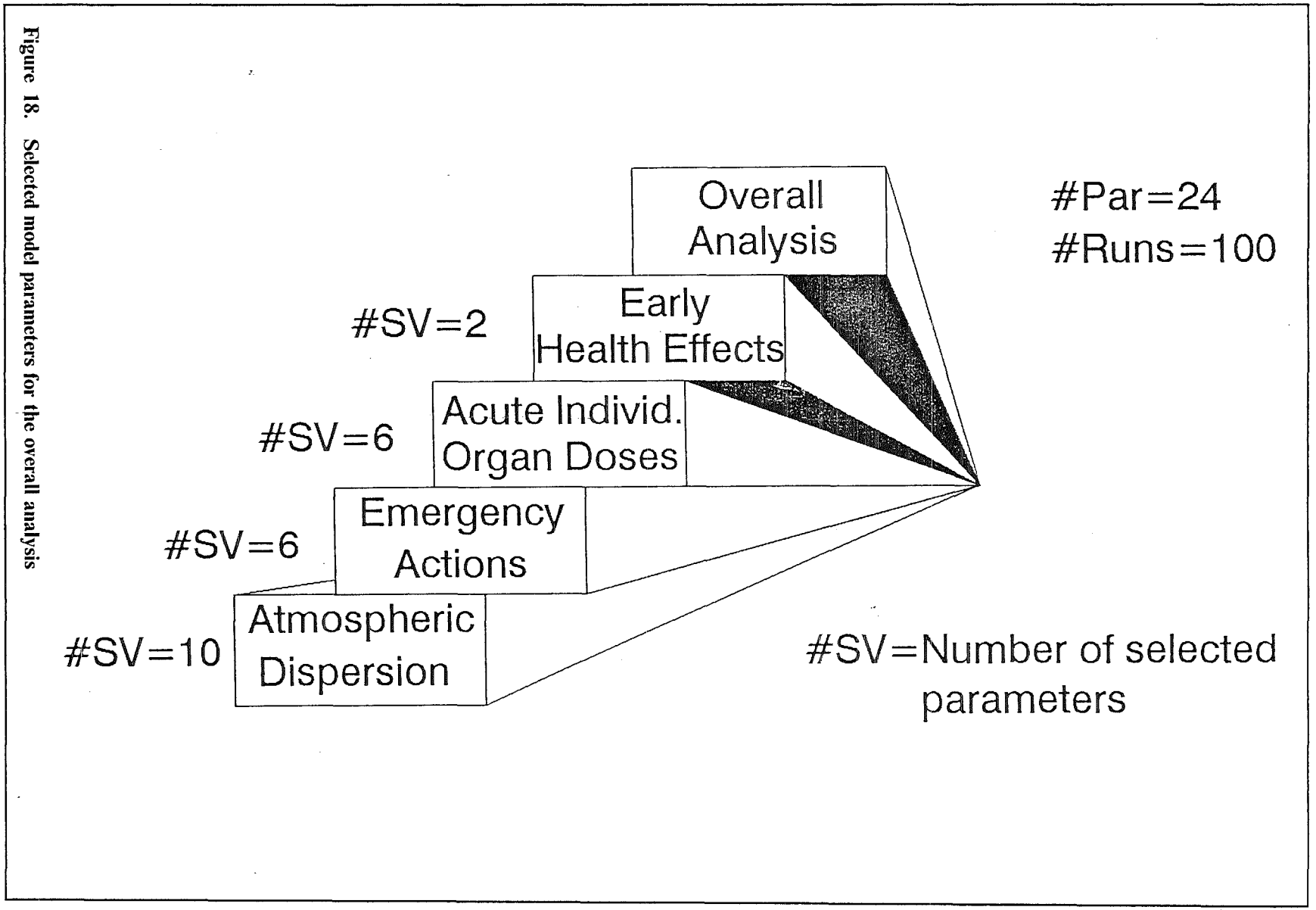


Figure 18. Selected model parameters for the overall analysis

to see in which ranges of dose values the submodules cause uncertainties and how this changes with distance (compare the upper part of Figure 19 to Figure 21).

In the case of the acute bone marrow doses (see Figure 22 to Figure 24) the distance dependence is even more expressed. The dose uncertainties at the inner radius are dominated by ARATIH (36%), $\sigma_z(S)$(E,F) (28%), DCFIO (12%) and the initial delay time TINA in area A (11%). At the outer radius GRWRTB (63%), ARATIH (17%) and the mixing layer height HMIX (11%) are significant.

When transforming acute doses into risks of early health effects, the uncertainties of the D_{50} - values of the dose - risk relationships become important. At 0.875 km distance it contributes with 27% and 49% to the confidence bounds of the risk of pulmonary and hematopoietic syndrome, respectively. The influence of the model parameters relevant for the uncertainties of acute doses are reduced correspondingly.

Finally, the CCFDs of the number of early deaths result, when multiplying individual risks with the number of people in the corresponding grid element and summing over all azimuthal and radial distance bands. The uncertainties of the number of fatalities from pulmonary syndrome are mainly caused by the parameters of the DCF module: DCFIO and ARATIH contribute with 59% to the (5%, 95%) confidence bounds of the 99% quantiles (see Figure 27). Only about 30% come from the D_{50} - uncertainties. The contribution of the countermeasure module is negligible (as it was for the individual risks and doses).

A similar result is obtained for the number of early death from hematopoietic syndrome. The model parameters of the DCF module are responsible for about 50% of the confidence bounds (see Figure 28), the D_{50} contributes with 26%, the ATM module $\sigma_z(S)$ causes 17%, and only about 7% come from CTM.

It is possible to extract more detailed information from the submodule and overall analysis sensitivity tables provided in the Appendices. The intercomparison of all results obtained from the various investigations provides a clear view of the contributions of single submodels and their parameters to the overall analysis. It is one of the main conclusions of these investigations, that the results of uncertainty and sensitivity analyses strongly depend on the endpoints considered and, in particular, any statements about the importance of uncertain model parameters or the modules they belong to must refer to the accident consequence type considered.

DISTANCE [*km*]	IODCG [Bq/m^2]		IODCA [Bqs/m^3]	
	5 % value	95 % value	5 % value	95 % value
0.875	$5.13\ 10^{10}$	$1.29\ 10^{11}$	$5.13\ 10^{12}$	$1.02\ 10^{13}$
4.9	$2.04\ 10^{9}$	$2.57\ 10^{9}$	$1.02\ 10^{11}$	$3.24\ 10^{11}$
8.75	$6.46\ 10^{8}$	$1.02\ 10^{9}$	$4.07\ 10^{10}$	$1.02\ 10^{11}$

Note:
*) sample size n=100 ; calculations based on 99% fractiles

IODCG, IODCA = iodine activity concentrations (ground, air near ground)

Table 10. (5 %, 95 %) values of OVERALL - consequence variables iodine concentrations

DISTANCE [*km*]	CAECG [Bq/m^2]		CAECA [Bqs/m^3]	
	5 % value	95 % value	5 % value	95 % value
0.875	$1.62\ 10^{8}$	$8.13\ 10^{8}$	$4.07\ 10^{11}$	$6.46\ 10^{11}$
4.9	$2.04\ 10^{7}$	$6.46\ 10^{7}$	$2.04\ 10^{10}$	$5.13\ 10^{10}$
8.75	$8.13\ 10^{6}$	$2.57\ 10^{7}$	$6.46\ 10^{9}$	$1.29\ 10^{10}$

Note:
*) sample size n=100 ; calculations based on 99% fractiles

CAECG, CAECA = caesium activity concentrations (ground, air near ground)

Table 11. (5 %, 95 %) values of OVERALL - consequence variables caesium concentrations

DISTANCE [*km*]	DOSLU [*Sv*]		DOSBM [*Sv*]	
	5 % value	95 % value	5 % value	95 % value
0.875	$8.13\ 10^{0}$	$1.62\ 10^{1}$	$1.62\ 10^{0}$	$3.24\ 10^{0}$
4.9	$3.24\ 10^{-1}$	$8.13\ 10^{-1}$	$1.02\ 10^{-1}$	$2.04\ 10^{-1}$
8.75	$1.62\ 10^{-1}$	$2.57\ 10^{-1}$	$8.13\ 10^{-2}$	$1.29\ 10^{-1}$

Note:
*) sample size n=100 ; calculations based on 99% fractiles

DOSLU, DOSBM = acute individual doses (lung, bone marrow)

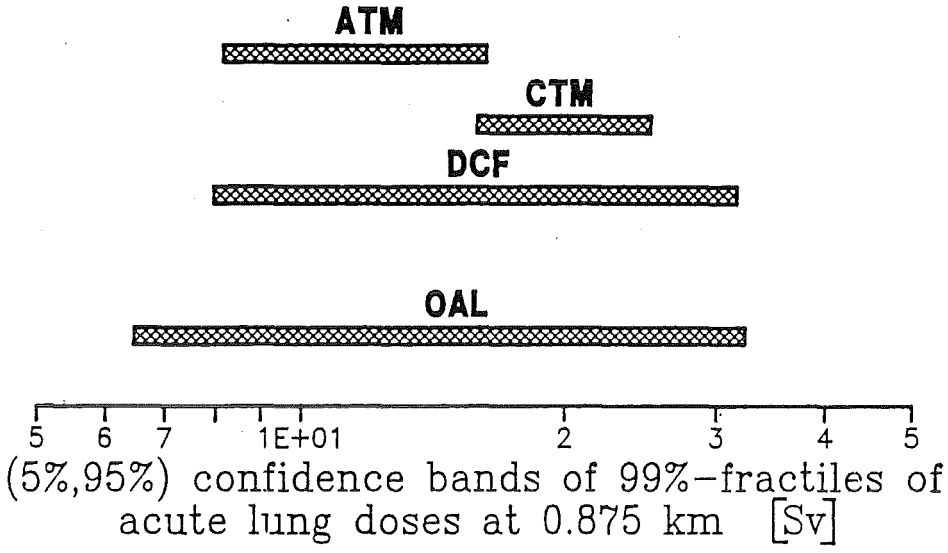
Table 12. (5 %, 95 %) values of OVERALL - consequence variables acute individual doses

CONSEQUENCE	5 % value	95 % value
RSKLUD1	$4.07\ 10^{-1}$	$6.46\ 10^{-1}$
RSKBMD1	$1.29\ 10^{-2}$	$1.02\ 10^{-1}$
POP(LU)	$1.29\ 10^{+2}$	$3.24\ 10^{+2}$
POP(BM)	$2.04\ 10^{+1}$	$5.13\ 10^{+1}$

Note:
*) sample size n=100 ; calculations based on 99% fractiles ;
D1 = distance 0.875 km

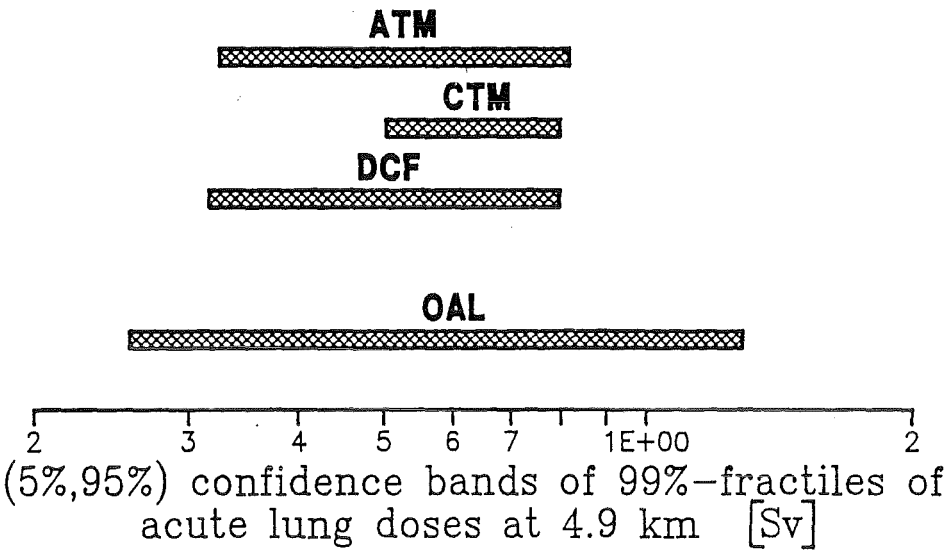
RSKLU, RSKBM = indivudual risks (pulmonary syndrome, hematopoietic syndrome)
POP(LU), POP(BM) = early fatalities (pulmonary syndrome, hematopoietic syndrome)

Table 13. (5 %, 95 %) values of OVERALL - consequence variables individual risks for early fatalities



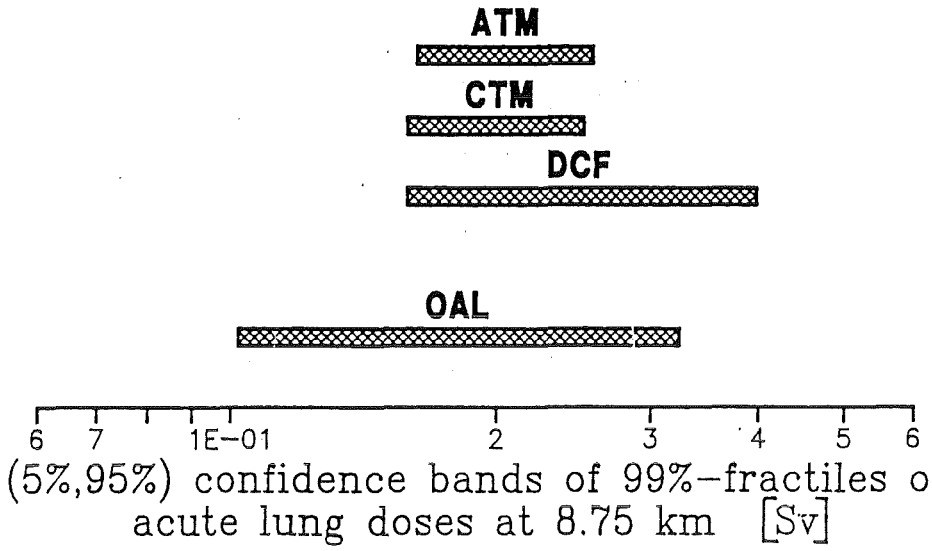
	ATM	CTM	DCF	HEM	OAL
$\sigma_z(E,F)$	89 % (—)				14 % (—)
VD(IOD)	15 % (—)				
PAUFA1		26 % (—)			3 % (—)
TINA		56 % (+)			4 % (+)
DCFIO			36 % (+)		36 % (+)
ARATIH			57 % (+)		45 % (+)

Figure 19. Uncertainties of acute lung doses (distance = 0.875 km):
Confidence bands and percentage contributions of model parameters



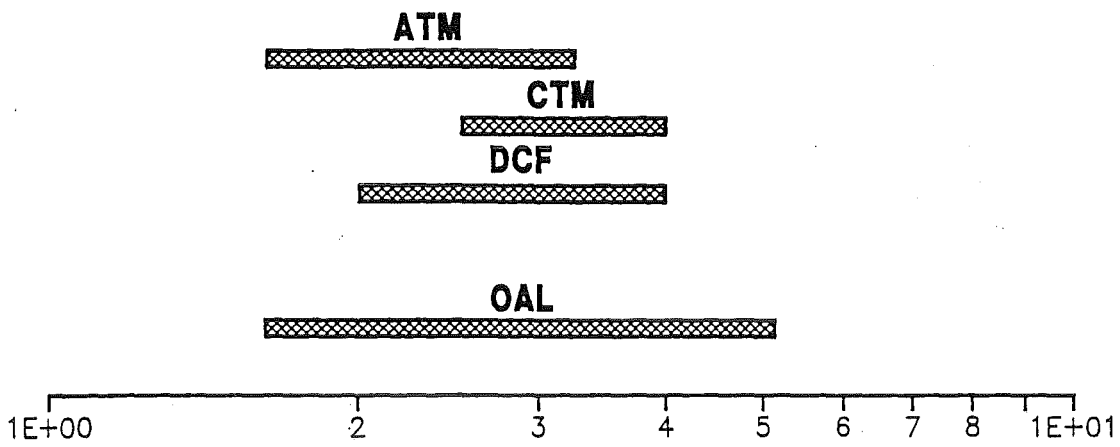
	ATM	CTM	DCF	HEM	OAL
$\sigma_z(E,F)$	85 % (−)				25 % (−)
VD(AER)	2 % (−)				
VD(IOD)	12 % (−)				3 % (−)
PAUFA1		64 % (−)			7 % (−)
TINA		29 % (+)			3 % (+)
DCFIO			19 % (+)		15 % (+)
ARATIH			67 % (+)		48 % (+)

Figure 20. Uncertainties of acute lung doses (distance = 4.9 km):
Confidence bands and percentage contributions of model parameters



	ATM	CTM	DCF	HEM	OAL
HMIX	64 % (—)				10 % (—)
$\sigma_z(E,F)$	13 % (—)				6 % (—)
VD(AER)	16 % (—)				
VD(IOD)					3 % (—)
GRWRTB		73 % (+)			10 % (+)
PAUFA1		16 % (—)			2 % (—)
TINA		7 % (+)			
DCFIO			22 % (+)		13 % (+)
ARATIH			69 % (+)		57 % (+)

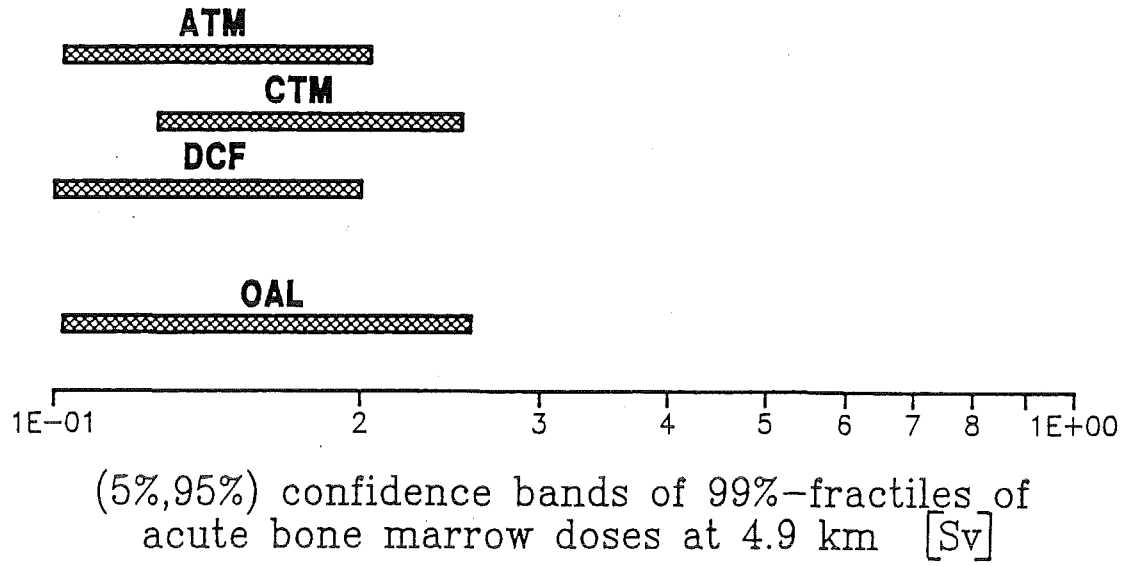
Figure 21. Uncertainties of acute lung doses (distance = 8.75 km):
Confidence bands and percentage contributions of model parameters



(5%,95%) confidence bands of 99%-fractiles of acute bone marrow doses at 0.875 km [Sv]

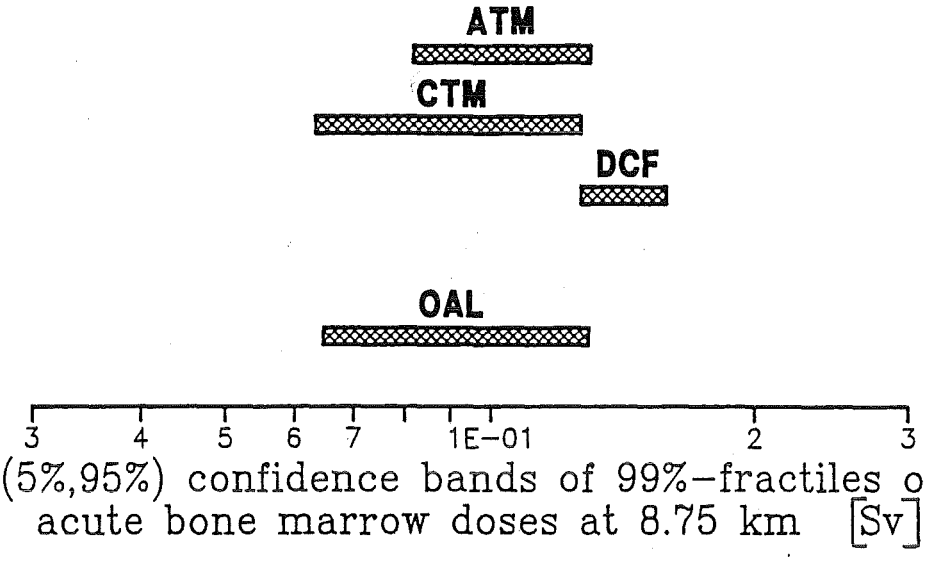
	ATM	CTM	DCF	HEM	OAL
$\sigma_z(E,F)$	93 % (—)				28 % (—)
VD(IOD)	6 % (—)				
PAUFA1		5 % (—)			3 % (—)
PAUFA5		9 % (+)			
TINA		81 % (+)			11 % (+)
DCFSR			9 % (+)		7 % (+)
DCFCS			10 % (+)		7 % (+)
DCFIO			18 % (+)		12 % (+)
ARATIH			54 % (+)		36 % (+)

Figure 22. Uncertainties of acute bone marrow doses (distance = 0.875 km): Confidence bands and percentage contributions of model parameters



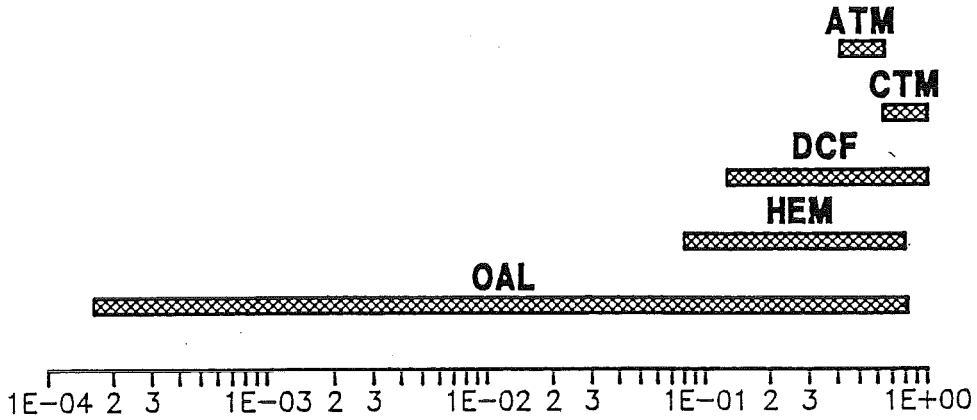
	ATM	CTM	DCF	HEM	OAL
HMIX	7 % (−)				2 % (−)
$\sigma_t(E,F)$	90 % (−)				34 % (−)
GRWRTB		19 % (+)			8 % (+)
IEVA2		15 % (−)			7 % (−)
PAUFA1		13 % (−)			
PAUFA5		14 % (+)			2 % (+)
TINA		40 % (+)			12 % (+)
DCFSR			5 % (+)		3 % (+)
DCFCS			14 % (+)		2 % (+)
DCFIO			5 % (+)		2 % (+)
AFHAUL1			7 % (+)		
AFFREI1			6 % (+)		
ARATIH			43 % (+)		24 % (+)

Figure 23. Uncertainties of acute bone marrow doses (distance = 4.9 km): Confidence bands and percentage contributions of model parameters



	ATM	CTM	DCF	HEM	OAL
HMIX	73 % (−)				11 % (−)
$\sigma_z(E,F)$	20 % (−)				8 % (−)
VD(IOD)	10 % (+)				
GRWRTB		99 % (+)			63 % (+)
DCFSR					2 % (+)
DCFCS			14 % (+)		2 % (+)
DCFIO			11 % (+)		
AFFREI1			18 % (+)		
ARATIH			35 % (+)		17 % (+)

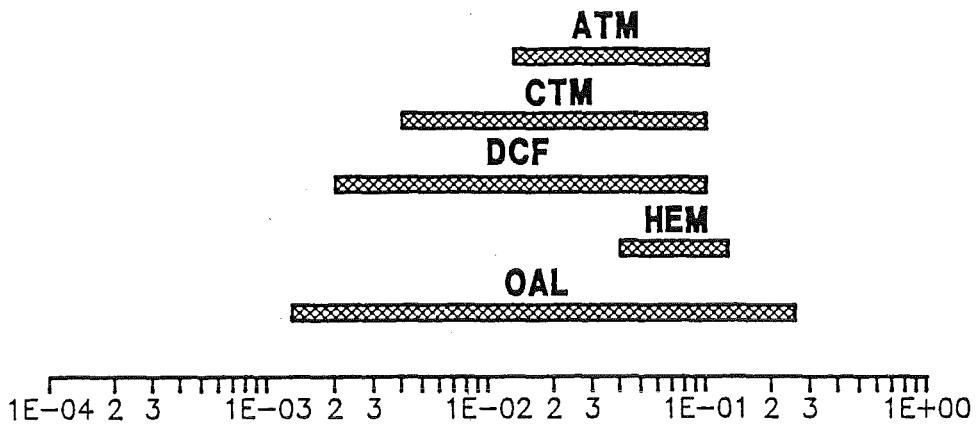
Figure 24. **Uncertainties of acute bone marrow doses (distance = 8.75 km):** Confidence bands and percentage contributions of model parameters



(5%,95%) confidence bands of 99%-fractiles of individual risk for early death from pulmonary syndrome at 0.875 km

	ATM	CTM	DCF	HEM	OAL
$\sigma_z(E,F)$	61 % (−)				11 % (−)
VD(AER)	10 % (−)				
VD(IOD)	27 % (−)				
TDELA		4 % (−)			
PAUFA1		18 % (−)			
PAUFA5		5 % (+)			
TINA		69 % (+)			2 % (−)
DCFIO			47 % (+)		32 % (+)
ARATIH			46 % (+)		28 % (+)
LGFD50				100 % (−)	27 % (−)

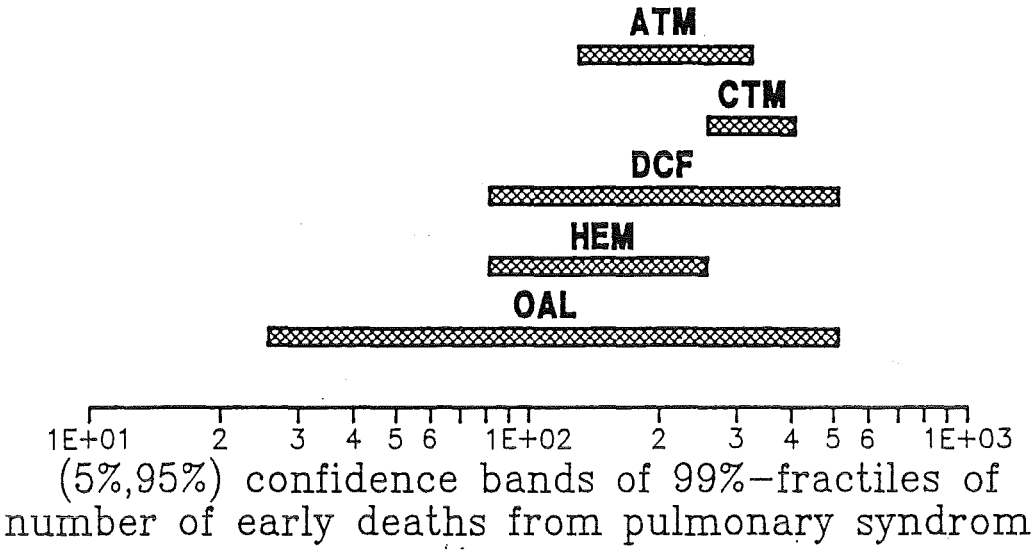
Figure 25. Uncertainties of individual risks for early death (pulmonary syndrome): Confidence bands and percentage contributions of model parameters



(5%,95%) confidence bands of 99%−fractiles of individual risk for early death from hematopoietic syndrome at 0.875 km

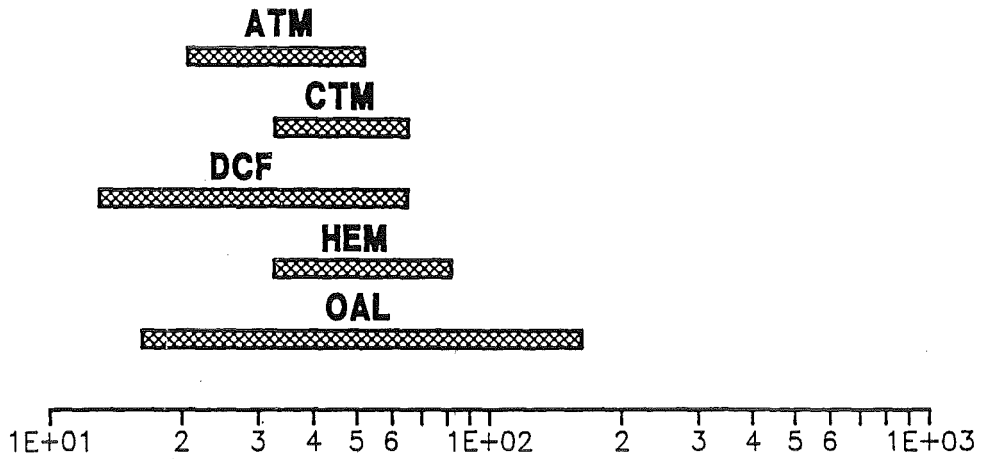
	ATM	CTM	DCF	HEM	OAL
$\sigma_z(E,F)$	100 % (−)				14 % (−)
PAUFA5		98 % (+)			14 % (+)
DCFIO			10 % (+)		5 % (+)
AFHAUL1			9 % (+)		2 % (+)
AFFREI1			72 % (+)		5 % (+)
ARATIH			8 % (+)		7 % (+)
BMFD50				99 % (−)	49 % (−)

Figure 26. Uncertainties of individual risks for early death (hematopoietic syndrome): Confidence bands and percentage contributions of model parameters



	ATM	CTM	DCF	HEM	OAL
$\sigma_z(E,F)$	87 % (−)				11 % (−)
VD(IOD)	14 % (−)				
PAUFA1		17 % (−)			
PAUFA5		5 % (+)			
TINA		71 % (+)			2 % (+)
DCFIO			38 % (+)		32 % (+)
ARATIH			53 % (+)		27 % (+)
LGFD50				99 % (−)	29 % (−)

Figure 27. Uncertainties of the number of early death (pulmonary syndrome): Confidence bands and percentage contributions of model parameters



(5%,95%) confidence bands of 99%-fractiles of number of early deaths from hematopoietic syndrome

	ATM	CTM	DCF	HEM	OAL
$\sigma_z(E,F)$	99 % (−)				17 % (−)
PAUFA1		8 % (−)			3 % (−)
PAUFA5		44 % (+)			2 % (+)
TINA		48 % (+)			2 % (+)
DCFSR			5 % (+)		3 % (+)
DCFCS			6 % (+)		2 % (+)
DCFIO			27 % (+)		13 % (+)
AFHAUL1			5 % (+)		2 % (+)
AFFREI1			8 % (+)		
ARATIH			47 % (+)		30 % (+)
BMFD50				99 % (−)	26 % (−)

Figure 28. Uncertainties of the number of early death (hematopoietic syndrome): Confidence bands and percentage contributions of model parameters

4. Summary

This report presents applications of uncertainty analysis methods and computer codes to accident consequence models of the program system UFOMOD.

A Latin hypercube sampling design code is used to generate a set of different input parameter values for running the subsystem NE of UFOMOD. A graphics program produces CCFDs and estimated confidence bands. The variability of consequences with respect to changes in uncertain input parameter values is evaluated by a sensitivity analysis code, providing partial rank correlation coefficients (PRCCs) and percentage contributions (so - called 'coefficients of determination', R^2) of uncertain model parameters to variations in consequence values. Thus the ranked influence of the uncertain parameters on the different consequence types could be shown.

Uncertainty analyses of UFOMOD started on a submodule basis and ended with an overall analysis. From the enitirety of all investigations and their results the following conclusion can be drawn:

- Submodel analyses are important
  - to understand the sources of uncertainties and their propagation to the different endpoints of an accident consequence assessment,
  - to justify the selection of parameters for overall analyses.
- The contributions of submodels and their parameters to the confidence bands strongly depend on the endpoints considered in the accident consequence assessment.
- The results of the overall analyses are consistent with those obtained from the single submodel investigations.
- The vertical dispersion parameters for stable atmospheric conditions are important contributors to uncertainties of all results. (This is a problem for all Gaussian-type models).
- For acute doses and early health effects, the dose model causes much larger uncertainties than the model describing emergency actions. The dominance of the breathing rate requires better modelling.
- Changes in the evacuation area A (shift against wind direction, sector angle) and in the driving times do not contribute significantly to uncertainties.
- The parameters of the health effects model, in particular the D_{50} - values are important, but do not dominate the uncertainties in the number of early effects.

More Details, Figures and Tables

Appendix A.1 describes the partial (rank) correlation coefficient and some significance testing problems.

Appendix A.2 gives some remarks concerning the coefficient of determination, R^2.

Appendices B and C comprise a detailed set of figures for uncertainty and sensitivity analyses, respectively. If necessary some legends to understand abbreviations are added. The figures and tables are given in the following sequence:

- UNCERTAINTY (confidence curves)
  - **Activity concentrations** (iodine, aerosols) on ground surface and in the air near ground
  - **Acute individual doses** (lung, bone marrow)
  - **Individual risks** (pulmonary syndrome, hematopoietic syndrome)
  - **Early fatalities** (pulmonary syndrome, hematopoietic syndrome)

  for the DCF-, HEM- and OAL - analysis.

- SENSITIVITY (Tables of PRCC values)
  - ATM - Analysis
  - CTM - Analysis
  - DCF - Analysis
  - HEF - Analysis
  - OAL - Analysis

Appendix A. Some Mathematical Details

A.1 Partial correlation coefficients

A.1.1 Definition

This paragraph follows some results presented in [16].

Sensitivity analysis in conjunction with Latin hypercube sampling is based on the construction of regression models. The observations

$$(X_{1i},X_{2i}, \ldots ,X_{ki},Y_i) \qquad i=1,\ldots,n$$

are used to construct models of the form

$$Y_{est} = b_0 + \sum_q b_q Z_q$$

subject to the constraint that

$$\Sigma(Y - Y_{est})^2$$

be minimized. b_0 , B_q are constants and each Z_q is a function of $X_1, \ldots ,X_k$.

An important property of least squares regression is that

$$\Sigma(Y - Y_m)^2 = \Sigma(Y - Y_{est})^2 + \Sigma(Y_{est} - Y_m)^2$$

where Y_m is the mean of the Y_i-values.

The R^2 - value (**coefficient of determination**) for a regression falls between 0 and 1 and is defined by

$$R^2 = \frac{\Sigma(Y_{est} - Y_m)^2}{\Sigma(Y - Y_m)^2}$$

The closeness of an R^2 - value to 1 provides an indication of how successful the regression model is in accounting for the variation in Y.

For a regression model of the form

$$Y_{est} = b_0 + b_1 Z$$

with an R^2 - value of r^2, the number $sign(b_1)|r|$ is called the correlation coefficient between Y and Z, where $sign(b_1) = 1$ if $b_1 \geq 1$, and $sign(b_1) = -1$ if $b_1 < 1$. This number provides a measure of linear relationship between these two variables. When more than one independent variable is under consideration, *partial correlation coefficients* are used to provide a measure of the linear relationships between Y and the individual independent variables. The *partial correlation coefficient* between Y and an individual variable Z_p is obtained from the use of a sequence of regression models. The following two regression models are constructed:

$$Y'_{est} = a_0 + \sum_{q \neq p} a_q Z_q \quad \text{and}$$

$$Z'_{est} = c_0 + \sum_{q \neq p} c_q Z_q \ .$$

Then, the results of the two preceding regressions are used to define the new variables $Y - Y'_{est}$ and $Z_p - Z'_p$. By definition, the **partial correlation coefficient between** Y and Z_p is the simple correlation coefficient between $Y - Y'_{est}$ and $Z_p - Z'_p$. Therefore, the partial correlation coefficient provides a measure of the linear relationship between Y and Z_p with the linear effects of the other variables removed.

Example:

Sometimes the apparent correlation between two variables may be due in part to the direct influence on both of the other variables: Y and X_1 are correlated, but are both influenced by a variable X_2 . The influence of X_2 on Y and X_1 must be removed. *Simple linear regression* of Y resp. X_1 on X_2 gives:

$$Y' = \beta_0 + \beta_1 X_2, \quad X'_1 = \gamma_0 + \gamma_1 X_2$$

Define new variables (Y - Y') and $(X_1 - X'_1)$. The simple correlation (based on the Pearson product moment correlation) between the 'residuals' (Y - Y') and $(X_1 - X'_1)$ is called the **partial correlation coefficient between Y and X_1, given X_2** (i.e., the linear influence of X_2 on both Y and X_1 removed), and is denoted by $r_{1Y.2}$:

$$r_{1Y.2} = \frac{r_{1Y} - r_{12} r_{Y2}}{\sqrt{(1 - r_{12}^2)(1 - r_{Y2}^2)}} \qquad [14]$$

r_{1Y} , r_{12} , r_{Y2} are simple Pearson product moment correlations of the corresponding variables. For more details see [?3], [16], [20], [25] and [38].
□

A.1.2 Significance tests

Following [7], the well-known Pearson product-moment correlation formula can be used to estimate Pearson's partial correlation coefficient. Spearman's rank correlation ρ has also been extended to measure partial rank correlation.

Partial correlation coefficients (PRCs) are correlation coefficients on conditional distributions. The distribution of the partial correlation coefficients depends on the multivariate distribution function of the underlying variables. Therefore PRCs may not be directly used as test statistics in nonparametric tests.

Starting from some well-known theorems, we may nevertheless do some approximative tests and analyses.

Step 1:

Find the distribution of the sampling correlation coefficient for random variables (X,Y) with bivariate normal distribution.

Theorem (Pitman's test): (see [30])

Let $u_i = (x_i, y_i)$ (i = 1,...,n) be a random sample from a bivariate normal distribution with correlation r. Let r_s be the sample correlation coefficient (Pearson's product moment coefficient):

$$r_s = \frac{\sum_i (y_i - y_m)(x_i - x_m)}{\left[\sum_i (y_i - y_m)^2 \sum_i (x_i - x_m)^2\right]^{\frac{1}{2}}} \qquad [15]$$

Let r = 0 then

$$T_s = r_s \sqrt{\frac{(n-2)}{(1-r_s^2)}} \qquad [16]$$

is distributed as Student's t with (n-2) degrees of freedom.
□

Theorem: (see [31] or [35])

Let $(z_1, \ldots, z_k)$ be a random sample from a k-dimensional normal distribution and $r_{ij,u_1,\ldots,u_p} = 0$ where $r_{ij,u_1,\ldots,u_p}$ is the partial correlation coefficient) of order p (p = k-2). $u_1, \ldots, u_p$ are p = k-2 numbers from {1,...k} which are different from i and j. That means the *partial* correlation between Z_i and Z_j is tested, say, while the indirect correlation due to $Z_{u_1}, \ldots, Z_{u_p}$ is eliminated. Let $r_{s;ij,u_1,\ldots,u_p}$ be the sample partial correlation coefficient) of order p (p = k-2). Take n samples from the vector z, then

$$T_s = r_{s;ij,u_1,\ldots,u_p} \sqrt{\frac{(n-2-p)}{(1-r^2_{s;ij,u_1,\ldots,u_p})}} \qquad [17]$$

is distributed as Student's t with (n-2-p) degrees of freedom.
□

Step 2:

Try to find adequate approximate formulas for non-normal situations.

Let $w_i = (u_i, v_i)$ (i = 1,...,n) be a random sample from a bivariate distribution with correlation r. Let r_s be the sample correlation coefficient. Transform the sample values $(u_1, \ldots, u_n)$ and $(v_1, \ldots, v_n)$ into their order statistics $(u_{(1)}, \ldots, u_{(n)})$ and $(v_{(1)}, \ldots, v_{(n)})$. Then do an *expected normal scores transformation:* Replace the order statistics of the (u,v)-variables by the expected value of the corresponding order statistics of standard normal variates (X,Y). Then r_s transforms approximately to ψ_s:

$$r_s \sim \psi_s = \frac{\sum_i E(x_{(i)})E(y_{(i)})}{\sqrt{\sum_i E^2(x_{(i)}) \sum_i E^2(y_{(i)})}} \qquad [18]$$

(This is clear from the hint that for a N(0,1)-distributed variable X one has $\Sigma E(X_{(i)}) = 0$ because of $E(X_{(i)}) = -E(X_{(n-i+1)})$.

ψ_s can be used for an expected normal scores test of the hypothesis that U and V are uncorrelated.

[7] explains the role of the expected normal scores as well defined numbers which replace the unpleasant behaviour connected with using the order statistics from normal variables themselves. The procedure is based only on the ranks of the observations and is therefore a *rank test.*

Fisher and Yates (see [4]) suggested the analogue to Pitman's test using the exact normal scores instead of the the original data and applied the usual parametric procedures to these expected normal scores as a nonparametric procedure.

Step 3:

Give the significance test procedure.

The procedure is as follows:

The 'null' hypothesis reads: "No *partial* correlation exists between Y (the consequence variable) and X_i (one of the uncertain model parameters)", while the indirect influence due to to the other model parameters is eliminated.

Then, for a sample of size n, the partial sample rank correlation, $\rho_{s;Y_i,u_1,\ldots,u_p}$, between Y and X_i has to be calculated. ρ_s is then compared with the quantiles of the distribution of the test statistic. The comparison is made at a certain prescribed level of significance, α.

The 'null' hypothesis of *no* correlation is rejected, if the correlation value ρ_s leads to $|\rho_s| \geq T_{\alpha/2,n}$, the **critical value**, where $T_{\alpha/2,n}$ is a quantile of the test statistic's distribution.

$$T_{\alpha/2,n} \sim \frac{t_{\alpha/2,n-k}}{\sqrt{n-k+t^2_{\alpha/2,n-k}}} \qquad [19]$$

$t_{\alpha/2,n-k}$ is the (1 - α/2)-quantile of the t-distribution with n-k degrees of freedom (compare [22] or [32]). Eq. [19] is easily derived from Eq. [17] .

Example:

For k = 20 uncertain input model parameters and α = 0.05 significance level, the partial rank correlation value (PRCC), ρ, is significant, if its absolute value is greater than 0.43 (40 runs), 0.25 (80 runs) or 0.16 (100 runs) , respectively.

A.2 Remarks to R^2- values

Here some additional hints for motivation of the *coefficient of determination,* R^2, are given.

The *total variation* of the consequence variable, Y, is defined as $\Sigma(Y - Y_m)^2$, i.e. the sum of squares of the deviation of values of Y from the mean Y_m.

$$\Sigma(Y - Y_m)^2 = \Sigma(Y - Y_{est})^2 + \Sigma(Y_{est} - Y_m)^2$$

The first term on the right is called the *unexplained variation* while the second term is called the *explained variation* (by a regression model), so called because the deviations $(Y_{est} - Y_m)$ have a defined pattern while the deviations $(Y - Y_{est})$ behave in a random or unpredictable manner.

The ratio of explained variation to the total variation is called the *coefficient of determination,* R^2

$$R^2 = \frac{\Sigma(Y_{est} - Y_m)^2}{\Sigma(Y - Y_m)^2}$$

Remark:

In this report all R^2 - values R^2_s are normalized by R^2_t .

$$R^2 = \left(\frac{R^2_s}{R^2_t}\right) \times 100,$$

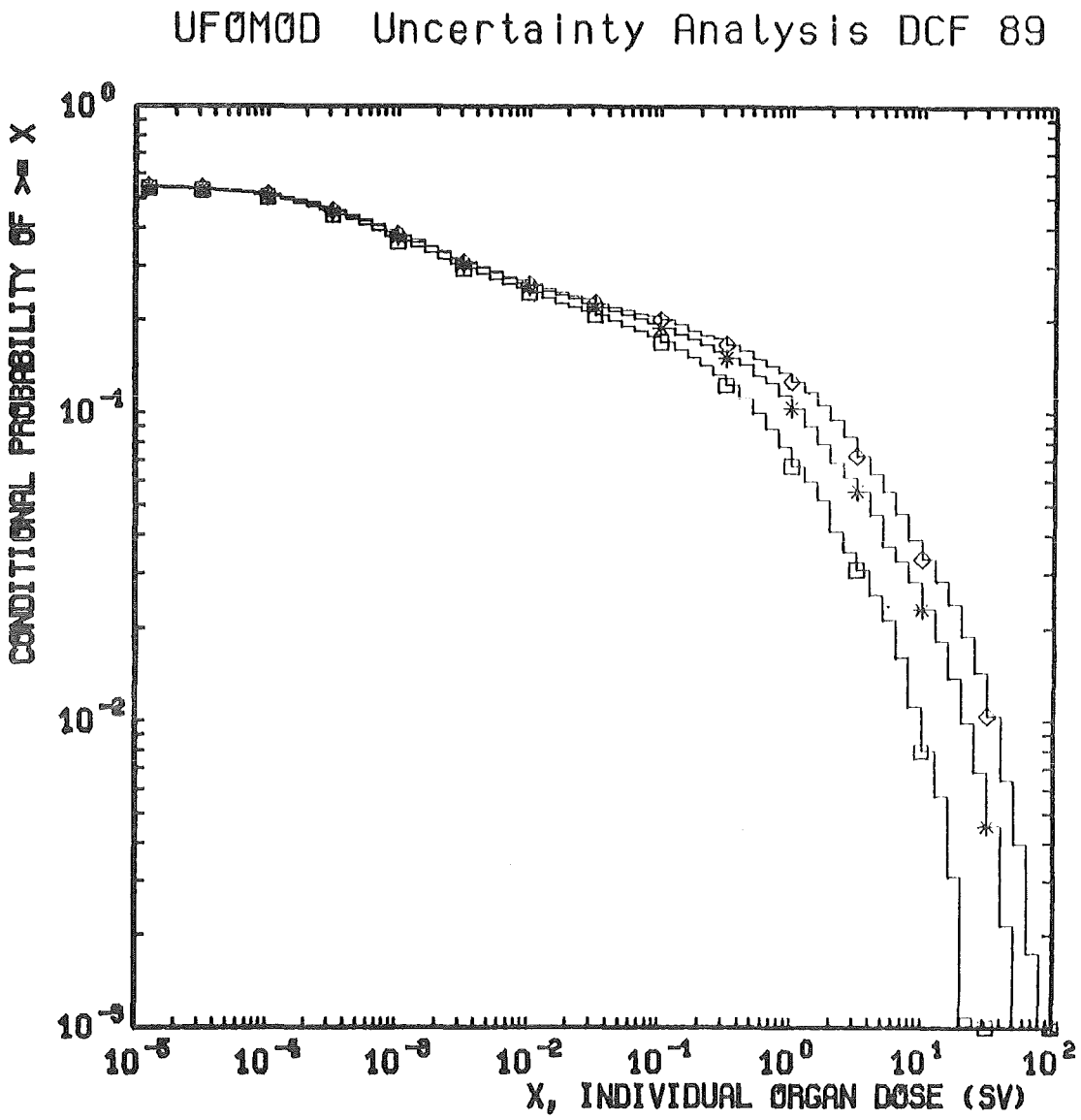
where R^2_s , R^2_t are calculated by the SANDIA - PRCSRC-code (see [25]) and the R^2_t - values are calculated with *all* (i.e. the complete set of) model parameters.

Appendix B. Uncertainty Analyses (Figures)

B.1 DCF ANALYSIS

B.1.1 Doses

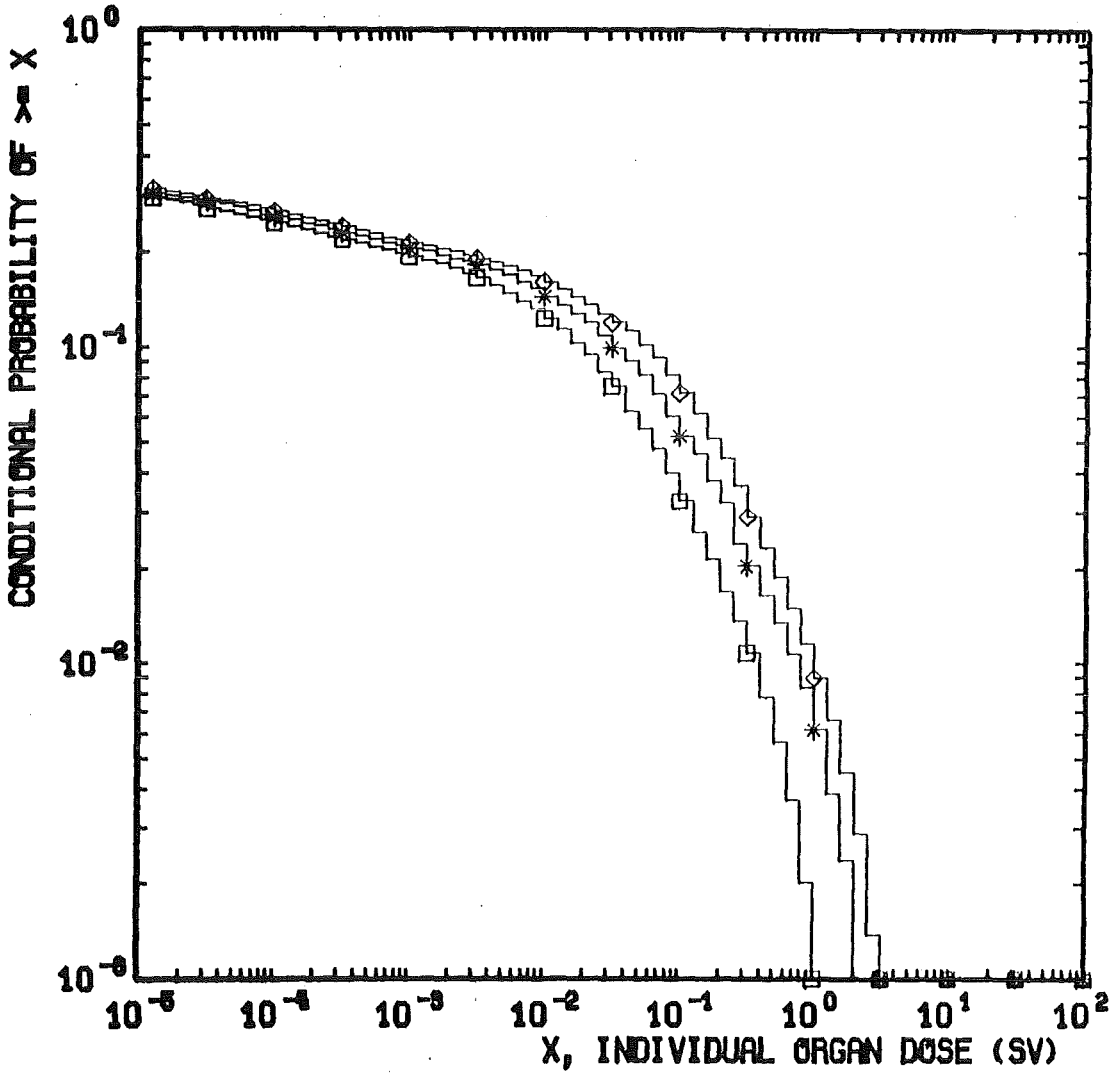
In this section confidence curves are shown
for acute individual doses (lung, bone marrow) at three distances.
Number of runs = 60.



Individual acute dose
Organ.....: lung
Distance .....: 0.875 km

✱ : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

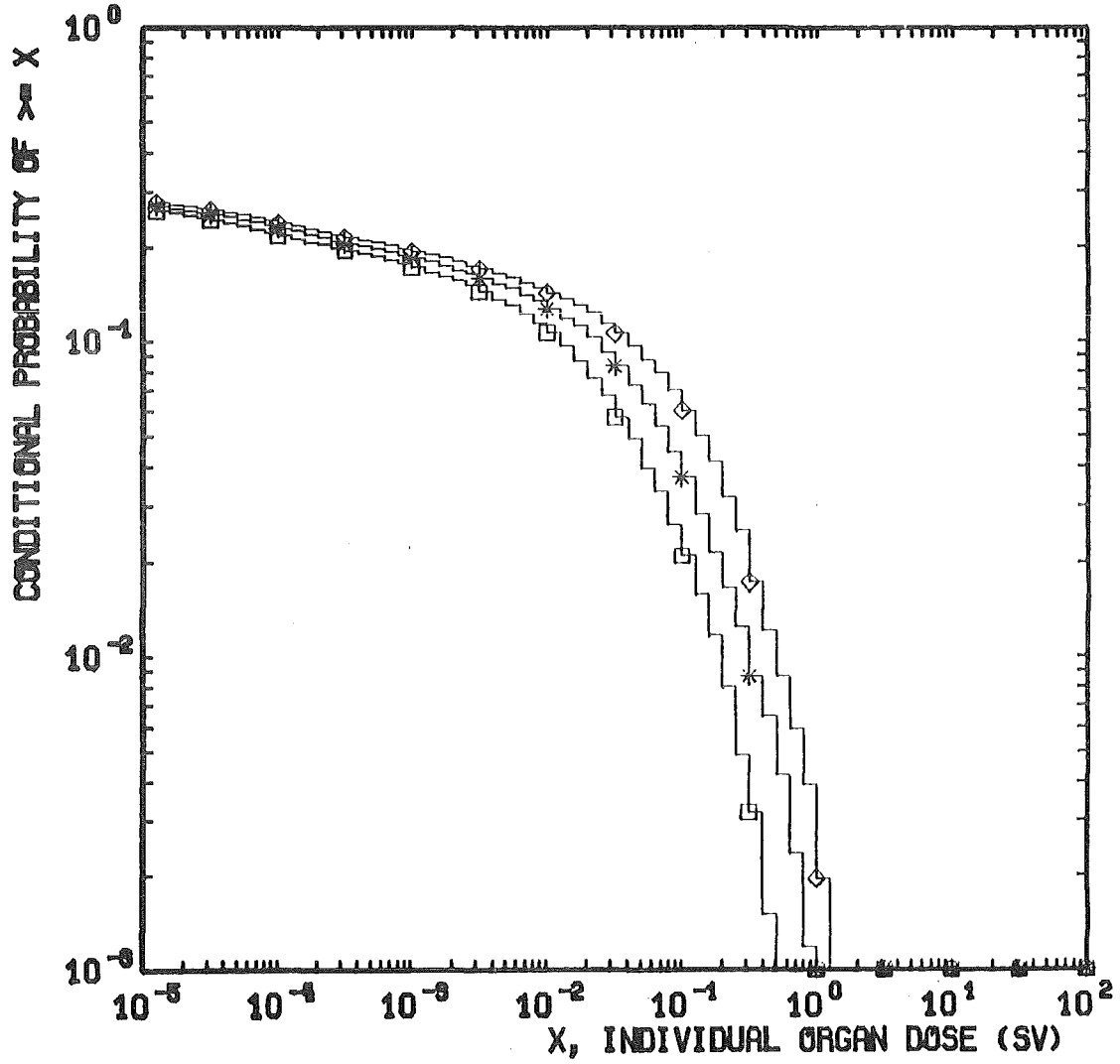
REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS



Individual acute dose
Organ.....: lung
Distance .....: 4.9 km

* : Ref.-Curve
□ : 5% -Curve
◆ : 95% -Curve

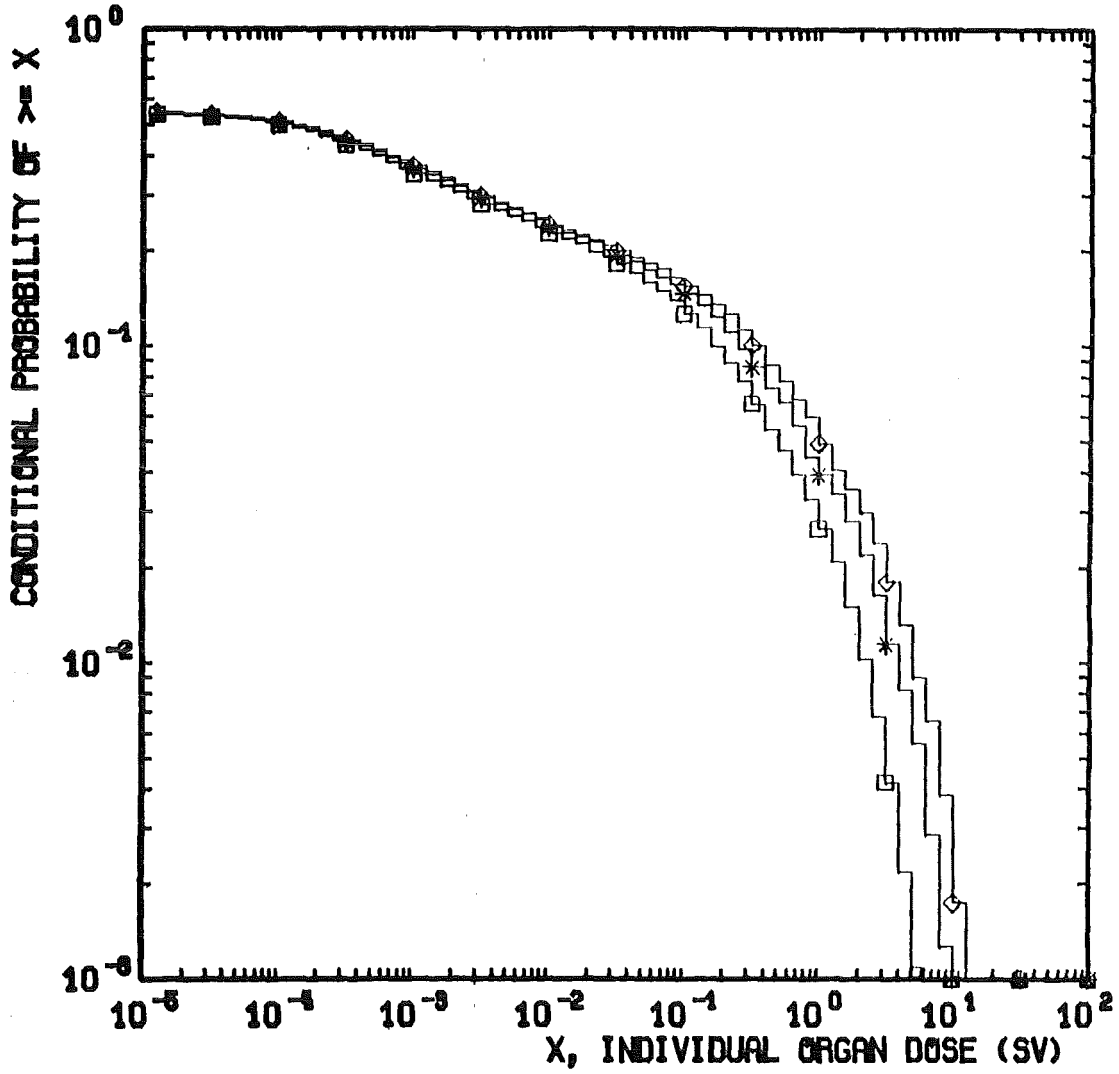
REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS



Individual acute dose
Organ.....: lung
Distance .....: 8.75 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS

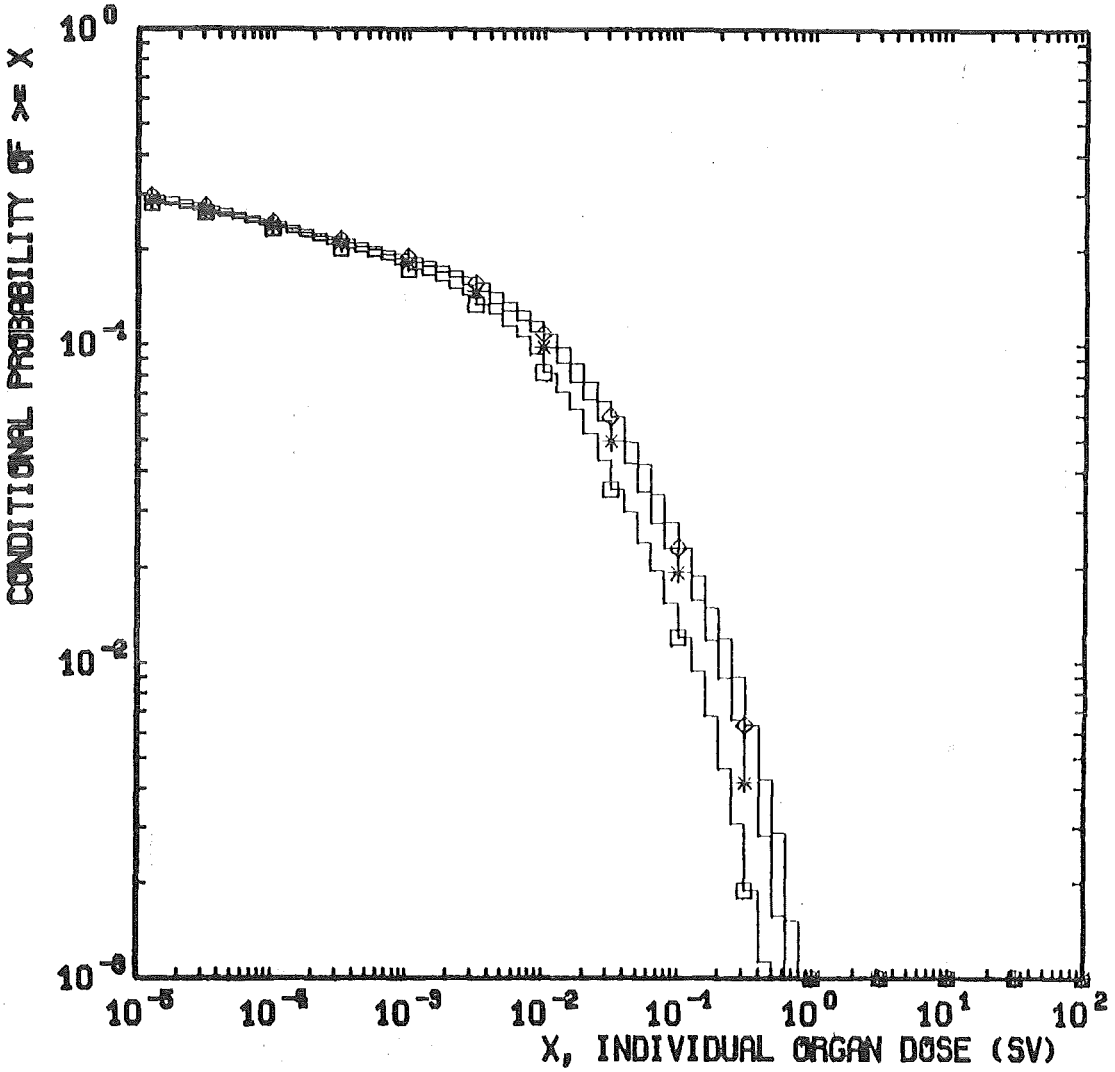


Individual acute dose
Organ.....: bone marrow
Distance .....: 0.875 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS

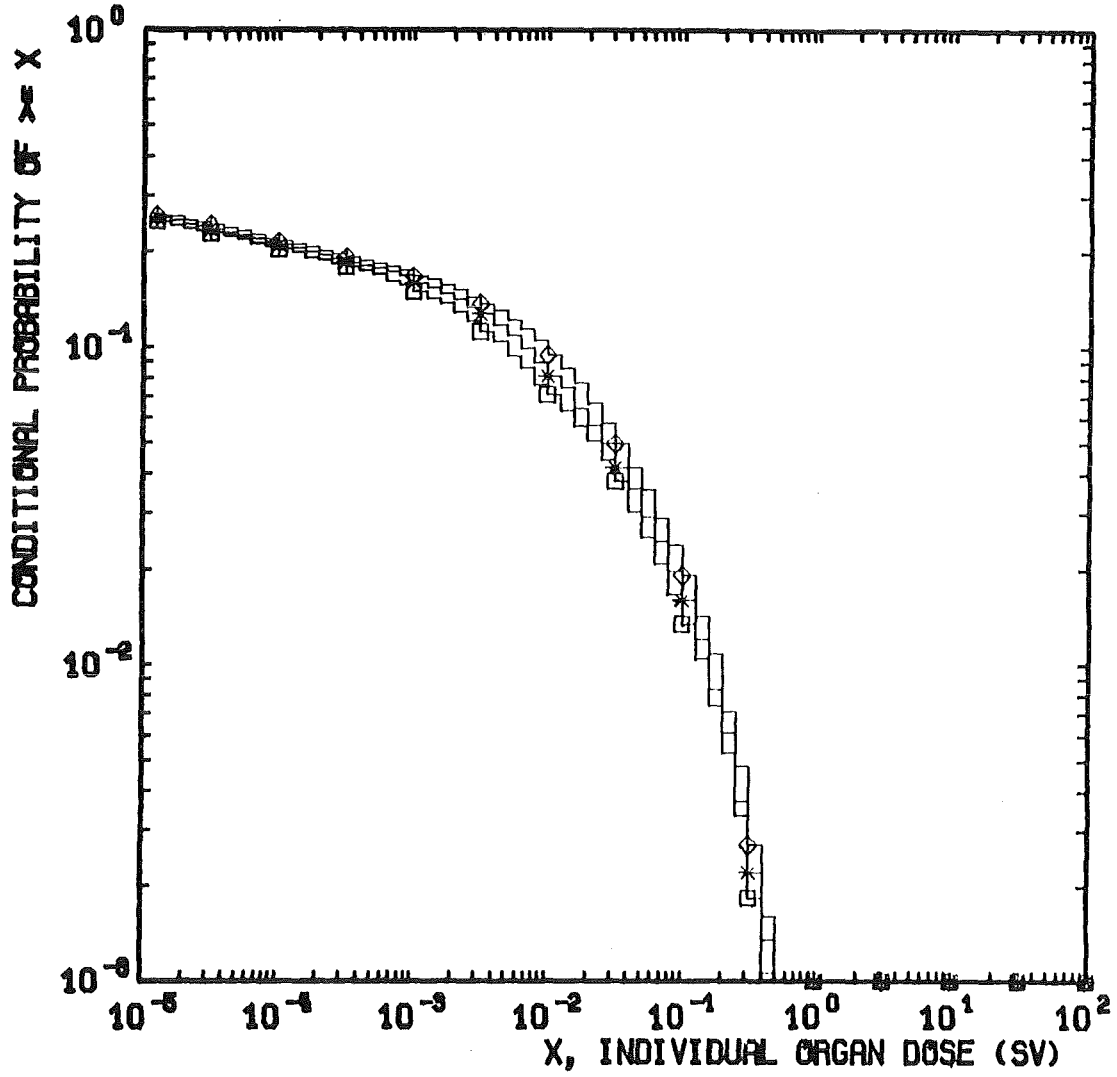


Individual acute dose
Organ.....: bone marrow
Distance .....: 4.9 km

*: Ref.-Curve
□: 5% -Curve
◇: 95% -Curve

KfK INR

REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS



Individual acute dose
Organ.....: bone marrow
Distance .....: 8.75 km

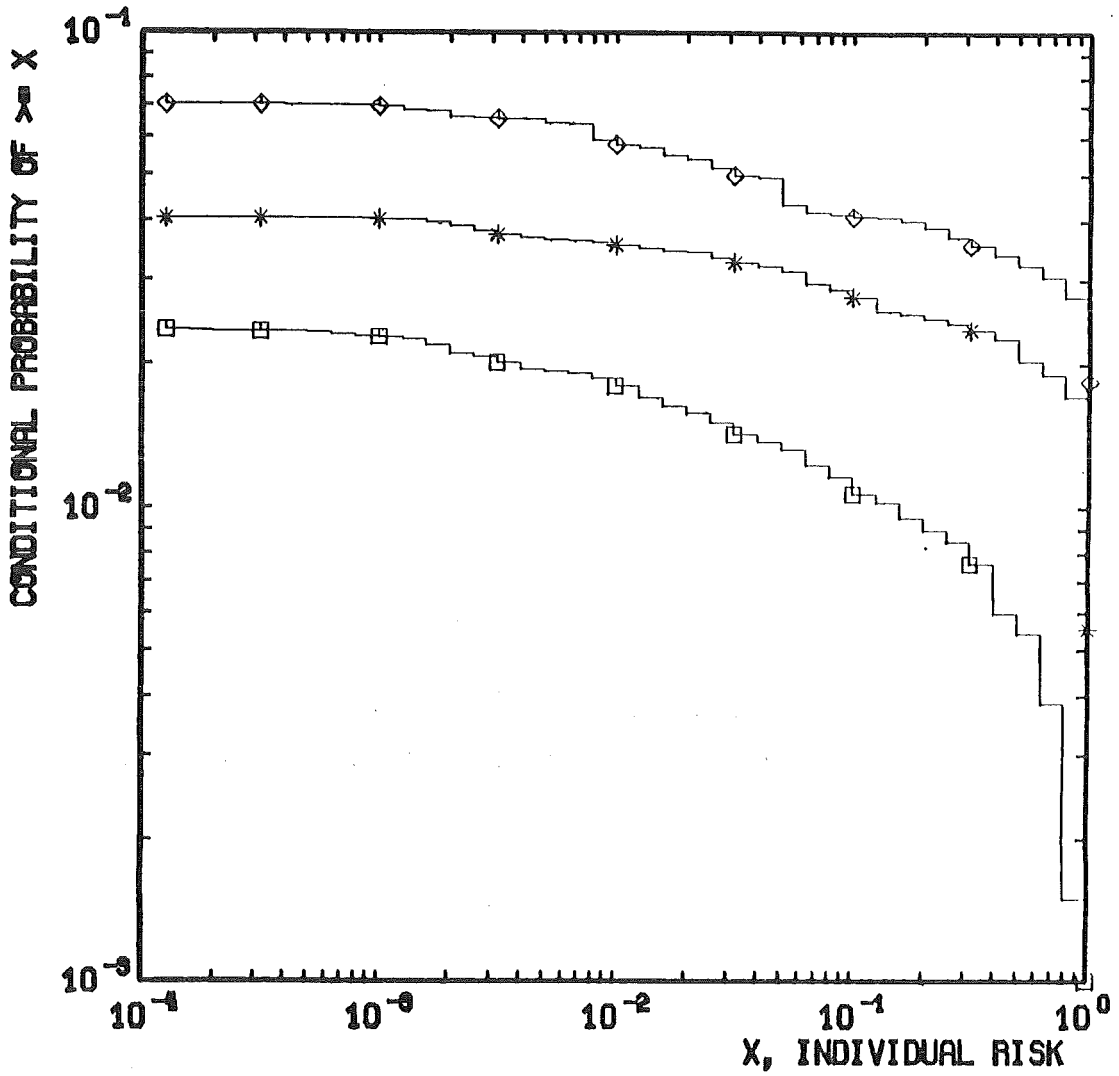
* : Ref.-Curve
▫ : 5% -Curve
◆ : 95% -Curve

KfK INR

REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS

B.1.2 Risks

In this section confidence curves are shown
for acute indidual risks (pulmonary, hematopietic syndrome).
Number of runs = 60.

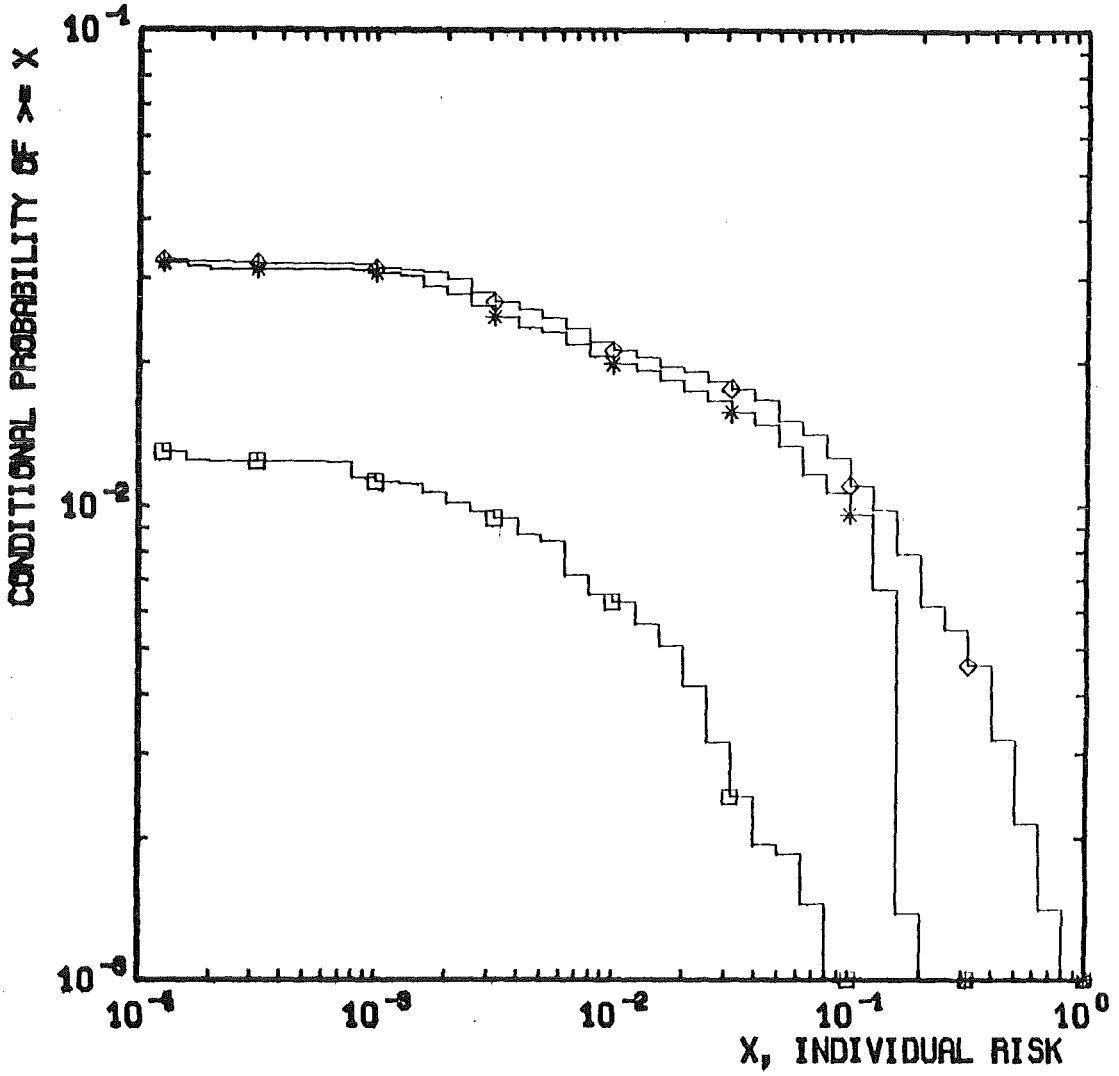


Individual riek
Health effect.....: pulmonary syndrome
Distance .....: 0.875 km

✱ : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

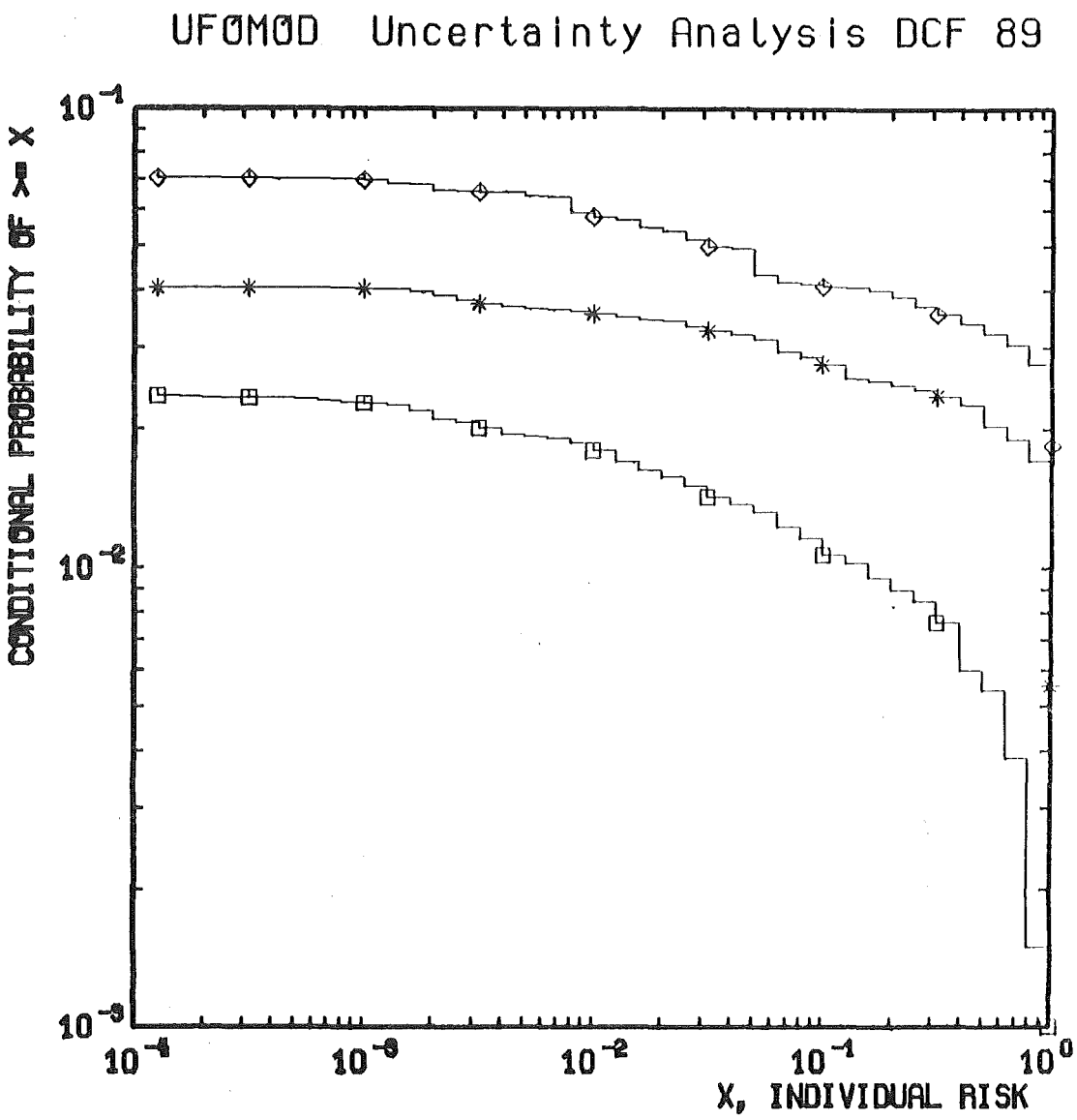
REFERENCE CCFD OF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Individuel riek
Health effect.....: hematopoietic syndrome
Dietance .....: 0.875 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

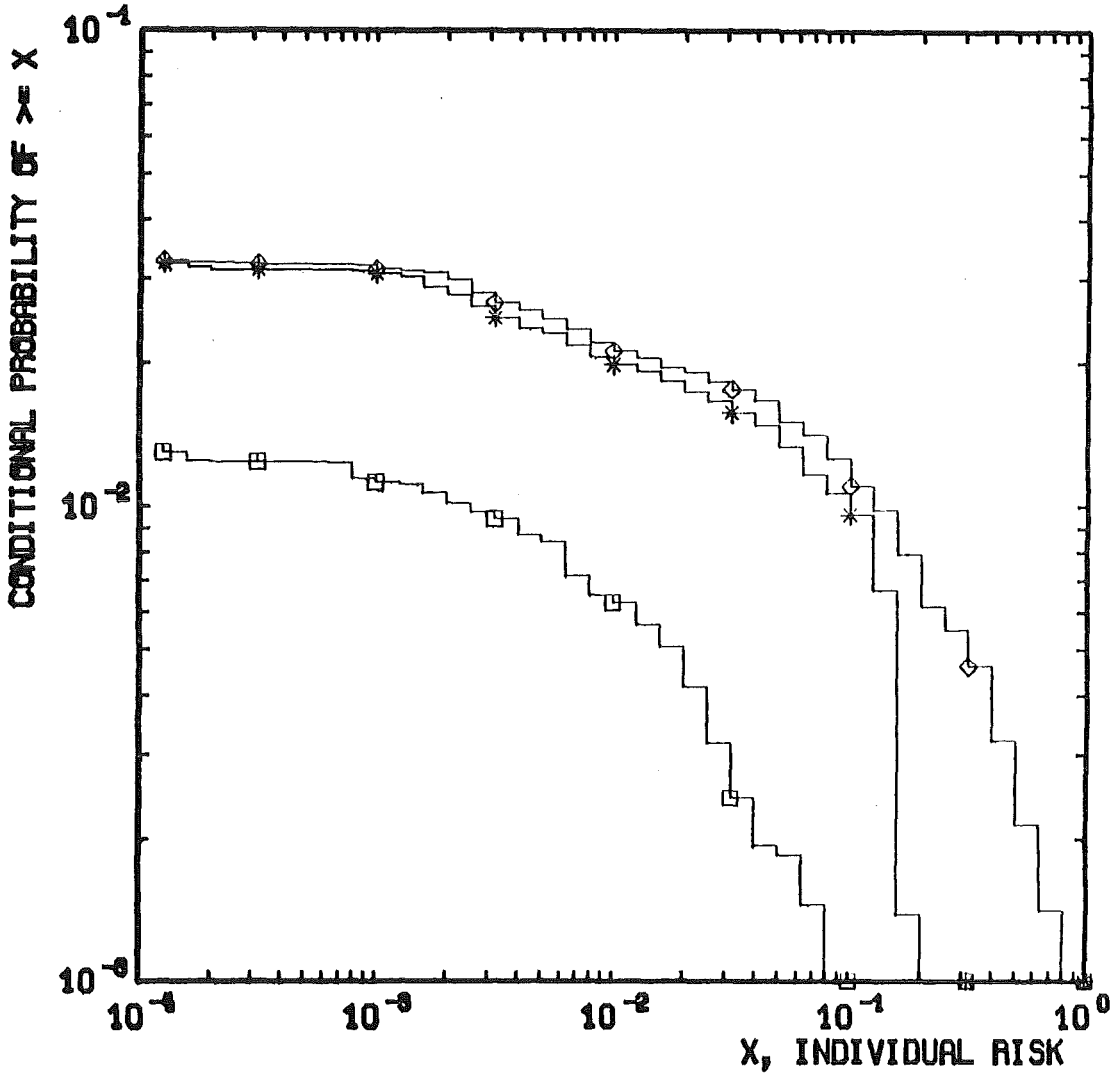
REFERENCE CCFD OF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Individual risk
Health effect.....: pulmonary syndrome
Distance .....: 0.875 km

✱ ; Ref.-Curve
□ : 5% -Curve
◇ ; 95% -Curve

REFERENCE CCFD OF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



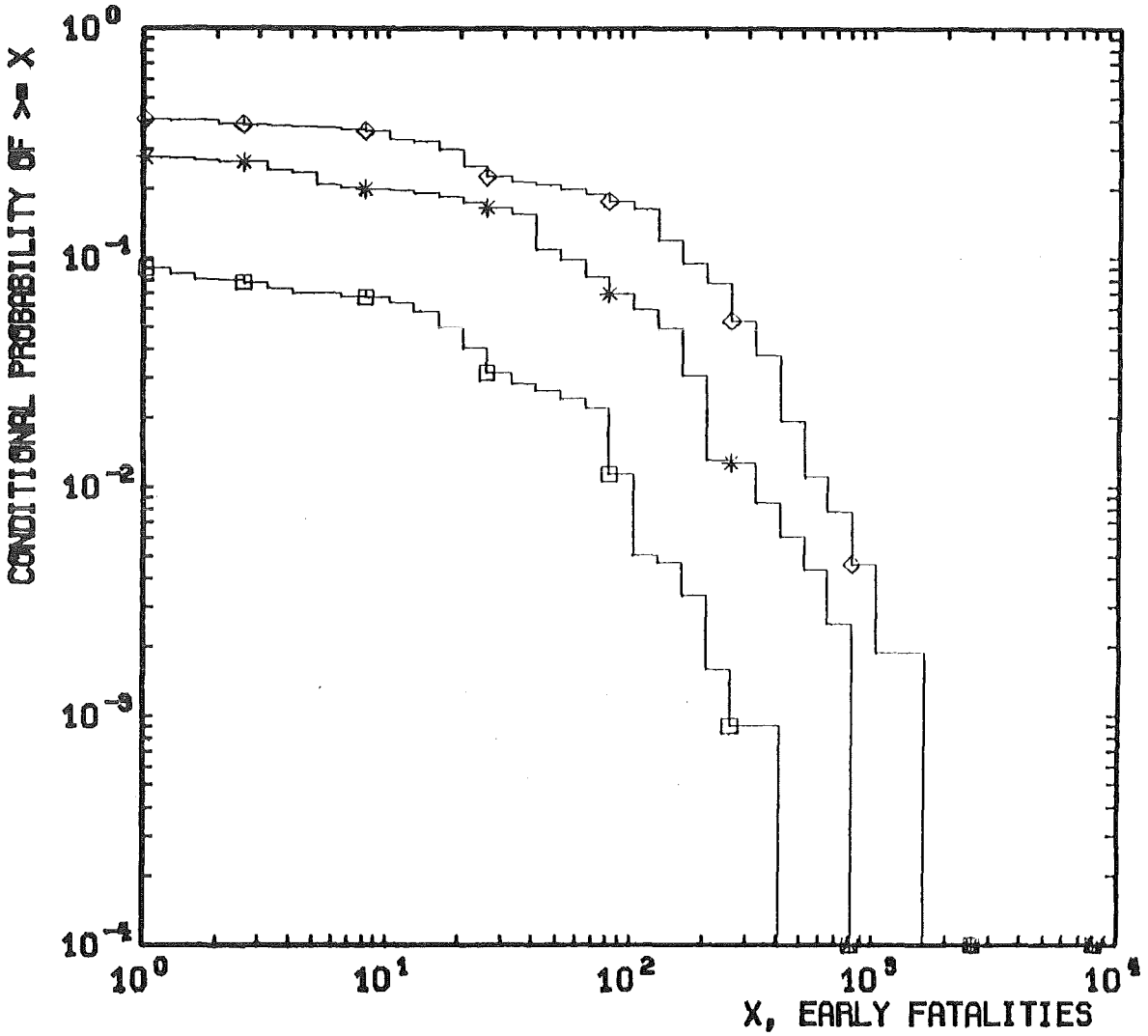
Individual risk
Health effect.....: hematopoietic syndrome
Distance .....: 0.875 km

✱ : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

REFERENCE CCFD OF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

B.1.3 Health Effects

In this section confidence curves are shown
for early health effects (pulmonary, hematopoietic syndrome).
Number of runs = 60.

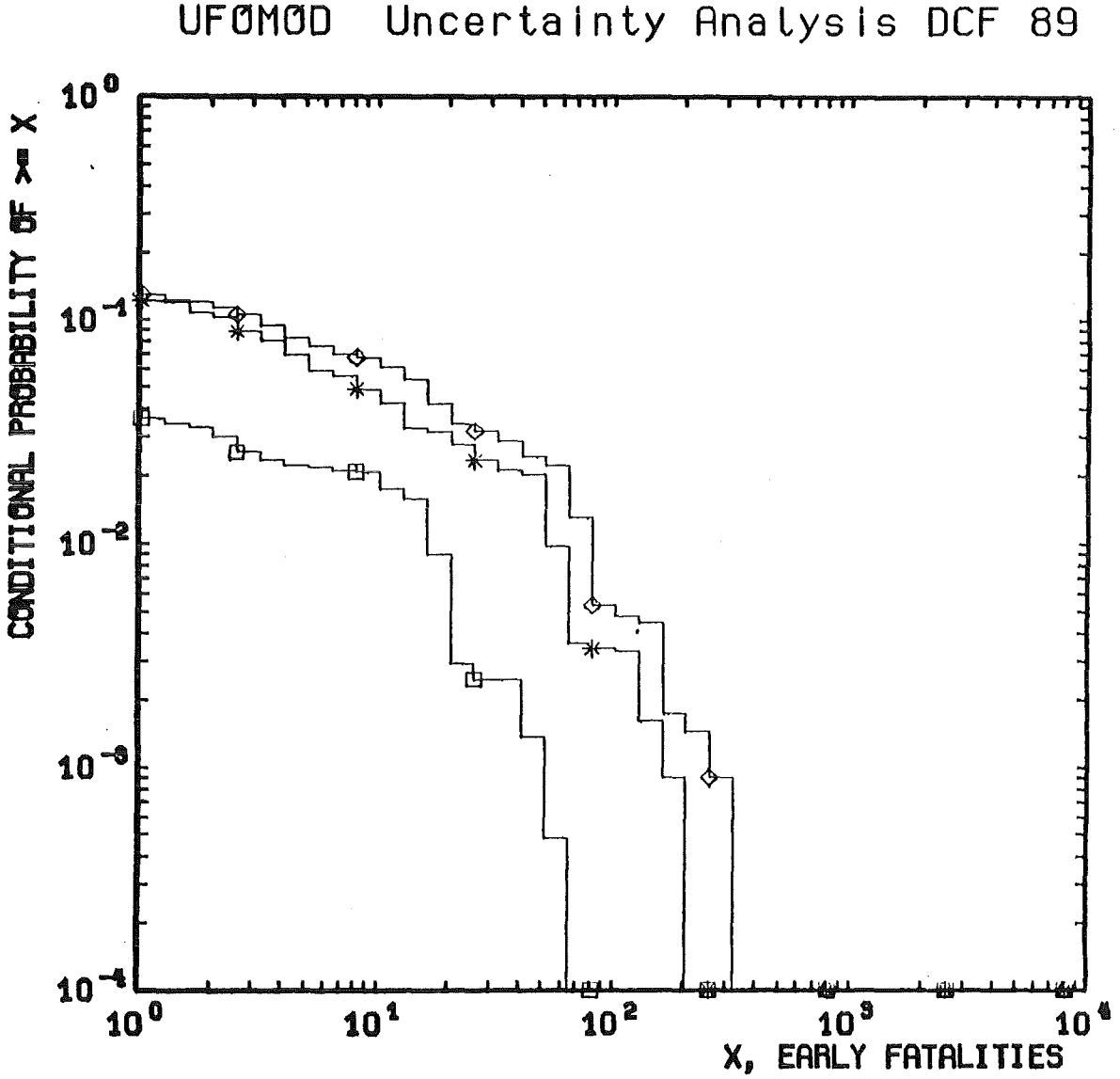


Early fatalities
Health effect.....: pulmonary syndrome

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF EARLY FATALITIES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

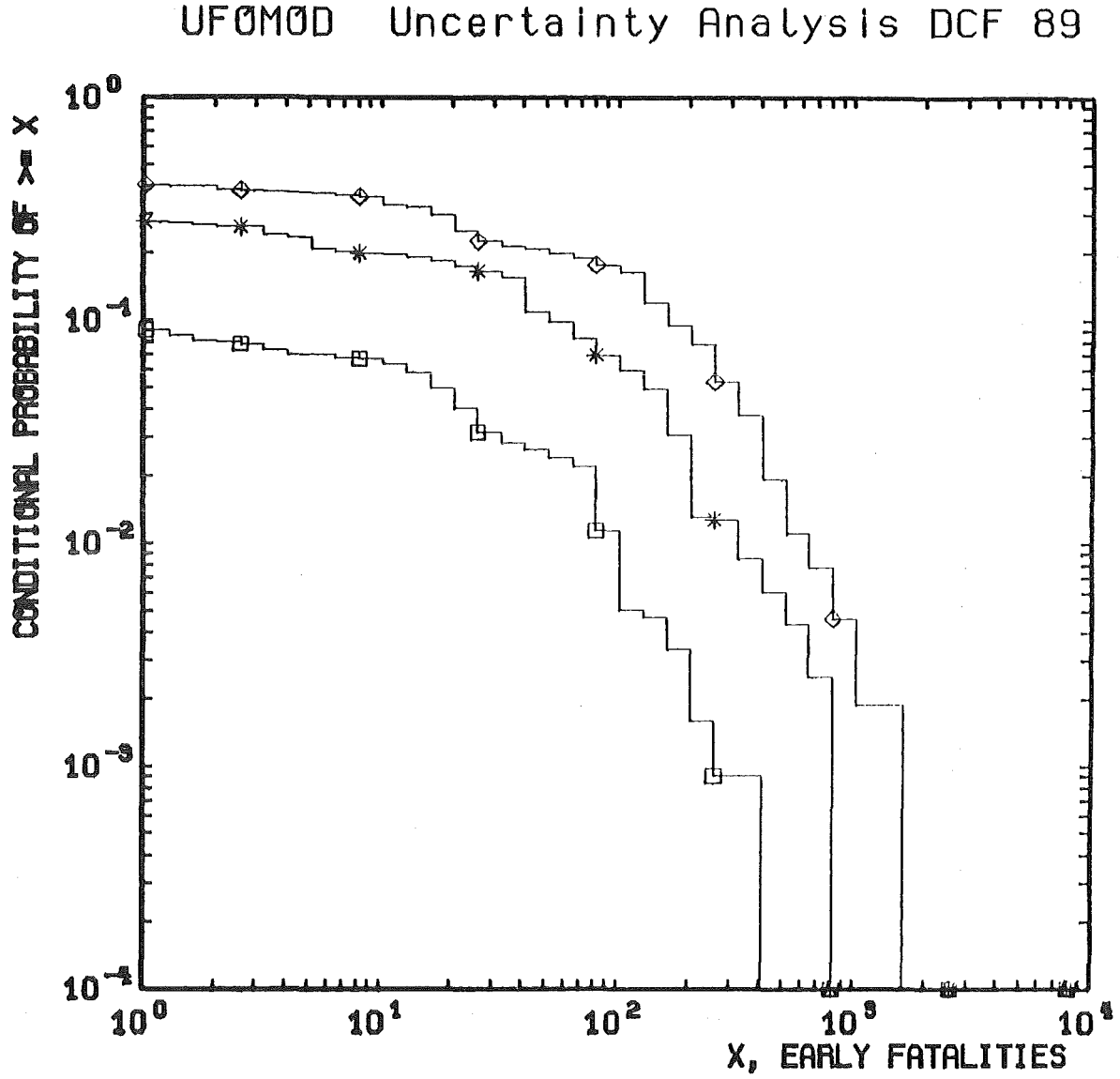


Early fatalities
Health effect.....: hematopoietic syndrome

✱ : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF EARLY FATALITIES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

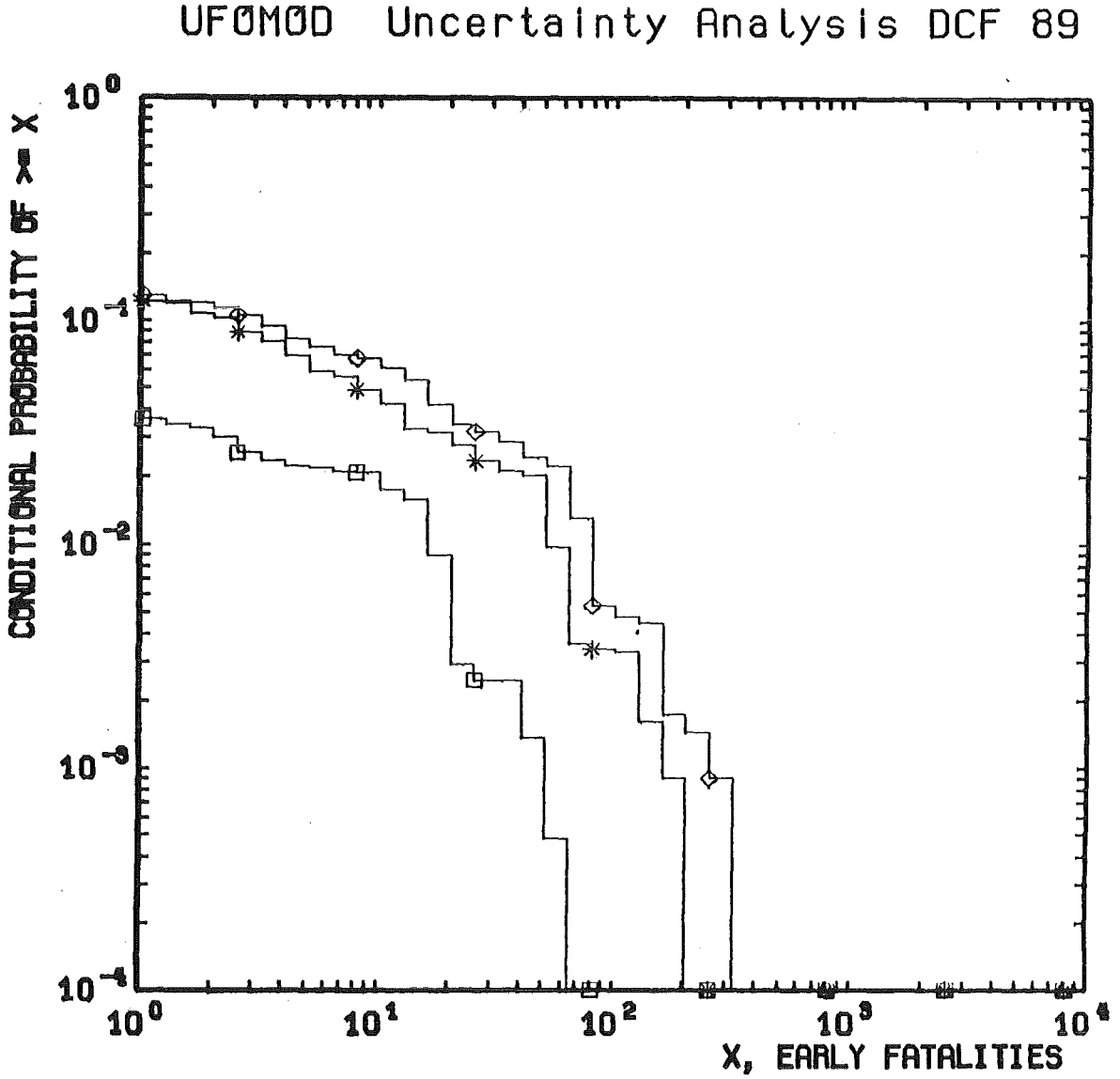


Early fatalities
Health effect.....: pulmonary syndrome

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF EARLY FATALITIES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Early fatalities
Health effect.....: hematopoietic syndrome

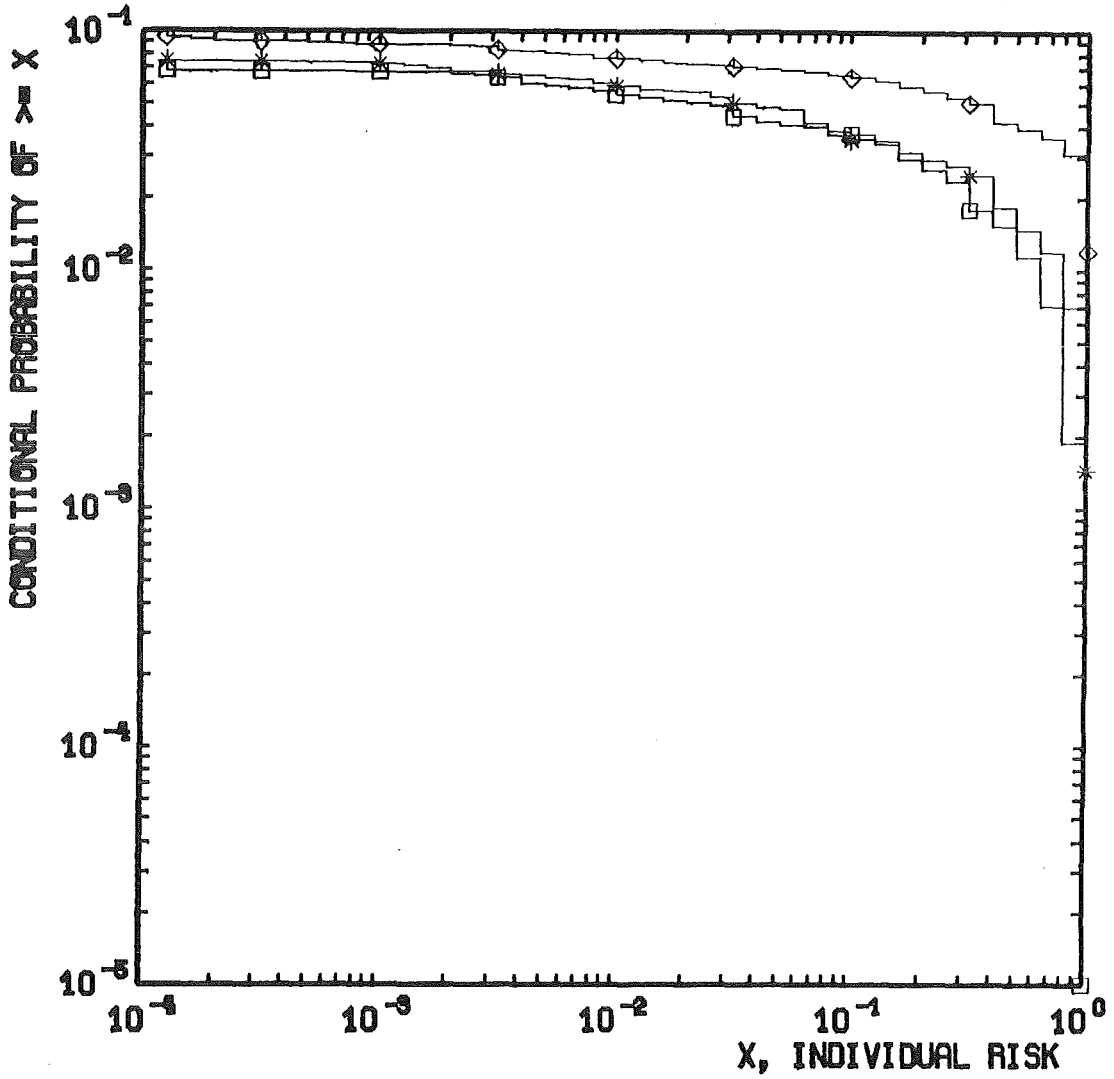
* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

REFERENCE CCFD OF EARLY FATALITIES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

B.2 HEM ANALYSIS

B.2.1 Risks

In this section confidence curves are shown
for acute indidual risks (lung function impairment, pulmonary syndrome,
hematopoietic syndrome, gastrointestinal syndrome, mortality (all
effects)).
Number of runs = 40.

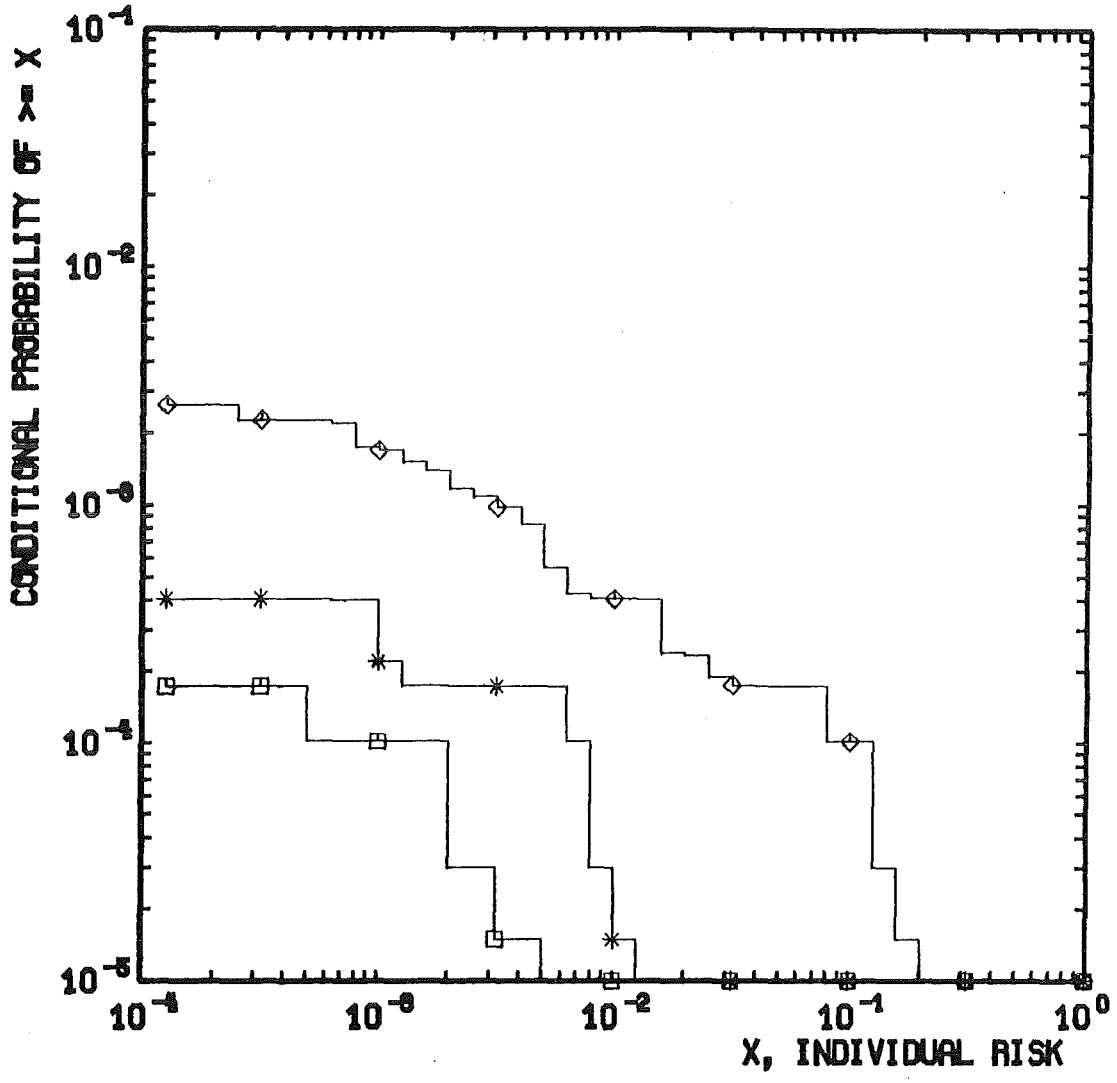


Individual risk
Health effect.....: lung function impairment
Distance .....: 0.875 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

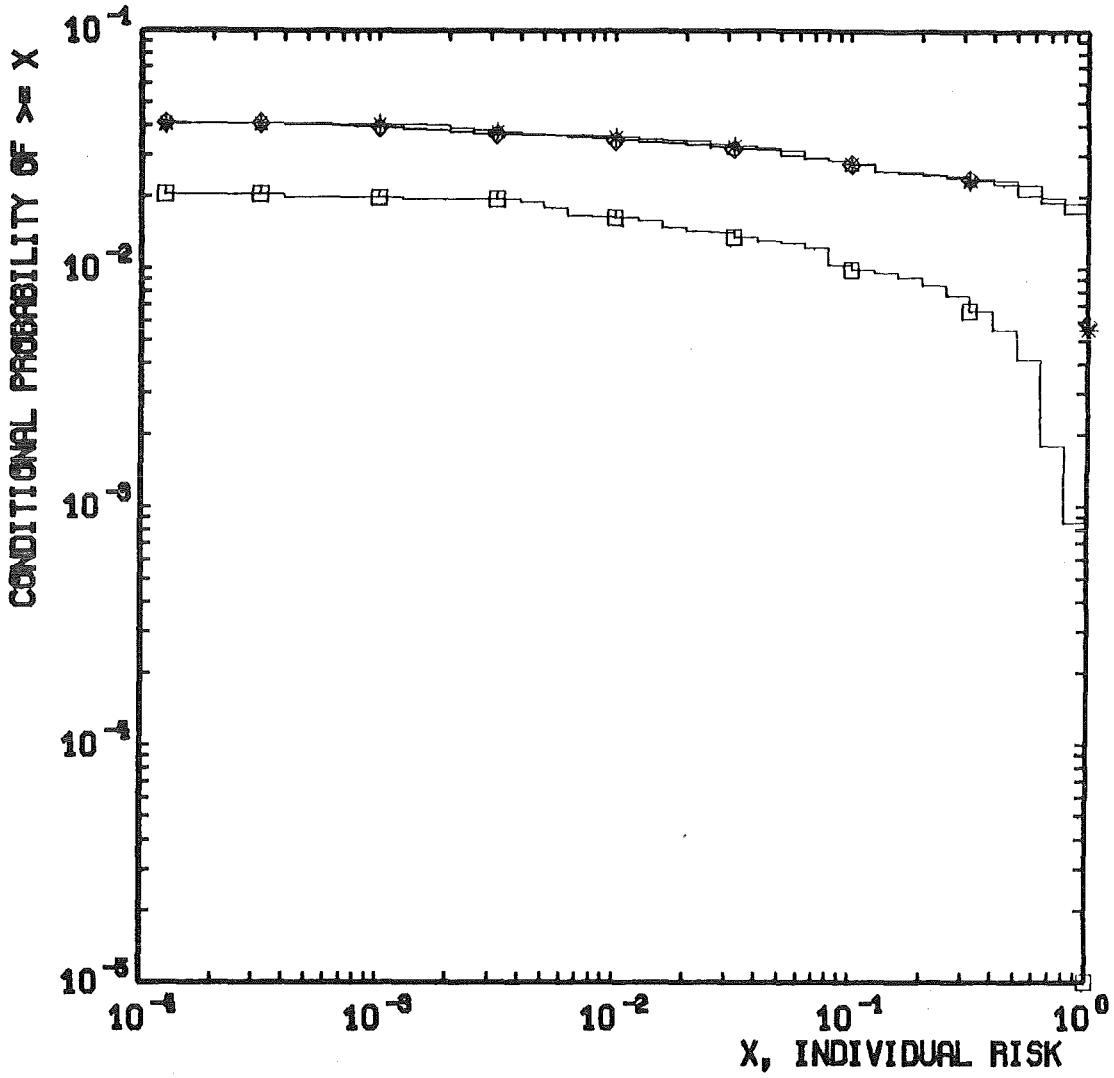


Individual riek
Health effect.....: lung function impairment
Distance .....: 4.8 km

✱ : Ref.-Curve
⧈ : 5% -Curve
◈ : 95% -Curve

KfK INR

REFERENCE CCFD OF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

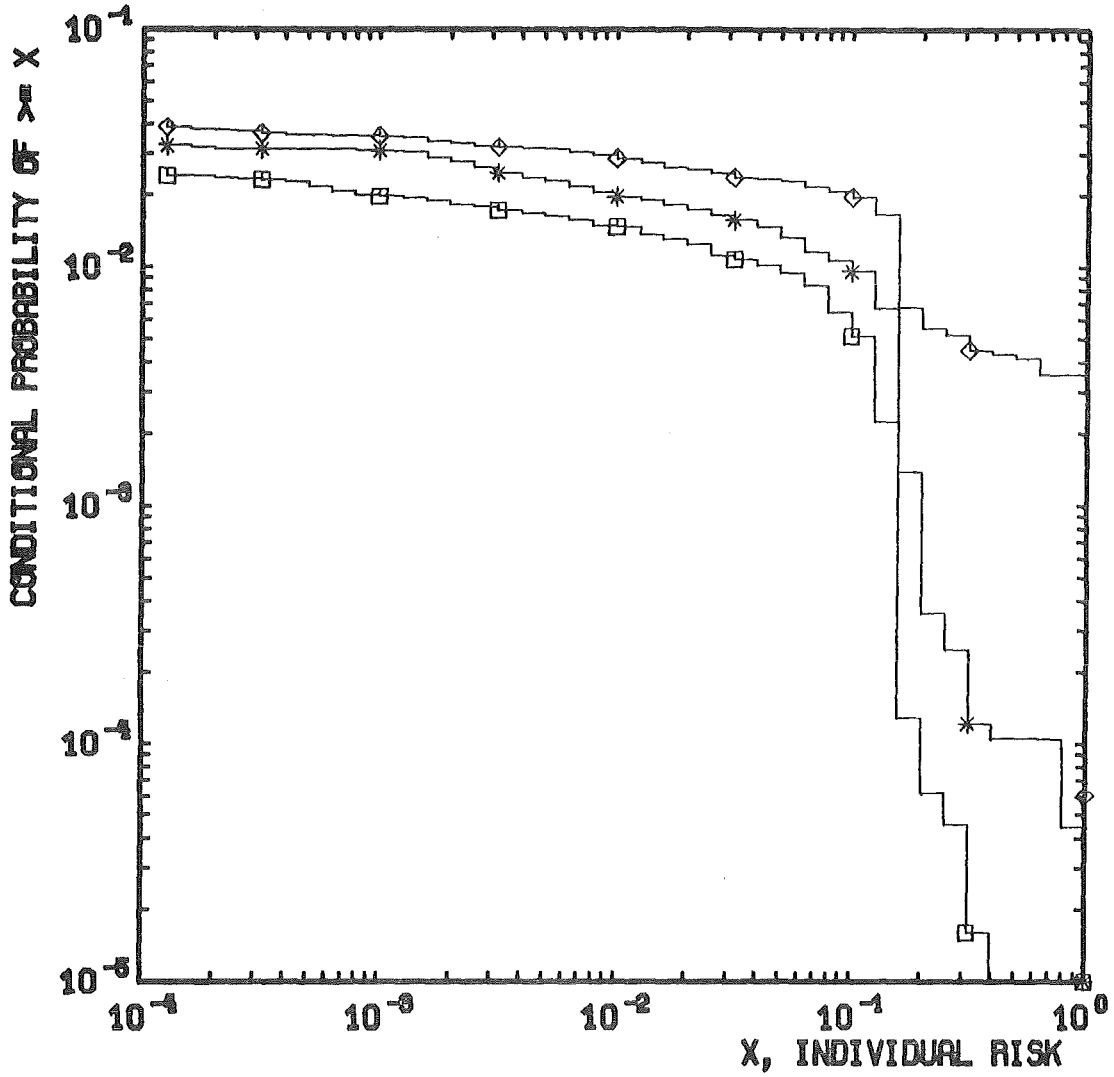


Individual risk
Health effect.....: pulmonary syndrome
Distance .....: 0.875 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

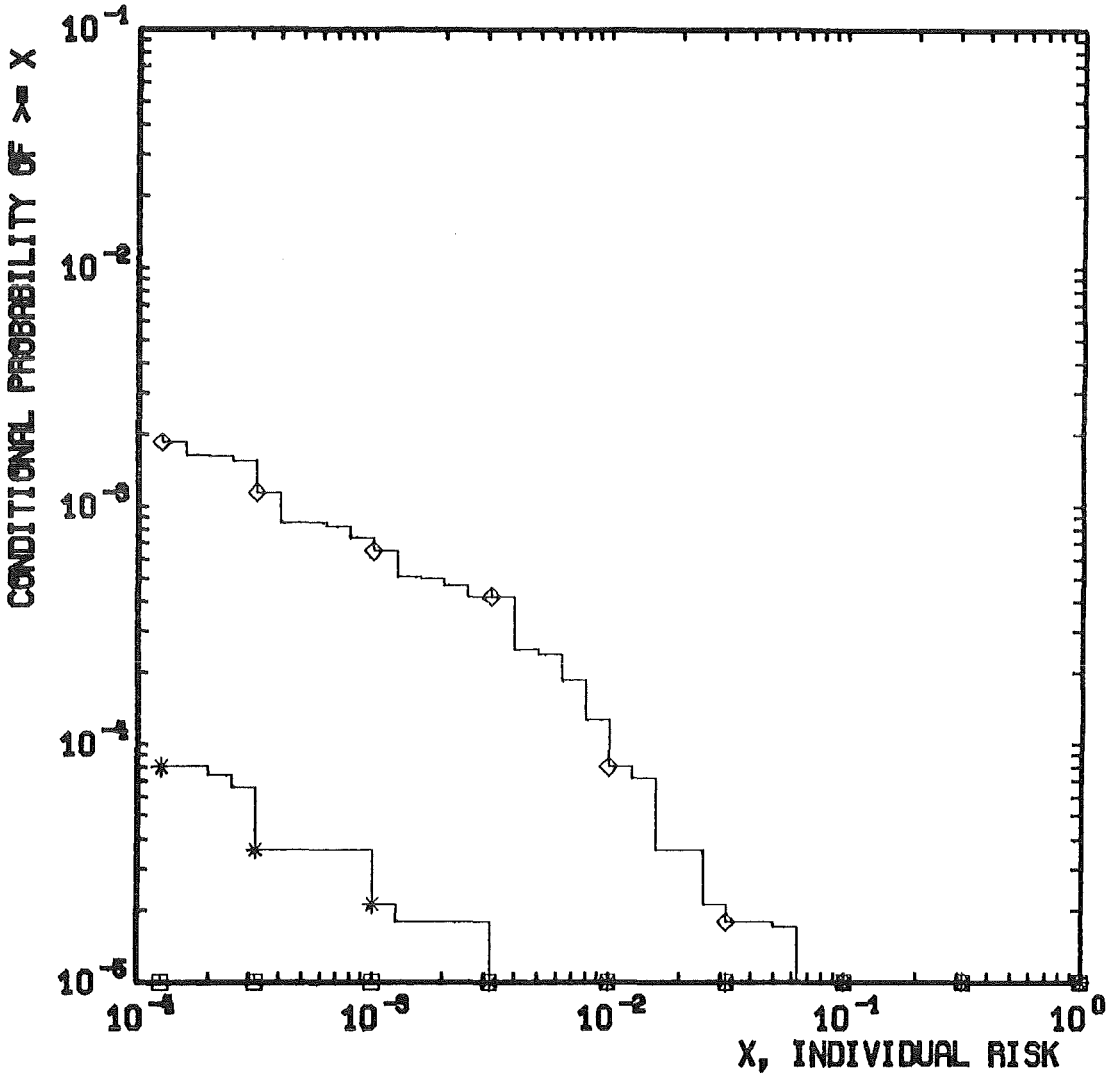
REFERENCE CCFD OF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Individual riek
Health effect.....: hematopoietic syndrome
Distance .....: 0.875 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

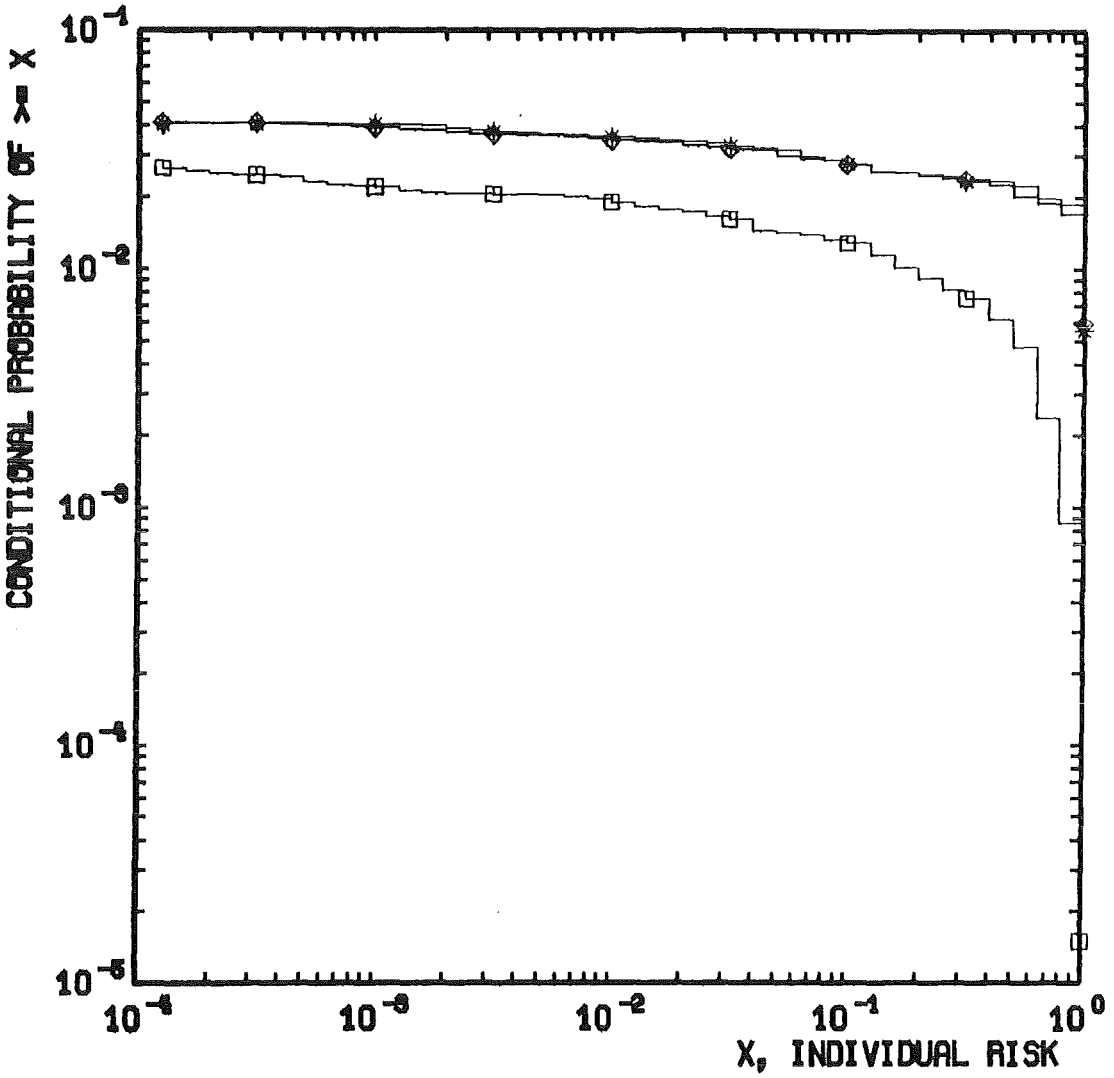
REFERENCE CCFD OF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Individual risk
Health effect.....: gastrointestinal syndrome
Distance .....: 0.875 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

REFERENCE CCFD OF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Individual risk
Health effect.....: mortality (all effects)
Distance .....: 0.875 km

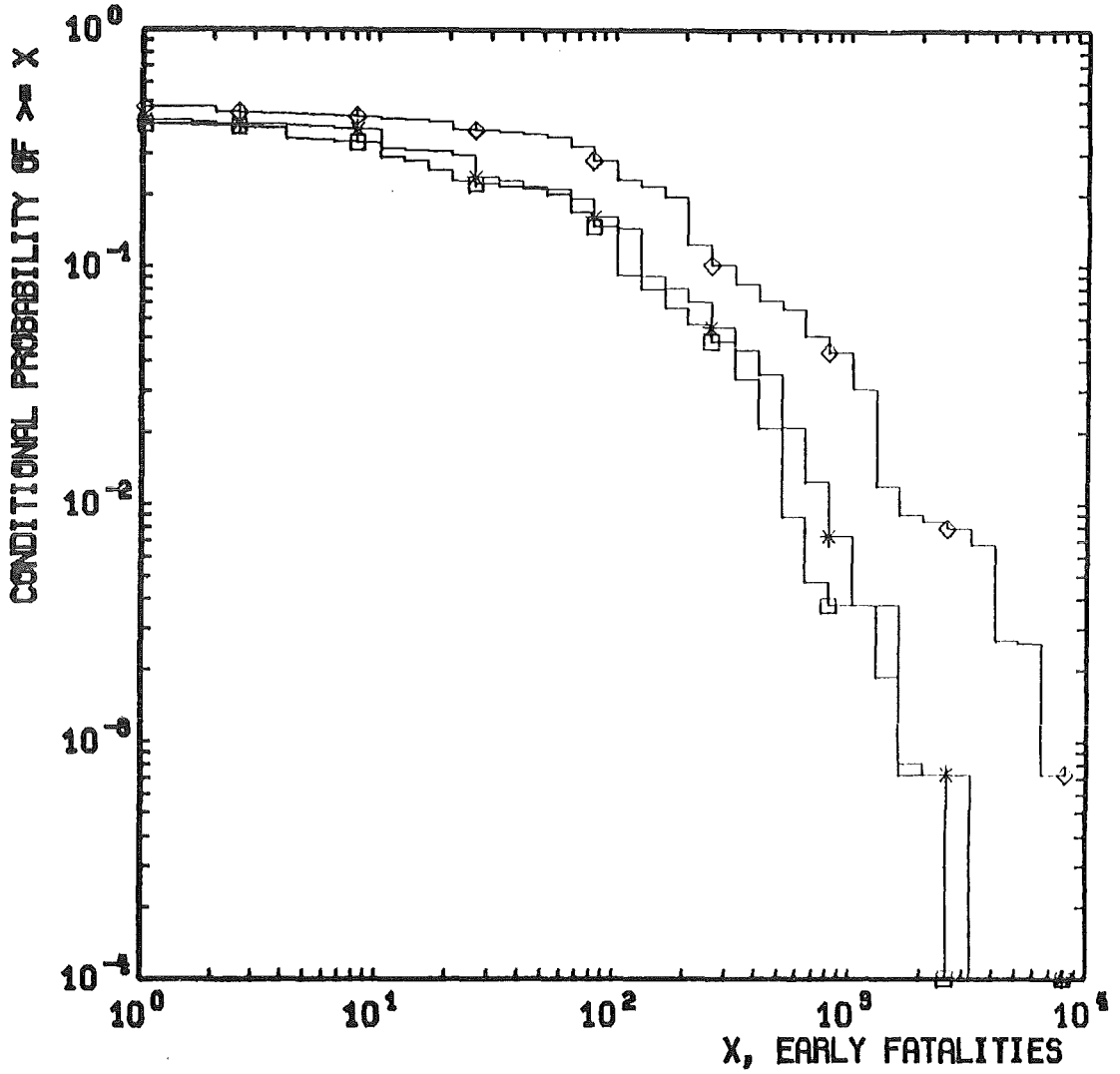
* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

B.2.2 Health Effects

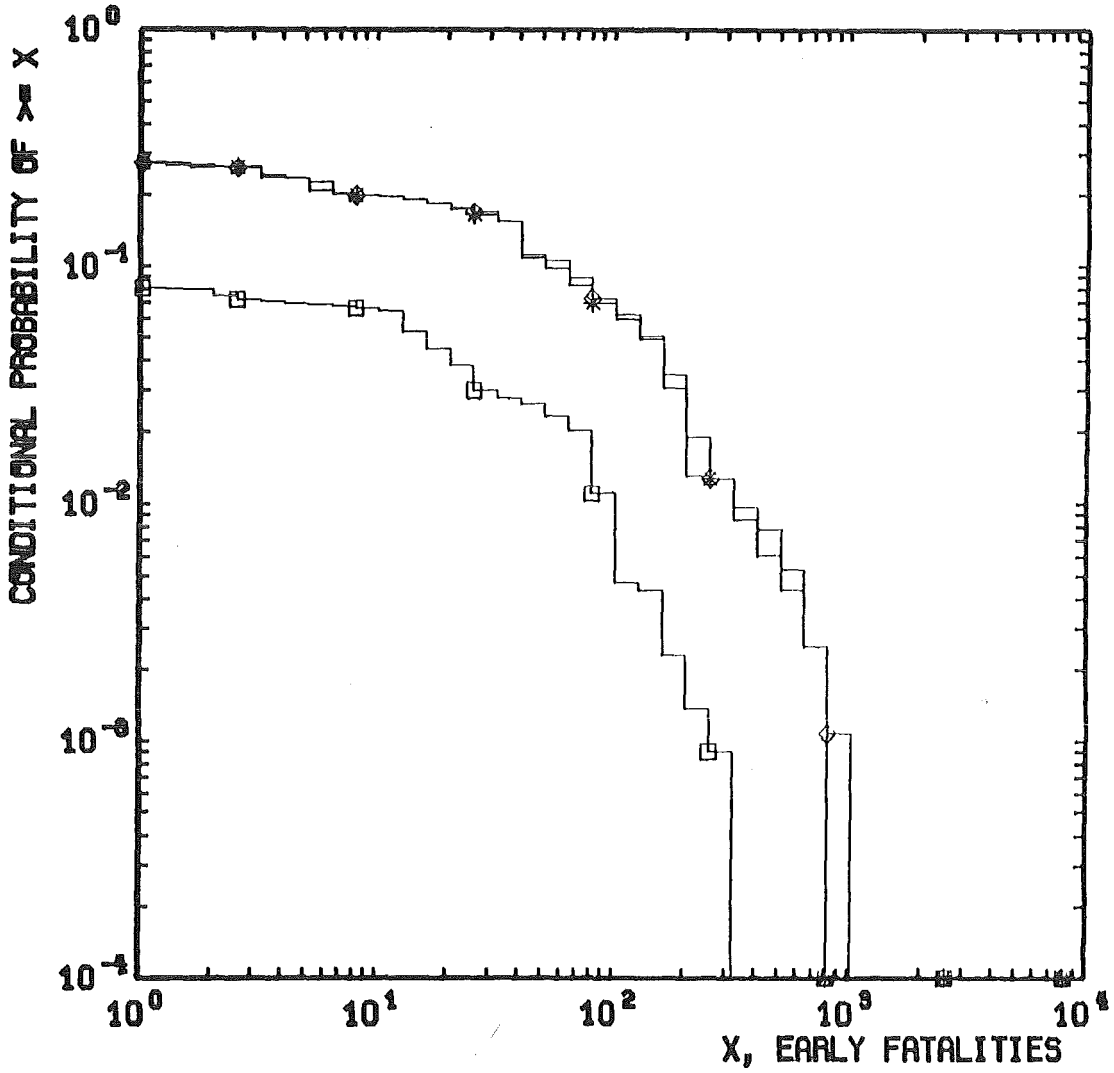
In this section confidence curves are shown
for early health effects (lung function impairment, pulmonary syndrome, hematopoietic syndrome, gastrointestinal syndrome, mortality (all effects)).
Number of runs = 40.



Early fatalities
Health effect.....: lung function impairment

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

REFERENCE CCFD OF EARLY FATALITIES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

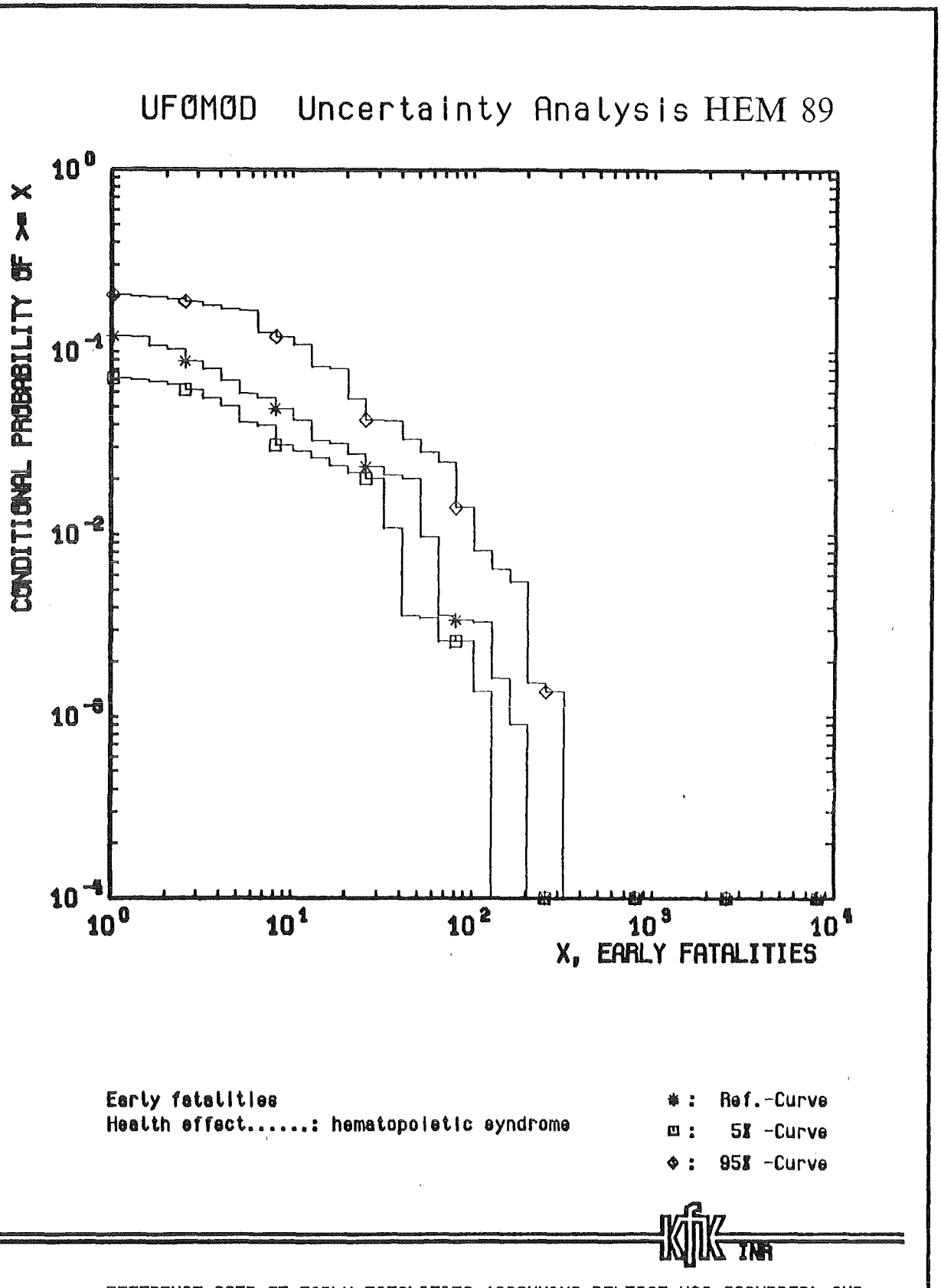


Early fatalities
Health effect.....: pulmonary syndrome

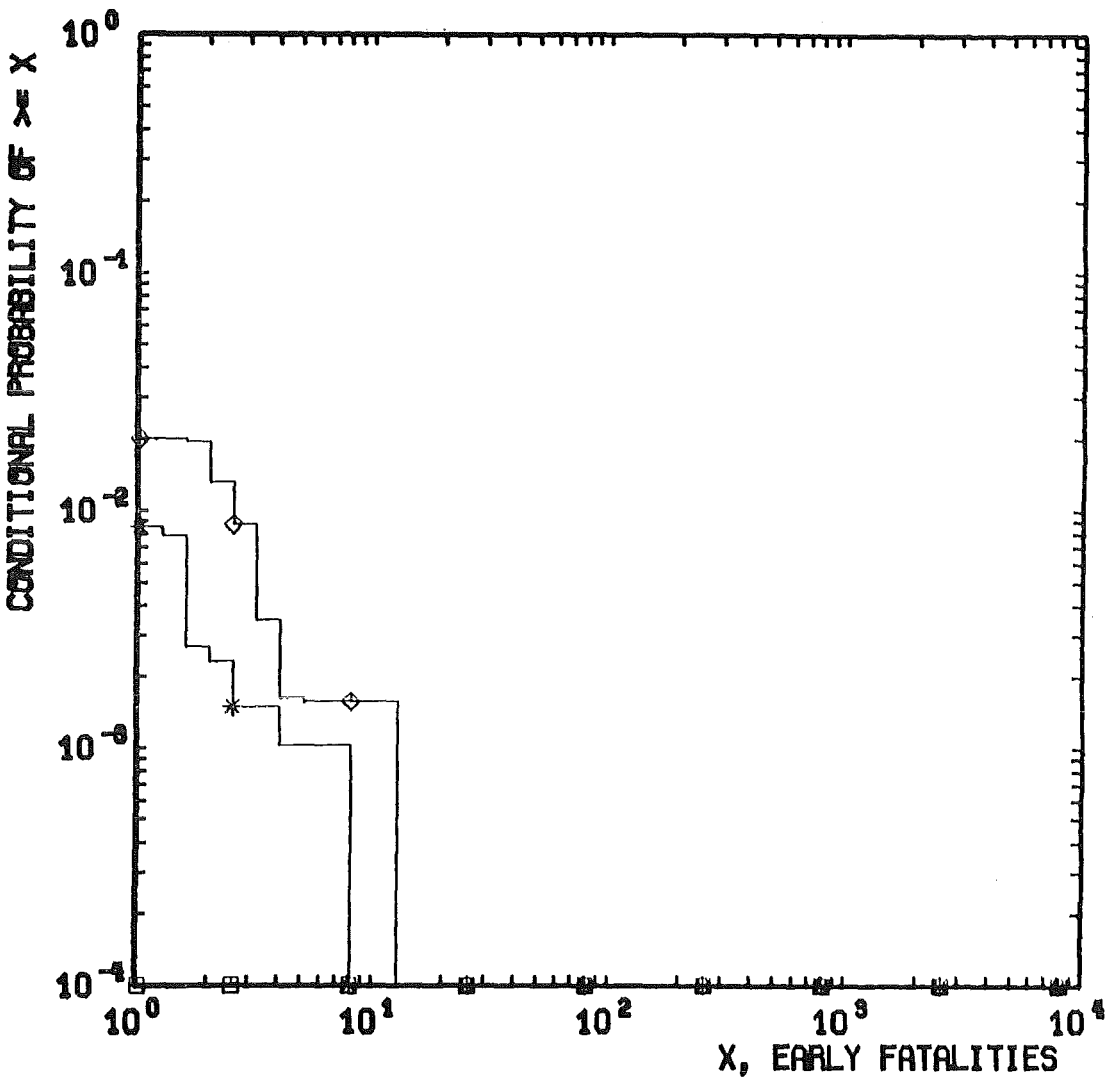
✱ : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF EARLY FATALITIES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



REFERENCE CCFD OF EARLY FATALITIES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

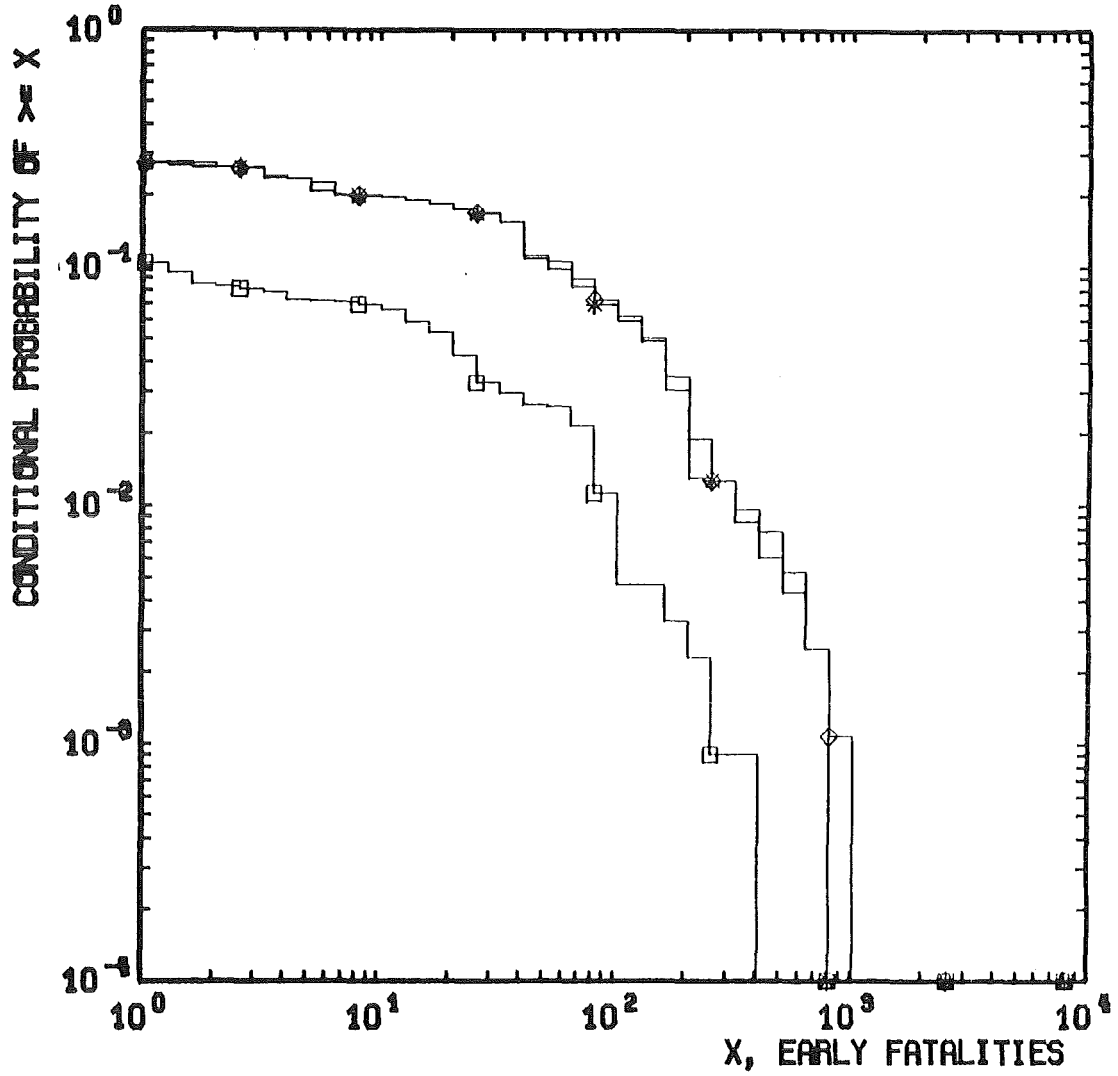


Early fatalities
Health effect.....: gastrointestinal syndrome

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF EARLY FATALITIES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Early fatalities
Health effect.....: mortality (all effects)

✱ : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF EARLY FATALITIES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

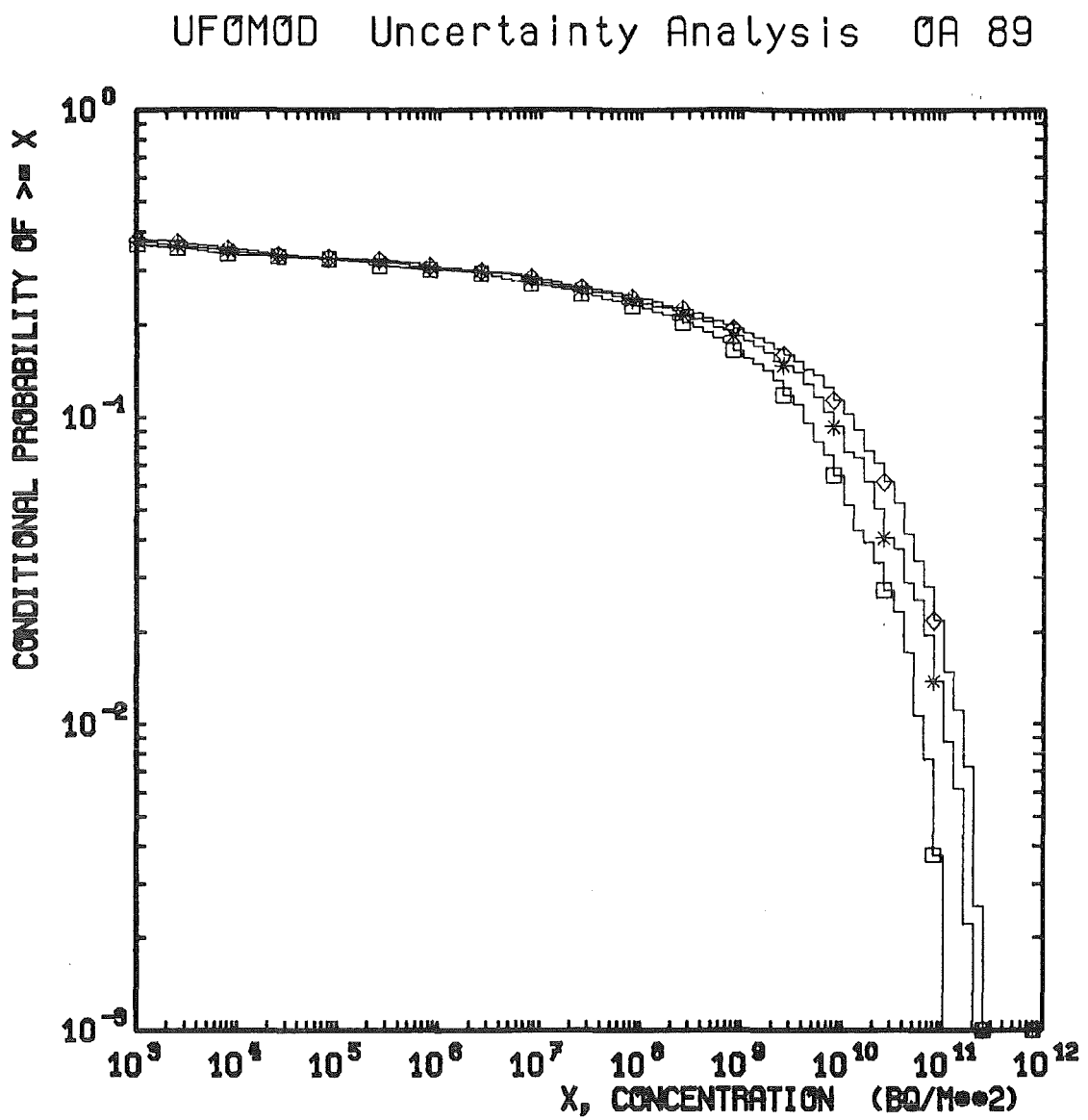
B.3 OVERALL ANALYSIS

B.3.1 Activity Concentrations

In this section confidence curves are shown
for activity concentrations (I-131, Cs-137) at three distance intervals
on ground surface and in the air near ground.
Number of runs = 100.

Sequence of figures:

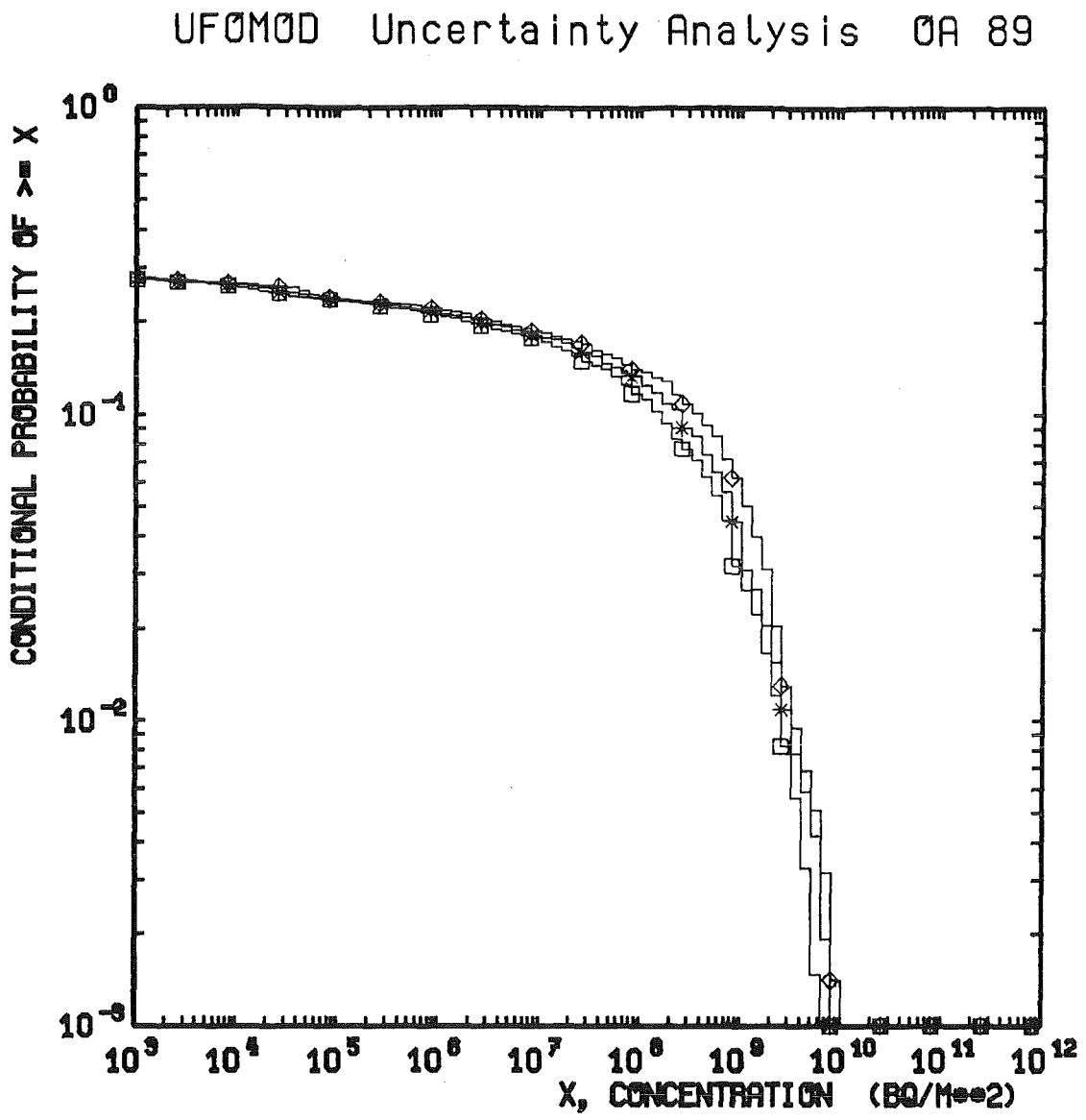
- Iodine
  - on ground surface
  - in the air near ground
- Aerosols
  - on ground surface
  - in the air near ground



Concentration on ground surface
Nuclide .....: I - 131
Distance .....: 0.875 km

* : Ref.-Curve
□ : 5% -Curve
◆ : 95% -Curve

REFERENCE CCFD OF THE CONCENTRATIONS (ASSUMING REALEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

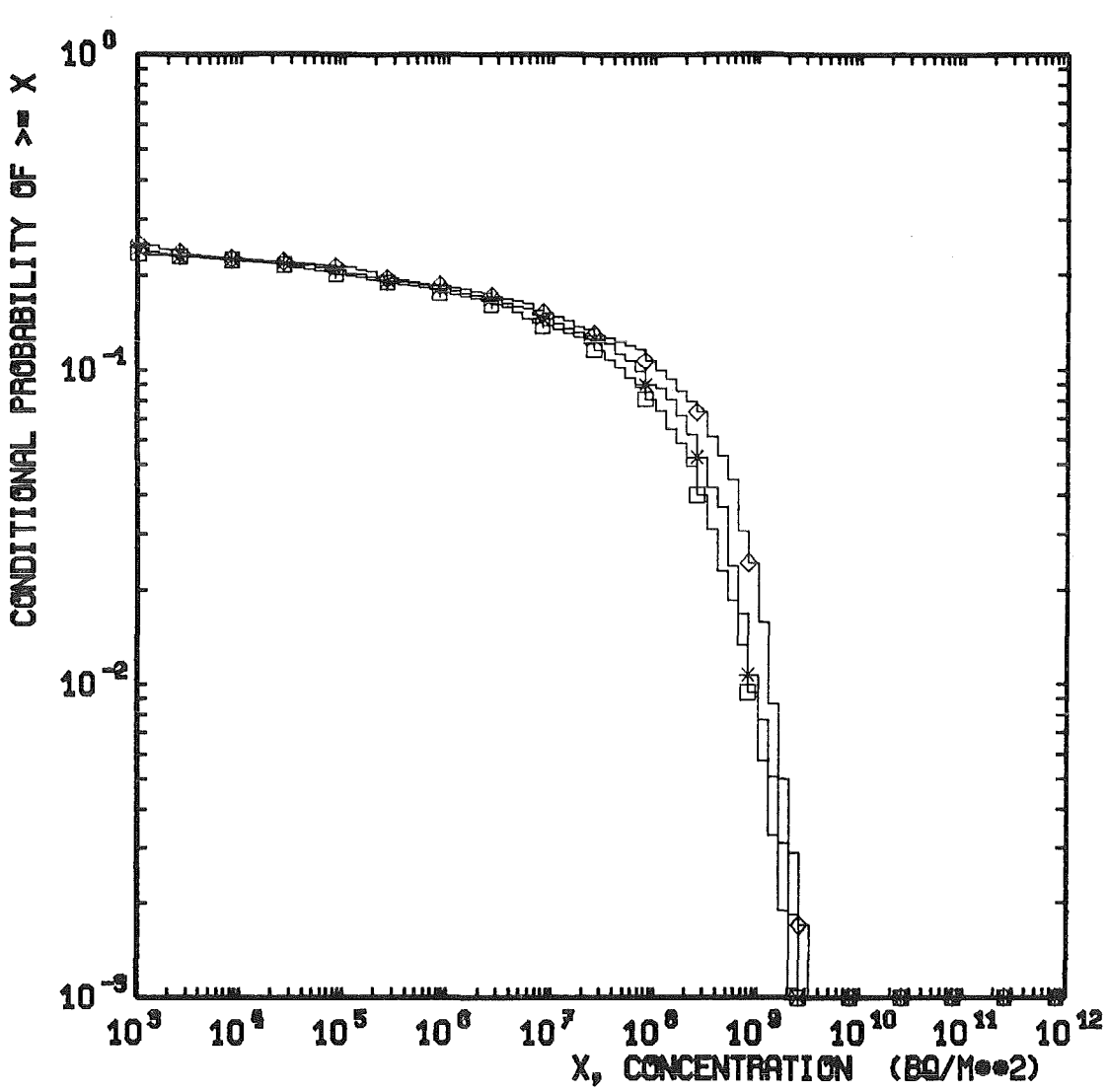


Concentration on ground surface
Nuclide .....: I - 131
Distance .....: 4.9 km

* : Ref.-Curve
□ : 5% -Curve
◆ : 95% -Curve

KfK INR

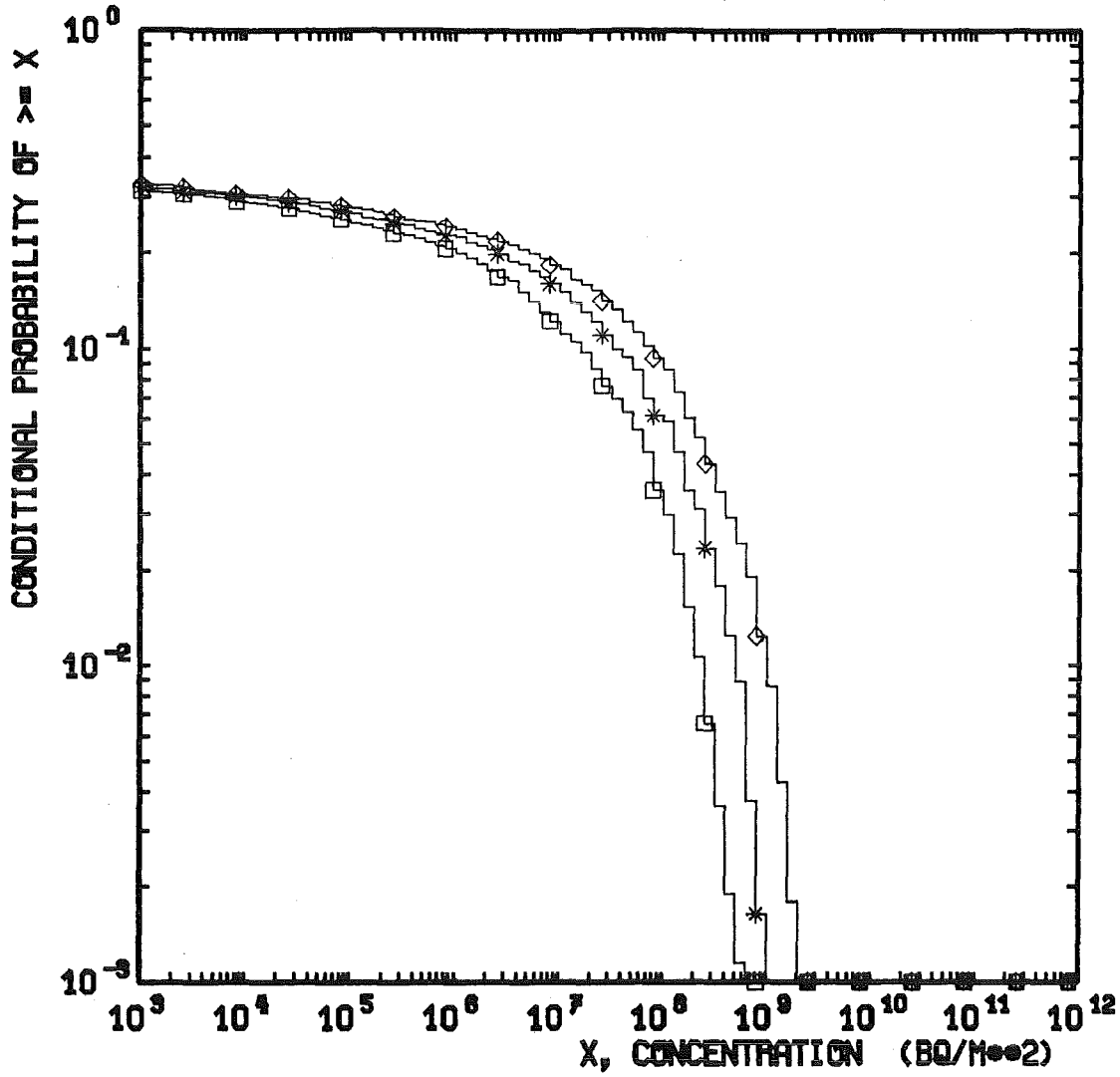
REFERENCE CCFD OF THE CONCENTRATIONS (ASSUMING REALEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Concentration on ground surface
Nuclide .....: I - 131
Distance .....: 8.75 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

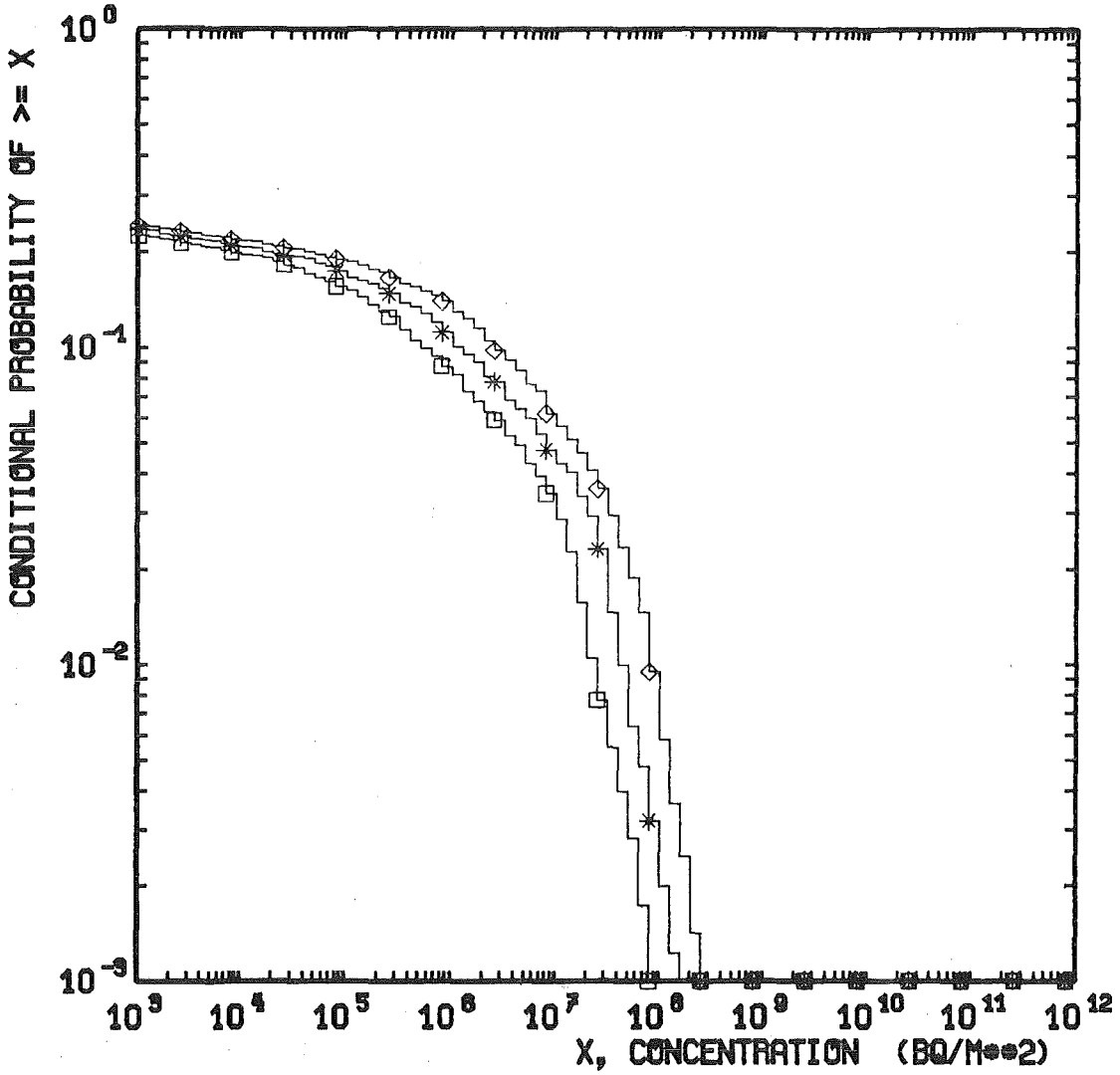
REFERENCE CCFD OF THE CONCENTRATIONS (ASSUMING REALEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Concentration on ground surface
Nuclide .....: Cs - 137
Distance .....: 0.875 km

* : Ref.-Curve
⊡ : 5% -Curve
◈ : 95% -Curve

REFERENCE CCFD OF THE CONCENTRATIONS (ASSUMING REALEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

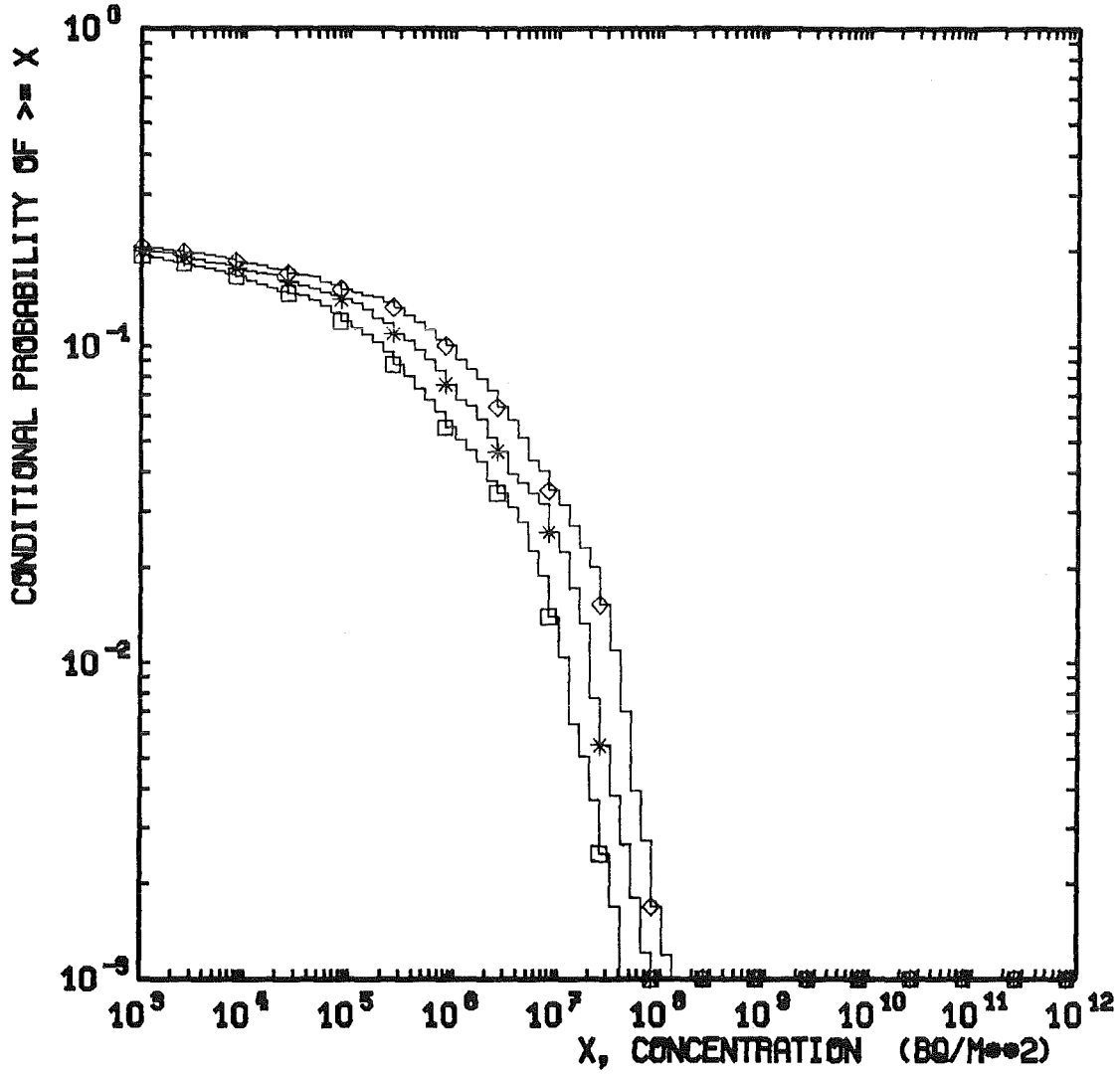


Concentration on ground surface
Nuclide .....: Cs - 137
Distance .....: 4.9 km

* : Ref.-Curve
□ : 5% -Curve
◆ : 95% -Curve

KfK INR

REFERENCE CCFD ØF THE CONCENTRATIONS (ASSUMING REALEASE HAS ØCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BØUNDS AT DISCRETE PØINTS ØF THE X - AXIS.

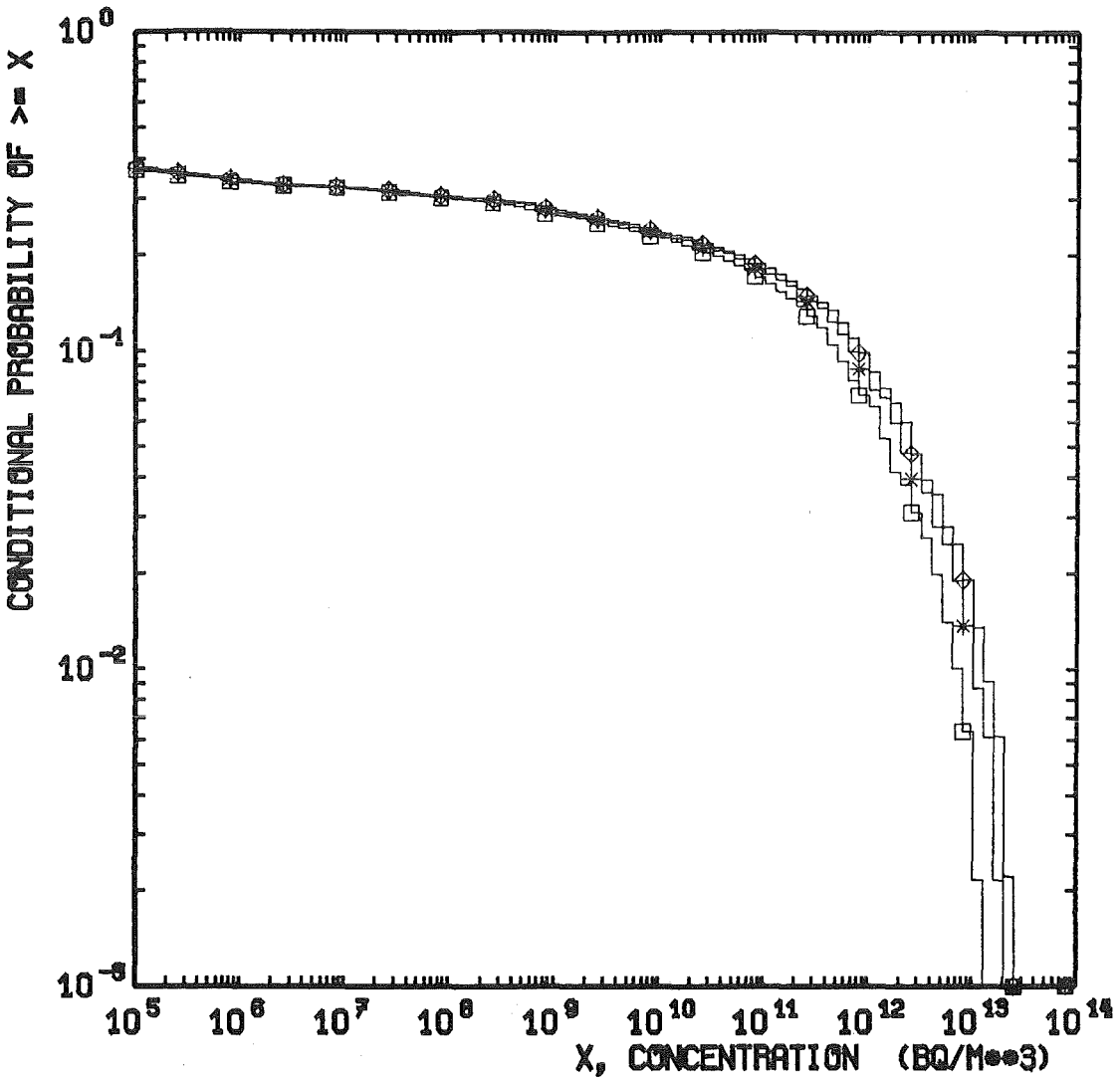


Concentration on ground surface
Nuclide .....: Cs - 137
Distance .....: 8.75 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF THE CONCENTRATIONS (ASSUMING REALEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

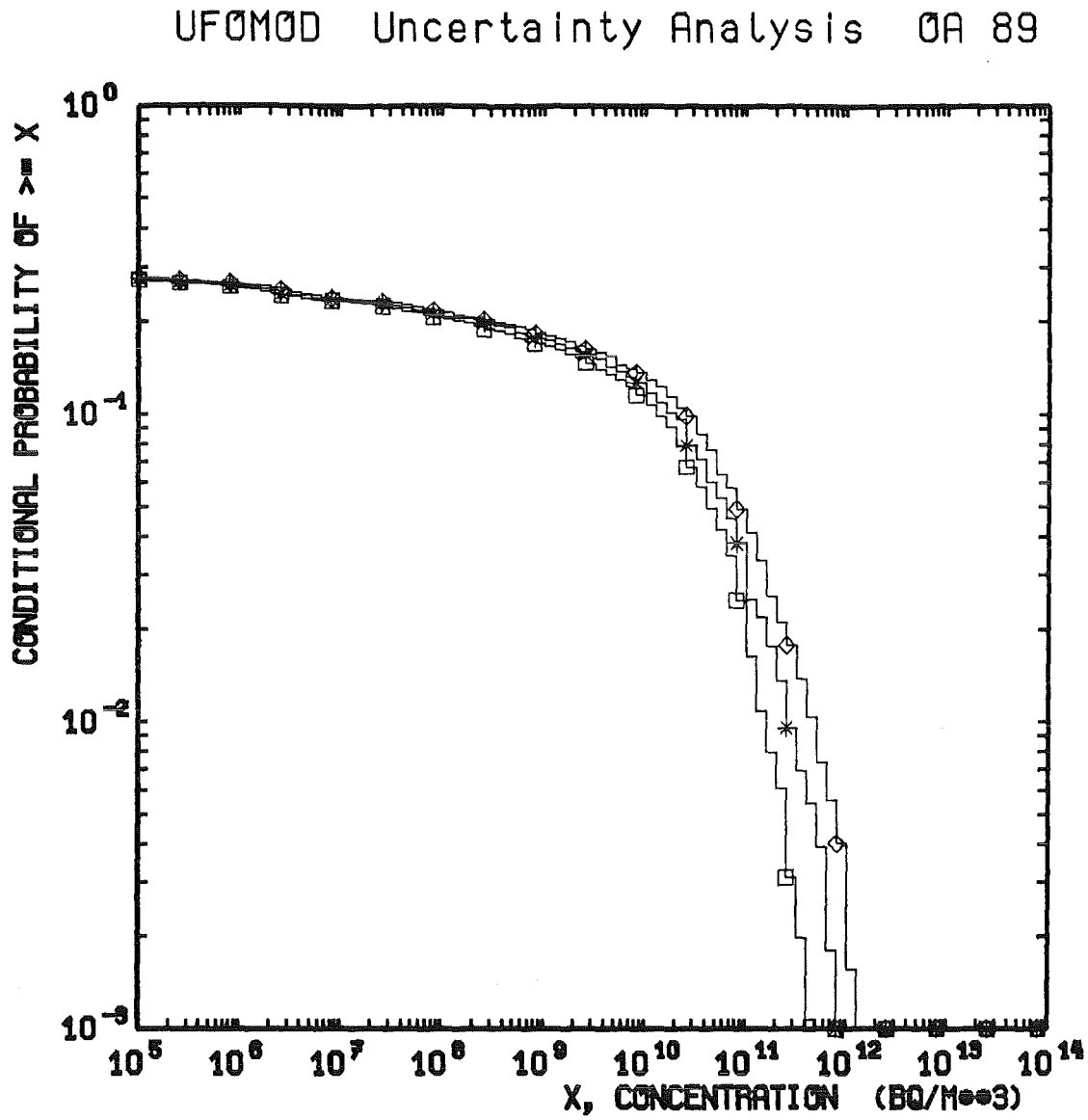


Concentration in the air near ground (1 m height)
Nuclide .....: I - 131
Distance .....: 0.875 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

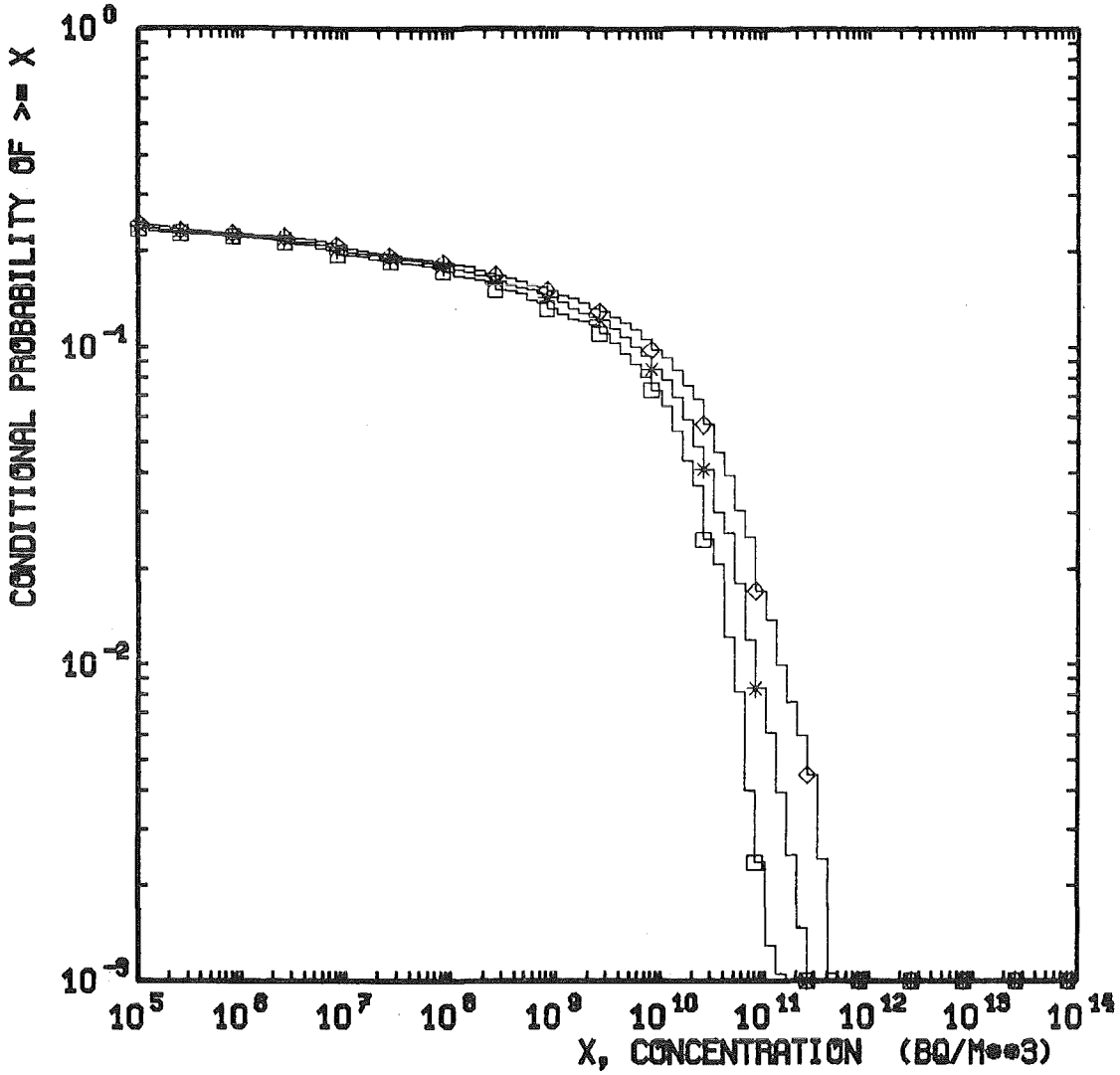
REFERENCE CCFD OF THE CONCENTRATIONS (ASSUMING REALEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Concentration in the air near ground (1 m height)
Nuclide .....: I - 131
Distance .....: 4.9 km

* : Ref.-Curve
▫ : 5% -Curve
◆ : 95% -Curve

REFERENCE CCFD OF THE CONCENTRATIONS (ASSUMING REALEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

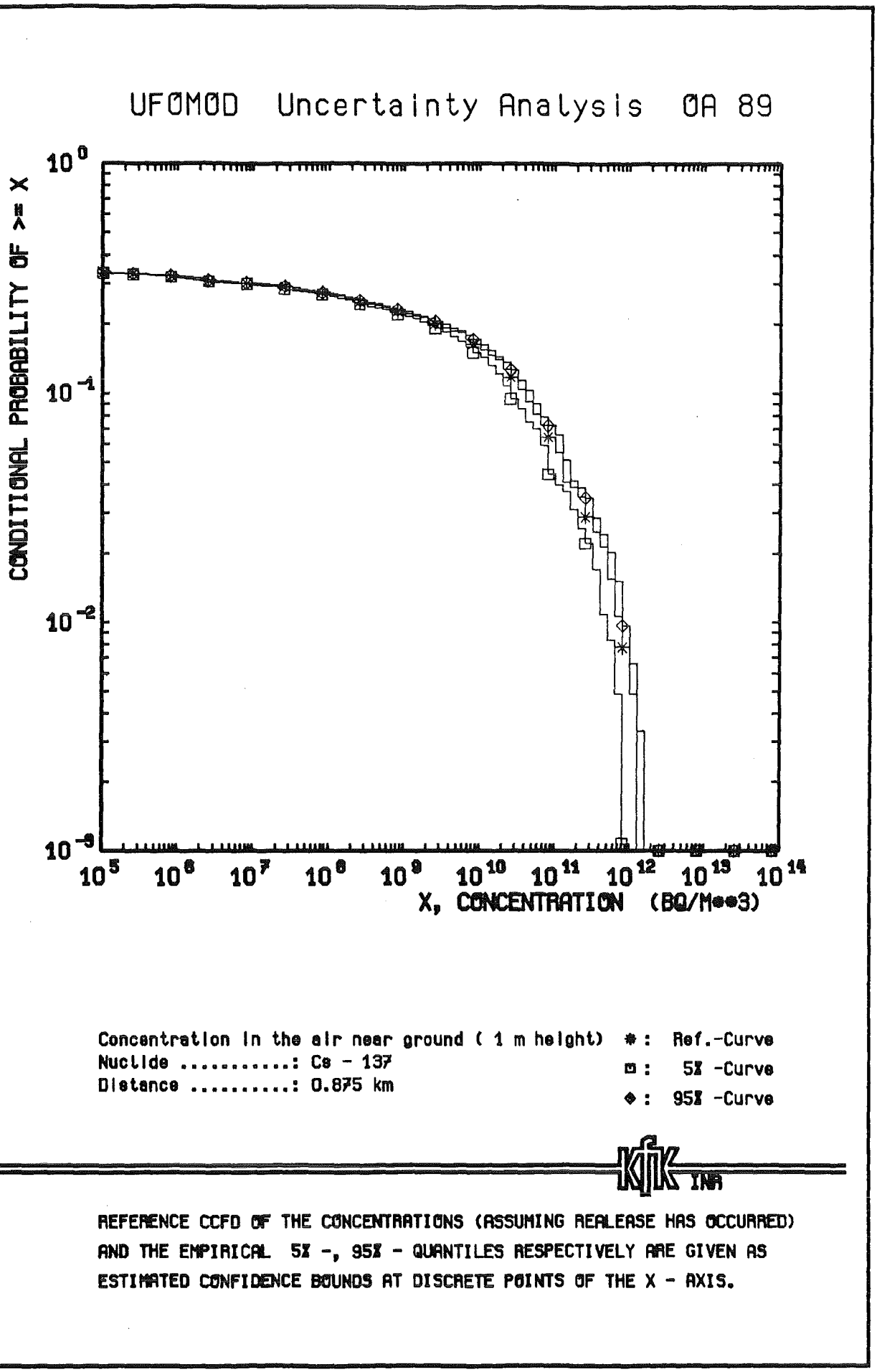


Concentration in the air near ground (1 m height)
Nuclide .....: I - 131
Distance .....: 8.75 km

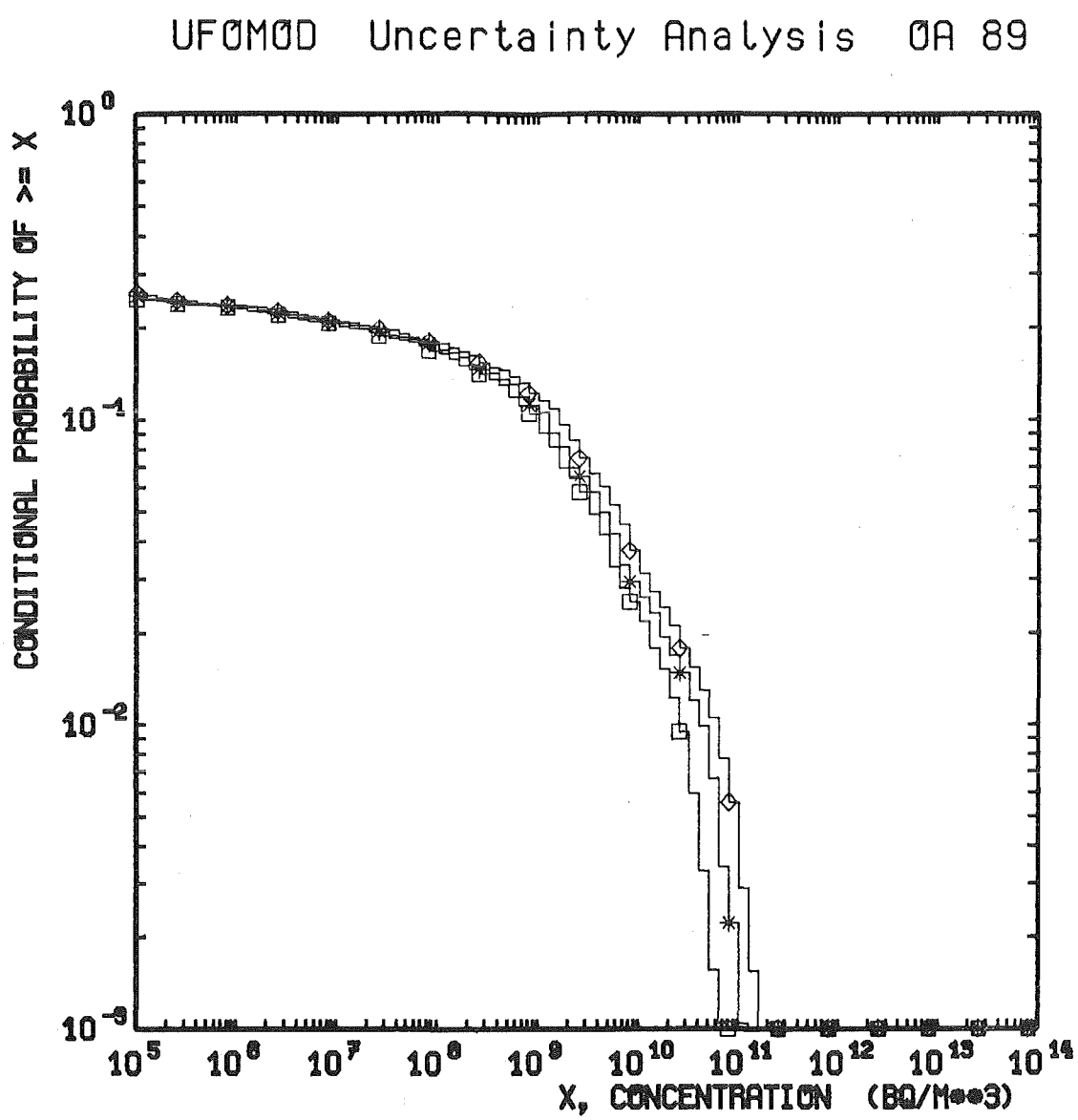
* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF THE CONCENTRATIONS (ASSUMING REALEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



REFERENCE CCFD OF THE CONCENTRATIONS (ASSUMING REALEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

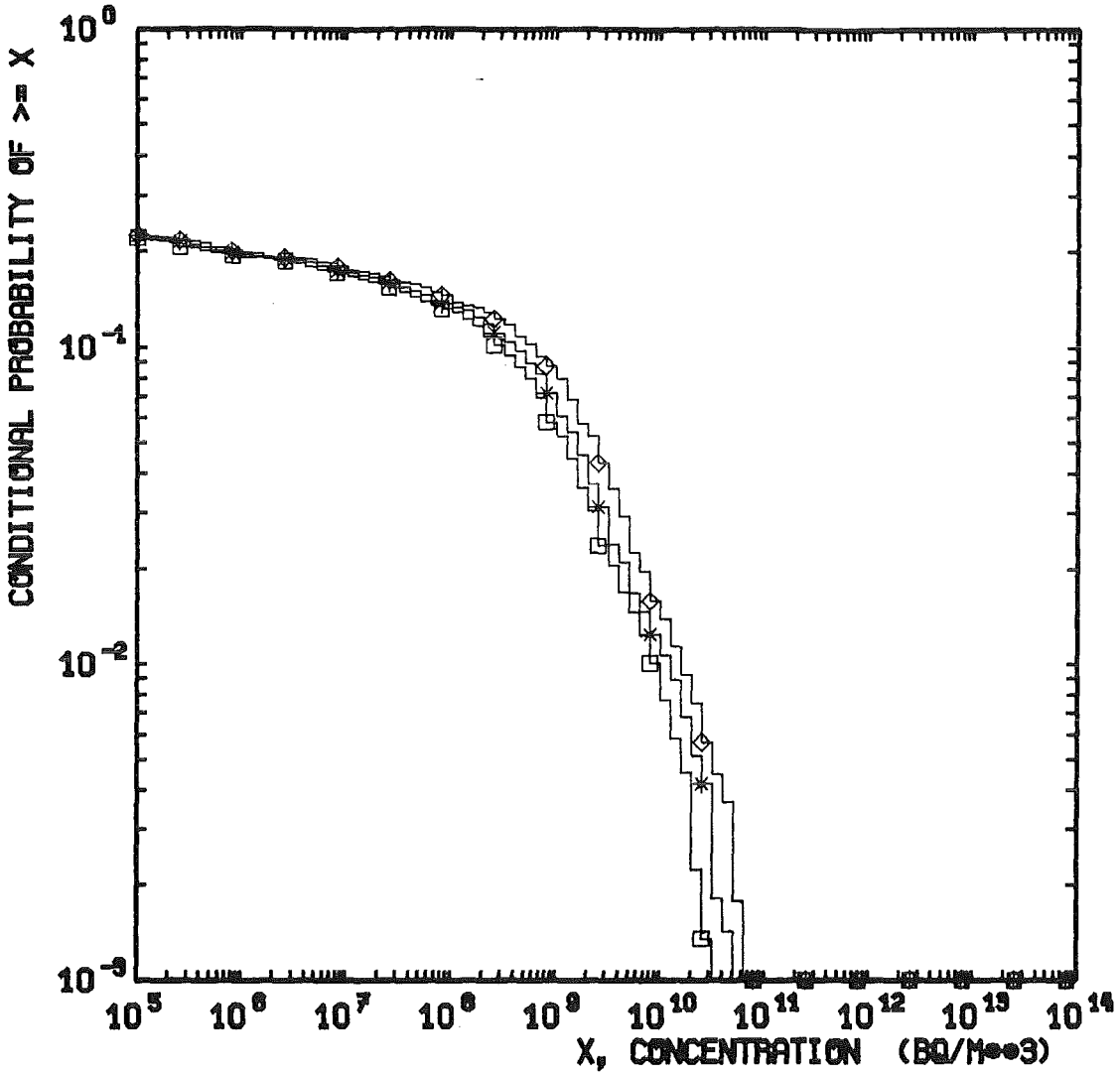


Concentration in the air near ground (1 m height)
Nuclide .....: Cs - 137
Distance .....: 4.9 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF THE CONCENTRATIONS (ASSUMING REALEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Concentration in the air near ground (1 m height)
Nuclide .....: Cs - 137
Distance .....: 8.75 km

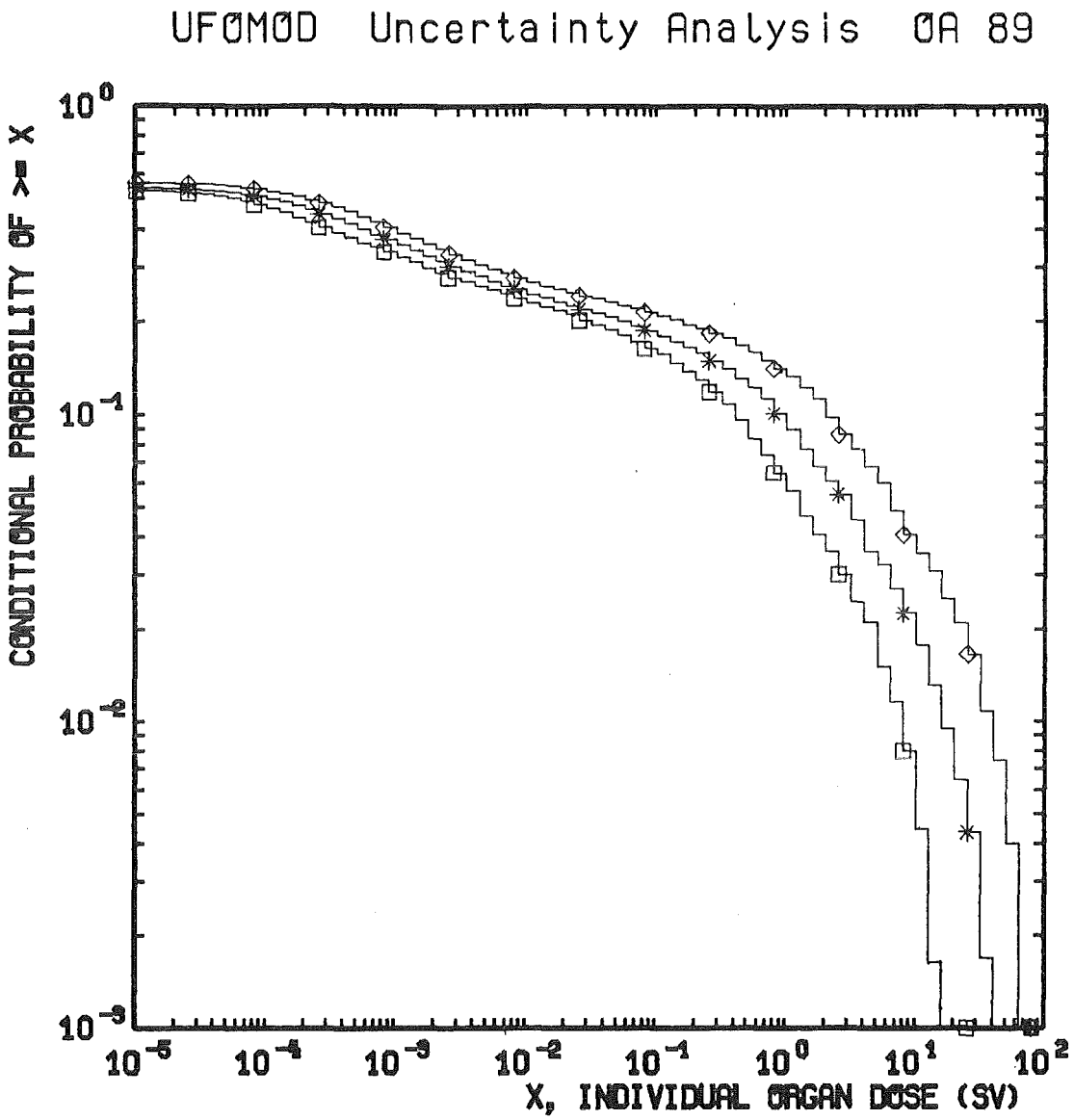
* : Ref.-Curve
□ : 5% -Curve
◆ : 95% -Curve

KfK INR

REFERENCE CCFD OF THE CONCENTRATIONS (ASSUMING REALEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

B.3.2 Doses

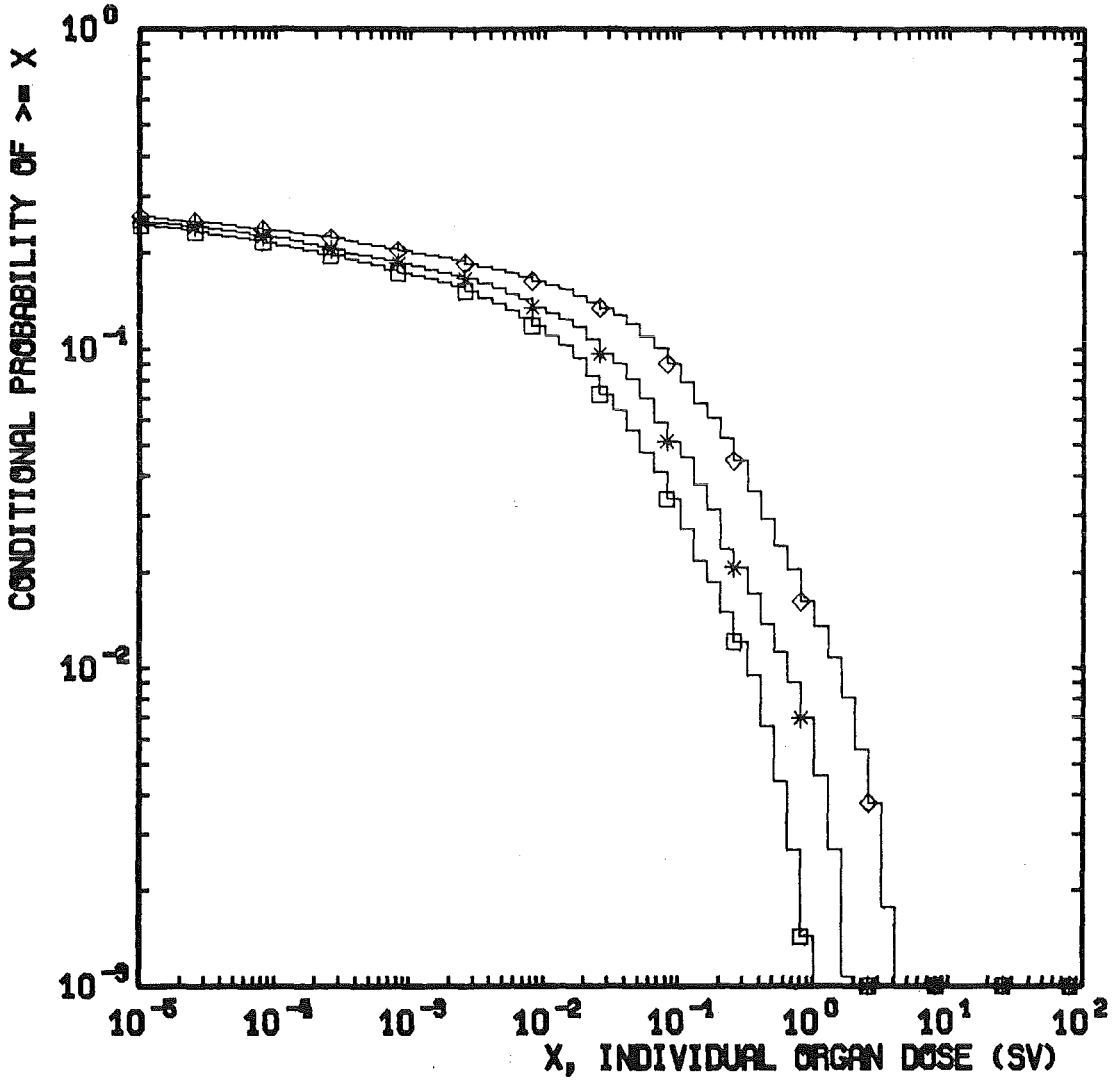
In this section confidence curves are shown
for acute individual doses (lung, bone marrow) at three distances.
Number of runs = 100.



Individual acute dose
Organ.....: lung
Distance .....: 0.875 km

* : Ref.-Curve
□ : 5% -Curve
◆ : 95% -Curve

REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS

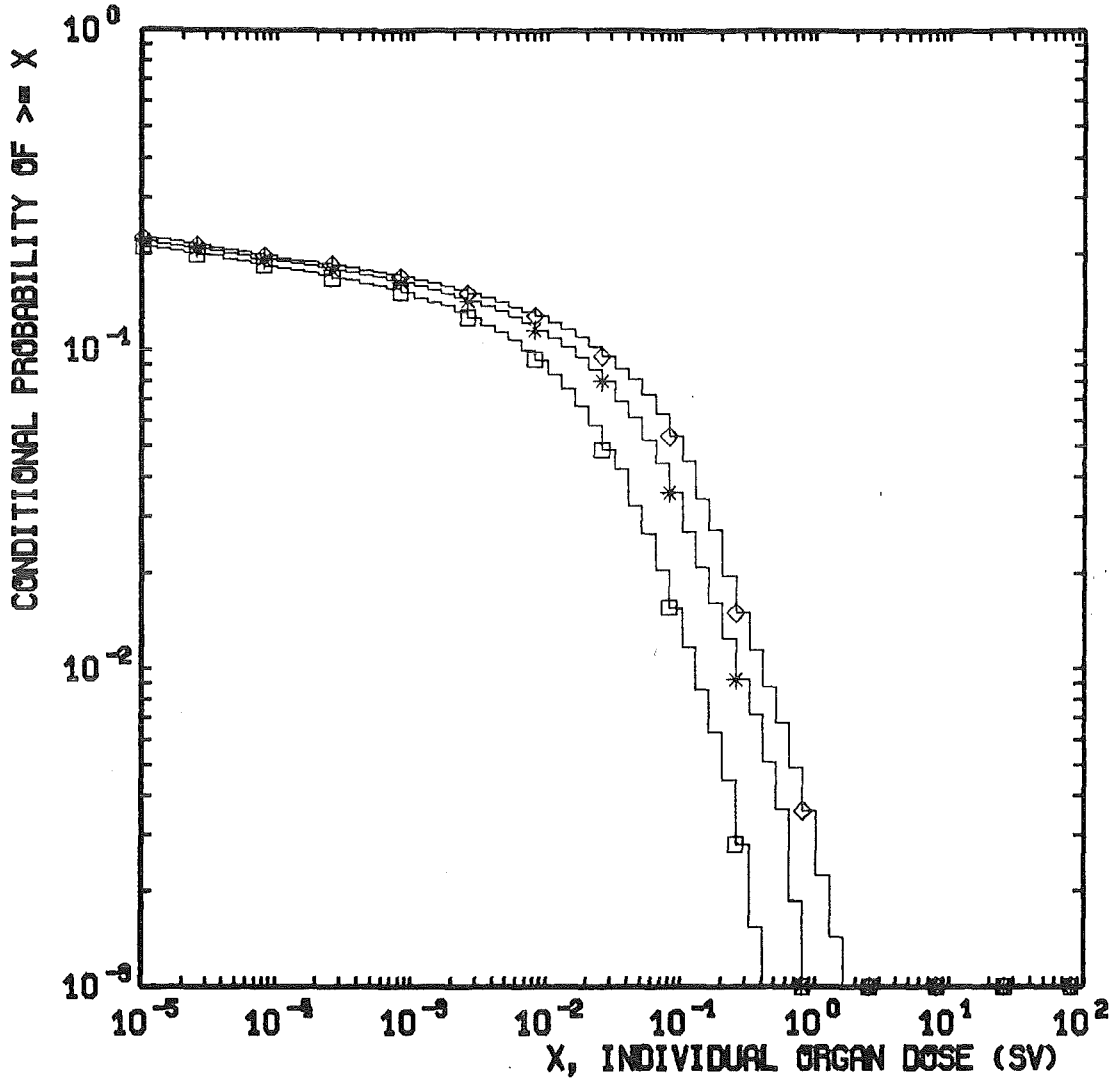


Individual acute dose
Organ.....: lung
Distance .....: 4.9 km

* : Ref.-Curve
□ : 5% -Curve
◆ : 95% -Curve

KfK INR

REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS

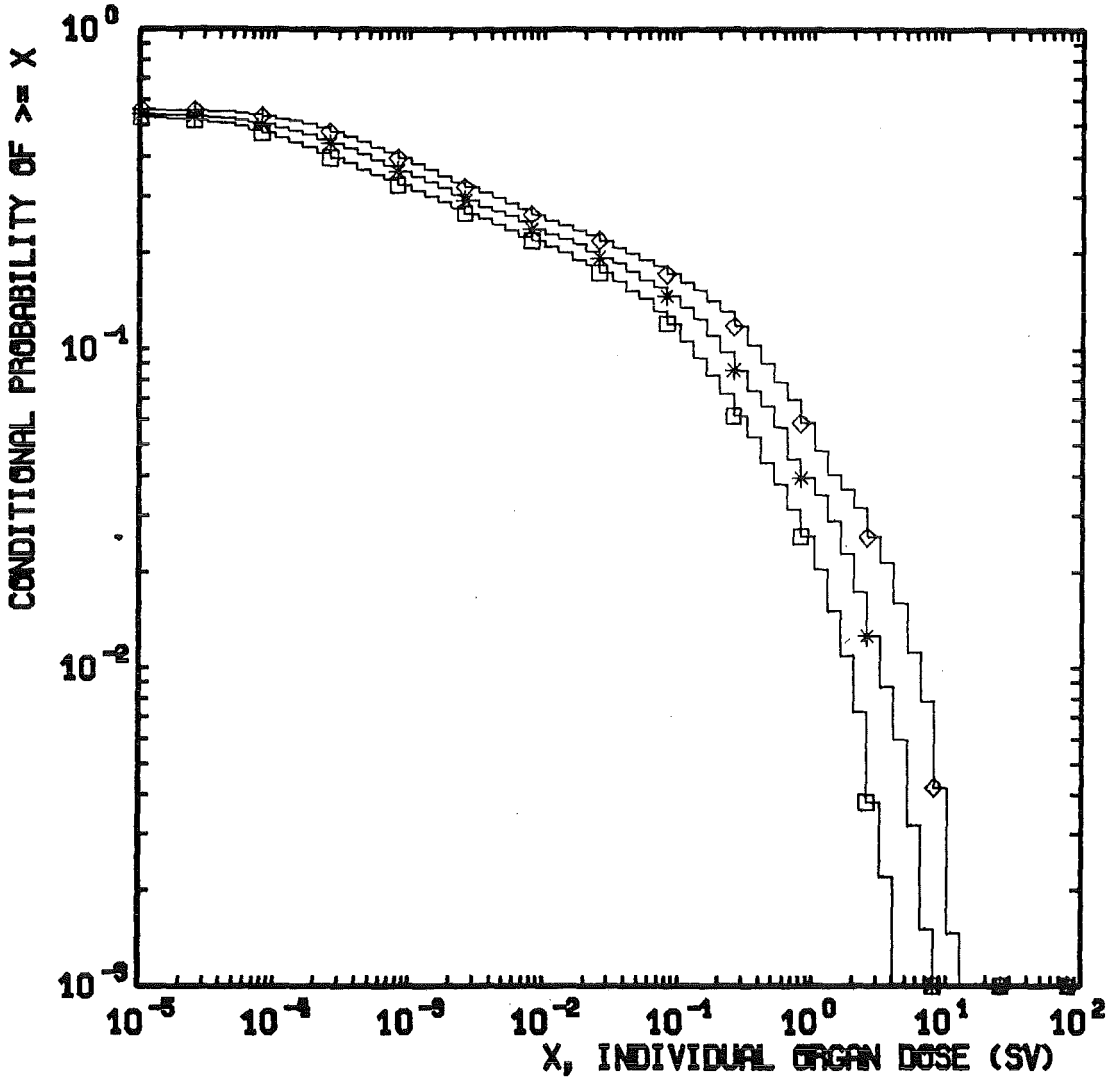


Individual acute dose
Organ.....: lung
Distance .....: 8.75 km

* : Ref.-Curve
▫ : 5% -Curve
◆ : 95% -Curve

KfK INR

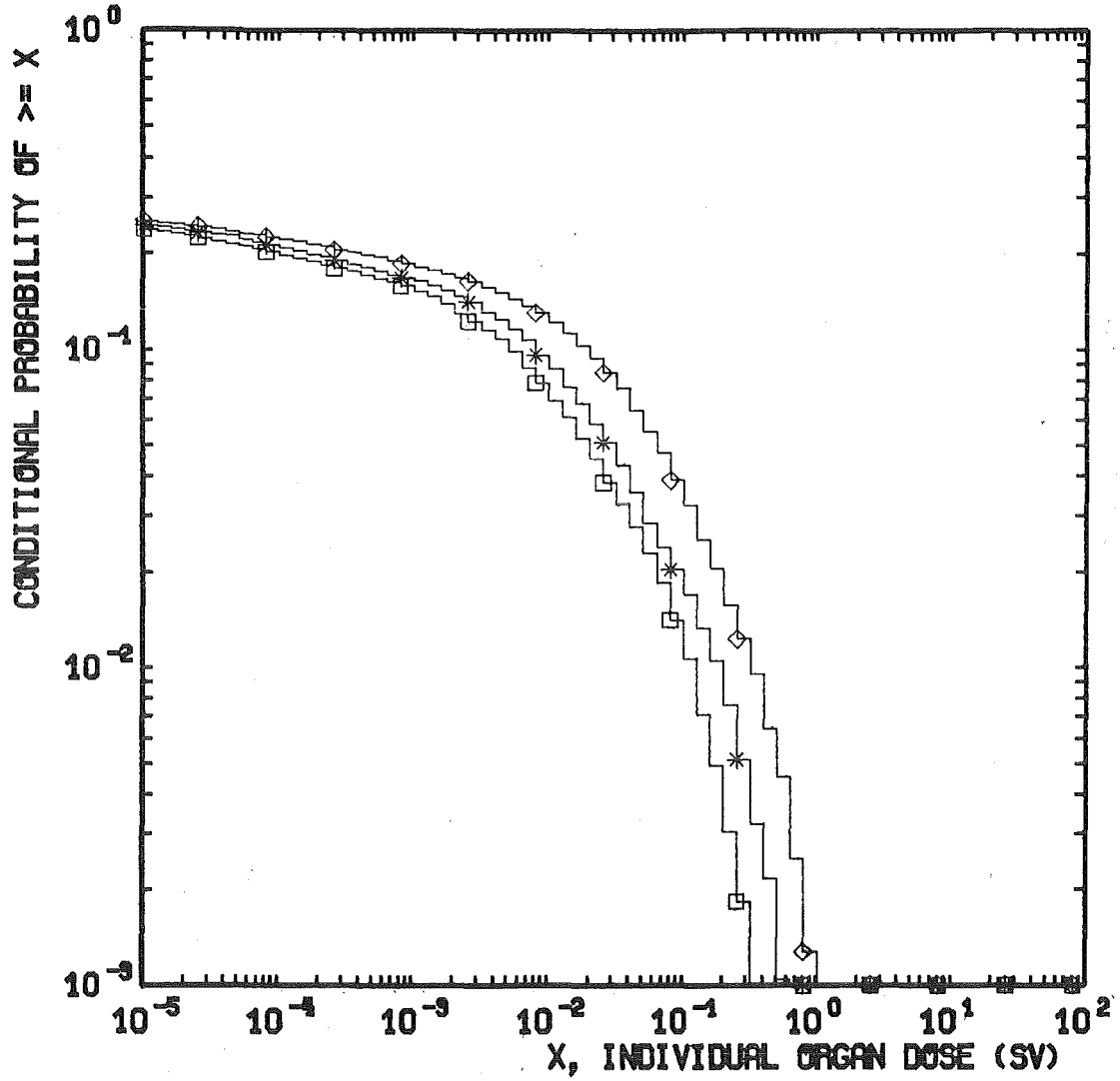
REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS



Individual acute dose
Organ.....: bone marrow
Distance .....: 0.875 km

* : Ref.-Curve
▫ : 5% -Curve
◆ : 95% -Curve

REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS

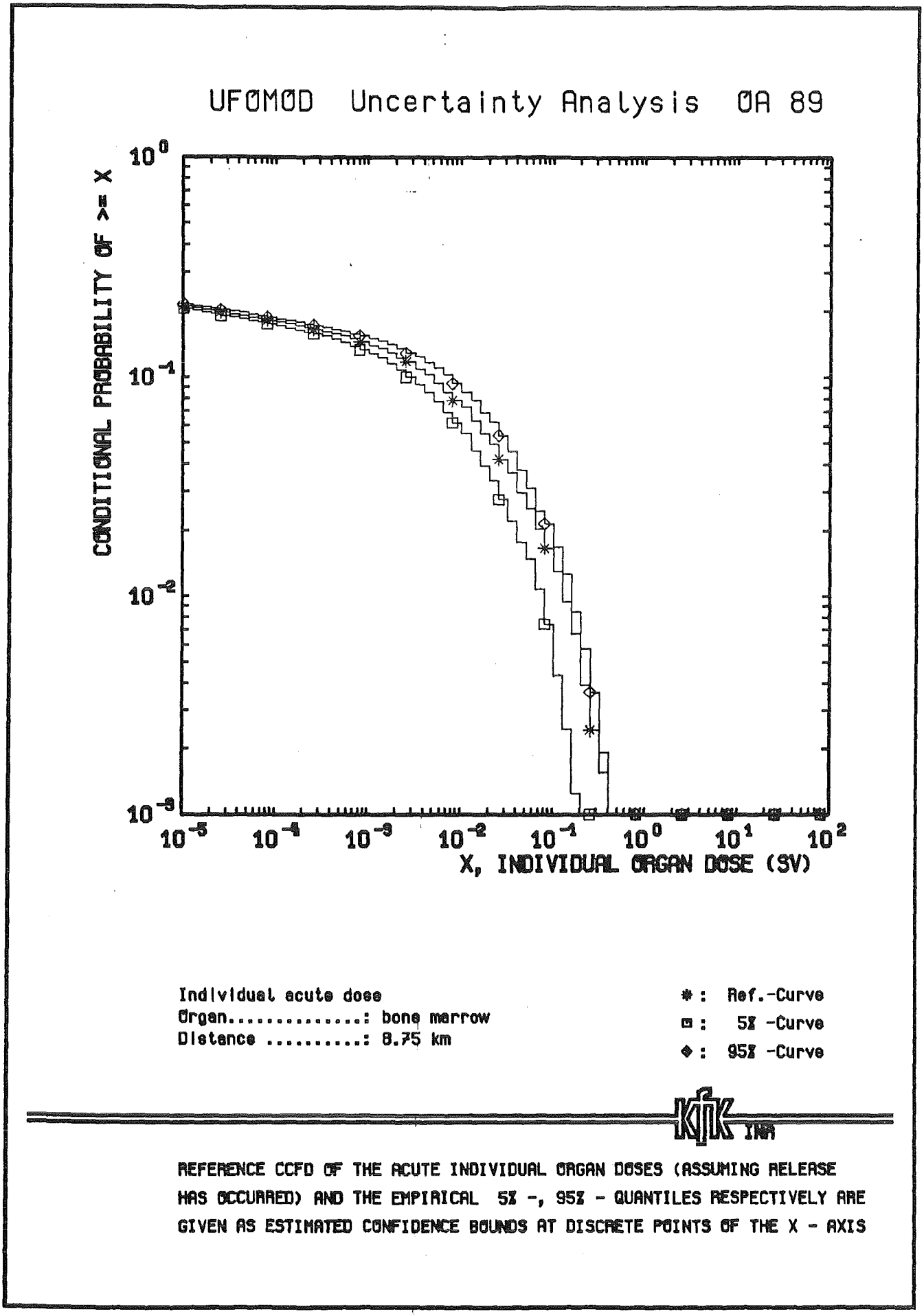


Individual acute dose
Organ.....: bone marrow
Distance .....: 4.9 km

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

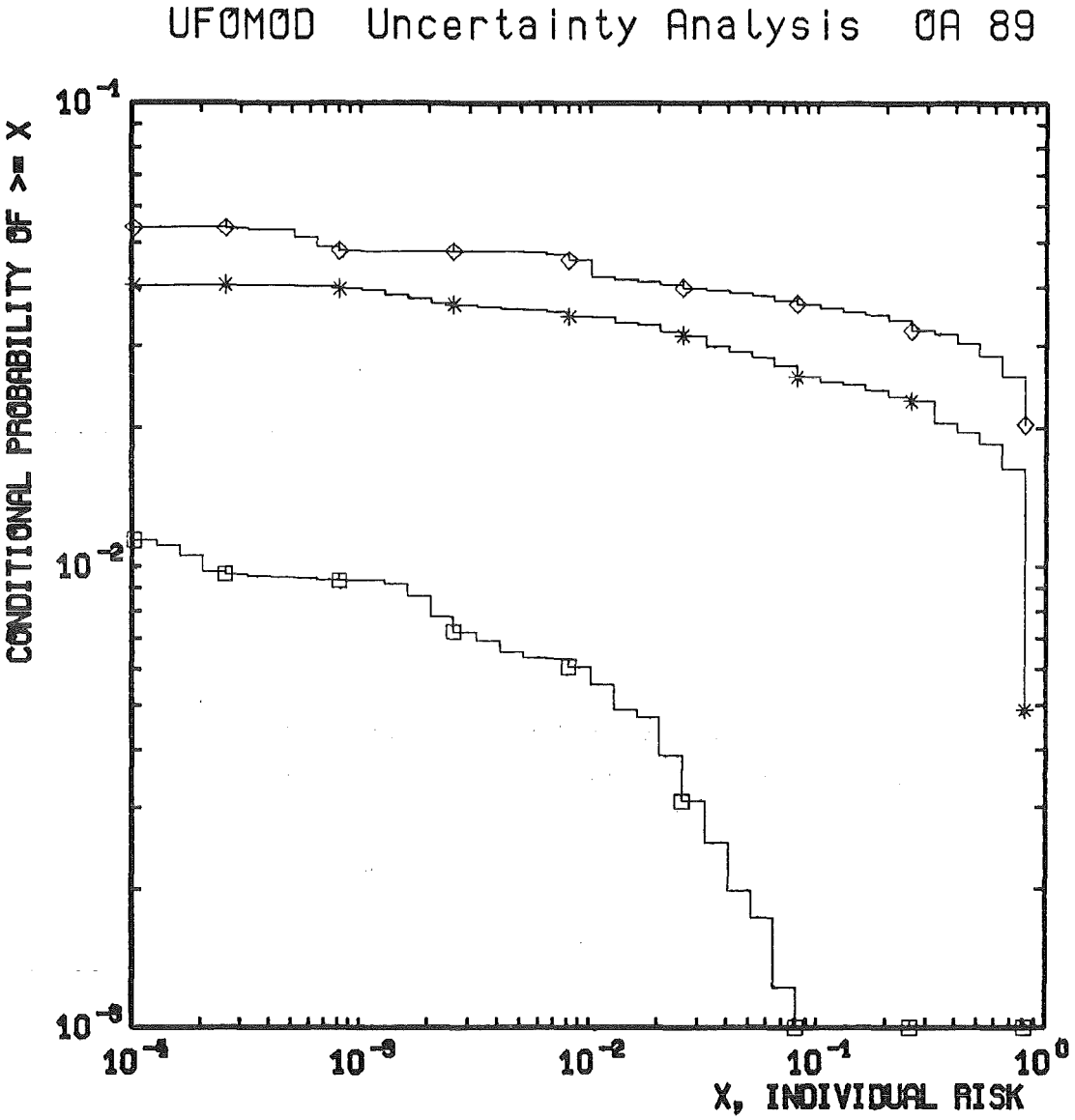
REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS



REFERENCE CCFD OF THE ACUTE INDIVIDUAL ORGAN DOSES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS

B.3.3 Risks

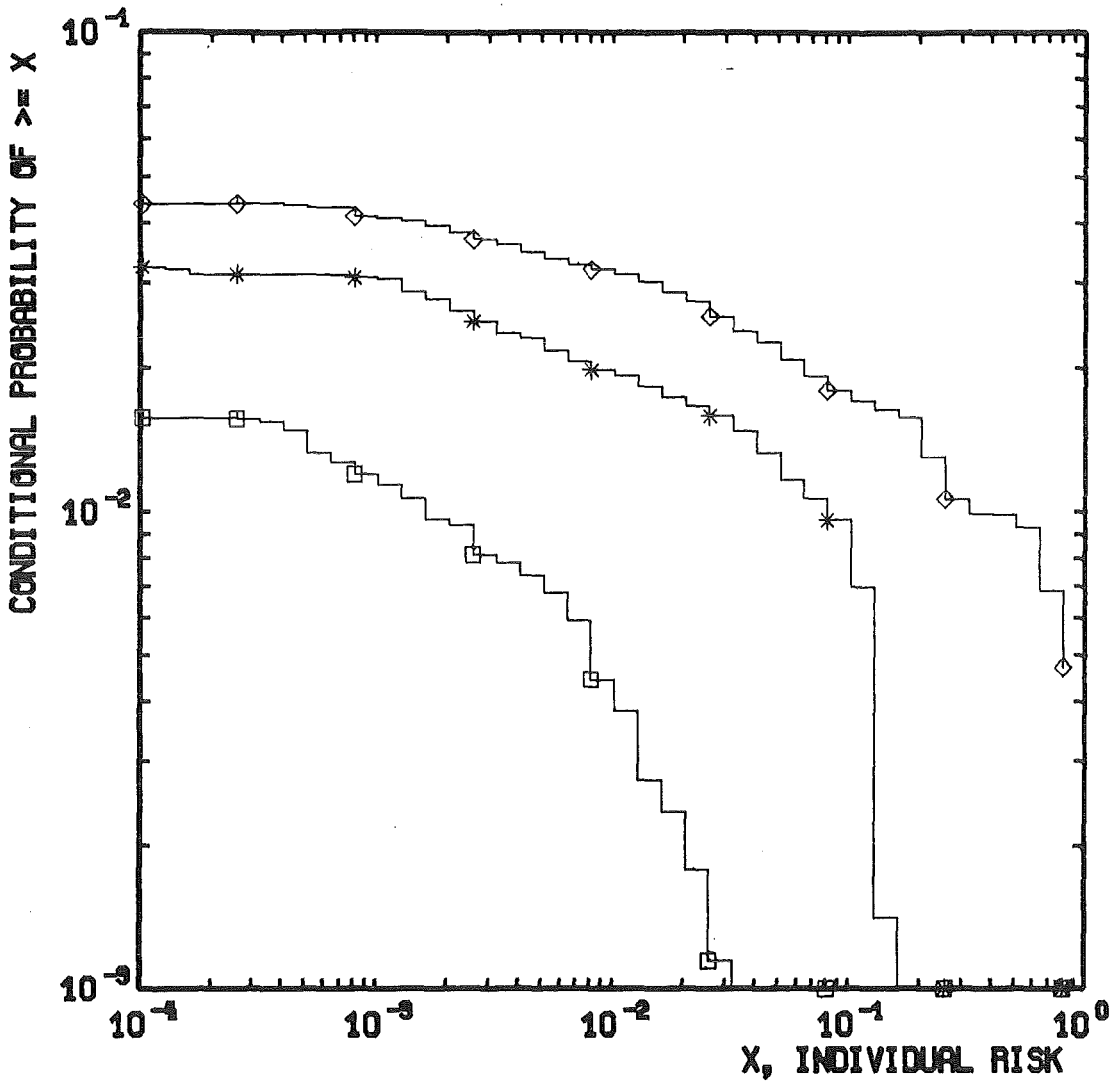
In this section confidence curves are shown
for acute indidual risks (pumonary, hematopietic syndrome).
Number of runs = 100.



Individual risk
Health effect.....: pulmonary syndrome
Distance .....: 0.875 km

*: Ref.-Curve
□: 5% -Curve
◆: 95% -Curve

REFERENCE CCFD OF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



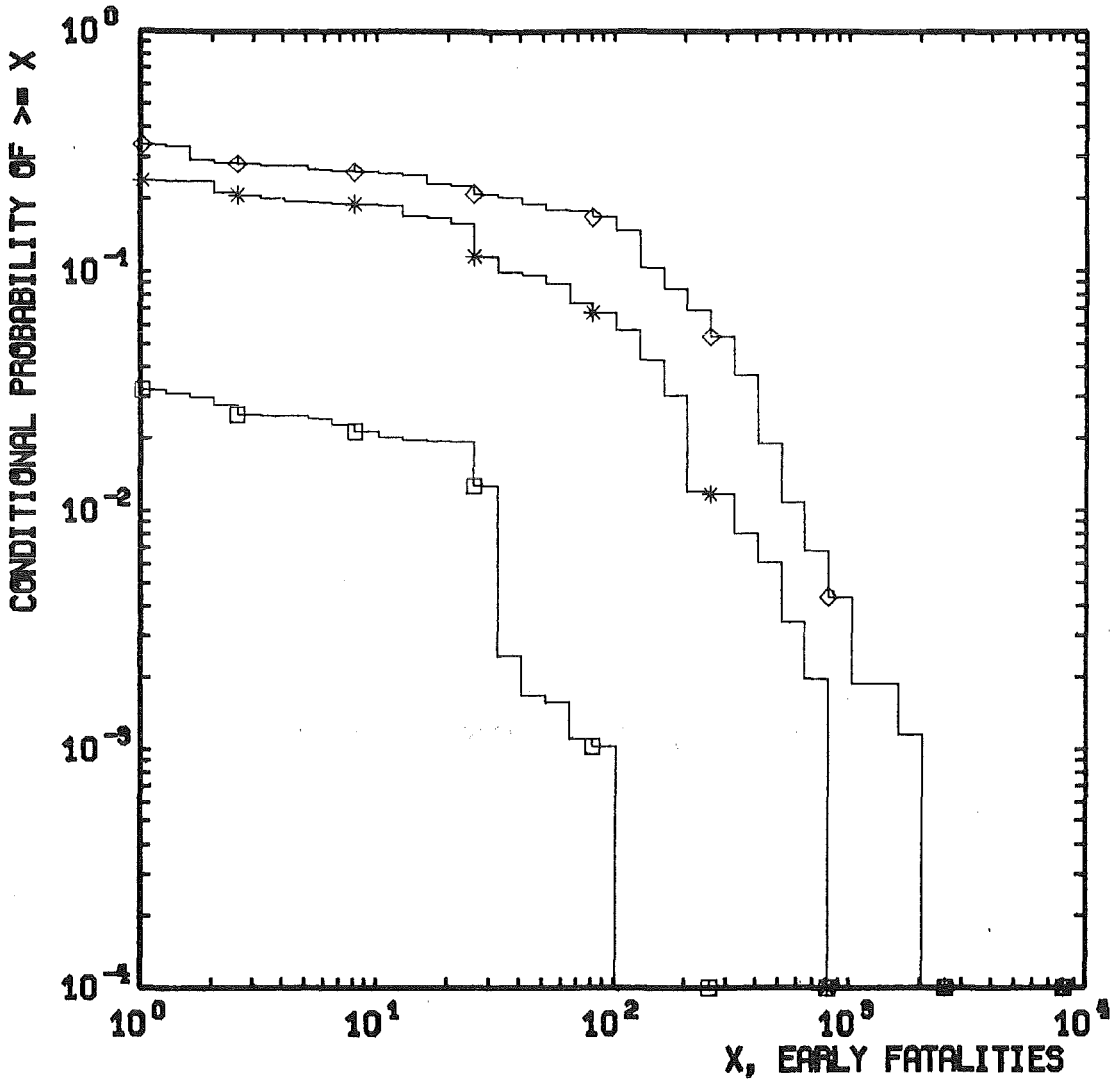
Individual riek
Health effect.....: hematopoietic syndrome
Distance .....: 0.875 km

* : Ref.-Curve
□ : 5% -Curve
◆ : 95% -Curve

REFERENCE CCFD ØF THE INDIVIDUAL RISKS (ASSUMING RELEASE HAS ØCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE PØINTS ØF THE X - AXIS.

B.3.4 Health Effects

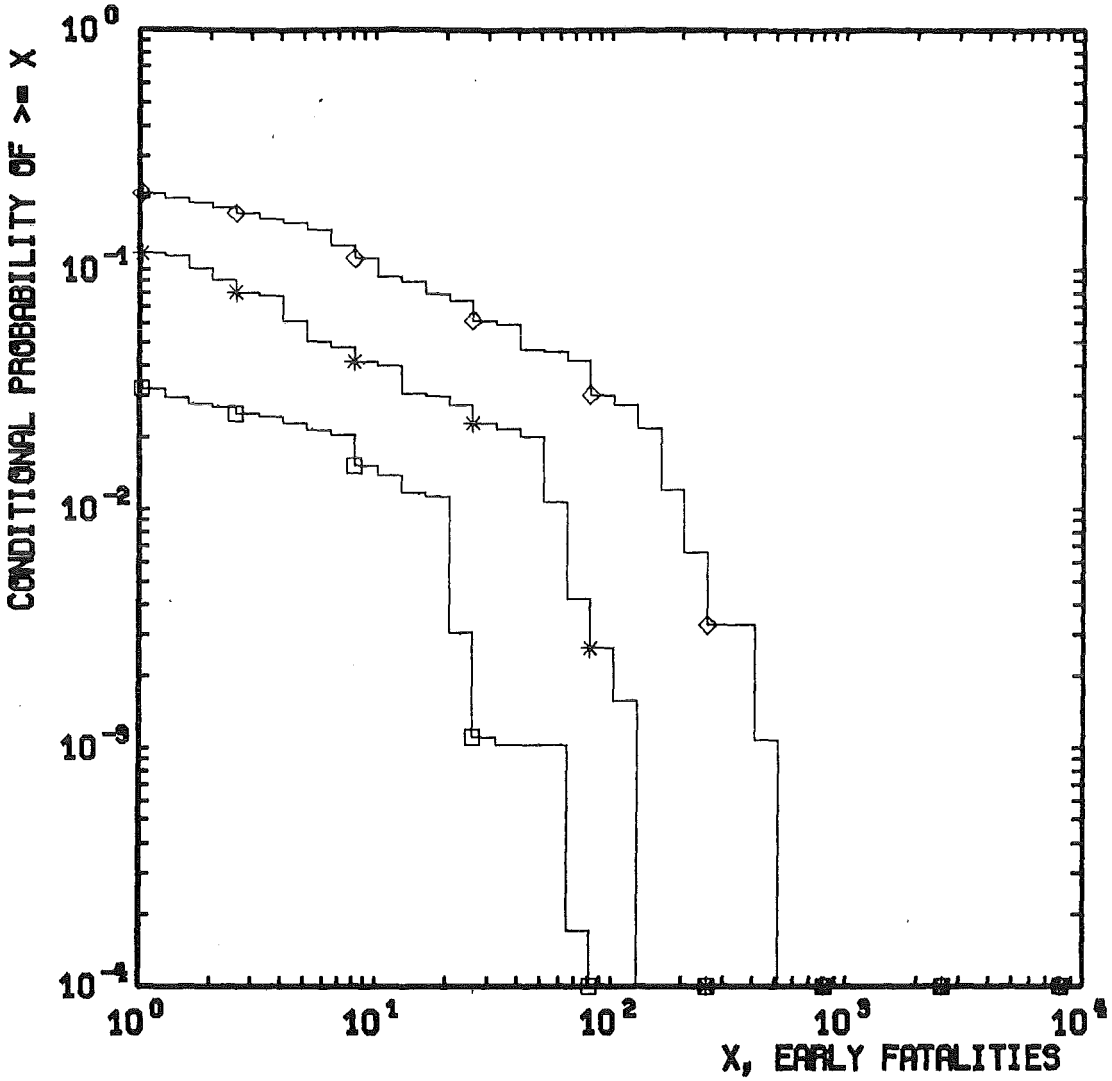
In this section confidence curves are shown
for early health effects (pulmonary, hematopoietic syndrome).
Number of runs = 100.



Early fatalities
Health effect.....: pulmonary syndrome

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

REFERENCE CCFD OF EARLY FATALITIES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.



Early fatalities
Health effect.....: hematopoietic syndrome

* : Ref.-Curve
□ : 5% -Curve
◇ : 95% -Curve

KfK INR

REFERENCE CCFD OF EARLY FATALITIES (ASSUMING RELEASE HAS OCCURRED) AND THE EMPIRICAL 5% -, 95% - QUANTILES RESPECTIVELY ARE GIVEN AS ESTIMATED CONFIDENCE BOUNDS AT DISCRETE POINTS OF THE X - AXIS.

Appendix C. Sensitivity Analyses (Tables of PRCC values)

Legends for reading the PRCC - tables

(The legends for the model parameters and the corresponding consequence variables from the atmospheric dispersion submodule (ATM) sensitivity analysis are given in the legend for the OVERALL (OAL) analysis.)

Legends for reading the PRCC - tables (CTM - ANALYSIS)

The following list gives the name and the meaning of the parameters:

TINA (TINB)	initial delay of actions in area A (B) [h], where A is geometrically determined (keyhole - shaped) and area B is defined by an isodose line.
TDELA	delay time between end of release and end of sheltering period in area A [h]
PAUFA(i) (PAUFB(i))	fraction of population with different behaviour during the sheltering period in area A (B) • i=1: spontaneous evacuation in cars at the start of the sheltering period. • i=5: percentage of people who cannot be reached by the warning systems or stay outdoors intentionally. • i=2,3,4: percentage of peoples sheltered in cellars and in buildings with low and high shielding factors, respectively.
GRWRTB	intervention dose level (IL) for emergency actions in area B
IEVA2	index of last outer radius of the keyhole-shaped area A
WGRNZA	angle of keyhole sector of area A (in degrees)
WSHIFT	azimuthal shift of the keyhole sector of area A against the wind direction of the first release phase (WSHIFT>0: rotation clockwise)
TDRA	50 % - fractile of driving time to leave area A at 10 km radius (daytime) with respect to population density PD [P/km²], where $100 < PD \leq 500$ The values are derived from [36] and [37].

The following list gives the name and the meaning of the consequence variables:

DOSLUD1	individual acute dose (lung)	at	D1	(0.875 km)
DOSLUD2	individual acute dose (lung)	at	D2	(4.9 km)
DOSLUD3	individual acute dose (lung)	at	D3	(8.75 km)
DOSBMD1	individual acute dose (bone marrow)	at	D1	(0.875 km)
DOSBMD2	individual acute dose (bone marrow)	at	D2	(4.9 km)
DOSBMD3	individual acute dose (bone marrow)	at	D3	(8.75 km)
RSKLUD1	individual risk (pulmonary syndrome)	at	D1	(0.875 km)
RSKLUD2	individual risk (pulmonary syndrome)	at	D2	(4.9 km)
RSKLUD3	individual risk (pulmonary syndrome)	at	D3	(8.75 km)
RSKBMD1	individual risk (hematopoietic syndrome)	at	D1	(0.875 km)
RSKBMD2	individual risk (hematopoietic syndrome)	at	D2	(4.9 km)
RSKBMD3	individual risk (hematopoietic syndrome)	at	D3	(8.75 km)
POP(LU)	early fatalities (pulmonary syndrome)			
POP(BM)	early fatalities (hematopoietic syndrome)			

Legends for reading the PRCC - tables (DCF - ANALYSIS)

The following list gives the name and the meaning of the parameters:

DCFxx(t)		dose conversion factors for *xx, where xx* $\in$ *(Sr-89, Ru-106, Te-132, I-131,133,135, Cs-134,137, Ba-140)* integrated over the time interval t=1,2,3,4 (organ dependent) of the protracted exposure
ARATIH		breathing rate (inhalation)
AFHAUL(i)	(i=1,2,3)	shielding factor (houses with low shielding) 1. cloudshine 2. groundshine 3. inhalation
AFHAUF(i)	(i=1,2,3)	shielding factor (houses with high shielding) 1. cloudshine 2. groundshine 3. inhalation
AFKELL(i)	(i=1,2,3)	shielding factor (in cellars) 1. cloudshine 2. groundshine 3. inhalation
AFAUTO(i)	(i=1,2)	shielding factor (inside cars) 1. cloudshine 2. groundshine
AFFREI(i)	(i=1,2)	shielding factor (outdoors) 1. cloudshine 2. groundshine

The following list gives the name and the meaning of the consequence variables:

DOSLUD1	individual acute dose (lung)	at D1 (0.875 km)
DOSLUD2	individual acute dose (lung)	at D2 (4.9 km)
DOSLUD3	individual acute dose (lung)	at D3 (8.75 km)
DOSBMD1	individual acute dose (bone marrow)	at D1 (0.875 km)
DOSBMD2	individual acute dose (bone marrow)	at D2 (4.9 km)
DOSBMD3	individual acute dose (bone marrow)	at D3 (8.75 km)
RSKLUD1	individual risk (pulmonary syndrome)	at D1 (0.875 km)
RSKBMD1	individual risk (hematopoietic syndrome)	at D1 (0.875 km)
POP(LU)	early fatalities (pulmonary syndrome)	
POP(BM)	early fatalities (hematopoietic syndrome)	

Legends for reading the PRCC - tables (HEM - ANALYSIS)

The following list gives the name and the meaning of the parameters:

LGMD50(t)	t=1,2,3,4	the dose that would induce lung function impairment in half the population exposed during time interval t
THRESLGM(t)	t=1,2,3,4	threshold dose for exposure during time interval t (lung function impairment)
LGFD50(t)	t=1,2,3,4	the dose that would induce pulmonary syndrome in half the population exposed during time interval t
THRESLGF(t)	t=1,2,3,4	threshold dose for exposure during time interval t (pulmonary syndrome)
BMFD50(t)	t=1,2,3	the dose that would induce hematopoietic syndrome in half the population exposed during time interval t
THRESBMF(t)	t=1,2,3	threshold dose for exposure during time interval t (hematopoietic syndrome)
GIFD50(t)	t=1,2	the dose that would induce gastroindestinal syndrome in half the population exposed during time interval t
THRESGIF(t)	t=1,2	threshold dose for exposure during time interval t (gastroindestinal syndrome)
LGMSHP		shape parameter (lung function impairment)
LGFSHP		shape parameter (pulmonary syndrome)
BMFSHP		shape parameter (hematopoietic syndrome)
GIFSHP		shape parameter (gastrointestinal syndrome)

The following list gives the name and the meaning of the consequence variables:

RSKLMD1	individual risk (lung function impairment)	at	D1 (0.875 km)
RSKLMD2	individual risk (lung function impairment)	at	D2 (4.9 km)
RSKLFD1	individual risk (pulmonary syndrome)	at	D1 (0.875 km)
RSKBMD1	individual risk (hematopoietic syndrome)	at	D1 (0.875 km)
RSKGID1	individual risk (gastrointest. syndrome)	at	D1 (0.875 km)
RSKTTD1	individual risk (mortality: all effects)	at	D1 (0.875 km)
POPLUM	early fatalities (lung function impairment)		
POPLUF	early fatalities (pulmonary syndrome)		

POP(BM)	early fatalities (hematopoietic syndrome)
POP(GI)	early fatalities (gastrointestinal syndrome)
POPTOT	early fatalities (mortality: all effects)

Legends for reading the PRCC - tables (ATM and OVERALL - ANALYSIS)

The following list gives the name and the meaning of the parameters:

h_m		mixing height
$\sigma_z(S)$		horizontal plume diffusion for stability class S (S ∈ {A,B,C,D,E,F})
Λ_{AE}		washout coefficients of aerosols
$v_d(AE)$		dry deposition of aerosols
$v_d(IO)$		dry deposition of elementary iodine
GRWRTB		intervention criteria for evacuation of area B (B is defined by an isodose line)
TDELA		delay time between end of release and end of sheltering period in area A [h], where A is geometrically determined (keyhole - shaped)
IEVA2		index of last outer radius belonging to area A
PAUFA(i)		fraction of population with different behaviour during the sheltering period in area A 1. in cars (spontaneous evacuation) 2. in cellars 3. in buildings with low shielding 4. in buildings with high shielding 5. outside, rural area
TINA		initial delay of actions in area A [h]
DCFxx(t)		dose conversion factors for *xx* *xx* ∈ *(Sr-89, I-131,133,135, Cs-134,137)* integrated over the time interval t=1,2,3,4 (organ dependent) of the protracted exposure
AFHAUL(1)		shielding factor (houses with low shielding) cloudshine
AFFREI(1)		shielding factor (outdoors) cloudshine
ARATIH		breathing rate (inhalation)
LGFD50(t)	t=1,2,3,4	the dose that would induce pulmonary syndrome in half the population exposed during time interval t
THRESLGF(t)	t=1,2,3,4	threshold dose for exposure during time interval t (pulmonary syndrome)

BMFD50(t)	t=1,2,3	the dose that would induce hematopoietic syndrome in half the population exposed during time interval t
THRESBMF(t)	t=1,2,3	threshold dose for exposure during time interval t (hematopoietic syndrome)

The following list gives the name and the meaning of the consequence variables:

IODCGD1	concentration of	I-131 on ground surface	at D1 (0.875 km)
IODCGD2	concentration of	I-131 on ground surface	at D2 (4.9 km)
IODCGD3	concentration of	I-131 on ground surface	at D3 (8.750 km)
IODCAD1	concentration of	I-131 in air near ground	at D1 (0.875 km)
IODCAD2	concentration of	I-131 in air near ground	at D2 (4.9 km)
IODCAD3	concentration of	I-131 in air near ground	at D3 (8.750 km)
CAECGD1	concentration of	Cs-137 on ground surface	at D1 (0.875 km)
CAECGD2	concentration of	Cs-137 on ground surface	at D2 (4.9 km)
CAECGD3	concentration of	Cs-137 on ground surface	at D3 (8.750 km)
CAECAD1	concentration of	Cs-137 in air near ground	at D1 (0.875 km)
CAECAD2	concentration of	Cs-137 in air near ground	at D2 (4.9 km)
CAECAD3	concentration of	Cs-137 in air near ground	at D3 (8.750 km)
DOSLUD1	individual acute dose	(lung)	at D1 (0.875 km)
DOSLUD2	individual acute dose	(lung)	at D2 (4.9 km)
DOSLUD3	individual acute dose	(lung)	at D3 (8.75 km)
DOSBMD1	individual acute dose	(bone marrow)	at D1 (0.875 km)
DOSBMD2	individual acute dose	(bone marrow)	at D2 (4.9 km)
DOSBMD3	individual acute dose	(bone marrow)	at D3 (8.75 km)
RSKLUD1	individual risk	(pulmonary syndrome)	at D1 (0.875 km)
RSKBMD1	individual risk	(hematopoietic syndrome)	at D1 (0.875 km)
POP(LU)	early fatalities	(pulmonary syndrome)	
POP(BM)	early fatalities	(hematopoietic syndrome)	

C.1 ATM - Analysis

In this section PRCCs are shown for

- activity concentrations (I-131, Cs-137) at three distance intervals on ground surface and in the air near ground
- acute individual doses (lung, bone marrow) at three distance intervals
- acute individual risks (pulmonary, hematopoietic syndrome)
- early fatalities (pulmonary, hematopoietic syndrome)

Number of runs = 40.

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UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) CONCENTRATIONS PART 1 OF 8

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.35 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.55 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

40M (40P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	IODCGD1		IODCGD1		IODCGD2		IODCGD2		IODCGD3		IODCGD3	
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)	40M	(%)	40P	(%)
HMIX					-.74(2)	28	-.40(2)	27	-.96(1)	69	-.91(1)	69
SIGZ(A)		#		#		#		#		#	-.37(4)	#
SIGZ(B)		#		#		#		#		#		#
SIGZ(C)		#		#		#		#		#		#
SIGZ(D)	-.49(4)	#		#	-.44(3)	#		#		#		#
		#24		#26		#23		#53		# 6		#18
SIGZ(E)	-.63(3)	#		#		#	-.45(1)	#		#		#
SIGZ(F)	-.74(2)	#	-.82(2)	#		#		#		#	.53(3)	#
LD(AER)					.40(4)	2						
VD(AER)												
VD(IOD)	.98(1)	76	.95(1)	67	.81(1)	48			.91(2)	29	.70(2)	18
(RSQ(TOTAL)		97		92		82		45		95		88)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) CONCENTRATIONS PART 2 OF 8

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.35 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.55 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

40M (40P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	IODCAD1		IODCAD1		IODCAD2		IODCAD2		IODCAD3		IODCAD3	
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)	40M	(%)	40P	(%)
HMIX					-.71(2)	3	-.38(2)		-.93(2)	23	-.86(2)	21
SIGZ(A)												
SIGZ(B)												
SIGZ(C)												
SIGZ(D)	-.39(4)								-.35(3)		-.40(3)	
		56		57		7		5		1		4
SIGZ(E)	-.61(3)				-.42(3)						.39(4)	
SIGZ(F)	-.68(2)		-.69(2)				-.36(3)				.39(5)	
LD(AER)												
VD(AER)												
VD(IOD)	-.91(1)	47	-.79(1)	49	-.97(1)	89	-.97(1)	96	-.97(1)	73	-.95(1)	72
(RSQ(TOTAL)		91		79		96		95		96		92)

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.35 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.55 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

40M (40P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	CAECGD1		CAECGD1		CAECGD2		CAECGD2		CAECGD3		CAECGD3	
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)	40M	(%)	40P	(%)
HMIX							-.36(4)	1	-.64(3)	2	-.50(3)	2
SIGZ(A)												
SIGZ(B)												
SIGZ(C)	-.57(4)				-.35(4)				-.38(5)			
SIGZ(D)		14		12		10		18		4		8
SIGZ(E)												
SIGZ(F)	-.63(3)		-.77(2)		-.62(3)		-.51(3)		-.46(4)		-.36(4)	
LD(AER)	.91(2)	16	.73(3)	4	.96(1)	53	.89(1)	46	.97(1)	65	.94(1)	71
VD(AER)	.98(1)	71	.98(1)	86	.94(2)	38	.86(2)	36	.93(2)	30	.83(2)	21
VD(IOD)												
(RSQ(TOTAL)		97		97		96		89		96		92)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) CONCENTRATIONS PART 4 OF 8

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.35 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.55 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

40M (40P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	CAECAD1		CAECAD1		CAECAD2		CAECAD2		CAECAD3		CAECAD3	
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)	40M	(%)	40P	(%)
HMIX	.41(4)				-.57(2)	4			-.87(1)	51	-.79(1)	52
SIGZ(A)												
SIGZ(B)												
SIGZ(C)												
SIGZ(D)	-.47(3)											
		100		97		93		98		36		35
SIGZ(E)	-.89(2)		-.55(2)		-.49(3)		-.43(2)					
SIGZ(F)	-.98(1)		-.87(1)		-.89(1)		-.86(1)		-.75(2)		-.59(2)	
LD(AER)			.41(3)									
VD(AER)									-.57(3)	8	-.54(3)	12
VD(IOD)												
(RSQ(TOTAL)	98		89		90		86		86		77)	

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.35 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.55 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

40M (40P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	DOSLUD1		DOSLUD1		DOSLUD2		DOSLUD2		DOSLUD3		DOSLUD3	
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)	40M	(%)	40P	(%)
HMIX					-.70(3)	13			-.93(1)	70	-.75(1)	64
SIGZ(A)		#		#		#		#		#		#
SIGZ(B)	-.44(4)	#		#		#		#		#		#
SIGZ(C)		#		#		#		#		#		#
SIGZ(D)	-.43(5)	#		#		#		#		#		#
		#93		#89		#70		#85		#16		#13
SIGZ(E)	-.81(2)	#	-.51(3)	#	-.50(4)	#	-.57(2)	#		#		#
SIGZ(F)	-.93(1)	#	-.86(1)	#	-.80(1)	#	-.78(1)	#	-.67(3)	#		#
LD(AER)	.37(6)											
VD(AER)							-.38(4)	2	-.72(2)	12	-.47(2)	16
VD(IOD)	-.79(3)	8	-.66(2)	15	-.71(2)	17	-.56(3)	12	-.40(4)	2		
(RSQ(TOTAL)		97		88		87		84		91		67)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) CONCENTRATIONS PART 6 OF 8

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.35 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.55 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

40M (40P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	DOSBMD1		DOSBMD1		DOSBMD2		DOSBMD2		DOSBMD3		DOSBMD3	
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)	40M	(%)	40P	(%)
HMIX	.40(4)				-.73(2)	17	-.54(2)	7	-.94(1)	78	-.87(1)	73
SIGZ(A)	#		#		#		#		#		#	
SIGZ(B)	#		#		#		#		#		#	
SIGZ(C)	#		#		#		.42(3)#		#		#	
SIGZ(D)	-.67(3)#		#		#		#		#		#	
	#100		#93		#78		#90		# 7		#20	
SIGZ(E)	-.90(2)#		-.65(2)#		-.56(3)#		-.40(4)#		#		#	
SIGZ(F)	-.96(1)#		-.78(1)#		-.79(1)#		-.83(1)#		-.55(3)#		-.47(3)#	
LD(AER)									.42(4)	2		
VD(AER)									-.40(5)	2		
VD(IOD)			-.49(3)	6					.72(2)	11	.55(2)	10
(RSQ(TOTAL)		98		87		86		82		91		82)

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.35 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.55 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

40M (40P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	RSKLUD1		RSKLUD1		RSKBMD1		RSKBMD1	
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)
HMIX								
SIGZ(A)		#		#		#		#
SIGZ(B)		#		#		#		#
SIGZ(C)		#		#		#		#
SIGZ(D)		#		#		#		#
		#88		#61		#100		#100
SIGZ(E)	-.84(2)	#		#	-.88(2)	#	-.89(2)	#
SIGZ(F)	-.90(1)	#	-.41(2)	#	-.98(1)	#	-.92(1)	#
LD(AER)								
VD(AER)			-.36(3)	10				
VD(IOD)	-.82(3)	14	-.51(1)	27				
(RSQ(TOTAL)		95		59		98		96)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) CONCENTRATIONS PART 8 OF 8

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.35 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.55 (40 RUNS, 10 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

40M (40P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	POP(LU)		POP(LU)		POP(BM)		POP(BM)	
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)
HMIX								
SIGZ(A)		#		#		#		#
SIGZ(B)	-.36(5)	#		#	-.44(3)	#		#
SIGZ(C)		#		#		#		#
SIGZ(D)	-.44(4)	#		#	-.43(4)	#		#
		#92		#87		#100		#99
SIGZ(E)	-.56(3)	#	-.70(3)	#	-.91(2)	#	-.36(2)	#
SIGZ(F)	-.94(1)	#	-.88(1)	#	-.97(1)	#	-.93(1)	#
LD(AER)								
VD(AER)								
VD(IOD)	-.81(2)	11	-.75(2)	14				
(RSQ(TOTAL)		96		92		98		94)

C.2 CTM - Analysis

In this section PRCCs are shown for

- acute individual doses (lung, bone marrow) at three distance intervals
- acute individual risks (pulmonary, hematopoietic syndrome)
- early fatalities (pulmonary, hematopoietic syndrome)

Number of runs = 50.

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UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) COUNTERMEASURES PART 1 OF 4

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.31 (50 RUNS, 9 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.49 (50 RUNS, 9 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER

50M (50P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	DOSLUD1		DOSLUD1		DOSLUD2		DOSLUD2		DOSLUD3		DOSLUD3	
#RUNS	50M	(%)	50P	(%)	50M	(%)	50P	(%)	50M	(%)	50P	(%)
TINA	.97(1)	81	.70(1)	56	.91(1)	50	.66(2)	29	.57(3)	2	.43(3)	7
TDELA					.40(6)				.53(4)			
PAUFA(1)	-.87(2)	15	-.54(2)	26	-.88(2)	33	-.79(1)	64	-.87(2)	21	-.54(2)	16
PAUFA(5)	.56(4)	3			.64(3)	11						
GRWRTB					.58(4)	3			.96(1)	73	.81(1)	73
IEVA2					-.42(5)	7				1		
WGRNZA	.31(5)		-.34(3)	6	-.33(8)	1	-.31(3)	3				
WSHIFT												
TDRA	.58(3)	2			.39(7)	1			.42(5)	2		
(RSQ(TOTAL)		96		62		92		73		94		73)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) COUNTERMEASURES PART 2 OF 4

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.31 (50 RUNS, 9 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.49 (50 RUNS, 9 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER

50M (50P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	DOSBMD1		DOSBMD1		DOSBMD2		DOSBMD2		DOSBMD3		DOSBMD3	
#RUNS	50M	(%)	50P	(%)	50M	(%)	50P	(%)	50M	(%)	50P	(%)
TINA	.98(1)	78	.91(1)	81	.75(1)	37	.68(1)	40	.67(2)	1		
TDELA												
PAUFA(1)	-.73(4)	4	-.44(3)	5	-.49(5)	9	-.48(3)	13	-.63(3)	1		
PAUFA(5)	.86(2)	12	.55(2)	9	.62(4)	22	.41(5)	14	.54(4)			
GRWRTB					.69(2)	27	.62(2)	19	.99(1)	96	.92(1)	99
IEVA2	.39(5)				-.64(3)	23	-.45(4)	15				
WGRNZA												
WSHIFT												
TDRA	.80(3)	6	.43(4)	5	.41(6)	4			.56(4)	1		
(RSQ(TOTAL)		97		85		82		72		99		85)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) COUNTERMEASURES PART 3 OF 4

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.31 (50 RUNS, 9 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.49 (50 RUNS, 9 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER

50M (50P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	RSKLUD1		RSKLUD1		RSKBMD1		RSKBMD1	
#RUNS	50M	(%)	50P	(%)	50M	(%)	50P	(%)
TINA	.96(1)	72	.84(1)	69	.86(2)	14		
TDELA			-.35(4)	4	.65(4)	4	.40(3)	
PAUFA(1)	-.87(2)	19	-.61(2)	18	-.45(5)	1		
PAUFA(5)	.68(3)	7	.37(3)	5	.98(1)	80	.99(1)	98
GRWRTB								
IEVA2	.35(5)						.31(5)	
WGRNZA	-.32(6)				-.41(6)		-.44(2)	
WSHIFT							-.37(4)	
TDRA	.56(4)	2			.74(3)	4		
(RSQ(TOTAL)		95		77		96		99)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) COUNTERMEASURES PART 4 OF 4

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.31 (50 RUNS, 9 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.49 (50 RUNS, 9 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER

50M (50P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	POP(LU)		POP(LU)		POP(BM)		POP(BM)	
#RUNS	50M	(%)	50P	(%)	50M	(%)	50P	(%)
TINA	.96(1)	68	.88(1)	71	.92(2)	20	.89(1)	48
TDELA					.68(3)	4		
PAUFA(1)	-.89(2)	20	-.66(2)	17	-.63(5)	2	-.62(3)	8
PAUFA(5)	.77(3)	9	.39(3)	5	.98(1)	76	.88(2)	44
GRWRTB								
IEVA2	.42(5)							
WGRNZA	-.41(6)		-.38(4)	2	-.31(7)		-.32(5)	
WSHIFT	-.32(7)	1			-.33(6)	2		
TDRA	.61(4)	3			.68(4)	2	.39(4)	
(RSQ(TOTAL)		95		83		97		90)

C.3 DCF - Analysis

In this section PRCCs are shown for

- acute individual doses (lung, bone marrow) at three distance intervals
- acute individual risks (pulmonary, hematopoietic syndrome)
- early fatalities (pulmonary, hematopoietic syndrome)

Number of runs = 60.

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UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) (DCF) PART 1 OF 4

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.31 (60 RUNS, 20 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.49 (60 RUNS, 20 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR PAIRS OF INDEPENDENT PARAMETERS (AFHAUL1,AFHAUL2), (AFHAUF1,AFHAUF2), (AFKELL1,AFKELL2), (AFAUTO1,AFAUTO2), (AFFREI1,AFFREI2) RESPECTIVELY

60M (60P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	DOSLUD1		DOSLUD1		DOSLUD2		DOSLUD2		DOSLUD3		DOSLUD3	
#RUNS	60M	(%)	60P	(%)	60M	(%)	60P	(%)	60M	(%)	60P	(%)
DCFSR												
DCFRU	.50(3)	2	.39(6)	1	.54(4)	2	.57(3)	4	.54(3)	2	.46(4)	2
DCFTE	.39(6)	1	.42(4)	1	.43(6)	1	.44(5)	1	.44(4)	1	.52(3)	3
DCFIO	.91(2)	35	.90(2)	36	.88(2)	26	.81(2)	19	.89(2)	27	.82(2)	22
DCFCS												
DCFBA												
ARATIH	.94(1)	56	.94(1)	57	.95(1)	61	.94(1)	67	.95(1)	67	.93(1)	69
AFHAUL3	.41(5)	1	.43(3)	1	.45(5)	1	.44(6)	1				
AFHAUF3					.38(7)	1	.34(7)	1				
AFKELL3	.48(4)	1	.41(5)		.55(3)	1	.56(4)	2				
AFHAUL1												
AFHAUF1												
AFKELL1												
AFAUTO1												
AFFREI1					.34(8)							
AFHAUL2												
AFHAUF2												
AFKELL2												
AFAUTO2												
AFFREI2												
(RSQ(TOTAL)	96		62		92		73		94		73)	

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) (DCF) PART 2 OF 4

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.31 (60 RUNS, 20 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.49 (60 RUNS, 20 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR PAIRS OF INDEPENDENT PARAMETERS (AFHAUL1,AFHAUL2), (AFHAUF1,AFHAUF2), (AFKELL1,AFKELL2), (AFAUTO1,AFAUTO2), (AFFREI1,AFFREI2) RESPECTIVELY

60M (60P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	DOSBMD1		DOSBMD1		DOSBMD2		DOSBMD2		DOSBMD3		DOSBMD3	
#RUNS	60M	(%)	60P	(%)	60M	(%)	60P	(%)	60M	(%)	60P	(%)
DCFSR	.62(4)	10	.54(4)	9	.57(6)	7	.43(6)	5	.71(2)	14		
DCFRU												
DCFTE												
DCFIO	.77(2)	20	.70(2)	18	.61(5)	8	.38(8)	5	.69(4)	13	.33(4)	11
DCFCS	.65(3)	9	.60(3)	10	.66(4)	9	.67(2)	14	.69(3)	11	.40(3)	14
DCFBA			.41(5)	7	.37(10)	4	.50(4)	8	.44(5)	6		
ARATIH	.91(1)	53	.88(1)	54	.91(1)	45	.86(1)	43	.92(1)	61	.54(1)	35
AFHAUL3	.35(7)				.39(9)		.36(9)	1				
AFHAUF3							.33(10)	2				
AFKELL3	.40(6)	1	.36(6)		.43(7)	1	.57(3)	6				
AFHAUL1	.32(8)	2			.69(3)	11	.49(5)	7				
AFHAUF1												
AFKELL1												
AFAUTO1					.42(8)	2						
AFFREI1	.47(5)	3			.72(2)	13	.38(7)	6			.41(2)	18
AFHAUL2			-.33(7)									
AFHAUF2												
AFKELL2												
AFAUTO2												
AFFREI2												
(RSQ(TOTAL)		90		87		91		86		90		57)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) (DCF) PART 3 OF 4

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.31 (60 RUNS, 20 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.49 (60 RUNS, 20 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR PAIRS OF INDEPENDENT PARAMETERS (AFHAUL1,AFHAUL2), (AFHAUF1,AFHAUF2), (AFKELL1,AFKELL2), (AFAUTO1,AFAUTO2), (AFFREI1,AFFREI2) RESPECTIVELY

60M (60P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	RSKLUD1		RSKLUD1		RSKBMD1		RSKBMD1	
#RUNS	60M	(%)	60P	(%)	60M	(%)	60P	(%)
DCFSR								
DCFRU								
DCFTE								
DCFIO	.93(2)	44	.89(2)	47	.78(1)	24	.75(2)	10
DCFCS								
DCFBA								
ARATIH	.93(1)	49	.90(1)	46	.75(3)	23	.71(3)	8
AFHAUL3	.39(4)	1			.39(5)	2	.35(6)	1
AFHAUF3								
AFKELL3	.51(3)		.50(3)	3				
AFHAUL1					.50(4)	14	.56(4)	9
AFHAUF1								
AFKELL1								
AFAUTO1	.31(5)							
AFFREI1					.75(2)	31	.91(1)	72
AFHAUL2								
AFHAUF2								
AFKELL2								
AFAUTO2								
AFFREI2							.53(5)	
(RSQ(TOTAL)	93		90		86		93	)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) (DCF) PART 4 OF 4

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.31 (60 RUNS, 20 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.49 (60 RUNS, 20 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR PAIRS OF INDEPENDENT PARAMETERS (AFHAUL1,AFHAUL2), (AFHAUF1,AFHAUF2), (AFKELL1,AFKELL2), (AFAUTO1,AFAUTO2), (AFFREI1,AFFREI2) RESPECTIVELY

60M (60P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	POP(LU)		POP(LU)		POP(BM)		POP(BM)	
#RUNS	60M	(%)	60P	(%)	60M	(%)	60P	(%)
DCFSR					.33(6)	2	.40(6)	5
DCFRU								
DCFTE	.32(6)							
DCFIO	.93(2)	42	.92(2)	38	.81(2)	26	.78(2)	27
DCFCS					.51(4)	6	.50(4)	6
DCFBA								
ARATIH	.94(1)	51	.94(1)	53	.88(1)	53	.86(1)	47
AFHAUL3	.47(4)	1	.44(4)	1	.33(7)		.39(7)	1
AFHAUF3			.40(5)	1				
AFKELL3	.51(3)	1	.52(3)	1				
AFHAUL1					.37(5)	3	.40(5)	5
AFHAUF1								
AFKELL1	.34(5)	1	.33(6)	1				
AFAUTO1								
AFFREI1					.66(3)	15	.53(3)	8
AFHAUL2								
AFHAUF2								
AFKELL2								
AFAUTO2								
AFFREI2								
(RSQ(TOTAL)	93		94		88		86	)

C.4 HEM - Analysis

In this section PRCCs are shown for

- acute individual risks (lung function impairment, pulmonary syndrome, hematopoietic syndrome, gastrointestinal syndrome, mortality (all effects)).
- early fatalities (lung function impairment, pulmonary syndrome, hematopoietic syndrome, gastrointestinal syndrome, mortality (all effects)).

Number of runs = 40.

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UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) (HEM) PART 1 OF 2

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.34 (40 RUNS, 8 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.54 (40 RUNS, 8 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR PAIRS OF INDEPENDENT PARAMETERS (LGMD50,LGMSHP), (LGFD50,LGFSHP), (BMFD50,BMFSHP), (GIFD50,GIFD50)

40M (40P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	RSKLMD1		RSKLMD1		RSKLMD2		RSKLMD2		RSKLFD1		RSKLFD1	
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)	40M	(%)	40P	(%)
LGMD50	-.95(1)	65	-.67(2)	40	-.98(1)	99						
LGFD50	.91(2)	39	.76(1)	61					-1.00(1)	99	-.96(1)	100
BMFD50												
GIFD50												
LGMSHP					-.91(2)							
LGFSHP									-.57(2)		-.55(2)	
BMFSHP												
GIFSHP												
(RSQ(TOTAL)		97		82		96				100		94)

	RSKBMD1		RSKBMD1		RSKGID1		RSKGID1		RSKTTD1		RSKTTD1	
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)	40M	(%)	40P	(%)
LGMD50												
LGFD50									-.99(1)	98	-.96(1)	100
BMFD50	-1.00(1)	99	-.94(1)	99					-.44(2)	2		
GIFD50					-.97(1)	99						
LGMSHP												
LGFSHP											-.52(2)	
BMFSHP	-.71(2)											
GIFSHP					-.60(2)							
(RSQ(TOTAL)		100		95		96				99		94)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) (HEM) PART 2 OF 2

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.34 (40 RUNS, 8 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.54 (40 RUNS, 8 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR PAIRS OF INDEPENDENT PARAMETERS (LGMD50,LGMSHP), (LGFD50,LGFSHP), (BMFD50,BMFSHP), (GIFD50,GIFD50)

40M (40P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	POPLUM		POPLUM		POPLUF		POPLUF		POP(BM)		POP(BM)	
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)	40M	(%)	40P	(%)
LGMD50	-.97(1)	98	-.97(1)	98								
LGFD50	.51(2)	4	.62(3)	4	-.99(1)	99	-.97(1)	99	.36(3)	1		
BMFD50									-.99(1)	99	-.95(1)	99
GIFD50			-.67(2)									
LGMSHP	-.45(3)											
LGFSHP					-.73(2)							
BMFSHP									-.74(2)			
GIFSHP			-.46(4)									
(RSQ(TOTAL)	96		98		99		97		99		94	)

	POP(GI)		POP(GI)		POPTOT		POPTOT			
#RUNS	40M	(%)	40P	(%)	40M	(%)	40P	(%)		
LGMD50										
LGFD50					-.97(1)	98	-.96(1)	98		
BMFD50					-.49(2)	3				
GIFD50	-.99(1)	99	-.55(1)	99						
LGMSHP										
LGFSHP										
BMFSHP										
GIFSHP										
(RSQ(TOTAL)	99		50		97		96			)

C.5 OVERALL - Analysis

In this section PRCCs are shown for

- activity concentrations (I-131, Cs-137) at three distance intervals on ground surface and in the air near ground
- acute individual doses (lung, bone marrow) at three distance intervals
- acute individual risks (pulmonary, hematopoietic syndrome)
- early fatalities (pulmonary, hematopoietic syndrome)

Number of runs = 100.

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TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.22 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.37 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

100M (100P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	IODCGD1		IODCGD1		IODCGD2		IODCGD2		IODCGD3		IODCGD3	
#RUNS	100M	(%)	100P	(%)	100M	(%)	100P	(%)	100M	(%)	100P	(%)
HMIX					-.75(2)	15	-.34(2)	12	-.94(1)	65	-.80(1)	70
SIGZ(A)	#		#		#		#		#		#	
SIGZ(B)	#		#		#		#		#		#	
SIGZ(C)	-.24(5)	#	-.24(4)	#	#		#		#		#	
SIGZ(D)	-.53(4)	#		#	-.46(4)	#		#		#		#
		#23		#27		#33		#65		# 3		# 6
SIGZ(E)	-.62(3)	#	-.26(3)	#	-.37(5)	#	-.41(1)	#		#		#
SIGZ(F)	-.79(2)	#	-.78(2)	#	-.59(3)	#	-.25(3)	#		#		#
LD(AER)												
VD(AER)												
VD(IOD)	.98(1)	77	.96(1)	71	.89(1)	50			.88(2)	27	.55(2)	17
GRWRTB												
TDELA												
IEVA2												
PAUFA(1)												
PAUFA(5)												
TINA												
DCFSR												
DCFCS												
DCFIO												
AFHAUL1												
AFFREI1												
ARATIH												
LGFD50												
BMFD50												
(RSQ(TOTAL)	98		94		88		51		92		70)	

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) (OAL) PART 2 OF 8

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.22 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.37 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

100M (100P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	IODCAD1	IODCAD1	IODCAD2	IODCAD2	IODCAD3	IODCAD3
#RUNS	100M (%)	100P (%))	100M (%)	100P (%)	100M (%)	100P (%)
HMIX			-.65(2) 6	-.44(2) 2	-.88(2) 28	-.77(2) 21
SIGZ(A)	#	#	#	#	#	#
SIGZ(B)	#	#	#	#	#	#
SIGZ(C)	#	-.29(3)#	#	#	#	#
SIGZ(D)	-.43(4)#	#	-.36(4)#	#	#	#
	#66	#54	#10	# 3	# 1	# 1
SIGZ(E)	-.63(3)#	#	-.31(5)#	-.32(3)#	#	#
SIGZ(F)	-.75(2)#	-.76(2)#	-.39(3)#	-.29(4)#	#	#
LD(AER)						
VD(AER)						
VD(IOD)	-.88(1) 32	-.83(1) 39	-.96(1) 84	-.96(1) 93	-.95(1) 74	-.92(1) 79
GRWRTB						
TDELA						
IEVA2						
PAUFA(1)						
PAUFA(5)						
TINA						
DCFSR						
DCFCS						
DCFIO						
AFHAUL1						
AFFREI1						
ARATIH						
LGFD50						
BMFD50						
(RSQ(TOTAL)	92	85	93	94	93	89)

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.22 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.37 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

100M (100P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	CAECGD1		CAECGD1		CAECGD2		CAECGD2		CAECGD3		CAECGD3	
#RUNS	100M	(%)	100P	(%)	100M	(%)	100P	(%)	100M	(%)	100P	(%)
HMIX									-.50(3)	2		
SIGZ(A)	#		#		#		#		#		-.28(5)	#
SIGZ(B)	#		#		#		#		#		#	
SIGZ(C)	#		#		#		#		#		.30(4)	#
SIGZ(D)	#		#		#		#		#		#	
	#	8	#	10	#	8	#	11	#	2	#	6
SIGZ(E)	-.28(4)	#	-.41(4)	#		#		#		#		#
SIGZ(F)	-.64(3)	#	-.73(2)	#	-.55(3)	#	-.42(3)	#	-.37(4)	#	-.35(3)	#
LD(AER)	.88(2)	13	.69(3)	2	.93(1)	54	.83(1)	51	.96(1)	69	.94(1)	80
VD(AER)	.97(1)	76	.98(1)	85	.90(2)	34	.78(2)	35	.89(2)	22	.73(2)	11
VD(IOD)												
GRWRTB												
TDELA												
IEVA2												
PAUFA(1)												
PAUFA(5)												
TINA												
DCFSR												
DCFCS												
DCFIO												
AFHAUL1												
AFFREI1												
ARATIH												
LGFD50												
BMFD50												
(RSQ(TOTAL)	96		96		92		81		94		90)	

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) (OAL) PART 4 OF 8

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.22 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.37 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

100M (100P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	CAECAD1		CAECAD1		CAECAD2		CAECAD2		CAECAD3		CAECAD3	
#RUNS	100M	(%)	100P	(%)	100M	(%)	100P	(%)	100M	(%)	100P	(%)
HMIX					-.66(2)	5	-.43(3)	2	-.85(1)	40	-.79(1)	37
SIGZ(A)	#		#		#		#		#		#	
SIGZ(B)	#		#		#		#		#		#	
SIGZ(C)	-.24(5)#		#		#		#		#		#	
SIGZ(D)	-.61(3)#		#		#		#		#		#	
	#99		#97		#91		#95		#51		#50	
SIGZ(E)	-.94(2)#		-.67(2)#		-.65(3)#		-.61(2)#		-.34(4)#		-.36(4)#	
SIGZ(F)	-.98(1)#		-.86(1)#		-.92(1)#		-.89(1)#		-.79(2)#		-.67(2)#	
LD(AER)									-.29(5)	1		
VD(AER)	-.37(4)				-.41(4)	1	-.30(4)	1	-.42(3)	3	-.43(3)	6
VD(IOD)												
GRWRTB												
TDELA												
IEVA2												
PAUFA(1)												
PAUFA(5)												
TINA												
DCFSR												
DCFCS												
DCFIO												
AFHAUL1												
AFFREI1												
ARATIH												
LGFD50												
BMFD50												
(RSQ(TOTAL)	99		89		94		91		87		82)	

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.22 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.37 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

100M (100P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	DOSLUD1		DOSLUD1		DOSLUD2		DOSLUD2		DOSLUD3		DOSLUD3	
#RUNS	100M	(%)	100P	(%)	100M	(%)	100P	(%))	100M	(%)	100P	(%)
HMIX					-.43(7)	3	-.23(11)		-.75(3)	14	-.60(4)	10
SIGZ(A)	.23(11)#		.25(9)#		#		#		#		#	
SIGZ(B)	-.29(9)#		-.28(8)#		-.27(10)#		-.32(8)#		-.31(6)#		-.28(6)#	
SIGZ(C)	#		#		#		#		#		#	
SIGZ(D)	-.25(10)#		#		#		#		#		#	
	#14		#14		#18		#25		# 7		# 6	
SIGZ(E)	-.47(4)#		-.35(7)#		-.37(8)#		-.48(5)#		#		#	
SIGZ(F)	-.46(6)#		-.53(3)#		-.51(5)#		-.48(6)#		-.27(8)#		#	
LD(AER)					-.24(11)				-.28(7)		-.28(7)	
VD(AER)							-.23(12)		-.23(9)			
VD(IOD)	-.39(7)		-.41(5)	1	-.53(4)	2	-.56(3)	3	-.58(4)	3	-.54(5)	3
GRWRTB									.50(5)	3	.63(3)	10
TDELA					.29(9)		.29(9)					
IEVA2												
PAUFA(1)	-.47(5)	3	-.39(6)	3	-.47(6)	4	-.50(4)	7			-.26(8)	2
PAUFA(5)												
TINA	.68(3)	6	.50(4)	4	.54(3)	5	.45(7)	3				
DCFSR												
DCFCS												
DCFIO	.94(1)	39	.92(2)	36	.86(2)	23	.79(2)	15	.84(2)	21	.74(2)	13
AFHAUL1	.34(8)		.24(10)		.22(12)		.24(10)					
AFFREI1												
ARATIH	.94(2)	39	.93(1)	45	.92(1)	46	.91(1)	48	.93(1)	54	.90(1)	57
LGFD50												
BMFD50												
(RSQ(TOTAL)		95		94		93		92		92		89)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) (OAL) PART 6 OF 8

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.22 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.37 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

100M (100P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	DOSBMD1		DOSBMD1		DOSBMD2		DOSBMD2		DOSBMD3		DOSBMD3	
#RUNS	100M	(%)	100P	(%)	100M	(%)	100P	(%)	100M	(%)	100P	(%)
HMIX					-.46(5)	6	-.30(11)	2	-.83(2)	20	-.65(3)	11
SIGZ(A)	#		#		#		#		#		#	
SIGZ(B)	-.23(14)#		#		#		#		#		#	
SIGZ(C)	-.26(12)#		#		#		#		#		#	
SIGZ(D)	#		#		#		#		#		#	
	#28		#28		#29		#34		# 8		# 8	
SIGZ(E)	-.49(7)#		-.38(7)#		-.36(10)#		-.32(10)#		#		#	
SIGZ(F)	-.56(6)#		-.56(5)#		-.57(4)#		-.67(2)#		-.42(7)#		-.39(5)#	
LD(AER)									-.27(8)		-.25(9)	
VD(AER)												
VD(IOD)							-.28(13)	1				
GRWRTB					.43(7)	5	.54(5)	8	.92(1)	49	.91(1)	63
TDELA	.29(10)	1										
IEVA2					-.61(3)	10	-.56(4)	7				
PAUFA(1)	-.33(9)	3	-.32(8)	3								
PAUFA(5)	.25(13)				.28(12)	1	.33(9)	2				
TINA	.80(2)	17	.63(4)	11	.63(2)	14	.60(3)	12				
DCFSR	.57(5)	5	.52(6)	7	.24(13)	2	.28(12)	3	.44(6)	3	.32(6)	2
DCFCS	.64(4)	4	.63(3)	7	.36(9)	2	.39(6)	2	.59(4)	3	.42(4)	2
DCFIO	.78(3)	13	.69(2)	12	.39(8)	2	.37(7)	2	.44(5)	1	.29(7)	
AFHAUL1	.43(8)	1	.28(9)		.44(6)	3	.36(8)	1	.23(10)		.26(8)	
AFFREI1	.26(11)				.31(11)	1			.27(9)		.23(10)	
ARATIH	.89(1)	30	.86(1)	36	.76(1)	24	.76(1)	24	.80(3)	19	.70(2)	17
LGFD50												
BMFD50												
(RSQ(TOTAL)		93		90		86		86		93		89)

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.22 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.37 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

100M (100P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	RSKLUD1		RSKLUD1		RSKBMD1		RSKBMD1	
#RUNS	100M	(%)	100P	(%)	100M	(%)	100P	(%)
HMIX								
SIGZ(A)	#		#		#		.25(9)#	
SIGZ(B)	#		#		#		#	
SIGZ(C)	#		#		#		#	
SIGZ(D)	#		#		#		#	
	#11		#11		#21		#14	
SIGZ(E)	-.35(6)#		#		-.31(10)#		-.29(8)#	
SIGZ(F)	-.42(4)#		-.41(4)#		-.55(4)#		-.39(7)#	
LD(AER)								
VD(AER)	-.24(8)							
VD(IOD)	-.39(5)		-.30(5)					
GRWRTB			.22(7)					
TDELA								
IEVA2								
PAUFA(1)	-.24(9)	1						
PAUFA(5)					.49(5)	4	.65(2)	14
TINA	.26(7)	1	.28(6)	2				
DCFSR					.33(7)	2		
DCFCS					.32(9)			
DCFIO	.91(1)	35	.82(1)	32	.64(3)	8	.47(5)	5
AFHAUL1					.47(6)	2	.43(6)	2
AFFREI1					.33(8)	1	.53(4)	5
ARATIH	.90(2)	28	.81(2)	28	.80(2)	21	.57(3)	7
LGFD50	-.90(3)	28	-.80(3)	27				
BMFD50					-.87(1)	37	-.87(1)	49
(RSQ(TOTAL)		94		88		89		86)

UFOMOD SENSITIVITY ANALYSIS (LHS-DESIGN) (OAL) PART 8 OF 8

TABLE ENTRIES REPRESENT THE VALUE OF THE PARTIAL RANK CORRELATION COEFFICIENT (AND ITS RANK) FOR EACH COMBINATION OF SELECTED INDEPENDENT AND SELECTED DEPENDENT VARIABLE, PROVIDED THAT THE ABSOLUTE VALUE OF THIS COEFFICIENT IS GREATER THAN T(ALPHA) = 0.22 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.05 SIGNIFICANCE LEVEL
(E.G. THE CRITICAL VALUE IS T(ALPHA) = 0.37 (100 RUNS, 24 PARAMETERS)
FOR ALPHA = 0.001 SIGNIFICANCE LEVEL)

THE PERCENTAGE CONTRIBUTIONS TO UNCERTAINTY ARE GIVEN FOR EACH INDEPENDENT PARAMETER OR A GROUP OF INDEPENDENT PARAMETERS (SIGY) RESPECTIVELY

100M (100P) MEANS: SENSITIVITY ANALYSIS BASED ON MEAN VALUES (99 % - VALUES), RESPECTIVELY

	POP(LU)		POP(LU)		POP(BM)		POP(BM)	
#RUNS	100M	(%)	100P	(%)	100M	(%)	100P	(%)
HMIX								
SIGZ(A)	#		#		#		#	
SIGZ(B)	#		#		#		#	
SIGZ(C)	#		#		#		#	
SIGZ(D)	#		#		#		#	
	#11		#11		#17		#17	
SIGZ(E)	-.35(6)#		-.27(7)#		-.39(10)#		-.35(11)#	
SIGZ(F)	-.47(4)#		-.51(4)#		-.57(4)#		-.56(5)#	
LD(AER)								
VD(AER)	-.23(8)		-.22(9)					
VD(IOD)	-.42(5)		-.43(6)					
GRWRTB								
TDELA	.23(9)				.29(12)	1		
IEVA2								
PAUFA(1)			-.25(8)	1	-.31(11)	2	-.45(9)	3
PAUFA(5)					.52(5)	4	.38(10)	2
TINA	.27(7)	1	.45(5)	2			.45(8)	2
DCFSR					.42(9)	2	.50(7)	3
DCFCS					.44(7)	1	.58(4)	2
DCFIO	.91(1)	32	.90(1)	32	.74(3)	10	.80(3)	13
AFHAUL1					.49(6)	1	.54(6)	2
AFFREI1					.44(8)	1	.24(12)	
ARATIH	.90(3)	28	.89(3)	27	.85(2)	20	.89(1)	30
LGFD50	-.91(2)	30	-.90(2)	29				
BMFD50					-.92(1)	39	-.89(2)	26
(RSQ(TOTAL)		94		94		93		93)

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