STUDSVIK/NP-89/65

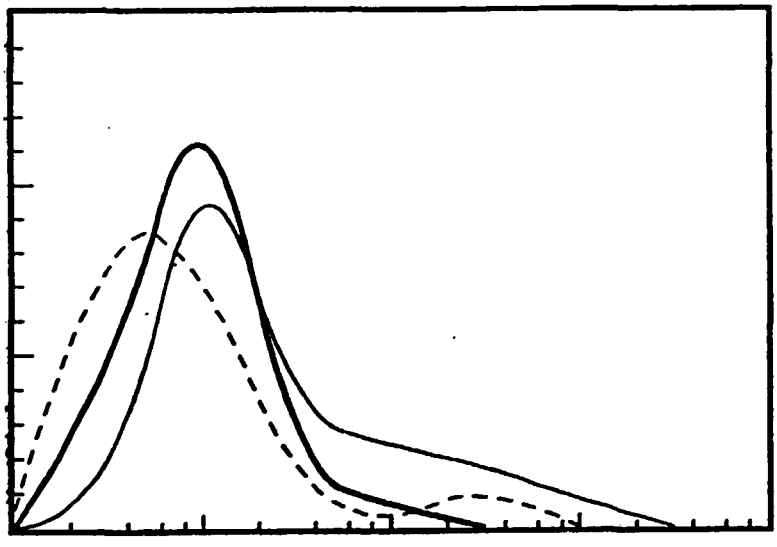
Studsvik Report

UNCERTAINTY AND SENSITIVITY ANALYSIS IN NUCLEAR ACCIDENT CONSEQUENCE ASSESSMENT

A study of the parameter uncertainty propagation through a complex dispersion, dose and health effect model

Olof Karlberg

Distribution of model responses



Consequences

Studsvik Nuclear

STUDSVIK NUCLEAR

STUDSVIK NP-89/65

1989-04-10

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Abstract

This report contains the results of a four year project in research contracts with the Nordic Cooperation in Nuclear Safety and the National Institute for Radiation Protection (projct nr P 314.88).

An uncertainty/sensitivity analysis methodology consisting of Latin Hypercube sampling and regression analysis was applied to an accident consequence model. A number of input parameters were selected and the uncertaintys related to these parameters were estimated within a Nordic group of experts.

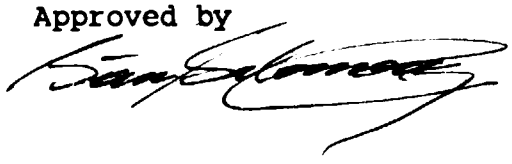
Individual doses, collective doses, health effects and their related uncertaintys were then calculated for three release scenarios and for a representative sample of meteorological situations. From two of the scenarios the acute phase after an accident were simulated and from one the long time consequences. The most significant parameters were identified.

The outer limits of the calculated uncertainty distributions are large and will grow to several order of magnitudes for the low probability consequences. The uncertainty in the expectation values are typical a factor 2-5 (1 Sigma). The variation in the model responses due to the variation of the weather parameters is fairly equal to the parameter uncertainty induced variation.

The most important parameters showed out to be different for each pathway of exposure, which could be expected. However, the overall most important parameters are the wet deposition coefficient and the shielding factors.

A general discussion of the usefullness of uncertainty analysis in consequence analysis is also given.

Approved by



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Table,

1 Introduction

Mathematical models are important tools for summarizing current knowledge and information in a variety of scientific fields. Models provide a rapid means of testing new ideas and, where reliability allows, provide predictions about the long term results of system modification. As model based decisions become more common, the methods of evaluating their reliability also become important.

In this document uncertainty and sensitivity analysis are applied to the consequence assessments of some hypotetical ractor accident scenarios. The primary goal has been to study the general behaviour and usefulness of such an analysis, but also to get an idea of the overall uncertainty in a typical assessment and to identify those submodels and/or input parameters that significantly contributes to this uncertainty.

Similar studies and more comprehensive ones has been going on the last decade, and today uncertainty analysis is recognized as an important tool in consequence assessment.

The use of the terms uncertainty and sensitivity analysis is some times unclear. In this report, uncertainty analysis means the quantification of the uncertainty in a model respons in terms of statistical quantities like standard deviations etc, and sensitivity analysis is the identification of important parameters and the more general behaviour of the model when input parameters are varied.

This study involves only the uncertainty of the model response caused by uncertainty in the input parameters. Other sources of uncertainty, i e inability of the model itself to describe the physical/chemical events must be studied with experimental tools or with comparisions with other models. However, model uncertainty can be simulated in a simplified way by introducing "model uncertainty factors" in critical parts of the model.

The methodology used in this study is, in a summarized form, Latin Hypercube sampling from given input parameter probability density functions (pdf's) and correlation and regression analysis of the model responses against the sampled parameter values. The methodology is implemented in a suite of codes called PRISM (Gardner, 1983).

2 Background

The study is a part of the Nordic Cooperation in Nuclear Safety, and has been carried out in three phases.

- Phase 1 Evaluation of existing techniques of uncertainty analysis and calculations of some test cases (Karlberg, 1985).

- Phase 2 Identification of significant parameters, scenarios and source terms. Estimation of pdf's for the selected parameters (Karlberg, 1988)

- Phase 3 Calculation of consequences and uncertainties for the selected scenarios. Identification of important parameters.

In phase 1, different methods for uncertainty analysis, such as Simple Monte Carlo, Discrete Variable approach, Moment Matching and Response Surface Techniques, were studied in a literature survey (Hofer 1984, Alpert 1984). No indications were found, that any of the named methodologies is more suitable then the PRISM one for this type of study, although the latter methodology had to be used by practical and budget reasons.

The most relevant parameters, based on the test calculations in phase 1, were selected in phase 2, and assigned to uncertainty pdf's by a Nordic group of experts according to a standardised precedure. A selection of scenarios were also carried out.

Finally in phase 3, the consequences and their output pdf's as well as the ranking of the most important parameters were calculated with the UNIDCS and PRISM codes for these scenarios.

3 Description of the PRISM code system

This section contains a brief description of the PRISM code suite. A detailed description is given in Garder, 1983.

The code suite is designed for uncertainty analysis on any model code that reads input parameter values and writes model responses.

The analysis is carried out in three consequtive steps:

PRISM1

PRISM2 (linked to the analysed model)

PRISM3.

3.1 PRISM1 - Generation of input parameter pdf's

Each parameter is assigned to a pdf, that could be either of uniform, triangular or normal type, distributed on both linear or logaritmic scale. A pdf is defined by a upper and lower limit (uniform) plus the most probable value (triangular) and a standard deviation (normal).

The inverse cumulative density function (icdf) of each pdf is then used to sample N no of parameter value sets from each 1/N part of the icdf's.

This technique, called Latin Hypercube sampling (LHA) ensures that the whole part of the pdf will be equally sampled and thus reduces the necessary number of samples, N, compared to random sampling.

An important feature of the PRISM-1 code is the possibility of assigning correlations (as well as zero correlation) between parameters. A method suggested by Iman and Conover, 1982, is used in the code to ensure the proper correlation (or non-correlation) between all parameters. This is important for the final correlation analysis between parameters and responses in PRISM3.

3.2 PRISM-2 Calculation of model responses

The model code to be analysed is normally put as an subroutine to the PRISM2 code. For each of the N sets of parameter values, the model responses are calculated and stored on a disc file. In this case, PRISM2 is not used, instead the UNIDOS code is adjusted to the output specifications of PRISM1 and to the input specifications of PRISM3.

The calculation flow is schematically given by (FORTRAN)

```
PROGRAM UNIDOS
  .
  .
DO 10 i = 1,N
READ PARAMETERS
.
.
C PERFORM MODEL CALCULATIONS
.
.
10 WRITE RESPONSES
.
.
END
```

3.3 PRISM3 - Relations between input parameter pdf's and responses

There are two major analysis carried out in the PRISM3 code, besides a general statistical output of the model responses - a correlation analysis and a regression analysis.

The correlation analysis include the simple Pearson correlation coefficient between parameters and responses and the Spearman rank correlation coefficient between the ranks of the parameter and the responses (lowest value have rank = 1, highest rank N).

The square of the correlation coefficient represents the fraction of variance of a response (or an other parameter) that could be accounted for by the parameter.

In the regression analysis, the parameters that accounts for the largest part of the variation in a response are selected. This is carried out in a step by step method (IMSL routine RLSTP).

First, regression is made against all parameters. The parameter that will give the smallest sum of squares will be selected. Next, regression will be made against the remaining parameters, and the parameter that will reduce the sum of squares the most, together with the first parameter, will be selected next. The procedure will stop when no parameter can reduce the sum of squares with a given value. A list of the selected parameters and their percentual contribution to the variability of the analysed response is printed.

4 Description of the UNIDOSE consequence model

UNIDOSE (Karlberg, 1979) is used to model the consequences of accidental airborne releases. It calculates dispersion in the air, deposition on the ground, doses and health effects to individuals as well as to populations. The model was used in the CSNI Benchmark study (NEA/OECD, 1984). Only a schematic description and simplified formulas will be given here.

4.1 Dispersion and deposition model

UNIDOSE uses an ordinary straight line Gaussion model, with dispersion classes according to the Pasquill classification system and with dispersion parameter values according to Martin and Tiqvart, 1968.

The vertical dispersion is limited with by input given inversion heights, one for each class. When σ_z exceeds the inversion height, the vertical Gaussian distribution is replaced with an uniform one. Consideration is also taken to initial dispersion around the reactor building for ground releases. For release durations longer then 0.5 hour, σy is increased according to the formula below.

$$\frac{\sigma_y}{\sigma_{yo}} = (\text{Release time}/0.5)^{0.33}$$

The effect of meandering at low wind speeds is accounted for by

$$\sigma_{ym} = \sigma_y - (\sigma_y - 0.5 \cdot t) * \frac{U_m - u}{U_m - 1} \quad ; \; 1<u<2 \text{ m/s}$$

Where t is the plume travel time (s), u the windspeed and U_m the upper wind speed were the meandering effect is assumed to start. At u = 1 m/s, σy will equal $0.5 \cdot t$ and will be independent of Pasquill class. Windspeeds less than 1 m/s will be set to 1. U_m is normally set to 2 m/s.

The dry and wet deposition rate (Bq/m²·s) are calculated as

$$W_{dry} = V_d \cdot \chi \ (z = 1 \text{ m})$$

$$W_{wet} = \lambda \cdot \int_0^{\infty} \chi \ (z) \ dz$$

where V_d is the dry deposition velocity and λ the washout coefficient. Plume depletion is considered with subtraction of the deposited activity up to the actual down wind distance, and the depletion is assumed to occure along the entire height of the plume.

The net deposited activity is reduced with a run off factor that could be specified separately for rural and urban areas.

For chronic exposure, consideration is taken to weathering. Gale's formula is used, but the constants can be specified in input.

The wet deposited activity is reduced with a run off factor that could be specified separately for rural and urban areas.

For chronic exposure, consideration is taken to weathering. Gale's formula is used, but the constants can be specified in input.

The major drawbacks of the dispersion model is that wind speed slow down and short time rain storms cannot be handled properly.

4.2 Meteorological sampling

The meteorological input to UNIDOSE consists of hourly mean values of windspeed, wind direction, rain intensity and Pasquill class. In order to get a representative sample of data, where low wind and rain situations are included with respect to their occurence at the low probability end of the CCDF curve, stratified sampling have been used.

The data were classified in 17 weather classes and 2 situations were randomly sampled from each class. Table 4.2.1 shows the selected data and their probability of occurence.

4.3 Cloud-shine dose

The external gamma-dose from the passing cloud is calculated with a finite plume model, where the dose is calculated with integration over the actual activity concentration. This calculation involves a large amount of computing time, and is therefore performed in two steps.

In the first step, the dose is evaluated for discrete values of down wind and crosswind distance, plume height, energy of gamma-rays and Pasquill class, and stored on a disc file. The final calculation for an actual situation is then performed with interpolation in these tables and with summation over the released nuclides.

Consideration is taken to decay and build up of daughter nuclides during the delay time in the reactor, and during plume transport.

Shielding factors can be specified separately for urban and rural areas and for individual and for collective dose calculations.

4.4 Ground shine dose

The ground shine dose is calculated in a similar way as the cloud shine dose. The precalculated table contains now only values for different energies.

The dose is integrated to an arbitrary time with respect to the start and end of deposition. Consideration is taken to decay and build up of doughter nuclides in the air as well as on the ground. Shielding factors are specified similar to the cloud shine shielding factors.

4.5 Inhalation dose

The inhalation dose is calculated as a product of the time integrated activity concentration ($Bq \cdot s/m^3$) at ground level, the inhalation dose conversion factor (Sv/Bq) the breathing rate (m^3/s) and a house filtering factor that could be specified separately for urban and rural areas and for individual and collective doses. The breathing rate is set to 23 m^3/day and the dose conversion factors are from WASH 1400.

4.6 Ingestion doses

The ingestion doses to an individual is calculated as the product of the deposited activity (Bq/m^2), the time-integrated concentration factor for the actual foodstuff ($m^2 \cdot year/kg$), the individual consumption of locally produced foodstuff (kg/year) and the ingestion dose conversion factor (Sv/Bq).

The collective dose is calculated in a similar way but the individual consumption is replaced with the product of the fraction of area used for production of the food stuff and the production per area factor (kg/m^2), and integration is carried out over the whole area.

The time-integrated concentration factor is separated for direct deposition and root-uptake. If deposition occure off growing season, only root-uptake is considered. The factors were calculated with the BIOPATH code.

4.7 Health effects

Two types of health effects are considered - acute and chronic.

The acute effect - dose distribution is assumed to be cumulative normal, where the distribution is defined by the 50 % affection dose.

The chronic effects is calculated as a product of the collective dose and a chronic effect probability factor.

The dose input to the health effect model could be selected from any pathway or combinations of pathways and from to up to five different organs in the body.

4.8 Statistical treatment - CCDF's

Doses and health effects are calculated for each meteorological situation and conditional cumulative density functions (CCDF) as well as expectation values and other statistical quantities are calculated.

5 Scenario's and counter measures

In cooperation with the source term group within the Nordic Cooperation, six set of release categories were selected, shown in table 5.1. Category A1 - A3 represents severe accidents with core melt downs and with rupture of the containment. Category C1 represents similar accident, but with mitigation systems in operation.

These release categories are constructed only for the purpose of analysing the behaviour of consequence models and have no relation to real sites.

The site, meteorological data, population distribution as well as countermeasures used in this study are therefore selected without any purpose of representing any real site or real conditions.

Release category A and B will lead to consequences of the magnitude that all sorts of counter measures is necessary. Since the purpose of this study is to quantify uncertainties in consequences and not to study the effects of different countermeasures, and also due to the principal problem of involving authority decided countermeasures in an uncertainty analysis, simplified assumptions regarding countermeasures have been used.

Release category A1 and A3 have been selected to represent severe accidents where evacuation is necessary. For these categories, only the exposure received during plum passage and 24 hours after is considered.

For release category C1, no countermeasures at all is assumed, except for indoor staying during plume passage.

The site and meteorological data from the CSNI Benchmarc study is used. The selected release categories, the assumed countermeasures and site data are summarized below.

Release Category: A1, A3

Duration of external exposure:	Plume passage and 24 hours after.
Pathways of exposure:	External dose during plume pas sage. External dose from the ground. Inhalation dose during plume passage.
Counter measures:	Indoor staying during plume passage. Evacuation after 24 hours for the whole population.
Acute health effects based on:	Lung, bonemarrow and thyroid dose with 30 days internal exposure.
Chronic health effects based on:	Lung, bonemarrow and thyroid dose with 50 years internal exposure.

Release category C1

Duration of external exposure:	Plume passage and 50 years after.
Pathways of exposure:	Inhalation during plume passage. External dose during plume passage. External dose from the ground. Ingestion pathways.
Counter measures:	Indoor staying during plume passage.
No acute health effects:	
Chronic health effects as for A1 and A3:	
Population data:	Fictive distribution with 50 persons per km2 and 5 population centras.
Meteorological data:	Indian Point, one year

6 Parameter uncertainty estimates and selection of model responses

There are basically two types of parameters involved in consequence assessment models. Both types will influence the results in a similar way, but the nature of these parameters are different.

The first type, represented by the i.e. the wind speed, have a naturally variation with time that could be easily quantified with a frequency distribution. The other type, represented by i.e. the inhalation dose conversion factor, is probably time-invariant and have, within a given population at least, a exact but unknown value.

For a decision maker, it probably does not matter whether the variation of consequences originates from either type of parameters, but the important thing is that uncertainty originating from the first type of parameter can not be improved, but uncertainty from the latter type can, on the contrary, be reduced with research and/or better estimates. It is therefore necessary to separate these types of parameters and to include only parameters of the latter type in the study. The first types of parameters are instead included as independent variables of the CCDF curves.

The selection of parameters used in the study was based on the results of the test calculations in phase 1, on the limitations of the UNIDOSE code and on the scenarios.

The parameter uncertainty evaluation in phase 2 was carried out in a Nordic group of experts. The following experts contributed to the evaluation.

- Dispersion and deposition	Göran Nordlund, FMI, Finland
- Shielding, run off and weathering	Jörn Roed, RISÖ, Denmark
- Doses, health effects	Jon B Reitan, Ulf Tveten, IFE, Norway
- Ingestion pathways	Sture Nordlinder, Ulla Bergström, STUDSVIK, Sweden

The experts had to specify the uncertainty distributions for the selected parameters according to a special procedure. They could choose between the different types of distribution as described in section 3, and they specified the different parameters related to the selected distribution. Table 6.1 shows the results of the evaluation.

One major problem with a study of this type is to select the most significant model responses for the uncertainty and sensitivity analysis. If one, i.e. look only at the final results, in this case the total no of early and late fatalities, the important parameters from the sensitivity analysis will originate form the dominant pathway of exposure only. It is therefore necessary to study each pathway separate.

One could perform such an analysis on a single meteorological situation of course, and thus exclude variation from parameters of the first type. Since the CCDF:s , however, represents a more complete information of resulting consequences, the expectation value and the 95 percentile of the CCDF were selected as model responses for the analysis.

The model was run on a CDC Cyber computer, one run for each release case. Since the computer was availiable free of charge during night time, and since many parameters were involved, 500 iterations were made each run. It is not necessary to make that many iterations, a discussion of this problem is made in section 7.3.

For release case A1 and A3, the following quantities were analysed (exposures from plume passage and 24 hours after).

- Inhalation lung dose at 2 km
- 24 hour ground bone marrow dose from dry deposited activity at 2 km.
- Corresponding from wet deposited activity.
- Cloud-shine bone marrow dose at 2km.
- Total lung dose from plume passage and 24 hours at 2 km.
- Total collective lung dose out to 500 km from plume passage and 24 hours.
- Early fatalities

- Early radiation illness cases

- Late cancer cases.

For relase case C1, the following quantitys were analysed (exposures form plume passage and 50 years after).

- Total plume passage bonemarrow dose at 2km.

- 50 years ground bone marrow dose at 2 km.

- 50 years individual ingestion bone marrow doses at 2 km.

- Total 50 years bone marrow dose.

- Total collective plume passage bonemarrow dose.

- 50 years collective ground bone marrow dose.

- 50 years collective ingestion bone marrow dose.

- Total collective 50 years bone marrow dose.

7 Results

7.1 Uncertainty in model responses

Figures 7.1.1.a - 7.1.1.h shows the CCDF:s for a selection of these quantitys. The uncertainty bands, denoted 1 - 99 %, is the 5:th lowest and highest value at each point of the curve out of 500 runs. These bands thus represents the extreme outer bands of the distributions, but it is difficult to say whether they really corresponds to the true 1 -99% levels. The reason to choose the 5:th highest and lowest values are computational only.

Figure 7.1.2.a - 7.1.2.c shows the results in a somewhat different way. Here, the lowest value, the 5, 25, 50, 75 and 95 percentiles and the highest value (the 7 columns within the vertical lines) are plotted for the mean and 95 percentile of the CCDF for each quantity.

Finally, the actual distributions of the mean and 95 percentile are plotted in figure 7.1.3.a - 7.1.3.h.

The distribution of the most probable values, i.e no parameter variation at all, is also plotted for release case A1 (figure 7.1.3.a-c). These curves represents consequently the "uncertainty" from the naturally varying parameters, i.e the wind speed, stability etc. For this case, one can see that this "uncertainty" is quite similar to the uncertainty from the analysed parameters.

The following conclusions could be drawn:

In release case A1 and A3, the dominating pathway of exposure is inhalation during plume passage due to the relative high release fractions of Tellurium and Ruthenium. Release case C1 is completely dominated by the ingestion doses, but one should remember that all contaminated foodstuff are consumed.

The uncertainty in the probability that a consequence will be exceeded (figures 7.1.1.a-h) is growing very large at the low probability end of the curves, up 4-5 orders of magnitude, and there is no significant differences between the pathways of exposure. At a probability level of 95% (0.05 on the ordinate) the uncertainty is 1 - 2 orders of magnitude.

The uncertainties of the mean and 95% level of consequences (figures 7.1.2.a-c) are smaller. The qoutient between highest and lowest, which roughly corresponds to the 1 - 99% values in the CCDF curves, varies between 1 order of magnitude (cloud-shine dose), to 3 orders of magnitude (inhalation dose, collective total dose and the health-effects). The variation within one standard deviation (16% to 84%) is a factor 3 to 5 for most of the analysed consequences.

Note also the long tails of the distributions for the acute fatalities release case A1.

7.2 Identification of important parameters

Tables 7.2.1 to 7.2.3 shows the results of the regression analysis and the identification of important parameters. These tables summarizes the output from PRISM3, and an example of a full printout is shown in table 7.2.4.

The % COV column indicates the amount of variance that is explained by the uncertainty of the listed parameters. Differences in the results of the ranked and unranked regression indicates that there is a non-linear dependence between the parameter and the model response. Only covariances greater then 1 % are included in the tables. The high accuracy of these values are only due to the printout format, and have no real significance.

The difference between the analysis of the 95% value and the mean of the CCDF is not so large. Tendencys found for the meanvalues seems to be enlarged for the 95 percentiles

The overall most significant parameter for release category A1 and A3 is the wet deposition parameter, which is both negatively (plume depletion) and positively (increased wet deposition) correlated to the exposure.

The tables are summarized below

Release category A1 and A3

- Inhalation lung dose at 2 km:
  wet deposition, inhalation dose conversion factor and house filter factor.

- 24 hour ground bone marrow dose from dry deposited activity at 2 km:
  dry deposition, ground shielding and wet deposition

- Corresponding from wet deposited activity:
  wet deposition and ground shielding

- Cloud-shine bone marrow dose at 2km:
  plume shileding

- Total lung dose from plume passage and 24 hours at 2 km:
  same as for inhalation dose

- Total collective lung dose out to 500 km from plume passage and 24 hours:
  wet deposition

- Early fatalities:
  wet deposition

- Early illness:
  wet deposition

- Late cancer cases:
  wet deposition

Release category C1

- Total plume passage bonemarrow dose at 2km:
  plume shielding

- 50 years ground bone marrow dose at 2 km:
  ground shielding

- 50 years individual ingestion bone marrow doses at 2 km:
  food transfer factor

- Total 50 years bone marrow dose:
  food transfer factor

- Total collective plume passage bone marrow dose:
  plume shielding

- 50 years collective ground bone marrow dose:
  wet deposition

- 50 years collective ingestion bone marrow dose:
  food transfer factor

- Total collective 50 years bone marrow dose:
  food transfer factor

7.3 General aspects of the analysis

The number of iterations that have to be carried out in order to achieve the desired accuracy is crucial for the computer costs. Therefore, three runs with 50, 100 and 500 iterations were carried out, and the results is shown in table 7.3.1. As could be seen, the 50 and 100 iteration runs detected some false dependences, even from parameters not present in the calculations, but the conclusions made from these runs would be similar. Especially for the ranked regression, the differences are small.

8 Conclusions

The goals for this project have been to answer, or at least try to answer, the following questions.

1 How large are the uncertaintys in the results of a typical assessment.

2 Can these uncertaintys be reduced, and if so, to what extent.

3 Does uncertainty/sensitivity analysis improve consequence analysis

   a For the scientist, who carries out the analysis

   b For a decision maker

4 Which methods could be used, how easily can they be implemented into existing codes and how expensive are these methods to use.

The answer on the first question depends on what measure of uncertainty is to be used, i.e 1 - 99 % limits or variations within one standard deviation, and which quantity is used as result, i.e expectation values or 95 percentiles. The uncertainty grows rapidly with decreasing probability of occurence to several order of magnitudes at the low probability end of the CCDF curve. If one looks on the expectation value of the CCDF and variation within one standard deviation, the uncertainty is a factor 2 - 5 up and down.

The sensitivity analysis indicates which parameters causes the uncertainty. For some of these, such as the wet deposition coefficient or the dose conversion factors, it is not an easy task to reduce the uncertainty related to them. For others, like the shielding factors, improvements are more feasable. Sensitivity analysis could therefore be used in a cost/benefit way.

It is also possibly to compare the uncertainty from the analysed parameters with the variation or "uncertainty" induced by the naturally variating parameters (wind speed etc). There is no need to reduce the first type of uncertainty, at least from a decision makers point of view, to a large extent lower than then the latter. In this studys, these uncertaintys turned out to be fairly equal.

On the third question, the answer is, I believe, yes for both the scientist and the decisison maker. Without uncertainty analysis, the estimates of parameter values must be made conservative in order to get an upper limit of the consequences, sometimes leading to overconservative and almost useless results. With uncertainty analysis it is possible to use the most probable values in connection with a probability distributions, which is a more natural way to quantify the influence of a parameter. For the scientist, the cost/benefit approach to sensitivity analysis is very useful.

The decision maker wants to know the range of consequences for a given accident scenario, disregarding the sources of this variation, and with uncertainty analysis he/she can achieve this information. However, one problem is to find out procedures that present the results in a understandeble form.

On the fourth question, an answer could only be given for the methodology implemented in the PRISM codes.

With a dynamic structure as in the PRISM codes, it is very easy to perform uncertainty analysis on any code that reads parameter values and outputs model responses.

The computer costs are directly related to the necessary number of runs, and is therefore depending on the type of analysis that is to be performed. However, 50 to 100 runs seems to be adquate for most applications.

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Table 4.2.1

Selected meteorological situations with stratified sampling

Date	Wind-sector, 10-degree	Wind speed m/s	Rain mm/h	Pasquill class	Probability of occurence
80 919 1	27	3.0	2.0	4	.02717
80 41413	22	3.5	1.0	4	.02717
80 1 219	13	12.5	4.4	5	.00411
80 525 4	23	5.0	4.4	4	.00411
80101610	20	1.8	0.0	2	.00679
80 9 612	36	2.0	0.0	3	.00679
80 82116	17	4.0	0.0	3	.02346
80 73013	5	3.0	0.0	1	.02346
8010 910	14	5.5	0.0	1	.02574
80 62510	19	7.5	0.0	1	.02574
80 92816	14	9.0	0.0	1	.00274
80 517 8	20	8.3	0.0	3	.00274
80 814 6	20	1.0	0.0	4	.04201
80 92410	36	1.5	0.0	4	.04201
801015 8	16	3.8	0.0	4	.06398
80 6 918	36	4.0	0.0	4	.06398
8010 723	13	8.0	0.0	4	.10576
80 21715	19	6.0	0.0	4	.10576
80 115 1	14	9.5	0.0	4	.02460
80 2 214	14	9.0	0.0	4	.02460
801128 6	25	1.0	0.0	5	.05434
80 5 7 9	8	.5	0.0	5	.05434
801120 4	17	2.3	0.0	5	.04966
80 72019	7	3.0	0.0	5	.04966
80 320 7	19	4.5	0.0	5	.03893
80 22521	23	8.0	0.0	5	.03893
80111724	2	11.0	0.0	5	.00479
80 429 3	15	9.0	0.0	5	.00479
80 32920	28	.5	0.0	6	.01564
80 7 7 4	7	.8	0.0	6	.01564
80122321	14	2.3	0.0	6	.00868
80 7 622	17	2.8	0.0	6	.00868
80 92524	20	4.5	0.0	6	.00160
80 613 4	2	5.8	0.0	6	.00160
80 613 4	2	5.8	0.0	6	.00160

Table 5.1

Definition of source terms

Release category	Release delay (h)	Release duration (h)	Release height (m)	Nuclide groups Xe/Kr	I	Cs-Rb	Te-Sb	Ba-Sr Ru-La
A1	1	3	20	1.0	0.1	0.1	0.1	0.01
A2	10	3	20	1.0	0.1	0.1	0.1	0.01
A3	1	3	100	1.0	0.1	0.1	0.1	0.01
B1	1	3	20	1.0	0.01	0.01	0.01	0.001
B2	1	3	100	1.0	0.01	0.01	0.01	0.001
C1	1	3	20	1.0	0.001	0.001	0.001	0.0001

Table 6.1

Selected parameters and estimated uncertainties

Code name	Distr type	Std. dev	Low. lim.	Upp. lim.	Most prob.	Parameter description
'SY,A-D,X<1'	'T'	0	0.33	3.0	1.0	Error of sigma-Y, A-D, X<10km
'SY,E-F,X<1'	'T'	0	0.6	1.6	"	" E-F "
'SY,A-D,X>1'	'T'	0	0.3	3.3	"	" A-D X>10km
'SY,E-F,X>1'	'T'	0	0.5	1.7	"	" E-F "
'SZ,A-D,X<1'	'T'	0	0.27	4.0	"	Error of sigma-Z, A-D X<10km "
'SZ,E-F,X<1'	'T'	0	0.55	1.9	"	" E-F "
'SZ,A-D,X>1'	'T'	0	0.5	2.0	"	" A-D X>10km
'SZ,E-F,X>1'	'T'	0	0.24	4.4	"	" E-F "
'MIXINGH, A'	'T'	0	0.27	2.0	1500	Mixing height (m), Pasquill A
'MIXINGH, B'	'T'	0	0.30	2.5	1200	" B
'MIXINGH, C'	'T'	0	0.2	2.2	1000	" C
'MIXINGH, D'	'T'	0	0.1	2.9	750	" D
'MIXINGH, E'	'T'	0	0.25	1.9	400	" E
'MIXINGH, A'	'T'	0	0.24	1.9	400	" F
'MEAND, FAC'	'T'	0	0.5	1.5	-	Meandering factor, see text
'MEAND, UO '	'T'	0	0.6	1.5	2.0	Upper wind speed for meandering
'DRYD,PART '	'T'	0	0.33	6.6	0.3	Dry dep. for particles, (cm/s)
'DRYD,EL. I'	'T'	0	0.2	3	1.0	" el. Iodine "
'WETD,PART '	'T'	0	0.03	20	1.5E-4	Washout coeff., particles (s-1)
'WETD,EL. I'	'T'	0	0.5	5	2.0E-5	" el. Iodine "
'SHIELD,P,R'	'N'	0.5	0.5	1.7	0.12	Plume shielding, rural area
'SHIELD,P,U'	'N'	0.5	0.5	2.0	0.01	" urban "
'SHIELD,G,R'	'N'	0.25	0.5	1.5	0.10	Ground shielding, rural "
'SHIELD,G,U'	'N'	0.30	0.6	1.6	0.05	" urban "
'FILTER '	'LN'	0.4	0.4	2.0	0.5	Filter factor for houses
'RUNOFF,R '	'N'	0.1	.75	1.25	0.2	Run off, rural areas
'RUNOFF,U '	'N'	0.1	.67	1.33	0.4	" urban "
'WEATHERING'	'N'	0.5	0.5	2.0	0.3	Fraction of short time weathering
'T1/2 WEATH'	'LN'	0.4	0.5	2.0	300	Corresponding, $T_{\frac{1}{2}}$ (days)
'DOSOMVANDL'	'T'	0	0.33	3.33	W1400	Dose conv. fact., inhal. and inges.
'D-50 '	'T'	0	0.8	1.2	Diff	50% affection level, early effects
'LEUKEMI '	'T'	0	0.1	2.5	0.002	No of cancers per manSv, leukemi
'OTHR CANC'	'T'	0	0.16	1.66	0.03	" , other canc
'LUNG CANC '	'T'	0	0.33	3.33	0.006	" , lung canc
'THYR CANC '	'T'	0	0.16	1.33	0.03	" , thyroid
'INTFOOD '	'T'	0	.2	3.33	Diff	Food concentration factor (m2/kg)
'CONSUMPT. '	'T'	0	.5	2	Diff	Individual consumption, (kg/year)
'AREAFRACT.'	'T'	0	.5	2		Fraction of area used for growth
'PRODUCT. '	'T'	0	.5	2		Production of foodstuff, (kg/m2*y)
'T1/2 W LT '	'T'	0.4	0.5	2.0		Long time weathering $T_{\frac{1}{2}}$, (s)
'WINTER SH '	'T'	0	0.5	1.5		Shielding factor for winter cond.

Assumed correlations

'SHIELD,P,U'	'SHIELD,G,U'	0.5
'SHIELD,P,R'	'SHIELD,G,R'	0.5

Table 7.2.1

Identification of important parameters Release category A1.
Doses from plume passage and 24 hours.

Unranked regression Parameter	% cov	Ranked regression Parameter	% cov
Inhalation lung dose at 2 km, 95 % of CCDF			
DOSOMVANDL	26.6944	WETD,PART	35.6814
WETD,PART	24.2592	FILTER	27.8991
FILTER	21.1009	DOSOMVANDL	26.8149
DRYD,PART	1.77596	DRYD,PART	1.26777
SZ,E-F,X<1	1.32522		
Inhalation lung dose at 2 km, mean of CCDF			
DOSOMVANDL	24.9791	WETD,PART	35.5450
WETD,PART	23.6255	FILTER	27.7120
FILTER	20.9221	DOSOMVANDL	26.1841
SZ,A-D,X<1	1.69712	SZ,A-D,X<1	1.62645
DRYD,PART	1.26232	SY,A-D,X<1	1.10365
SZ,E-F,X<1	1.15498		
Ground-shine bonemarrow dose, dry deposition, at 2 km, 95 % of CCDF			
DRYD,PART	48.3616	DRYD,PART	52.5784
SHIELD,G,R	17.5649	SHIELD,G,R	17.3100
WETD,PART	16.0986	WETD,PART	16.1911
MEAND, U0	2.45586	MEAND, U0	2.56801
SY,E-F,X<1	1.76312	SY,E-F,X<1	2.23113
SZ,E-F,X<1	1.74894	SZ,E-F,X<1	1.81277
Ground-shine bonemarrow dose, dry deposition, at 2 km, mean of CCDF			
DRYD,PART	46.6807	DRYD,PART	53.6022
WETD,PART	15.0083	WETD,PART	15.4203
SHIELD,G,R	14.9051	SHIELD,G,R	14.6324
SZ,A-D,X<1	4.26888	SZ,A-D,X<1	4.25232
SY,A-D,X<1	3.21448	SY,A-D,X<1	2.06640
SZ,E-F,X<1	1.59429	SZ,E-F,X<1	1.46357
MEAND, FAC	1.15357	MEAND, FAC	1.04488
		SY,E-F,X<1	1.01619
Ground-shine bonemarrow dose, wet deposition, at 2 km, 95% of CCDF			
SHIELD,G,R	29.2484	WETD,PART	32.4713
WETD,PART	24.2070	SHIELD,G,R	28.3516
SY,E-F,X<1	5.11264	SY,E-F,X<1	5.75402
RUNOFF,R	4.81452	RUNOFF,R	4.14021
DRYD,PART	3.48132	DRYD,PART	3.43065
MEAND, U0	2.23396	MEAND, U0	1.99596

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Table 7.2.1 (Cont'd)

Identification of important parameters Release category A1. Doses from plume passage and 24 hours.

Unranked regression Parameter	% cov	Ranked regression Parameter	% cov
Ground-shine bonemarrow dose, wet deposition, at 2 km, mean of CCDF			
WETD,PART	25.2506	WETD,PART	35.6696
SHIELD,G,R	24.2486	SHIELD,G,R	23.6780
SY,A-D,X<1	11.6433	SY,A-D,X<1	11.1658
RUNOFF,R	5.16925	RUNOFF,R	3.59451
MEAND, FAC	1.91384	DRYD,PART	2.08305
DRYD,PART	1.71492	SY,E-F,X<1	1.64661
SY,E-F,X<1	1.34337	MEAND, FAC	1.00861
Cloud-shine bonemarrow dose at 2 km, 95 % of CCDF			
SHIELD,P,R	71.4186	SHIELD,P,R	73.6403
MEAND, U0	17.1812	MEAND, U0	14.9722
WETD,PART	1.98478	WETD,PART	1.82081
DRYD,PART	1.70649	DRYD,PART	1.62714
Cloud-shine bonemarrow dose at 2 km, mean of CCDF			
SHIELD,P,R	80.5163	SHIELD,P,R	83.3083
MEAND, FAC	5.51001	SY,A-D,X<1	4.11802
SY,A-D,X<1	4.94983	MEAND, FAC	4.17908
MEAND, U0	2.39069	WETD,PART	2.22584
WETD,PART	2.24094	MEAND, U0	2.02320
DRYD,PART	1.02950		
Total lung dose at 2 km, 95 % of CCDF			
DOSOMVANDL	27.1272	WETD,PART	32.5914
WETD,PART	23.4769	FILTER	27.7188
FILTER	21.4642	DOSOMVANDL	26.2888
SY,E-F,X<1	1.48253	SY,E-F,X<1	1.45969
SZ,E-F,X<1	1.49032	MEAND, U0	1.43137
DRYD,PART	1.25809	SHIELD,G,R	1.20051
Total lung dose at 2 km, mean of CCDF			
DOSOMVANDL	25.7521	WETD,PART	28.2316
WETD,PART	20.8347	FILTER	27.8767
FILTER	21.6340	DOSOMVANDL	25.9846
SZ,A-D,X<1	1.92166	SY,A-D,X<1	3.41985
SY,A-D,X<1	1.78766	SZ,A-D,X<1	1.91492
SZ,E-F,X<1	1.31041	SHIELD,G,R	1.82197

Table 7.2.1 (Cont'd)

Identification of important parameters Release category A1.
Doses from plume passage and 24 hours.

Unranked regression Parameter	% cov	Ranked regression Parameter	% cov
Collective total lung dose out to 500 km, 95 % of CCDF			
WETD,PART	15.9439	WETD,PART	67.4849
DOSOMVANDL	7.29676	DOSOMVANDL	13.7987
FILTER	3.88326	FILTER	12.7940
DRYD,PART	1.36090		
SZ,E-F,X<1	1.05407		
Collective total lung dose out to 500 km, mean of CCDF			
WETD,PART	17.9752	WETD,PART	68.2258
DOSOMVANDL	6.62303	FILTER	13.6715
FILTER	4.19835	DOSOMVANDL	12.5331
DRYD,PART	1.37491		
Acute fatalities, 95 % of CCDF			
WETD,PART	17.4283	WETD,PART	42.8702
DOSOMVANDL	12.5319	DOSOMVANDL	19.3123
FILTER	10.7992	FILTER	17.5218
DRYD,PART	2.04619	LD-50	1.65917
SZ,E-F,X<1	1.52924		
RUNOFF,R	1.05988		
Acute fatalities, mean of CCDF			
DOSOMVANDL	11.4564	DOSOMVANDL	27.6012
WETD,PART	10.6151	FILTER	25.0527
FILTER	9.49622	WETD,PART	8.66026
DRYD,PART	1.91458	SHIELD,G,R	5.06591
RUNOFF,R	1.32954	LD-50	2.71780
SZ,E-F,X<1	1.27676	SZ,A-D,X<1	1.41633
Acute illness, 95 % of CCDF			
WETD,PART	34.7362	WETD,PART	46.3250
DOSOMVANDL	10.3472	DOSOMVANDL	8.67572
FILTER	6.16428	SHIELD,G,U	6.71943
SHIELD,G,U	3.82823	FILTER	6.46569
DRYD,PART	1.86889	SY,A-D,X<1	3.22695
SZ,E-F,X<1	1.77199	LD-50	2.84677
SY,A-D,X<1	1.12993	RUNOFF,U	1.55299
		MEAND, FAC	1.40337
		SZ,E-F,X<1	1.20323
		DRYD,PART	1.14445

Table 7.2.1 (Cont'd)

Identification of important parameters Release category A1.
Doses from plume passage and 24 hours.

Unranked regression Parameter	% cov	Ranked regression Parameter	% cov
Acute illness, mean of CCDF			
WETD,PART	31.2920	WETD,PART	57.4569
DOSOMVANDL	9.79495	DOSOMVANDL	6.74108
FILTER	6.79287	SHIELD,G,U	5.50483
DRYD,PART	2.91960	FILTER	5.35413
SZ,E-F,X<1	1.56585	LD-50	2.54461
SHIELD,G,U	1.33216	SY,A-D,X<1	2.53805
		DRYD,PART	2.09432
		MEAND, FAC	1.76947
		RUNOFF,U	1.19116
Late cancers, 99% of CCDF			
WETD,PART	14.4920	FILTER	21.5950
DRYD,PART	14.0450	WETD,PART	21.8624
DOSOMVANDL	12.7615	DRYD,PART	19.8863
FILTER	11.5076	DOSOMVANDL	18.0702
THYR CANC	3.35422	THYR CANC	10.5436
Late cancers, 99% of CCDF			
WETD,PART	16.3166	WETD,PART	25.2148
DOSOMVANDL	13.9342	FILTER	21.4299
DRYD,PART	13.8739	DRYD,PART	19.5996
FILTER	12.5699	DOSOMVANDL	17.7169
THYR CANC	4.14670	THYR CANC	10.4666

Table 7.2.2

Identification of important parameters Release category A3. Doses from plume passage and 24 hours.

Unranked regression Parameter	% cov	Ranked regression Parameter	% cov
Inhalation lung dose at 2 km, 95 % of CCDF			
DOSOMVANDL	25.5624	WETD,PART	29.8086
WETD,PART	20.1279	DOSOMVANDL	26.5537
FILTER	20.6072	FILTER	25.5639
SY,A-D,X<1	6.62165	SY,A-D,X<1	7.90389
		SZ,E-F,X<1	1.56327
Inhalation lung dose at 2 km, mean of CCDF			
DOSOMVANDL	26.1845	FILTER	29.4208
FILTER	23.7291	DOSOMVANDL	27.4684
WETD,PART	14.7642	WETD,PART	18.2150
SY,A-D,X<1	6.90175	SY,A-D,X<1	7.42898
SZ,E-F,X<1	4.03723	SZ,E-F,X<1	6.14701
Ground-shine bone marrow dose, dry deposition, at 2 km, 95 % of CCDF			
DRYD,PART	53.3383	DRYD,PART	62.8852
SHIELD,G,R	9.46610	SHIELD,G,R	9.54433
SY,A-D,X<1	8.72003	WETD,PART	8.07006
WETD,PART	7.90637	SY,A-D,X<1	7.66465
SZ,E-F,X<1	1.12653	SZ,E-F,X<1	1.37798
Ground-shine bone marrow dose, dry deposition, at 2 km, mean of CCDF			
DRYD,PART	52.1848	DRYD,PART	61.5628
SY,A-D,X<1	8.47280	SY,A-D,X<1	7.80799
SHIELD,G,R	7.99833	SHIELD,G,R	7.47102
SZ,E-F,X<1	6.24091	SZ,E-F,X<1	6.80213
WETD,PART	5.04028	WETD,PART	4.28614
		SZ,A-D,X<1	2.12156
Ground-shine bone marrow dose, wet deposition, at 2 km, 95% of CCDF			
WETD,PART	34.0922	WETD,PART	41.7525
SHIELD,G,R	29.4374	SHIELD,G,R	29.7793
SY,E-F,X<1	5.30147	SY,E-F,X<1	5.74057
RUNOFF,R	5.13473	RUNOFF,R	4.14921

Table 7.2.2 (Cont'd)

Identification of important parameters Release category A3.
Doses from plume passage and 24 hours.

Unranked regression Parameter	% cov	Ranked regression Parameter	% cov
Ground-shine bone marrow dose, wet deposition, at 2 km, mean of CCDF			
WETD,PART	46.2605	WETD,PART	57.7118
SHIELD,G,R	19.1260	SHIELD,G,R	17.6622
SY,A-D,X<1	8.95218	SY,A-D,X<1	8.11010
RUNOFF,R	4.14256	RUNOFF,R	2.65084
SY,E-F,X<1	1.66349	SY,E-F,X<1	1.71252
Cloud-shine bone marrow dose at 2 km, 95 % of CCDF			
SHIELD,P,R	70.9407	SHIELD,P,R	77.6463
SY,A-D,X<1	7.51691	MEAND, U0	5.42342
MEAND, U0	4.60848	SY,A-D,X<1	4.62575
MEAND, FAC	3.09934	WETD,PART	2.92586
WETD,PART	2.76398	MEAND, FAC	1.61383
Cloud-shine bone marrow dose at 2 km, mean of CCDF			
I.BM.4.ME		I.BM.4.ME	
SHIELD,P,R	91.8020	SHIELD,P,R	92.8313
WETD,PART	2.34122	WETD,PART	2.16080
SY,A-D,X<1	2.04561	SY,A-D,X<1	1.74469
MEAND, FAC	1.75781	MEAND, FAC	1.34070
Total lung dose at 2 km, 95 % of CCDF			
DOSOMVANDL	19.1611	SHIELD,G,R	17.9657
FILTER	16.1399	FILTER	15.8638
SHIELD,G,R	8.53079	DOSOMVANDL	14.1845
SY,A-D,X<1	7.23691	SY,A-D,X<1	7.25285
SY,E-F,X<1	3.06100	SY,E-F,X<1	4.70316
SZ,E-F,X<1	2.74715	SZ,E-F,X<1	4.29701
RUNOFF,R	2.08954	RUNOFF,R	3.05757
Total lung dose at 2 km, mean of CCDF			
SY,A-D,X<1	20.7708	SY,A-D,X<1	20.9697
FILTER	17.6435	FILTER	16.5418
DOSOMVANDL	16.5725	SHIELD,G,R	12.8947
SHIELD,G,R	10.6736	DOSOMVANDL	12.7932
WETD,PART	3.75604	WETD,PART	8.44823
SZ,E-F,X<1	3.10330	SZ,E-F,X<1	3.92085
RUNOFF,R	2.66444	RUNOFF,R	2.35279
SY,E-F,X<1	1.74516	SY,E-F,X<1	1.64904

Table 7.2.2 (Cont'd)

Identification of important parameters Release category A3.
Doses from plume passage and 24 hours.

Unranked regression Parameter	% cov	Ranked regression Parameter	% cov
Collective total lung dose out to 500 km, 95 % of CCDF			
WETD,PART	17.0447	WETD,PART	86.6647
DOSOMVANDL	3.97517	FILTER	5.31261
FILTER	2.43669	DOSOMVANDL	4.97445
Collective total lung dose out to 500 km, mean of CCDF			
WETD,PART	17.8257	WETD,PART	83.9799
DOSOMVANDL	4.32490	FILTER	6.44126
FILTER	2.68424	DOSOMVANDL	6.10314
Acute fatalities, 95 % of CCDF			
WETD,PART	7.94972	WETD,PART	43.2614
LD-50	3.57969	SHIELD,G,R	12.2069
SHIELD,G,R	3.42256	LD-50	4.96953
DOSOMVANDL	2.99730	SHIELD,G,U	2.97094
FILTER	2.86168	RUNOFF,R	1.70527
SY,E-F,X<1	2.38779	FILTER	1.47280
SHIELD,G,U	2.07201	MEAND, FAC	1.41374
RUNOFF,U	1.13869	DOSOMVANDL	1.35202
T1/2 W LT	1.00346	SY,E-F,X<1	1.04297
Acute fatalities, mean of CCDF			
WETD,PART	65.2184	WETD,PART	72.3923
SHIELD,G,R	15.0375	SHIELD,G,R	14.1778
LD-50	2.56706	LD-50	2.26296
RUNOFF,R	2.04441	RUNOFF,R	1.86833
Acute illness, 95 % of CCDF			
SHIELD,G,U	24.5869	SHIELD,G,U	31.9865
WETD,PART	13.6022	WETD,PART	30.3552
SY,A-D,X<1	6.11513	RUNOFF,U	5.09820
RUNOFF,U	4.83765	LD-50	3.54728
LD-50	3.11043	SZ,E-F,X<1	1.84605
		SY,A-D,X<1	1.09991

Table 7.2.2 (Cont'd)

Identification of important parameters Release category A3. Doses from plume passage and 24 hours.

Unranked regression Parameter	% cov	Ranked regression Parameter	% cov
Acute illness, mean of CCDF			
SHIELD,G,U	19.3794	WETD,PART	29.1913
WETD,PART	14.7856	SHIELD,G,U	23.2844
SY,A-D,X<1	8.79334	LD-50	5.38671
LD-50	4.39145	RUNOFF,U	3.94135
RUNOFF,U	4.33823	SY,A-D,X<1	3.68918
SHIELD,G,R	1.90486	SHIELD,G,R	2.61491
UTSLÄPPTID	1.07314	SZ,E-F,X<1	1.36128
Late cancers, 95% of CCDF			
WETD,PART	20.9918	WETD,PART	38.4236
DOSOMVANDL	15.0846	FILTER	19.6640
FILTER	11.2922	DOSOMVANDL	16.9954
DRYD,PART	7.88462	THYR CANC	9.32787
THYR CANC	4.06154	DRYD,PART	8.95172
Late cancers, mean of CCDF			
WETD,PART	23.6955	WETD,PART	41.3611
DOSOMVANDL	15.5720	FILTER	19.4553
FILTER	11.6568	DOSOMVANDL	17.2464
DRYD,PART	6.40017	THYR CANC	9.70112
THYR CANC	4.67151	DRYD,PART	6.55876

Table 7.2.3

Identification of important parameters Release category C1.
Doses from plume passage and 50 years.

Unranked regression Parameter	% cov	Ranked regression Parameter	% cov
Total plume passage bone marrow dose at 2km, 95 % of CCDF			
SHIELD,P,R	47.9547	SHIELD,P,R	49.8466
MEAND, U0	21.5650	MEAND, U0	18.6555
DOSOMVANDL	8.33469	DOSOMVANDL	6.89838
FILTER	7.08216	FILTER	6.67792
WETD,PART	2.49426	WETD,PART	2.05203
SHIELD,G,R	1.54151	SHIELD,G,R	1.99349
Total plume passage bone marrow dose at 2km, mean of CCDF			
SHIELD,P,R	65.8609	SHIELD,P,R	68.0103
MEAND, FAC	8.66332	MEAND, FAC	7.08924
DOSOMVANDL	6.48502	FILTER	5.98475
FILTER	5.77909	DOSOMVANDL	5.06377
MEAND, U0	2.93111	SHIELD,G,R	2.39453
SHIELD,G,R	2.25284	MEAND, U0	2.35331
Ground-shine 50 year bonemarrow dose at 2km, 95 % of CCDF			
SHIELD,G,R	39.2256	SHIELD,G,R	38.7651
WEATHERING	17.2111	WEATHERING	15.6664
SY,E-F,X<1	5.58372	SY,E-F,X<1	5.95732
T1/2 W LT	4.47955	WETD,PART	4.19377
RUNOFF,R	3.06255	T1/2 W LT	4.02038
MEAND, U0	2.99457	MEAND, U0	3.35094
WETD,PART	1.95065	RUNOFF,R	2.85929
Ground-shine 50 year bonemarrow dose at 2km, mean of CCDF			
SHIELD,G,R	29.2156	SHIELD,G,R	30.0075
WEATHERING	15.8235	WEATHERING	15.3546
SY,A-D,X<1	13.5414	SY,A-D,X<1	12.7706
T1/2 W LT	3.82886	WETD,PART	4.85649
RUNOFF,R	3.69154	T1/2 W LT	3.51298
MEAND, FAC	1.88984	RUNOFF,R	2.86500
WETD,PART	1.62831	MEAND, FAC	1.73902
MEAND, U0	1.21839	SY,E-F,X<1	1.39429
WINTER SH	1.16219	MEAND, U0	1.18378
		WINTER SH	1.14982
Total ingestion bone marrow dose at 2 km, 95 % of CCDF			
INTFOOD	32.0872	INTFOOD	40.9341
DOSOMVANDL	28.7781	DOSOMVANDL	29.9931
CONSUMPT.	12.8251	CONSUMPT.	11.9767
SY,E-F,X<1	1.42023	MEAND, U0	1.46134
MEAND, U0	1.18411	SY,E-F,X<1	1.31666

Total ingestion bone marrow dose at 2 km, mean of CCDF

INTFOOD	30.2518	INTFOOD	39.0532
DOSOMVANDL	28.7434	DOSOMVANDL	28.8181
CONSUMPT.	12.9269	CONSUMPT.	12.8009
SY,A-D,X<1	2.87130	SY,A-D,X<1	2.98395
MEAND, U0	1.09273	MEAND, U0	1.48850
		MEAND, FAC	1.05797

Collective bone marrow dose from plume passage, 95 % of CCDF

FILTER	20.8792	SHIELD,P,R	20.8730
DOSOMVANDL	17.0431	FILTER	19.1551
SHIELD,P,R	14.6561	DOSOMVANDL	15.8448
SZ,E-F,X>1	12.8026	SHIELD,P,U	13.5460
SHIELD,P,U	11.8851	SZ,E-F,X>1	12.1498
SY,E-F,X>1	2.58598	SY,E-F,X>1	3.32113

Collective bone marrow dose from plume passage, mean of CCDF

SHIELD,P,R	50.2046	SHIELD,P,R	55.8163
FILTER	12.3416	FILTER	11.3659
DOSOMVANDL	11.2420	DOSOMVANDL	10.0051
SY,E-F,X>1	4.92807	SY,E-F,X>1	5.30410
MEAND, FAC	5.00584	MEAND, FAC	3.75428
SHIELD,P,U	2.31589	SHIELD,P,U	1.81317
SZ,E-F,X>1	1.51302	SZ,E-F,X>1	1.04806
SY,A-D,X>1	1.21655		

Collective bone marrow dose from 50 years ground-shine, 95% of CCDF

WETD,PART	28.4215	WETD,PART	35.1644
SHIELD,G,U	13.4543	SY,A-D,X<1	16.4466
WEATHERING	9.43191	SHIELD,G,U	13.0968
SY,A-D,X<1	7.56340	WEATHERING	11.6500
T1/2 W LT	1.86271	T1/2 W LT	2.31805
RUNOFF,U	1.36060	RUNOFF,U	2.05995
SY,A-D,X>1	1.15674		

Table 7.2.3 (Cont'd)

Identification of important parameters Release category C1.
Doses from plume passage and 50 years.

Unranked regression Parameter	% cov	Ranked regression Parameter	% cov
Collective bone marrow dose from 50 years ground-shine, mean of CCDF			
WETD,PART	46.8523	WETD,PART	63.6901
WEATHERING	7.15100	WEATHERING	11.5109
SHIELD,G,U	4.19590	SHIELD,G,R	7.83405
SHIELD,G,R	3.40050	SHIELD,G,U	3.70147
T1/2 W LT	1.73172	T1/2 W LT	2.82717
		SY,A-D,X<1	1.21821
Collective ingestion bone marrow dose, 99% of CCDF			
INTFOOD	29.9238	INTFOOD	38.8247
DOSOMVANDL	27.6195	DOSOMVANDL	32.6621
AREAFRACT.	12.9150	PRODUCT.	11.3963
PRODUCT.	9.77688	AREAFRACT.	10.0834
Collective ingestion bone marrow dose, mean of CCDF			
INTFOOD	29.9508	INTFOOD	38.6985
DOSOMVANDL	27.7766	DOSOMVANDL	32.4304
AREAFRACT.	12.8412	PRODUCT.	11.3286
PRODUCT.	9.62925	AREAFRACT.	10.0639

Table 7.2.4

Example of full printout of regression analysis from PRISM3

DEPENDENT VARIABLE I.LU.1.95 UNRANKED REGRESSIONS
MEAN = 2181.73 R2 = 75.16

INDEPENDENT VARIABLES	DF	MEAN	SEQUENTIAL SUM OF SQS	SLOPE	PRODUCT	R2 IMPROVE
INTERCEPT	1			619.958		
DOSOMVANDL	1	1.55330	5.069344E+08	1522.86	2365.45	26.6944
WETD,PART	1	7.01000	4.606886E+08	-213.811	-1498.82	24.2592
FILTER	1	1.00884	4.007125E+08	2080.58	2098.97	21.1009
DRYD,PART	1	2.64340	3.372605E+07	-183.030	-483.823	1.77596
SZ,E-F,X<1	1	1.15001	2.516635E+07	-799.997	-920.008	1.32522
ERROR	494		4.718009E+08	MSE =	955063.	
TOTAL	499		1.899029E+09			

DEPENDENT VARIABLE I.LU.1.95 RANKED REGRESSIONS
MEAN = 250.500 R2 = 91.66

INDEPENDENT VARIABLES	DF	MEAN	SEQUENTIAL SUM OF SQS	SLOPE	PRODUCT	R2 IMPROVE
INTERCEPT	1			168.824		
WETD,PART	1	250.500	3.716802E+06	-.598759	-149.989	35.6814
FILTER	1	250.500	2.906143E+06	.519932	130.243	27.8991
DOSOMVANDL	1	250.500	2.793207E+06	.517482	129.629	26.8149
DRYD,PART	1	250.500	132059.	-.112604	-28.2073	1.26777
ERROR	495		868414.	MSE =	1754.37	
TOTAL	499		1.041663E+07			

Table 7.3.1

Regression analysis of 50, 100 and 500 iterations for 95 percentile of inhalation lung dose at 2km, release case A1.

N=50		N=100		N=500	
Unranked regression					
DOSOMVANDL	25.9	WETD,PART	23.7	DOSOMVANDL	26.6
WETD,PART	17.6	FILTER	22.1	WETD,PART	24.2
FILTER	17.3	DOSOMVANDL	19.6	FILTER	21.1
DRYD,PART	3.92	DRYD,PART	2.34	DRYD,PART	1.77
THYR CANC	4.04	MIXINGH, B	1.75	S2,E-F,X<1	1.32
TERMEFFEKT	4.02	SY,E-F,X<1	1.28		
T1/2 W LT	3.21	MEAND, U0	1.19		
VAKANT 2	1.93	MEAND, FAC	1.02		
SHIELD,G,R	2.84				
VAKANT 4	1.82				
MIXINGH, E	1.43				
MIXINGH, A	1.51				
CONSUMPT.	1.26				
VAKANT 3	1.21				
SY,E-F,X>1	1.28				
Ranked regression					
WETD,PART	40.78	WETD,PART	37.3	WETD,PART	35.6
FILTER	31.19	FILTER	26.7	FILTER	27.8
DOSOMVANDL	19.31	DOSOMVANDL	27.7	DOSOMVANDL	26.8
SHIELD,G,R	1.147			DRYD,PART	1.26

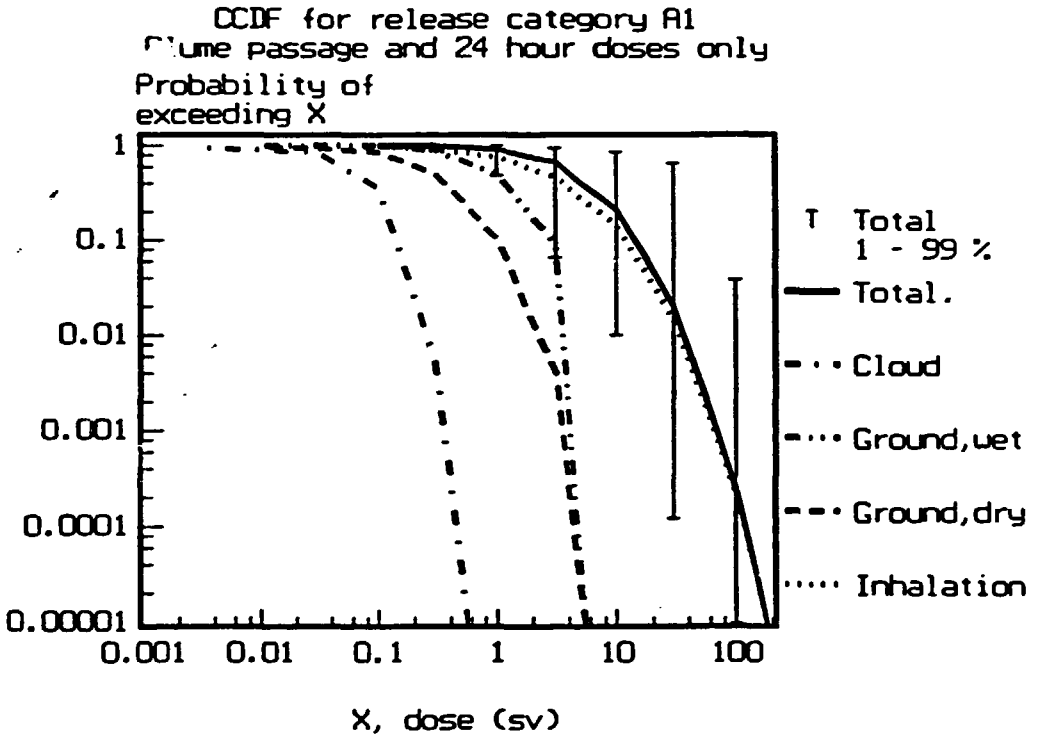

Figure 7.1.1.a

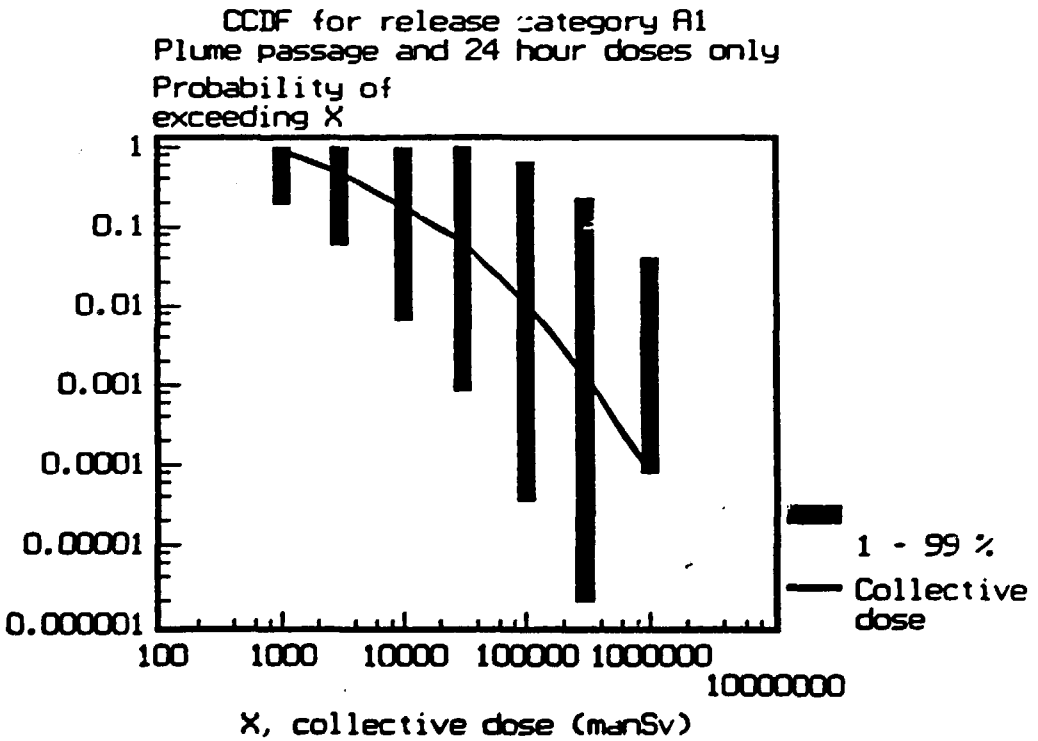

Figure 7.1.1.b

Note: **The results presented represent fictive source terms and site assumptions, and have therefore no signigicance to any real sites.**

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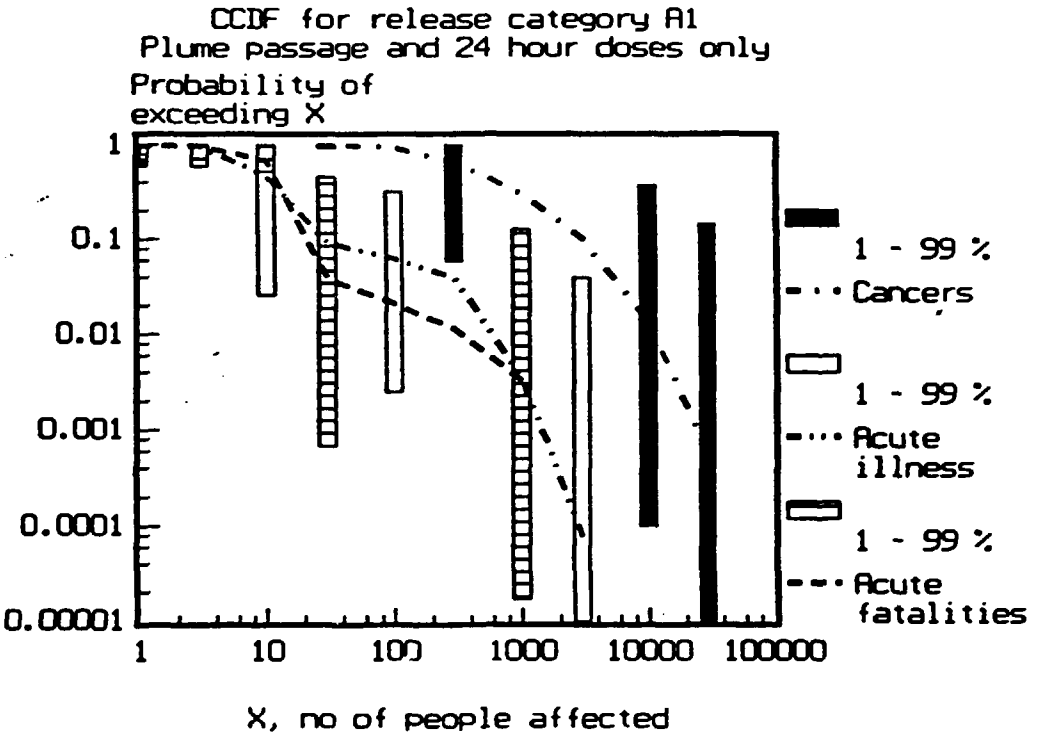

Figure 7.1.1.c

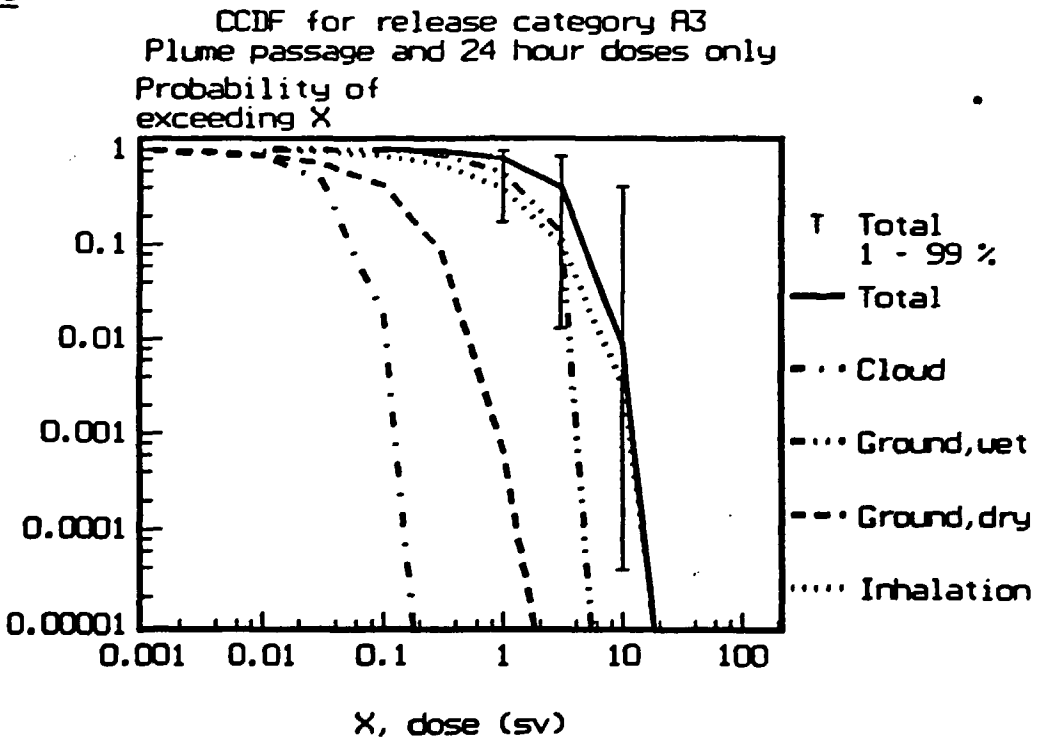

Figure 7.1.1.d

Note: The results presented represent fictive source terms and site assumptions, and have therefore no signigicance to any real sites.

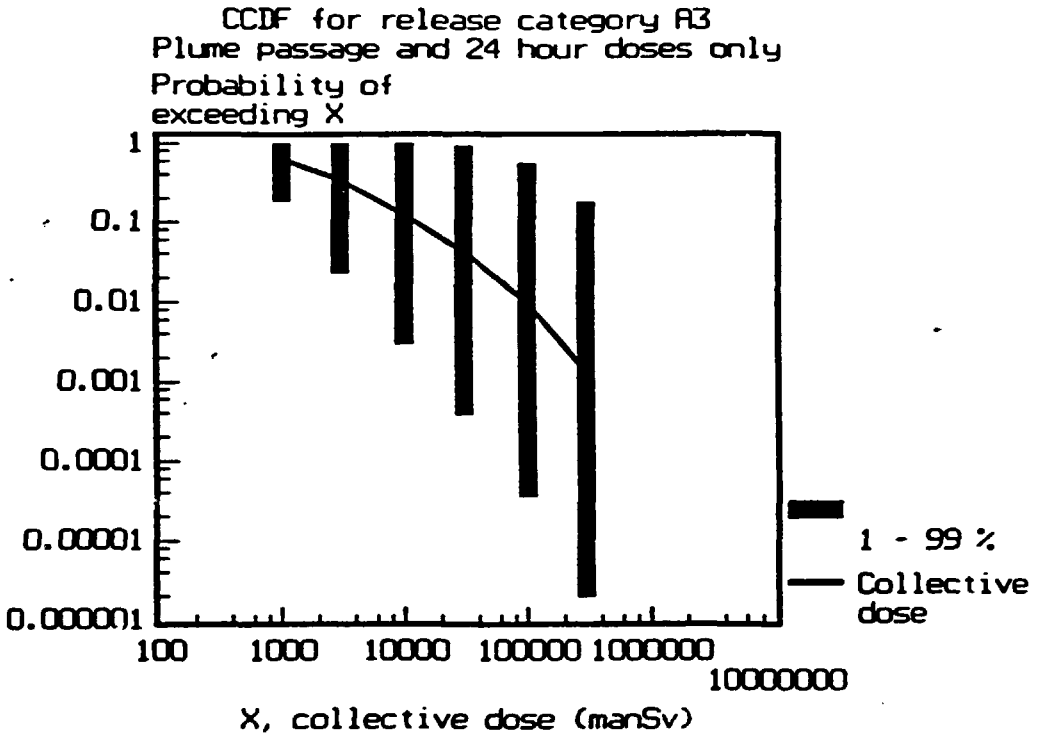

Figure 7.1.1.e

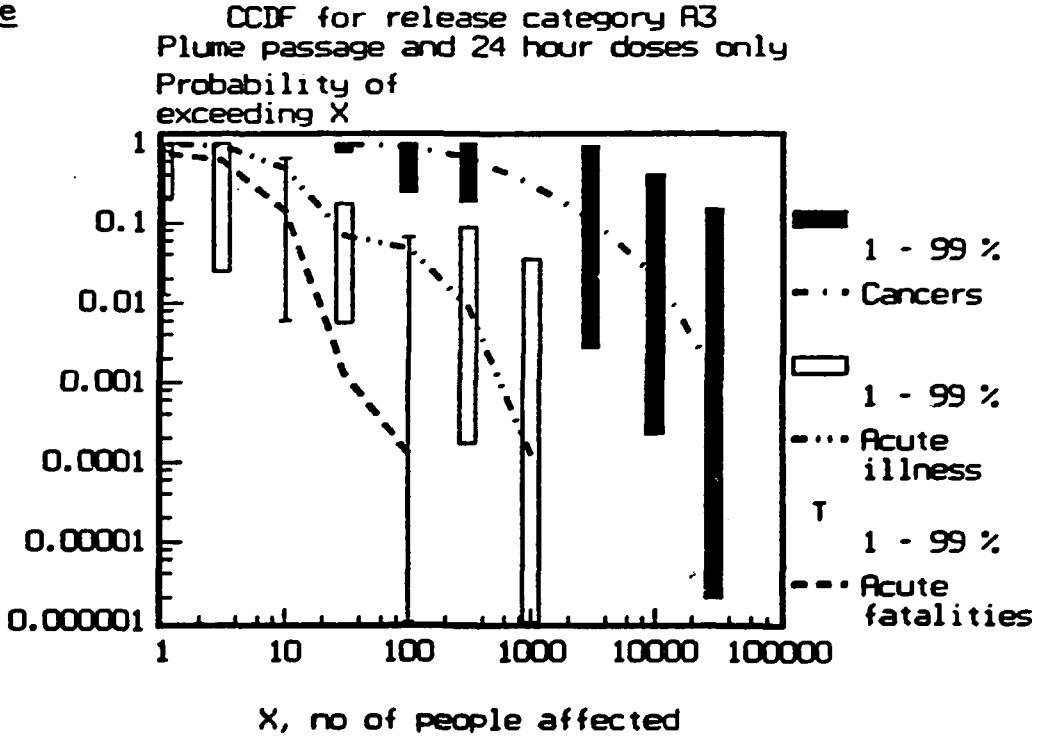

Figure 7.1.1.f

Note: **The results presented represent fictive source terms and site assumptions, and have therefore no signigicance to any real sites.**

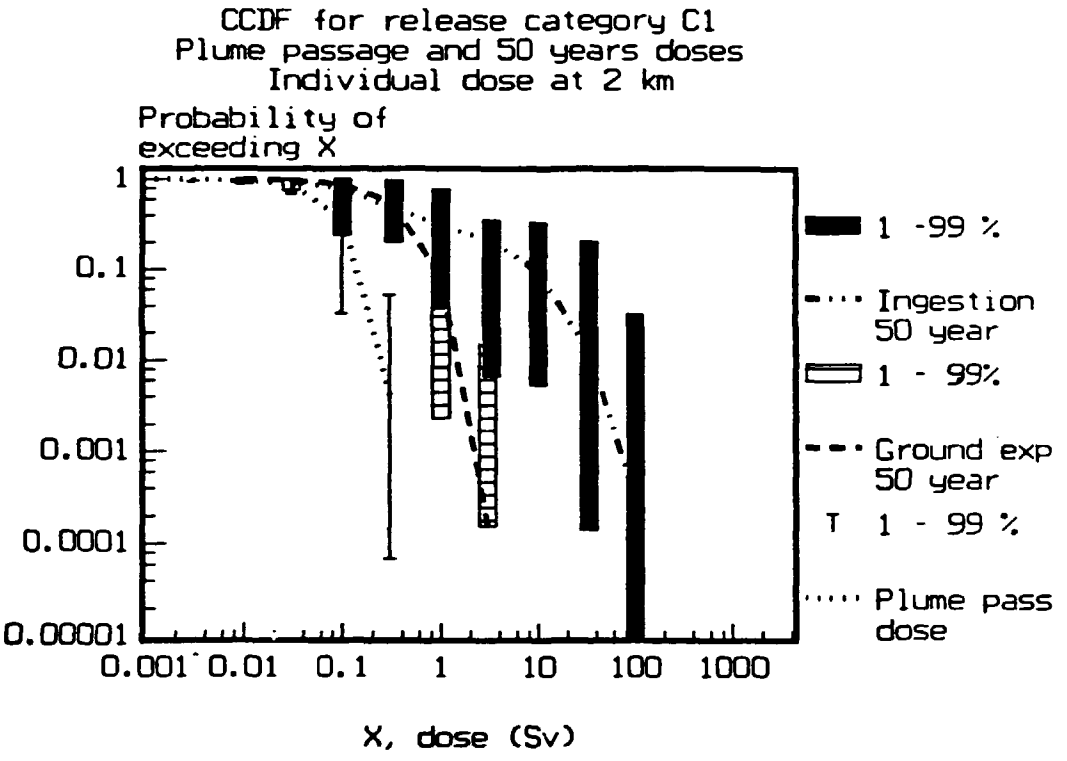

Figure 7.1.1.g

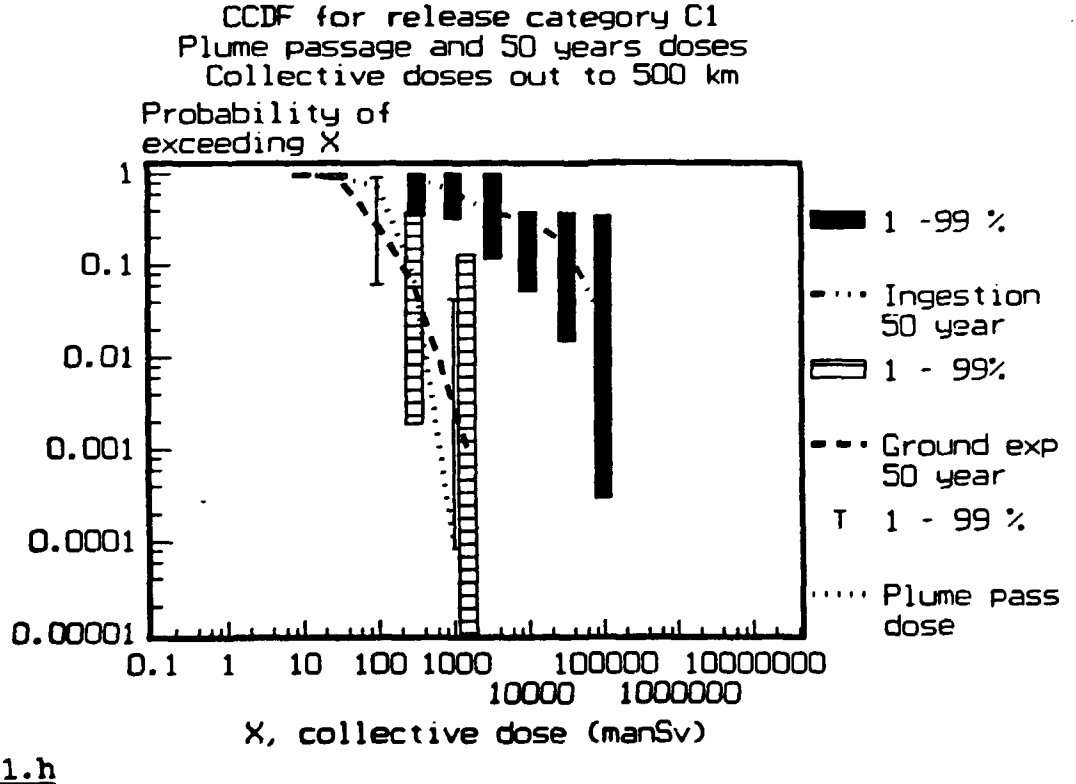

Figure 7.1.1.h

Note: The results presented represent fictive source terms and site assumptions, and have therefore no signigicance to any real sites.

STURAPP NPE/HE

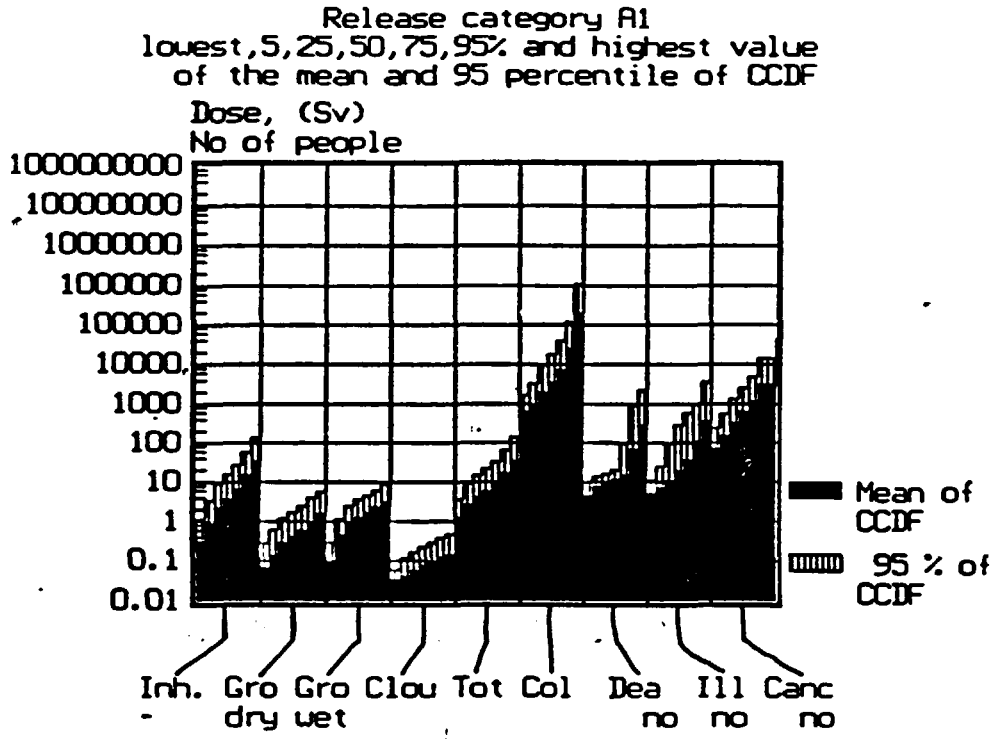

Figure 7.1.2.a

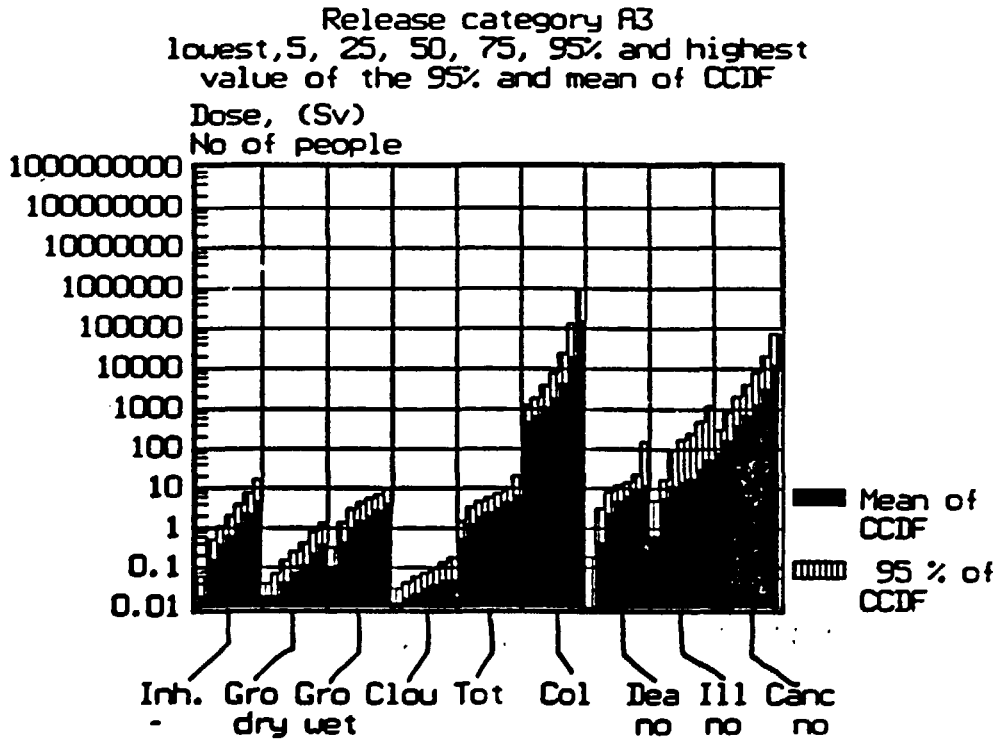

Figure 7.1.2.b

Note: **The results presented represent fictive source terms and site assumptions, and have therefore no signigicance to any real sites.**

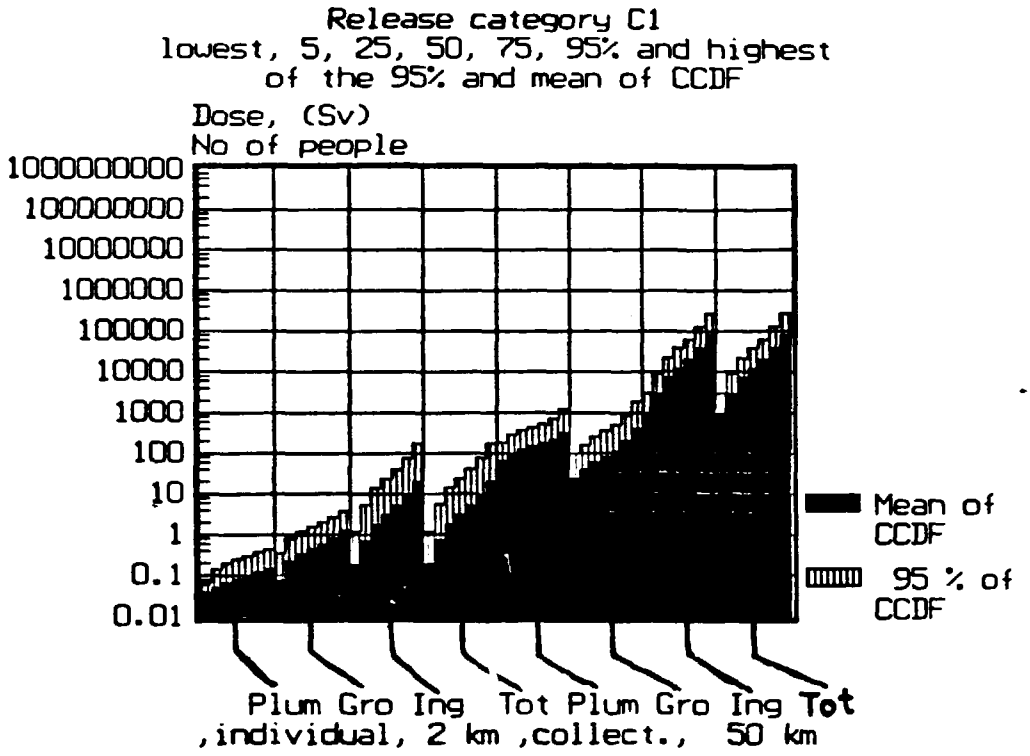

Figure 7.1.2.c

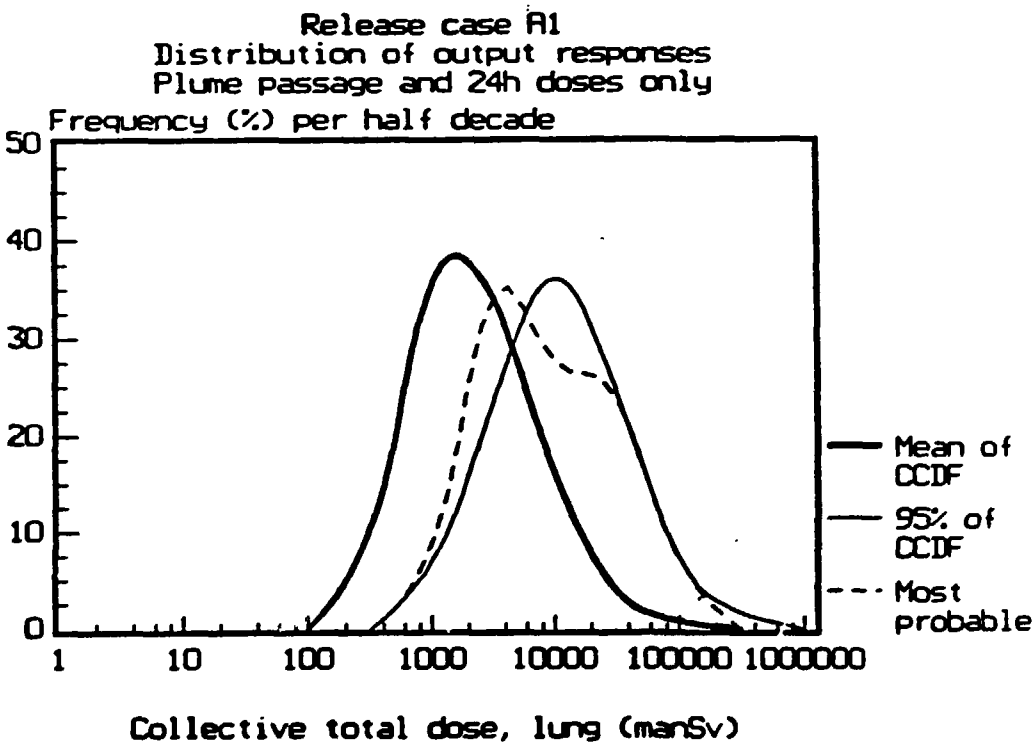

Figure 7.1.3.a

Note: The results presented represent fictive source terms and site assumptions, and have therefore no signigicance to any real sites.

STURAPP NPE/HE

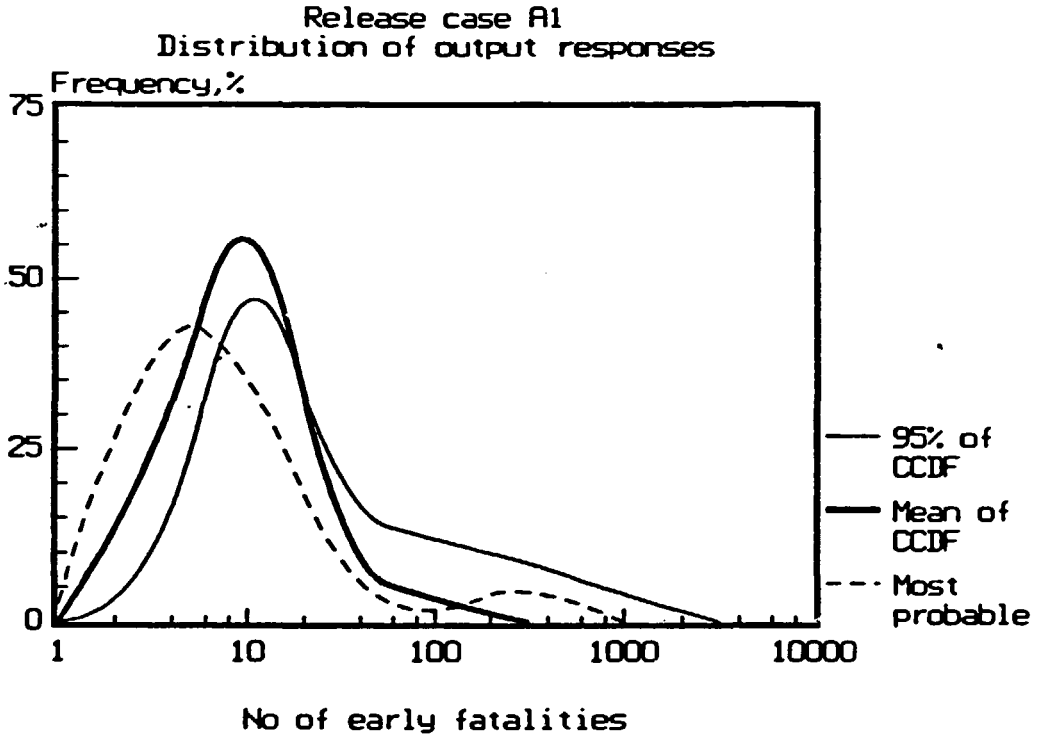

Figure 7.1.3.b

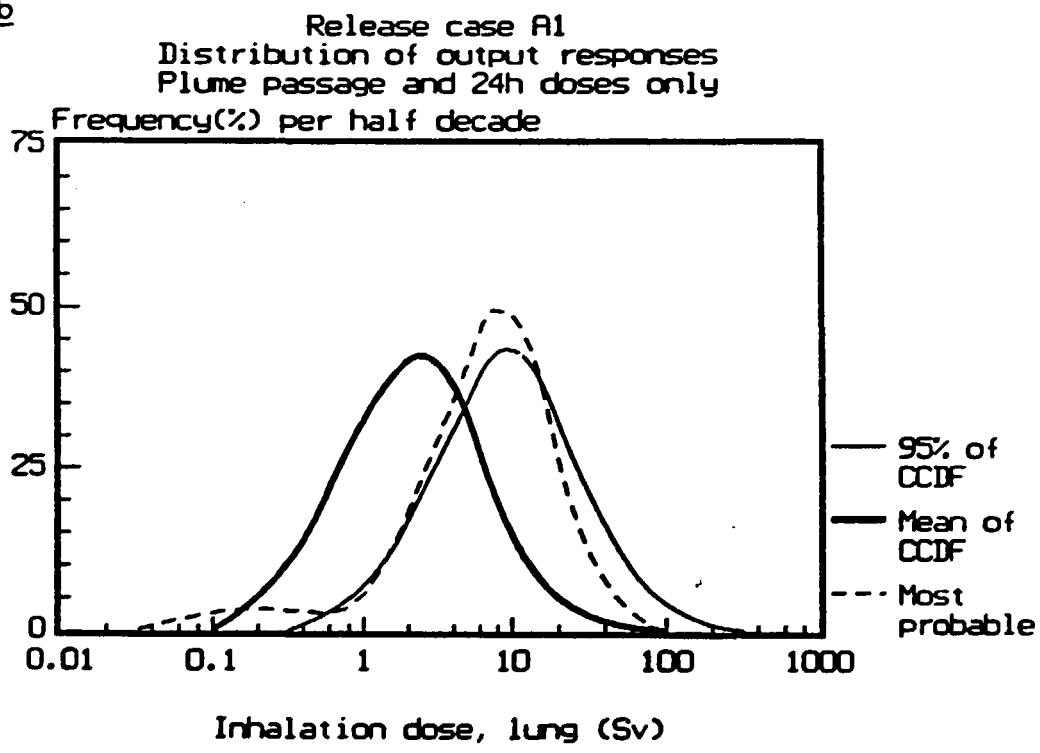

Figure 7.1.3.c

Note: **The results presented represent fictive source terms and site assumptions, and have therefore no signigicance to any real sites.**

STURAPP NPE/HE

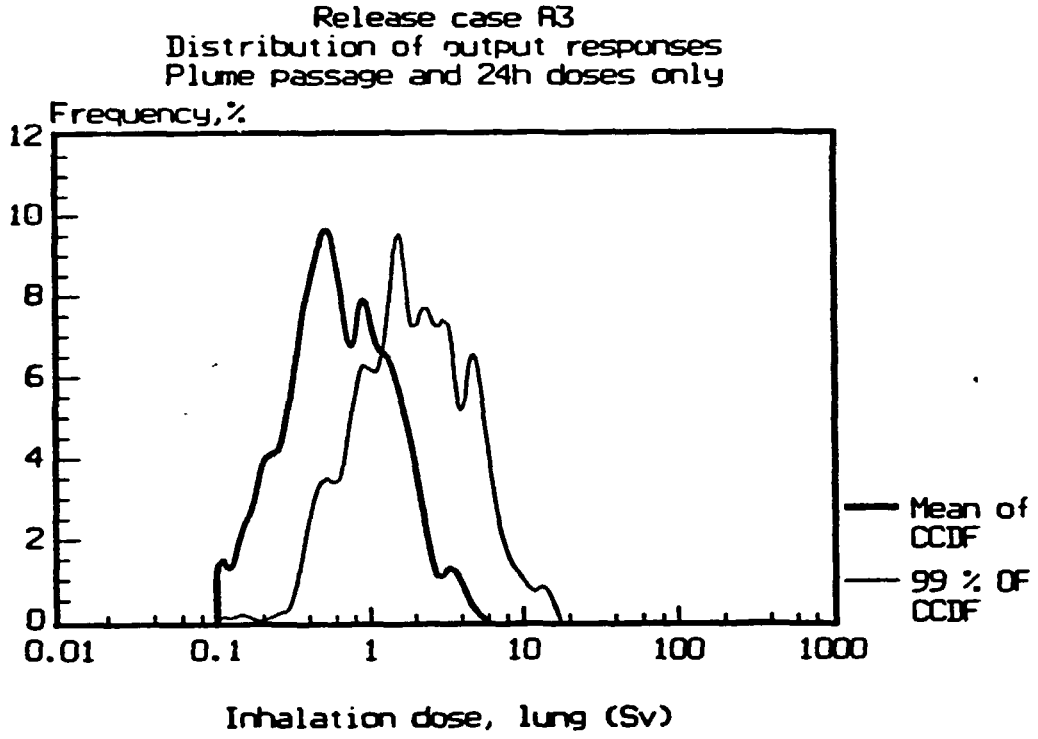

Figure 7.1.3.d

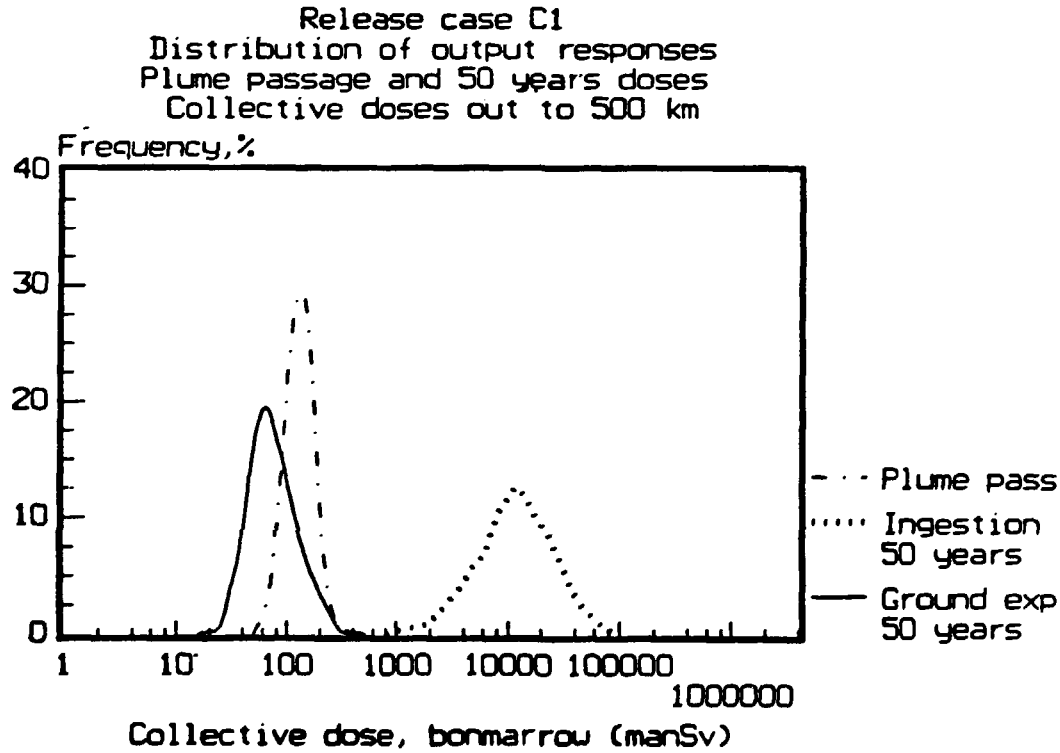

Figure 7.1.3.e

Note: The results presented represent fictive source terms and site assumptions, and have therefore no signigicance to any real sites.

STURAPP NPE/HE

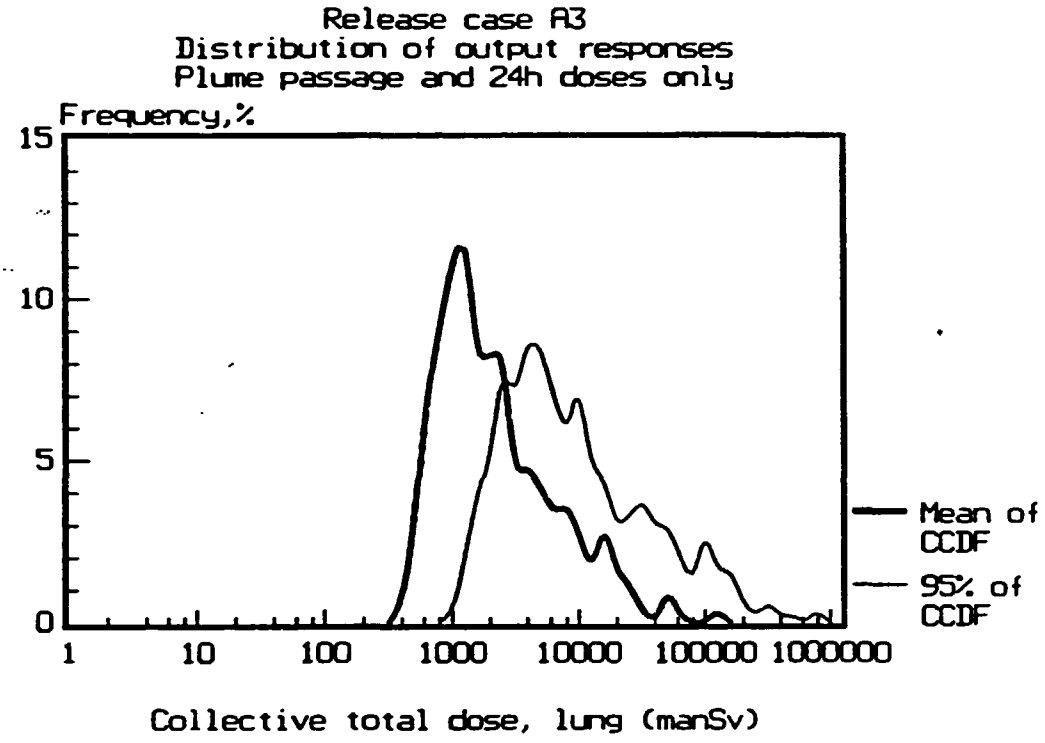

Figure 7.1.3.f

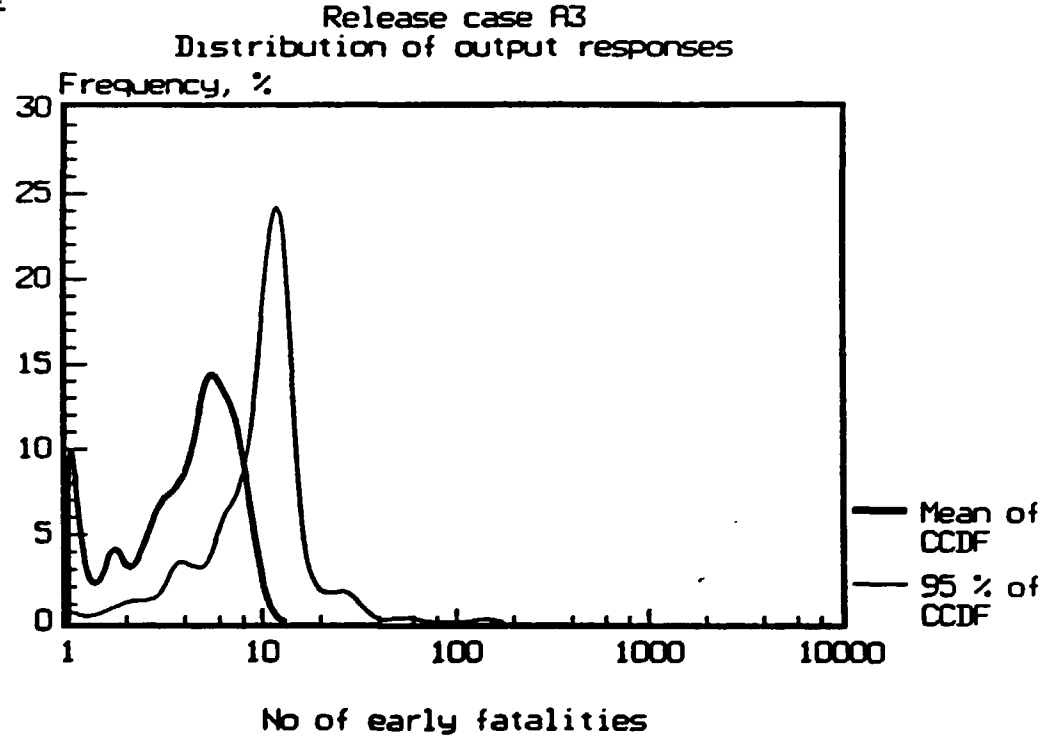

Figure 7.1.3.g

Note: The results presented represent fictive source terms and site assumptions, and have therefore no signigicance to any real sites.

STURAPP NPE/HE

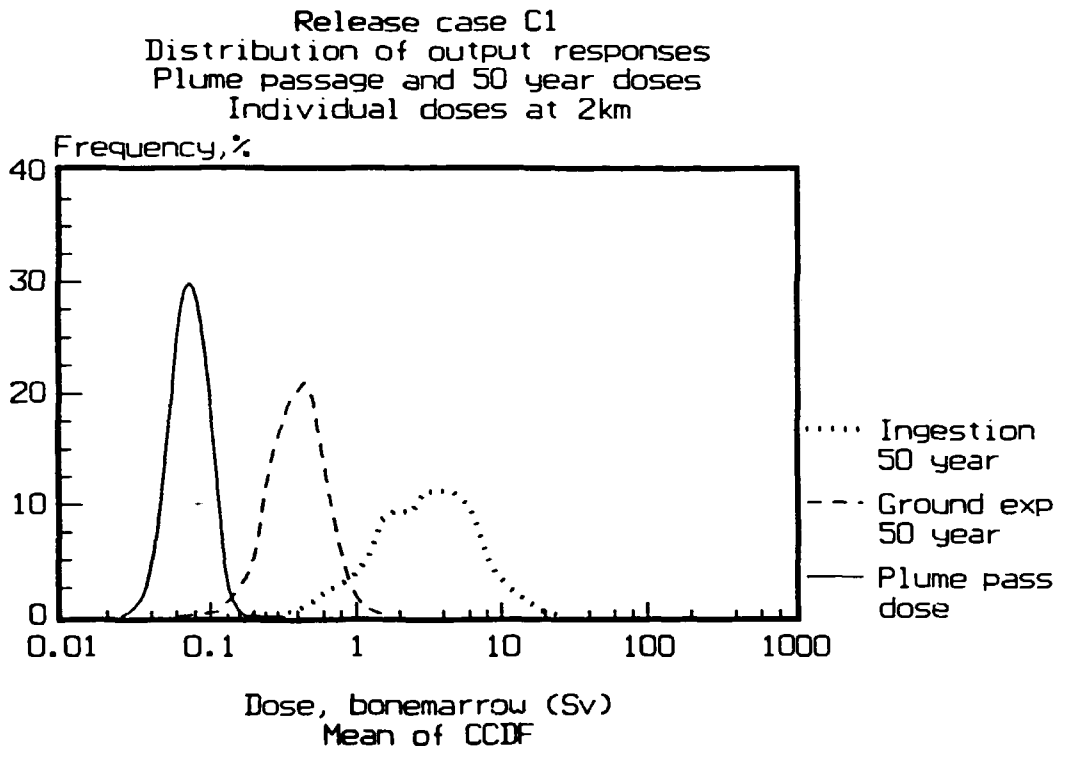

Figure 7.1.3.h

Note: The results presented represent fictive source terms and site assumptions, and have therefore no signigicance to any real sites.

STUDSVIK/NP-89/65

UNCERTAINTY AND SENSITIVITY ANALYSIS IN NUCLEAR ACCIDENT CONSEQUENCE ASSESSMENT

A study of the parameter uncertainty propagation through a complex dispersion, dose and health effect model

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