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D. Meyer* and W. Raskob*
Institut für Neutronenphysik und Reaktortechnik

*Fa. D.T.I. Dr. Trippe Ingenieurgesellschaft m.b.H., Karlsruhe

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Forschungszentrum Karlsruhe GmbH
Postfach 3640, 76021 Karlsruhe

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Abstract

The recently developed PC-program DOSELOOK for scaling and easily combining precalculated dose values of nuclide specific unit releases was converted into the EXCEL Spreadsheet program DOSEEX. In particular all the scaling possibilities from DOSELOOK were transferred into DOSEEX. A user guide of the program is presented in chapter 2. Intercomparison calculations between DOSEEX and the computer codes UFOTRI and COSYMA, for testing the scaling possibilities, can be found in chapter 3. Unit air concentration factors were calculated for several dispersion parameter sets as presented also in chapter 3. To identify the scenario which results in the highest dose in the vicinity of the plant for a release height of 100m, distance dependent early dose values and effective doses of the most exposed individual are given for different combinations of atmospheric stabilities and wind speed.

Abschlußbericht über Modellentwicklungen (DOSEEX) und Dosisabschätzungen im Rahmen von ITER für das Jahr 1994

Zusammenfassung

Das kürzlich entwickelte PC-Programm DOSELOOK zur einfachen Kombination und Skalierung vorberechneter Dosiswerte von nuklidspezifischen Einheitsfreisetzungen wurde in das EXCEL Soreadsheet-Program DOSEEX konvertiert. Insbesondere wurden alle Skalierungsmöglichkeiten von DOSELOOK in DOSEEX transferiert. Die Benutzeranleitung ist in Kapitel 2 beschrieben. Um die Skalierungsroutinen zu testen wurden Vergleichsrechnungen zwischen DOSEEX und den Unfallfolgenmodellen COSYMA und UFOTRI durchgeführt (Kap. 3). Außerdem wurden normierte bodennahe Luftkonzentrationen für verschiedene Sätze von Ausbreitungsparametern berechnet. Es wurden Untersuchungen durchgeführt, um diejenige Ausbreitungssituation zu identifizieren, die zur höchsten Dosisbelastung bei Freisetzungen in 100m Höhe führt. Für verschiedene Kombinationen von Ausbreitungsbedingungen wurden sowohl die 7-Tage Dosis als auch die Effektivdosis jeweils am höchst belasteten Aufpunkt berechnet.

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1. Introduction

This report summarises results obtained by KfK-INR during 1994 in the area of environmental dose calculations using the computer codes UFOTRI /RAS93/, NORMTRI /RAS94/ and COSYMA /COS91/. Within the last contract period, the PC-program DOSELOOK was developed which can be used to scale and to easily combine precalculated dose values of unit releases of up to 290 fusion/fission relevant nuclides for 5 exposure pathways - external irradiation from the ground and cloud, inhalation during plume passage, inhalation of resuspended material and ingestion of contaminated foodstuffs - for estimating radiation doses resulting from source terms with non-unit release rates. Additionally, it is possible to adjust the run conditions via input parameters, such as building dimensions, stack height above ground level, site terrain obstacles, release duration, wind speed, stability class, sigma parameters and rain intensities. However, this is an approximative procedure and only possible if the conditions do not change in time and space.

As the Joint Central Team of ITER (JCT) was more interested in a software that runs on a Macintosh e.g. Mac-EXCEL, the conversion into an EXCEL macro was performed. All the scaling possibilities are included in the EXCEL spreadsheet DOSEEX. The version 1.0 of DOSEEX, including a draft user guide is delivered to the JCT, the final documentation is presented in chapter 2. Additionally, intercomparison calculations between DOSEEX and the computer codes UFOTRI and COSYMA can be found in chapter 3.

Following intensive discussions with the JCT, support was provided in finalising the dose/release information for ground level and elevated release cases. To this purpose unit concentration factors were calculated for several dispersion parameter sets such as those known from Mol /BUL72/, Klug /KLU69/ and Karlsruhe-Jülich /STO94/. The results, especially the unit chi/q curves are presented in chapter 3. Additionally, distance dependent dose values of the MEI were calculated for elevated releases and different atmospheric stratifications. Therefrom it is possible to identify the scenario which results in the highest dose in the vicinity of the plant assuming a release height of 100m and stationary dispersion conditions.

2. The computer program DOSEEX

2.1 Objective

The aim of the EXCEL-Macro DOSEEX is to allow fast and easy dose assessments of various source terms. Unit releases (**1.0 E12 Bq/h**) of 290 radionuclides for different distance bands and five pathways were investigated. Dose values for the most exposed individual (MEI) as well as the collective dose assuming an uniform population distribution of **100 persons/km^2** were precalculated and tabulated into Microsoft EXCEL 4.0 for the present database.

With DOSEEX it is now possible to combine easily precalculated dose values from a unit release of up to 290 fusion/fission relevant nuclides into one source term with **non-uniform release rates.** The user can decide, whether he wants to determine the dose values of the original database or to approximately scale the database to other input parameters via a scoping tool. Following parameters can be considered in the scoping tool (the values used for the ITER calculations are listed in brackets):

- Building dimensions (height of 40 m and width of 100 m)
- Stability class (very stable, F)
- Sigma parameters (MOL)
- Site terrain roughness (30 cm)
- Release duration (1 hour)
- Release height (10 m)
- Wind speed (0.5 m/s)
- Rain intensity (0.0)

Within one run of DOSEEX one source term can be evaluated. The MEI values with the non-uniform release rates are calculated at certain distance bands. This is done for every selected nuclide as well as accumulated for the complete source term. The MEI value is split up into the contributions of the five pathways:

- internal irradiation from inhalation during the plume passage
- internal irradiation from inhalation from resuspended material
- external irradiation from the cloud
- external irradiation from the ground
- internal irradiation from ingestion.

Within one run (for one release scenario) a new EXCEL-spreadsheet will be created with following contents:

- Doses for the MEI at certain distance bands per nuclide
- Contribution of the pathways in % per nuclide
- Summed MEI for all selected nuclides
- Contribution of the pathways in % for the summed MEI
- Collective dose between two distance bands (CDOSP)
- Contribution of the pathways in % per nuclide
- Collective dose over the whole area (CDOSS)
- Contribution of CDOSP values of the CDOSS values per nuclide
- Summed collective dose between two distance bands and over the whole area for all nuclides and the contribution of the pathways in %

2.2. Scoping tool

For approximately scaling to other input parameters as used for the run which are stored in the basic data set, a scoping tool module provides the following possibilities of change:

- Building dimensions
- Stability class
- Sigma parameters
- Site terrain parameters
- Release duration
- Stack height versus ground level
- Wind speed
- Rain intensity

The application of the scoping tool is only possible if the meteorological input parameters are **constant** in time and space. Since most of the above mentioned parameter changes cause highly non-linear results, a simple rule is in general not applicable. Therefore, in the scoping tool again the Gaussian dispersion equation is used to approximately scale new release and dispersion conditions. The procedure is such, that the code calculates first the unit air concentration for the basic conditions, provided as defaults by the data set loaded, and thereafter, in a second step, the code determines the unit air concentration for the new conditions including the desired changes. The same will be done for the deposited concentration. Dividing the old and the new value for air and soil concentration will result in two scaling factors, one for doses influenced by the air concentration (inhalation and irradiation from the passing cloud), the other for doses based on the radionuclide concentration on the soil surface (irradiation from ground, inhalation from resuspended material and the ingestion pathway).

As the depletion effects of fallout and washout are considered in the basic calculations, the scaling formalism contains all features of the Gaussian dispersion equation for the concentration in air (equation 1) and the concentration on the soil surface (equation 2).

$$C_{air} = \frac{1}{\pi u \sigma_{yg} \sigma_{zg}} \exp\left[-\frac{H^2}{2\sigma_{zg}{}^2} \right] \cdot fallout \cdot washout \qquad (1)$$

with

$$fallout = \exp\left[-\frac{v_d}{u} \cdot \sqrt{\frac{2}{\pi}} \cdot \frac{x}{\sigma_{zg}} \right] \qquad (1a)$$

$$washout = \exp\left[-\frac{\lambda}{u} \cdot x \right] \qquad (1b)$$

and

$$C_{soil} = v_d \cdot C_{air} \qquad (2)$$

with

x	=	Radial distance in m
c_{air}	=	Unit air concentration near ground surface in s/m^3
c_{soil}	=	Unit ground concentration in m^{-2}
H	=	Effective source height in m

v_d = Deposition velocity (set to 0.001 m/s)
u = Wind speed at dispersion height in m/s
σ_{yg} = Sigma y including special effects in m
σ_{zg} = Sigma z including special effects in m
λ = Washout coefficient ($= 8 \cdot 10^{-5} \cdot rain^{0.8}$) in 1/s
rain = Rain intensity in mm/h

Based on the equations 1 and 2, two calculations are performed for the air and two for the ground surface, each of them with the original input parameter set as well as with the modified one. The factor between the basic and modified results for ground surface and for air, will be multiplied with the doses of the respective pathways. This procedure will be carried out for every distance band and every nuclide in the data set. But it has to be mentioned that processes such as the radioactive decay are not considered in the scoping procedure. Therefore, one has to be careful when applying the scoping tool to radionuclides with a very short half life. Problems have been found out when applying the scoping tool to tritium, iodine and noble gases. In general it is requested to perform more calculations with different release scenarios than simply to scale some basic results for various release conditions.

Building dimensions

An initial broadening of the plume σ_0, representing the initial mixing due to the building wake effects, is added to the basic sigmas

$$\sigma_{yg} = \sqrt{\sigma_y^2 + \sigma_{y0}^2} \qquad (3)$$

and

$$\sigma_{zg} = \sqrt{\sigma_z^2 + \sigma_{z0}^2} \qquad (4)$$

with

σ_y = basic sigma y parameter (equ. 5)
σ_z = basic sigma z parameter (equ. 6)
σ_{y0} = initial sigma from building wake effects: σ_{y0} = width / 4.3
σ_{z0} = initial sigma from building wake effects: σ_{z0} = height / 2.15
height = height of the building (old or new) in m
width = width of the building (old or new) in m

Stability class and sigma parameters

The basic release scenarios, as defined in the description, contain only one single atmospheric stability class, which remains constant for the whole travel time of the plume. This stability condition can be modified via the scoping tool. But a change in the atmospheric stability is necessarily linked with a change in the dispersion parameters, because in the Gaussian formula (equ. 1), the various atmospheric stability conditions are considered via the appropriate values for the sigma parameters. The scoping tool uses a power law approach for calculating the distance dependent sigma values.

$$\sigma_y = ya \cdot x^{yb} \tag{5}$$

and

$$\sigma_z = za \cdot x^{zb} \tag{6}$$

with

σ_y = basic sigma y parameter in m
σ_z = basic sigma z parameter in m
x = distance from release point in m
ya = constant dependent on stability class and sigma scheme (horizontal diffusion)
yb = constant dependent on stability class and sigma scheme (horizontal diffusion)
za = constant dependent on stability class and sigma scheme (vertical diffusion)
zb = constant dependent on stability class and sigma scheme (vertial diffusion)

A new value has to be assigned to each of the four values ya, yb, za, zb, of equations 5 and 6. Both equations will be applied twice with the new and old parameters. The old value is provided as default by the scoping tool menu. If the release height differs from the reference height of 10m, the wind speed u in equation 1 is corrected with equation 9, because a new atmospheric stability class causes a new exponent (wpe) for the wind speed correction with height. However, if the release height changes also, both corrections, the new release height + the new wpe value are considered in equation 9.
If desired, also a complete different set of dispersion parameters (e.g. change from MOL to KLUG) can be introduced via new values for ya, yb, za, zb.

stability category	diffusion coefficients			
	ya	yb	za	zb
A	0.946	0.796	1.321	0.711
B	0.826	0.796	0.950	0.711
C	0.586	0.796	0.700	0.711
D	0.418	0.796	0.520	0.711
E	0.297	0.796	0.382	0.711
F	0.235	0.796	0.311	0.711

Table 1: Sigma parameters for the MOL set

Site terrain obstacles

Changes in the height of site terrain obstacles (surface roughness) result in a different vertical turbulent mixing rate, thus the sigma z value has to be modified. This will be done by scaling sigma z with the following equation:

$$\sigma_{zr} = \sigma_z \cdot (araun / araua)^{0.2} \tag{7}$$

with

σ_{zr} = sigma z resulting from the change of the roughness height
araua = old roughness length in cm
araun = new roughness length in cm

Release duration

Assuming different release durations, several changes of the atmospheric dispersion conditions may occur. Among others, the wind direction, the wind speed and the atmospheric stability class may change with time. However, the scaling tool considers only the change of the wind direction if the release duration will be modified. Wind speed and stability class remain constant due to the definition of the basic release scenario. A change in the wind direction with time causes changes of the lateral spread of the plume. This is described by the sigma y value in the Gaussian formula (equ. 1). A simple power law approach is used to take these effects into account:

$$\sigma_{yd} = \sigma_y \cdot \left(\frac{1}{dura \; / \; durn} \right)^{0.25} \qquad (8)$$

with

σ_{yd} = sigma y resulting from the change of the release duration
dura = old time of the release duration in minutes
durn = new time of the release duration in minutes

Stack height

The value of the stack height H from the basic Gaussian equation has to be replaced by the new value, but with the assumption that a stack release is never influenced by a building (no building wake effect). Additionally, the wind speed of the basic run has to be modified for the second run and adapted to the new release height via the power law approach:

$$u_n = u_r \cdot \left(\frac{H_n}{H_r} \right)^{wpe} \qquad (9)$$

with

u_n = wind speed in the new release height in m/s
u_r = wind speed in the reference height (10m) in m/s
H_n = new release height in m
H_r = reference height (10 m)
wpe = function dependent on the stability class
(A: 0.07; B: 0.13; C: 0.21; D: 0.34; E: 0.44; F:0.44)

Wind speed

If the release height is not changed, no special formalism is necessary. Both values for the wind speed, the old and new one, will be inserted in the equation 1.

Rain intensity

The process of wet deposition is considered as washout from the whole plume. The washout coefficient depends on the rain intensity (equ. 1b). The rain intensity may be changed in a new data set. But it is important that the rain intensity value of the old data set is 0. The rain cases precalculated with COSYMA stop with the precipitation after 2 hours. However, the default data sets included in the package do not contain rain and can be used for scaling without any problem. However, the scaling for tritium, iodine and noble gasses is not recommended. For tritium the scaling with rain is only sufficiently exact if the stability class remains unchanged; otherwise the complex behaviour of the plants included in UFOTRI can not be re-evaluated with the scoping tool.

2.3 Database

The database consists of precalculated doses for most exposed individual and collective doses (the population distribution is 100 persons/km^2) of unit releases (1.E12 Bq/h) for one special release scenario. The MEI and the collective doses are tabulated into two Microsoft EXCEL spreadsheets. The definition of the doses - exposure times and integration times - are further explained in the data sets itself.

The data files comprise:

- 290 nuclides (fusion/fission), see Table 18 in the Appendix A
- 5 exposure pathways
- 18 radial distance bands per exposure pathways

Distance Nr.	Distance [m]
1	145
2	180
3	320
4	500
5	680
6	1000
7	1500
8	2000
9	3200
10	5000
11	6800
12	10000
13	15000
14	20000
15	32000
16	46000
17	68000
18	100000

Table 2: The radial distance bands of the database

2.4 Input-interface

The user is guided through a series of dialogue boxes, which offer options and parameters to enter and select. For changing, move the cursor and activate the window; enter the values or select the options, click OK or CONTINUE. The CANCEL button redisplays the MAIN-macro to begin a new run.

Following parameters can be considered:

Specifying options

Following calculations can be selected in the Opening dialogue box (Fig. 1)

- Only the MEI determination (the database can be scaled by the scoping tool or not)
- Only the calculation of the collective doses (database can be scaled or not)
- MEI determination + collective dose calculation (the database can be scaled or not)

Nuclides

There are three possibilities to determine the nuclides :

calling a predetermined or a personal prestored nuclide group,
selecting the nuclides from the nuclide list, consisting of the 290 nuclides,
choosing all nuclides.

To open the prestored groups click *1 Nuclide Group* and than **OK** in the **Opening** dialogue box (Fig. 1). The name of the nuclide group can be chosen in the **Nuclide Group Input** dialogue box (Fig. 2).

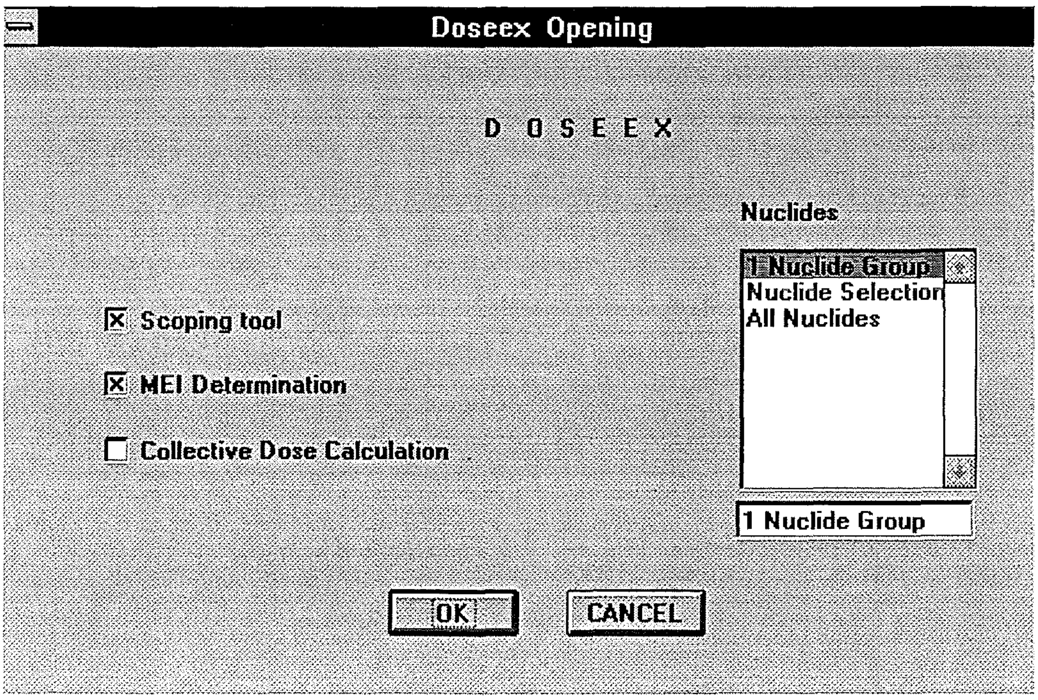

Figure 1: Opening dialogue box

Four nuclide groups are predetermined:

Beryllium	**Copper**	**MANET 2**	**V-5Ti**
NA-24	CO-60	CR-51	NA-24
SC-46	NI-63	MN-54	AR-39
MN-54	CU-64	MN-56	AR-41
CO-57	ZN-65	CO-57	AR-42
CO-58	AG-108M	CO-58	CA-45
CO-58	AG-110M	CO-60	CA-47
CO-60	CD-109	MO-99	SC-46
KR-85	SB-124		SC-47
KR-88			SC-48
XE-133			
XE-135			

The nuclides of the selected group can be approved by clicking the OK or can still be changed by clicking the MODIFY button in the **Nuclide Group Input dialogue box**. The **Nuclide Input** box will appear, the nuclides can be changed and the name of the new personal nuclide group has to be entered. Maximal 50 groups can be stored with 100 nuclides in one group. With the DELETE button in the **Nuclide Group-Input** dialogue box a group can be deleted.

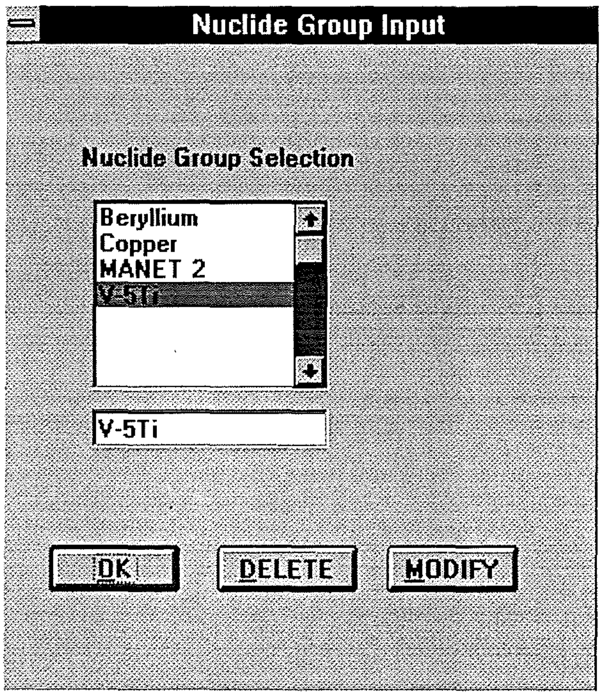

Figure 2: Nuclide group input dialogue box

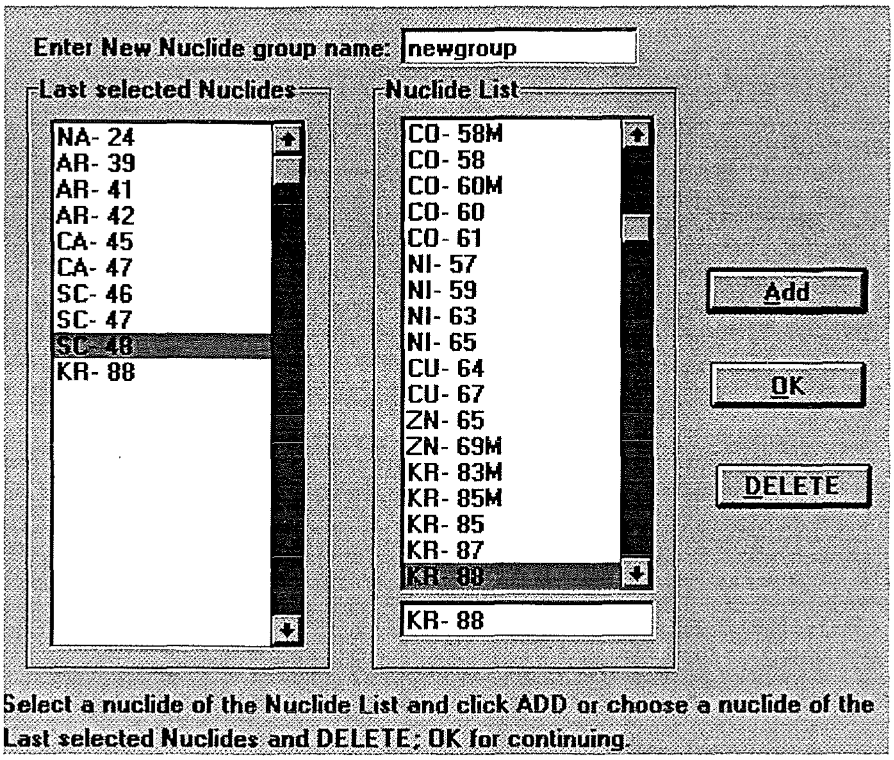

Figure 3: Nuclide input dialogue box

When choosing ***Nuclide Selection*** in the **Opening** dialogue box (Fig. 1), the nuclides can be selected in the **Nuclide Input** dialogue box by pressing the ADD button (Fig 4). The selection of the nuclides is finished by pressing the OK button. This new nuclide group can be stored for further runs by entering a nuclide group name in the next dialogue box (Fig. 5). Maximal 100 nuclides can be selected in one group and maximal 50 groups can be stored.

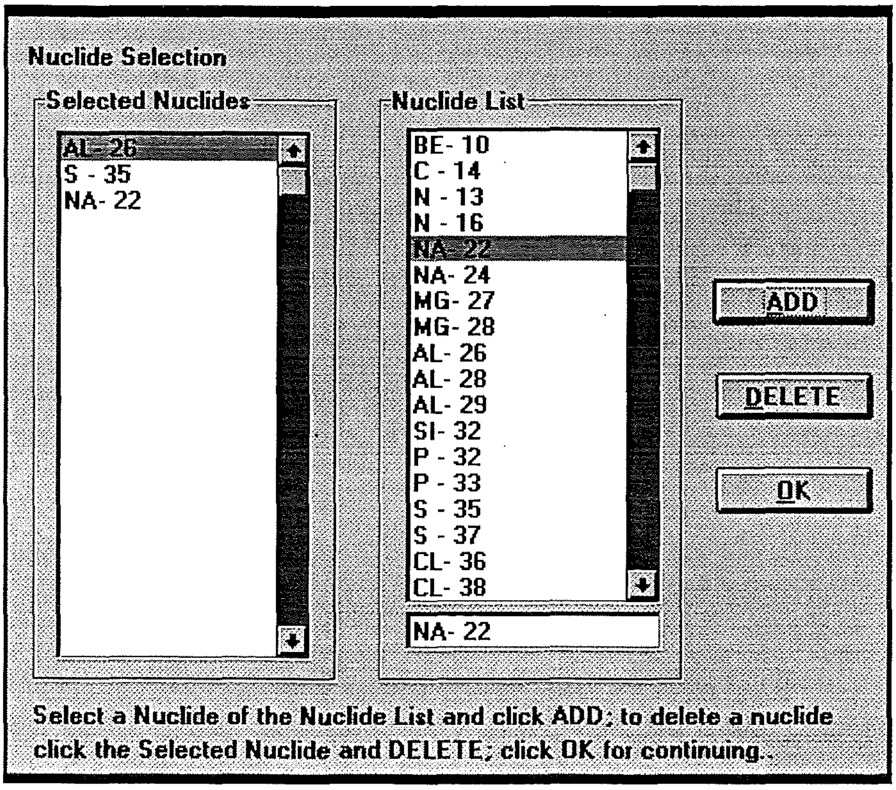

Figure 4: Nuclide selection dialogue box

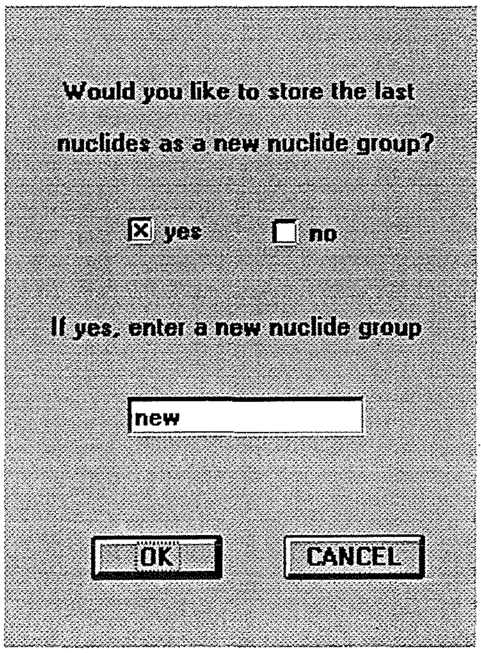

Figure 5: New group dialogue box

Enter *All Nuclides* in the **Opening** dialogue box to determine the doses for all nuclides. In the following dialogue box it is possible to enter a single value for the release rates for all nuclides or to choose varying release rates for every nuclide (Fig. 6). If different values are desired, a nuclide mask appears for each nuclide.

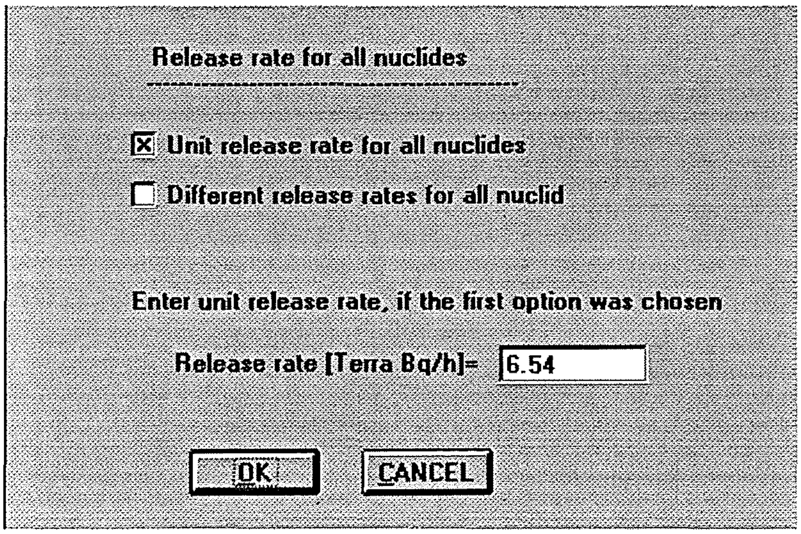

Figure 6: Release input for all nuclides

Release rates

A mask will appear for each selected nuclide. Move the mouse to the input field of the release rate; enter the value and press **RETURN**. This results in the appearance of the next nuclide. One can also select a nuclide via the button for the next nuclide (button 5 in Fig. 7). Close the mask after the definition of all release rates (button 7 in Fig. 7). Do not enter 0 as value for a release rate. The output spreadsheet will have errors, beginning with #.

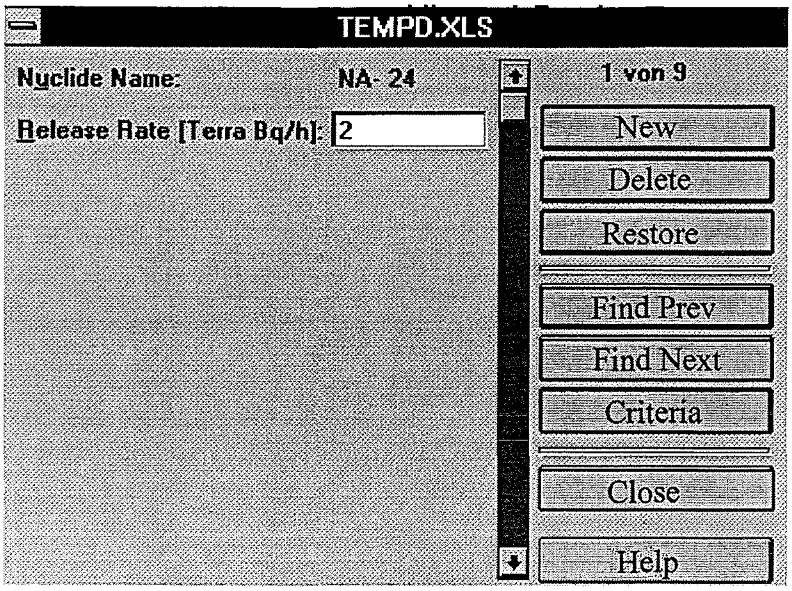

Figure 7: Nuclide mask

Data files

The data set names of the input spreadsheets for the MEI (INDIV.XLS) and the collective doses (COLLEC.XLS) can be changed, if desired (Fig. 8). The Macro DOSEEX needs the temporary dataset TEMPD.XLS. The data set name for the output spreadsheet is entered by the user. It will be created in the given directory. One should enter a new data set name for each run, as the content of the data set will be deleted by writing the new information on the disk.

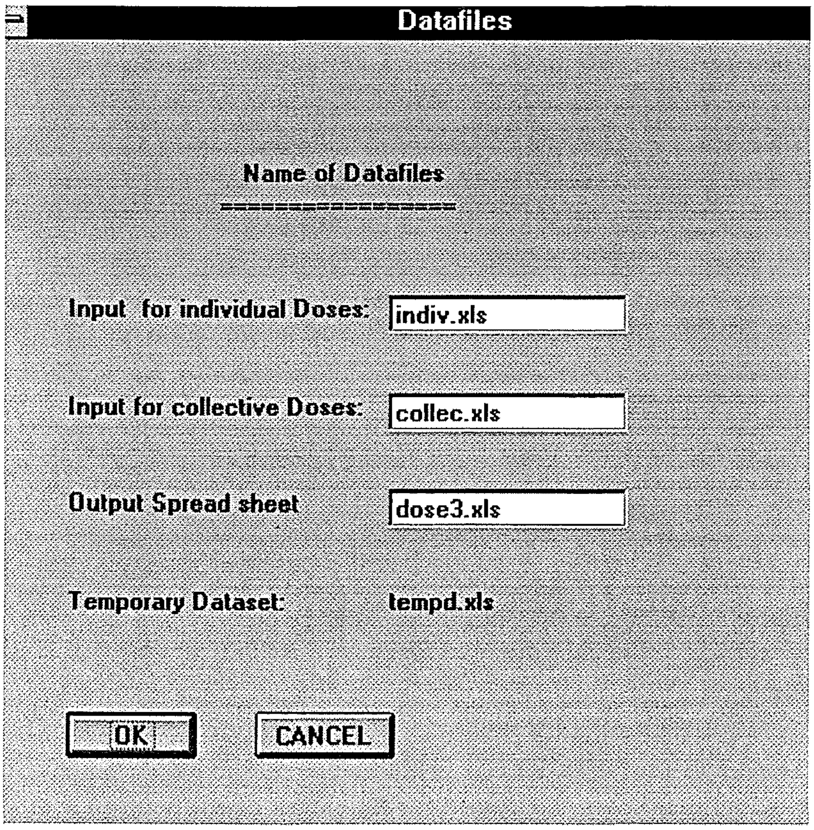

Figure 8: Data file dialogue box

Pathways

The doses can be calculated for selected pathways or for all five pathways (Fig. 9).

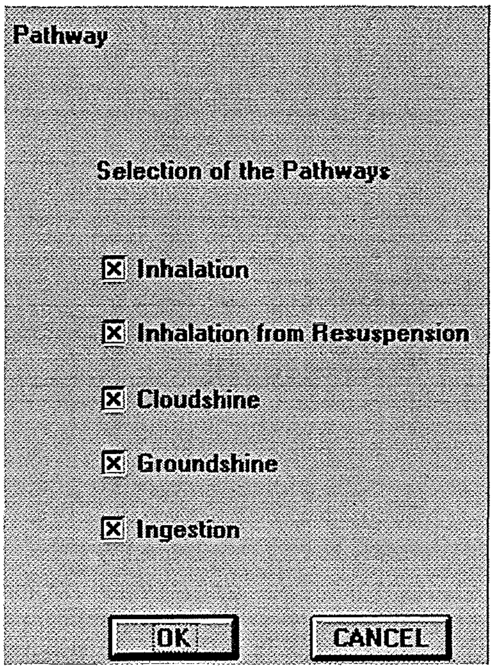

Figure 9: Pathway dialogue box

Distance bands

Several distance bands can be selected for determining the MEI. For each distance band a new dialogue box appears. Click the **CONTINUE** button, if no other distance band is desired (Fig. 10)

For calculating the collective doses, the inner and outer distance band are to be selected. The calculation over the whole area is always performed in the program (Fig. 11).

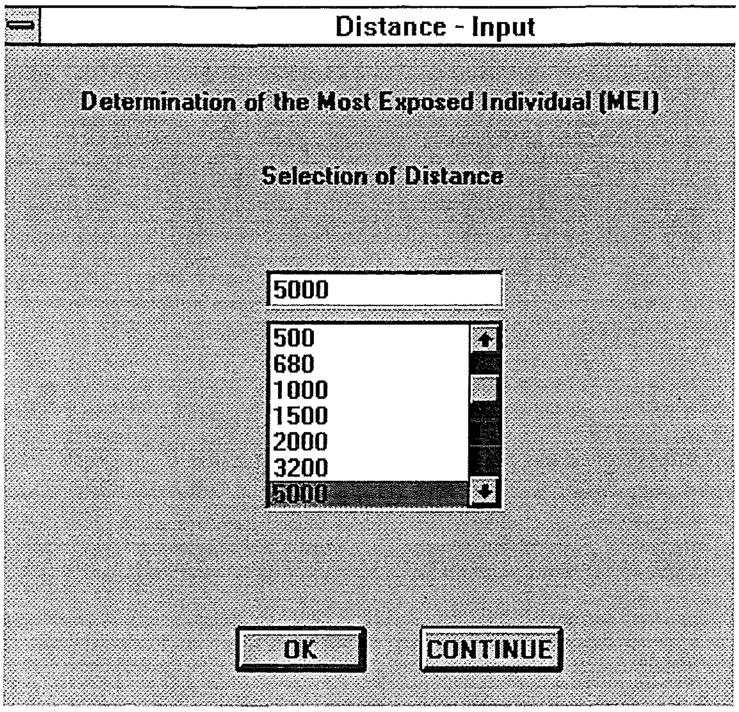

Figure 10: Distance dialogue box for the MEI determination

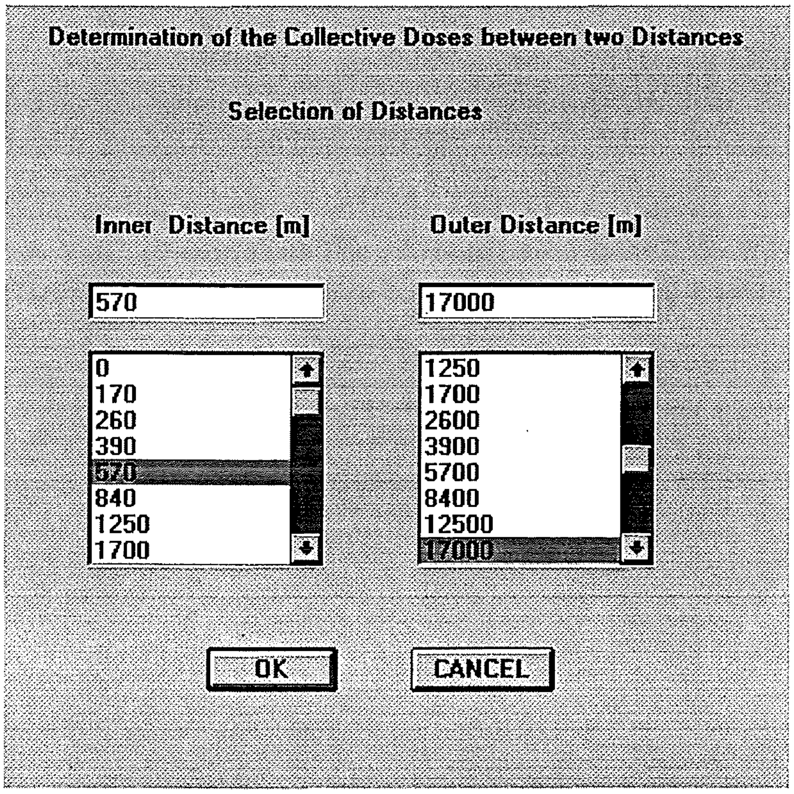

Figure 11: Distance dialogue box for the Collective Dose calculation

Population distribution

The collective dose can be determined for the original population distribution or can be changed in Fig. 12. To change the distribution, click the steering option for changing and enter the new value.

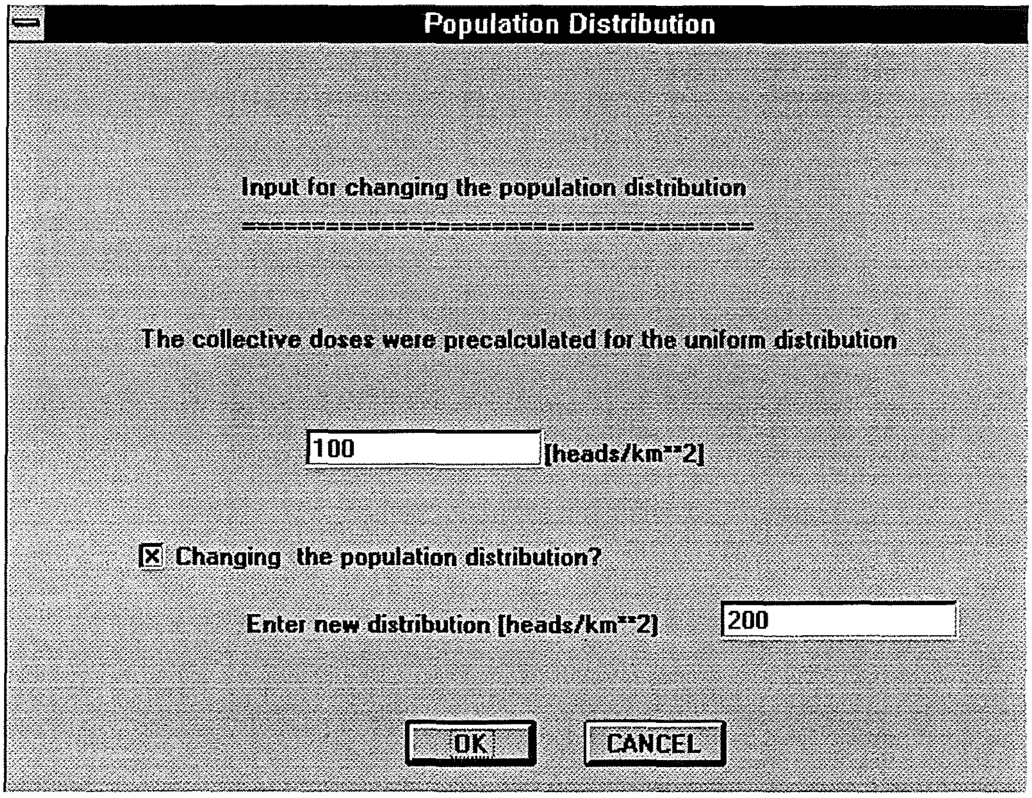

Figure 12: Population Distribution dialogue box

Scoping tool parameters

For scaling the database, the new and old parameters are displayed in separate windows. For changing, only the new values can be modified as the old ones should represent the actual parameters for the precalculated dose data set. However, one should check the old values carefully too. If a new Mol dispersion set is desired (first option in Fig.13), only the class is to be entered in Fig. 14, otherwise the class and the sigma parameters. The new value for the rain intensity is listed separately and can be entered in Fig.15.

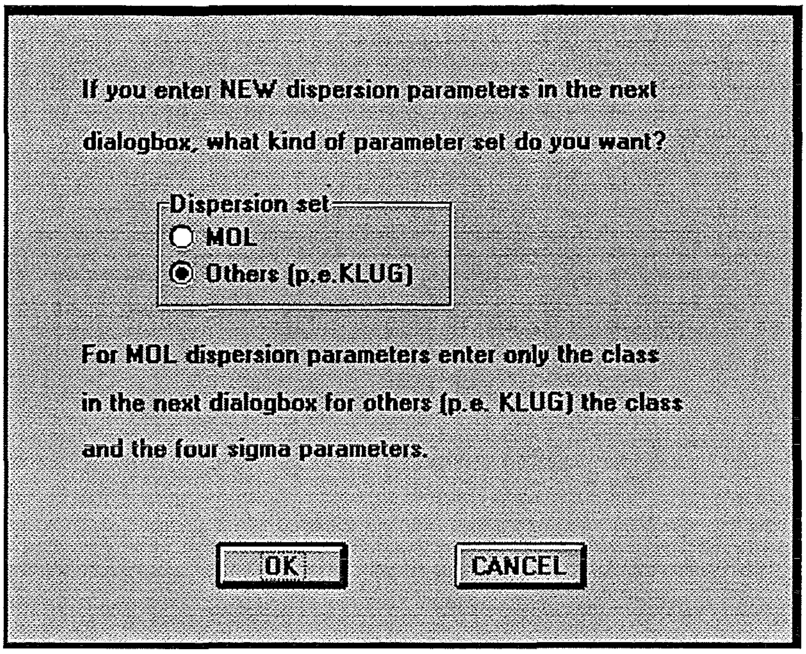

Figure 13: Dispersion set dialogue box

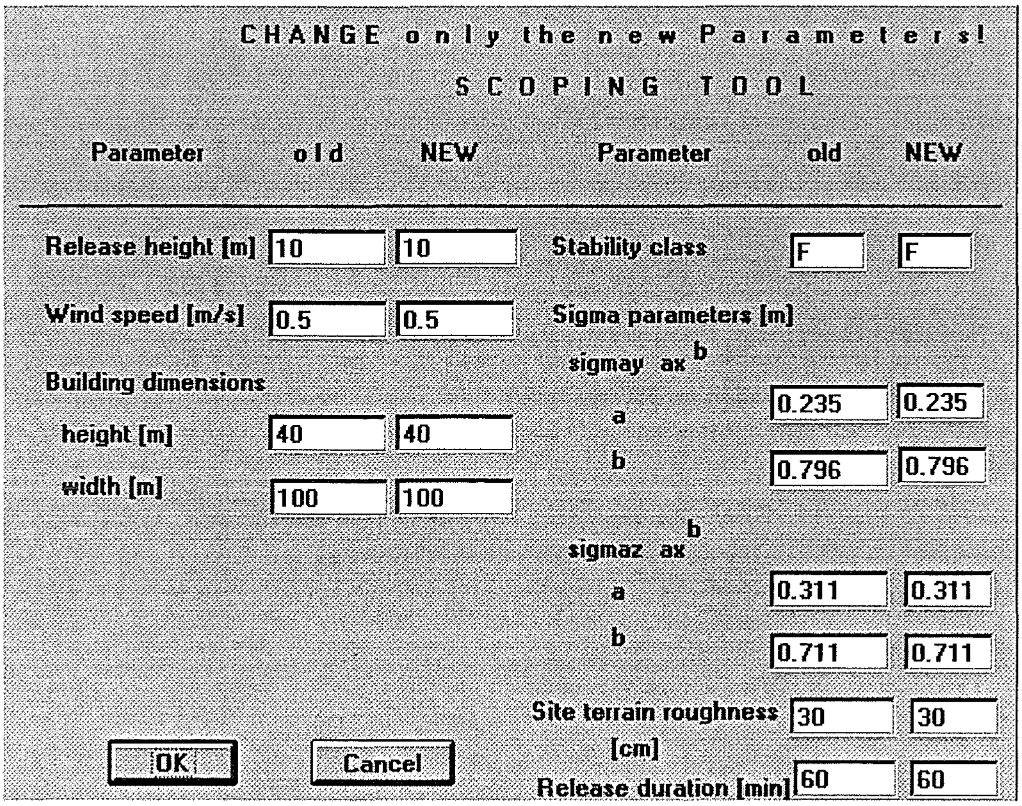

Figure 14: Scoping tool dialogue box

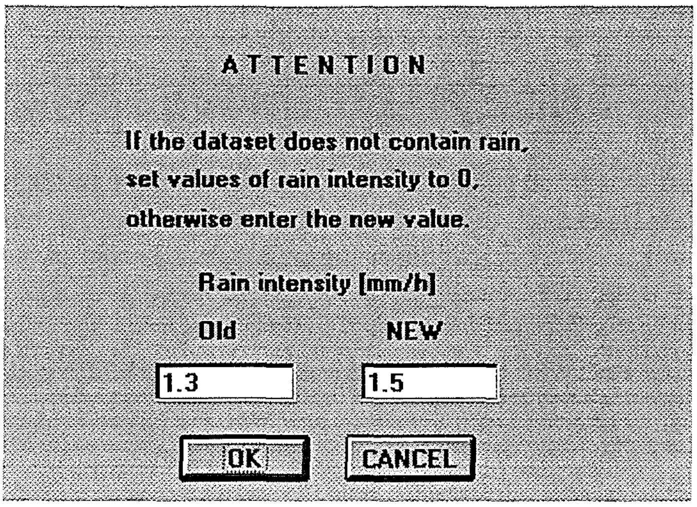

Figure 15: Rain dialogue box

2.5 Contents of the EXCEL-Macros and the Tables

Following macros and tables must be available on the hard disk in the working directory:

Macros:

MAIN.XLM	Opening macro
DOSELOOK.XLM	Steering of the macro; determination of the MEI
COLLDOS.XLM	Determination of the collective doses
PATHSEL.XLM	Selection of the pathways
NUGRUP.XLM	Predetermined nuclide group selection
NSEL.XLM	Personal nuclide group selection
SCOPTOOL.XLM	Scoping tool

Tables:

EDEIND.XLS	Database for effective individual doses (EDE of the MEI)
EDECD.XLS	Database for effective collective doses (CEDE)
EARLYIND.XLS	Database for early individual doses (early dose of the MEI)
EARLYCD.XLS	Database for early collective doses
SCOPTOOL.XLS	Temporary dataset for the scoping tool
TEMPD.XLS	Temporary dataset for the determination of the MEI and the collective doses
DOSE.XLS	Output spreadsheet

2.6 Running of the EXCEL-Macro

For running the macro, open the folder on the hard disk and double click the steering macro MAIN.XLM. Thereafter press running the macro and select the choice offered in the open window (Fig. 1). On a Macintosh-PC, at least 4 MB of memory should be assigned to the EXCEL program. A mathematical co-processor is recommended. The input parameter of each data set are included in the header which is shown in the output spreadsheet.

3. Dose calculations

3.1 Comparative calculations with DOSEEX, UFOTRI and COSYMA

To get an impression of the accuracy of the scaling features in DOSEEX, comparative calculations with the accident consequence assessment (ACA) codes UFOTRI and COSYMA, which were also used to obtain the standard data set of DOSEEX, have been performed. The basic unit dose data set in DOSEEX were obtained with the following parameters:

- release height of 10m with building wake effects (100m width and 40 m height)
- stability class F
- wind speed 0.5 m/s
- no rain
- sigma parameter set MOL
- solar irradiation of 80 W/m^2

Five scenarios have been chosen to test some of the features. The different input parameters are listed in Table 3. The early dose as well as the EDE for the MEI were obtained at a distance of 1 km from the release point. Five nuclides were selected, representing different behaviours of a dispersed material. Tritium was considered in both forms, HT and HTO. Co-60 was selected as aerosol, Ar-41 as noble gas and Mg-27 as a short living nuclide with a half live of about 10 minutes. The results of the comparison are shown in the Tables 4 to 8.

	release height (m)	stability class	wind speed (m/s)	rain (mm/h)	sigma parameter set
case 1	10	D	4.0	no	MOL
case 2	10	A	0.5	no	MOL
case 3	100	C	1.0	no	MOL
case 4	10	A	2.0	no	KLUG
case 5	100	D	4.0	1.0	MOL

Table 3: Five test cases for the intercomparison calculations between UFOTRI, COSYMA and DOSEEX

	early dose (Sv)		EDE (Sv)	
	ACA-code	DOSEEX	ACA-code	DOSEEX
HT	5.1E-10	9.1E-10	2.2E-8	2.9E-8
HTO	8.9E-8	7.4E-8	1.0E-6	2.7E-7
Co-60	1.6E-4	1.6E-4	3.0E-3	3.0E-3
Mg-27	1.5E-7	1.3E-8	1.5E-7	1.3E-8
Ar-41	2.8E-7	1.6E-7	2.8E-7	1.6E-7

Table 4: Doses for Scenario 1. Intercomparison of DOSEEX, UFOTRI and COSYMA (MEI at 1 km distance)

In general, the early doses are overestimated by DOSEEX in the case of tritium as HT-gas, but for the EDEs the values result higher and lower. The main reason for that, at least in case of the early dose, may be found in the fixed deposition velocity in DOSEEX in contrast to the variable one in UFOTRI. The deposited HT und thus the reemitted HTO plays the dominating role in the early dose contribution. A second factor, which acts in the opposite direction by influencing the ingestion dose, are the different solar irradiation values applied in UFOTRI (see Table 9). The solar irradiation is no scaling parameter in DOSEEX as the dependencies are too complex. UFOTRI, however, uses higher solar irradiation intensities for neutral and unstable stability classes. This causes a higher OBT build-up rate and thus a higher ingestion dose, even in the case when the HTO concentration in the plant is the same. These different solar irradiation intensities appear to be the main reason for the overestimation of the EDE for HTO-releases. Additionally, the higher solar irradiation result also in higher HTO uptake rates by the plants. DOSEEX underestimates the ingestion dose by about a factor of 3 to 4 in all cases which indicates that a simple correction factor may be introduced in the code for compensation. However, the user may correct the EDE by his own. A problem which may be solved in the next release of DOSEEX is the overprediction of the HT doses due to the presence of rain. HT is not washed out due to rain but this is simply assumed in DOSEEX as for all the other radionuclides with dry deposition velocities greater than zero.

The comparison for the aerosol Co-60 proves very well. The highest difference occurs for the rain case 5. For all other scenarios the difference is only some percent. The dependency of the decay time is very well demonstrated for the radionuclide Mg-27. If the wind speed in the release height is higher than in the original data set (all cases except case 2 and 3), the doses obtained by DOSEEX are lower than those from COSYMA. The wind speed in case 3 is lower at the release height of 100m as the correction for the stability class F results in a wind speed of about 3 m/s at this height. The doses of case 2 are also lower, however, this seems to be the result of the changing stability class. The geometry of the plume changes with the stability class. As the dose from Mg-27 is dominated by the irradiation from the passing cloud, the plume geometry, besides the concentration, is very important for the dose. But the plume geometry, expressed in the plume correction factors, is not specially considered in DOSEEX. This effect can also be found for the noble gas Ar-41. The dose of this radionuclide is solely dominated by the irradiation from the passing cloud.

From all these tests the conclusion may be drawn, that the applicability of DOSEEX for aerosols is rather good if the doses are dominated by the exposure pathways inhalation, ingestion or irradiation from the ground. Even for tritium in the form of HTO an agreement can be achieved when changing the stability class , however, only by using a correction factor of 3 to 4 for the scaled ingestion dose . But applications to other special radionuclides such as HT, noble gases and very short living isotopes have to be considered very carefully. However, these radionuclides appear to be not those dominating a source from a fusion plant.

	early dose (Sv)		EDE (Sv)	
	ACA-code	DOSEEX	ACA-code	DOSEEX
HT	7.3E-10	1.3E-9	5.1E-7	4.3E-8
HTO	1.1E-7	1.1E-7	1.5E-6	4.0E-7
Co-60	2.4E-4	2.4E-4	4.4E-3	4.4E-3
Mg-27	4.2E-8	1.9E-8	4.2E-8	1.8E-8
Ar-41	5.7E-7	2.3E-7	5.7E-7	2.3E-7

Table 5: Doses for Scenario 2. Intercomparison of DOSEEX, UFOTRI and COSYMA (MEI at 1 km distance)

	early dose (Sv)		EDE (Sv)	
	ACA-code	DOSEEX	ACA-code	DOSEEX
HT	3.8E-10	7.3E-10	2.2E-8	2.3E-8
HTO	6.5E-8	5.9E-8	8.4E-7	2.2E-7
Co-60	1.3E-4	1.3E-4	2.4E-3	2.4E-3
Mg-27	1.2E-7	1.0E-8	1.2E-7	1.0E-8
Ar-41	3.3E-7	1.3E-7	3.3E-7	1.3E-7

Table 6: Doses for Scenario 3. Intercomparison of DOSEEX, UFOTRI and COSYMA (MEI at 1 km distance)

	early dose (Sv)		EDE (Sv)	
	ACA-code	DOSEEX	ACA-code	DOSEEX
HT	1.9E-10	2.5E-10	8.1E-9	7.9E-9
HTO	2.7E-8	2.0E-8	3.8E-7	7.4E-8
Co-60	4.5E-5	4.4E-5	8.2E-4	8.1E-4
Mg-27	4.8E-8	3.5E-9	4.8E-8	3.5E-9
Ar-41	1.2E-7	4.4E-8	1.2E-7	4.4E-8

Table 7: Doses for Scenario 4. Intercomparison of DOSEEX, UFOTRI and COSYMA (MEI at 1 km distance)

	early dose (Sv)		EDE (Sv)	
	ACA-code	DOSEEX	ACA-code	DOSEEX
HT	1.9E-11	1.3E-9	5.9E-9	4.2E-8
HTO	3.2E-8	2.3E-8	1.0E-6	3.1E-7
Co-60	3.0E-5	4.2E-5	9.8E-3	4.1E-3
Mg-27	5.9E-8	2.6E-9	5.9E-8	2.6E-9
Ar-41	8.0E-8	2.9E-8	8.0E-8	2.9E-8

Table 8: Doses for Scenario 5. Intercomparison of DOSEEX, UFOTRI and COSYMA (MEI at 1 km distance)

3.2 Investigations about the worst case release scenario from stack of 100 m height

The basic combination of wind speed and stability is shown in Table 9. The values have been taken from /STO94/. The only exception is the wind speed for stability class F which has to be set to 0.5 m/s as UFOTRI does not accept lower wind velocities as input. As the solar irradiation is very important for the uptake of HTO by the crops, those values have been defined too. However, as the stationarity expressed in the basic guidelines for the dose calculations for ITER prevent changing environmental conditions, the solar irradiation has to be constant during the simulation process which lasts for about 70 hours. The selected solar irradiation values are therefore slightly smaller than the observed values to take into account also night-time conditions. Otherwise, the build-up of OBT, which is dominating the dose at all, would be highly overestimated. Even with these solar irradiation values the doses seem to be rather high.

stability class	wind speed (m/s)	solar irradiation (W/m^2)
A	0.9	350
B	1.3	300
C	1.7	250
D	2.0	200
E	1.2	120
F	0.5	80

Table 9: Combination of stability class, wind speed (at 10 m height) and solar irradiation

The highest early dose due to an HTO-release (beyond 1 km distance) has been obtained for the combination of MOL and stability class F (see Table 10 and Figure 16). The highest EDE due to an HTO-release has been found for MOL and stability class A (see Table 11 and Figure 17). The main reason for this discrepancy is the ingestion dose which dominates the EDE. The ingestion dose, however, is strongly linked to the tritium uptake by the plants and the OBT formation rate. The uptake rate as well as the OBT formation rate are higher under solar irradiation conditions which can be found for the unstable stratifications.

The highest early dose due to a release of HT (beyond 1 km distance) has been obtained for the combination of KLUG and a stability class F (see Table 16 and Figure 22). The highest EDE due to an HT-release was obtained for the combination of MOL and stability class F (see Table 15 and Figure 21). These findings differ from those of the HTO cases. One reason is that the reemission process dominates the dose due to an HT-release. This shifts the concentration maximum to farther distances and supports narrow plumes. This is also the reason why the air concentration is not a good indicator for doses due to HT-releases. As the HT does not enter the plant directly from the passing cloud, the solar irradiation is only important for the OBT formation but not for the direct uptake of tritium via the leaves. The deposited tritium is the main source for incorporation of tritium in the plants.

distance (m)	stability class					
	A	B	C	D	E	F
500	**3.7E-5**	**2.5E-5**	1.5E-5	5.3E-6	1.3E-6	3.8E-7
680	2.8E-5	2.2E-5	**1.7E-5**	9.3E-6	5.0E-6	3.4E-6
1000	1.8E-5	1.6E-5	1.5E-5	**1.1E-5**	1.1E-5	1.5E-5
1500	1.1E-5	1.0E-5	1.1E-5	9.7E-6	**1.4E-5**	2.8E-5
2000	7.4E-6	7.3E-6	8.4E-6	8.2E-6	1.3E-5	**3.1E-5**
3200	3.7E-6	3.8E-6	4.6E-6	4.9E-6	9.2E-6	2.5E-5
5000	2.0E-6	2.1E-6	2.6E-6	2.8E-6	5.7E-6	1.7E-5
6800	1.2E-6	1.5E-6	1.8E-6	2.0E-6	4.1E-6	1.2E-5
10000	6.6E-7	8.9E-7	1.0E-6	1.2E-6	2.6E-6	8.9E-6

Table 10: Distance dependent early dose (Sv) of the MEI (release of 3.7E14 Bq of tritium in form of HTO, release height 100m, sigma parameter set MOL, the highest value is highlighted)

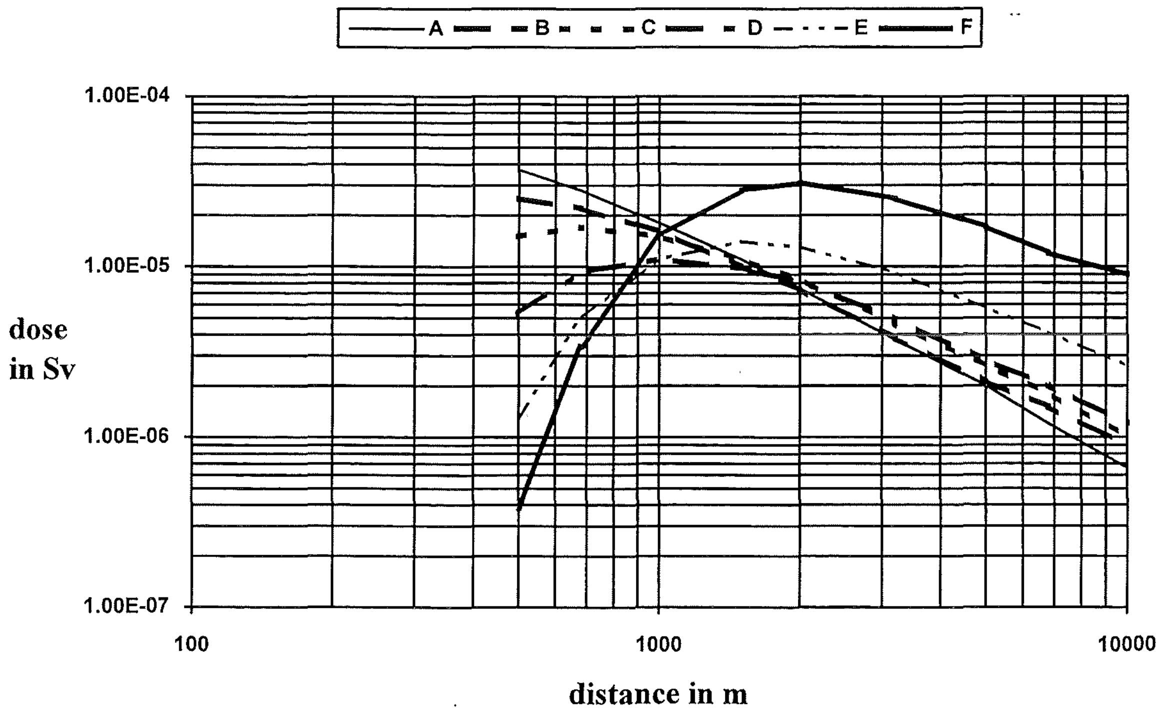

Figure 16: Distance dependent early dose of the MEI (release of 3.7E14 Bq of tritium in form of HTO, release height 100m, sigma parameter set MOL)

distance (m)	stability class					
	A	B	C	D	E	F
500	**6.2E-4**	**3.8E-4**	2.1E-4	6.3E-5	9.9E-6	1.5E-6
680	4.7E-4	3.3E-4	**2.3E-4**	1.1E-4	3.7E-5	1.4E-5
1000	3.0E-4	2.4E-4	2.0E-4	**1.3E-4**	8.2E-5	6.2E-5
1500	1.8E-4	1.5E-4	1.4E-4	1.1E-4	**1.0E-4**	1.2E-4
2000	1.2E-4	1.1E-4	1.1E-4	9.4E-5	1.0E-4	**1.3E-4**
3200	6.1E-5	5.7E-5	6.0E-5	5.6E-5	7.0E-5	1.1E-4
5000	3.2E-5	3.1E-5	3.4E-5	3.2E-5	4.3E-5	7.1E-5
6800	2.1E-5	2.1E-5	2.1E-5	2.2E-5	3.1E-5	5.1E-5
10000	1.1E-5	1.2E-5	1.3E-5	1.3E-5	1.9E-5	3.8E-5

Table 11: Distance dependent EDE (Sv) of the MEI (release of 3.7E14 Bq of tritium in form of HTO, release height 100m, sigma parameter set MOL, the highest value is highlighted)

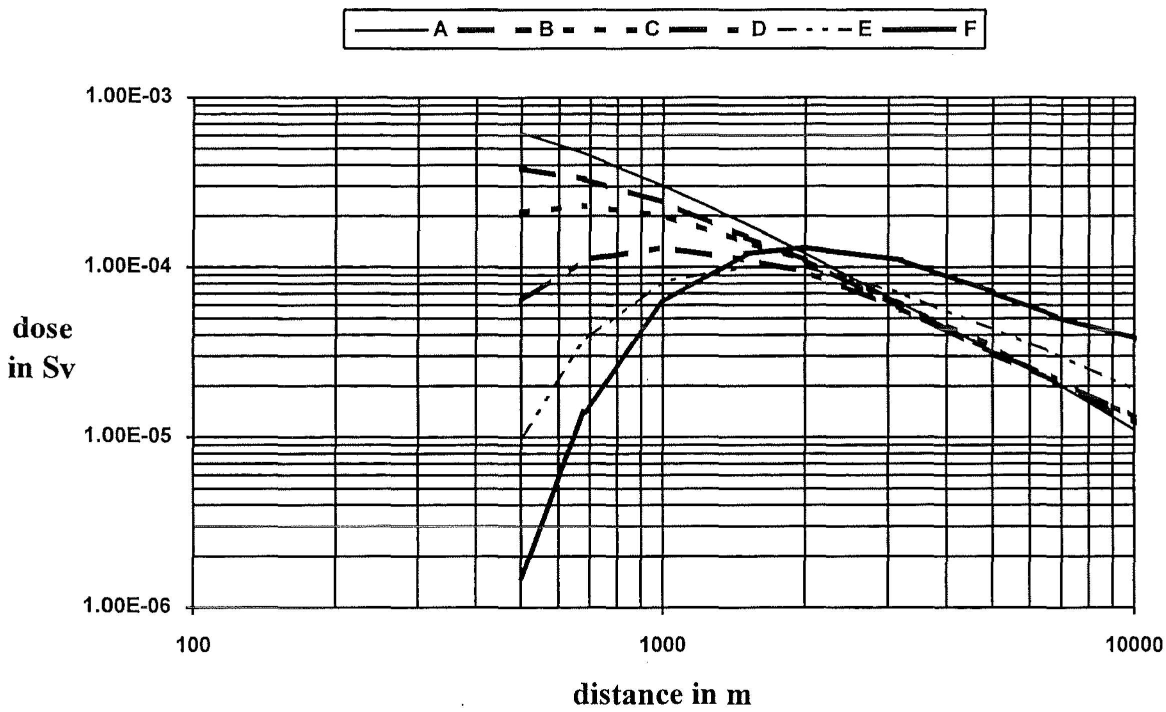

Figure 17: Distance dependent EDE of the MEI (release of 3.7E14 Bq of tritium in form of HTO, release height 100m, sigma parameter set MOL)

distance (m)	stability class					
	A	B	C	D	E	F
500	1.1E-7	7.3E-8	4.1E-8	9.7E-9	6.2E-10	9.4E-11
680	**1.2E-7**	**1.0E-7**	7.8E-8	3.4E-8	9.1E-9	8.1E-10
1000	8.9E-8	8.4E-8	**8.0E-8**	4.9E-8	3.6E-8	3.1E-8
1500	6.4E-8	6.6E-8	7.1E-8	**9.5E-8**	6.3E-8	9.6E-8
2000	5.5E-8	6.0E-8	6.9E-8	6.2E-8	**8.9E-8**	**1.7E-7**
3200	3.1E-8	3.4E-8	4.1E-8	3.9E-8	6.8E-8	1.6E-7
5000	1.9E-8	2.2E-8	2.7E-8	2.7E-8	5.3E-8	1.5E-7
6800	1.5E-8	1.7E-8	2.1E-8	2.2E-8	4.7E-8	1.4E-7
10000	9.0E-9	1.1E-8	1.3E-8	1.7E-8	3.1E-8	1.1E-7

Table 12: Distance dependent early dose (Sv) of the MEI (release of 3.7E14 Bq of tritium in form of HT, release height 100m, sigma parameter set MOL, the highest value is highlighted)

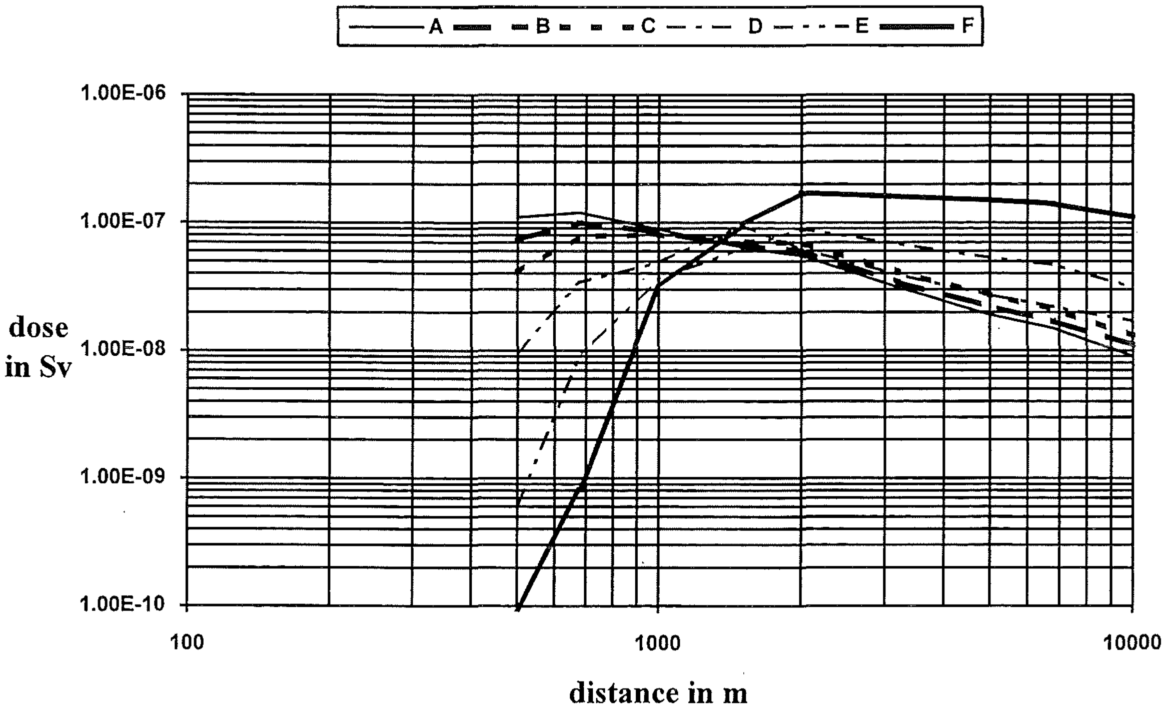

Figure 18: Distance dependent early dose of the MEI (release of 3.7E14 Bq of tritium in form of HT, release height 100m, sigma parameter set MOL)

distance (m)	stability class					
	A	B	C	D	E	F
500	**1.3E-5**	**8.1E-6**	4.6E-6	1.5E-6	3.8E-7	1.4E-7
680	1.0E-5	7.2E-6	**5.2E-6**	2.6E-6	1.4E-6	1.3E-6
1000	6.6E-6	5.2E-6	4.5E-6	**3.1E-6**	3.2E-6	5.6E-6
1500	4.0E-6	3.4E-6	3.3E-6	2.7E-6	**4.1E-6**	1.1E-5
2000	2.8E-6	2.5E-6	2.6E-6	2.3E-6	4.0E-6	**1.2E-5**
3200	1.5E-6	1.3E-6	1.4E-6	1.4E-6	2.8E-6	1.0E-5
5000	8.1E-7	7.5E-7	8.2E-7	8.2E-7	1.8E-6	6.8E-6
6800	5.5E-7	5.3E-7	5.7E-7	5.7E-7	1.3E-6	5.0E-6
10000	2.8E-7	3.0E-7	3.4E-7	3.4E-7	7.8E-7	3.7E-6

Table 13: Distance dependent EDE (Sv) of the MEI (release of 3.7E14 Bq of tritium in form of HT, release height 100m, sigma parameter set MOL, the highest value is highlighted)

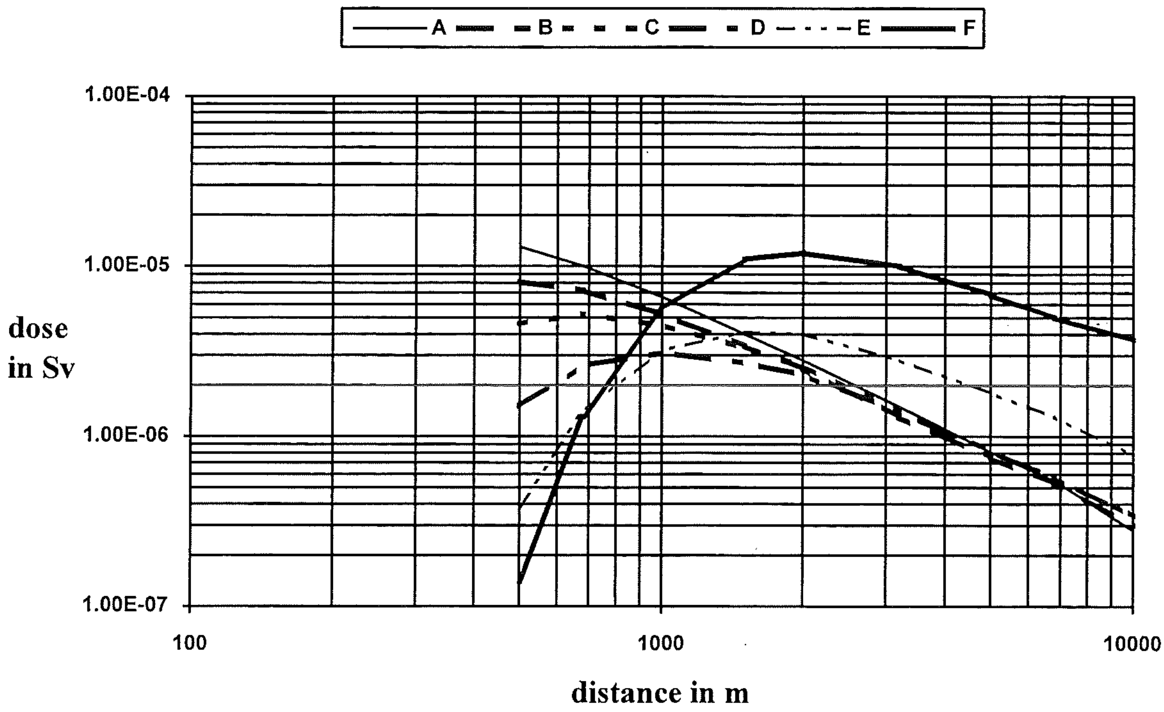

Figure 19: Distance dependent EDE of the MEI (release of 3.7E14 Bq of tritium in form of HT, release height 100m, sigma parameter set MOL)

distance (m)	stability class					
	A	B	C	D	E	F
500	**2.4E-5**	5.1E-6	3.8E-11	-		
680	1.8E-5	1.2E-5	1.5E-8	8.4E-13		
1000	9.4E-6	**1.4E-5**	7.1E-7	2.0E-9		
1500	4.7E-6	1.0E-5	3.8E-6	1.6E-7		
2000	2.6E-6	7.4E-6	**6.0E-6**	8.6E-7		
3200	1.0E-6	3.5E-6	5.7E-6	3.1E-6		
5000	5.9E-7	1.8E-6	3.8E-6	**4.4E-6**		
6800	4.7E-7	1.1E-6	2.7E-6	4.2E-6		
10000	2.4E-7	5.5E-7	1.6E-6	3.1E-6		1.5E-7
15000	2.1E-7	3.5E-7	8.6E-7	2.0E-6	**4.8E-6**	1.1E-6
20000	1.7E-7	2.8E-7	6.0E-7	1.5E-6	4.4E-6	2.8E-6
32000	1.1E-7	1.8E-7	3.3E-7	8.1E-7	2.9E-6	6.3E-6
50000	7.2e-8	1.3E-7	2.3E-7	4.5E-7	1.8E-6	8.5E-6
68000	6.2E-8	1.0E-7	1.8E-7	3.2E-7	1.3E-6	**8.6E-6**
100000	3.9E-8	5.9E-8	1.2E-7	2.3E-7	8.3E-7	7.0E-6

Table 14: Distance dependent early dose (Sv) of the MEI (release of 3.7E14 Bq of tritium in form of HTO, release height 100m, sigma parameter set KLUG, the highest value is highlighted)

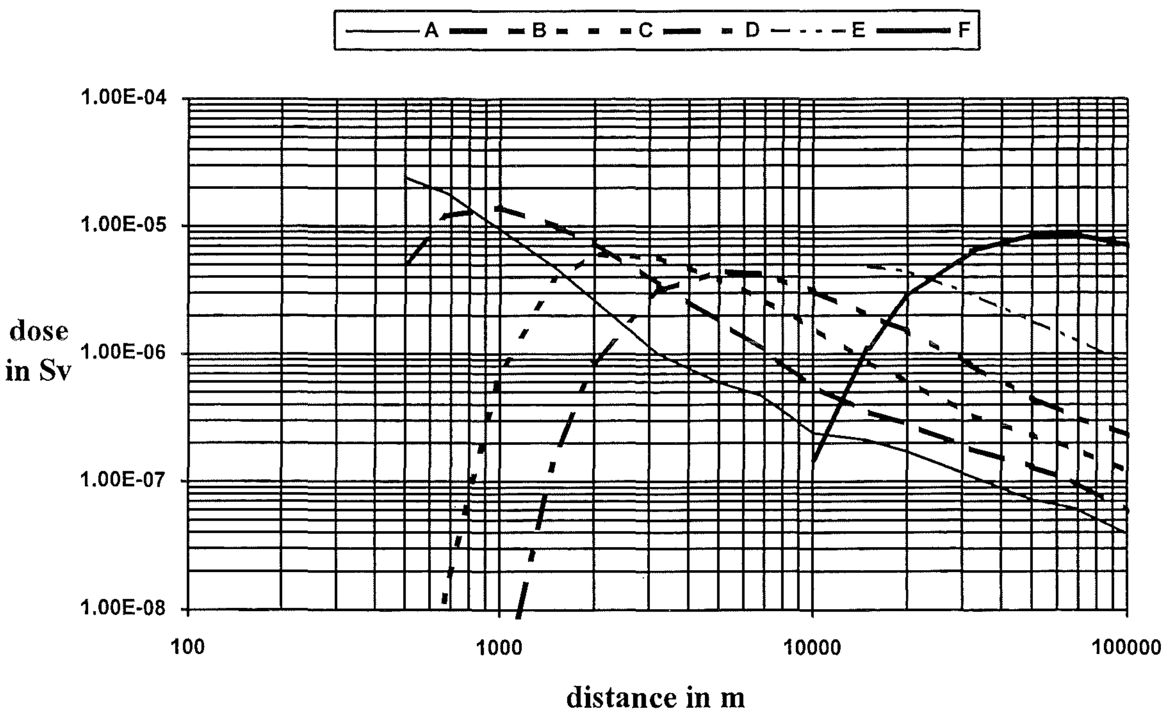

Figure 20: Distance dependent early dose of the MEI (release of 3.7E14 Bq of tritium in form of HTO, release height 100m, sigma parameter set KLUG)

distance (m)	stability class					
	A	B	C	D	E	F
500	**4.0E-4**	7.8E-5	5.2E-10	-		
680	3.0E-4	1.8E-4	2.0E-7	9.9E-12		
1000	1.6E-4	**2.1E-4**	9.7E-6	2.3E-8		
1500	7.1E-5	1.5E-4	5.1E-5	1.8E-6		
2000	4.1E-5	1.1E-4	**8.1E-5**	1.0E-5		
3200	1.6E-5	5.3E-5	7.8E-5	3.6E-5		
5000	9.5E-6	2.6E-5	5.2E-5	**5.1E-5**		
6800	7.0E-6	1.6E-5	3.6E-5	4.9E-5		
10000	4.9E-6	8.4E-6	2.1E-5	3.6E-5	-	6.4E-7
15000	3.4E-6	5.1E-6	1.1E-5	2.3E-5	**3.7E-5**	4.8E-6
20000	2.8E-6	4.1E-6	7.7E-6	1.7E-5	3.4E-5	1.2E-5
32000	1.7E-6	2.7E-6	4.2E-6	9.2E-6	2.3E-5	2.9E-5
50000	1.2E-6	1.8E-6	2.9E-6	5.1E-6	1.5E-5	**3.8E-5**
68000	8.7E-7	1.4e-6	2.2E-6	3.5E-6	1.1E-5	3.8E-5
100000	5.0E-7	7.6E-7	1.5E-6	2.5E-6	8.9E-6	3.0E-5

Table 15: Distance dependent EDE (Sv) of the MEI (release of 3.7E14 Bq of tritium in form of HTO, release height 100m, sigma parameter set KLUG, the highest value is highlighted)

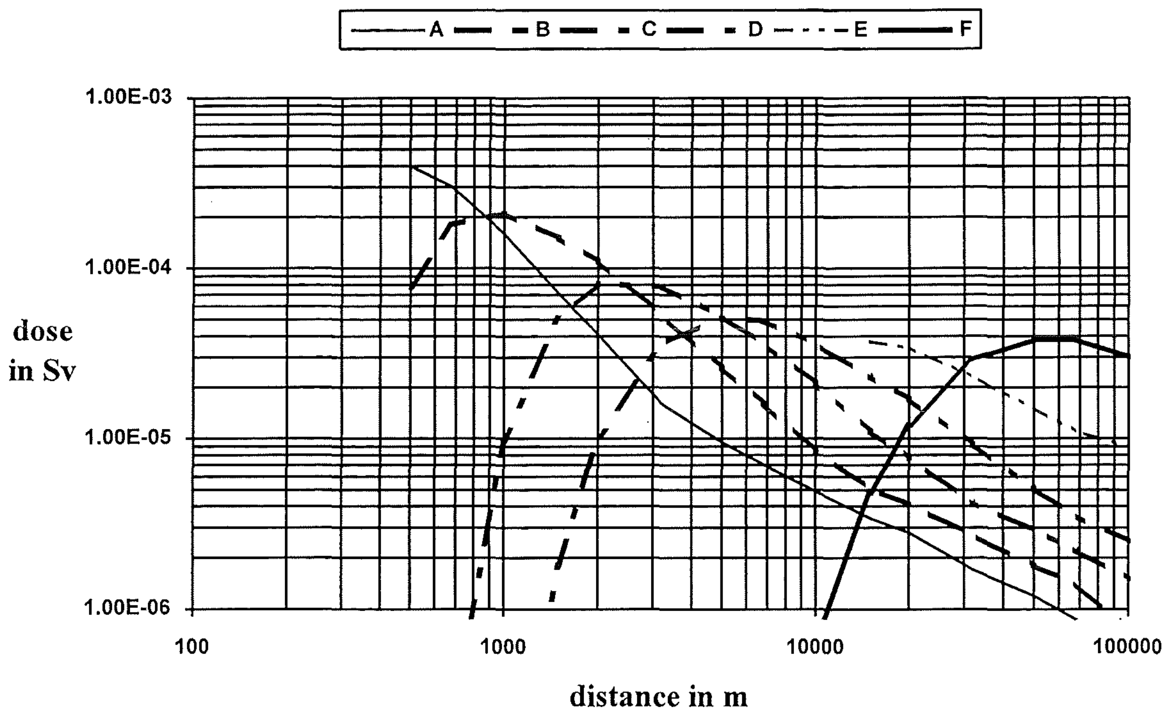

Figure 21: Distance dependent EDE of the MEI (release of 3.7E14 Bq of tritium in form of HTO, release height 100m, sigma parameter set KLUG)

distance (m)	stability class					
	A	B	C	D	E	F
500	4.6E-8	6.4E-9	3.6E-15	-		
680	**7.3E-8**	3.1E-8	6.4E-13	3.6E-17		
1000	5.8E-8	5.0E-8	1.0E-9	8.4E-14		
1500	3.9E-8	5.6E-8	9.5E-9	1.1E-10		
2000	3.0E-8	**5.7E-8**	2.7E-8	1.6E-9		
3200	1.5E-8	3.4E-8	3.0E-8	6.1E-9		
5000	8.4E-9	2.2E-8	**3.1E-8**	1.3E-8		
6800	6.6E-9	1.6E-8	3.0E-8	**1.9E-8**		
10000	4.4E-9	1.0E-8	2.0E-8	1.7E-8	-	3.3E-10
15000	3.1E-9	6.0E-9	1.3E-8	1.4E-8	9.0E-9	3.0E-9
20000	2.9E-9	4.1E-9	1.1E-8	1.4E-8	2.4E-8	1.2E-8
32000	2.1E-9	3.5E-9	7.0E-9	1.0E-8	2.5E-8	2.8E-8
50000	1.8E-9	2.9E-9	5.3E-9	8.0E-9	2.6E-8	8.5E-8
68000	1.7E-9	2.7E-9	4.7E-9	7.3E-9	2.9E-8	1.5E-7
100000	1.4E-9	2.0E-9	3.8E-9	6.1E-9	**3.0E-8**	**2.0E-7**

Table 16: Distance dependent early dose (Sv) of the MEI (release of 3.7E14 Bq of tritium in form of HT, release height 100m, sigma parameter set KLUG, the highest value is highlighted)

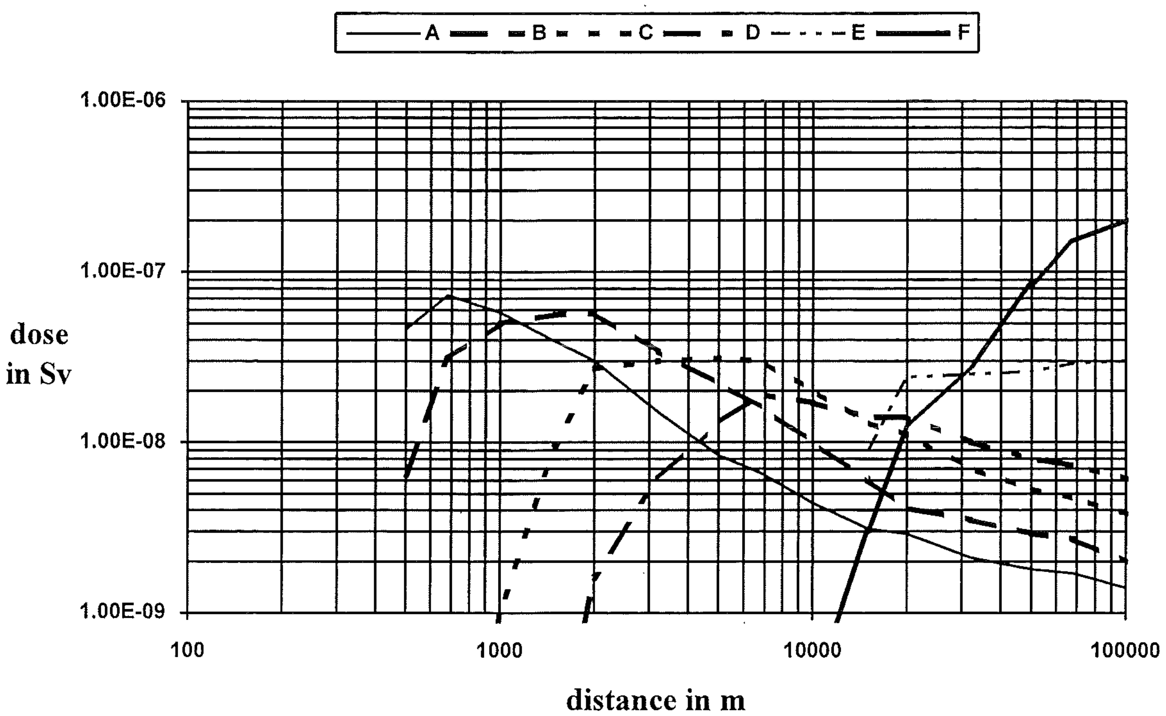

Figure 22: Distance dependent early dose of the MEI (release of 3.7E14 Bq of tritium in form of HT, release height 100m, sigma parameter set KLUG)

distance (m)	stability class					
	A	B	C	D	E	F
500	**8.5E-6**	1.7E-6	1.6E-15	-		
680	6.5E-6	3.9E-6	6.4E-13	3.6E-17		
1000	3.4E-6	**4.6E-6**	2.1E-7	8.4E-14		
1500	1.6E-6	3.4E-6	1.1E-6	4.3E-8		
2000	9.7E-7	2.5E-6	**1.8E-6**	2.4E-7		
3200	3.9E-7	1.2E-6	1.8E-6	8.6E-7		
5000	2.3E-7	6.2E-7	1.2E-6	1.2E-6		
6800	1.8E-7	4.1E-7	9.0E-7	**1.2E-6**		
10000	1.2E-7	2.1E-7	5.3E-7	9.1E-7		5.9E-8
15000	8.6E-8	1.3E-7	3.0E-7	6.1E-7	**1.5E-6**	4.4E-7
20000	7.3E-8	1.1E-7	2.1E-7	4.7E-7	1.4E-6	1.1E-6
32000	5.0E-8	7.3E-8	1.2E-7	2.8E-7	1.1E-6	2.6E-6
50000	3.8E-8	5.4E-8	8.8E-8	1.7E-7	7.7E-7	3.9E-6
68000	3.1E-8	4.6E-8	7.2E-8	1.3E-7	6.1E-7	**4.5E-6**
100000	1.9E-8	2.6E-8	5.3E-8	1.0E-7	4.7E-7	4.5E-6

Table 17: Distance dependent EDE (Sv) of the MEI (release of 3.7E14 Bq of tritium in form of HT, release height 100m, sigma parameter set KLUG, the highest value is highlighted)

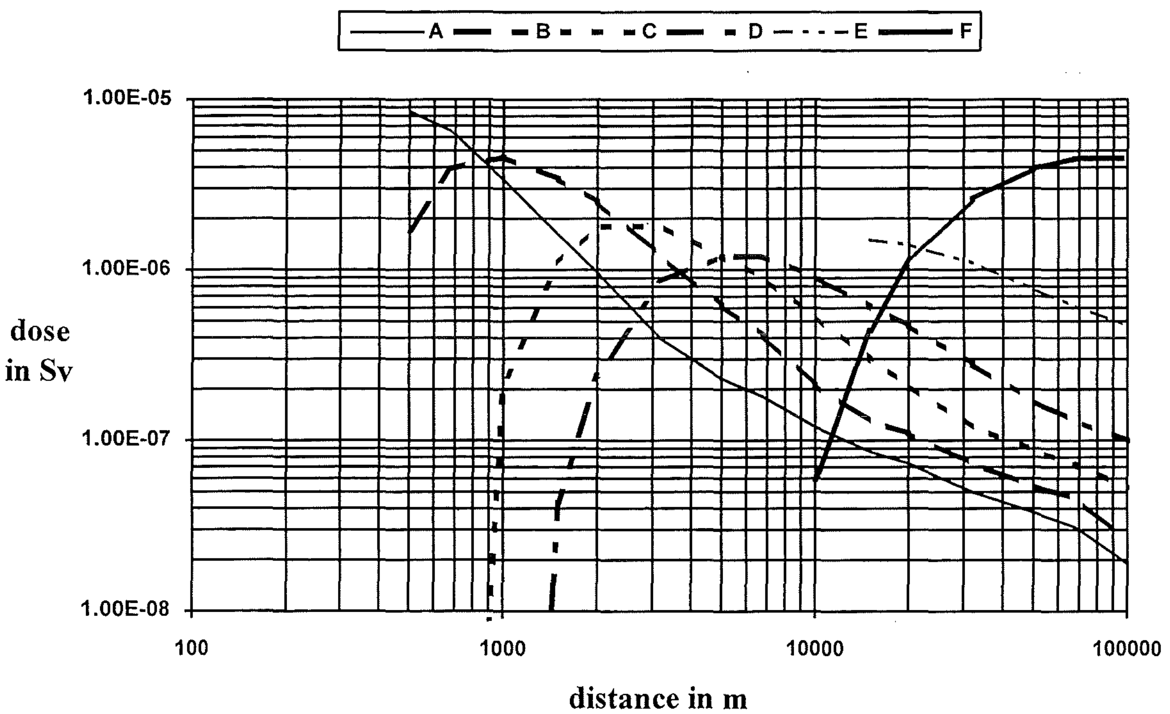

Figure 23: Distance dependent EDE of the MEI (release of 3.7E14 Bq of tritium in form of HT, release height 100m, sigma parameter set KLUG)

3.3 Normalised air concentrations from unit releases with different sets of sigma parameters

Normalised air concentrations (chi/q) have been obtained for unit releases from an elevated source of 100 m. The main goal was to identify the peak chi/q values for ITER relevant release situations when applying 3 different sets of sigma parameters. The first one, Karlsruhe-Jülich, is the requested sigma parameter set within the German licensing processes. This set represents dispersion conditions in rough terrain with obstacles of 10m and higher (trees and urban area). The averaging times are about 1 hour. The second one, KLUG, has been widely used in Germany in the past and it represents the opposite from the former set namely smooth terrain (grass) and short sampling times (10 minutes). The plumes are rather narrow. For this study, the sampling times have been corrected to 1 hour by applying equation 8 of chapter 2. The third one, MOL, lays in between of the two others. It has been determined in Belgium and can be applied for medium rough terrain (bushes and other obstacles of some meter height). Again the sampling time is about 1 hour.

Three combinations of wind speed and stability have been applied. First, the combination from Table 8 in chapter 2 has been used but with the exception, that now the wind speed for the stability class F is set to 0.4 m/s as recommended in /STO94/. The reference height of the wind velocity is 10 m. The wind speed is then scaled to the release height of 100m by using the power law function implemented in UFOTRI and COSYMA. In a second scenario, the reference height of the wind speed was set to the release height of 100 m which means that the wind speed remain unchanged. In a third scenario the wind velocity was fixed to 1 m/s at 100 m height. The results of the calculations are documented in 9 figures in the Appendix B.

Only distances farther than 1 km from the release point are of interest, as it is assumed that the fence of a future fusion site may be situated at this point. The peak chi/q results always in different stability classes dependent on the sigma scheme. In general, the fixed wind speed at 100 m height shows the highest air concentrations as the wind velocity which is scaled from 10 m to 100m is higher for all scenarios.

The stability classes C and D can be identified as worst case conditions for the Karlsruhe-Jülich sigma set. The fixed wind velocities of 1 m/s at 100 m show the highest air concentrations. These observations differ for the results with the sigma parameter set KLUG. Here, the stability classes B to F can result in the highest air concentrations, dependent on the chosen wind speed distribution. For the default set at 10 m height and at 100 m height, the stability class B is leading, whereas for the fixed wind velocity of 1 m/s at 100 m, the stability classes D, E and F show nearly the same peak chi/q, however, in different distances from the release point (between 1 km to 2 km). The third sigma parameter set MOL shows a third behaviour differing from the two others. Here, the stability class F results always in the highest air concentrations obtained beyond 1 km distance. Only in case of the fixed wind speed of 1.0 m/s at 100 m height also the stability classes D and E have similar chi/q values in the vicinity of the plant. The overall highest chi/q value was obtained for the combination of MOL, stability class F and fixed default wind speed at 100 m height (0.4 m/s), which is, however, an over-conservatism and is a result only from arbitrary assumptions. Under conditions as presented in Table 8, again the combination of MOL and stability class F is leading, however with a lower chi/q as before.

Again it has to be pointed out, as demonstrated in chapter 3.2, that the air concentration is not always a good indicator for the highest dose. This is the fact especially for HT because its dose is dominated by the reemitted HTO and not by the HT itself.

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APPENDIX A

No	Nuclide	No	Nuclide	No	Nuclide
1	BE- 10	46	CO- 58M	91	NB- 92M
2	C - 14	47	CO- 58	92	NB- 93M
3	N - 13	48	CO- 60M	93	NB- 94
4	N - 16	49	CO- 60	94	NB- 95M
5	NA- 22	50	CO- 61	95	NB- 95
6	NA- 24	51	NI- 57	96	NB- 96
7	MG- 27	52	NI- 59	97	NB- 97
8	MG- 28	53	NI- 63	98	MO- 93
9	AL- 26	54	NI- 65	99	MO- 99
10	AL- 28	55	CU- 64	100	MO-101
11	AL- 29	56	CU- 67	101	TC- 99M
12	SI- 32	57	ZN- 65	102	TC- 99
13	P - 32	58	ZN- 69M	103	TC-101
14	P - 33	59	KR- 83M	104	RU-103
15	S - 35	60	KR- 85M	105	RU-105
16	S - 37	61	KR- 85	106	RU-106
17	CL- 36	62	KR- 87	107	PD-103
18	CL- 38	63	KR- 88	108	PD-107
19	AR- 37	64	SE- 75	109	RH-103M
20	AR- 39	65	SE- 79	110	RH-105
21	AR- 41	66	RB- 83	111	AG-108
22	AR- 42	67	RB- 84	112	AG-108M
23	K - 40	68	RB- 86	113	AG-110M
24	K - 42	69	RB- 88	114	AG-111
25	K - 44	70	RB- 89	115	CD-109
26	CA- 41	71	SR- 85	116	CD-113M
27	CA- 45	72	SR- 89	117	SN-113
28	CA- 47	73	SR- 90	118	SN-117M
29	SC- 44	74	SR- 91	119	SN-119M
30	SC- 44M	75	SR- 92	120	SN-121M
31	SC- 46	76	SR- 93	121	SN-123
32	SC- 47	77	Y - 88	122	SN-126
33	SC- 48	78	Y - 90M	123	SB-124
34	TI- 45	79	Y - 90	124	SB-125
35	TI- 51	80	Y - 91M	125	SB-126
36	V - 49	81	Y - 91	126	SB-127
37	CR- 51	82	Y - 92	127	SB-128L
38	MN- 53	83	Y - 93	128	SB-129
39	MN- 54	84	ZR- 89	129	SB-130L
40	MN- 56	85	ZR- 93	130	SB-131
41	FE- 55	86	ZR- 95	131	TE-121
42	FE- 59	87	ZR- 97	132	TE-121M
43	FE- 60	88	NB- 91	133	TE-123M
44	CO- 56	89	NB- 91M	134	TE-125M
45	CO- 57	90	NB- 92	135	TE-127M

Table 18: List of the nuclide names

No	Nuclide	No	Nuclide	No	Nuclide
136	TE-127	188	PM-151	240	RE-184M
137	TE-129M	189	SM-145	241	RE-186
138	TE-129	190	SM-146	242	RE-186M
139	TE-131M	191	SM-151	243	RE-188
140	TE-131	192	SM-153	244	RE-188M
141	TE-132	193	EU-150	245	OS-185
142	TE-133M	194	EU-152M	246	OS-191
143	TE-133	195	EU-152	247	OS-194
144	TE-134	196	EU-154	248	IR-192
145	I -125	197	EU-155	249	IR-192N
146	I -129	198	EU-156	250	PT-193
147	I -130	199	GD-150	251	HG-203
148	I -131	200	GD-151	252	TL-202
149	I -132	201	GD-153	253	TL-204
150	I -133	202	GD-159	254	TL-206
151	I -134	203	TB-150	255	PB-203
152	I -135	204	TB-157	256	PB-205
153	XE-131M	205	TB-158	257	PB-210
154	XE-133M	206	TB-160	258	BI-206
155	XE-133	207	TB-161	259	BI-207
156	XE-135M	208	DY-159	260	BI-208
157	XE-135	209	DY-165	261	BI-210
158	XE-138	210	DY-165M	262	PO-208
159	CS-134M	211	HO-163	263	PO-209
160	CS-134	212	HO-166	264	PO-210
161	CS-135	213	HO-166M	265	RA-226
162	CS-136	214	ER-169	266	U -234
163	CS-137	215	TM-168	267	U -235
164	CS-138	216	TM-170	268	U -238
165	BA-131	217	TM-171	269	NP-237
166	BA-133	218	YB-169	270	NP-238
167	BA-135M	219	YB-175	271	NP-239
168	BA-137M	220	LU-173	272	PU-236
169	BA-139	221	LU-174	273	PU-238
170	BA-140	222	LU-174M	274	PU-239
171	LA-137	223	LU-176	275	PU-240
172	LA-140	224	LU-176M	276	PU-241
173	LA-141	225	LU-177	277	PU-242
174	LA-142	226	HF-175	278	AM-241
175	CE-139	227	HF-178M	279	AM-242M
176	CE-141	228	HF-179M	280	AM-242
177	CE-143	229	HF-180M	281	AM-243
178	CE-144	230	HF-181	282	CM-242
179	PR-143	231	HF-182	283	CM-243
180	PR-145	232	TA-179	284	CM-244
181	ND-147	233	TA-182	285	CM-245
182	PM-143	234	TA-183	286	CM-246
183	PM-145	235	W -181	287	CM-247
184	PM-147	236	W -185	288	CM-248
185	PM-148M	237	W -187	289	HT
186	PM-148	238	W -188	290	HTO

Table 18: List of the nuclide names (continued)

Appendix B:

Chi/q values for the sigma schemes Karlsruhe-Jülich, KLUG and MOL

Sigma parameter set Karlsruhe-Jülich, fixed wind speed at 100 m height

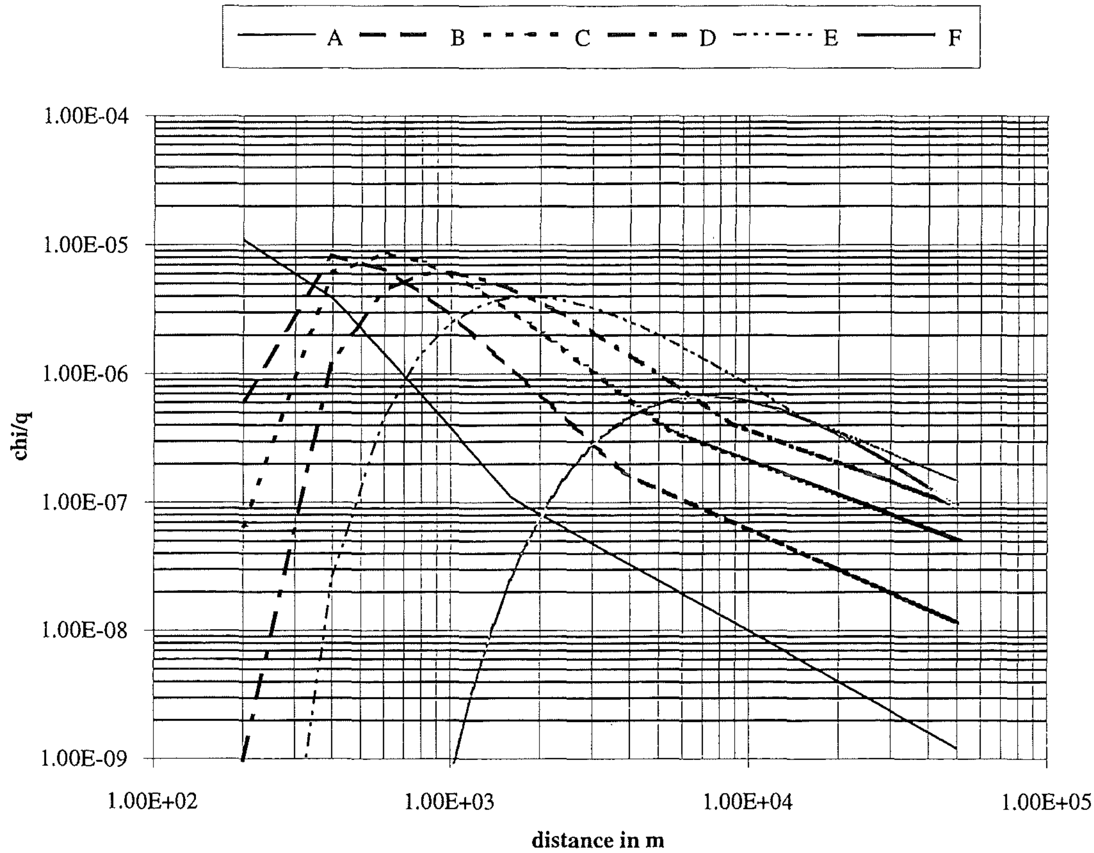

Figure 24: Chi/q values from unit releases of 100 m height. Reference wind speed height = 100m. Combination of stability class and wind speed according to Table 9 (but reference height now 100m)

Sigma parameter set Karlsruhe-Jülich, fixed wind speed at 100 m height (1m/s)

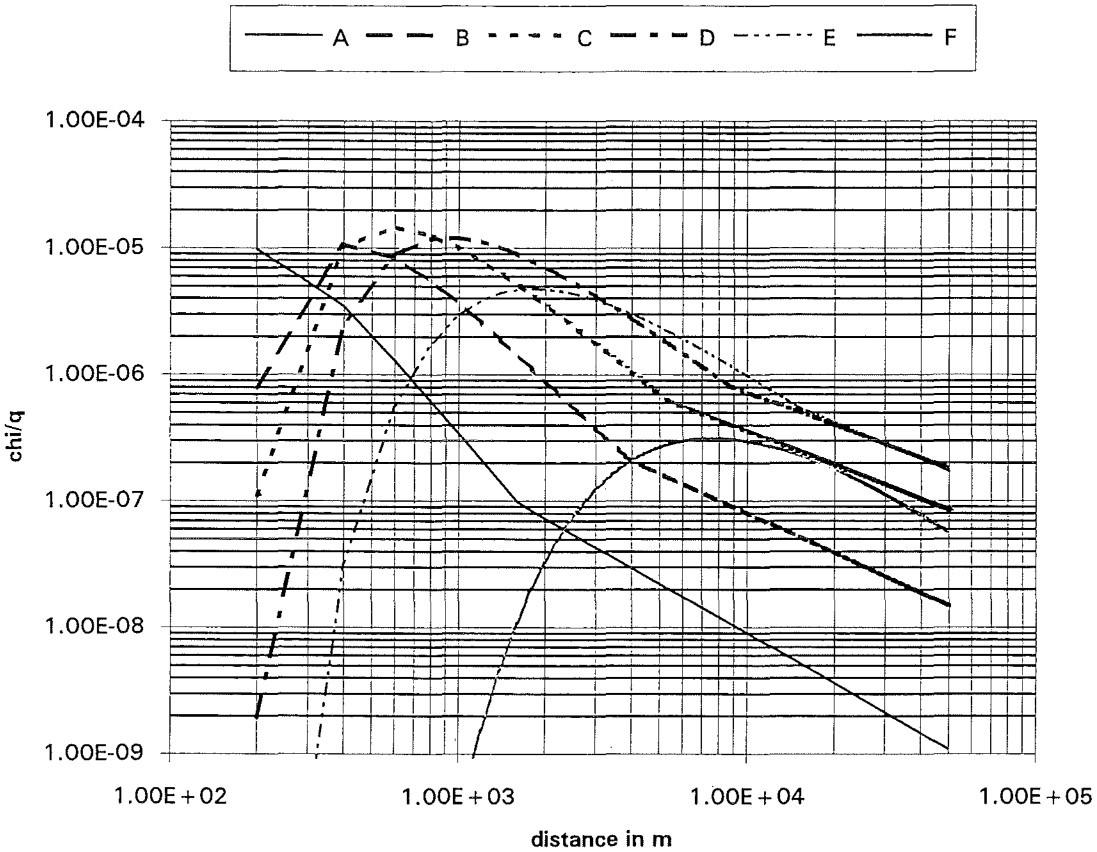

Figure 25: Chi/q values from unit releases of 100 m height. Reference wind speed height of 100m with fixed wind speed of 1 m/s in 100 m height.

Sigma parameter set Karlsruhe-Jülich, variable wind speed at 100 m height

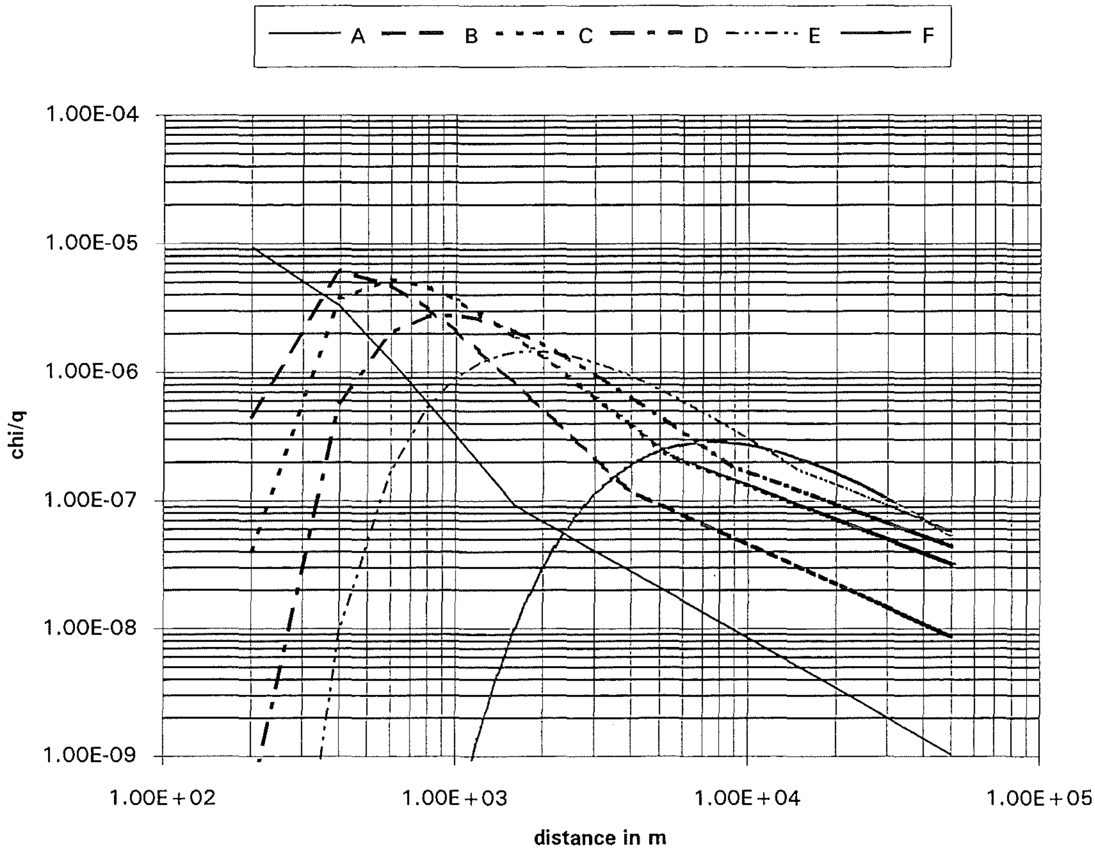

Figure 26: Chi/q values from unit releases of 100 m height. Reference wind speed height of 10m. Combination of stability class and wind speed according to Table 9

Sigma parameter set KLUG, fixed wind speed at 100 m height

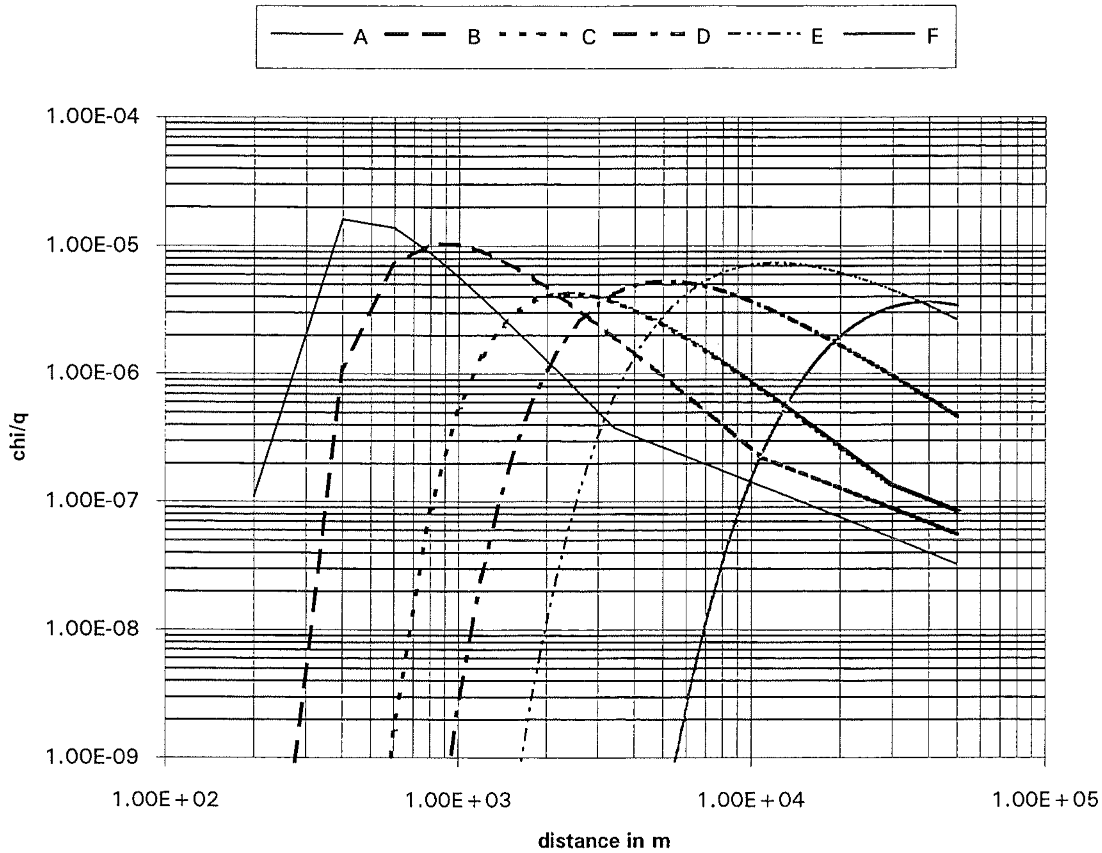

Figure 27: Chi/q values from unit releases of 100 m height. Reference wind speed height = 100m. Combination of stability class and wind speed according to Table 9 (but reference height now 100m)

Sigma parameter set KLUG, fixed wind speed at 100 m height (1m/s)

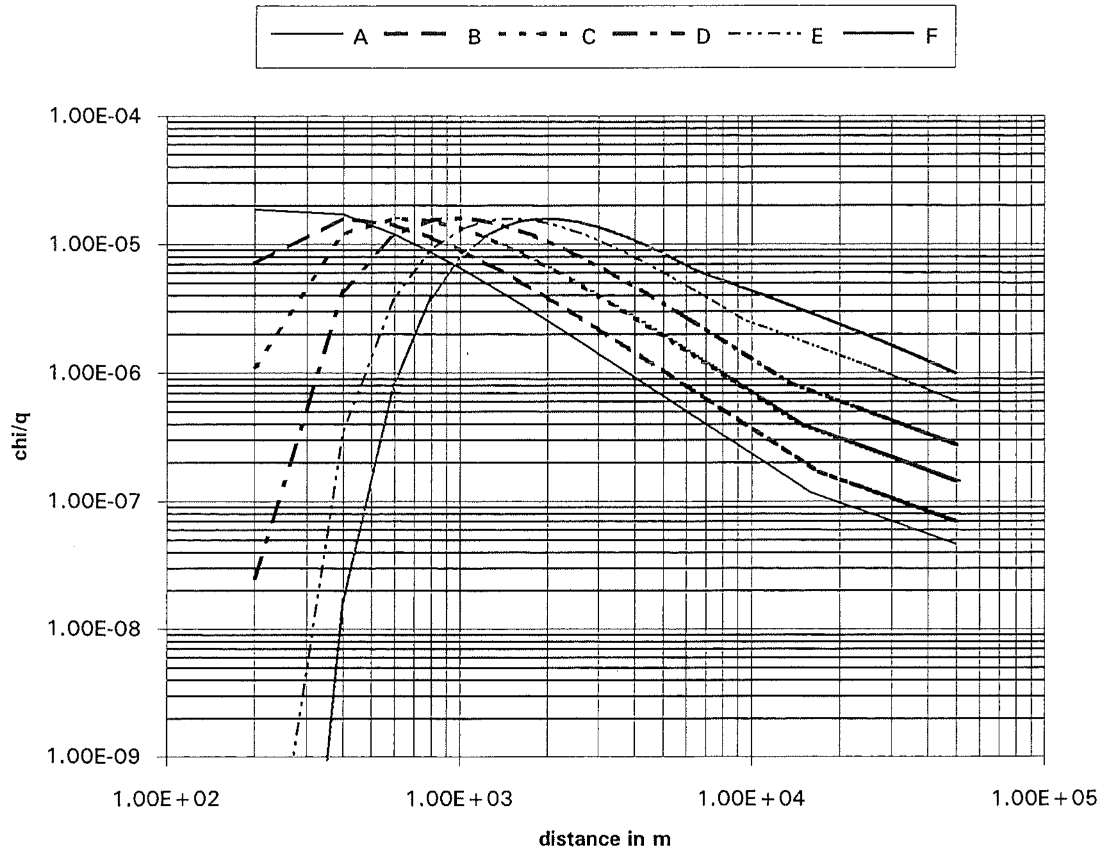

Figure 28: Chi/q values from unit releases of 100 m height. Reference wind speed height of 100m with fixed wind speed of 1 m/s in 100 m height.

Sigma parameter set KLUG, variable wind speed at 100 m height

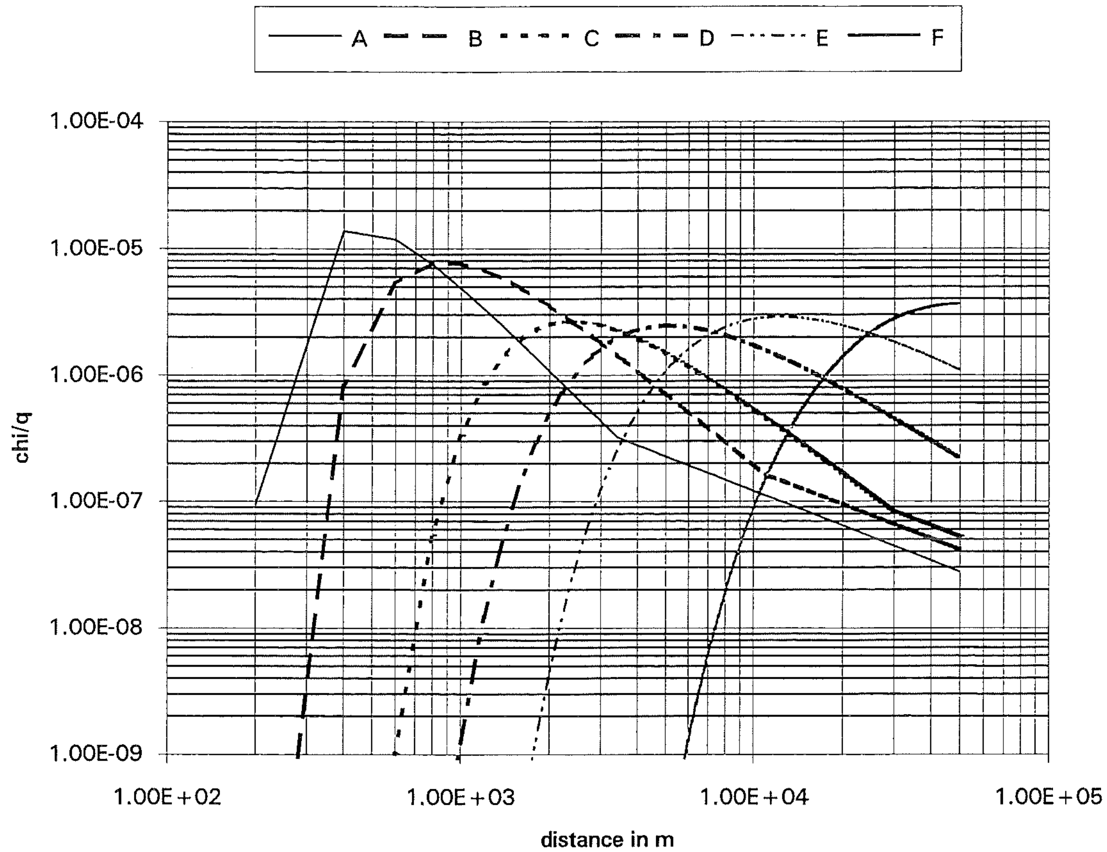

Figure 29: Chi/q values from unit releases of 100 m height. Reference wind speed height of 10m. Combination of stability class and wind speed according to Table 9

Sigma parameter set MOL, fixed wind speed at 100 m height

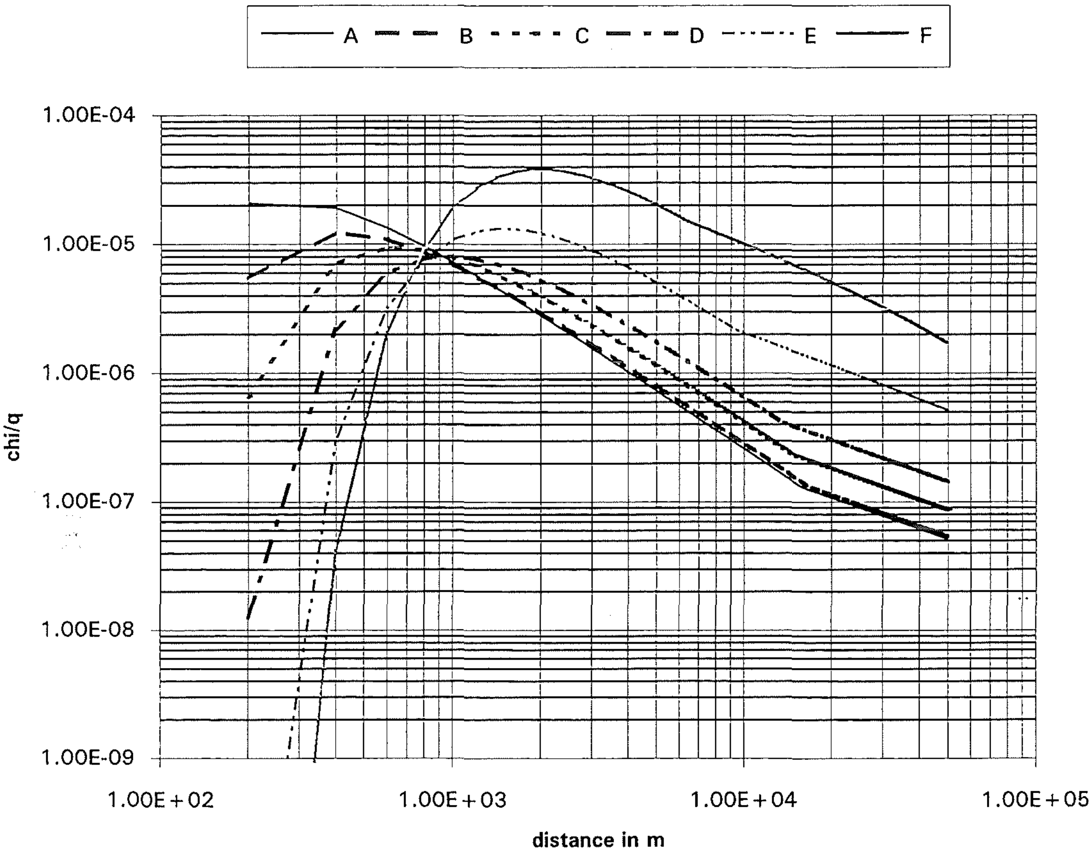

Figure 30: Chi/q values from unit releases of 100 m height. Reference wind speed height = 100m. Combination of stability class and wind speed according to Table 9 (but reference height now 100m)

Sigma parameter set MOL, fixed wind speed at 100 m height (1m/s)

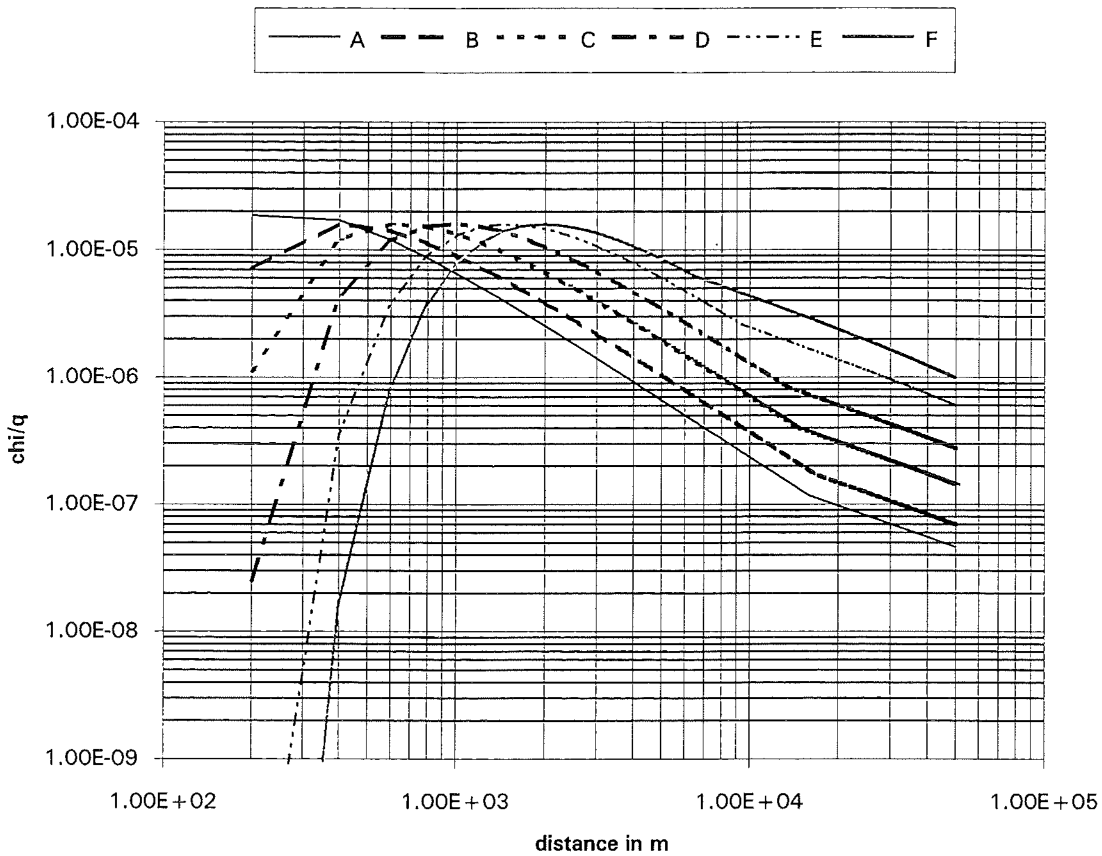

Figure 31: Chi/q values from unit releases of 100 m height. Reference wind speed height of 100m with fixed wind speed of 1 m/s in 100 m height.

Sigma parameter set MOL, variable wind speed at 100 m height

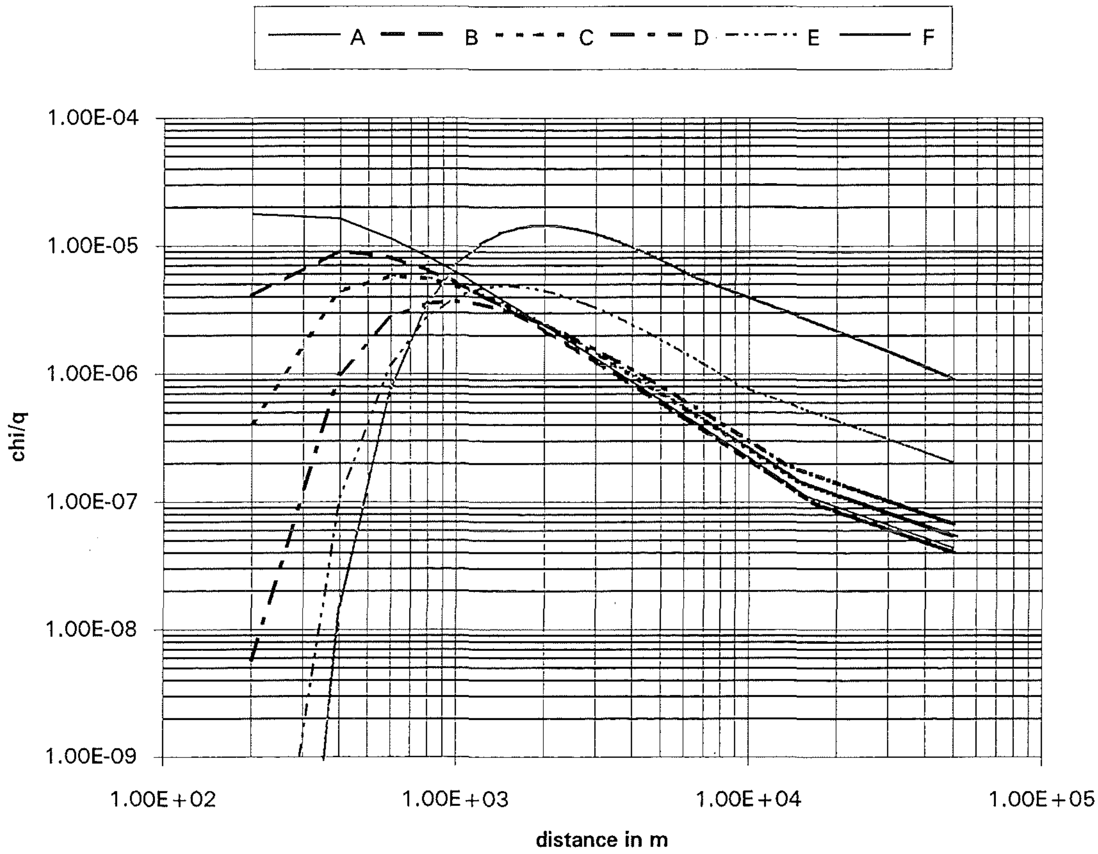

Figure 32: Chi/q values from unit releases of 100 m height. Reference wind speed height of 10m. Combination of stability class and wind speed according to Table 9