

Modelling NORM in the environment

EMRAS Project, NORM Working Group

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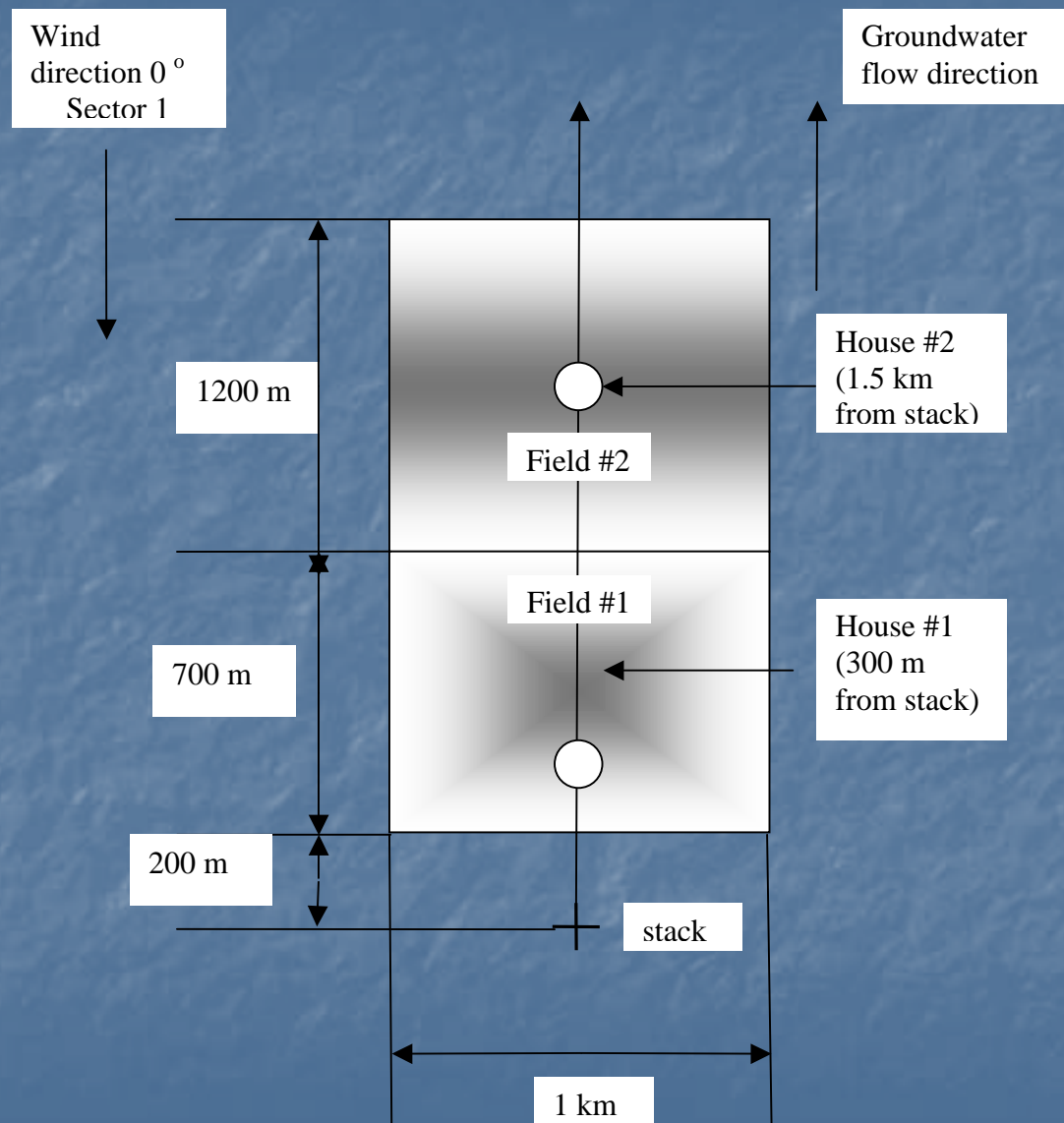
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Hypothetical point source scenario

- Point source
 - Single stack
 - 2 receptors (houses) at 300 and 1500 m
 - Wind rose data
 - Atmospheric stability data
 - Rainfall, occupancy and dietary data
 - Discharge data (Pb-210, Po-210)

- Predict
 - Air concentrations
 - Deposition & resuspension
 - Surface concentrations
 - Soil concentrations
 - Doses (external, food chain, inhalation)

Point source scenario



Annual wind rose data

Sector	Wind Direction	Frequency
		(%)
1	345° - < 15°	4.6
2	15° - < 45°	5.4
3	45° - < 75°	7.6
4	75° - < 105°	5.4
5	105° - < 135°	3.8
6	135° - < 165°	7.4
7	165° - < 195°	14.1
8	195° - < 225°	20.3
9	225° - < 255°	13.3
10	255° - < 285°	7.5
11	285° - < 315°	6
12	315° - < 345°	4.1

Annual atmospheric stability and wind speed data

Pasquill stability category	Frequency	Mean Wind Speed
	(%)	(m s ⁻¹)
A	0.5	1
B	0.5	1.5
C	4	2.5
D	28	5
E	38	8
F	27	6
G	2	4

Stack discharge data for the point source scenario

Effective stack height	100	m
Air discharge rate	100	m ³ s ⁻¹
²¹⁰ Pb discharge rate	100	Bq s ⁻¹
²¹⁰ Po discharge rate	100	Bq s ⁻¹

Dietary data

drinking water	well		400	L a ⁻¹
irrigation	river		1	L m ⁻² d ⁻¹ for 100 days
cattle	river		60	L d ⁻¹
sheep	river		6	L d ⁻¹
diet	fish		5	kg a ⁻¹
	grains	+ grain products	80	kg a ⁻¹
	fruits	+ juices	80	kg a ⁻¹
	vegetables		70	kg a ⁻¹
	meat	+ sausages	40	kg a ⁻¹
	milk	+ milk products	90	kg a ⁻¹
	root crops	without tubers	70	kg a ⁻¹
	tubers		90	kg a ⁻¹

Occupancy data

indoors – sleeping	8	h
indoors - light exercise	8	h
outdoors - light exercise	4	h
outdoors - heavy exercise	4	h

PC-CREAM 98

PC CREAM – (Consequences of Releases to the Environment: Assessment Methodology) is a suite of models and data for assessing the radiological consequences of the discharge of routine radioactive releases of aerial and liquid effluents to members of the population of concern

PC-CREAM 98

Methodology used with PC-CREAM

The processes modeled in PC-CREAM that influence the transfer of radionuclides in the receiving terrestrial environment are:

- Deposition from the atmosphere
- Migration of radionuclides in soil
- Transfer to plants
- Transfer to animals

PC-CREAM 98

- **ASSESSOR**, the assessment program, has the central dose assessment function within the programs.
- **FARMLAND** is a dynamic compartment model for evaluating the transfer of radionuclides through food chains following routine continuous releases to the atmosphere.
- **PLUME** is a Gaussian plume atmospheric dispersion model for calculating average radioactivity concentrations in air.
- **DORIS** is a marine dispersion model for European waters capable of calculating radioactivity concentrations in seawater, and marine sediments.
- **GRANIS** is a model for calculating external gamma exposure to an individual from deposited radioactivity in soil.
- **RESUS** is a time dependent resuspension model for calculating annual average activity concentrations in air due to the resuspension of previously deposited activity.

PC-CREAM 98

- To calculate the aerial dispersion factors, the **PLUME** program was used to generate the dispersion data libraries for ^{210}Po and ^{210}Pb , using the meteorological data provided.
- Next, a library of concentrations of ^{210}Po and ^{210}Pb in foodstuffs was created using the **FARMLAND** module. For this assessment, the undisturbed soil model was selected. Food consumption rates were those provided in the HPS scenario description.

PC-CREAM 98

- The **RESUS** module was run to calculate a library of time integrated resuspended activity concentrations in air of ^{210}Po and ^{210}Pb for the model's default integration times.
- Finally, using the habit data and discharge data provided, and using the output library files created from the various modules within PC-CREAM, food concentrations and the individual committed effective doses to the residents were calculated using **ASSESSOR**.

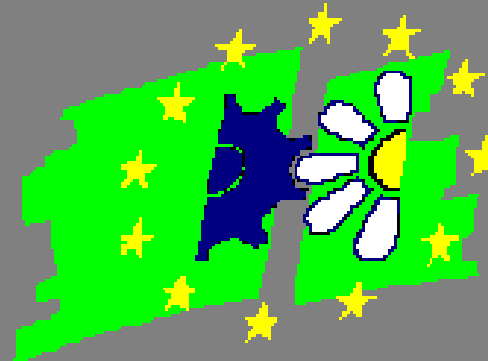
PC-CREAM 98

PC-CREAM 98

Consequences of Releases to the Environment
Assessment Methodology

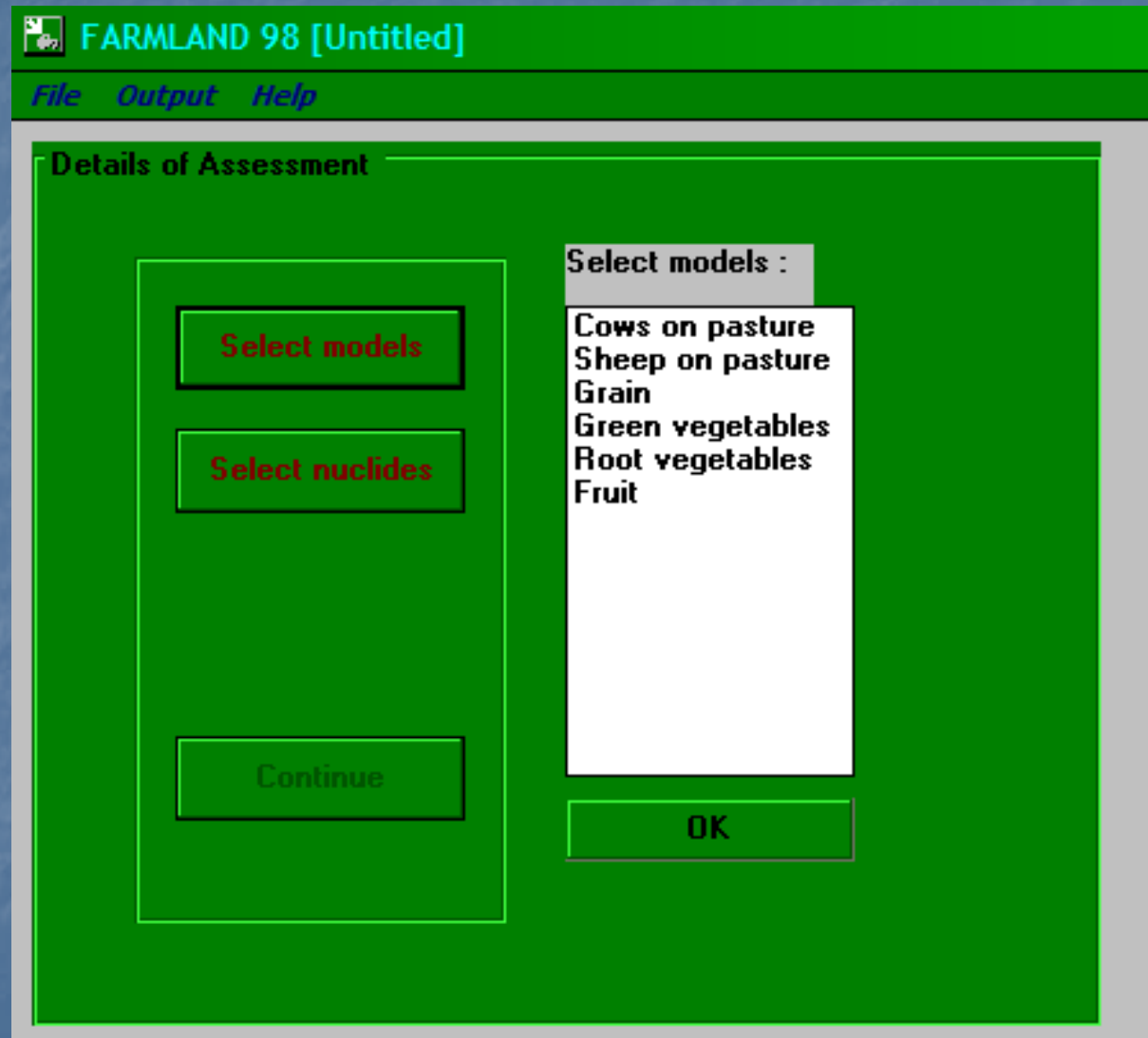


National Radiological Protection Board

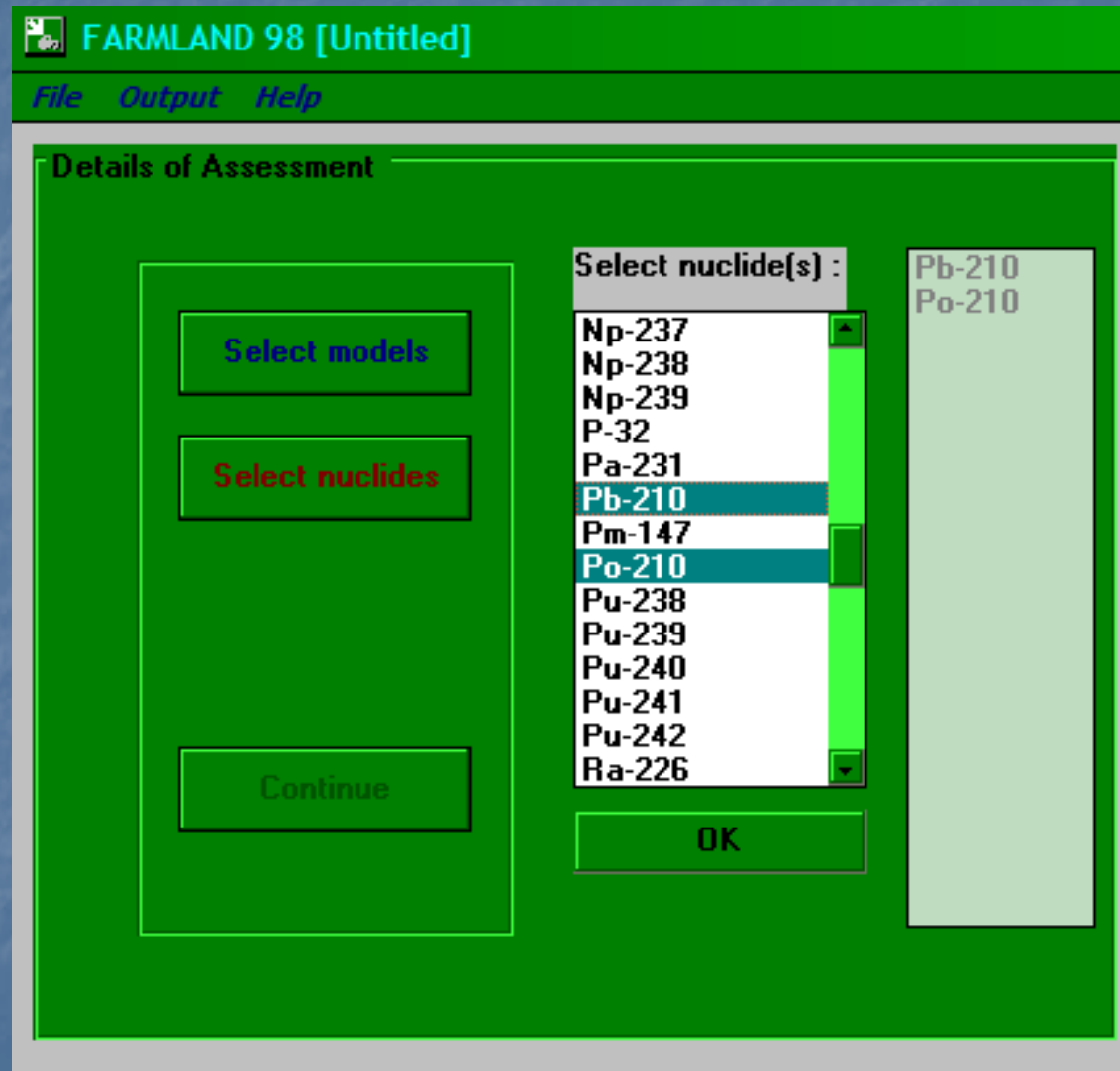


*European Commission
Directorate-General
Environment, Nuclear Safety
and Civil Protection (DGXI)*

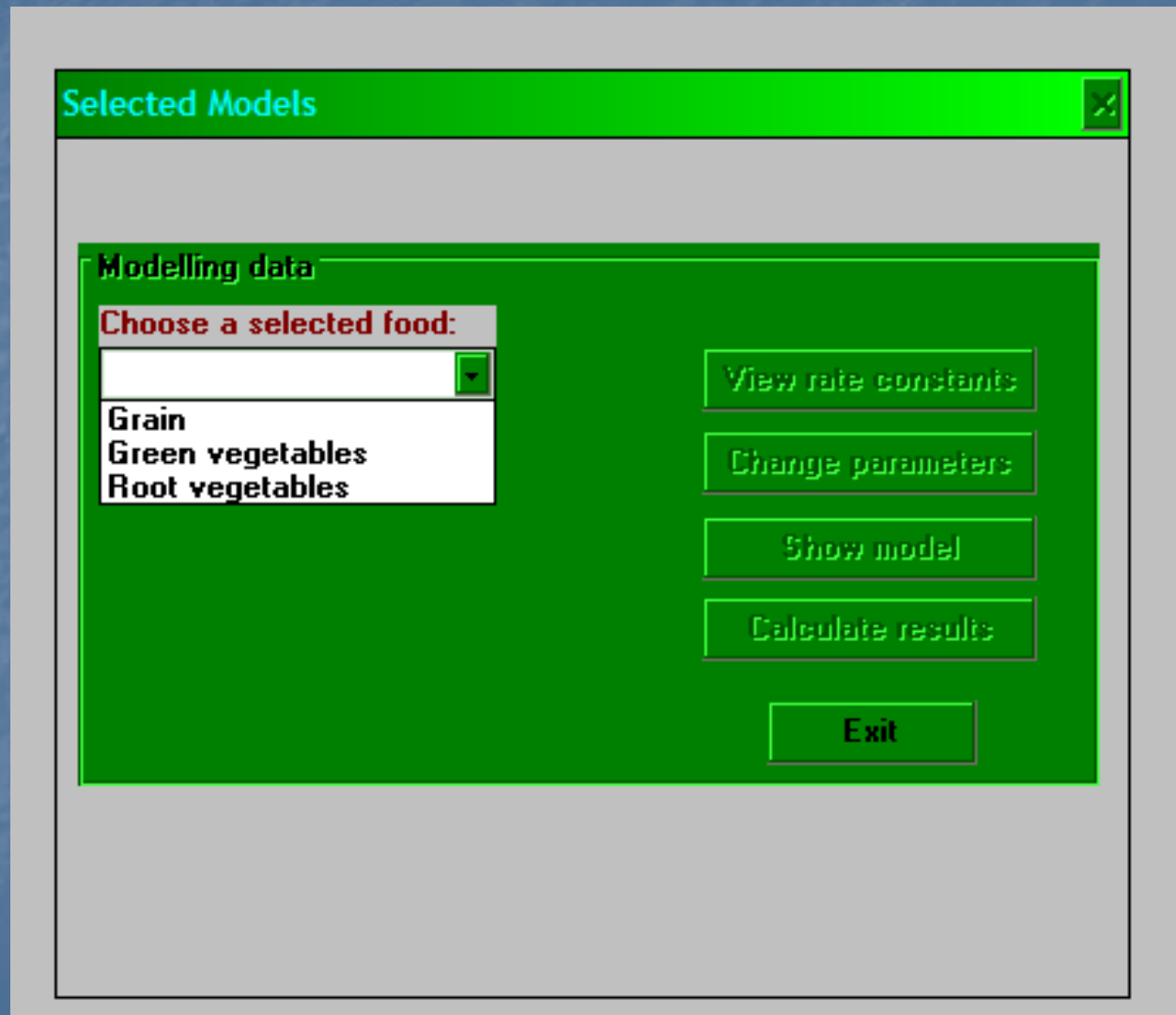
PC-CREAM 98 FARMLAND



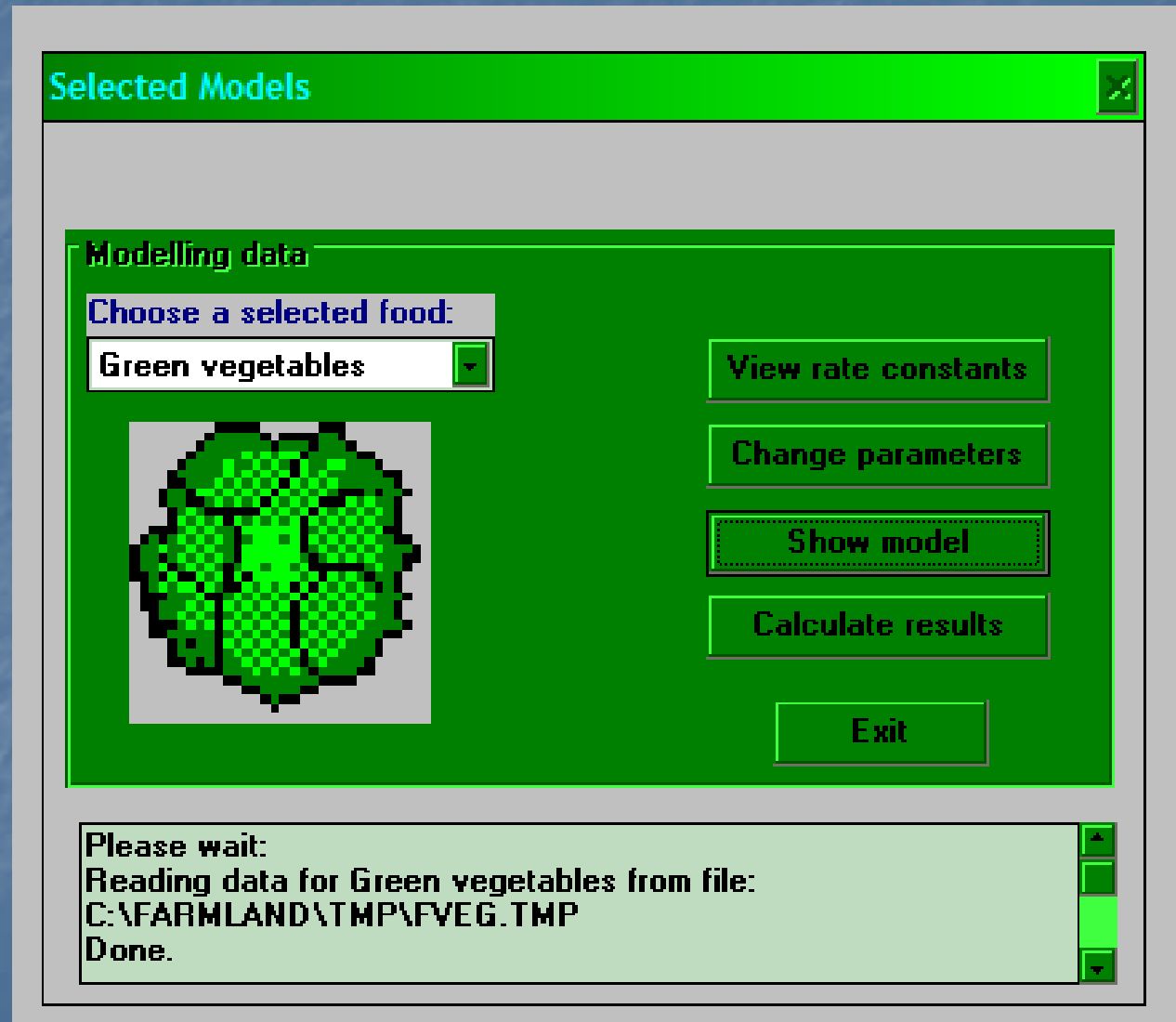
PC-CREAM 98 FARMLAND



PC-CREAM 98 FARMLAND



PC-CREAM 98 FARMLAND



PC-CREAM 98 FARMLAND

Input For Running COMA

Green vegetables

Input parameters for COMA:

Title of run:
PC FARMLAND - Green vegetables

Initial continuous deposition (Bq/km²/d) 8.64E+10

Output times

Soil concentrations required.
 Preparation losses included.

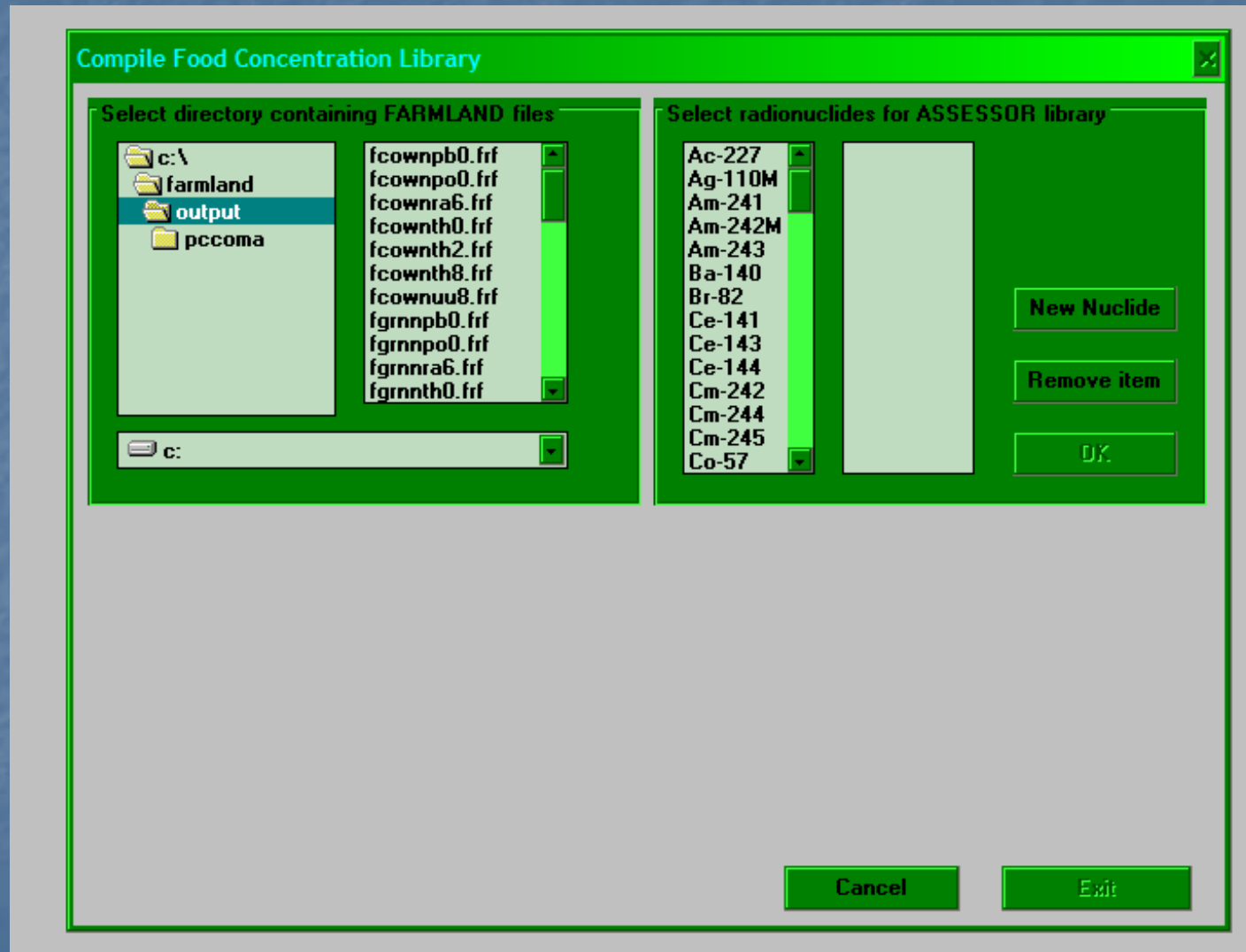
File definitions:

Directory for COMA output:
C:\FARMLAND\output\pccoma\

Directory for model results:
C:\FARMLAND\output\

Filename for model results:
fveg****

PC-CREAM 98 FARMLAND



PC-CREAM 98 GRANIS

Run Options

- Soil migration and external dose
- External dose only

Soil migration details

Nuclides

Source and Times

Soil Model Data

External dose details

Material Comp

PC-CREAM 98 GRANIS

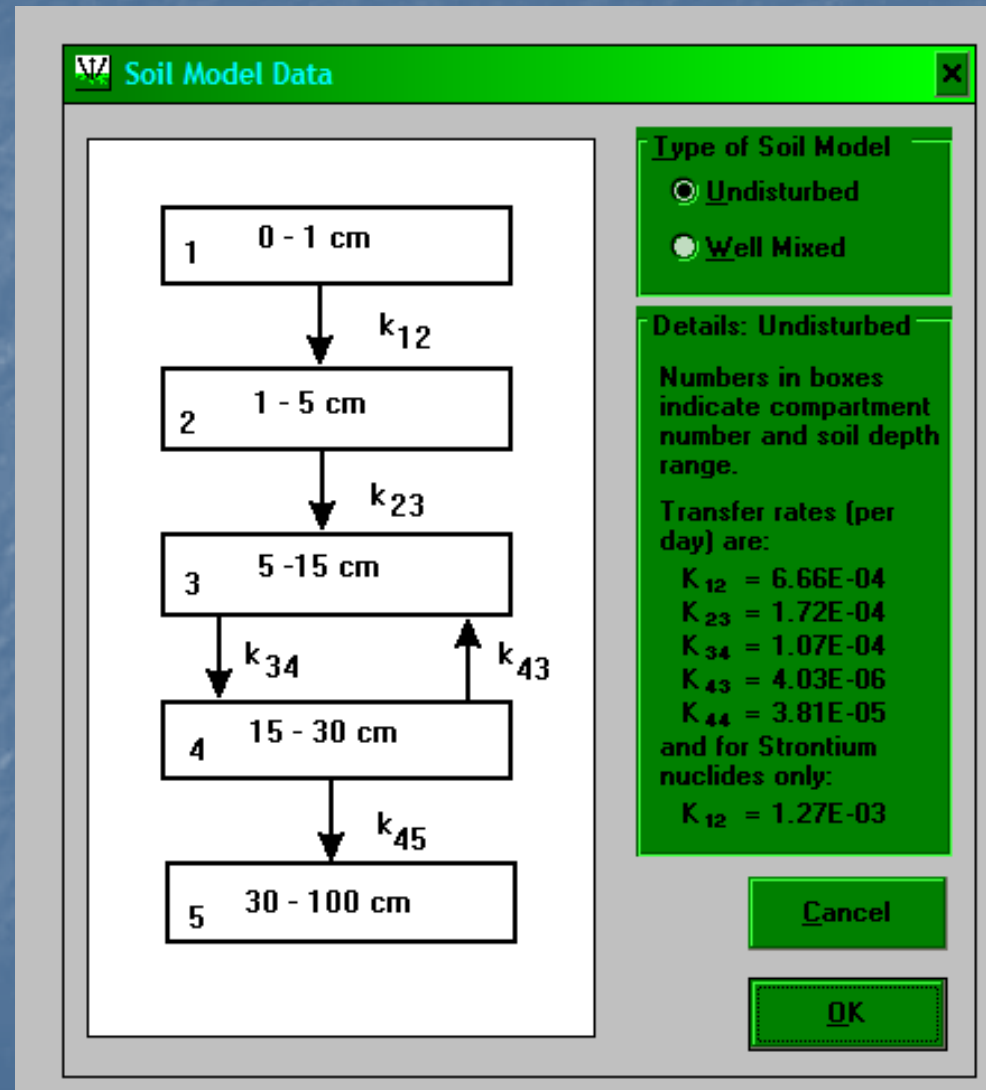
Nuclide Data [X]

6 Selected Decay Chains

Nuclides available	Parent	Daughter(s)	Decay Rate(d ⁻¹)	Nuclides which are considered to be short-lived with respect to their parents are followed by (s).
AC-227	PB-210	BI-210(s)	8.52E-05	
AC-228		PO-210	0.138	
AG-110M			0.00501	
AM-241	RA-226		1.19E-06	
AM-242		RN-222(s)	0.181	
AM-242M		PO-218(s)	327	
AM-243		PB-214	37.2	
AM-244		BI-214	50.2	
AM-244M		PO-214(s)	3.65E+08	
AS-76		PB-210	8.52E-05	
BA-140		BI-210(s)	0.138	
BI-210		PO-210	0.00501	
BR-82				
CA-45				
CE-141	U-238		4.25E-13	
CE-144		TH-234(s)	0.0288	
CF-244		PA-234M(s)	853	
CL-36		U-234	7.77E-09	
CM-242		TH-230	2.47E-08	

Buttons: Add, Remove, Remove All, Cancel, OK

PC-CREAM 98 GRANIS



PC-CREAM 98 GRANIS

Material Composition and Density Data

Number of Materials:

Material 1 **Material 2** Material 3

Name: 6 elements selected

Enter Density (g cm⁻³):

Elements available

- 7 NITROGEN
- 9 FLUORINE
- 11 SODIUM
- 12 MAGNESIUM
- 15 PHOSPHORUS
- 16 SULPHUR
- 18 ARGON
- 19 POTASSIUM
- 20 CALCIUM
- 22 TITANIUM
- 25 MANGANESE
- 56 BARIUM
- 58 CERIUM

Element	Atomic Number	Mass Fraction
OXYGEN	8	0.6
SILICON	14	0.25
CARBON	6	0.07
HYDROGEN	1	0.04
ALUMINIUM	13	0.03
IRON	26	0.01

Sum of fractions:

Material Allocation

Layer 1:

Layer 2:

Layer 3:

Layer 4:

Layer 5:

PC-CREAM 98 PLUME

Other Information [X]

Site Details:

Site Name: megalopolis Effective Release Height (in m): 100

Distance Data

Number of Distances: 2

	Distance (km)
1	2.5
2	4

Wind Data

Uniform

Site Specific Met. Data

File: UNI50D

Roughness Length

0.01m

0.04m

0.10m

0.30m

0.40m

1.00m

4.00m

Stability Category Classification Scheme

Pasquill Hosker Doury

Cancel

OK

PC-CREAM 98 PLUME

Discharge Data [X]

File

Select Nuclide 3 nuclides selected (2 parents and 1 daughters):

Nuclide	Discharge Rate (Bq/s)	Deposition Velocity (10^{-3}ms^{-1})	Washout Coeff (10^{-4}s^{-1})
RA-226	1	1	1
PB-210	1	1	1
BI-210	PB-210	1	1

AC-227
AC-228
AG-110M
AM-241
AM-242
AM-243
AM-244
AM-244M
AR-41
AS-76
BA-140
BI-210
BI-211
BI-212
BI-214
BR-82
C-14
CE-141
CE-144
CM-242
CM-243
CM-244

Add Nuclide
Remove Nuclide
Remove All

Cancel OK

PC-CREAM 98 RESUS

Select Nuclides

Nuclide Data

- NA-24
- P-32
- S-35
- CL-36
- K-42
- CA-45
- CR-51
- MN-54
- FE-55
- CO-57
- CO-58
- FE-59

Add

Remove

Remove All

User Specified

Select Nuclides

- RA-226
- TH-228
- TH-230
- TH-232
- U-238


Cancel

OK

PC-CREAM 98 ASSESSOR

Assessments to Include 

Please select discharge mode(s) to be used in assessment:


<input checked="" type="checkbox"/> Atmospheric Discharges	
<input type="checkbox"/> Marine Discharges	
<input type="checkbox"/> River Discharges	

Marine unavailable as Inland site chosen

OK

PC-CREAM 98 ASSESSOR

Assessment Details


Atmospheric

Discharge Point Data

Collective - Population

Integration Times

Discharge Data

Exposure Pathways

Receptor Point Data

Meteorological Data

Ingestion Rates

Occupancy/Inh Rates

Dose Type:

Individual Dose

Collective Dose

PC-CREAM 98 ASSESSOR

Atmospheric Discharge Point Data [X]

Edit

Individual Data

Discharge Point	Name of Point	Distance (m)	Bearing (deg)	Release Height (m)	Dispersion file (PLUME)
1	Stack 1	0	0	PLUME100	<input type="checkbox"/> Cream default

Collective Dose

Representative Release Height (m): Cream default

Individual Dose
 Collective Dose

PC-CREAM 98 ASSESSOR

Atmospheric Discharge Data [X]

File Edit Dose Type

File:

Individual Dose - Stack 1

Nuclide	Discharge Rate (Bq/y)	f1	Absor. Type
Pb-210	1.00E+00	0.2	M
Ra-226	1.00E+00	0.2	M

Add Nuclide

Remove Nuclide

Clear Table

Cancel

OK

Individual Dose

Collective Dose

PC-CREAM 98 ASSESSOR

The screenshot displays the 'Atmospheric Exposure Pathway Selection - Individual Doses' dialog box within the PC-CREAM 98 ASSESSOR software. The dialog box is titled 'Atmospheric Exposure Pathway Selection - Individual Doses' and features a close button (X) in the top right corner. It is divided into several sections:

- Selection list of Pathways for Atmospheric Discharges:** This section contains two radio buttons: 'Consumption Pathways' (selected) and 'External/Inhalation Pathways'.
- Pathways Chosen:** A list box containing the following items:
 - Consumption of cow meat
 - Consumption of cow's milk
 - Consumption of cow's milk products
 - Consumption of cow liver
 - Consumption of sheep meat
 - Consumption of sheep liver
 - Consumption of green vegetables
 - Consumption of root vegetables
 - Consumption of grain
- Input Data libraries:** This section contains two radio buttons: 'Cream Default' and 'User Defined' (selected). Below these is a 'Select Model Output' button.
- Age Groups Concerned:** This section contains three checkboxes: 'Infant (1 year old)', 'Child (10 years old)', and 'Adult' (checked).
- Buttons:** At the bottom of the dialog box are four buttons: 'Clear All Pathways', 'Remove Pathway', 'Cancel', and 'OK'.

Below the dialog box, a portion of another window is visible, showing the 'Occupancy/Inhalation Rates' section with a 'Dose Type:' label and two checkboxes: 'Individual Dose' (checked) and 'Collective Dose'.

PC-CREAM 98 ASSESSOR

Assessment Details

Terrestrial Food Ingestion Data - Individual doses

Age groups

Adult assessment

	Rate Type	Ingestion Rate (kg/y)	Fraction Ingested Produced Locally	Scaled Ingestion Rate
cow meat	Critical	45.0	1.0	45.0
cow's milk	Critical	240.0	1.0	240.0
cow's milk products	Critical	60.0	1.0	60.0
cow liver	Critical	10.0	1.0	10.0

Cancel OK

Dose Type:
 Individual Dose
 Collective Dose

PC-CREAM 98 ASSESSOR

Assessment Details

Atmospheric - Occupancy and Inhalation Rate Data for Individual Doses

Age Groups

Adult assessment

Receptor Point Name	Time Spent There (h/y)	Fraction Spent Indoor	Location Factor Cloud Gamma	Location Factor Deposited Gamma
Receptor Point 1	8760	0.9	0.2	0.1

Adult Inhalation Rate (m³ y⁻¹)

Cancel OK

Occupancy/Inh Rates

Dose Type:

Individual Dose

Collective Dose

PC-CREAM 98 ASSESSOR

Assessment Details

Atmospheric - Occupancy and Inhalation Rate Data for Individual Doses

Age Groups

Adult assessment

Receptor Point Name	Time Spent There (h/y)	Fraction Spent Indoor	Location Factor Cloud Gamma	Location Factor Deposited Gamma
Receptor Point 1	8760	0.9	0.2	0.1

Adult Inhalation Rate (m³ y⁻¹)

Cancel OK

Occupancy/Inh Rates

Dose Type:

Individual Dose

Collective Dose

PC-CREAM 98 ASSESSOR

View Nuclides [X]

Nuclides available in the chosen data libraries

Activity concentrations in terrestrial food: Non default file
S-35 Cr-51 Mn-54 Fe-55 Fe-59 Co-58
Co-60 Zn-65 Sr-89 Sr-90 Zr-95 Nb-95
Tc-99 Ru-103 Ru-106 Ag-110m Sb-124 Sb-125

External gamma dose from deposited activity: Non default file
S-35 Cr-51 Mn-54 Fe-55 Fe-59 Co-58
Co-60 Zn-65 Sr-89 Sr-90 Y-90 Zr-95
Nb-95 Tc-99 Ru-103 Ru-106 Ag-110m Sb-124

Resuspended air concentrations: Non default file
S-35 Cr-51 Mn-54 Fe-55 Fe-59 Co-58
Co-60 Zn-65 Sr-89 Sr-90 Zr-95 Nb-95
Tc-99 Ru-103 Ru-106 Ag-110m Sb-124 Sb-125

External beta from deposited activity: Default file
H-3 C-14 P-32 S-35 Ar-41 Cr-51
Mn-54 Fe-55 Fe-59 Co-58 Co-60 Zn-65
Se-75 Kr-85 Kr-85m Kr-87 Kr-88 Kr-89

Cloud beta dose: Default file
H-3 C-14 P-32 S-35 Ar-41 Cr-51
Mn-54 Fe-55 Fe-59 Co-58 Co-60 Zn-65
Se-75 Kr-85 Kr-85m Kr-87 Kr-88 Kr-89

Nuclides available in the chosen PLUME files for individual stacks

PLUME file for stack 1: Non default file
Pb-210 Ra-226

PLUME file for stack 2: Default file

PLUME file for stack 3: Default file

PLUME file for stack 4: Default file

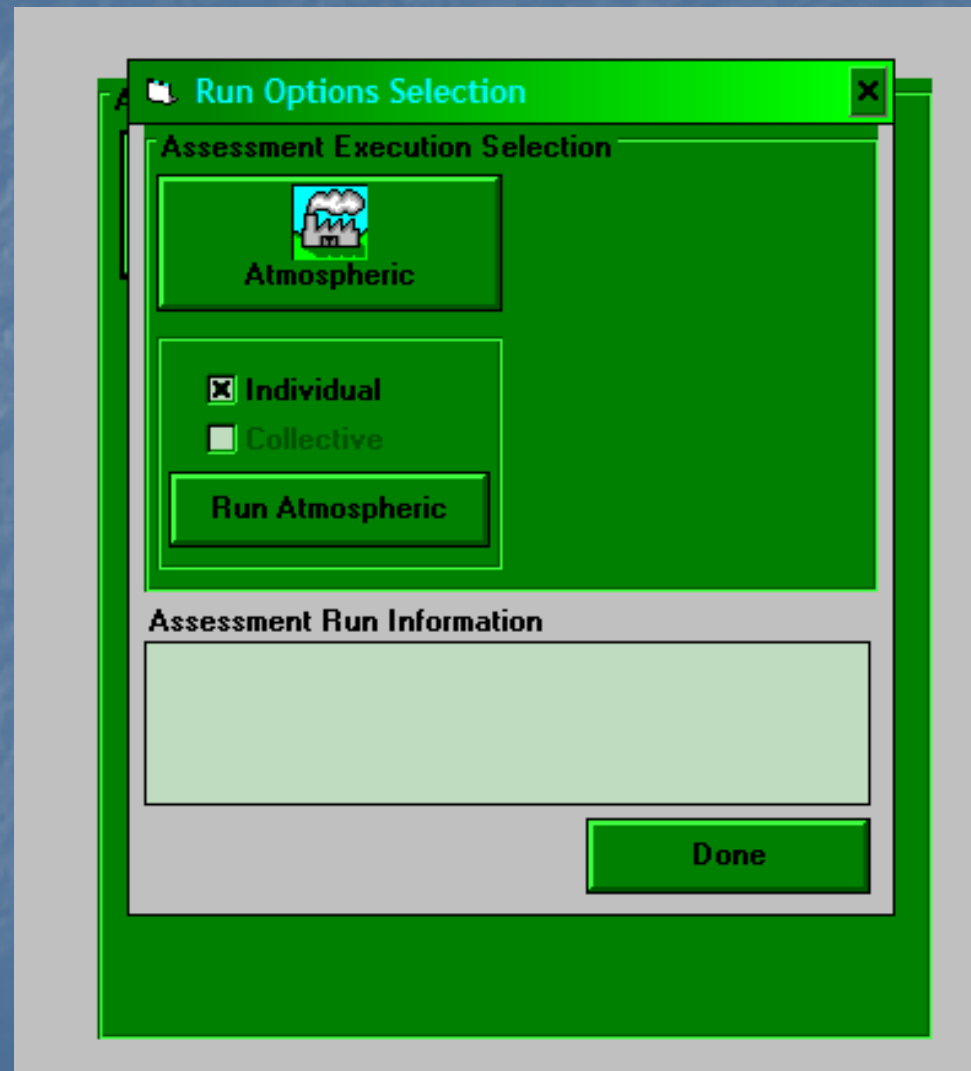
PLUME file for stack 5: Default file

Nuclides available in the chosen PLUME file for collective stack
PLUME file for collective stack: Default file

Nuclides available in the file selected for a Marine assessment
Nuclide list available for the Marine model: Default file

Close

PC-CREAM 98 ASSESSOR



PC-CREAM 98 ASSESSOR

Graphic Information

Select Assessment

Atmospheric
 Marine
 River

Select run

MEGA1

IAQA1.NCH

Breakdown by nuclide.
Individual dose to Adults in year 1

Select Assessment Type

Individual
 Collective

Pie Chart Option

Nuclide Breakdown
 Pathway Breakdown

Select Age Group

Infant
 Child
 Adult

Select Integration Times

1 Year
 5 Years
 50 Years
 500 Years
 10,000 Years
 Collective

Select Stack

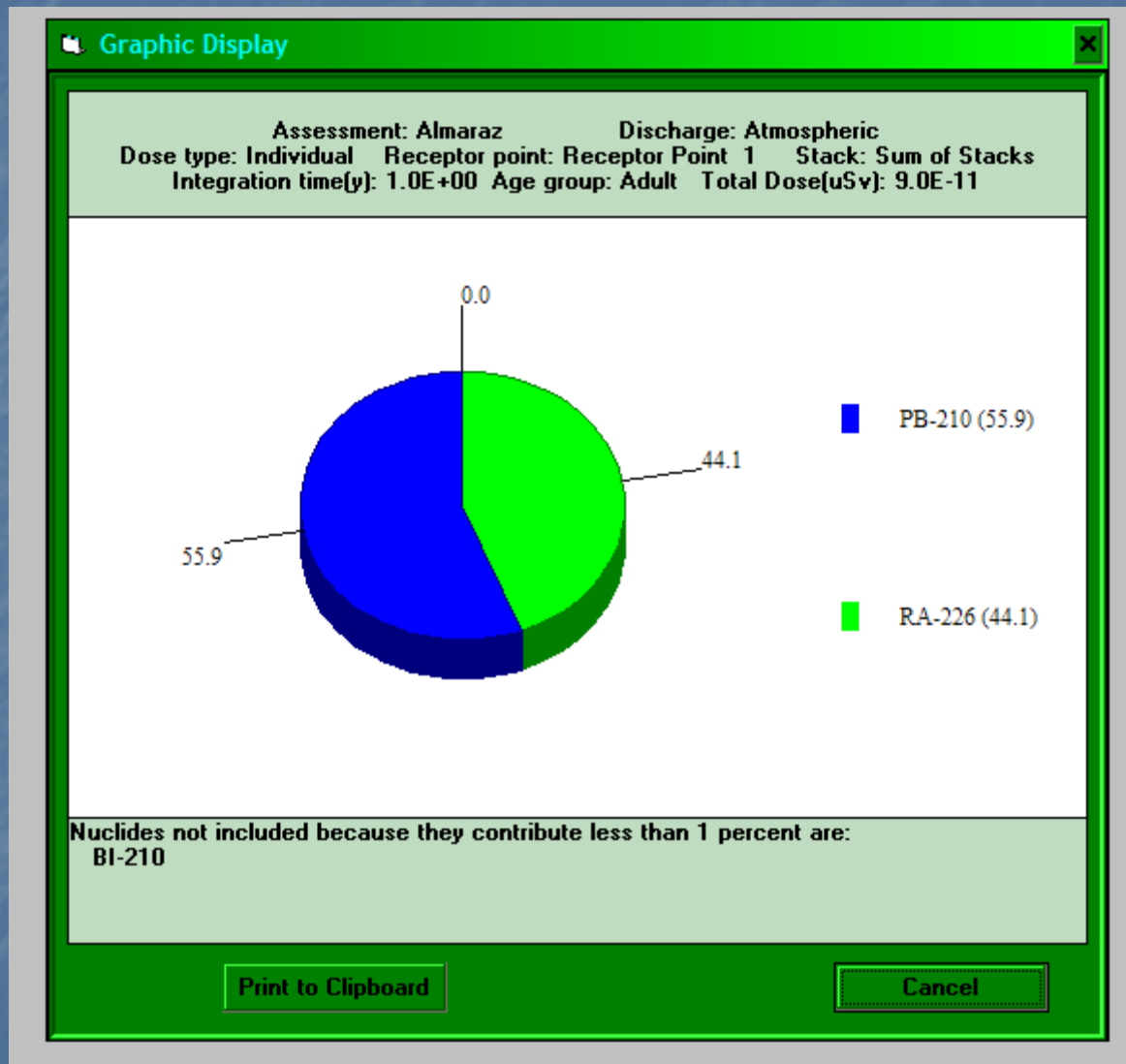
Sum of Stacks
 Stack 1
 Stack 2
 Stack 3
 Stack 4
 Stack 5

Select Receptor point

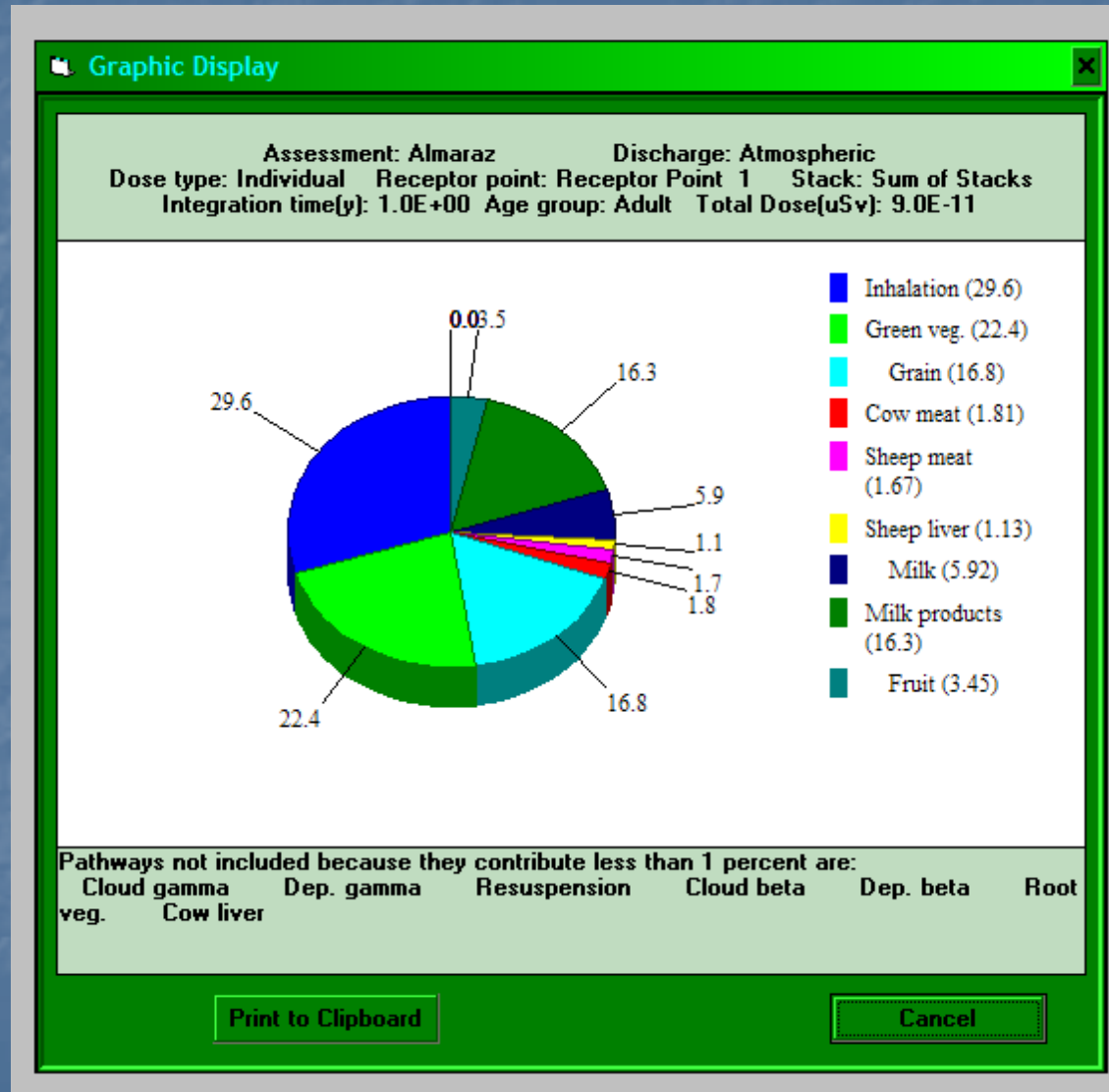
Receptor Poi
 Receptor B
 Receptor C
 Receptor D
 Receptor E

Draw Graph Cancel

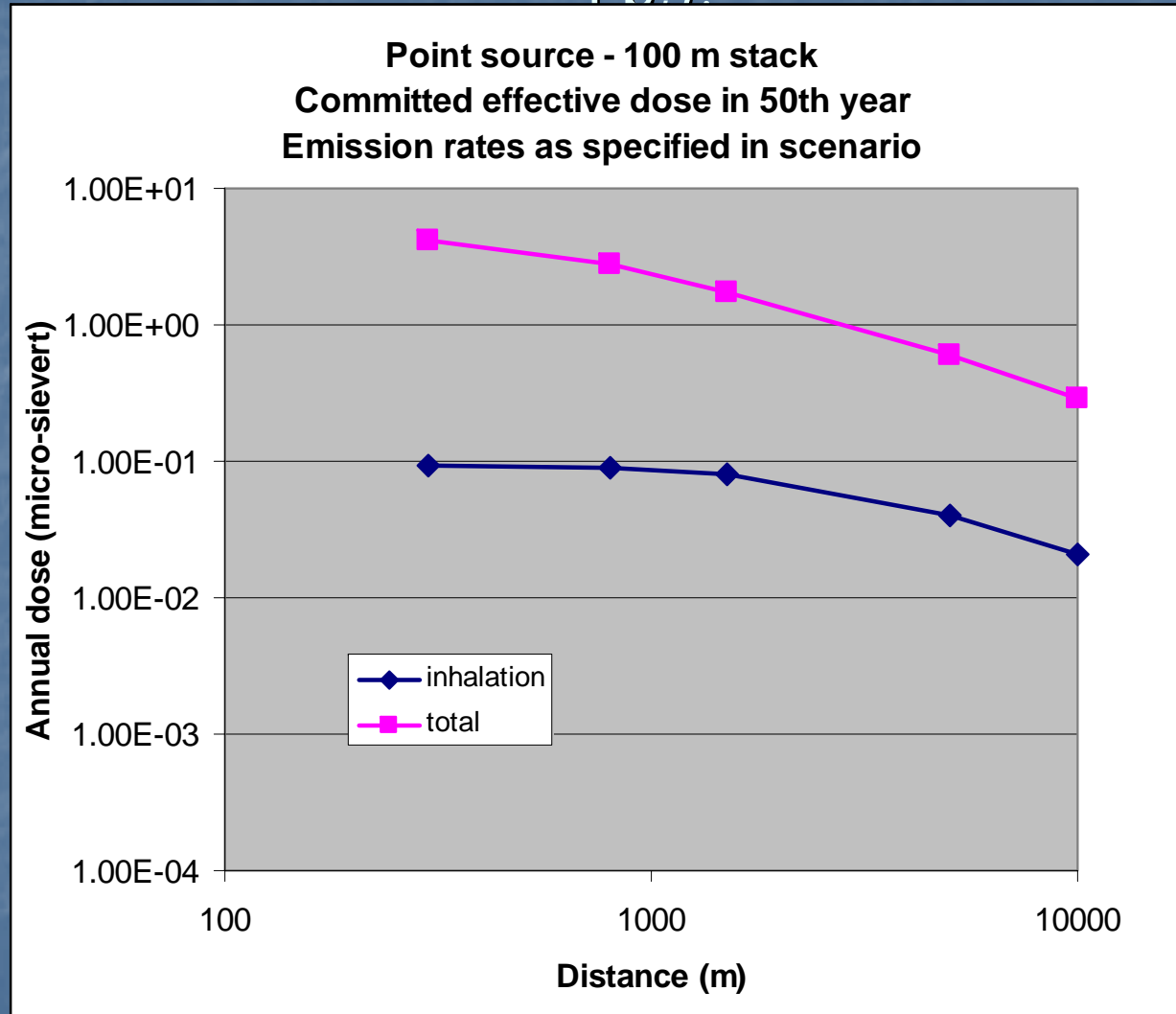
PC-CREAM 98 ASSESSOR



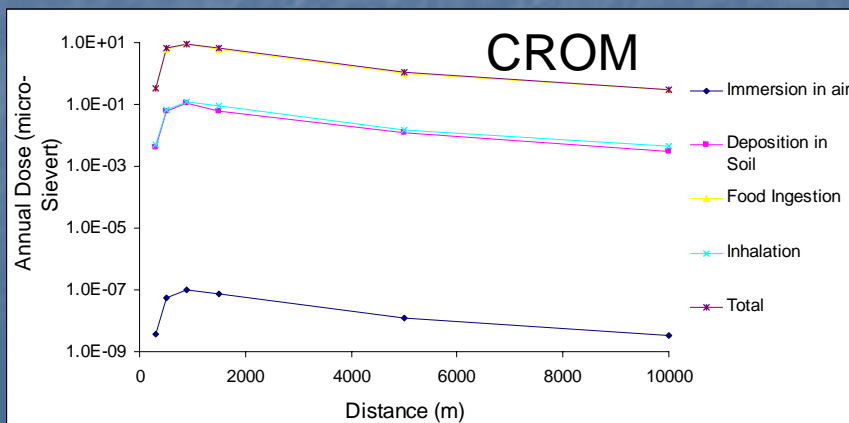
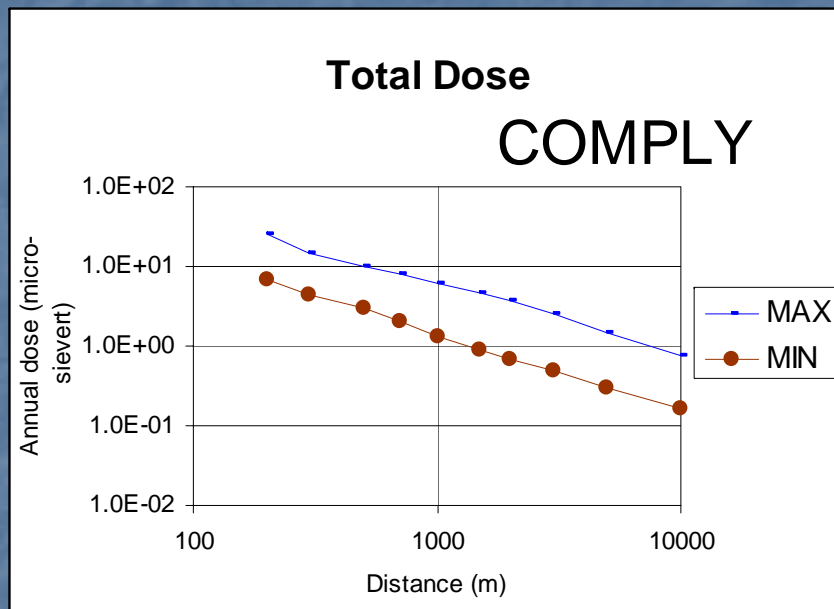
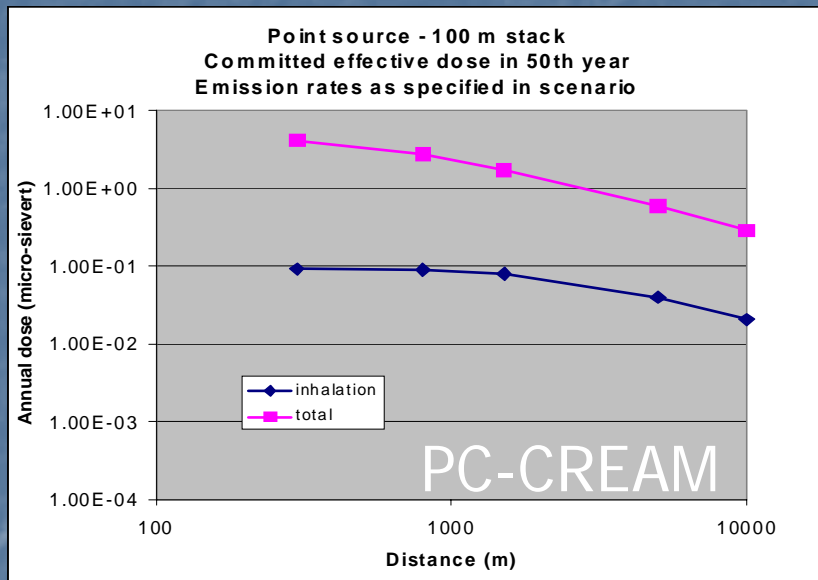
PC-CREAM 98 ASSESSOR



Inhalation and total doses calculated for the hypothetical point-source scenario using PC-CREAM (radionuclides ^{210}Po , ^{210}Pb .)



Modelling the hypothetical scenario



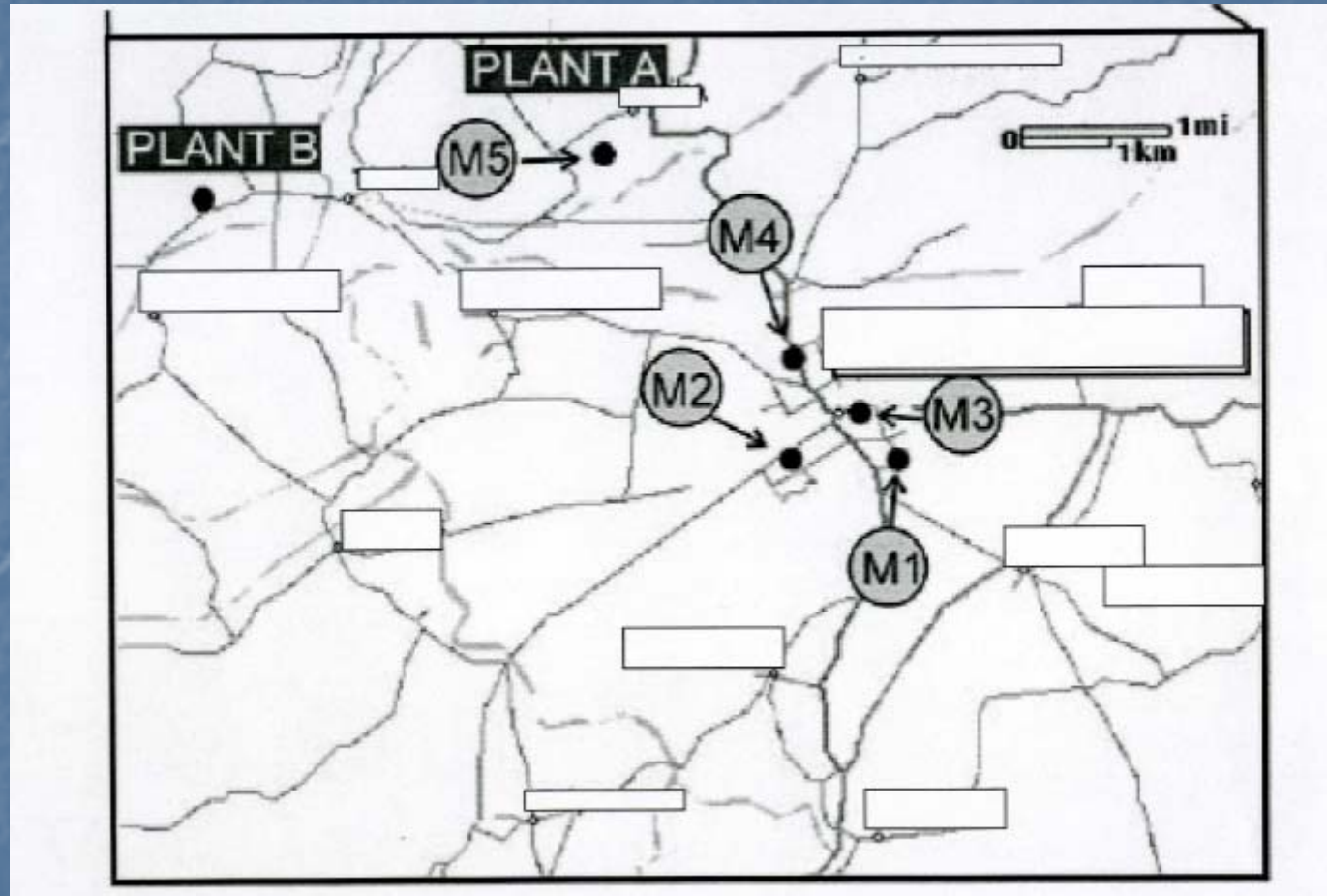
Modelling the hypothetical scenario

- Point source tests
 - COMPLY – 2 modellers tested, results the same
 - PC-CREAM - 2 modellers tested, results the same, both noted difficulties in manipulating files – wind rose data and nuclide library
 - CROM – 1 modeller tested
 - COMPLY doses calculated higher than PC-CREAM doses but CROM in good agreement with PC-CREAM
 - COMPLY and CROM are screening models and PC-CREAM is a very detailed impact assessment model

Real point source scenario

- 2 power plants, 5 stacks
- Data
 - Discharge data (Ra-226, Ra-228)
 - 5 monitoring points
 - Air concentrations
 - Soil concentrations
 - Rainfall
 - Wind data
 - No dietary data

Point Source Scenario



M1-5 =
monitoring
points

↑ = north

Modelling real point source scenario

There are two power plants (A and B), and five sampling sites (M1 to M5). Power plant B is 3 km due west of Plant A.

In ASSESSOR, Stack 1 = Plant A, is described as distance zero, bearing zero. Stack 2 = Plant B, is described as distance 3000 metres and bearing 270 degrees.

Integration time: 50 years for an adult.

Discharge data:

Discharges of ^{226}Ra and ^{238}U (assuming ratio of 1:1) from

Plant A 50,000 MBq a⁻¹ = 5×10^{10} Bq a⁻¹.

Plant B 3,500 MBq a⁻¹ = 3.5×10^9 Bq a⁻¹.

Exposure pathways: all consumption pathways were used, and all external /inhalation pathways were used except for those concerned with beta doses.

The distances and bearings of the sampling points

Sampling point	Distance from unit A (km)	Bearing from unit A (degrees)
M1	3,800	135
M2	2,800	157
M3	3,100	135
M4	2,300	135
M5	300 (minimum value accepted)	0

Modelling real point source scenario

- **Meteorological Data:** the data supplied in the scenario description was not suitable for use in PC-CREAM. Therefore the UNI50D.MET default file from PC-CREAM was used, together with the Pasquill/Smith scheme of stability factors.
- **Ingestion rates:** these were all set to average values, except for cow's milk and grain which were set at 'critical' values.
- **Occupancy/Inhalation rates:** these were set to the PC-CREAM default values.
- Receptor deposition values (Bq m^{-2}) for ^{238}U and ^{232}Th were extracted from the relevant plist100.ps! file. This file provided deposition rates in $\text{Bq m}^{-2} \text{ s}^{-1}$. These values then converted to values in Bq m^{-2} .

Modelling real point source scenario

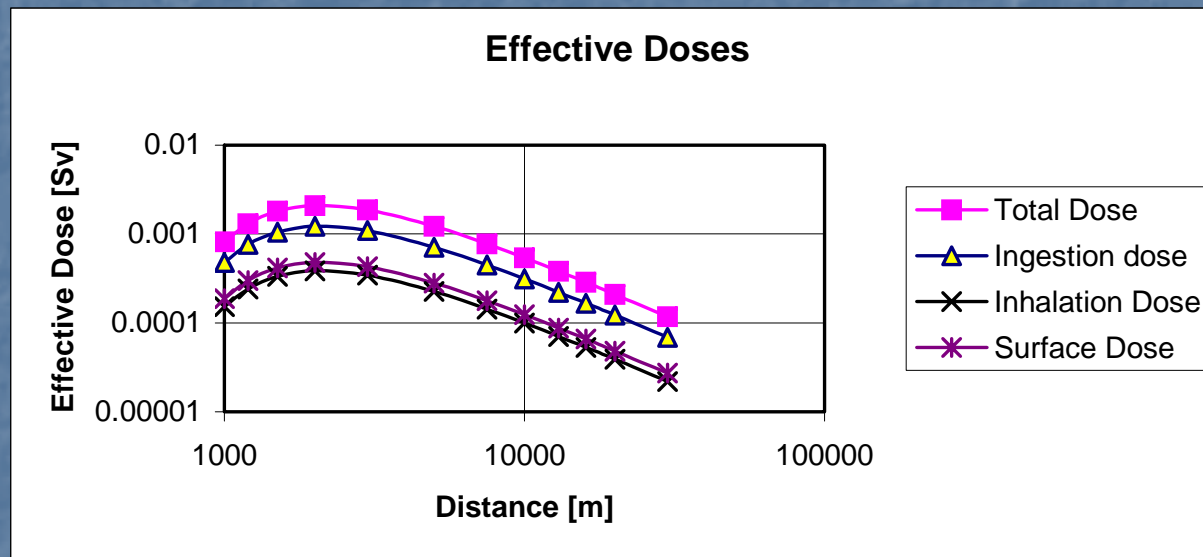
Real scenario - lignite power plant

Predicted and reported deposition rates

	PC CREAM		Measured	
	^{238}U (Bq m ⁻²)	^{232}Th (Bq m ⁻²)	^{238}U (Bq m ⁻²)	^{232}Th (Bq m ⁻²)
Plant A	2.5 – 4.1	0.12 – 0.19		
Plant B	1.5 – 2.8	0.07 – 0.14		
Total	4.0 – 6.9	0.19 – 0.33	2.36 – 11.02	0.19 – 1.20

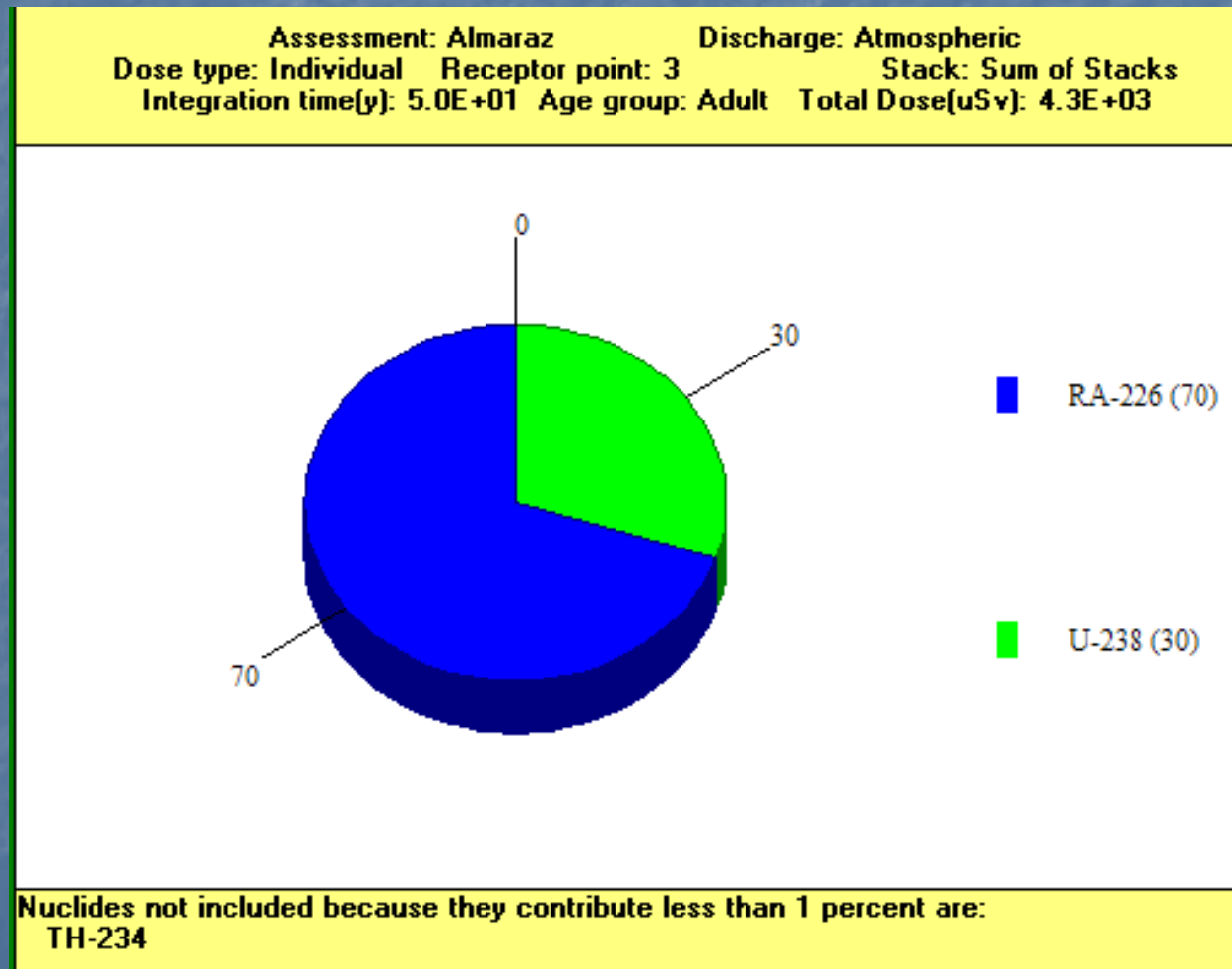
Modelling real point source scenario

Predicted annual doses from COMPLY

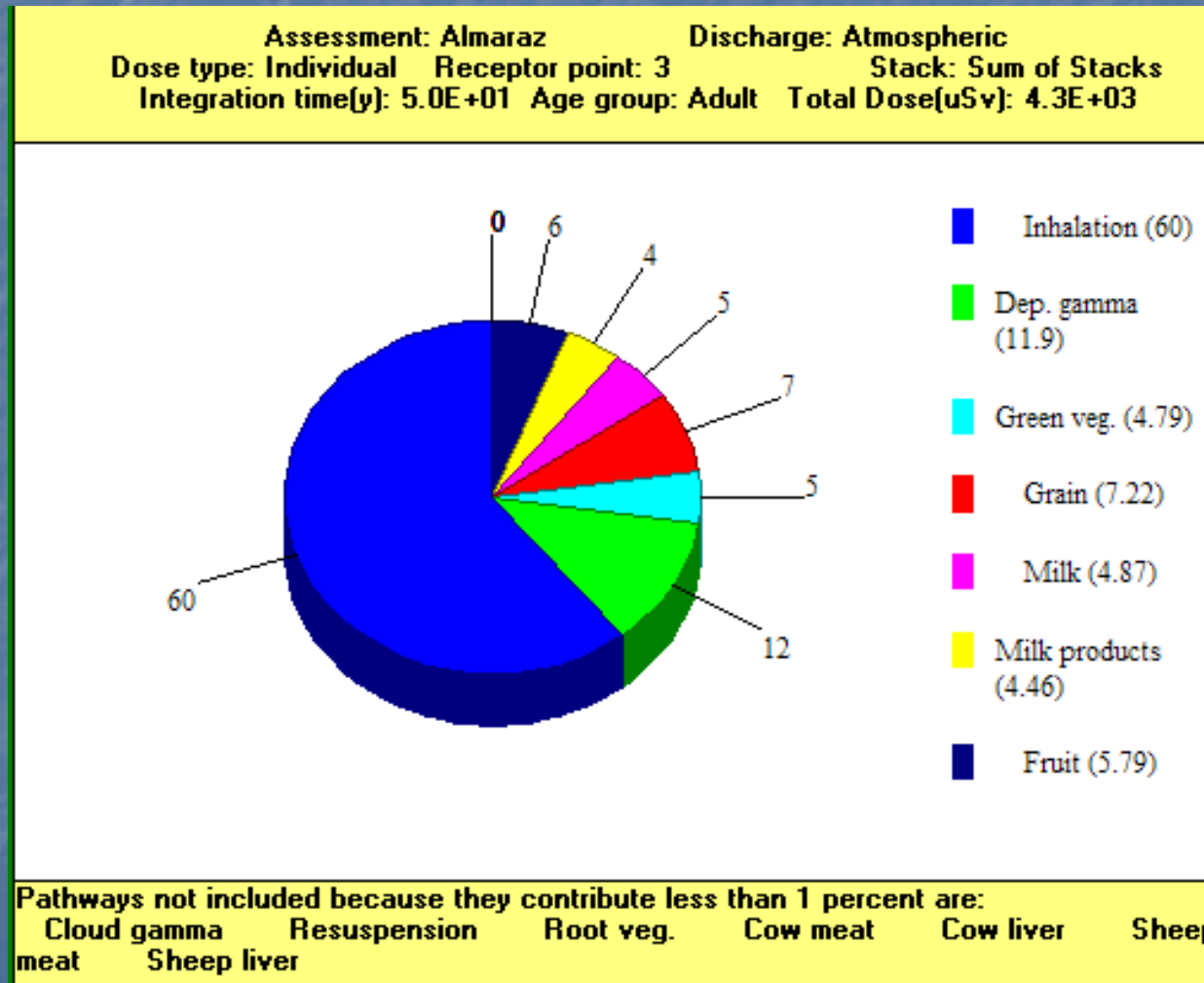


PC-CREAM predicts a range of 2.8 – 4.3 mSv, depending on what receptor and what stack is being considered

Calculated ^{226}Ra and ^{238}U concentrations at receptor point M3



Calculated doses for different pathways at receptor point M3



Summary

- Hypothetical scenarios are useful for model development and testing, but do not allow model validation
- Real scenarios require assumptions to deal with non-ideal situations
- There is still a good deal of work to do on the real scenarios
- There is still considerable scope for model development, particularly for situations involving multiple area sources and feedback processes - e.g. Gela