NATIONAL DOSE ASSESSMENT WORKING GROUP

PAPER 8-02: NDAWG AUTHORISATION INTERCOMPARISON STUDY

N Hesketh & J G Smith

1 INTRODUCTION

Radiation dose assessments are carried out as an input to the process of granting an authorisation to an organisation to discharge radioactive material to the environment. Generally three independent dose assessments are carried out by the applicant, the relevant environment agency and the Foods Standards Agency (FSA). Different results may be obtained in these different assessments depending on the models and assumptions used and how cautious the approach to the dose assessment is.

In the past the Radioactive Waste Management Advisory Committee (RWMAC) expressed concern over the lack of transparency in the reporting of prospective dose assessments as part of the consultation process for the review of nuclear licensed site disposal authorisations under Radioactive Substances Act 1993 (RSA93) (UK Parliament, 1993). RWMAC also commented specifically on the level of pessimism used in dose assessments carried out by the Ministry of Agriculture Fisheries and Food (now FSA) (FSA, 2001).

In response to these concerns the FSA organised a ‘Consultative Exercise on Dose Assessments’ (CEDA) in October 2000, to discuss the recommendations. One of the most important findings during CEDA was the requirement of harmonisation between the different dose assessment methodologies (FSA, 2001). As a consequence of this the National Dose Assessment Working Group (NDAWG) was set up to bring together people and organisations with responsibility for, and/or an interest in, the assessment of radiation doses to the public from the operation of the nuclear industry and from minor users of radioactivity. The aims of NDAWG include ‘development of coherent transparent methods for the assessment of radiation dose to the public’ (NDAWG, 2003).

Having been established for over three years NDAWG is reviewing the extent to which it is achieving its aims and following its terms of reference (see www.ndawg.org). As part of this review the Radiation Protection Division of the Health Protection Agency (HPA-RPD, formerly the National Radiological Protection Board (NRPB)) was asked to critically examine recent dose assessments carried out as part of the authorisation process. The aim of this review was to determine the similarities and differences between the different assessments and to examine whether the methods adopted were consistent with the principles for the assessment of public doses developed by the Environment Agencies, FSA and NRPB (Joint Environment Agencies, 2002). This report outlines the comparison carried out for NDAWG for proposed authorised discharges from the UKAEA site at Winfrith in Dorset.

1.1 Outline of report

In Section 2 of this report the applications made for authorisation to release radioactive material to the atmospheric, marine and freshwater environments are summarised. Sections 3 to 5 give details of the comparisons between the dose assessment methodologies used and the estimated doses, and in Section 6 a summary of the findings is given and some conclusions drawn.

2 DISCHARGE SCENARIOS

The United Kingdom Atomic Energy Authority (UKAEA) has applied for a discharge authorisation from its Winfrith site, which includes proposed releases of radioactive material to the atmospheric and marine environments. It has also applied for an authorisation to release groundwater, pumped from beneath buildings on the Winfrith site, contaminated with tritium (^{3}H) into the nearby River Frome. As a requirement of the authorisation process prospective dose assessments were carried out for all these releases by the applicant, Environment Agency (EA) and FSA. (AEA-Technology, 1999; AEA-Technology, 2000; EA, 2001; FSA, 2005)

Dose assessments were carried out on behalf of the applicant (UKAEA) by AEA-Technology for atmospheric and marine discharges. In the case of the possible discharge of ^{3}H contaminated groundwater to the River Frome the UKAEA carried out a dose assessment based on an earlier screening study (Mobbs & Oatway, 2004) carried out by NRPB, now HPA-RPD. (Note that the NRPB screening study was carried out to assess the possible radiological impact of tritium in groundwater beneath the Winfrith site and not specifically for authorisation purposes so that deliberately cautious assumptions were adopted.)

For marine discharges the dose assessments took into account the contribution made by Waste Management Technology Limited (WMTL), which is based at UKAEA Winfrith and discharges its liquid wastes through the UKAEA pipeline.

An application by WMTL has also been made for authorisation to discharge radioactive waste to the atmospheric and marine environments from its premises based at UKAEA Winfrith. Dose assessments have been carried out by the applicant, EA and FSA for these discharges, and as stated previously, doses due to marine discharges have been included in the dose assessments carried out for UKAEA Winfrith. The dose assessments were carried out for WMTL by Serco Assurance Limited (AEA-Technology, 2003; EA, 2001; FSA, 2004)

3 DISCHARGES TO THE RIVER FROME

3.1 Dose estimates from river discharges

The exposure pathways assumed in the dose assessments and the doses calculated for each of these pathways are given in Table 1. It can be seen that the doses from each assessment are not in good agreement. The differences in estimated activity concentrations of ^{3}H in filtered river water and in the assumed consumption rates of freshwater fish used in the assessments explain the differences in the estimated ingestion doses. The differences for riverbank walking are explained in the Table.

Table 1 Exposure pathways and individual doses following the proposed discharge of tritium into the River Frome

	Individual Dose ($\mu Sv\ y^{-1}$)		
Pathway	UKAEA	EA	FSA
Riverbank walking	$2.0\ 10^{-2}$ *	0.0 #	$7.1\ 10^{-14}$ #
Ingestion of freshwater fish	$3.0\ 10^{-2}$	$5.7\ 10^{-4}$	$6.1\ 10^{-4}$
Ingestion of drinking water	$1.0\ 10^{0}$	$3.8\ 10^{-2}$	N/A
Total	**$1.0\ 10^{0}$**	**$3.9\ 10^{-2}$**	**$6.1\ 10^{-4}$**

* dose due to inhalation of water vapour and adsorption of ^{3}H into the body via skin

doses due to external exposure to river sediments

3.2 Comparison of river discharge assessment methodologies

The approach to the calculation of dose was essentially the same for all three assessments as they all used a screening methodology. Although the doses given in Table 1 are all very small there are significant differences between them. The reasons for these differences are accounted for below.

3.2.1 Source terms

These calculations are based on either measured activity concentrations in water or discharge limits and dilution models.

- Activity concentration of ^{3}H in filtered river water
    - UKAEA – used an activity concentration of 100 Bq l^{-1}, which is a conservative value and is based on recent measurements of ^{3}H concentrations in groundwater, which ranged between 10 and 110 Bq l^{-1} and assumes no dilution when entering the river. This very cautious approach was used originally as a screening calculation and not specifically for the authorisation.
    - EA – used an activity concentration of 3.55 Bq l^{-1}, which is based on the proposed annual discharge limit of tritium of 750 GBq y^{-1} and the average flow rate for the River Frome of 6.7 m^{3} s^{-1} measured at the East Stoke Flume Monitoring Station.

- FSA – this dose assessment was based on the proposed annual discharge limit of tritium of 750 GBq y^{-1} and a 'worst case' flow rate of 2.1 m^3 s^{-1}. The activity concentration in water was not provided in the FSA report but was calculated to be 11.4 Bq l^{-1}, based on the data provided and using the 'simple screening model' in PC CREAM (Mayall et al, 1997)

3.2.2 Models used

Very simple models were used in these assessments. Both UKAEA and EA estimated activity concentrations in the water using a simple dilution factor while FSA used the ADO model (Round, 1998) in combination with concentration factors recommended by the International Atomic Energy Agency (IAEA) (IAEA, 1994).

3.2.3 Derivation of the critical group

In its assessment, UKAEA based the habits of the critical group on national survey data (Smith & Jones, 2003). The assessment carried out by EA was also based on national survey data but took site-specific information into consideration (EA, 2005). FSA used site-specific data (McTaggart, 2004). A summary of the data used is given below:

- Drinking water rates
  - UKAEA and EA – Infants 260 l y^{-1}, Children 350 l y^{-1} and Adults 600 l y^{-1}
  - FSA – not considered
- Freshwater fish consumption rates
  - UKAEA – Infants 1 kg y^{-1}, Children 5 kg y^{-1} and Adults 20 kg y^{-1}
  - EA – Infants 1 kg y^{-1}, Children 5 kg y^{-1} and Adults 10 kg y^{-1}
  - FSA – Adults 3 kg y^{-1}

3.2.4 Transparency of methodologies

In order to test the transparency of the authorisation assessments, the data given in each of them were used to carry out simulations using the 'simple screening model' in PC CREAM. In all cases very good agreement was found between the doses presented by the three organisations and those found by HPA-RPD.

4 ATMOSPHERIC DISCHARGE FROM UKAEA AND WMTL

4.1 Dose estimates from atmospheric discharges

The exposure pathways included in each dose assessment and the corresponding calculated doses are given in Table 2. There are a number of differences between the dose estimates which arise as a result of the assumptions made and data used. These differences are discussed in more detail in Section 4.2.

Table 2 Exposure pathways and individual doses to critical group following the proposed atmospheric discharges from UKAEA Winfrith and WMTL

	Individual Dose (μSv y^{-1})					
Pathway	UKAEA	EA (UKAEA)	FSA (UKAEA)#	WMTL	EA (WMTL)	FSA (WMTL) #
External irradiation from airborne and deposited radioactive material	$1.0\ 10^{-2}$	$2.4\ 10^{-10}$	<<1 / << 1	$9.0\ 10^{0}$ †	$2.3\ 10^{-6}$	< 1 / < 1
Inhalation of airborne and re-suspended radioactive material	$2.7\ 10^{-1}$	$3.6\ 10^{-3}$	< 1 / < 1		$1.6\ 10^{0}$	< 1 / < 1
Ingestion of						
Milk	$1.5\ 10^{0}$ *	$7.1\ 10^{-2}$	2 / < 1 *		0	5 / < 1*
Milk products	N/A	N/A	N/A		N/A	N/A
Green vegetable		$2.5\ 10^{-3}$			0	
Root vegetables and potatoes		$4.8\ 10^{-3}$			0	
Cow meat		$2.0\ 10^{-4}$			0	
Cow liver	N/A	$0.0\ 10^{0}$	N/A		0	N/A
Sheep meat	N/A	$0.0\ 10^{0}$			0	
Sheep Liver	N/A	$0.0\ 10^{0}$	N/A		0	N/A
Fruit	N/A	$1.5\ 10^{-3}$			0	
Legumes	N/A	N/A		N/A	N/A	
Poultry	N/A	N/A		N/A	N/A	
Eggs	N/A	N/A		N/A	N/A	
Grain	N/A	N/A	N/A		N/A	N/A
Total	**$1.8\ 10^{0}$**	**$8.4\ 10^{-2}$**	**2 / 1**	**$9.0\ 10^{0}$**	**$1.6\ 10^{0}$**	**5 / 1**

* Dose is total for all food pathways listed

Doses are 'possible doses' defined as the upper estimate to the critical group from discharges at the maximum permitted levels (97.5th percentile) / 'probable doses' defined as the estimate of the most likely dose to the critical group from discharges at the maximum permitted levels (50th percentile). The dose from terrestrial food consumption includes that from seafood

† Dose is total for all exposure pathways listed

4.2 Comparison of atmospheric discharge assessment methodologies

4.2.1 Source terms

The source terms used in each assessment are given in Table 3. There are some differences in ^{3}H and ^{14}C discharges and the choice of radionuclide to represent total α and β/γ activities. It is clear that changes in the size of the source term for a particular radionuclide will have a linear effect on the dose estimate for that radionuclide. The implications for dose estimates of other differences in source terms include the following parts.

- The total β/γ activities used in the assessments for proposed UKAEA releases are represented by ^{60}Co for UKAEA and EA, and by ^{137}Cs for FSA. In the assessments for proposed WMTL releases total β/γ activities are represented by ^{60}Co, ^{129}I and ^{137}Cs for WMTL, EA and FSA respectively. If released at the same rate the highest total dose will be from exposure to ^{129}I. For example, following a ground level release at a distance of 500 m from the release point the doses from consuming milk for ^{60}Co, ^{137}Cs and ^{129}I are in the ratio 1: 1: 160. In the case of the inhalation of airborne material the ratios for dose are 6: 1: 12.

- The total α activities used in the assessments for proposed UKAEA releases are represented by ^{239}Pu in all cases. For proposed WMTL releases total α activities are represented by ^{239}Pu for EA and FSA, and by ^{241}Am for WMTL. If released at the same concentrations the highest total dose will be from exposure to ^{239}Pu. Following a ground level release at a distance of 500 m from the release point the doses from the inhalation of airborne material for ^{241}Am and ^{239}Pu are in the ratio 1: 7.

Table 3 Source terms used in atmospheric assessments (Bq y^{-1})

	Operator		EA			FSA		
UKAEA		0 m		30 m	40 m		13 m	20 m
	^{3}H	5.0 10^{12}	^{3}H	1.8 10^{11}	3.8 10^{12}	^{3}H	3.8 10^{12}	1.8 10^{11}
	^{14}C	1.0 10^{10}	^{14}C	0.0 10^{0}	6.0 10^{9}	^{14}C	6.0 10^{9}	0.0 10^{0}
	^{239}Pu	2.0 10^{6}	^{239}Pu	2.0 10^{6}	0.0 10^{0}	^{239}Pu	0.0 10^{0}	2.0 10^{6}
	^{60}Co, ^{137}Cs*	5.0 10^{6}	^{60}Co	5.0 10^{6}	0.0 10^{0}	^{137}Cs	0.0 10^{0}	5.0 10^{6}
	Operator		EA			FSA		
WMTL		0 m		10 m			10 m	70 m
	^{3}H	1.95 10^{13}	^{3}H	2.0 10^{13}		^{3}H	5.0 10^{11}	1.95 10^{13}
	^{14}C	3.0 10^{10}	^{14}C	3.0 10^{10}		^{14}C	0.0 10^{0}	3.0 10^{10}
	^{241}Am, ^{234}U #	1.0 10^{5}	^{239}Pu	1.0 10^{5}		^{239}Pu	0.0 10^{0}	1.0 10^{5}
	^{60}Co	1.0 10^{5}	^{129}I	1.0 10^{5}		^{137}Cs	0.0 10^{0}	1.0 10^{5}

* Assumed ^{60}Co is used in the assessment as it gives the higher annual dose per unit discharge

\# Assumed ^{241}Am is used in the assessment as it gives the higher annual dose per unit discharge

4.2.2 Models used

The models used in each assessment are identified in Table 4 (Mayall et al, 1997; EPA, 1993; CERC, 2000; Johnson & Mitchell, 1993). All models are appropriate for the type of dose assessments being considered. In all cases dose coefficients for inhalation and ingestion have been taken from ICRP 72 (ICRP, 1996). There is wide variation between activities in air and foods calculated by the models, which appears to be dependent on the scenario and radionuclides assessed. However, the trends suggest the following conclusions.

- In general, PC-CREAM gives higher activity concentrations in air than ADMS. This is particularly true for ^{3}H and ^{14}C but there is variation with other radionuclides used in the assessments

- PC-CREAM gives higher activity concentrations in food than the 'specific activity method' used by FSA for ^{3}H and ^{14}C. For other radionuclides SPADE gives higher activity concentrations in food than PC-CREAM.

Table 4 Models used in dose assessments

Pathway	UKAEA	EA (UKAEA)	FSA (UKAEA)	WMTL	EA (WMTL)	FSA (WMTL)
External irradiation from airborne and deposited radioactive material	PC CREAM*	PC CREAM & FGR-12	ADMS	PC CREAM	PC CREAM & FGR-12	ADMS
Inhalation of airborne and re-suspended radioactive material	PC CREAM	PC CREAM	ADMS	PC CREAM	PC CREAM	ADMS
Ingestion of terrestrial food	PC CREAM	PC CREAM	SPADE#	PC CREAM	PC CREAM	SPADE

* Doses from external irradiation are based on data given in NRPB-DL4, which is now obsolete

^{3}H and ^{14}C are modelled using the specific activity method given in the FSA Assessment Handbook

4.2.3 Derivation of the critical group

Each assessment methodology adopts a different technique for defining the critical group. However, they all generally follow the guidance given in 'Principles for the Assessment of Prospective Public Doses' (Joint Environment Agencies, 2002), and assume infants (1 year old), children (10 years old) and adults (>17 years old) to be exposed. The properties of the critical group used in each assessment are given in Tables 5 and 6. The techniques used to derive them and the implications for dose estimates are summarised below.

UKAEA assumed a cautious ground level release with receptor points 100, 500, 1000, 1500, 2000 and 3500 m from the release point. Food consumption rates are based on national surveys (Simmonds et al, 1995), and all foods are assumed to be locally produced. The critical group was identified as those receiving the highest dose and were adults living 500 m from the discharge point.

WMTL assumed 5 release heights (0, 5, 6, 10 and 15 m) from 4 stacks with each release height having 5 potential receptor points, these ranging between 300 and 2275 m. Food consumption rates used were PC CREAM default values for critical consumers which are based on national surveys (Simmonds et al, 1995). The same also applies for the values used for occupancy times, indoor location factors and time spent indoors (Simmonds et al, 1995). The critical group was selected as being 500 m from a ground level release. This is a conservative estimate of the distance of the nearest residence to the stack and takes into account wind flow effects around buildings, and will tend to give an overestimation of dose.

EA used actual release heights from UKAEA Winfrith of 40 m for the SGHWR stack and 30 m for the A59 stack and, from WMTL, of 10 m for the B482 stack. Four candidate critical groups were identified using local habit data and the actual locations of the different groups (McTaggart, 2004). Initially generic UK critical group habit data were used for food consumption rates, occupancy times, indoor location factors and time spent indoors (Mayall et al, 1997; Smith & Jones, 2003). Once the most important exposure pathways were identified for each group the worst site-specific habit data were selected for each candidate critical group used in the dose assessment. For UKAEA and WMTL discharges the critical groups were identified as infants living 325 m away and adult workers located 100 m from the site fence respectively. In the case of adult workers they were assumed not to consume locally produced food, as they do not reside in the local area.

FSA assumed release heights from UKAEA Winfrith of 13 m for the SGHWR stack and 20 m for the A59 stack. These are effective stack heights and are a 1/3 and 2/3 of the actual stack heights respectively and are chosen to take account of the effects of nearby buildings on the plume dispersion. For WMTL a release height of 70 m is assumed for the main building and 10 m for the incinerator. Food consumption rates, occupancy times and time spent indoors are taken from site-specific data (McTaggart, 2004), with indoor location factors being generic UK data (Brown & Jones, 1993). For non-food doses a “determining habitation” is used, which gives the highest dose and is selected from a number of properties identified from maps and habit surveys. For food consumption doses a “reference location” is used, which is the location giving the highest dose and must be at least 100 m from the site fence. All food consumed is assumed to be produced at the “reference location”. In this assessment the “determining habitation” and “reference location” were the same for both UKAEA and WMTL releases. Doses calculated by FSA could not be directly compared to those given by other assessments due to the way doses from food consumption are calculated. For each food group the dose per kg of food eaten is calculated and combined with consumption rate data for individual consumers. From the distribution of doses the 50th percentile of the distribution is used to calculate the ‘probable’ dose and the 97.5th percentile of the distribution is used to calculate the ‘possible’ dose.

For these assessments the most important factors controlling differences in the reported doses are identified as:

- Stack height – at 500 m downwind lowering the stack height from 10 m to 0 m doubles the total dose and lowering the stack height from 40 m to 0 m increases the total dose by a factor of about 30. A number of release heights were considered in some of the assessments but ultimately those giving the highest dose were used.
- Distance from release point – the consequences of increasing the receptor point distance depend on the effective release height. For a height of 10 m increasing the receptor point distance from 100 m to 500 m will decrease the total dose by a factor of about 6. A number of receptor point distances were considered in some of the assessments but ultimately those giving the highest dose were used.
- Food consumption rates – differences in food consumption rates between WMTL and EA account for an increase in total ingestion dose of 3.4 μSv y^{-1}, which trebles the total dose. EA uses site-specific data which are much lower than the generic UK data used by WMTL.
- Occupancy times and location factors – increasing occupancy times from 3900 h y^{-1} to 8760 h y^{-1} and location factors from 0.7 to 0.9 doubles the total dose.

Table 5 Properties of the critical groups identified by the dose assessments for proposed atmospheric releases from UKAEA Winfrith

Critical Group Data	UKAEA	EA	FSA
Age group	Adult	Infant	Adult
Distance from release point (m)	500 m	325 m and 182° from SGHWR	Reference Location 275 m west and 425 m north of SGHWR Determining Habitation 100 m west and 450 m south of SGHWR
Food consumption rates (kg y^{-1})	Milk = 240 Green vegetables = 80 Root vegetables and potatoes = 130	Milk = 160 Green vegetables = 5.6 Root vegetables and potatoes = 10.7 Cow meat = 0.4 Cow liver = 0 Sheep meat = 0 Sheep liver = 0 Fruit = 3.4	N/A*
Inhalation rate (m^3 y^{-1})	7.3 10^3	1.9 10^3	7.3 10^3
Occupancy (h y^{-1})	8760 #	8760	2500 (probable dose)
Fraction of time spent indoors	0.9 #	0.9	0.9
Location factor			
cloud γ	0.2 #	0.2	0.2
deposited γ	0.1 #	0.1	0.1

* Food consumption rates can't be given due to the method FSA uses to calculate food consumption doses. For each food group the dose per kg of food eaten is calculated and combined with consumption rate data for individual consumers. From the distribution of doses the 50th percentile of the distribution is used to calculate the 'probable' dose and the 97.5th percentile of the distribution is used to calculate the 'possible' dose

It was assumed that the default data provided by PC CREAM was used by UKAEA

Table 6 Properties of the critical groups identified by the dose assessments for proposed atmospheric releases from WMTL

Critical Group Data	WMTL	EA	FSA
Age group	Infant	Adult (worker)	Infant
Distance from release point (m)	500 m following a ground level release	100 m and 80° from B482	Reference Location 275 m west and 425 m north of SGHWR Determining Habitation 100 m west and 450 m south of SGHWR
Food consumption rates (kg y^{-1})	Milk = 320 Milk products = 45 Green vegetables = 15 Root vegetables and potatoes = 45 Cow meat = 10 Cow liver = 2.75 Sheep meat = 3 Sheep liver = 2.75 Grain = 30 Fruit = 35	Critical group are workers near to, but outside, site fence. They are assumed not to consume locally produced foodstuffs.	N/A*
Inhalation rate (m^3 y^{-1})	1.9 10^3	8.1 10^3	1.9 10^3
Occupancy (h y^{-1})	8760	3900	1000 (probable dose)
Fraction of time spent indoors	0.9	0.7	0.9
Location factor			
cloud γ	0.2	0.2	0.2
deposited γ	0.1	0.1	0.1

* Food consumption rates can't be given due to the method FSA uses to calculate food consumption doses. For each food group the dose per kg of food eaten is calculated and combined with consumption rate data for individual consumers. From the distribution of doses the 50th percentile of the distribution is used to calculate the 'probable' dose and the 97.5th percentile of the distribution is used to calculate the 'possible' dose

4.2.4 Transparency of methodologies

To see if the methods presented were transparent, dose assessments were carried out for the critical groups identified using PC CREAM and the data given in Tables 5 and 6. Good agreement was found between doses determined using PC CREAM and those estimated by UKAEA, WMTL and EA. However, the FSA assessment could not be repeated due to the way FSA estimates a distribution of doses and because the detailed data of consumption rates of food were unavailable.

5 MARINE DISCHARGE FROM UKAEA AND WMTL

5.1 Dose estimates from marine discharges

The exposure pathways included in each dose assessment and the corresponding calculated doses are given in Table 7. There are a number of differences between the dose estimates which arise as a result of the assumptions made and data used. These differences are discussed in more detail in Section 5.2.

Table 7 Exposure pathways and individual doses to critical group following the proposed marine discharges from UKAEA Winfrith and WMTL

	Individual Dose (μSv y^{-1})			
Pathway	UKAEA	WMTL	EA	FSA #
External exposure to contaminated beach sediment	$1.5\ 10^{1}$ $	<$1.0\ 10^{-1}$ $	$0.0\ 10^{0}$	5 / < 2†
Inhalation of re-suspended beach sediment and sea-spray			$2.3\ 10^{-3}$	
External exposure to contaminated fishing gear	N/A		$7.3\ 10^{-5}$	
Ingestion of				
Sea Fish			$6.7\ 10^{0}$*	2 / < 1*
Molluscs				
Crustaceans				
Total	**$1.5\ 10^{1}$**	**<$1.0\ 10^{-1}$**	**$6.7\ 10^{0}$**	**7 / 2**

* Values given are the total doses from the consumption of sea fish, molluscs and crustaceans combined

Doses are 'possible doses' defined as the upper estimate to the critical group from discharges at the maximum permitted levels (97.5th percentile) / 'probable doses' defined as the estimate of the most likely dose to the critical group from discharges at the maximum permitted levels (50th percentile). The dose from food consumption includes that from terrestrial foods

† Dose is total dose from external exposure to contaminated beach sediment, contaminated fishing gear and while swimming, and from bait digging in sand and while on a boat

$ Dose is total for all exposure pathways listed

5.2 Comparison of marine assessment methodologies

5.2.1 Source terms

The source terms used in each assessment are given in Table 8. There are small differences in ^{3}H and α-radionuclide discharges between UKAEA, EA and FSA, with β/γ-radionuclide discharges being the same. However, different combinations of α and β/γ-emitting radionuclides are used in these assessments. The same applies to WMTL but releases are much lower as only their own releases are assessed. The changes in the size of the source term for a particular radionuclide have a linear effect on the dose estimate for that radionuclide.

Table 8 Source terms used in marine assessments (Bq y^{-1})

UKAEA*		WMTL		EA*		FSA*	
^{3}H	$2.4\ 10^{14}$	^{3}H	$1.8\ 10^{14}$	^{3}H	$2.3\ 10^{14}$	^{3}H	$2.3\ 10^{14}$
α-emitter	$2.1\ 10^{10}$	^{234}U	$6.0\ 10^{9}$	^{239}Pu	$2.2\ 10^{10}$	^{239}Pu	$2.2\ 10^{10}$
β/γ-emitter	$3.0\ 10^{12\#}$	^{14}C, ^{60}Co, ^{137}Cs	$1.6\ 10^{10\dagger}$	^{60}Co	$2.6\ 10^{11}$	^{60}Co	$1.0\ 10^{12}$
Others	$2.0\ 10^{9\#}$			^{65}Zn	$3.3\ 10^{10}$	^{137}Cs	$2.0\ 10^{12}$
				$^{90}Sr/^{90}Y$	$7.1\ 10^{11}$		
				^{137}Cs	$2.0\ 10^{12}$		

* source term includes releases from both UKAEA and WMTL

\# not known which radionuclides are used

† not known the fraction of each radionuclide

5.2.2 Models used

The models used in each assessment are identified in Table 9 (Simmonds et al, 1995; EPA, 1993; Round, 1998). All models are appropriate for the type of dose assessments being considered. In all cases dose coefficients for inhalation and ingestion have been taken from ICRP 72 (ICRP, 1996). In the assessment carried out by EA the critical group was assumed not to be exposed to contaminated beach sediment and therefore the consequences of using FGR-12 have not been determined. Only comparisons between CREAM and ADO can be made based on the assessments carried out by FSA and EA. The findings are as follows;

- CREAM gives higher dose per unit mass of seafood consumed than ADO
- ADO gives higher dose per unit hour for exposure to fishing gear than CREAM

Table 9 Models used in dose assessments

Pathway	UKAEA	WMTL	EA	FSA*
External exposure to contaminated beach sediment	PC CREAM	PC CREAM	FGR-12	ADO
Inhalation of re-suspended beach sediment and sea-spray	PC CREAM	PC CREAM	PC CREAM	
External exposure to contaminated fishing gear	N/A	PC CREAM	PC CREAM	
Ingestion of seafood	PC CREAM	PC CREAM	PC CREAM	ADO

* Dose is total dose from external exposure to contaminated beach sediment, contaminated fishing gear and while swimming, and from bait digging in sand and while on a boat

5.2.3 Derivation of critical group

Each assessment methodology adopts a similar technique for defining the critical group, which follows the guidance given in ‘Principles for the Assessment of Prospective Public Doses’ (Joint Environment Agencies, 2002), and assumes infants (1 year old), children (10 years old) and adults (>17 years old) are exposed. The properties of the critical group used in each assessment are given in Table 10. The techniques used to derive them and the implications for dose estimates are summarised below.

UKAEA assumed that the critical group consumed all seafood from the local compartment and consumption rates are based on site-specific data. Some of the data relating to habits (notably those relating to minors) and to environmental characteristics (the inhalation of sea-spray and exposure to beach sediment) are hypothetical and are considered cautious.

WMTL assumed that the critical group consumed seafood at critical rates given as defaults by PC CREAM, and was exposed to beach sediment, contaminated fishing gear and sea-spray for PC CREAM default times. These values are based on generic UK habit data. It was assumed that all seafood consumed was caught from the local compartment.

EA chose a fisherman and family at Weymouth Bay as the candidate critical group. Adults were assumed to handle fishing gear contaminated with sediment. Initially generic UK habit data were used to determine which exposure pathways were likely to be important. Once the most important exposure pathways were identified for each group the worst site-specific habit data were selected for each candidate critical group used in the dose assessment.

FSA chose a critical group whose members are assumed to obtain all their marine foods from the local fishing area. Its location ("determining habitation") was identified from a Winfrith habits survey and from environmental monitoring. Consumption rates of seafood and occupancy times are taken from the Winfrith habits survey. However, as the number of individuals identified in the survey, from age groups other than adults, is extremely small, consumption ratios as given in the RIFE report are used (RIFE, 2004).

For these assessments the most important factors controlling differences in the reported doses appear to be:

- ingestion rates of seafood
- occupancy rates on beach sediment

Table 10 Properties of the critical groups identified by the dose assessments for proposed marine discharges from UKAEA Winfrith and WMTL

Critical Group Data	UKAEA	WMTL	EA	FSA
Age group	Adult	Adult	Adult	Adult

Food consumption rates (kg y^{-1})	Seafish = 76.7 Molluscs = 20.0 Crustaceans = 5.0	Seafish = 100.0 Molluscs = 20.0 Crustaceans = 20.0	Seafish = 11.8 Molluscs = 5.4 Crustaceans = 13.7	N/A*
Inhalation rate (m^3 y^{-1})	7.3 10^3	7.3 10^3	7.3 10^3	7.3 10^3
Occupancy (h y^{-1})	1000 (for all pathways)	Coastal sediment = 2000 Fishing gear = 2000 Inhalation of sea-spray = 2000	Coastal sediment = 0 Fishing gear = 1200 Inhalation of sea-spray = 8760	440 (probable dose)

* Food consumption rates can't be given due to the method FSA uses to calculate food consumption doses. For each food group the dose per kg of food eaten is calculated and combined with consumption rate data for individual consumers. From the distribution of doses the 50th percentile of the distribution is used to calculate the 'probable' dose and the 97.5th percentile of the distribution is used to calculate the 'possible' dose

5.2.4 Transparency of methodologies

Again, the dose assessments for each of the critical groups identified were duplicated using PC CREAM and the data from Table 10. However, only the EA assessment could be replicated and very good agreement was found between the estimated doses. Comparison with the UKAEA assessment could not be carried out as it was unclear which radionuclides had been used to represent α-emitters and β/γ-emitters. For the WMTL assessment it was not clear how the release rate of β/γ-emitters was distributed between ^{14}C, ^{60}Co and ^{137}Cs. The FSA assessment could not be repeated due to the method of estimating a distribution of doses used and because detailed data for the consumption rates of seafood are unavailable.

6 CONCLUSION

The dose assessments generally follow the guidance given in 'Principles for the Assessment of Prospective Public Doses' (Joint Environment Agencies, 2002) in that they: identify the source term; use validated models; identify relevant exposure pathways; identify critical habits and data for exposure pathways; identify candidate critical groups from realistic combinations of critical habits; estimate doses for candidate critical groups; identify the critical group; and calculate total dose. In many cases a screening model approach has been used based on cautious assumptions. This is appropriate given the relatively low estimated doses and provided the cautious nature of the assumptions is explicit.

It is also an important requirement that the dose assessment is transparent ie the assumptions made and data and models used are clearly identified. This is essential if the dose estimates are to be used appropriately. For example, if it is known that a very cautious assessment has been carried out but the doses are still very small the regulator can be confident that the dose criteria will not be exceeded. In a number of cases it was possible to duplicate the dose estimates using the data provided and PC CREAM, showing that this transparency in the dose calculation was evident. The information provided for all the different EA dose assessments was such that it was clear what had been done, what data had been used and so the doses could be replicated. For the FSA dose assessments most of the data were clearly presented and it was possible to find out the methods used and to explain the likely cause of any differences in estimated doses. However, it is not possible to repeat the FSA assessments for food ingestion as it is not clear what food intake rates are used. For each food group the dose per kg of food eaten is calculated and combined with consumption rate data for individual consumers. From the distribution of doses the 50^{th} percentile of the distribution is used to calculate the 'probable' dose and the 97.5^{th} percentile of the distribution is used to calculate the 'possible' dose. Therefore, consumption rates can be extremely dependent on the food item which gives the greatest dose for that individual. The UKAEA dose assessment for releases to atmosphere and to the marine environment did not provide all of the data required to completely understand what was done. UKAEA has been asked for clarification of particular points but has had difficulty in responding, as the person who originally carried out the assessment is no longer working for the Authority. This demonstrates the importance of transparency in the assessment.

Although there are differences in the different assessments many of them are small. Where larger differences are found (e.g. the freshwater release case) this is because a very cautious screening approach has been used by one organisation and, as the doses are relatively low, it has not been necessary to refine the assessment. Generally the most important sources of the difference between the assessments are the assumptions on the location and habits of the critical group, together with the radionuclide used to represent α or β/γ emitting radionuclides. Differences due to the models used for the transfer of radionuclides through the environment are generally of a lower order.

7 REFERENCES

AEA-Technology (1999). Methodology for Assessing Radiological Impacts of Winfrith Liquid Effluent Discharges at Arish Mell. WSED(99)P3.

AEA-Technology (2000). Generalised Dose per Unit Discharge from Atmospheric Discharges at Winfrith. WSED(99)P2.

AEA-Technology (2003). Application for an Authorisation under Section 13 of the Radioactive Substances Act 1993: Supporting Information. Appendix 4-Dose Calculations. Report AEAT/SHE(03)001, June 2003.

Brown J and Jones JA (1993). Location Factors for the Modification of External Doses. NRPB Radiological Protection Bulletin. No. 144, p10.

Cambridge Environmental Research Consultants (2000). ADMS 3.1 Technical Specifiation.

Environment Agency (2005). Radiological Assessment – UKAEA Winfrith and WMTL Winfrith. Authorisation Review 2004-2005. Monitoring & Assessment Process Group Technical Report MAPG/TR/2005/003, June 2005.

Environmental Protection agency (1993). External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12, EPA-402-R-93-081 (Oak Ridge National Laboratory, Oak Ridge, TN, U. S. Environmental Protection Agency, Washington, DC.

Food Standards Agency (2001). Consultative Exercise on Dose Assessments (CEDA). Food Standards Agency, ISBN1-904026-00-1, May 2001.

Food Standards Agency (2004). Prospective Dose Assessment of Winfrith Technology Centre (Waste Management Technology Limited). Radiological Protection and Research Management Division, August 2004.

Food Standards Agency (2005). Prospective Dose Assessment of the UKAEA Winfrith Site. Emergency Planning, Radiation and Incidents Division, May 2005.

International Atomic Energy Authority (1994). Handbook of parameter values for the prediction of radionuclide transfer in temperate environments. IAEA Technical Reports Series No. 364, IAEA, Vienna.

International Commission on Radiological Protection (1996). Age-dependent doses to members of the public from intake of radionuclides: Part 5. Compilation of ingestion and inhalation dose coefficients. ICRP Publication 72. Ann ICRP, 26 (1).

Johnson RH and Mitchell NG (1993). The SPADE suite of codes: SPADE 3.0 PC Version; volume 1, User manual. WS Atkins Technical Note M1722-TN5.

Joint Environment Agencies (2002). Authorisation of Discharges of Radioactive Waste to the Environment: Principles for the Assessment of Prospective Public Doses. December 2002.

Mayall A, Cabianca T, Attwood C, Fayers CA, Smith JG, Penfold J, Steadman D, Martin G, Morris TP and Simmonds JR (1997). PC CREAM-97 (PC CREAM-98 code update) NRPB, Chilton NRPB-SR-296 (EUR 17791).

McTaggart KA (2004). Radiological Habits Survey: Winfrith, 2003. CEFAS Environmental Report RL02/04.

Mobbs SF and Oatway WB (2004). An Assessment of the Radiological Impact of Tritium in Groundwater beneath the Winfrith Site. Contract Report NRPB-EA/16/2004.

National Dose Assessment Working Group (2003). Paper 4.01 Summary of agreements and actions from 3rd meeting. 10th June 2003. London.

RIFE (2004). Radioactivity in Food and the Environment, 2003. EA, EHS, FSA and SEPA, Warrington, Belfast, London and Stirling. RIFE (9) CEFAS.

Round GD (1998). Individual Doses from Discharges of Liquid Effluents to the Aquatic Environment: Dosimetric ModelADO. CEFAS Environmental Technical Note RL08/98. Lowestoft.

Simmonds JR, Lawson G and Mayall A (1995). Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment. Radiation Protection 72 Luxembourg, EC, EUR 15760.

Smith KR and Jones AL (2003). Generalised Habit Data for Radiological Assessments. NRPB-W41.

UK Parliament (1993). The radioactive Substances Act 1993. HMSO. ISBN 0 10 541293 7.