Prospective Dose Assessment of the Dounreay Site Restoration Site

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Summary

The Food Standards Agency (FSA) is a statutory consultee to the Scottish Environment Protection Agency (SEPA) under the Radioactive Substances Act 1993 and is responsible for assessing the effects of proposed radioactive discharges on the safety of food. The FSA has assessed the potential impact of radioactive waste discharges from the Dounreay Site Restoration Limited (DSRL) at Dounreay in response to the operator's application to SEPA for revised discharge authorisations.

The Food Standards Agency has no objection to the discharge limits requested by DSRL. The requested limits are acceptable on the grounds of food safety.

Prospective assessments show that doses to the potentially most exposed members of the public (the Reference Individuals) are below the dose limit of 1000μSv/year, the site dose constraint of 500μSv/year and the source dose constraint of 300μSv/year. The assessed total dose to the Reference Individuals for discharges at the maximum limits requested by DSRL is 208 μSv/year, of which 8.7μSv/year was via food pathways. The limits requested by the DSRL are summarised in Table 1 and a comparison is made with doses calculated based upon the extant limits.

The calculated dose is an estimate of the most likely dose that the reference individual would receive from discharges at the same levels. The probability that these assessed doses will actually be received by the reference individual is small, as actual discharges will be below the maximum authorised limits.

In arriving at these prospective doses, the FSA has calculated the potential dose to members of the public arising from the consumption of food and from other exposure pathways. The methodology considered combinations of pathways that the FSA regard as reasonable but not extreme. Reasonable future practices were also included because dose calculations were not restricted to pathways and agricultural practices currently existing near the site.

The DSRL application reflects continuing decontamination operations, the reactors are shut down and the requested limits reflect this change. The requested limits for the whole site are lower than the authorised limits currently in place. For some nuclides and buildings the requested limits are higher than the current limits. The requested limits would in general reduce the headroom between actual discharges and the limits permitted. It does not necessarily follow that levels of radioactivity in food and the environment near DSRL Dounreay will reduce significantly in the near future.

Radioactive particles from DSRL Dounreay are present on the seabed close to the site. The impact of these particles on local seafood consumers has previously been assessed by the FSA [Ref 1]. The FSA has not considered the particles in this assessment as it concerns DSRL's request for an authorisation for future discharges.

1. Introduction

Discharges of radioactive wastes to the environment in Scotland are regulated by the Scottish Environment Protection Agency (SEPA) under the Radioactive Substances Act 1993 (RSA93), as amended. Under this Act, the Food Standards Agency (FSA) is a statutory consultee to SEPA on authorisations to discharge radioactive wastes and is responsible for advice to SEPA on food safety. Contamination of the food chain by authorised discharges is a significant pathway of exposure to man-made radioactivity. To ensure the safety of food, the FSA uses computer models to predict the levels of radioactivity in food that might result from discharges at the maximum authorised level, which is the worst case. The Government has specified limits and constraints on the dose that a member of the public may receive. These apply to the total dose received from all combinations of food and non-food pathways. This assessment is principally concerned with the safety of food, but it includes non-food pathways of exposure to allow comparison of estimated doses with annual dose limits and constraints. Direct shine is excluded, as its contribution to dose is small as the reactors are no longer operational.

DSRL has requested changes to some of the current discharge limits [Ref 2]. Tables 1 and 2 give the requested and current limits respectively.

2. Dose Assessment Methodology

2.1 Overview

The methodology combines information from observations (food consumption rates, occupation times in the area, working practices and measurements at nuclear sites) with assumptions about the possible and realistic lifestyles that might occur. The FSA has assessed doses to those people who might live close to the site and who could obtain a large part of their diet from local terrestrial and aquatic sources [Ref 3]. The person who, because of realistic combinations of their habits, could receive the highest dose, is the 'Reference Individual'. Annex 1 gives details of the assessment method.

2.2 Prospective Dose

Doses presented in this document are forecasts based on discharges at the maximum permitted by the requested limits. Under normal operation, however, discharges from the site are unlikely to reach these limits and hence the doses received by the reference individual and the public in general will be less than those predicted and reported here.

The FSA ensures a margin of safety in its assessments by using cautious assumptions on the lifestyle and location of the reference individual and for the parameters used in modelling atmospheric and aquatic dispersion of radioactivity and its transfer into foods. The assessed prospective dose to the critical group is an upper estimate of the dose that could be received and it will be higher than that which will actually be received by the critical group.

The total dose to the public from all practices and past controlled releases must not exceed the annual dose limit of 1000 μSv (excluding medical exposures and natural background). In addition, the dose calculated to arise from future discharges should not exceed the site constraint of 500 μSv/year and the source constraint of 300 μSv/year [Ref. 4].

For each food group, a dose per kilogram of food eaten was calculated and combined with consumption rate data for a large number of people. The result is a distribution of ingestion doses. The consumption rates are brought together using a profile method. The dose from non-food pathways (e.g. external exposure, dose from inhalation) was added to these food doses to obtain the total doses reported.

Annex 2 gives details of how the impact of the requested limits were assessed using to the FSA methodology [Ref 3].

3. Dose Assessment Results

3.1 Prospective dose assessment results

For discharges at the requested limits, the assessed dose to an adult Reference Individual via the food chain was 8.7 μSv/year for discharges at the maximum requested discharge limits. The dose via the food chain based upon extant discharge limits was 21.4 μSv/year. The profile used for the purposes of the dose calculation, based upon the 2003 Habits Survey was that of an adult high rate consumer of Fish and "Other" Vegetables, who spends a great deal of time over sand.

These doses do not include a contribution from direct radiation from the site ("shine"). This is unlikely to add more than a few μSv/year to the assessed doses.

3.2 Doses from results of environmental monitoring (retrospective doses)

Monitoring of food and the environment around Dounreay shows that doses to the public are below the dose limit. The FSA and SEPA publish monitoring data annually in the 'Radioactivity in Food & the Environment' (RIFE) report [Ref 5], with a commentary and a retrospective assessment of the doses received by local groups based on the levels of radioactivity found in foods. The radioactivity measured in the environment includes past and present waste discharged from Dounreay as well as from other sources (e.g. other nuclear establishments, weapons testing and Chernobyl fallout). In contrast, this assessment only considers the doses from future discharges as requested by the DSRL. A direct comparison between doses calculated for past discharges and assessments of potential future doses is not valid. Calculations based on monitoring data will include contributions from sources other than Dounreay. The assessment of potential future doses only considers the effect of the Dounreay site.

4. Conclusion

The Food Standards Agency in Scotland welcomes the overall reduced discharge limits proposed by the applicant.

The Maximum Total Dose, based upon the Extant Limits was 344 microsieverts, of which 21.4 microsieverts was due to food exposure pathways. The Maximum Total Dose, based upon the Proposed Limits was 208 microsieverts, of which 8.7 microsieverts was due to food exposure pathways.

Given the nature of the application and the discharge levels being proposed by the applicant, the FSA(S) would not object to SEPA granting DSRL an authorisation containing the requested discharge limits at Dounreay. The requested limits are acceptable on the grounds of food safety and the potential impact on food safety.

Table 1: Requested Discharge Limits

Liquid Discharges		
	Nuclide	Requested Limit (Bq/yr)
	Tritium	1.04E+14
	Sodium-22	1.30E+10
	Strontium-90	2.74E+11
	Caesium-137	1.27E+12
	Americium-241	1.50E+07
	Beta Emitters	2.73E+12
	Alpha Emitters	3.67E+09
Gaseous Discharges		
Area	Nuclide	Requested Limit (Bq/yr)
Fuel Cycle Area	Tritium	5.13E+11
	Beta Emitters	1.46E+09
	Alpha Emitters	6.48E+06
	Iodine-129	1.00E+09
Prototype Fast Reactor	Tritium	7.50E+13
	Krypton-85	5.69E+14
	Beta Emitters	7.80E+08
	Alpha Emitters	1.28E+05
Dounreay Fast Reactor	Tritium	2.70E+12
	Krypton-85	3.00E+12
	Beta Emitters	7.00E+08
	Alpha Emitters	3.00E+05
East Minor Sources	Tritium	2.00E+10
	Krypton-85	4.00E+12
	Beta Emitters	1.70E+06
	Alpha Emitters	3.70E+05
West Minor Sources	Tritium	1.10E+10
	Beta Emitters	4.00E+04
	Alpha Emitters	1.10E+04

Table 2: Current Discharge Limits

Liquid Discharges		
	Nuclide	Limit (Bq/yr)
	Tritium	6.90E+12
	Strontium-90	7.70E+11
	Caesium-137	1.07E+12
	Beta Emitters	4.37E+12
	Alpha Emitters	1.10E+11
	Sodium-22	1.80E+12
Gaseous Discharges		
Area	Nuclide	Limit (Bq/yr)
Fuel Cycle Area	Tritium	2.00E+12
	Krypton-85	3.00E+15
	Iodine-129	1.10E+09
	Beta Emitters	4.50E+10
	Alpha Emitters	9.80E+08
Prototype Fast Reactor	Tritium	1.07E+13
	Krypton-85	4.00E+12
	Beta Emitters	5.15E+07
	Alpha Emitters	6.06E+06
Dounreay Fast Reactor	Tritium	1.00E+07
	Krypton-85	4.00E+08
	Beta Emitters	1.50E+09
	Alpha Emitters	1.00E+07
East Minor Sources	Krypton-85	1.00E+12
	Beta Emitters	3.71E+08
	Alpha Emitters	1.37E+07
West Minor Sources	Tritium	1.00E+10
	Beta Emitters	7.50E+07
	Alpha Emitters	3.00E+05

Table 3: Comparison of prospective doses to an adult member of the local population groups from gaseous and liquid discharges at current and requested limits.

Pathway	Dose Based Upon Current Limits (μSv/yr)[1]	Dose Based Upon Prospective Limits (μSv/yr)[1]
Food Pathways (High Rate Fish & Legume Consumer)	21.4	8.7
Inhalation	5.4	0.8
External Exposure (High Rate Exposure over Sand)	317	198
Total	344	208

[1]These doses do not include a contribution from direct radiation ("shine").

These Doses were calculated for Adults, which represents the highest exposures using the Profile methods from the habits survey report.

Annex 1

1 Dose calculations

Assessment of the impact of annual discharge limits assumes that all discharges occur uniformly over the year and are equal to the maximum levels that would be allowed if the limits requested by the UKAEA were in place. Assessment of the impact of current discharges at the maximum allowed level was also carried out. The FSA used site specific meteorological and marine data in conjunction with mathematical dispersion models to calculate potential levels of environmental contamination. Annex 2 gives details of the models and methods used, and the assumptions made in their application.

The FSA assessment considered the all the radionuclides specified in the current authorisation and in the requested authorisation. The foodstuffs considered in the assessment are: Legumes; potatoes; root vegetables; leafy green vegetables; domestic fruit; lamb; beef; poultry; milk; eggs; fish; shellfish; crustacea. Doses received via food and non-food pathways were calculated for three age groups: adults (>17 yrs), children (10 yrs) and infants (1 yr). Predicted concentrations of radionuclides in different foods are combined with food consumption rate data [Ref 7] and dose coefficients [Ref 8] for each age group to calculate annual doses from all radionuclides.

The FSA modelled the dispersion of radionuclides discharged to atmosphere using the ADMS [Ref 9] atmospheric dispersion model. ADMS calculates ground level air concentrations and deposition to ground and crops. Transfer into the environment and into food was modelled using the Soil-Plant-Animal Dynamic Evaluation (SPADE) model [Ref 10 and 11]. SPADE is the FSA's food chain model and calculates radionuclide concentrations (Bq kg^{-1}) in crops and animal products.

The FSA modelled dispersion in the sea using the WAT model [Ref 12] to evaluate the radionuclide concentration in seawater. It then used the ADO model [Ref. 13] to evaluate concentrations in seafoods and sediments using concentration factors recommended by the International Atomic Energy Agency [Ref. 14]. The WAT and ADO models were implemented in a Graphic User Interface called Prame.

Direct radiation shine from the site has not been included in the dose calculations.

2 The Reference Individuals

The FSA has identified the population groups that might receive the highest exposures from gaseous and liquid discharges from the Dounreay site. A member of the group that receives the highest dose is referred to as the 'reference individual'. If the dose received by the critical group is acceptable then any other group is also adequately protected. The reference individuals used by the FSA are notional in that it may not comprise currently identifiable persons. The characteristics of the reference individuals include behaviour that a reasonable person would not consider extreme, although such behaviour may not be present now. This ensures that no reasonably foreseeable human activity is overlooked when assessing the impact of discharges from the Dounreay site.

2.1 Groups close to the site

The FSA has identified the Reference Individuals close to the site. The reference persons obtain seafoods from the Dounreay coastal area and terrestrial foods from the reference location. The reference location is the area where food contamination from atmospheric discharges would be greatest, in terms of dose received by consumers. The reference location must be at least 100 m from the site fence and on land that is suitable for agricultural production, even if it is not currently used as such (e.g. it may presently be recreational ground or fallow land). Land that is built on is not considered.

3 Food pathways

3.1 Terrestrial food

The terrestrial food groups considered in the assessment are: milk, domestic fruit, leafy green vegetables, legumes, beef, lamb, potatoes, root vegetables, eggs and poultry. The FSA did not consider cereals in these calculations because food production and distribution of grains involves mixing and dilution with cereals grown elsewhere. The critical group obtains all their locally sourced terrestrial foods except cereals from the reference location.

3.2 Aquatic food

The aquatic food groups considered in this assessment are fish, molluscs, and crustaceans. Local habit surveys may occasionally identify other foods that could be contaminated by discharges such as laverbread or practices such as the use of seaweed as a soil conditioner. Local habit surveys have not shown that these practices occur in this area.

3.3 Combination of Food Pathways

The FSA combined the doses from terrestrial and aquatic foods using the data derived from terrestrial and aquatic habit surveys. The terrestrial data set contains information on a person's consumption of locally produced terrestrial foods close to several coastal nuclear installations in the UK. As consumption of locally produced seafoods depends on the availability of different species, the use of national data is not appropriate. Therefore, the FSA used data from the local aquatic habit survey for the calculation of doses from seafoods.

For both terrestrial and marine foods, the FSA used the assessed concentrations of radionuclides in the foods to calculate the dose that a person would receive from consumption of 1 kg of each of the food. These dose per unit consumption values are multiplied by the consumption rate data reported in habit surveys to give the doses from consumption of each of the food groups separately for terrestrial and aquatic foods and for each age group. Total doses were calculated for each individual. This gives a distribution of doses corresponding to the habits of the different individuals in the surveys.

4 Non-food pathways

The FSA assumes that members of the Reference Individuals live in a location close to the site such that they could receive the highest dose from inhalation of and immersion in the plume. This location is the determining habitation. The determining habitation will always be an existing habitable building but may not necessarily be the house nearest the site fence. Maps and habit surveys were used to identify potential determining habitations.

The FSA calculated air concentrations of radionuclides for each of the residential properties close to the site, using the ADMS model, and that property which gave the maximum dose was selected as the determining habitation.

4.1 External radiation

The FSA calculated the dose rate from irradiation by krypton-85 in the plume. This dose rate was then multiplied by the amount of time the members of the critical group spent at the determining habitation. As the beta particles emitted by krypton-85 have a short range there was no need to take account of building shielding.

4.2 Inhalation

The FSA calculated inhalation doses to members of the critical group at the determining habitation. Air concentrations for each radionuclide were multiplied by the appropriate dose coefficients and by the times spent at the determining location given in paragraph 4.1 above

4.3 External Irradiation from sediment

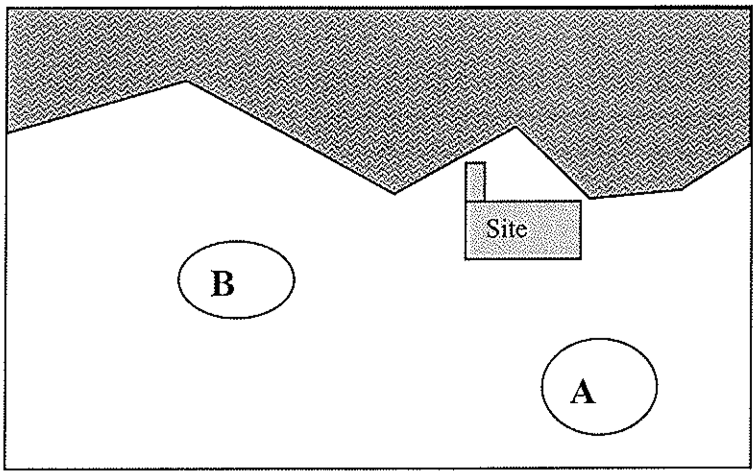
Discharges to the sea may lead to accumulation of radionuclides on shore including areas where people spend time. The FSA used the WAT and ADO models, as implemented in the PRAME Graphic User Interface. [Refs. 12 and 13] to calculate the dose rate from exposure to this source of radiation. It then multiplied the dose rate by occupancy data taken from the Dounreay Habits Survey [Ref. 7] to give total doses from this pathway.

5 Combination of pathways

To calculate a total dose the FSA then combined the doses from different pathways. Simple addition of doses from the different pathways is likely to over estimate the dose that members of the critical group would receive. The FSA used combinations of pathways that it believes give an upper bound of the doses that could be received without being unduly pessimistic. Figure 1 [Ref 3] summarises the method of calculating doses from terrestrial foods, aquatic foods and other pathways.

Figure 1: Summary of the FSA method for calculating the critical group dose.

The Geography (schematic)



Key:
A = the "determining habitation" where the critical group live
B = the "reference location" where food is produced.

The method

Critical group	Three age groups are considered in the calculations.
(1) Food dose	Terrestrial food produced at B, aquatic foods obtained from local sources. Consumption rate data for all local foods obtained from a combination of Terrestrial Pathways Surveys conducted in the vicinity of coastal nuclear sites in the UK combined with predicted radioactivity concentrations to give dose distribution. Aquatic food consumption rates are taken from a local habit survey.
(2) Dose from inhalation and plume immersion	Live at A and spend some time outdoors and on contaminated sediments as shown by habit survey data.

Annex 2: Methodology used in assessing the impact of atmospheric and aquatic annual discharges

The following table details some aspects of the methodology used, and assumptions made in assessing the potential dose to the critical group at the requested and current discharge limits.

1	Discharge source term		
	Aspect	**Atmospheric discharges**	**Aquatic discharges**
1.1	Amount of radio-activity discharged per year	Discharges are assumed to occur at the maximum amounts allowed by the requested or current limits.	
1.2	Assumptions on non-specific limits	The FSA modelled beta emitters as casesium-137 and alpha emitters as plutonium-239. These assumptions maximise the assessed doses.	The FSA modelled beta emitters as casesium-137 and alpha emitters as plutonium-239. These assumptions maximise the assessed doses.
1.3	Timing of discharge	Discharges are assumed to take place continuously at an uniform rate.	
1.4	Chemical form	Tritium is assumed to be released as tritiated water vapour.	The FSA assumed that the chemical forms of future discharges would be similar to those of recent discharges.
1.5	Discharge point	The FSA has conservatively assumed the following stack heights, based on information supplied by the UKAEA: Fuel Cycle Area: 30m Prototype Fast Reactor 30m Dounreay Fast Reactor 30m East Minor Sources 0m West Minor Sources 0m	Radioactivity enters the sea via the site discharge pipeline.

2.	Dispersion modelling		
	Aspect	**Atmospheric discharges**	**Aquatic discharges**
2.1	Models and versions used	ADMS a long term release model is used [Ref 9]. Account was taken of the 'plume rise' due to the exit velocity of the discharged gases.	Activity concentrations in seawater evaluated using the WAT advection diffusion model [Ref 12].
2.2	Source of parameter values used	Site-specific meteorological data provided by the Met. Office, from Kirkwall Met. Station was used.	Parameters obtained from hydrographic charts and knowledge of British coastal waters.
2.3	Assumptions used	Site-specific rainfall data used.	
2.4	Evaluation points	Ground level air concentrations (Bq/m^3) and deposited activity (Bq/m^2) are determined at the determining habitation and reference location respectively) using ADMS [Ref 9].	Water concentrations (Bq/l) is determined by WAT modelling [Ref 12].

3	**Environmental uptake and transfer into food**		
	Aspect	**Atmospheric discharges**	**Aquatic discharges**
3.1	Models and versions used	Concentrations of radionuclides in foodstuffs are determined using the FSA's foodchain model, SPADE 4.6, with appropriate input parameters for each nuclide and each food product [Ref 11].	Concentration of radionuclides in aquatic foods and doses from external pathways are determined using ADO [Ref 13].

4	Exposure pathways		
	Aspect	**Atmospheric discharges**	**Aquatic discharges**
4.1	Location of food production	All foods consumed are assumed to be produced at the point where deposition leads to the highest impact (i.e. reference location). This point lies at least 100m from the site boundary. This takes account of the area of land necessary for the production of an individual's annual food supply.	Aquatic foods are assumed to be collected from the vicinity of Dounreay
4.2	Location of inhalation, cloud shine and external exposure from deposited material	Inhalation and cloud 'shine' are assumed to occur at the existing habitation receiving the highest ground level air concentration (i.e. determining habitation).	Contaminated sediments are assumed to be deposited along the Dounreay coastline.
4.3	Occupancy rates	The occupancy rates are derived from local habits surveys.	The amount of time spent over sediments is derived from local habit surveys.
4.4	Timing of food collection	It is assumed that crops are harvested and consumed when their radionuclide concentrations have reached equilibrium. Post-harvest decay corrections are applied for short lived nuclides. Animals are culled and animal products consumed throughout the year at peak nuclide concentrations.	Seafoods are collected throughout the year.
4.5	Consumption of food	Data from compilation of habit surveys at coastal sites in the UK was used	Data taken from the Dounreay habits survey [Ref. 7]

5	Calculation of doses		
	Aspect	**Atmospheric discharges**	**Aquatic discharges**
5.1	Calculation of total foodchain dose	Dose per kg values of each food group were combined with' consumption rate data obtained from habit surveys. The FSA then calculated an ingestion dose for each individual. The "Profiles" method was used to provide realistic estimates of the exposure rates.	
5.2	Source of dose coefficients	Dose coefficients for ingestion and inhalation are taken from the European Basic Safety Standards Directive [Ref 8]	
5.3	External dose from plume	The dose from krypton-85 was evaluated using air concentration values form ADMS and conversion factors from Ref 15	

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Glossary

ADMS	Atmospheric dispersion model used by the FSA
ADO	A model used for calculating the doses received by consumers from the discharge of liquid radioactive waste
Cloud Shine	External radiation from the plume of radioactive material
Community Food Intervention Levels (CFILs)	European Community Food Intervention Levels which specify the maximum permitted concentrations of radioactivity in food following a radiological emergency.
Reference Individual	A representative person from the group of people likely to be exposed to the highest levels of radiation in a population
Determining Habitation	The habitation where the occupants are assessed to receive the highest doses from discharges through non-food pathways. These will include inhalation, ground shine, and cloud shine doses. The exact location will depend on dispersion of nuclides in the environment, not just proximity to the site.
Direct Shine	Direct radiation from facilities on the nuclear site
FSA	The Food Standards Agency
R91 STAR	A model used for short term atmospheric dispersion calculations
Reference Location	A representative point suitable for agricultural production where the combined deposition of all nuclides from all stacks and outlets from the site, when discharged at rates equivalent to the requested limits, gives the highest impact via consumption of food.
SEPA	The Scottish Environment Protection Agency
SPADE	The model used by the FSA to calculate concentrations of radioactivity in terrestrial foods
STARH-3	A computer model used for calculating concentrations of H-3 in foods following short term releases.
Sv, μSv	sievert; unit of radiation equivalent dose. A microSv (μSv) is one millionth of a sievert.
UKAEA	The United Kingdom Atomic Energy Authority, owners of the Dounreay site.
WAT	A model used for calculating the dispersion and dilution of radioactivity in the sea