Prospective Dose Assessment of Magnox, Hunterston A Power Station February 2012

radiation@foodstandards.gsi.gov.uk

Summary

As a statutory consultee to the Scottish Environment Protection Agency under the Radioactive Substances Act 1993, the Food Standards Agency is responsible for assessing the potential effects of proposed radioactive discharges on the safety of food. The Food Standards Agency has assessed the potential impact of radioactive waste discharges from the Magnox power station at Hunterston in response to the operator's application for discharge authorisations [Ref. 1].

The Food Standards Agency welcomes the requested discharge limits for reauthorisation. Discharges at the requested limits would not unduly affect the safety of locally produced foods. The major contribution to the dose received by a consumer of locally produced foods is from radioactive material incorporated into sediments.

Prospective assessments of the requested discharge limits indicate that doses to representative person will be within the source dose constraint of 300μSv/y. The possible assessed dose to the representative person for discharges at 100% of the requested discharge limits is 190 μSv/y. The assessment has been carried out on the basis of the limits requested by Magnox [Ref. 1], which are summarised in table 2.

In arriving at these assessed doses, we have calculated the potential dose arising from the consumption of food and from other exposure pathways. However, we have chosen to consider only those combinations of pathways that we regard as reasonable but not extreme.

Later sections of this document provide details of the assessment methodology and results.

The dose reported represents an upper estimate of the dose that the representative person would receive from discharges at 100% of the discharge limits. The probability of the prospective dose actually being received is small, as actual discharges are likely to be below the permitted discharge limits.

Table 1: Assessed Doses to the Representative Person from Discharges at the Proposed Limits.

Adult	
Dose	190 μSv/year

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 (the Agency) is a statutory consultee to SEPA on proposed limits to discharge radioactive wastes and is responsible for 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 Agency uses computer models to predict the levels of radioactivity in food that might result from discharges at the discharge limits. Dose limits and constraints are specified for the total dose that a member of the public may receive. This total dose could be received via food or non-food pathways. Although principally concerned with the safety of food, the Agency assessment includes non-food pathways of exposure to radiation so that estimated doses may be compared with annual limits and constraints.

Magnox North has requested changes of some of the current discharge limits [Ref 1]. The proposed limits are given in table 2.

2. Dose Assessment Methodology

2.1 Overview

The methodology combines information from observations (habits, behaviours, locations and measurements at nuclear sites) with assumptions about the possible and realistic habits that might occur. Doses are assessed 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 2]. The group of people who, because of realistic combinations of these habits, receives the highest dose, is referred to as the 'Representative Individual'. The assessment methodology is described in Annex 1 and detailed in Annex 2.

2.2 Prospective Dose

Doses presented in this document are forecasts based on discharges at 100% of the proposed limits. Under normal operation, however, discharges from the site are unlikely to reach these limits and hence the doses received by the Representative Person and the public in general will be less than that predicted and reported here. Each year the retrospective dose to members of the public are calculated using monitoring data that arise from the actual radioactive discharges; these are published in the annual RIFE (Radioactivity in Food & the Environment) report [Ref 3]. The assessed dose to the members of the public in the area around Hunterston as a result of previous discharges is expected to be lower than those reported here.

To assess prospective doses to the public, the Agency ensures a margin of safety by using cautious assumptions on the habits and locations of the "Representative Person" and for parameters used in atmospheric and aquatic dispersion and food chain modelling. These assumptions, combined with the use of the discharge limits rather than the likely discharges, mean that the assessed prospective dose to the Representative

Individual is an upper estimate of the dose that could be received and it may be higher than that actually received by the Representative Individual.

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 [Ref. 4], and the source constraint of 300 μSv/year.

Details of the methodology used to assess the impact of the proposed limits, which are published [Ref 2], are given in Annexes 1 and 2.

3. Dose Assessment Results

3.1 Prospective dose assessment results

Tables 2 gives assessed doses at current and requested limits to the Representative Person. For discharges at the requested limits, the assessed dose to an adult is 190 μSv/year at 100% of the requested discharge limits. This total of 190 μSv/year can be compared with the source constraint of 300 μSv/year. This dose does not include a contribution from direct radiation from the site ("shine").

3.2 Doses from results of environmental monitoring (retrospective doses)

The Scottish Environment Protection Agency carries out environmental monitoring around the Magnox site at Hunterston. These monitoring data are published annually in the RIFE report 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 originates from historic and current waste discharges and includes the effect of other sources (e.g. other nuclear establishments, weapons testing and Chernobyl fallout).

It is not appropriate to compare retrospective doses estimated from environmental monitoring with the prospective doses presented in this document, because doses estimated from monitoring data relate to current and historical discharges. In addition, monitoring-based doses are calculated using measured concentrations of radionuclides in food and the environment whereas prospective doses are based on concentrations predicted by models for discharges at the authorised limits.

3.3 Assessed dose at currently authorised discharge levels

The Agency has assessed the potential impact of the discharges of radioactive waste from the Hunterston 'A' site in response to the sites request for the future discharges of radioactive waste. At the current authorised discharge limits, the assessed prospective dose to the "Representative Individual" is 190 μSv/y. This dose has been calculated using the same methods and assumptions that were used to calculate the doses at the requested limits

4 Short Term Discharge Limits

The discharge limits requested by Magnox are such that there is no need for the Food Standards Agency to request that short-term limits or reporting levels be included in the Authorisation. Short-term limits are requested in some circumstances to ensure that concentrations of radioactive material in foods do not exceed the Community Food Intervention Levels [Ref. 5]

5. Conclusion

The Agency does not object to SEPA granting Magnox an authorisation containing the requested discharge limits at Hunterston A.

.

Table 2: **Requested Discharge Limits**

Liquid Discharges	Nuclide	Requested Limit (TBq/yr)
	Tritium	0.7
	Other Beta Emitters	0.6
	Alpha Emitters	0.04
	Pu-241	1
Gaseous Discharges	Nuclide	Requested Limit (TBq/yr)
	Tritium	0.02
	Carbon-14	0.002
	Beta Particulates	0.000006

Table 3: Proposed Quarterly Notification Levels

Liquid Discharges	Nuclide	Requested QNL
	Tritium	350 GBq
	Other Beta Emitters	300GBq
	Alpha Emitters	20GBq
	Pu-241	200GBq
Gaseous Discharges	Nuclide	Requested QNL
	Tritium	10GBq
	Carbon-14	1GBq
	Beta Particulates	30MBq

Table 4: Summary of Annual Calculated Doses

Pathway	**Dose (microsievert)**
Food (Terrestrial)	0.069
Food (Aquatic)	189
Inhalation	0.00347
External (Terrestrial)	8.35e-8
External (Aquatic)	1.38
Total	190.4

The above doses were calculated for Adult Pathways Identified as Reference Individual.

Annex 1

1 Dose calculations

Assessments of annual dose assume that all discharges occur uniformly over the year and are equal to the limits. Site specific meteorological and marine data are used in conjunction with mathematical dispersion models to calculate potential levels of environmental contamination. Details of the models and methods used, and the assumptions made in their application, are provided in Figure 1.

The radionuclides specified in the current authorisation and in the requested authorisation were considered in the assessment. The foodstuffs considered in the assessment are: legumes, potatoes, root vegetables, leafy green vegetables, domestic fruit, lamb, beef, poultry, milk, eggs, wildfowl and fish. Shellfish and crustacea have not been considered as the habits survey [Ref. 6] did not report consumption of local shellfish by the local population. 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. 6] and dose coefficients [Ref. 7] for each age group to calculate annual doses from all radionuclides.

The dispersion of radionuclides discharged to atmosphere is modelled using the ADMS [Ref. 8] atmospheric dispersion model. ADMS calculates ground level air concentrations and depositions to ground and crops. Transfer into the environment and into food is modelled using the Soil-Plant-Animal Dynamic Evaluation (SPADE) model [Refs. 9 and 10]. SPADE is the Food Standard Agency's food chain model and is used to calculate radionuclide concentrations (Bq kg^{-1}) in crops and animal products.

Calculation of doses via the marine pathways is carried out using the Wat/ADO model [Refs. 11 and 12] to evaluate the radionuclide concentration in seawater. Concentration in foodstuffs were evaluated using concentration factors (CFs) recommended by the IAEA (Ref 13).

External irradiation from contaminated sediments is a significant pathway at this site [Ref 6] and doses from this pathway are incorporated in the assessment. Direct radiation shine from the site has not been considered.

2 The Representative Person

Population groups that might receive higher exposures from gaseous and liquid discharges from the Hunterston 'A' site have been identified in this assessment. The group that was identified to receive the highest dose is the 'Representative Person.' If the dose calculated for the 'Representative Person' is acceptable then any other group in the population is considered to be adequately protected. The Representative Person used by the Food Standards Agency is notional in that it may not correspond to an identifiable individual. The characteristics of the Representative Person will include behaviour that a reasonable person would not consider extreme, even though such behaviour may not be present at the moment.

2.1 Sources of foods

The Representative Person is assumed to obtain his or her marine foodstuffs from the Hunterston coastal area and terrestrial foods from the *reference location*. This is the location where food contamination from atmospheric discharges would be greatest. 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 upon is considered unsuitable for agricultural production. However, where the reference location cannot physically support the production of particular food groups, a more appropriate location is used for these foods.

The activity concentrations in these foodstuffs have been derived using the ADMS [Ref. 8] and SPADE [Refs. 9 and 10] assessment codes for terrestrial foods and the Wat/ADO model [Refs. 11 and 12] combined with empirically derived concentration factors for the marine foods. Doses as a result of consumption of foods, both terrestrial and marine, have been evaluated by making use of data set derived by combining information obtained from the habits surveys carried out by Cefas [Ref.6] for SEPA around the Hunterston sites.

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, wildfowl and poultry. Cereals were excluded because food production and distribution of grains involves mixing and dilution with uncontaminated cereals. A radius of 5 km was used to define the area within which consumption data was collected.

The Representative Person is assumed to obtain all his or her locally sourced terrestrial foods from the reference location**.**

3.2 Aquatic food

The aquatic food group considered in this assessment was fish. Results from local habit surveys may occasionally identify other food groups contaminated via an aquatic pathway such as the consumption of seaweed as laverbread or terrestrial foods grown in soil fertilised with seaweed. The local habit survey has not shown that these practices occur in this area.

4 Non-food pathways

In addition to the potential dose from ingestion of food that might become contaminated by waste discharges, the movement of radionuclides through the air, ground and water can deliver dose via other pathways.

For those pathways relating to the discharge of radioactive material into the atmosphere, it is assumed that people may live in a location close to the site where they could potentially receive the highest dose from inhalation and immersion in the plume. This location is referred to as the *determining habitation***.** The determining habitation will always be an existing habitable building but may not necessarily be the house nearest the site fence. Studying maps and habit surveys identifies potential determining habitations.

Exposure to radioactive material incorporated into sand and sediments occur at the locations close to the discharge point identified in the local habits survey

Air concentrations and ground depositions are determined for each of the potential properties close to the site, using the ADMS model, and that property which gives the maximum dose is selected as the determining habitation. Exposures to radioactive material incorporated into sand and sediment is calculates using the Wat and ADO models.

Calculation of doses from non-food pathways is necessary to determine which group of people will potentially receive the highest total dose and how this dose compares with limits and constraints.

4.1 External radiation

Individuals may be exposed to external radiation from the plume and from radionuclides deposited on the ground. The extent of such exposures depends upon the time that an individual spends at a given location (occupancy) and the protection afforded by housing (shielding).
Discharges to the sea may lead to accumulation of radionuclides on shore areas over which people will spend time and on material that people may handle such as fishing gear, and hence the 'Representative Individual' being exposed to radiation.

4.2 Inhalation and plume 'shine'

Inhalation and plume 'shine' (direct exposure from the radioactive gases passing overhead) are assumed to occur at the determining habitation receiving the highest ground level air concentration. People breathing the air containing radionuclides receive an inhalation dose. It is calculated using air concentrations of radionuclides, age-dependent breathing rates and inhalation dose coefficients for each radionuclide. A set of assumptions is made regarding occupancy at the determining habitation, and time spent outdoors, to give doses from inhalation and immersion in the plume.

5 Combination of pathways

The doses from the different pathways are combined using a modified version of the 'profiles' method developed for the reporting of retrospective doses in the RIFE report [Ref. 14]. This method is summarised below:

Starting with the first pathway, A, identified in the habit survey those adults who have a consumption or occupancy rate between the maximum rate observed and 1/3rd of the maximum rate are identified. The mean rates, for this sub-population, for all habit pathways are calculated. This array of habit rates is then referred to as profile A. The process is then repeated for the next pathway to give profile B which represents the habits of the sub-population which has a rate for pathway B between the maximum value and 1/3rd of the maximum. The process is continued until profiles representing all the observed pathways have been calculated.
As there are generally few data in habit surveys for children and infants, profiles for these age groups are obtained by multiplying the food consumption rates in adult profiles by the ratio of the consumption rates of these age groups to the adult rate obtained from national food consumption surveys [Ref. 15]. For non-food exposure pathways the adult rates are used except for those pathways (e.g. baitdigging, wildfowling etc.) which are not appropriate to these age groups. In these cases zero is used.

In the case of prospective dose assessments these profiles are modified in two ways to provide a degree of conservatism. Firstly the rates are rounded up, and secondly the amount of time spent in the determining habitation is adjusted so that the total amount of time spent at the determining habitation and on sand, mud etc. incorporating radioactive material totals 8000 hours a year.

For each profile each of the calculated rates is multiplied by the appropriate dose per kg or hour value. The doses are then summed for each rate in the profile. The profile which gives rise to the largest dose, for whichever age group, is then taken to be the habits of the "Representative Individual". The dose obtained from this profile is the dose received by the Representative Individual.

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

The method

Critical group	Three age groups are considered in the calculations.
(1) Food dose	Terrestrial food produced at Reference Location, aquatic foods obtained from local sources.
(2) Dose from inhalation and plume immersion	. Live at Determining Habitation 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 impact to members of the public from radioactivity discharged at the current and proposed 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 limits.	
1.2	Assumptions on non-specific limits	It is assumed that "beta particulate" gaseous discharge limits were Co-60, as this is nuclide which has the highest impact of those which could be discharged.	Alpha activity was assumed to be Pu-239 and beta activity Cs-134
1.3	Timing of discharge	Discharges are assumed to take place continuously	
1.4	Chemical form	Tritium is assumed to be released as tritiated water. ^{14}C is assumed to be carbon dioxide.	It is assumed that the chemical forms of future discharges will be similar to those of recent history.
1.5	Discharge point	The discharges are assumed to be through a 15m stack.	It has been assumed that the radioactivity enters the Sea via the 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 8]. Account was taken of the 'plume rise' due to the exit velocity of the discharged gases.	Activity concentrations in seawater evaluated using the WAT single compartment model [Ref. 11].
2.2	Source of parameter values used	A full Pasquill Stability Analysis is used, based on site-specific meteorological data, provided by the Met. Office from Prestwick Met. station.	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 calculated at the determining habitation and reference location.	Water concentrations (Bq/l) are determined by WAT modelling [Ref. 11].

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 Agency's foodchain model, SPADE 4.6, with appropriate input parameters for each nuclide and each food product [Ref. 10].	Concentration of radionuclides in aquatic foods and doses from external pathways are determined using ADO [Ref. 12].

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 Hunterson (as determined by habits survey)
4.2	Location of inhalation, cloud shine, direct shine and external exposure from deposited material	Inhalation, plume 'shine' and external exposure from deposited material 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 Ayrshire 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 (e.g. S-35) where appropriate. Animals are culled and animal products consumed throughout the year at peak nuclide concentrations.	Activities are based on the equilibrium values observed from monitoring programmes.
4.6	Consumption of food	Rates are derived from the habits survey [Ref. 6]	

5	Calculation of doses		
	Aspect	**Atmospheric discharges**	**Aquatic discharges**
5.1	Calculation of total dose	Dose per kg values of each food group and per hour for non-food pathways were combined with real individual's consumption and other habit rate data using the profiles method	
5.2	Source of dose coefficients	Values for ingestion and inhalation are taken from the European Basic Safety Standards Directive [Ref. 17]	
5.3	External dose from plume	External exposure assessed using air concentrations from ADMS and conversion factors [Ref. 17]	

References

[1] SEPA, Application by Magnox for Authorisation to Dispose of Radioactive Waste from Hunterston A Power station.

[2] Assessment Methodology for the Potential Impact on Food of Radioactive Discharges to the Environment. FSA (2007).

[3] Radioactivity in Food and the Environment: 2010. RIFE-16. EA, E&HS, FSA and SEPA, London (2011).

[4] CM2919, Review of radioactive waste management policy, 1995. HMSO, London

[5] Council Regulation (Euratom) No 2218/89 of 18/7/89 amending Regulation No 3954/87 (1987). Laying down maximum permissible levels of radioactive contamination of foodstuffs and of feedstuffs following a nuclear accident or any other case of radiological emergency. Official Journal No L211, 22/7/89.

[6] Sherlock, J.R., Tipple, J.R., Clyne F.J. Radiological Habits Survey, Hunterston, 2007. CEFAS Environment Report RL05/11

[7] Council Directive 96/29/Euratom (1996). Laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation. Official Journal No L159, vol. 39, 29/6/96

[8] CERC, ADMS 3.1 Technical Specification (2000) *Cambridge Environmental Research Consultants.*

[9] Johnson, R.H. and Mitchell, N.G., (1993). The SPADE suite of codes: SPADE 3.0 PC Version; volume 1, User manual. WS Atkins Technical Note M1722-TN5.

[10] Mitchell, N.G., (1999). A handbook for the SPADE suite of models for radionuclide transfer through terrestrial foodchains. in Mouchel Report 48112.

[11] Round, G.D., 1998. Individual doses from discharges of liquid effluents to the sea: Water concentration model – WAT. CEFAS Environment Report RL2/98, Lowestoft.

[12] Round, G.D., 1998. Individual Doses From Discharges Of Liquid Effluents To The Aquatic Environment: Dosimetric Model ADO. CEFAS Environmental Technical Note RL08/98. Lowestoft.

[13] IAEA Technical Reports Series No. 364. Handbook of parameter values for the prediction of radionuclide transfer in temperate environments.

[14] Camplin, W.C., Grzechnik. M., Smedley. C., Methods for Assessment of Total Dose in the Radioactivity in Food and the Environment Report. National Dose Assessment Working Group Report NDAWG/3/2005 (2005).

[15] Byrom. J., Robinson. C., Simmonds. J.R., Walters. B., Taylor. R.R. Food consumption rates for use in generalised radiological dose assessments. J Radiol Prot 1995, Vol.15 No 4 pgs 335 to 341.

[16] Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment. European Commission Report EUR 15760 EN. (1995)