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Methodology and models used to calculate individual and collective doses from the recycling of metals from the dismantling of nuclear installations

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Methodology and models used to calculate individual and collective doses from the recycling of metals from the dismantling of nuclear installations

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Foreword

This document explains in detail the methodology and models used to calculate individual and collective doses resulting from the recycling of metals from the dismantling of nuclear installations. The results of these calculations are the basis for the mass specific clearance levels recommended by the Group of Experts established under Article 31 of the Euratom Treaty and published in the publication Radiation Protection No 89 "Recommended radiological protection criteria for the recycling of metals from the dismantling of nuclear installations".

A similar technical document, Radiation Protection No 101: "Basis for the definition of surface contamination clearance levels for recycling or reuse of metals arising from the dismantling of nuclear installations" contains the information on the derivation of the surface specific clearance levels.

The preparation of this document was rather time consuming. NRPB was entrusted with the task of compiling the scenarios, parameter values, and equations used by different institutes involved in the work over many years (IPSN, ANPA, SCK-CEN and Brenk Systemplanung). This working document then was submitted to a thorough process of quality assurance and editing. I am pleased to acknowledge in particular the efforts of Herman Puchta, who started this work while working with the Commission as an expert detached from the State of Bavaria and who finalised the present document.

The effort spent in preparing this publication is justified by the need to ensure full transparency of the approach and traceability of the values. It will in addition facilitate similar work carried out in Member States or outside the European Union and contribute to the harmonisation of clearance levels proposed internationally.

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Abstract

This report provides the technical basis for the calculation of mass specific clearance levels published in Radiation Protection No 89. The document gives an overview of the exposure scenarios that were used and of the calculated maximum individual doses for different types of metals. A comprehensive description of the scenarios and parameters is given separately for the recycling of steel and for copper and aluminium. A further Annex provides the information for the calculation of collective does. Finally the nuclide specific data are given for the 109 nuclides for which calculations have been performed.

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1 Introduction

In May 1996 a new Basic Safety Standards (BSS) Directive was adopted by the Member States of the EU[1]. One of the requirements of the new standards is that the disposal, recycling and re-use of material containing radioactive substances is subject to prior authorisation by national competent authorities. However, the BSS state that the authorities may specify clearance levels below which such materials are no longer subject to the requirements of the standards. The clearance levels shall be based on the general criteria for exemption laid down in Annex 1 of the BSS Directive and take into account guidance provided by the Community.

Although the concept of clearance had not yet been introduced into Community legislation, in 1984 the Group of Experts, set up under the terms of Article 31 of the Euratom Treaty, convened a Working Party to establish radiological protection criteria appropriate to the recycling of materials from nuclear establishments. Their guidance was published in 1988[2]. Since then there have been a number of studies on recycling of slightly radioactive materials and there has been new advice on radiological protection criteria. Therefore the Article 31 Group of Experts decided in 1990 to reconvene the Working Party to expand and update the 1988 recommendations. Their revised criteria and clearance levels were published in 1998[3]. They considered a range of metals: steel, steel alloys, aluminium, aluminium alloys, copper, and copper alloys. They also considered both mass specific clearance levels and surface contamination.

In order to derive these clearance levels it was necessary to develop a set of exposure scenarios. These scenarios were developed in technical work carried out on behalf of the European Commission by IPSN, ANPA, SCK-CEN and Brenk System Planung and examined by an expert group of the Article 31 Group of Experts. The scenarios for the mass specific clearance levels were subsequently drawn together and implemented on a spreadsheet by NRPB for a total of 109 radionuclides. For those radionuclides exemption values have been defined in the BSS and their half-life is greater than 60 days.

This document gives the derived mass specific clearance levels and describes the exposure scenarios used to calculate these values for steel, copper and aluminium, in terms of individual and collective doses, and also contains the underlying nuclide specific data. The exposure scenarios for surface contamination of metals are described in a separate document[4].

2 Structure of this document

Table 1 summarises the exposure scenarios and Table 2 lists the radionuclides with short lived daughter products assumed to be in secular equilibrium.

The details of the calculations are contained in 4 appendices.

Appendix A describes the scenarios and parameters for calculating individual doses arising from the recycling of steel. It also presents the individual doses in Sv y^{-1} per Bq g^{-1}.

The calculations for copper and aluminium recycling are given in Appendix B.

The derived clearance levels, based on the most restrictive metal recycling scenarios and an individual dose criterion of 10 µSv y^{-1}, are given in Table 3 of main text for all 109 radionuclides. Tables 4, 5 and 6 list the maximum individual dose per unit activity concentration (bulk and surface) and the corresponding most restrictive scenarios for steel, copper and aluminium recycling for 31 radionuclides.

Appendix C describes the scenarios and parameters used to calculate collective doses from recycling of steel, copper and aluminium. The collective doses were calculated for 1 Bq g^{-1} of each nuclide (Table 7 and tables in Appendix C). These results were then scaled by the (rounded) clearance levels calculated on the basis of the individual dose criterion and the resulting collective dose per year of practice is given in ref. 3. For nearly all the nuclides the collective doses were significantly below the criterion of 1 man Sv per year of practice described in Annex 1 of the BSS. In 2 cases they were of the order of 1 man Sv y^{-1}. Ref. 3 concluded that in reality the

1 man Sv y^{-1} criterion would not be exceeded when the recommended clearance levels were used and hence an optimisation study was not necessary.

Appendix D gives the nuclide specific data for the 109 nuclides considered by the Group of Experts.

3 References

1 Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation. Official Journal of the European Communities L 159 of 29 June 1996.

2 Commission of the European Communities. Radiological protection criteria for the recycling of materials from the dismantling of nuclear installations, RP 43, Luxembourg 1988.

3 European Commission. Recommended radiological protection criteria for the recycling of metals from the dismantling of nuclear installations, RP 89, Luxembourg 1998.

4 European Commission. Basis for the definition of surface contamination clearance levels for the recycling or reuse of metals arising from the dismantling of nuclear installations, RP 101, Luxembourg 1999.

4 Acknowledgements

NRPB would like to acknowledge the work done by other organisations in developing the exposure scenarios and their subsequent advice on the interpretation of the scenarios for implementation onto a spreadsheet by NRPB.

Steel scenarios:	H Garbay and P Guetat (IPSN);
copper and aluminium scenarios:	C Brun-Yaba (IPSN);
external doses from radiation sources of different geometry:	L Bologna and R Mezzanotte (ANPA);
and collective doses:	P Govaerts (SCK-CEN).

5 Tables

The following tables are given here:

Table 1: Summary of scenarios

Table 2: List of radionuclides with short lived progeny assumed to be in equilibrium

Table 3: Mass specific clearance levels for steel, copper and aluminium

Table 4: Derived maximum individual dose and corresponding most restrictive scenario for ferrous metal recycling

Table 5: Derived maximum individual dose and corresponding most restrictive scenario for copper recycling

Table 6: Derived maximum individual dose and corresponding most restrictive scenario for aluminium recycling

Table 7: Collective dose per unit activity concentration from metal scrap recycling

Table 1: Summary of Scenarios

Scenario	Steel	Copper	Aluminium	Collective dose
Scrap yard	External (transport) Inhalation (cutting)	External (transport)	External (transport)	
Foundry	External (heap) Inhalation of dust (melting) Ingestion of dust (melting)	External (heap) Inhalation of dust (melting) Ingestion of dust (melting)	External (heap) Inhalation of dust (melting) Ingestion of dust (melting)	Steel, copper, aluminium: External (heap) Inhalation of dust (melting)
Atmospheric emission	Inhalation External Ingestion	Inhalation External Ingestion	Inhalation External Ingestion	
Treatment of by-products and purification treatment		External (slag processing, electro refining) Inhalation (dust compacting, zinc recovery, slag processing)	External (slag processing) Inhalation (slag processing)	Copper: External (electro refining) Inhalation (dust compacting, zinc recovery) Aluminium: External (slag processing) Inhalation (slag processing)
Post refining	External (manufacture) Inhalation of dust (metal processing)	Inhalation (manufacture)	Inhalation (manufacture)	Steel: External (manufacture) Inhalation of dust (metal processing) Copper, aluminium: Inhalation of dust (metal processing)

Table 1 (cont.)				
Scenario	Steel	Copper	Aluminium	Collective dose
Use of products (occupational)	External (machine, kitchen, process vessel, ships)	External (brass laboratory object, large decoration, brass musical instrument)	External (office furniture, fishing boat, office ceiling)	Aluminium: External (office ceiling)
Use of products (domestic)	External (reinforcement bars, radiator)	External (brass kitchen fitting) Ingestion (pig meat)	External Ingestion (saucepan particles)	Steel: External (reinforce-ment bars, radiator) Copper: External (brass kitchen fitting) Aluminium: External (radiator, car engine)
Disposal or use of by-products	*Disposal:* Landfill workers: (External, inhalation of dust, ingestion of dust) Residential (landfill public): (External, inhalation of dust, ingestion of soil and food). *Use:* Inhalation (slag field - football player, spectator)	*Disposal:* Landfill workers: (Skin contamination, external, inhalation of dust, ingestion of dust) Residential(landfill public): (External, inhalation of dust, ingestion of soil and food). *Use:* Inhalation (slag field - football player, spectator)	*Disposal:* Landfill workers: (Skin contamination, external, inhalation of dust, ingestion of dust) Residential (landfill public): (External, inhalation of dust, ingestion of soil and food). *Use:* External (concrete ceiling)	*Disposal:* Steel, copper, aluminium: Residence pathways *Use:* Aluminium: External (concrete ceiling)

Table 2: List of radionuclides with short lived progeny assumed to be in equilibrium

Parent	Progeny included in secular equilibrium
Sr-90+	Y-90
Zr-95+	Nb-95, Nb-95m
Ru-106+	Rh-106
Ag-108m+	Ag-108
Ag-110m+	Ag-110
Sn-113+	In-113m
Sb-125+	Te-125m
Sn-126+	Sb-126m, Sb-126
Te-127m+	Te-127
Cs-137+	Ba-137m
Ce-144+	Pr-144, Pr-144m
Pb-210+	Bi-210
Ra-226+	Rn-222, Po-218, Pb-214, Bi-214, Po-214
Ra-228+	Ac-228
Th-228+	Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208, Po-212
Th-229+	Ra-225, Ac-225, Fr-221, At-217, Bi-213, Tl-209, Po-213, Pb-209
Ac-227+	Fr-223, Th-227 , Ra-223, Rn-219 , Po-215 , Pb-211, Bi-211, Tl-207, Po-211
U-235+	Th-231
U-238+	Th-234, Pa-234m , Pa-234
Np-237+	Pa-233
Pu-244+	U-240, Np-240m, Np-240
Am-242m+	Np-238, Am-242
Am-243+	Np-239
Cm-247+	Pu-243

Table 3: Mass specific clearance levels which result in a derived maximum individual dose of 10 µSv/y

Nuclide	Clearance levels (Bq/g)		
	Steel scrap	Copper scrap	Aluminium scrap
H3	1,37E+03	8,57E+04	1,79E+04
C14	7,62E+01	2,66E+03	5,54E+02
Mn54	1,63E-00	4,01E-00	3,83E-00
Fe55	2,68E+04	3,35E+04	6,99E+04
Co60	5,76E-01	1,15E-00	1,17E-00
Ni59	3,84E+05	1,98E+04	8,74E+04
Ni63	2,95E+05	1,48E+04	1,24E+05
Zn65	5,32E-01	5,20E-00	5,19E-00
Sr90+	1,44E+01	8,93E-00	4,04E+01
Nb94	4,03E-01	8,99E-01	5,65E-01
Tc99	3,88E+01	3,75E+02	5,27E+02
Ru106+	1,44E-00	6,98E-00	9,19E-00
Ag108m+	8,22E-01	8,55E-01	2,15E-00
Ag110m+	5,06E-01	5,28E-01	1,15E-00
Sb125+	3,22E-00	3,86E-00	3,38E-00
Cs134	2,07E-01	2,32E-00	5,81E-01
Cs137+	5,76E-01	6,65E-00	1,62E-00
Pm147	5,94E+03	7,53E+04	3,01E+04
Sm151	7,43E+03	1,61E+05	4,05E+04
Eu152	4,60E-01	2,66E-00	7,94E-01
Eu154	5,20E-01	2,41E-00	7,25E-01
U234	3,16E-00	6,81E-00	1,55E-00
U235+	3,50E-00	7,59E-00	8,09E-01
U238+	3,71E-00	8,11E-00	1,84E-00
Np237+	5,94E-01	3,09E-00	7,01E-00
Pu238	2,70E-01	1,54E-00	3,51E-00
Pu239	2,48E-01	1,45E-00	3,29E-00
Pu240	2,48E-01	1,45E-00	3,29E-00
Pu241	1,29E+01	7,98E+01	1,81E+02
Am241	3,09E-01	1,71E-00	3,90E-00
Cm244	5,21E-01	2,72E-00	6,19E-00
Na-22	1,45E-01	1,52E-00	3,95E-01
S-35	5,74E+02	1,05E+04	2,92E+03
Cl-36	1,32E+01	3,03E+02	3,61E+02
K-40	1,78E-00	1,79E+01	5,40E-00
Ca-45	5,82E+02	5,93E+02	1,40E+03
Sc-46	3,01E-01	7,25E-01	4,27E-01
Mn-53	2,95E+04	3,75E+05	1,79E+06
Co-56	4,22E-01	8,03E-01	8,23E-01
Co-57	1,54E+01	1,79E+02	3,01E+01
Co-58	1,39E-00	3,57E-00	3,28E-00
As-73	1,36E+03	1,43E+02	4,60E+02
Se-75	3,03E-00	3,86E-00	2,96E-00
Se-79	1,80E+01	8,33E+01	2,45E+02
Sr-85	1,48E-00	2,74E-00	1,76E-00
Y-91	9,28E+01	2,97E+01	9,19E+01
Zr-93	7,94E+03	5,32E+01	1,11E+01
Zr-95+	9,00E-01	9,40E-01	5,69E-01
Nb-93m	1,65E+04	1,79E+03	3,74E+02
Mo-93	1,70E+02	8,14E+03	2,30E+03
Tc-97	3,60E+02	3,48E+03	2,17E+03

Table 3 (cont.)			
Tc-97m	7,05E+03	9,93E+02	1,62E+03
Pd-107	1,20E+06	2,66E+04	2,22E+05
Cd-109	2,21E+01	3,22E+02	1,82E+02
Sn-113+	1,64E-00	1,97E+01	3,69E-00
Sn-126+	1,77E-01	1,96E-00	4,41E-01
Sb-124	7,72E-01	8,06E-01	4,60E-01
Te-123m	1,23E+01	1,13E+01	9,82E-00
Te-127m+	1,55E+02	5,17E+01	5,04E+02
I-125	2,95E-00	1,41E+02	1,43E+02
I-129	4,02E-01	1,92E+01	6,30E+01
Cs-135	2,21E+01	8,63E+02	3,25E+02
Ce-139	1,18E+01	1,13E+01	9,39E-00
Ce-144+	1,06E+01	1,82E+01	2,09E+01
Sm-147	3,08E-00	6,70E+01	1,72E+01
Eu-155	6,91E+01	6,48E+01	3,00E+01
Gd-153	5,00E+01	4,54E+01	1,90E+01
Tb-160	5,93E-01	1,35E-00	8,17E-01
Tm-170	6,58E+02	7,22E+01	7,11E+02
Tm-171	1,65E+04	7,41E+02	3,69E+03
Ta-182	4,87E-01	1,17E-00	6,90E-01
W-181	1,53E+02	7,01E+02	5,97E+01
W-185	1,01E+03	6,82E+02	6,29E+03
Os-185	5,08E-01	5,56E-00	4,95E-00
Ir-192	1,70E-00	6,38E-00	4,29E-00
Tl-204	3,40E+02	3,53E+02	5,08E+02
Pb-210+	6,49E-02	1,33E-00	2,77E-01
Bi-207	9,26E-01	9,55E-01	5,77E-01
Po-210	1,84E-00	2,10E+01	1,46E-00
Ra-226+	3,51E-01	8,52E-01	5,01E-01
Ra-228+	6,60E-01	1,58E-00	9,51E-01
Ac-227+	1,79E-02	2,40E-02	5,00E-03
Th-228+	4,00E-01	1,06E-00	5,97E-01
Th-229+	1,16E-01	5,76E-01	1,31E-00
Th-230	2,97E-01	1,65E-00	3,76E-00
Th-232	2,68E-01	1,58E-00	3,60E-00
Pa-231	2,12E-01	5,20E-01	1,18E-00
U-232	8,03E-01	1,78E-00	4,05E-00
U-233	3,09E-00	6,71E-00	1,52E+01
U-236	3,41E-00	7,35E-00	1,67E+01
Pu-236	7,43E-01	3,56E-00	8,09E-00
Pu-242	2,70E-01	1,49E-00	3,39E-00
Pu-244+	2,70E-01	1,54E-00	2,66E-00
Am-242m+	3,23E-01	1,93E-00	4,38E-00
Am-243+	3,09E-01	1,71E-00	3,90E-00
Cm-242	5,04E-00	1,25E+01	2,84E+01
Cm-243	4,31E-01	2,31E-00	5,26E-00
Cm-245	3,00E-01	1,71E-00	3,90E-00
Cm-246	3,03E-01	1,71E-00	3,90E-00
Cm-247+	3,30E-01	1,85E-00	2,93E-00
Cm-248	8,25E-02	4,87E-01	1,11E-00
Bk-249	1,86E+02	4,63E+02	1,05E+03
Cf-248	3,38E-00	7,59E-00	1,72E+01
Cf-249	4,24E-01	1,03E-00	2,34E-00
Cf-250	8,74E-01	2,10E-00	4,78E-00
Cf-251	4,18E-01	1,01E-00	2,29E-00
Cf-252	1,49E-00	3,56E-00	8,09E-00
Cf-254	7,25E-01	1,60E-00	4,78E-00
Es-254	3,45E-00	7,72E-00	1,75E+01

Table 4: Derived maximum individual dose and most restrictive scenario for ferrous metal recycling calculations

Nuclide	Maximum dose (μSv y^{-1} per Bq g^{-1})	Steel recycling scenarios
H3	7,30E-03	Steel plant (Atmos)
C14	1,31E-01	Steel plant IF (ING)
Mn54	6,12E-00	Boat AF (EXT)
Fe55	3,73E-04	Steel plant IF (ING)
Co60	1,74E+01	Boat AF (EXT)
Ni59	2,60E-05	Boat AF (EXT)
Ni63	3,39E-05	Steel plant IF (ING)
Zn65	1,88E+01	Dust L. AF W (EXT)
Sr90+	6,94E-01	Steel plant IF (ING)
Nb94	2,48E+01	Slag L. IF W (EXT)
Tc99	2,57E-01	Slag L. IF Child
Ru106+	6,94E-00	Dust L. AF W (EXT)
Ag108m+	1,22E+01	Boat AF (EXT)
Ag110m+	1,98E+01	Boat AF (EXT)
Sb125+	3,11E-00	Boat AF (EXT)
Cs134	4,83E+01	Dust L. AF W (EXT)
Cs137+	1,74E+01	Dust L. AF W (EXT)
Pm147	1,68E-03	Player IF (INH)
Sm151	1,35E-03	Player IF (INH)
Eu152	2,17E+01	Slag L. IF W (EXT)
Eu154	1,92E+01	Slag L. IF W (EXT)
U234	3,16E-00	Player IF (INH)
U235+	2,86E-00	Player IF (INH)
U238+	2,70E-00	Player IF (INH)
Np237+	1,68E+01	Player IF (INH)
Pu238	3,70E+01	Player IF (INH)
Pu239	4,04E+01	Player IF (INH)
Pu240	4,04E+01	Player IF (INH)
Pu241	7,74E-01	Player IF (INH)
Am241	3,23E+01	Player IF (INH)
Cm244	1,92E+01	Player IF (INH)

Table 5: Derived maximum individual dose and most restrictive scenario for copper recycling calculations

Nuclide	Maximum dose ($\mu Sv\ y^{-1}$ per $Bq\ g^{-1}$)	Copper recycling scenarios
H3	1,17E-04	Refining (INH)
C14	3,76E-03	Refining (INH)
Mn54	2,49E-00	Transport scrap (EXT)
Fe55	2,98E-04	Refining (INH)
Co60	8,66E-00	Transport scrap (EXT)
Ni59	2,52E-00	Musical instrument (SKIN)
Ni63	6,74E-04	Refining (INH)
Zn65	1,92E-00	Transport scrap (EXT)
Sr90+	1,12E-00	Musical instrument (EXT effective)
Nb94	1,11E+01	Musical instrument (EXT effective)
Tc99	2,66E-02	Landfill Child
Ru106+	1,43E-00	Transport scrap (EXT)
Ag108m+	1,17E+01	Musical instrument (EXT effective)
Ag110m+	1,89E+01	Musical instrument (EXT effective)
Sb125+	2,59E-00	Musical instrument (EXT effective)
Cs134	4,31E-00	Transport scrap (EXT)
Cs137+	1,50E-00	Transport scrap (EXT)
Pm147	6,64E-01	Musical instrument (SKIN)
Sm151	6,19E-05	Football player (INH)
Eu152	3,76E-00	Musical instrument (EXT effective)
Eu154	4,16E-00	Musical instrument (EXT effective)
U234	1,47E-00	Manufacture of ingots (INH)
U235+	1,32E-00	Manufacture of ingots (INH)
U238+	1,23E-00	Manufacture of ingots (INH)
Np237+	3,24E-00	Manufacture of ingots (INH)
Pu238	6,48E-00	Manufacture of ingots (INH)
Pu239	6,91E-00	Manufacture of ingots (INH)
Pu240	6,91E-00	Manufacture of ingots (INH)
Pu241	1,25E-01	Manufacture of ingots (INH)
Am241	5,83E-00	Manufacture of ingots (INH)
Cm244	3,67E-00	Manufacture of ingots (INH)

Table 6: Derived maximum individual dose and most restrictive scenario for aluminium recycling calculations

Nuclide	Maximum dose ($\mu Sv\ y^{-1}$ per $Bq\ g^{-1}$)	Aluminium recycling scenarios
H3	5,60E-04	Refining (INH)
C14	1,80E-02	Refining (INH)
Mn54	2,61E-00	Transport scrap (EXT)
Fe55	1,43E-04	Refining (INH)
Co60	8,53E-00	Transport scrap (EXT)
Ni59	1,14E-04	Refining (INH)
Ni63	8,09E-05	Refining (INH)
Zn65	1,93E-00	Transport scrap (EXT)
Sr90+	2,47E-01	Fishing boat (EXT)
Nb94	1,77E+01	Slag processing (EXT)
Tc99	1,90E-02	Landfill Child
Ru106+	1,09E-00	Refining (INH)
Ag108m+	4,64E-00	Transport scrap (EXT)
Ag110m+	8,67E-00	Transport scrap (EXT)
Sb125+	2,96E-00	Slag processing (EXT)
Cs134	1,72E+01	Slag processing (EXT)
Cs137+	6,19E-00	Slag processing (EXT)
Pm147	3,33E-04	Slag processing (INH)
Sm151	2,47E-04	Slag processing (INH)
Eu152	1,26E+01	Slag processing (EXT)
Eu154	1,38E+01	Slag processing (EXT)
U234	6,46E-00	Slag processing (INH) (AG3)
U235+	1,24E+01	Slag processing (EXT) (AG3)
U238+	5,42E-00	Slag processing (INH) (AG3)
Np237+	1,43E-00	Slag processing (INH)
Pu238	2,85E-00	Slag processing (INH)
Pu239	3,04E-00	Slag processing (INH)
Pu240	3,04E-00	Slag processing (INH)
Pu241	5,51E-02	Slag processing (INH)
Am241	2,57E-00	Slag processing (INH)
Cm244	1,62E-00	Slag processing (INH)

Table 7: Collective dose per unit activity concentration from metal scrap recycling calculations

Nuclide	Collective dose (manSv)		
	Steel scrap	Copper scrap	Aluminium scrap
H3	6,25E-09	8,38E-09	2,82E-08
C14	2,01E-07	2,70E-07	9,10E-07
Mn54	1,58E-02	1,05E-05	2,74E-04
Fe55	1,81E-07	1,70E-08	2,20E-08
Co60	3,14E-01	4,29E-04	2,56E-03
Ni59	1,18E-06	2,09E-06	4,36E-07
Ni63	3,66E-08	2,84E-06	4,12E-07
Zn65	9,16E-04	7,90E-06	1,56E-04
Sr90+	8,74E-03	4,64E-03	2,55E-03
Nb94	2,47E-01	8,81E-02	6,62E-02
Tc99	4,89E-03	1,04E-02	7,43E-03
Ru106+	1,12E-03	3,86E-05	6,26E-05
Ag108m+	2,19E-00	6,66E-02	9,81E-03
Ag110m+	4,18E-02	8,77E-04	7,16E-04
Sb125+	2,16E-02	5,06E-04	2,63E-04
Cs134	7,66E-05	1,56E-04	5,94E-04
Cs137+	6,02E-04	4,54E-03	4,98E-03
Pm147	7,39E-09	1,56E-09	2,19E-08
Sm151	2,09E-07	3,80E-07	2,79E-07
Eu152	3,21E-03	4,76E-03	4,50E-03
Eu154	1,45E-03	2,53E-03	2,58E-03
U234	1,32E-04	5,37E-04	4,69E-04
U235+	1,06E-02	6,44E-03	4,50E-03
U238+	1,46E-02	4,08E-03	1,39E-03
Np237+	1,99E-02	1,14E-02	5,86E-03
Pu238	3,43E-04	1,70E-03	4,72E-04
Pu239	5,39E-04	2,36E-03	8,29E-04
Pu240	5,34E-04	2,35E-03	8,24E-04
Pu241	2,62E-06	1,93E-05	2,89E-06
Am241	5,30E-04	2,10E-03	7,52E-04
Cm244	8,17E-05	6,02E-04	9,39E-05

APPENDIX A

Exposure Scenarios and Parameters Used to Calculate Individual Doses Arising from the Recycling of Steel

Contents

Appendix A

1 Introduction

This appendix describes the methodology and models used to calculate the individual doses arising from the recycling of steel contaminated with radionuclides. These doses were then used in the derivation of the associated clearance levels[1]. Section 2 describes the methodology and also contains a general discussion on parameters. Section 3 describes the scenarios, formulae and parameters used to calculated doses and section 4 gives tables of doses from the scenarios. The radionuclide dependent factors are all given in Appendix D.

2 Methodology and general discussion

2.1 Methodology

The methodology adopted comprises the following stages:

- selection of source terms and physical, chemical and radioactive characterization of the source;
- description of the processes to be undergone by the materials (all treatments applied to the materials themselves and to the treatment residues);
- description of scenarios which, during processing or the use of recycled products, could involve exposure of persons;
- selection of characteristic parameters for these scenarios;
- calculation of annual individual doses;
- comparison of results with acceptable dose levels;
- proposal of derived clearance levels.

The first five stages are described in this Appendix; the remaining two stages are addressed in ref. 1 (see also Table 3 in the main text of this report).

2.2 Recycling capacity of steel plants

The quantity of very low level activity steel arising from the dismantling of nuclear power plants in the EU is estimated to be a total of 10 000 tonnes per year.

In this study it is considered that a maximum of 4000 tonnes per year of dismantled carbon steel is treated in an arc furnace with an average annual capacity of 400 000 tonnes. Also a maximum of 2000 tonnes per year of dismantled special or stainless steel is treated in an induction furnace plant with an average annual capacity of 200 000 tonnes.

Table 2.1 gives the amount of dismantled steel considered in the scenarios together with the amount of dust and slag generated. Also given is the average capacity of the steel plants and the specific concentration factors for dust and slag (see 2.3.2).

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TABLE 2.1 Quantities of steel and waste products assumed in steel smelting operations

Type of steel	Type of furnace	Amount of dismantled steel $t\ y^{-1}$	Capacity of steel plant $t\ y^{-1}$	Dust production rate $kg\ t^{-1}$	Amount of dust produced from dismantled steel $t\ y^{-1}$	Specific concentration for dust	Slag production rate $kg\ t^{-1}$	Amount of slag produced from dismantled steel $t\ y^{-1}$	Specific concentration factor for slag
Carbon steel	Arc	4000	400,000	15	60	67	150	600	6.7
Alloyed or stainless steel	Induction	2000	200,000	1.5	3	670	20	40	50

2.3 Choice of parameters and influence on results

As far as possible, the different parameters are referenced.

2.3.1 Radionuclide distribution factor

For each radionuclide investigated, it is necessary to know the fraction of the activity originally present in the waste low activity steel which may be transferred to the ingots, the slag and the dust after refining.

Experiments conducted in industrial environments or in laboratories on element distribution during refining did not yield results covering all the radioactive isotopes which could be present in the recovered metals[2]. This was generally due to their extremely low content in the metals. Where measurements were not possible, values are assessed on the basis of the physico-chemical characteristics of the elements. Maximum values are taken, with the result that the sum of the three fractions representing transfer to ingots, slags and dusts or fumes often exceeds 1. This choice generally yields conservative results. The values for steel are given in Table 3.1 in Appendix D.

2.3.2 Specific concentration factor

This factor is the ratio of the mass of material processed to the mass of post-refining by-products (dust or slag). The values are given in Table 2.1. Note that in Table 2.1 the amount of dust and slag produced refers only to the amount of dismantled steel and not the total.

2.3.3 Atmospheric concentrations

The values selected in this study are based on experimental results when possible[3] and are estimated in other cases.

2.3.4 Radiological data

Radiological data are given in Appendix D.

Inhalation and ingestion dose coefficients refer to effective doses for workers and public[4].

The maximum value was taken from reference 4 for each nuclide where there was more than one value.

2.3.5 Fraction of very low level waste (VLLW)

The composition of the steel being treated or used by an individual, in terms of the fraction of very low level waste steel (VLLW) in the material, is a very important parameter. The fraction is easily calculated for scenarios located in metal refineries by using the ratio of the mass of dismantled steel and the capacity of the steel plant given in Table 2.1. However, for all the post-refining scenarios, these parameters are far more difficult to assess and can vary considerably with the size of the processing plants in relation to the size of the initial metal refinery and with the metallurgical quality of the finished manufactured product. Conservative values have been adopted for these parameters, taking account of the actual industrial conditions involved.

2.3.6 Radioactive decay

In general no radioactive decay is taken into account during the scenario other than in the public residence scenario (3.6.1.4) where the waste is assumed to decay for the period before residence occurs (30 years for dust waste and 10 years for slag waste). Radioactive decay over the crop growing period is also taken into account in scenario 3.3.

Different pathways and exposed persons were considered with in each category giving a total of 24 sets of calculations. These are described below.

2.3.7 Human habit data

Exposure by external irradiation of workers in the installations considered is easy to represent accurately in exposure scenarios, since only routine, repetitive tasks are involved. However, external exposure by utilisation of manufactured products is far more difficult to define and is represented by a few generic scenarios. The size of the sources and the exposure periods chosen for these generic scenarios are such that a broad range of widely differing cases can be covered.

When parameter values had to be estimated they were based on the assumption that a scenario must represent realistic situations applied to a representative group of individuals. The values were chosen to be in a reasonable range for generic considerations.

3 Description of scenarios and formulae used in the calculation of doses to the critical group

The scenarios were chosen to enable calculation of the dose received by an individual in the critical group from waste steel having a activity concentration of one unit (1 Bq g^{-1}) upon leaving the nuclear installation, taking into account the processing subsequently undergone in the metal recovery industry.

Six categories of scenarios were considered, as follows:

- exposure in a scrap yard
- exposure in a foundry
- atmospheric emission
- exposure during post refining process
- exposure related to use of products
- exposure related to the disposal or use of by-products.

In the following text, the word ”dose” will be used in place of effective dose for external exposures and committed effective dose for ingestion and inhalation scenarios.

3.1 Exposure in a scrap yard (worker exposure)

The main exposures in a scrap yard are irradiation from transporting scrap and inhalation from cutting scrap into smaller sizes.

3.1.1 External exposure during scrap transport

This scenario assumes exposure of a driver for a part of the year who transports scrap metal from the nuclear facility to the scrap yard and then to the foundry. The source is represented by a cylindrical or thick disk source of 0.8 m in thickness and 0.2 m in diameter. Exposure of the worker is assumed to occur at 1.2 m distance with shielding by 0.5 cm of steel. It should be noted that there is no dilution of the steel from the nuclear facility.

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The dose is expressed by the equation below and the parameter values for this scenario are given in Table 3.1. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.1.

The annual external dose from a thick disc source is given by the following equation:

$$H = Am \cdot \rho m \cdot (DF_{ST} + Brem_{ST}) \cdot F \cdot t \quad (Sv\ y^{-1}) \qquad (1)$$

where:
- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
- ρm: density of the source material (g cm^{-3}), (= 7.8 g cm^{-3} for steel),
- DF_{ST}: dose factor per unit volume activity concentration for external exposure to gamma radiation from scrap during transport, represented by a thick disk or cylindrical volume (Sv h^{-1} per Bq cm^{-3}).
- $Brem_{ST}$: bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}) (See table 3.2 Appendix D),
- F: fraction of very low level (VLL) waste in the metal; ratio of the quantity of VLL metal waste to the total annual quantity of metal waste processed by the plant,
- t: annual time of exposure (h y^{-1}).

The term DF_* depends on the geometry and nuclide:

$$DF_* = K_c \cdot \sum_i E \cdot y \cdot (\mu/\rho)a \cdot \phi \cdot K \qquad (2)$$

where
- K_c : units conversion factor (5.76 10^{-7} Gy · g per MeV · Bq · h),
- E: energy of emission i (MeV),
- y: yield,
- (μ/ρ)a: mass absorption coefficient in air at the considered energy[5] (cm^2 g^{-1}),
- ϕ: flux from unit activity (cm), calculated for a given geometry by integration of the point source formula, equation (3),
- K: effective dose per absorbed dose at considered energy (Sv Gy^{-1}).

The point source formula including attenuation and buildup is:

$$\Phi_p = B \cdot \frac{S_o}{4\pi l^2} \cdot \exp(-\mu \cdot l) \qquad (3)$$

where
- S_o: source strength (Bq),
- l: distance between the source and the considered point (cm),
- B: build up factor,
- μ: attenuation coefficient (cm^{-1}),
- ϕ_p : flux (s^{-1} cm^{-2}).

It should be noted that the required photon flux is the flux from unit volume activity concentration since equation (1) contains the product Am · ρm · ϕ. Therefore the term S_o will not be included in the integrations of the point source formulae which follow.

The dose is expressed by the equation below and the parameter values for this scenario are given in Table 3.1. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.1.

Hence, for a thick disk or cylinder:

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$$\phi_{(cm)} = \frac{1}{2} \int_{O}^{L} dx \int_{O}^{R} B \cdot \frac{\exp(-(\mu \cdot x + \mu_s \cdot \delta) \cdot \sec \alpha)}{r^2 + (x+d)^2} \cdot r \cdot dr \qquad (4)$$

where:

μ and μ_s are attenuation coefficients for source and shield materials (cm^{-1}),
(see Figure 1 for remaining parameters).

Bremsstrahlung:

This was considered for nuclides where beta emissions were substantial. The energy distribution of bremsstrahlung has been obtained using the following formula (5):

$$\varepsilon(E) = 2kZ \int_{E}^{E_{MAX}} \chi(E') (E' - E) \, dE' \qquad (5)$$

where:

- E_{MAX}: maximum energy of the beta spectrum,
- $\chi(E')$: normalised beta spectrum which gives the number of beta particles per MeV per decay;
- Z: atomic number of the absorber;
- k: constant (assumed equal to $0.7 \cdot 10^{-3}$ MeV^{-1}).

TABLE 3.1 Data for external exposure from transport of scrap metal

Parameter	Value	Remarks
Source	Thick disk or cylinder	
Diameter (cm)	200	
Thickness (cm)	800	
Distance (cm)	120	
Time of exposure ($h\ y^{-1}$)	100	
Fraction of VLLW	1	Arc/induction furnace
Shield thickness (cm)	0.5	

3.1.2 Exposure by dust inhalation during cutting of scrap

The metal waste may need to be cut before melting. Taking account of the steel characteristics, the different metal pieces will be cut with different cutting techniques. In a scrap yard, the main techniques can be the press-shear, the oxyacetylene torch and the plasma torch.

In the framework of the EC cost-sharing research programme on ”Decommissioning of nuclear power plants” three cutting techniques are being studied.

Appendix A

Results have been obtained for uranium emission while cutting artificially contaminated steel with oxyacetylene torch. The following scenario is based on these results; all the alpha emitters are assumed to behave like uranium but as it is not possible to extrapolate to other radionuclides they have not been considered.

A worker stays eight hours a day in a closed working room, ventilated with an air renewal rate of 5 per hour. The cutting speed, obtained from the experiments, is 6 m per hour and the cut width is 1 cm.

The quantity of activity on the cut for a deposited surface activity of 1 Bq/cm^2 on both sides is 200 Bq/m. The released activity measured is 2 $Bq\ m^{-1}/Bq\ cm^{-2}$; the released fraction is then 10^{-2}. The total activity of the material cut for the duration of exposure is assumed to be $5.94\ 10^5$ Bq.

The source to operator distance for thermal cutting is estimated to be of the order of 1.5 m.

Parameter values for dust inhalation during cutting scrap are given in Table 3.2.

This scenario represents dispersal of particles in a contained volume from a source with a total activity A_t (low dimensions of the source compared to the size of the working room).

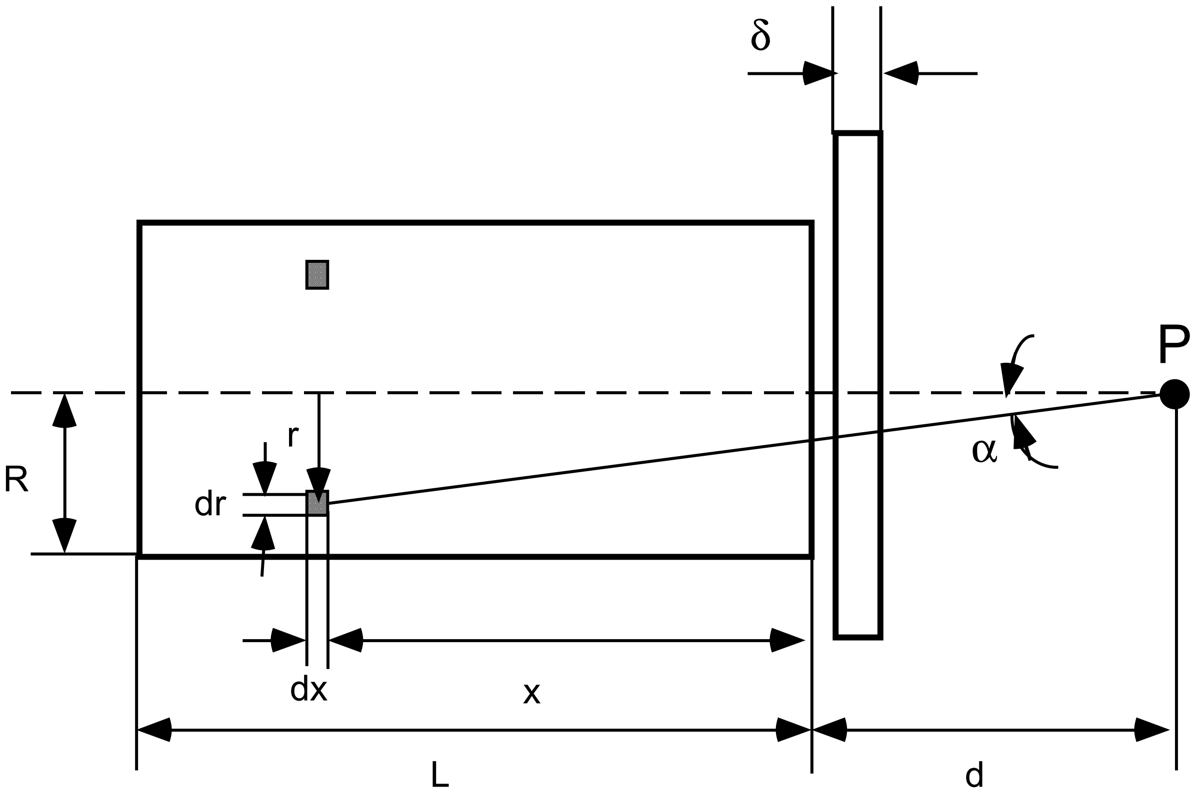

FIGURE 1 Diagram showing parameters for calculating flux ϕ from gamma sources

Appendix A

A fraction f_p of the source activity is released as inhalable particles in air. The aerosol velocity is v_a ($m\ s^{-1}$).

The contamination is assumed to be uniformly distributed in a hemispherical volume, the radius of which is increasing until the hemispherical volume is equal to the volume of the working room.

At t_1, the concentration inside the contaminated volume is, for a unit activity emitted:

$$c_{a1} = \frac{3}{2\pi\ (v_{á} \cdot t_1)^3} \qquad (6)$$

where:

$$v_{á} = 3600 \cdot v_a \qquad (m\ h^{-1}) \qquad (7)$$

The particles reach the operator, at a distance x from the source, at $t_1 = x/v_{á}$.

The dispersion of the particles is completed when the room volume is reached. Assuming the contaminated volume to be a hemisphere, this occurs at time t_2:

where:

$$t_2 = [(3\ V/2\pi)^{1/3}]/v_{á} \qquad (8)$$

and: V is the volume of room (m^3).

Between t_1 and t_2 the operator inhales an integrated concentration of particles in air C_1:

$$C_1 = \int_{t_1}^{t_2} c_{a1}(t)\ dt \qquad (9)$$

$$C_1 = [3/(4\pi \cdot v_{á}^{\ 3})] \cdot (t_1^{-2} - t_2^{-2}) \qquad (10)$$

When the room is uniformly contaminated the concentration decreases following the air renewal factor (deposition and radioactive decay are neglected).

The operator stays in the room until t_e, the concentration during this period is:

$$c_{a2}(t) = c_{a1}(t_2) \cdot \exp(-\delta_h \cdot (t - t_2)) \qquad (11)$$

where: δ_h is the air renewal factor (h^{-1}).

The integrated concentration is:

$$C_2 = \int_{t_2}^{t_e} c_{a2}(t)\ dt \qquad (12)$$

$$C_2 = [1/(V \cdot \delta_h)] \cdot [1 - \exp(-\delta_h \cdot (t_e - t_2))] \qquad (13)$$

The dose per year is given by:

$$H = (C_1 + C_2) \cdot A_t \cdot f_p \cdot F \cdot v_r \cdot n_e \cdot DF_{inh} \quad (Sv\ y^{-1}) \qquad (14)$$

where:

A_t: total activity of the material (Bq),

f_p: fraction of activity released in atmosphere,

F: fraction of VLL metallic waste in the cut material,

v_r: breathing rate (m^3 h^{-1}),

n_e: number of exposures per year (y^{-1}),

DF_{inh}: worker dose coefficient for inhalation (Sv Bq^{-1}) (Table 3.3 in Appendix D).

The dose resulting from exposure to $5.94{\cdot}10^5$ Bq of each radionuclide is presented in Table 4.1.

TABLE 3.2 Data for exposure by dust inhalation during cutting metal scrap

Parameter	Value	Remarks
Volume of the room (V) (m^3)	300	
Air renewal (δ_h) (h^{-1})	5	
Breathing rate (v_r) (m^3 h^{-1})	1.2	
Aerosol velocity (v_a) (m s^{-1})	0.5	
Source to operator distance (X) (m)	1.5	
Total activity of the material (Bq)	5.94 10^5	Experimental value
Released fraction of activity (f_p)	0.01	Experimental value
Fraction of VLLW	0.1	
Number of exposures per year (n_e)	1	
Exposure time (t_e) (h d^{-1})	8	

3.2 Exposure in a foundry (worker exposure)

The main exposures in the melting plant are due to the metal waste and the various treatments it undergoes (irradiation from a nearby scrap metal heap in a storage area, inhalation and ingestion of dust generated by metal refining processes, irradiation from proximity to ingot and finished products in a warehouse).

3.2.1 External exposure to a scrap metal heap in a foundry storage area

When the scrap metal is taken to a metal recovery plant, it is first stored, frequently in the open air, before undergoing treatment in the plant. For a generic scenario, the scrap heap can be considered as a right circular cone for g exposure with a worker position at 3 m from the source.

The dose is expressed by the equation below and the parameter values for these scenarios are given in Table 3.3. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.2.

The annual external dose from a truncated conical thick source is given by the following equation:

$$H = Am \cdot \rho m \cdot (DF_{SC} + Brem_{SC}) \cdot F \cdot t \quad (Sv\ y^{-1}) \qquad (15)$$

where:

Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),

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ρm: density of the source material (g cm^{-3}),
(= 7.8 g cm^{-3} for steel),

DF_{SC}: dose factor per unit volume activity concentration for external exposure to gamma radiation from scrap heap, represented by a right circular cone base diameter 3 m at 3 m, along axial direction (Sv h^{-1} per Bq cm^{-3}),

$Brem_{SC}$: bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}),
(Table 3.2 in Appendix D),

F: fraction of VLL metal waste; ratio of the quantity of VLL metal waste to the total annual quantity of metal waste processed by the plant,

t: annual time of exposure (h y^{-1}).

The term DF_{SC} is calculated from equation (2).

where: ϕ is the flux per unit volume activity concentration for a right circular cone, obtained by integrating the point source formula, equation (3).

$$\phi = \frac{1}{2} \int_o^L dx \int_o^{\alpha_{max}} B \cdot \exp(-(\mu \cdot x + \mu_s \cdot \delta) \cdot \sec\alpha) \cdot \tan\alpha \; d\alpha \quad (16)$$

where:

B: build up factor,

μ and μ_s attenuation coefficients for source and shield materials (cm^{-1})

cone angle α current variable (see Figure 2),

αmax angle between axis and generatrix of cone (= 0.464 radians)
(see Figure 2),

see Figure 2 for remaining parameters.

For bremsstrahlung radiation see formula (5) in section 3.1.1.

TABLE 3.3 Data for external exposure to a scrap metal heap in a foundry storage area

Parameter	Value	Remarks
Source	Right circular cone	Apparent diameter = 3 m distance = 3 m
Time of exposure (h y^{-1})	1800	
Fraction of VLLW	0.01	Arc/induction furnace

Appendix A

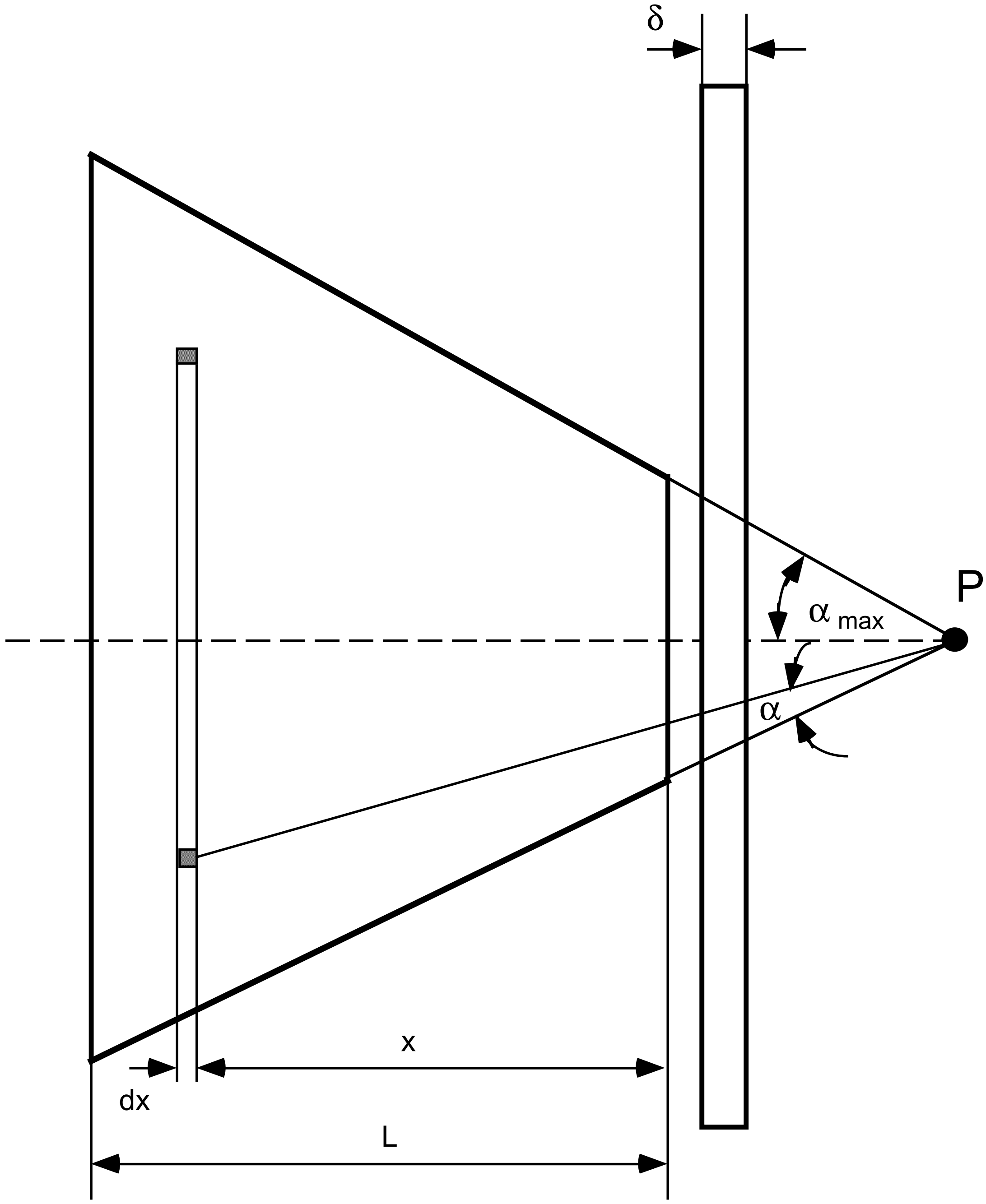

FIGURE 2 Diagram showing geometry for right circular cone

3.2.2 Internal exposure in a steelworks

3.2.2.1 Exposure by dust inhalation during melting and refining

During melting, the furnace gives off fumes or dust particles most of which are collected above the furnace and filtered. Remaining dust is dispersed in the melting bay atmosphere. Experiments conducted in different melting plants have enabled these parameters to be measured[1,3]. Two different cases are considered: carbon steel fabrication plants and alloyed steel fabrication plants. Parameters which may change between those two types of plants are mainly the size of the plant, the type of furnace and consequently the concentration of dust emission. Workers are exposed to dust generated when the furnace is charged, during the melting or refining processes and during the metal casting.

The generic inhalation exposure scenario is represented by a worker located in the melting bay who is permanently exposed to the mean dust concentration measured in the bay.

The dose is expressed by equation (17) below and the parameter values for exposure by dust inhalation during melting or refining in an arc furnace plant and in an induction furnace plant are given in Table 3.4.

The annual dose for exposure by inhalation in homogenous atmosphere is given by the following equation:

$$H = Cd \cdot DF_{inh} \cdot C_a \cdot V \cdot t \qquad (Sv\ y^{-1}) \qquad (17)$$

where:

- Cd: radionuclide concentration in the dust (Bq g^{-1}),
- DF_{inh}: worker dose coefficient for inhalation (Sv Bq^{-1}) (Table 3.3 in Appendix D),
- C_a: inhalable dust concentration in the air (g m^{-3}),
- V: breathing rate[6] (m^3 h^{-1}),
- t: annual time of exposure (h y^{-1}).

The radionuclide concentration in the dust is expressed by:

$$Cd = A_m \cdot r \cdot c_m \cdot F \qquad (Bq\ g^{-1}) \qquad (18)$$

where:

- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
- r: radionuclide distribution factor for dust during melting (Table 3.1 in Appendix D),
- cm: specific concentration factor in the dust = ratio of the mass of products processed to the mass of post-melting by-products obtained (dust),
- F: fraction of VLL metal waste, ratio of the quantity of VLL metal waste to the total annual quantity of metal waste processed by the plant. In the case of inhalation during melting or refining the factor also corresponds to the fraction of time during which a worker is exposed.

The doses corresponding to the melting of waste containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.2.

TABLE 3.4 Data for exposure by dust inhalation during melting and refining

Parameter	Value	Remarks
Breathing rate ($m^3\ h^{-1}$)		
- interm. activity	1.2	Ref. 6
Inhalable dust concentration in air ($g\ m^{-3}$)	$1.5 \cdot 10^{-3}$ $6.0 \cdot 10^{-4}$ *	Arc furnace Induction furnace
Time of exposure ($h\ y^{-1}$)	1800	
Fraction of VLLW	0.01	Arc/induction furnace
Specific concentration factor in fumes/dust	67 670	Arc furnace Induction furnace

Note
* estimated by comparison with arc furnace airborne dust concentration

3.2.2.2 Exposure by dust ingestion during melting and refining

Workers collect dust particles on the hands and on the face. Sometimes they may clean their face with their hands or, while smoking touch their lips with their hands. By doing this a fraction of dust is deposited on the lips and may be ingested. In the generic scenario the worker is assumed to ingest 0.15 g of dust per day.

The dose is expressed by equation (19) below and the parameter values for exposure by dust ingestion during melting and refining in an arc furnace plant and in an induction furnace plant are given in Table 3.5.

The annual dose from ingestion of dust is given by:

$$H = As \cdot DF_{ing} \cdot n \cdot s \qquad (Sv\ y^{-1}) \tag{19}$$

where :

As: surface radioactivity of the deposit ($Bq\ cm^{-2}$),

DF_{ing}: worker dose coefficient for ingestion ($Sv\ Bq^{-1}$), (Table 3.3 in Appendix D),

n: number of times the dust is removed from the surface per year,

s: surface area from which the dust is removed (cm^2).

The concentration of radionuclides in the surface deposit is expressed by:

$$As = Am \cdot r \cdot c_m \cdot e \cdot \rho \cdot F \qquad (Bq\ cm^{-2}) \tag{20}$$

where :

Am: activity concentration of the VLL metal waste when it leaves the nuclear installation ($Bq\ g^{-1}$),

r: radionuclide distribution factor in the dust during melting, (Table 3.1 in Appendix D),

c_m: specific concentration factor in the dust = ratio of the mass of products processed to the mass of post-melting by-products obtained,

e: thickness of the deposit (cm),

ρ: apparent density of the deposit (g cm^{-3}),

F: fraction of VLL metal waste, the ratio of the quantity of VLL metal waste to the total annual quantity of metal waste processed by the plant. In the case of ingestion during melting or refining the factor also corresponds to the fraction of time during which a worker is exposed.

The doses corresponding to the recycling of waste containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.2.

TABLE 3.5 Data for exposure by dust ingestion during melting and refining

Parameter	Value	Remarks
Surface of the deposit (cm^2)	2	
Thickness of the deposit (cm)	$3\ 10^{-3}$	
Number of times per day the dust deposit is ingested	5	
Number of days per year	225	
Apparent density of the deposit (g cm^{-3})	5	
Daily absorbed dust (g)	0.15	Calculated from above parameters
Fraction of VLLW	0.01	Arc/induction furnaces
Mass concentration factor in fumes	67 670	Arc furnace Induction furnace

3.3 Atmospheric emission in the steel plant environment

The radiological impact of atmospheric emission of dust and gas in the environment of the steel plant is considered in this scenario[7]. It includes the relevant pathways such as: inhalation of dust and gas, external exposure to dust deposit on the ground and ingestion of food produced near to the plant. The fraction of dust released (by the stack or by the roof) is estimated at 0.01 of the total dust generated. An individual is assumed to live at about 100 m from the plant and to spend 1100 hours per year outside in the garden. Doses are considered for the arc furnace only since this gives the largest quantities of waste by-products.

The total dose is the sum over all pathways: (inhalation, external and ingestion) and the appropriate formulae are given below. For releases of carbon and tritium doses are calculated using more explicit models as shown below.

The parameter values for exposure to atmospheric emissions from the steel plant are given in Table 3.6. The total doses for each radionuclide, corresponding to the recycling of waste containing 1 Bq g^{-1} are presented in Table 4.2.

3.3.1 Inhalation

The annual dose from inhalation of the plume is given by the following equation:

$$H_{inh} = Am \cdot (m \cdot 10^3) \cdot F \cdot r \cdot c_m \cdot æ \cdot f_t \cdot (V/3600) \cdot DF_{inh} \cdot d \quad (Sv\ y^{-1}) \qquad (21)$$

where:

Am: activity concentration of the VLL metal waste when it leaves the nuclear installation ($Bq\ g^{-1}$),
m: total mass of dust emitted (kg), for total capacity of arc furnace see Table 2.1,
F: fraction of VLL metal waste,
r: radionuclide distribution factor in the dust during melting, (Table 3.1 in Appendix D),
c_m: specific concentration factor in the dust = ratio of the mass of products processed to the mass of post-melting by-products obtained,
æ: average atmospheric transfer coefficient ($Bq\ m^{-3}$ per $Bq\ s^{-1}$), (takes the wind rose into account)[7],
f_t: occupancy factor, proportion of time in the emission,
V: breathing rate[6] ($m^3\ h^{-1}$),
DF_{inh}: public dose coefficient for inhalation ($Sv\ Bq^{-1}$), (Table 3.3 in Appendix D),
d: emitted dust fraction after filtration.

3.3.2 External exposure

The annual dose from external irradiation from deposited dust is given by the following equation:

$$H_{ext} = Am \cdot (m \cdot 10^3) \cdot F \cdot r \cdot c_m \cdot æ \cdot f_t \cdot v_d \cdot t_e \cdot DF_{\beta\gamma s} \cdot d \quad (Sv\ y^{-1}) \qquad (22)$$

where :

Am: activity concentration of the VLL metal waste when it leaves the nuclear installation ($Bq\ g^{-1}$),
m: total mass of dust emitted (kg),
F: fraction of VLL metal waste,
r: radionuclide distribution factor in the dust during melting (Table 3.1 in Appendix D),
c_m: specific concentration factor in the dust = ratio of the mass of products processed to the mass of post-melting by-products obtained,
æ: average atmospheric transfer coefficient, level-headed ($Bq\ m^{-3}$ per $Bq\ s^{-1}$), (takes the wind rose into account),
f_t: occupancy factor, proportion of time in the emission,
v_d: deposition velocity ($m\ s^{-1}$),
t_e: spent time on the deposit ($h\ y^{-1}$),
$DF_{\beta\gamma s}$: dose factor per unit activity due to external exposure to an infinite surface source[8] ($Sv\ h^{-1}$ per $Bq\ m^{-2}$), (Table 3.2 in Appendix D),
d: emitted dust ratio after filtration.

3.3.3 Ingestion

The annual dose from ingestion of vegetables grown near the plant is given by the following equation:

$$H_{ing} = Am \cdot (m \cdot 10^3) \cdot F \cdot r \cdot c_m \cdot æ \cdot (v_d \cdot f_c/Y) \cdot (q_i \cdot tv/365) \cdot DF_{ing} \cdot T_e \cdot d \quad (Sv\ y^{-1}) \tag{23}$$

where:

- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation ($Bq\ g^{-1}$),
- m: total mass of dust emitted per year (kg), for total capacity of arc furnace (see Table 2.1).
- F: fraction of VLL metal waste,
- r: radionuclide distribution factor in the dust during melting (Table 3.1 in Appendix D),
- c_m: specific concentration factor in the dust = ratio of the mass of products processed to the mass of post-melting by-products obtained (dust),
- æ: average atmospheric transfer coefficient, level-headed ($Bq\ m^{-3}$ per $Bq\ s^{-1}$), (takes into account the wind rose),
- v_d: deposition velocity ($m\ s^{-1}$),
- f_c: absorption ratio,
- Y: agricultural productivity (yield) ($kg\ m^{-2}$),
- q_i: annual quantity ingested ($kg\ y^{-1}$),
- DF_{ing}: public dose coefficient for ingestion ($Sv\ Bq^{-1}$) (Table 3.3 in Appendix D),
- T_e: decay during growing of the crops,
- d: emitted dust ratio after filtration.

where:

$$T_e = (1 - e^{-\delta v \cdot tv})/(\delta v \cdot tv) \tag{24}$$

$$\delta v = \text{biological decay constant} = \frac{0.693}{\text{Biological half-life}} \quad (d^{-1}) \tag{25}$$

tv: crops growing period (d).

The total annual dose is then:

$$H = H_{inh} + H_{ext} + H_{ing} \quad (Sv\ y^{-1}) \tag{26}$$

3.3.4 Gas atmospheric emission

Carbon and hydrogen are major elements of living organisms and hence are transferred naturally between atmosphere and living organisms. Carbon-14 and tritium will follow the same dispersion and concentration behaviour as non radioactive carbon and hydrogen.

3.3.4.1 Carbon emission

The carbon-14 content in foodstuff is linked to the quantity of carbon-14 which will be transferred from atmosphere. The natural average content of carbon in the atmosphere is 0.15 $g\ m^{-3}$ (Reference 9). The activity concentration of carbon-14 in the atmosphere (A_d) is given by the following equation:

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$$A_a = q_{a14} \cdot æ /(q_{m12} \cdot æ + c_n) \quad (\text{Bq g}^{-1} \text{ of carbon}) \qquad (27)$$

where:

q_{a14}: emission rate of carbon-14 at the stack (Bq s^{-1}),
$q_{a14} = A_m \cdot Q_f \cdot 10^6 \cdot t_{lC} \cdot F / 3.15 \cdot 10^7$,
A_m: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
Q_f: annual capacity of the steel plant (t y^{-1}), for arc furnace,
t_{lC}: release rate of linked carbon during melting,
F: fraction of VLL metal waste, ratio of the quantity of VLL metal waste to the total annual quantity of metal waste processed in the plant,
æ: average atmospheric transfer coefficient (Bq m^{-3} per Bq s^{-1}),
(takes into account the wind rose),
q_{m12}: emission rate of carbon -12 at the stack (g s^{-1}),
$q_{m12} = (F_m \cdot t_{lC} + F_{adC} \cdot t_{fC}) \cdot Q_f \cdot 10^6 / 3.15 \cdot 10^7$
F_m: proportion of carbon-12 in the melted steel,
F_{adC}: ratio of graphite added per tonne of metal melted,
t_{fC}: release rate of free carbon (from graphite) during melting,
c_n: natural average concentration of carbon in atmosphere (g m^{-3}).

Exposure by ingestion

Carbon-14 from atmosphere is transferred to vegetable, milk and meat, keeping the same ratio of ^{14}C to ^{12}C. The daily dietary intake of carbon is 300 g/day for a man and 210 g/day for a woman[6]. An average value is taken in the generic scenario: 255 g/day, corresponding to 93 kg/y.

The annual dose for exposure to carbon-14 by ingestion of food is given by the following equation:

$$H_{ing} = DF_{ing} \cdot CQ \cdot A_a \quad (\text{Sv y}^{-1}) \qquad (28)$$

where:

DF_{ing}: public dose coefficients for ingestion (Sv Bq^{-1})
(Table 3.3 in Appendix D),
CQ: annual average quantity of carbon ingested by an adult[6] (= 93 kg y^{-1}).

Exposure by inhalation

The annual dose for exposure to carbon-14 by inhalation is given by the following equation:

$$H_{ing} = DF_{inh} \cdot q_{a14} \cdot æ \cdot V \cdot t \quad (\text{Sv y}^{-1}) \qquad (29)$$

where:

DF_{inh}: public dose coefficient for inhalation of CO_2 (carbon-14) (Sv Bq^{-1})
(Table 3.3 in Appendix D),
æ: average atmospheric transfer coefficient (Bq m^{-3} per Bq s^{-1}),
(takes into account the wind rose),
q_{a14}: emission rate of carbon-14 at the stack (Bq s^{-1}),
t: annual exposure time (h y^{-1}),
V: breathing rate[6] (m^3 h^{-1}).

The total annual dose for exposure to carbon-14 is the sum of the annual doses by ingestion and by inhalation:

$$H = H_{ing} + H_{inh} \quad (Sv\ y^{-1}) \qquad (30)$$

3.3.4.2 Tritiated water vapour emission

The exposure pathways for atmospheric emission of tritiated water are inhalation, immersion in the plume and ingestion. The dose from immersion in the plume is assumed to be equal to the dose by inhalation. It is also assumed that the specific radioactivity in vegetables is equal to the average specific radioactivity in water vapour in the atmosphere.

The annual doses for exposure to tritium by inhalation in a plume (H_{inh}), immersion in a plume (H_{imm}) and ingestion of contaminated food (H_{ing}) are as follows:

$$H_{inh} = q_{a3} \cdot æ \cdot (V/3600) \cdot DF_{inh} \qquad (Sv\ y^{-1}) \qquad (31)$$

$$H_{imm} = H_{inh} \qquad (Sv\ y^{-1}) \qquad (32)$$

$$H_{ing} = (q_{a3}/3.15 \cdot 10^{7}) \cdot æ \cdot (10^{3}/R_{o}) \cdot CQ \cdot Df_{ing} \qquad (Sv\ y^{-1}) \qquad (33)$$

where:

q_{a3}: emission rate of tritium at the stack ($Bq\ y^{-1}$),
$q_{a3} = A_m \cdot Q_f \cdot 10^6 \cdot F$,
A_m: activity concentration of the VLL metal waste when it leaves the nuclear installation ($Bq\ g^{-1}$),
Q_f: annual capacity of the steel plant ($t\ y^{-1}$) for arc furnace,
F: fraction of VLL metal waste; ratio of the quantity of VLL metal waste to the total annual quantity of metal waste processed in the plant,
æ: average atmospheric transfer coefficient ($Bq\ m^{-3}$ per $Bq\ s^{-1}$), (takes the wind rose into account),
V: breathing rate[6] ($m^3\ h^{-1}$),
R_o: absolute atmosphere humidity content[9] (= 8 $g\ m^{-3}$),
CQ: annual average quantity of hydrogen ingested by an adult (108 $kg\ y^{-1}$),
DF_{inh}: public dose coefficient for inhalation ($Sv\ Bq^{-1}$), (Table 3.3 in Appendix D),
DF_{ing}: public dose coefficient for ingestion ($Sv\ Bq^{-1}$), (Table 3.3 in Appendix D).

The maximum total annual dose for exposure to tritium is the sum of the annual doses by inhalation, by immersion and by ingestion:

$$H = H_{inh} + H_{imm} + H_{ing} \quad (Sv\ y^{-1}) \qquad (34)$$

TABLE 3.6 Data for exposure by atmospheric emission in the steel plant environment

Parameter	Value	Remarks
Total mass of dust generated (kg)	6.10^{6}	Arc furnace (the most restrictive)
Emitted dust fraction of after filtration	0.01	
Atmospheric transfer coefficient (Bq m^{-3}/Bq s^{-1})	$1.2\ 10^{-5}$	Stack height = 30 m distance = 100 m wind rose = 0.2
Occupancy factor	0.8	
Fraction of VLLW	0.01	Arc furnace
Mass concentration factor in fumes	67	
Parameter specific to inhalation		
Breathing rate (m^3 h^{-1})	1	
Parameters specific to ground deposit (external)		
Deposition velocity (m s^{-1})	$5\ 10^{-3}$	
Deposition duration (h)	8760	
Spent time (h)	1100	3 h/day outside
Parameters specific to foodstuff (ingestion)		
Absorption ratio	0.25	
Biological half-life (days)	30	
Growing time of crops (days)	30	
Agricultural yield (kg m^{-2})	2	
Annual quantity ingested (kg y^{-1})	50	
Parameters specific to carbon and tritium		
Proportion of carbon-12 in the melted steel	3%	
Ratio of graphite added per tonne of metal melted	$4\ 10^{-3}$	
Natural average concentration of carbon in atmosphere. (g m^{-3})	0.15	
Release rate of linked carbon	0.01	
Release rate of free carbon	0.1	
Annual average quantity of carbon ingested by an adult (kg y^{-1})	93	
Annual average quantity of hydrogen ingested by an adult (kg y^{-1})	108	
Absolute atmosphere humidity content (g m^{-3})	8	
Annual capacity of steel plant (t y^{-1})	$4\ 10^{5}$	Arc furnace

3.4 Exposure during post-refining processes (worker exposure)

After refining, the metal is cast in ingots or elements of different shapes which are sent to a manufacturer to be treated and assembled. The ingots or by-products cast after refining come from a charge containing different batches of scrap metal, some of which were VLL waste batches. They consequently contain a variable proportion of the initial radioactivity which is expressed in the equations by a dilution coefficient. Metal is procured by the metal processing plant from several sources, necessitating an additional dilution coefficient. These dilution coefficients vary considerably, depending on the size of the receiving plant, on its size as compared with that of the supplying plants, on the degree of specialisation of the plant considered and in types of alloys produced.

3.4.1 Exposure during manufacture

3.4.1.1 External exposure to the ingots and products during manufacture

The scenario represents the exposure of a worker responsible for treatment or assembly. He is exposed to the metal pieces fabricated from VLL metal waste while he works with them. The mass of metal is represented by a right circular cone; the visible surface of which is likened to a disk 1 m in diameter at a distance of 1.5 m from the operator. This scenario is a generic one representing any work carried out near contaminated metal.

The dose is expressed by equation (35) below and the parameter values are given in Table 3.7. The doses corresponding to waste containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.3.

The annual external dose from a truncated slab source is given by the following equation:

$$H = Am \cdot \rho m \cdot (DF_I + Brem_I) \cdot F \cdot t \cdot r \quad (Sv\ y^{-1}) \qquad (35)$$

where:

- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
- ρm: density of the source material (g cm^{-3}) (= 7.8 g cm^{-3} for steel),
- DF_I: dose factor per unit volume activity concentration due to external exposure to gamma radiations from an ingot represented by a right circular cone at 1.5 m (Sv h^{-1} per Bq cm^{-3}), along an axial direction; this is based on equations (2), (3) and (16) assuming α_{max} = 0.322 radians, see Figure 2,
- $Brem_I$: bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}), (Table 3.2 Appendix D),
- F: fraction of VLL metal waste: ratio of the quantity of VLL metal waste to the total annual quantity of metal waste processed by the plant,
- t: annual time of exposure h y^{-1},
- r: radionuclide distribution factor in the ingot during melting (Table 3.1 in Appendix D).

TABLE 3.7 Data for external exposure to the ingots and products during manufacture

Parameter	Value	Remarks
Source	Right circular cone	Apparent diameter = 1 m, distance = 1.5 m
Time of exposure (h y^{-1})	1800	
Fraction of VLLW	0.01	Arc/induction furnace

3.4.1.2 Exposure by dust inhalation during metal processing

During the various processes involved in transforming the ingots and by-products into finished products, dust can be generated in the work area and exposure from inhalation should be taken into account.

The dose is given by equation (36) below and the parameter values for exposure by inhalation during metal processing are given in Table 3.8. The doses corresponding to waste containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.3.

The annual dose from inhalation is given by the following equation:

$$H = Cd \cdot DF_{inh} \cdot C_a \cdot V \cdot t \quad (Sv\ y^{-1}) \tag{36}$$

where:

- Cd: radionuclide concentration in the dust ($Bq\ g^{-1}$),
- DF_{inh}: worker dose coefficient for inhalation ($Sv\ Bq^{-1}$) (Table 3.3 in Appendix D),
- C_a: inhalable dust concentration in the air ($g\ m^{-3}$),
- V: breathing rate[6] ($m^3\ h^{-1}$),
- t: annual time of exposure ($h\ y^{-1}$).

The radionuclide concentration in the dust is expressed by:

$$Cd = Am \cdot r \cdot F \quad (Bq\ g^{-1}) \tag{37}$$

where:

- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation ($Bq\ g^{-1}$),
- r: radionuclide distribution factor for ingot during melting (Table 3.1 in Appendix D),
- F: ratio of the quantity of VLL metal waste to the total annual quantity of metal waste processed by the plant. In case of inhalation during melting or refining the factor also corresponds to the fraction of time during which a worker is exposed.

TABLE 3.8 Data for exposure by dust inhalation during metal processing

Parameter	Value	Remarks
Breathing rate ($m^3\ h^{-1}$) - interm. activity	1.2	Ref. 6
Inhalable dust concentration in air ($g\ m^{-3}$)	$1\ 10^{-3}$	
Time of exposure ($h\ y^{-1}$)	1800	
Fraction of VLLW	0.01	

3.5 Exposure related to use of product

There is obviously a very wide range of products that may be made from VLL metal waste.

In order to cover a wide range of possibilities, the generic scenarios consider geometrically simple sources. Their dimensions take into account the dimensions of the wide range of actual sources.

3.5.1 Occupational exposures (worker)

3.5.1.1 Work in front of a large machine

The machine considered is mainly made of carbon steel and is supposedly constructed with one or a few large pieces of metal; the fraction of VLL metal is assumed to be 0.1 corresponding to the fraction of VLL metal which can be present in the melting charge.

The individual exposed in his working environment is assumed to work near a semi-self acting apparatus (at 1 m on average) for 1500 h per year. The geometry assumed is a thick disk source with diameter of 1 m and thickness of 0.5 m.

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The external dose is given by equation (38) below and the parameter values are given in Table 3.9. The doses corresponding to waste containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.4.

The annual external dose from a large machine, represented by a thick disk or cylinder source, is given by the following equation:

$$H = Am \cdot \rho m \cdot (DF_M + Brem_M) \cdot F \cdot t \cdot r \qquad (38)$$

where:

- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
- ρm: density of the source material (g cm^{-3}), (= 7.8 g cm^{-3} for steel),
- DF_M: dose factor per unit volume activity concentration for external exposure to gamma radiations from large machine, represented by a thick disk or cylindrical volume at 1 m, along axial direction (Sv h^{-1} per Bq cm^{-3}), this is based on formulae (2), (3) and (4),
- $Brem_M$: bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}), (Table 3.2 in Appendix D),
- F: fraction of VLL metal waste,
- t: annual time of exposure (h y^{-1}),
- r: radionuclide distribution factor in the ingot during melting (Table 3.1 in Appendix D).

3.5.1.2 Work in a professional kitchen (stainless steel)

The work in a professional kitchen involves individuals standing in front of wide cookers or sinks made of stainless steel. The source is represented by a thick disk or cylinder source with a diameter of 1.2 m and a thickness of 3 mm. The worker spends on average 1500 h per year in front of this material at a mean distance of 1 m. The fraction of VLL metal in the composition of the kitchen material may vary from 0.01 to 1. A realistic value of 0.2 is considered in this generic scenario.

The external dose is given by equation (39) below and the parameter values are given in Table 3.9. The doses corresponding to waste containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.4.

The annual external dose from a professional kitchen, represented by a thick disk source is given by the following equation:

$$H = Am \cdot \rho m \cdot (DF_K + Brem_K) \cdot F \cdot t \cdot r \qquad (39)$$

where:

- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
- ρm: density of the source material (g cm^{-3}), (= 7.8 g cm^{-3} for steel),
- DF_K: dose factor per unit volume activity concentration due to external exposure to gamma radiations from a kitchen, represented by thick disk or cylindrical volume at 1 m, (along axial direction) (Sv h^{-1} per Bq cm^{-3}), this is based on formulae (2), (3) and (4),

$Brem_K$:	Bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}) (Table 3.2 in Appendix D),
F:	fraction of VLL metal waste,
t:	annual time of exposure (h y^{-1}),
r:	radionuclide distribution factor in the ingot during melting (Table 3.1 in Appendix D).

3.5.1.3 Work near a process vessel

In chemical industries, process vessels are widely used for various purposes. This scenario represents a worker near a semi self-acting process vessel for 500 h per year. The vessel is 2 m high, 1 m in diameter and 1 cm thick. The fraction of VLL metal entering the composition of the process vessel can range from 0.01 to 1; in this scenario the fraction is assumed to be 0.2. Calculations have been made assuming the process vessel represents a lateral cylindrical wall source closed at extremities by disks.

The external dose from the cylindrical wall source is given by equation (40) below and the parameter values are given in Table 3.9. The doses corresponding to waste containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.4.

The annual external dose from a process vessel, represented by a cylindrical wall is given by the following equation:

$$H = Am \cdot \rho m \cdot (DF_P + Brem_P) \cdot F \cdot t \cdot r \qquad (40)$$

where:

Am:	activity concentration of the VLL metal waste, when it leaves the nuclear installation (Bq g^{-1}),
ρm:	density of the source material (g cm^{-3}), (= 7.8 g cm^{-3} for steel),
DF_P:	dose factor per unit volume activity concentration due to external exposure to gamma radiation from a process vessel, represented by a cylindrical wall source at 1 m; (along lateral direction) (Sv h^{-1} per Bq cm^{-3}),
$Brem_P$:	bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}) (Table 3.2 in Appendix D).
F:	fraction of VLL metal waste,
t:	annual time of exposure (h y^{-1}),
r:	radionuclide distribution factor in the ingot during melting (Table 3.1 in Appendix D),

The term DF_P is derived from equation (2),

where: ϕ is the flux per unit volume activity concentration for a thick cylindrical wall in the lateral direction:

$$\phi = \frac{1}{4\pi} \int_V B \cdot \frac{\exp(-\mu \cdot x)}{d^2} dv + \frac{s}{4\pi} \int_A B \cdot \frac{\exp(-\mu \cdot \bar{x})}{d^2} dA \qquad (41)$$

where:

B: build up factor,
V: volume of the cylindrical wall,
d: distance between dV or dA and the point for which the dose is calculated,
s: thickness of each closure disk,
A: surface of each closure disk,
¯;x: average attenuation thickness seen from the disks,
µ: attenuation coefficient for source material,
x: path of self attenuation.

3.5.1.4 External exposure to a structural element of ships

Steel is used extensively in ship building. Trawlers can spend 2 or 3 day periods at sea, interspersed with 1 to 2 day periods ashore (or fewer but longer periods at sea with fewer but longer periods ashore). In general, sailors spend about 5,000 hours per year aboard ship. In the generic scenario, the exposure is considered as coming from a part of the hull near to which the sailor is standing; when he is not standing near the hull he is generally protected from irradiation by the different materials aboard. The source can be approximated by a thick disk or cylinder source with a diameter of 2 m and a thickness of 10 mm, the sailor standing at 1 m from the source.

The external dose is given by equation (42) below and the parameter values are given in Table 3.9. The doses corresponding to waste containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.4.

The annual external dose from a ship, represented by a thick disk source is given by the following equation:

$$H = Am \cdot \rho m \cdot (DF_S + Brem_S) \cdot F \cdot t \cdot r \qquad (42)$$

where:

Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
ρm: density of the source material (g cm^{-3}), (= 7.8 g cm^{-3} for steel),
DF_S: dose factor per unit volume activity concentration due to external exposure to gamma radiations from a ship, represented by a thick disk or cylindrical volume at 1 m, (along axial direction), (Sv h^{-1} per Bq cm^{-3}), this is based on equations (2), (3) and (4),
$Brem_S$: bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}) (Table 3.2 in Appendix D),
F: fraction of VLL metal waste,
t: annual time of exposure h y^{-1},
r: radionuclide distribution factor in the ingot during melting (Table 3.1 in Appendix D).

3.5.2 Domestic exposures

3.5.2.1 Use of reinforcement bars in a building (carbon steel)

The walls of a house are assumed to be made of two wire nettings inserted in a 20 cm concrete wall. However, it should be noted that 1 MeV radiation is attenuated by a factor of 0.94 under a 10 cm concrete shield ie, only 0.06 is transmitted. The scenario can then be approximated by considering the dose from one wire netting, situated under 5 cm concrete, since the contribution from the other reinforcement mesh in the wall is negligible. The floor composition is assumed to be similar to the wall composition. An individual is assumed to stand for 19 hours per day on the floor (the whole surface of the floor is considered) and 8 hours per day at a distance of 1m from a wall (one wall out of four main walls is considered).

The dose is given by equation (43) below, which takes into account the attenuation by a 5 cm concrete slabs. The parameter values are given in Table 3.10. The dose corresponding to the recycling of initial waste containing 1 Bq g^{-1} of each radionuclide is presented in Table 4.5

The annual external dose from reinforcement bars in the floor and ceiling is represented by thick disc or cylinder sources in the following equation.

$$H = Am \cdot \rho m \cdot (DF_F + Brem_F) \cdot F \cdot t_F \cdot r + Am \cdot \rho m \cdot (DF_W + Brem_W) \cdot F \cdot t_W \cdot r =$$
$$Am \cdot \rho m \cdot F \cdot r \cdot ((DF_F + Brem_F) \cdot t_F + (DF_W + Brem_W) \cdot t_W) \qquad (43)$$

where:

Am:	activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
ρm:	density of the source material (g cm^{-3}), (= 7.8 g cm^{-3} for steel),
DF_F, DF_W:	dose factor per unit volume activity concentration due to external exposure to gamma radiation from a thick disk or cylindrical volume at 1 m, (along axial direction), (Sv h^{-1} per Bq cm^{-3}), DF_F is for floor; DF_w is for wall; both include shielding for 5 cm concrete and are based on formulae (2), (3) and (4),
$Brem_F$, $Brem_W$:	bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}), (Table 3.2 in Appendix D),
F:	fraction of VLL metal waste,
t_F, t_W:	annual time of exposure (h y^{-1}),
r:	radionuclide distribution factor in the ingot during melting, (Table 3.1 in Appendix D).

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TABLE 3.9 Data for external exposure scenarios related to occupational use of equipment

Parameter	Scenario							
	Large machine 3.5.1.1		Kitchen 3.5.1.2		Process vessel 3.5.1.3		Ship 3.5.1.4	
	Value	Remarks	Value	Remarks	Value	Remarks	Value	Remarks
Source	thick disk or cylinder	Diam. = 1m	thick disk or cylinder	diam. = 1.2m	lateral cylindrical wall closed by 2 disks height = 2m, external external diam. = 1 m internal diam. = 0.98 m		thick disk or cylinder	diam. = 2m
Thickness (cm)	50		0.3		1		1	
Distance (m)	1		1		1	from external surface	1	
Time of exposure (h y^{-1})	1500	Semi self acting apparatus, the worker does not stay all the time at a short distance	1500		500	semi self acting apparatus	5000	
Fraction of VLLW	0.1	Carbon steel corresponds to the fraction in the melting charge	0.2	stainless steel	0.2	stainless steel	0.1	carbon steel

TABLE 3.10 Data for use of reinforcement bars in a building (carbon steel)

Parameter	Value	Remarks
- Exposure from the floor: Source	thick disk or cylinder source	thickness = 0.5 cm apparent diameter = 1.8 m distance = 1 m
Shield thickness (cm)	5	
Time of exposure (h y^{-1})	6270	19 h/d during 11 month
- Exposure from a wall: Source	thick disk or cylinder source	thickness = 0.5 cm apparent diameter = 1.4 m distance = 1 m
Shield thickness (cm)	5	
Time of exposure (h y^{-1})	2640	8 h/d during 11 month
Fraction of VLLW	0.025	0.1 in the furnace charge; 0.25 in the quantity of steel used in the building

3.5.2.2 External exposure near a radiator

The scenario considers a radiator situated in a bedroom, where the time of exposure is high. The radiator is represented by a thick disk or cylinder source with a diameter of 1 m; the distance from the source is 1.5 m. The thickness of the radiator walls is 0.5 cm.

The dose is given by equation (44) below and the parameter values are given in Table 3.11. The doses corresponding to the recycling of initial waste containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.5.

The annual external dose from a radiator, represented by a thick disk source is given by the following equation:

$$H = Am \cdot \rho m \cdot (DF_R + Brem_R) \cdot F \cdot t \cdot r \qquad (44)$$

where:

- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
- ρm: density of the source material (g cm^{-3}), (= 7.8 g cm^{-3} for steel),
- DF_R: dose factor per unit volume activity concentration due to external exposure to gamma radiation from a radiator, represented by thick disk or cylindrical volume at 1.5 m, (along axial direction), (Sv h^{-1} per Bq cm^{-3}), this is based on equations (2), (3) and (4),
- $Brem_R$: bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}), (Table 3.2 in Appendix D),
- F: fraction of VLL metal waste,
- t: annual time of exposure h y^{-1},
- r: radionuclide distribution factor in the ingot during melting (Table 3.1 in Appendix D).

TABLE 3.11 Data for external exposure near a radiator

Parameter	Value	Remarks
Source	thick disk source	thickness = 0.5 cm diameter = 1 m distance =1.5 m
Time of exposure (h y^{-1})	2640	
Fraction of VLLW	0.1	Carbon steel

3.6 Exposure related to the disposal or the use of by-products

3.6.1 Disposal of by-products

Disposal sites are classified according to their capacity to deal with different classes of waste ie, inert waste, innocuous waste (e.g. household refuse) or special waste (liable to have harmful effects such as industrial waste).

In this study disposal sites for innocuous or industrial waste are considered, since refinery slag is dispatched to both these types of site. The generic capacity of a disposal site for industrial waste is 50,000 tonnes per year and the generic capacity of a disposal site for innocuous waste is 150,000 tonnes per year.

The scenarios for slag and dust disposal in landfill are similar, the main differences are quantities of waste and capacities of the sites.

The quantity of arc furnace slag coming from the steel plant is 60,000 tonnes; the slag is sent to a municipal landfill with a capacity of 150,000 tonnes per year.

The quantity of induction furnace slag coming from the steel plant is lower at 4000 tonnes; the slag may be sent to a municipal landfill with a lower capacity than that considered above and is assumed to be 50,000 tonnes per year in this study.

The quantity of dust varies from 300 tonnes for an arc furnace to 6000 tonnes for an induction furnace. Dusts are sent to an industrial landfill, with a capacity of 50,000 tonnes per year.

External exposure, inhalation of dust and ingestion of dust by a worker spending 1800 h on the landfill site are considered, together with three residential scenarios representing adults, 10 years old children and 1 year old babies.

Exposures from disposal of slag at the disposal sites include:

- External exposure of workers during waste handling,
- Exposure by inhalation of dust during waste handling,
- Exposure by ingestion of dust particles during waste handling,

Residential scenarios include:

- External exposure of the public after closure of the site and its reuse for residence,
- Exposure of the public by inhalation during reuse of the site for residence,
- Exposure of the public from ingestion of produce grown on the site during its reuse for residence.

Doses due to disposal of 4 materials (arc furnace slag, induction furnace slag, arc furnace dust and induction furnace dust) are calculated for all these scenarios.

3.6.1.1 External exposure of workers from slag or dust disposal in a landfill (worker exposure)

This scenario represents an individual working in a truck cabin all day near the location being filled with waste. The source is represented by an infinite slab.

The dose is given by equation (45) below and the parameter values are given in Table 3.12. The doses corresponding to the recycling of waste initially containing 1 Bq g^{-1} of each radionuclide are presented for arc furnace slag and induction furnace slag in Tables 4.6 and 4.7 respectively. The doses for arc furnace dust and induction furnace dust are present in Tables 4.8 and 4.9.

The annual external dose from a landfill, represented by an infinite slab source is given by the equation:

$$H = Am \cdot (DF_{V\gamma} + DF_{V\beta}) \cdot G \cdot F \cdot r \cdot c_m \cdot t \cdot FL \qquad (45)$$

where:

- Am: activity concentration of the VLL metal waste when it leaves the installation (Bq g^{-1}),
- $DF_{V\gamma}$ dose factor per unit mass activity concentration due to external exposure to gamma radiation from a site, represented by an infinite slab source (Sv h^{-1} per Bq g^{-1}), (Table 3.2 in Appendix D),
- $DF_{V\beta}$ dose factor per unit mass activity concentration due to external exposure to beta radiation at 1 m from a landfill site represented by a semi-infinite slab source (Sv h^{-1} per Bq g^{-1}), this is based on equation (16), (Table 3.2 in Appendix D),
- G: geometry factor reflecting the solid angle from which the source is seen,
- F: fraction of VLL metal waste; ratio of the quantity of VLL metal waste to the total annual quantity of metal processed by the plant,
- r: radionuclide distribution factor in the slag or dust, during melting (Table 3.1 in Appendix D). The value will refer to the type of waste ie. slag or dust, not the exposure scenario,
- c_m: specific concentration factor in the slag or dust, ie the ratio of the mass of products processed to the mass of post-melting by-products obtained. This will be different for arc or induction furnaces. (see Table 3.12),
- t: annual time of exposure (h y^{-1}),
- FL: fraction of slag or dust in the landfill. This is a dilution factor which gives the ratio of the mass of furnace slag or dust to the total mass that can be disposed of in of the appropriate landfill.

The term $DF_{V\gamma}$ is calculated for an infinite slab source from reference 8, for soil of a density of 1.4 g cm^{-3}.

The term $DF_{V\beta}$ is calculated for a semi-infinite volume at 1m.

$$DF_{V\beta} = K_C \cdot \sum_i E \cdot y \cdot \exp\left(-(\mu/\rho)a \cdot \frac{m}{s}\right) \cdot K \qquad (46)$$

where:

- K_C: units conversion factor (2.88 10^{-7} Gy · g per MeV · Bq · h),
- E: energy of emission i (MeV),
- y: yield,
- $(\mu/p)a$: mass absorption coefficient in air [9] (cm^2 g^{-1}),
- m/s: mass to surface ratio of the material (g cm^{-2}),
- K: effective dose per absorbed dose in air for considered energy (Sv Gy^{-1}).

TABLE 3.12 Data for external exposure of workers from slag or dust disposal in a landfill

Parameter	Value	Remarks
Source	Infinite slab source	
Geometry factor	1	
Time of exposure (h y^{-1})	1800	
Fraction of VLLW	0.01	Fraction of VLLW in the steel plant
Specific concentration factor		
in slag	6.7, 50	Arc furnace, induction furnace.
in dust	67, 670	Arc furnace, induction furnace.
Fraction of slag in the landfill	0.4 0.08	AF: 60 000t/150 000t IF: 4 000t/50 000t
Fraction of dust in the landfill	0.12 0.006	AF: 6 000t/50 000t IF: 300t/50 000t

3.6.1.2 Inhalation by workers from slag or dust disposal in a landfill

The worker inhales the dust resuspended during driving the truck and shovelling the waste[11]. He spends 80% of his work time inside the cabin of the truck and 20% of the time outside the cabin. The dose is given by equation (47) below and the parameter values are given in Table 3.13.

All inhalable dust is presumed to arise entirely from waste materials on the site, so that dilution is represented by the fraction of VLLW slag or dust in the landfill.

The doses corresponding to the recycling of waste initially containing 1 Bq g^{-1} of each radionuclide are presented for arc furnace slag and induction furnace slag in Tables 4.6 and 4.7 respectively. The doses for arc furnace dust and induction furnace dust are presented in Tables 4.8 and 4.9.

The annual dose to a worker from inhalation of dust from a landfill is given by the following equation, which includes exposure both inside and outside of a truck.

$$H = (Cd \cdot DF_{inh} \cdot C_{aI} \cdot V \cdot t_I) + (Cd \cdot DF_{inh} \cdot C_{ao} \cdot V \cdot t_o)$$

ie:

$$H = Cd \cdot DF_{inh} \cdot V \cdot ((C_{aI} \cdot t_I) + (C_{ao} \cdot t_o)) \qquad (47)$$

where:

- Cd: radionuclide concentration in the dust (Bq g^{-1}),
- DF_{inh}: worker dose coefficient for inhalation (Sv Bq^{-1}), (Table 3.3 in Appendix D),
- C_{aI}: inhalable dust concentration in the truck cab (g m^{-3}),
- C_{ao}: inhalable dust concentration in the outside atmosphere (g m^{-3}),
- V: breathing rate (m^3 h^{-1}),
- t_I: annual time of exposure in the truck cab (h y^{-1}),
- t_o: annual time of exposure in the outside atmosphere (h y^{-1}).

The radionuclide concentration in the dust is expressed by:

$$Cd = Am \cdot r \cdot c_m \cdot F \cdot FL \cdot d \qquad (Bq\ g^{-1}) \qquad (48)$$

where:

Am: activity concentration of the VLL metal waste when it leaves the nuclear installation ($Bq\ g^{-1}$),
r: radionuclide distribution factor in the dust or slag during melting, (Table 3.1 in Appendix D),
c_m: specific concentration factor in the slag or dust = ratio of the mass of products processed to the mass of post-melting by-products obtained (dust),
F: fraction of VLL metal waste, ratio of the quantity of VLL metal waste to the total annual quantity of metal waste processed by the plant,
FL: fraction of slag or dust in the landfill, this is a dilution factor which gives the ratio of the mass of furnace slag or dust to thetotal mass that can be disposed of in the appropriate landfill,
d: dust dilution on the site.

TABLE 3.13 Data for inhalation by workers from slag or dust disposal in a landfill

Parameter	Value	Remarks
Specific concentration factor		
-in slag	6.7,	Arc furnace,
	50	induction furnace.
-in dust	67,	Arc furnace,
	670	induction furnace.
Breathing rate ($m^3\ h^{-1}$)		
- interm. activity	1.2	
Inhalable dust concentration		
- inside a cab ($g\ m^{-3}$)	$2\ 10^{-4}$	
- outside ($g\ m^{-3}$)	$1\ 10^{-3}$	
Time of exposure ($h\ y^{-1}$)		
- inside	1620	
- outside	180	
Dust dilution on the site	1	
Fraction of VLLW	0.01	Fraction of VLL in the steel plant
Fraction of slag in the landfill	0.4	AF: 60 000t/150 000t
	0.08	IF: 4 000t/50 000t
Fraction of dust in the landfill	0.12	AF: 6 000t/50 000t
	0.006	IF: 300t/50 000t

3.6.1.3 Ingestion by workers from slag or dust disposal in a landfill

The contamination can be deposited on any surface touched by the worker and then may be ingested inadvertently.

The dose is given by equation (49) below and the parameter values are given in Table 3.14.

Appendix A

The parameters for ingestion of dust are similar to those for ingestion of dust during melting or refining the steel. The deposited dust layer is presumed to arise entirely from waste materials on the site, so that no further dilution arises in addition to the fraction of VLLW slag or dust in the landfill (dust dilution factor = 1).

The doses corresponding to the recycling of waste initially containing 1 Bq g^{-1} of each radionuclide are presented for arc furnace slag and induction furnace slag in Tables 4.6 and 4.7 respectively. The doses for arc furnace dust and induction furnace dust are presented in Tables 4.8 and 4.9.

The annual dose for exposure by ingestion of dust is expressed by:

$$H = As \cdot DF_{ing} \cdot n \cdot s \qquad (Sv\ y^{-1}) \qquad (49)$$

where:

As: surface radioactivity of the deposit (Bq cm^{-2}),
DF_{ing}: worker dose coefficient for ingestion (Sv Bq^{-1}), (Table 3.3 in Appendix D),
n: number of times the dust is removed from the surface per year,
s: surface from which the dust is removed (cm^2).

The surface radioactivity of the deposit is expressed by:

$$As = A_m \cdot r \cdot c_m \cdot e \cdot \rho \cdot F \cdot F_L \cdot d \quad (Bq\ g^{-1}) \qquad (50)$$

where:

Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
r: radionuclide distribution factor in the slag or dust during melting, (Table 3.1 in Appendix D),
c_m: specific concentration factor in the slag or dust = ratio of the mass of products processed to the mass of post-melting by-products obtained,
e: thickness of the deposit (cm),
ρ: apparent density of the deposit (g cm^{-3}),
F: fraction of VLL metal waste: the ratio of the quantity of VLL metal waste to the total annual quantity of metal waste processed by the plant,
FL: fraction of slag or dust in the landfill, this is a dilution factor which gives the ratio of the mass of furnace slag or dust to the total mass that can be disposed of in the appropriate landfill,
d: dust dilution on the site.

TABLE 3.14 Data for ingestion by workers from slag or dust disposal in a landfill

Parameter	Value	Remarks
Size of the dusty surface (cm^2)	2	
Apparent density of the deposit ($g\ cm^{-3}$)	1	
Thickness of the deposit (cm)	$1\ 10^{-3}$	
Number of times per day the dust deposited is ingested	5	
Number of days per year ($d\ y^{-1}$)	225	
Dust dilution on the site	1	
Fraction of VLLW	0.01	Fraction of VLLW in the steel plant
Specific concentration factor -in slag -in dust	 6.7, 50 67, 670	 Arc furnace, induction furnace. Arc furnace, induction furnace.
Fraction of slag in the landfill	0.4 0.08	AF: 60 000t/150 000t IF: 4 000t/50 000t
Fraction of dust in the landfill	0.12 0.006	AF: 6 000t/50 000t IF: 300t/50 000t

3.6.1.4 Residential scenarios (public exposure)

These scenarios include the different pathways for the exposure of an individual resident on a closed landfill site (external exposure, inhalation of dust, ingestion of grown vegetables and inadvertent ingestion of soil). Adults, 10 year old children and 1 year old babies have different ways of life, these three scenarios take those differences into account by calculating doses for the 3 age groups.

The site of an ordinary landfill (slag) can be reused about 10 years after closure; the site of an industrial landfill (dust) may not be reused until at least 30 years at least after closure. The decay of the waste over those periods of time is taken into account.

All the parameters concerning specific concentration, fraction of waste in the landfill and fraction of VLLW are the same as in the disposal scenarios for workers, 3.6.1.1 to 3.6.1.3.

The dose is given by equation (51) below and the parameter values are given in Tables 3.15, 3.16 and 3.17. The doses corresponding to the recycling of waste initially containing 1 Bq g^{-1} of each radionuclide are presented for arc furnace slag and induction furnace slag in Tables 4.6 and 4.7 respectively. The doses for arc furnace dust and induction furnace dust are presented in Tables 4.8 and 4.9.

The annual total dose for exposure scenarios relating to residence on an old landfill including inhalation, external exposure and ingestion is given by the following equation:

$$H = Am \cdot F \cdot r \cdot c_m \cdot (FK_{inh} + FK_{ext} + FK_{ing}) \cdot T_a \cdot F_L \qquad (Sv\ y^{-1}) \qquad (51)$$

where:

Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),

F: ratio of the quantity of VLL metal waste to the total annual quantity of metal waste processed by the plant,

r: radionuclide distribution factor in the slag or dust during melting, (Table 3.1 in Appendix D),

c_m: specific concentration factor in the slag or dust considered = ratio of the mass of products processed to the mass of post-melting by-products obtained,

T_a; $$T_a = \exp(-\lambda \cdot t_a) \qquad (52)$$

where:

t_a: time before reuse of a site after closure of a landfill site, (10 y for slag waste; 30 y for dust waste),

λ: radioactive decay constant = $\frac{0.693}{T_{1/2}}$.

F_L: fraction of slag or dust in the landfill. This is a dilution factor which gives the ratio of the mass of furnace slag or dust to the capacity of the appropriate landfill.

with:

Inhalation exposures:

$FK_{inh} = FK_{inh1} + FK_{inh2} + FK_{inh3}$ (Sv y^{-1}/Bq g^{-1}) (53)

$FK_{inh1} = (C_{a1} \cdot V_1)t_{e1} \cdot DF_{inh}$ (Sv y^{-1}/Bq g^{-1}) (54) (10 y child only)

$FK_{inh2} = D_1(C_{a2} \cdot V_1)t_{e2} \cdot DF_{inh}$ (Sv y^{-1}/Bq g^{-1}) (55)

$FK_{inh3} = D_1(C_{a3} \cdot (V_1 \cdot t_{e3} + V_2 \cdot t_{e4}))DF_{inh}$ (Sv y^{-1}/Bq g^{-1}) (56)

External exposures:

$FK_{ext} = FK_{ext1} + FK_{ext2} + FK_{ext3}$ (Sv y^{-1}/Bq g^{-1}) (57)

$FK_{ext1} = t_{e1} (DF_{v\gamma} + DF_{v\beta})$ (Sv y^{-1}/Bq g^{-1}) (58) (10 y child only)

$FK_{ext2} = D_1 \cdot t_{e2} (DF_{v\gamma} + DF_{v\beta})$ (Sv y^{-1}/Bq g^{-1}) (59)

$FK_{ext3} = D_1 \cdot D_2 \cdot DF_{v\gamma} (t_{e3} + t_{e4})$* (Sv y^{-1}/Bq g^{-1}) (60)

Ingestion exposures:

$FK_{ing} = FK_{ing1} + FK_{ing2}$ (Sv y^{-1}/Bq g^{-1}) (61)

$FK_{ing1} = D_1 \cdot q_t \cdot DF_{ing}$ (Sv y^{-1}/Bq g^{-1}) (62)

$FK_{ing2} = D_1 \cdot D_3 \cdot DF_{ing} ((GVCF \cdot SL_{ing}) + (GVCF \cdot CB_{ing}) + (RVCF \cdot CR_{ing}) + (RVCF \cdot LK_{ing}) + (RVCF \cdot P_{ing}) + (GVCF \cdot B_{ing}) + (GVCF \cdot T_{ing}))$** (Sv·$y^{-1}$/Bq·$g^{-1}$) (63)

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* Inside a house beta radiation does not contribute to the dose.

** This assumes that the transfer from soil to plant is via root uptake only. Only root concentration factors for green vegetables and root vegetables are available and therefore the foods were split into these two groups.

where:

C_{a1}: dust concentration in atmosphere on cuts and fills (10 y child only) (g m^{-3}),
C_{a2}: dust concentration in atmosphere in the garden (g m^{-3}),
C_{a3}: dust concentration in atmosphere inside the house (g m^{-3}),
V_1: breathing rate for light and intermediate physical activity[6] (m^3 h^{-1}),
V_2: breathing rate when resting[6] (m^3 h^{-1}),
t_{e1}: time spent on cuts and fills (10 y child only) (h y^{-1}),
t_{e2}: time spent in the garden (h y^{-1}),
t_{e3}: time spent inside the house (h y^{-1}),
t_{e4}: time spent resting inside (h y^{-1}),
D_1: dilution of waste in the garden soil,
D_2: indoor radiation transmission (shielding factor),
D_3: food consumption fraction from the garden,
(see footnote for Table 3.17),
DF_{inh}: public dose coefficient for inhalation (Sv Bq^{-1}),
(Table 3.2 in Appendix D), 3 age groups unless stated otherwise,
$DF_{v\gamma}$: dose factor per unit mass specific radioactivity due to external exposure to gamma radiations from a landfill site represented by an infinite slab source (Sv h^{-1}/Bq g^{-1}),
(Table 3.2 in Appendix D), (see formula (45)),
$DF_{v\beta}$: dose factor per unit mass specific radioactivity due to external exposure to beta radiations from a landfill site represented by a semi-infinite slab source (Sv h^{-1}/Bq g^{-1})
(Table 3.2 in Appendix D), (see formula (45)),
DF_{ing}: public dose coefficient for ingestion (Sv Bq^{-1}),
(Table 3.2 in Appendix D), 3 age groups,
q_t: quantity of soil ingested (g y^{-1}),
GVCF: is root concentration factor for green vegetables,
(Table 3.4 in Appendix D),
RVCF: is root concentration factor for root vegetables,
(Table 3.4 in Appendix D),
SL_{ing}: is the adult consumption rate for salad (g y^{-1}),
CB_{ing}: is the adult consumption rate for cabbage (g y^{-1}),
CR_{ing}: is the adult consumption rate for carrots (g y^{-1}),
LK_{ing}: is the adult consumption rate for leeks (g y^{-1}),
P_{ing}: is the adult consumption rate for potatoes (g y^{-1}),
B_{ing}: is the adult consumption rate for beans (g y^{-1}),
T_{ing}: is the adult consumption rate for tomatoes (g y^{-1}).

Values for SL_{ing}, CB_{ing}, CR_{ing}, LK_{ing}, P_{ing}, B_{ing} and T_{ing} are given in the footnote to Table 3.17.

TABLE 3.15 Data for residence of an adult on an old landfill

All the parameters concerning specific concentration, fraction of waste in the landfill and fraction of VLLW are the same as in the scenarios for workers.

Parameter	Value	Remarks
Time before scenario (y)	10	Time before reuse of a site after closure of an ordinary landfill (containing slag)
	30	Time before reuse of a site after closure of an industrial landfill (containing dust)
Age of the individual (y)	30	
Consumption of soil (g y^{-1})	2	From vegetable consumption
Time spent in the garden (h y^{-1})	1100	Average of 3 h/day
Time spent in the house (h y^{-1})	4000	Average of 11 h/day
Time spent resting inside (h y^{-1})	2920	Average of 8 h/day
Dust concentration in the garden (g m^{-3})	2.10^{-5}	
Dust concentration in the house (g m^{-3})	1.10^{-5}	
Breathing rate (m^3 h^{-1}) - light and interm. physical activity - resting	 1 0.45	
Dilution in the garden soil*	0.03	dilution due to the mixing of waste when building the house
Food consumption fraction from the garden	0.2**	
Indoor radiations reduction (shielding)	0.1	

Note

* and **: cf. footnote for Table 3.17.

TABLE 3.16 Data for residence of a 10 year old child on an old landfill

All the parameters concerning mass concentration, fraction of waste in the landfill and fraction of VLLW are the same as in the scenarios for workers.

Parameter	Value	Remarks
Time before scenario (y)	10	Time before reuse of a site after closure of an ordinary landfill (containing slag)
	30	Time before reuse of a site after closure of an industrial landfill (containing dust)
Age of the individual (y)	10	
Consumption of soil (g y^{-1})	2	From vegetable consumption
Time spent on cuts and fills (h y^{-1})	100	
Time spent in the garden (h y^{-1})	500	Between 1 and 2 h day
Time spent inside the house (h y^{-1})	3145	Take into account some holidays, time after school and week-ends
Time spent resting inside (h y^{-1})	3350	Average of 10 h/day
Dust concentration on cuts and fills (g m^3)	$2\ 10^{-4}$	
Dust concentration in the garden (g m^{-3})	$2\ 10^{-5}$	
Dust concentration in the house (g m^{-3})	$1\ 10^{-5}$	
Breathing rate (m^3 h^{-1}) - light + interm. physical activity - resting	 0.6 0.27	
Dilution in the garden soil*	0.03	Dilution due to the mixing of waste when building the house
Dilution on cuts and fills	1	
Foodstuff consumption fraction from the garden	0.2**	
Indoor radiations reduction (shielding)	0.1	

Note
* and **: cf. footnote for Table 3.17.

TABLE 3.17 Data for residence of a 1 year old baby on an old landfill

All the parameters concerning mass concentration, fraction of waste in the landfill and fraction of VLLW are the same as in the scenarios for workers.

Parameter	Value	Remarks
Time before scenario (y)	10	Time before reuse of a site after closure of an ordinary landfill (containing slag)
	30	Minimum time before reuse of a site after closure of an industrial landfill (containing dust)
Age of the individual (y)	1	
Consumption of soil ($g\ y^{-1}$)	10	By playing on the ground
Time spent in the garden ($h\ y^{-1}$)	300	Less than 1 h day
Time spent inside the house ($h\ y^{-1}$)	3350	Average of 10 h/day during 335 days
Time spent resting inside ($h\ y^{-1}$)	4690	Average of 14 h/day during 335 days
Dust concentration in the garden ($g\ m^{-3}$)	$2\ 10^{-5}$	
Dust concentration in the house ($g\ m^{-3}$)	$1\ 10^{-5}$	
Breathing rate ($m^3\ h^{-1}$) - light + interm. physical activity - resting	 0.25 0.09	
Dilution in the garden soil*	0.03	Dilution due to the mixing of waste when building the house
Foodstuff consumption fraction from the garden	0.01**	
Indoor radiations reduction (shielding)	0.1	

Note

* After house excavations a fraction of waste may be stored in a heap on a surface over about 50 m^2. After this heap is levelled, it still stays about 3 cm in depth and is a mixture of waste and soil. When the garden and the kitchen garden are set up, this residue is mixed with all the soil over 300 m^2. If the root depth is about 15 cm, the dilution of waste in the garden is then 3% (i. e. 1.5 m^3/45 m^3).

** The annual consumption for adults and 10 years old children of produce from the garden is considered as being about 20% of the average annual adult consumption of vegetable; the annual consumption for a 1 year old baby from the garden is estimated as about 1% of the average adult annual consumption of vegetable. The basis is the average annual adult consumption in EC and in France: 20 kg salad, 10 kg cabbage, 20 kg carrot, 10 kg leek, 80 kg potatoes, 15 kg beans, 10 kg tomatoes[12].

3.6.2 Use of by-products

3.6.2.1 Exposures to dust from a football field made of slag

In Germany football fields may be made with materials containing slag. A generic scenario represents a person exposed to dust created by players during training or a game. 1% of the dust may come from the slag (for example the ground may be made partly with slag, all the slag may not arise from VLL metal waste, and a player or a spectator is not always on those types of fields).

3.6.2.1.1 Football player

A football player, junior or senior, trains for 4 h per week and plays one match per week; that is an average of 5 h 30 min per week. The player is assumed to play for 48 weeks of the year.

The dose due to inhalation of dust is given by equation (64) below and the parameter values are given in Table 3.18. The dose corresponding to the reuse of waste initially containing 1 Bq g^{-1} of each radionuclide is presented in Table 4.10, calculated for both arc and induction furnace slag.

The annual dose to a football player by inhalation of dust from a field made of slag is given by the following equation, which includes exposure from high physical activity and intermediate physical activity.

$$H = (Cd \cdot DF_{inh} \cdot C_{aH} \cdot V_H \cdot t_H) + (Cd \cdot DF_{inh} \cdot C_{aI} \cdot V_I \cdot t_I)$$

i. e.,

$$H = Cd \cdot DF_{inh} \cdot (C_{aH} \cdot V_H \cdot t_H + C_{aI} \cdot V_I \cdot t_I) \qquad (64)$$

where:

- Cd: radionuclide concentration in the dust (Bq g^{-1})
- DF_{inh}: public dose coefficient for inhalation (Sv Bq^{-1}) (Table 3.3 in Appendix D),
- C_{aH}: inhalable dust concentration in the air for high physical activity (g m^{-3}),
- C_{aI}: inhalable dust concentration in the air for intermediate physical activity (g m^{-3}),
- V_H: breathing rate for high physical activity (m^3 h^{-1}),
- V_I: breathing rate for intermediate physical activity (m^3 h^{-1}),
- t_H: annual time of exposure for high physical activity (h y^{-1}),
- t_I: annual time of exposure for intermediate physical activity (h y^{-1}).

The radionuclide concentration in the dust is expressed by:

$$Cd = Am \cdot r \cdot c_m \cdot F \quad (Bq\ g^{-1}) \qquad (65)$$

where:

- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
- r: radionuclide distribution factor for slag, during melting, (Table 3.1 in Appendix D),
- c_m: specific concentration factor in the slag = ratio of the mass of products processed to the mass of post-melting bi-products obtained (slag),
- F: fraction of VLL metal waste, general dilution in slag.

TABLE 3.18 Data for exposure by inhalation of a football player

Parameter	Value	Remarks
Breathing rate (m^3 h^{-1})		
- high physical activity	1.8	
- intermediate physical activity	1.5	
Inhalable dust concentration in air (g m^{-3})		
- during high physical activity	2 10^{-3}	
- during interm. physical activity	1 10^{-3}	
Time of exposure (h y^{-1})		
- of high physical activity	132	
- of interm. physical activity	132	
General dilution of VLLW slag in football field	0.01	
Specific concentration factor in slag		
- from arc furnace	6.7	
- from induction furnace	50	

3.6.2.1.2 Football spectator

The spectator attends the football matches and the cumulated duration over a year can be around 50 h. He stays on the sides of the field. The dose is given by equation (66) below and the parameter values for inhalation of dust are given in Table 3.19. The dose corresponding to the recycling of waste initially containing 1 Bq g^{-1} of each radionuclide is presented in Table 4.10.

The annual dose to a football spectator by inhalation from a field made of slag is given by the following equation:

$$H = Cd \cdot DF_{inh} \cdot C_a \cdot V \cdot t \quad (Sv\ y^{-1}) \qquad (66)$$

where:

Cd: radionuclide concentration in the dust (Bq g^{-1}),
DF_{inh}: public dose coefficient for inhalation (Sv Bq^{-1}) (Table 3.3 in Appendix D),
C_a: inhalable dust concentration in the air (g m^{-3}),
V: breathing rate for light physical activity (m^3 h^{-1}),
t: annual time of exposure (h y^{-1}).

The radionuclide concentration in the dust is expressed by:

$$Cd = A_m \cdot r \cdot c_m \cdot F \quad (Bq\ g^{-1}) \qquad (67)$$

where:

Am: activity concentration of the VLL waste metal when it leaves the nuclear installation (Bq g^{-1}),
r: radionuclide distribution factor for slag during melting (Table 3.1 in Appendix D),
c_m: specific concentration factor in the slag = ratio of the mass of products processed to the mass of post-melting by-products obtained,
F: fraction of VLL metal waste; general dilution in slag.

TABLE 3.19 Data for exposure by inhalation of a football spectator

Parameter	Value	Remarks
Breathing rate (m^3 h^{-1}) - light physical activity	 1	
Inhalable dust concentration in air (g m^{-3})	1 10^{-3}	
Time of exposure (h y^{-1})	50	
General dilution of VLLW slag in football field	0.01	
Specific concentration factor in slag - from arc furnace - from induction furnace	 6.7 50	

Section 4

Tables of doses

Appendix A

TABLE 4.1: ANNUAL DOSE RATES AT SCRAP YARD (Sv/y)

NUCLIDE	TRANSPORT (3.1.1) EXTERNAL	SCRAP CUTTING (3.1.2) INHALATION
H3	0,00E+01	
C14	0,00E+01	
Mn54	2,51E-06	
Fe55	0,00E+01	
Co60	8,66E-06	
Ni59	0,00E+01	
Ni63	0,00E+01	
Zn65	1,93E-06	
Sr90+	3,07E-07	
Nb94	4,63E-06	
Tc99	1,40E-10	
Ru106+	1,35E-06	
Ag108m+	4,21E-06	
Ag110m+	8,35E-06	
Sb125+	9,75E-07	
Cs134	4,36E-06	
Cs137+	1,54E-06	
Pm147	1,75E-11	
Sm151	3,21E-50	
Eu152	3,37E-06	
Eu154	3,78E-06	
U234	1,08E-11	
U235+	1,01E-07	
U238+	2,61E-07	2,93E-06
Np237+	2,71E-07	7,71E-06
Pu238	6,71E-13	1,54E-05
Pu239	4,61E-11	1,64E-05
Pu240	8,19E-13	1,64E-05
Pu241	2,47E-13	2,98E-07
Am241	1,43E-11	1,39E-05
Cm244	2,15E-18	8,73E-06
Na-22	6,59E-06	
S-35	2,47E-12	
Cl-36	7,96E-09	
K-40	5,60E-07	
Ca-45	6,92E-25	
Sc-46	6,48E-06	
Mn-53	0,00E+01	
Co-56	1,25E-05	
Co-57	5,02E-08	
Co-58	2,81E-06	
As-73	1,40E-13	
Se-75	4,91E-07	
Se-79	2,84E-12	
Sr-85	1,20E-06	
Y-91	1,06E-07	
Zr-93	6,47E-19	
Zr-95+	4,30E-06	
Nb-93m	7,36E-17	
Mo-93	4,12E-16	
Tc-97	7,09E-16	
Tc-97m	4,64E-11	

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TABLE 4.1 (cont.)		
Pd-107	7,50E-35	
Cd-109	0,00E+01	
Sn-113+	5,13E-07	
Sn-126+	5,13E-06	
Sb-124	6,05E-06	
Te-123m	9,75E-08	
Te-127m+	1,43E-08	
I-125	9,98E-14	
I-129	5,83E-14	
Cs-135	1,57E-11	
Ce-139	1,05E-07	
Ce-144+	1,15E-07	
Sm-147	0,00E+01	
Eu-155	6,96E-09	
Gd-153	9,52E-09	
Tb-160	3,24E-06	
Tm-170	1,45E-08	
Tm-171	1,01E-12	
Ta-182	4,02E-06	
W-181	1,95E-10	
W-185	5,73E-10	
Os-185	1,80E-06	
Ir-192	1,59E-06	
Tl-204	6,63E-09	
Pb-210+	2,72E-08	
Bi-207	4,47E-06	
Po-210	2,52E-11	
Ra-226+	5,49E-06	
Ra-228+	2,77E-06	
Ac-227+	5,86E-07	
Th-228+	5,05E-06	
Th-229+	5,19E-07	
Th-230	9,59E-11	
Th-232	2,15E-11	
Pa-231	4,24E-08	
U-232	5,89E-11	
U-233	6,36E-11	
U-236	7,96E-13	
Pu-236	9,75E-14	
Pu-242	7,23E-15	
Pu-244+	8,97E-07	
Am-242m+	1,22E-08	
Am-243+	1,43E-07	
Cm-242	2,53E-14	
Cm-243	1,13E-07	
Cm-245	2,46E-08	
Cm-246	1,01E-15	
Cm-247+	6,32E-07	
Cm-248	3,74E-15	
Bk-249	2,25E-13	
Cf-248	3,63E-16	
Cf-249	6,15E-07	
Cf-250	7,88E-13	
Cf-251	7,45E-08	
Cf-252	1,91E-13	
Cf-254	1,18E-18	
Es-254	1,99E-09	

Appendix A

TABLE 4.2: ANNUAL DOSE RATES FOR THE STEEL PLANT SCENARIOS (Sv/y)

NUCLIDE	SCRAP HEAP (3.2.1) EXTERNAL	MELTING (3.2.2.1) INHALATION		REFINING (3.2.2.2) INGESTION		ATMOSPHERIC ENVIRONMENT (3.3)
		ARC	INDUCTION	ARC	INDUCTION	
H3	0,00E+01	3,91E-11	1,56E-10	4,07E-10	4,07E-09	7,30E-09
C14	0,00E+01	1,26E-09	5,04E-09	1,31E-08	1,31E-07	1,03E-10
Mn54	2,82E-07	1,30E-10	5,21E-10	8,03E-10	8,03E-09	3,20E-10
Fe55	7,17E-13	9,99E-12	3,99E-11	3,73E-11	3,73E-10	1,90E-12
Co60	9,28E-07	1,85E-10	7,38E-10	3,84E-10	3,84E-09	1,07E-10
Ni59	3,38E-13	4,78E-13	1,91E-12	1,42E-12	1,42E-11	1,07E-13
Ni63	0,00E+01	1,13E-12	4,52E-12	3,39E-12	3,39E-11	2,73E-13
Zn65	2,09E-07	6,08E-09	2,43E-08	8,82E-08	8,82E-07	7,35E-09
Sr90+	1,27E-08	1,71E-08	6,83E-08	6,94E-08	6,94E-07	4,56E-09
Nb94	5,25E-07	5,43E-11	2,17E-10	3,84E-11	3,84E-10	1,73E-11
Tc99	3,62E-11	6,95E-12	2,78E-11	1,76E-11	1,76E-10	1,97E-12
Ru106+	9,08E-08	7,60E-08	3,04E-07	1,58E-07	1,58E-06	1,58E-08
Ag108m+	4,93E-07	4,12E-09	1,65E-08	5,20E-09	5,20E-08	1,71E-09
Ag110m+	9,36E-07	1,58E-09	6,34E-09	6,33E-09	6,33E-08	2,16E-09
Sb125+	1,17E-07	8,60E-11	3,44E-10	2,94E-10	2,94E-09	5,52E-11
Cs134	5,01E-07	2,08E-08	8,34E-08	4,30E-07	4,30E-06	2,96E-08
Cs137+	1,78E-07	1,45E-08	5,82E-08	2,94E-07	2,94E-06	1,97E-08
Pm147	8,14E-12	7,60E-12	3,04E-11	5,88E-12	5,88E-11	7,68E-13
Sm151	5,52E-15	5,64E-12	2,26E-11	2,22E-12	2,22E-11	5,16E-13
Eu152	3,73E-07	5,86E-11	2,34E-10	3,17E-11	3,17E-10	1,32E-11
Eu154	4,15E-07	7,60E-11	3,04E-10	4,52E-11	4,52E-10	1,56E-11
U234	3,54E-12	1,48E-08	5,90E-08	1,11E-09	1,11E-08	1,05E-09
U235+	1,73E-08	1,32E-08	5,30E-08	1,05E-09	1,05E-08	9,55E-10
U238+	1,35E-08	1,24E-08	4,95E-08	1,08E-09	1,08E-08	9,03E-10
Np237+	1,60E-08	3,26E-08	1,30E-07	2,51E-09	2,51E-08	5,46E-09
Pu238	5,63E-13	6,51E-08	2,60E-07	5,20E-09	5,20E-08	1,20E-08
Pu239	6,58E-12	6,95E-08	2,78E-07	5,65E-09	5,65E-08	1,31E-08
Pu240	6,05E-13	6,95E-08	2,78E-07	5,65E-09	5,65E-08	1,31E-08
Pu241	7,39E-14	1,26E-09	5,04E-09	1,06E-10	1,06E-09	2,51E-10
Am241	2,40E-10	5,86E-08	2,34E-07	4,52E-09	4,52E-08	1,05E-08
Cm244	2,65E-13	3,69E-08	1,48E-07	2,71E-09	2,71E-08	6,22E-09
Na-22	7,36E-07	4,34E-09	1,74E-08	7,24E-08	7,24E-07	1,69E-08
S-35	2,65E-12	2,39E-10	9,55E-10	1,74E-09	1,74E-08	8,92E-11
Cl-36	7,12E-10	1,11E-08	4,43E-08	2,10E-08	2,10E-07	1,67E-09
K-40	5,91E-08	6,51E-09	2,60E-08	1,40E-07	1,40E-06	7,04E-09
Ca-45	1,56E-20	4,99E-10	2,00E-09	1,72E-09	1,72E-08	1,03E-10
Sc-46	7,15E-07	1,04E-09	4,17E-09	3,39E-09	3,39E-08	1,49E-09
Mn-53	0,00E+01	3,91E-12	1,56E-11	3,39E-11	3,39E-10	1,69E-12
Co-56	1,32E-06	5,32E-11	2,13E-10	2,83E-10	2,83E-09	1,24E-10
Co-57	1,16E-08	6,51E-12	2,60E-11	2,37E-11	2,37E-10	6,22E-12
Co-58	3,22E-07	1,85E-11	7,38E-11	8,37E-11	8,37E-10	3,71E-11
As-73	9,55E-11	1,41E-11	5,64E-11	5,88E-11	5,88E-10	4,06E-12
Se-75	7,10E-08	3,69E-10	1,48E-09	5,88E-09	5,88E-08	5,33E-10
Se-79	3,30E-12	6,73E-10	2,69E-09	6,56E-09	6,56E-08	3,32E-10
Sr-85	1,46E-07	1,22E-10	4,86E-10	1,27E-09	1,27E-08	4,11E-10
Y-91	1,39E-09	1,32E-09	5,30E-09	5,43E-09	5,43E-08	3,66E-10
Zr-93	4,63E-14	3,15E-10	1,26E-09	3,17E-11	3,17E-10	1,83E-11
Zr-95+	4,93E-07	5,97E-11	2,39E-10	1,65E-10	1,65E-09	6,15E-11
Nb-93m	1,84E-12	1,87E-12	7,47E-12	2,71E-12	2,71E-11	3,07E-13
Mo-93	1,03E-11	3,04E-10	1,22E-09	5,88E-09	5,88E-08	3,06E-10
Tc-97	1,40E-11	3,47E-13	1,39E-12	1,88E-12	1,88E-11	2,98E-13
Tc-97m	3,31E-11	5,86E-12	2,34E-11	1,49E-11	1,49E-10	9,69E-13

Appendix A

TABLE 4.2 (cont.)						
Pd-107	5,46E-15	6,30E-13	2,52E-12	8,37E-13	8,37E-12	9,63E-14
Cd-109	4,68E-11	2,08E-08	8,34E-08	4,52E-08	4,52E-07	2,72E-09
Sn-113+	6,54E-08	4,19E-09	1,68E-08	1,71E-08	1,71E-07	2,88E-09
Sn-126+	6,05E-07	4,01E-08	1,60E-07	1,15E-07	1,15E-06	2,18E-08
Sb-124	6,56E-07	1,02E-10	4,08E-10	5,65E-10	5,65E-09	1,51E-10
Te-123m	1,75E-08	7,38E-10	2,95E-09	3,17E-09	3,17E-08	2,88E-10
Te-127m+	5,22E-11	1,38E-09	5,54E-09	5,58E-09	5,58E-08	3,39E-10
I-125	2,27E-10	1,58E-08	6,34E-08	3,39E-07	3,39E-06	1,41E-08
I-129	1,57E-10	1,11E-07	4,43E-07	2,49E-06	2,49E-05	1,02E-07
Cs-135	8,44E-12	2,15E-09	8,60E-09	4,52E-08	4,52E-07	2,71E-09
Ce-139	1,84E-08	3,04E-10	1,22E-09	5,88E-10	5,88E-09	1,61E-10
Ce-144+	1,29E-08	6,30E-09	2,52E-08	1,19E-08	1,19E-07	1,17E-09
Sm-147	0,00E+01	1,33E-08	5,32E-08	1,11E-09	1,11E-08	1,07E-09
Eu-155	3,10E-09	1,02E-11	4,08E-11	7,24E-12	7,24E-11	1,50E-12
Gd-153	4,30E-09	5,43E-12	2,17E-11	6,11E-12	6,11E-11	1,31E-12
Tb-160	3,62E-07	1,17E-11	4,69E-11	3,62E-11	3,62E-10	9,27E-12
Tm-170	1,15E-09	1,13E-11	4,52E-11	2,94E-11	2,94E-10	2,11E-12
Tm-171	1,29E-11	1,98E-12	7,90E-12	2,49E-12	2,49E-11	2,54E-13
Ta-182	4,39E-07	1,61E-11	6,43E-11	3,39E-11	3,39E-10	1,06E-11
W-181	8,61E-10	9,33E-12	3,73E-11	1,72E-10	1,72E-09	3,81E-11
W-185	9,20E-11	4,78E-11	1,91E-10	9,95E-10	9,95E-09	4,06E-11
Os-185	2,11E-07	3,04E-09	1,22E-08	1,15E-08	1,15E-07	5,47E-09
Ir-192	2,02E-07	5,32E-11	2,13E-10	1,58E-10	1,58E-09	3,87E-11
Tl-204	5,87E-10	1,35E-10	5,38E-10	2,94E-09	2,94E-08	1,26E-10
Pb-210+	4,69E-11	2,52E-06	1,01E-05	1,54E-05	1,54E-04	1,23E-06
Bi-207	5,03E-07	6,95E-11	2,78E-10	2,94E-10	2,94E-09	1,19E-10
Po-210	2,86E-12	4,78E-07	1,91E-06	5,43E-07	5,43E-06	1,53E-07
Ra-226+	6,00E-07	4,83E-07	1,93E-06	6,34E-07	6,34E-06	1,28E-07
Ra-228+	3,10E-07	3,75E-07	1,50E-06	1,52E-06	1,52E-05	2,34E-07
Ac-227+	7,92E-08	1,40E-04	5,58E-04	2,73E-06	2,73E-05	6,20E-06
Th-228+	5,28E-07	7,48E-08	2,99E-07	3,19E-09	3,19E-08	4,81E-09
Th-229+	6,70E-08	1,74E-07	6,98E-07	1,36E-08	1,36E-07	2,80E-08
Th-230	2,37E-11	6,08E-08	2,43E-07	4,75E-09	4,75E-08	1,09E-08
Th-232	7,55E-12	6,34E-08	2,54E-07	5,01E-09	5,01E-08	1,20E-08
Pa-231	5,88E-09	1,93E-07	7,73E-07	1,61E-08	1,61E-07	1,56E-08
U-232	1,43E-11	5,64E-08	2,26E-07	7,46E-09	7,46E-08	4,26E-09
U-233	1,75E-11	1,50E-08	5,99E-08	1,13E-09	1,13E-08	1,07E-09
U-236	2,50E-12	1,37E-08	5,47E-08	1,04E-09	1,04E-08	9,75E-10
Pu-236	1,59E-12	2,82E-08	1,13E-07	1,94E-09	1,94E-08	4,37E-09
Pu-242	7,72E-13	6,73E-08	2,69E-07	5,43E-09	5,43E-08	1,20E-08
Pu-244+	1,04E-07	6,51E-08	2,60E-07	5,45E-09	5,45E-08	1,20E-08
Am-242m+	2,70E-10	5,21E-08	2,09E-07	4,30E-09	4,30E-08	1,00E-08
Am-243+	2,50E-08	5,86E-08	2,34E-07	4,54E-09	4,54E-08	1,05E-08
Cm-242	1,14E-12	8,03E-09	3,21E-08	2,71E-10	2,71E-09	6,43E-10
Cm-243	1,81E-08	4,34E-08	1,74E-07	3,39E-09	3,39E-08	7,53E-09
Cm-245	6,04E-09	5,86E-08	2,34E-07	4,75E-09	4,75E-08	1,08E-08
Cm-246	6,80E-13	5,86E-08	2,34E-07	4,75E-09	4,75E-08	1,07E-08
Cm-247+	8,13E-08	5,43E-08	2,17E-07	4,30E-09	4,30E-08	9,82E-09
Cm-248	6,87E-13	2,06E-07	8,25E-07	1,74E-08	1,74E-07	3,93E-08
Bk-249	6,06E-13	2,17E-10	8,68E-10	2,19E-11	2,19E-10	1,80E-11
Cf-248	7,36E-13	1,32E-08	5,30E-08	6,33E-10	6,33E-09	9,68E-10
Cf-249	7,95E-08	9,77E-08	3,91E-07	7,91E-09	7,91E-08	7,82E-09
Cf-250	1,60E-12	4,78E-08	1,91E-07	3,62E-09	3,62E-08	3,79E-09
Cf-251	1,37E-08	9,99E-08	3,99E-07	8,14E-09	8,14E-08	7,93E-09
Cf-252	1,16E-12	2,82E-08	1,13E-07	2,04E-09	2,04E-08	2,22E-09
Cf-254	2,77E-16	4,78E-08	1,91E-07	9,04E-09	9,04E-08	4,75E-09
Es-254	3,24E-10	1,30E-08	5,21E-08	6,33E-10	6,33E-09	9,47E-10

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TABLE 4.3: ANNUAL DOSE RATES FOR MANUFACTURING SCENARIOS (Sv/y)

NUCLIDE	MANUFACTURE (3.4.1.1) EXTERNAL * ARC AND INDUCTION	PROCESSING (3.4.1.2) INHALATION *
H3	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01
Mn54	1,37E-07	2,59E-11
Fe55	3,48E-13	1,99E-11
Co60	4,51E-07	3,67E-10
Ni59	1,64E-13	4,75E-12
Ni63	0,00E+01	1,12E-11
Zn65	1,02E-08	6,05E-12
Sr90+	6,05E-10	1,70E-10
Nb94	2,56E-08	5,40E-11
Tc99	1,74E-12	6,91E-12
Ru106+	4,39E-09	7,56E-11
Ag108m+	2,40E-07	4,10E-10
Ag110m+	4,55E-07	1,58E-10
Sb125+	5,70E-08	8,56E-11
Cs134	2,44E-10	2,07E-13
Cs137+	8,66E-11	1,45E-13
Pm147	3,95E-15	7,56E-14
Sm151	2,68E-18	5,62E-14
Eu152	1,81E-10	5,83E-13
Eu154	2,01E-10	7,56E-13
U234	1,71E-13	1,47E-08
U235+	8,42E-10	1,32E-08
U238+	6,43E-10	1,23E-08
Np237+	7,62E-10	3,24E-08
Pu238	2,74E-14	6,48E-08
Pu239	3,20E-13	6,91E-08
Pu240	2,93E-14	6,91E-08
Pu241	3,59E-15	1,25E-09
Am241	1,17E-11	5,83E-08
Cm244	1,29E-14	3,67E-08
Na-22	3,58E-10	4,32E-14
S-35	1,29E-16	2,38E-13
Cl-36	3,41E-14	1,10E-12
K-40	2,86E-11	6,48E-14
Ca-45	8,83E-22	4,97E-12
Sc-46	3,47E-08	1,04E-11
Mn-53	0,00E+01	7,78E-13
Co-56	6,39E-07	1,06E-10
Co-57	5,66E-09	1,30E-11
Co-58	1,56E-07	3,67E-11
As-73	4,63E-11	1,40E-11
Se-75	3,45E-09	3,67E-12
Se-79	1,60E-14	6,70E-12
Sr-85	7,10E-09	1,21E-12
Y-91	2,90E-11	1,32E-11
Zr-93	2,25E-14	6,26E-10
Zr-95+	2,40E-07	1,19E-10
Nb-93m	9,08E-14	1,86E-12
Mo-93	5,08E-12	3,02E-11
Tc-97	6,88E-13	3,46E-13
Tc-97m	1,61E-12	5,83E-12

Appendix A

TABLE 4.3 (cont.)		
Pd-107	2,65E-15	6,26E-12
Cd-109	2,26E-12	2,07E-11
Sn-113+	3,19E-09	4,17E-12
Sn-126+	2,93E-08	3,99E-11
Sb-124	3,19E-07	1,02E-10
Te-123m	8,49E-10	7,34E-12
Te-127m+	2,60E-13	1,38E-11
I-125	1,10E-12	1,58E-12
I-129	7,65E-13	1,10E-11
Cs-135	4,09E-18	2,14E-14
Ce-139	8,93E-10	3,02E-12
Ce-144+	6,28E-10	6,27E-11
Sm-147	0,00E+01	1,32E-10
Eu-155	1,50E-12	1,02E-13
Gd-153	2,09E-10	5,40E-12
Tb-160	1,75E-08	1,17E-11
Tm-170	5,49E-12	1,12E-11
Tm-171	6,28E-13	1,97E-12
Ta-182	2,13E-08	1,60E-11
W-181	4,18E-10	9,29E-13
W-185	4,43E-11	4,75E-12
Os-185	1,02E-08	3,02E-12
Ir-192	9,86E-08	1,06E-10
Tl-204	2,80E-12	1,34E-12
Pb-210+	2,25E-13	2,51E-09
Bi-207	2,44E-07	6,91E-11
Po-210	1,39E-13	4,75E-09
Ra-226+	2,91E-08	4,81E-09
Ra-228+	1,50E-08	3,73E-09
Ac-227+	3,85E-09	1,39E-06
Th-228+	2,56E-08	7,45E-08
Th-229+	3,26E-09	1,74E-07
Th-230	1,16E-12	6,05E-08
Th-232	3,68E-13	6,31E-08
Pa-231	2,86E-10	1,92E-07
U-232	6,98E-13	5,62E-08
U-233	8,55E-13	1,49E-08
U-236	1,22E-13	1,36E-08
Pu-236	7,83E-14	2,81E-08
Pu-242	3,82E-14	6,70E-08
Pu-244+	5,04E-09	6,48E-08
Am-242m+	1,09E-13	5,19E-08
Am-243+	1,21E-09	5,83E-08
Cm-242	5,67E-14	7,99E-09
Cm-243	8,80E-10	4,32E-08
Cm-245	2,93E-10	5,83E-08
Cm-246	3,40E-14	5,83E-08
Cm-247+	3,95E-09	5,40E-08
Cm-248	3,41E-14	2,05E-07
Bk-249	2,89E-15	2,16E-10
Cf-248	3,68E-14	1,32E-08
Cf-249	3,86E-09	9,72E-08
Cf-250	7,89E-14	4,75E-08
Cf-251	6,64E-10	9,94E-08
Cf-252	5,74E-14	2,81E-08
Cf-254	1,35E-17	4,75E-08
Es-254	1,59E-11	1,30E-08

- different working places

Appendix A

TABLE 4.4: ANNUAL DOSE RATES FOR OCCUPATIONAL USES OF EQUIPMENT (Sv/y)

NUCLIDE	MACHINE (3.5.1.1) EXTERNAL ARC	KITCHEN (3.5.1.2) EXTERNAL INDUCTION	PROCESS VESSEL (3.5.1.3) EXTERNAL INDUCTION	BOAT (3.5.1.4) EXTERNAL ARC
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	2,25E-06	5,22E-07	1,25E-06	6,12E-06
Fe55	5,97E-12	1,61E-11	6,82E-12	5,54E-11
Co60	7,31E-06	1,48E-06	3,41E-06	1,74E-05
Ni59	2,81E-12	7,58E-12	3,21E-12	2,60E-11
Ni63	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Zn65	1,66E-07	3,51E-08	8,66E-08	4,09E-07
Sr90+	2,73E-08	1,00E-08	2,18E-08	1,06E-07
Nb94	4,18E-07	9,90E-08	2,36E-07	1,16E-06
Tc99	3,58E-11	4,84E-11	3,99E-11	2,86E-10
Ru106+	1,17E-07	3,51E-08	8,32E-08	3,95E-07
Ag108m+	3,97E-06	1,05E-06	2,41E-06	1,22E-05
Ag110m+	7,43E-06	1,69E-06	4,18E-06	1,98E-05
Sb125+	8,51E-07	2,71E-07	6,16E-07	3,11E-06
Cs134	4,00E-09	9,87E-10	2,36E-09	1,15E-08
Cs137+	1,43E-09	3,60E-10	8,42E-10	4,21E-09
Pm147	7,29E-14	1,28E-13	8,27E-14	6,34E-13
Sm151	4,60E-17	1,24E-16	4,29E-17	4,25E-16
Eu152	2,96E-09	6,76E-10	1,72E-09	7,80E-09
Eu154	3,29E-09	7,41E-10	1,86E-09	8,55E-09
U234	2,93E-12	3,98E-12	2,68E-12	2,43E-11
U235+	1,42E-08	9,20E-09	1,24E-08	8,62E-08
U238+	2,29E-08	8,58E-09	1,85E-08	8,97E-08
Np237+	2,94E-08	1,31E-08	2,31E-08	1,33E-07
Pu238	4,67E-13	9,69E-13	4,37E-13	4,21E-12
Pu239	5,05E-12	2,67E-12	3,98E-12	2,39E-11
Pu240	5,02E-13	1,02E-12	4,69E-13	4,48E-12
Pu241	6,10E-14	7,44E-14	5,72E-14	4,95E-13
Am241	2,00E-10	5,12E-10	1,88E-10	1,85E-09
Cm244	2,21E-13	5,97E-13	2,06E-13	2,04E-12
Na-22	5,83E-09	1,35E-09	3,24E-12	1,56E-08
S-35	2,25E-15	4,91E-15	2,16E-15	2,05E-14
Cl-36	1,01E-12	6,40E-13	8,48E-13	5,58E-12
K-40	4,65E-10	8,98E-11	2,87E-13	1,05E-09
Ca-45	0,00E+01	4,38E-19	8,18E-19	1,15E-18
Sc-46	5,64E-07	1,23E-07	3,03E-08	1,44E-06
Mn-53	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Co-56	1,04E-05	2,03E-06	5,45E-06	2,37E-05
Co-57	9,51E-08	7,00E-08	5,79E-08	6,47E-07
Co-58	2,54E-06	6,18E-07	1,49E-06	7,21E-06
As-73	8,08E-10	2,00E-09	3,88E-10	7,33E-09
Se-75	5,72E-08	2,39E-08	3,92E-09	2,56E-07
Se-79	2,79E-13	6,09E-13	2,67E-13	2,55E-12
Sr-85	1,16E-07	3,30E-08	7,35E-09	3,80E-07
Y-91	1,02E-09	4,07E-10	7,72E-10	4,18E-09
Zr-93	3,56E-13	1,08E-12	2,31E-13	3,46E-12
Zr-95+	3,90E-06	9,52E-07	1,78E-06	1,11E-05
Nb-93m	6,19E-13	3,74E-12	5,92E-14	1,48E-11
Mo-93	3,46E-11	2,10E-10	3,29E-11	8,31E-10
Tc-97	6,00E-12	2,67E-11	4,15E-13	1,05E-10
Tc-97m	2,30E-11	4,26E-11	1,25E-12	2,30E-10

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TABLE 4.4 (cont.)				
Pd-107	3,33E-14	1,40E-12	2,36E-15	4,20E-13
Cd-109	3,65E-11	8,33E-11	9,34E-12	3,06E-10
Sn-113+	5,23E-08	1,68E-08	5,76E-11	1,90E-07
Sn-126+	4,81E-07	1,28E-07	4,18E-10	1,47E-06
Sb-124	5,18E-06	1,11E-06	2,80E-06	1,29E-05
Te-123m	1,42E-08	8,00E-09	9,25E-10	8,15E-08
Te-127m+	7,02E-12	7,84E-12	5,86E-12	4,14E-11
I-125	2,11E-11	4,56E-11	6,74E-14	1,60E-10
I-129	1,45E-11	3,30E-11	5,32E-14	1,15E-10
Cs-135	7,48E-17	1,37E-16	7,14E-17	6,57E-16
Ce-139	1,50E-08	8,24E-09	9,75E-10	8,31E-08
Ce-144+	1,03E-08	2,76E-09	8,56E-11	2,96E-08
Sm-147	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Eu-155	2,56E-11	3,07E-11	1,41E-14	2,13E-10
Gd-153	3,57E-09	4,59E-09	1,81E-10	2,94E-08
Tb-160	2,87E-07	6,60E-08	1,71E-08	7,64E-07
Tm-170	1,76E-10	1,11E-10	1,48E-10	9,40E-10
Tm-171	1,09E-11	2,55E-11	4,87E-13	9,91E-11
Ta-182	3,46E-07	7,70E-08	1,80E-08	8,74E-07
W-181	7,23E-09	1,61E-08	3,51E-09	6,55E-08
W-185	1,04E-09	1,06E-09	9,48E-10	7,35E-09
Os-185	1,67E-07	4,42E-08	1,07E-08	4,99E-07
Ir-192	1,61E-06	5,19E-07	1,14E-06	5,89E-06
Tl-204	8,57E-11	5,69E-11	7,26E-11	4,78E-10
Pb-210+	6,96E-12	5,69E-12	5,76E-12	3,79E-11
Bi-207	3,97E-06	9,43E-07	2,31E-06	1,08E-05
Po-210	2,26E-12	5,41E-13	1,29E-13	6,28E-12
Ra-226+	4,74E-07	1,04E-07	5,52E-11	1,21E-06
Ra-228+	2,45E-07	5,66E-08	1,75E-11	6,55E-07
Ac-227+	6,35E-08	2,41E-08	1,34E-10	2,56E-07
Th-228+	4,18E-07	8,42E-08	1,60E-11	9,67E-07
Th-229+	5,35E-08	1,93E-08	3,86E-10	1,99E-07
Th-230	1,94E-11	2,04E-11	1,22E-12	1,33E-10
Th-232	6,21E-12	8,79E-12	4,17E-13	4,99E-11
Pa-231	4,73E-09	1,83E-09	7,02E-10	1,99E-08
U-232	1,16E-11	1,25E-11	9,54E-13	8,31E-11
U-233	1,44E-11	1,26E-11	2,13E-12	1,08E-10
U-236	1,97E-12	5,24E-12	1,48E-13	2,23E-11
Pu-236	1,02E-12	4,45E-12	1,26E-13	1,64E-11
Pu-242	4,27E-13	2,53E-12	7,67E-14	8,85E-12
Pu-244+	8,22E-08	2,08E-08	1,85E-13	2,41E-07
Am-242m+	2,24E-12	2,50E-12	2,01E-12	1,55E-11
Am-243+	2,02E-08	1,25E-08	9,44E-11	1,11E-07
Cm-242	4,86E-13	3,30E-12	9,35E-14	1,22E-11
Cm-243	1,46E-08	7,44E-09	1,01E-09	7,45E-08
Cm-245	4,94E-09	3,91E-09	3,71E-10	3,45E-08
Cm-246	1,99E-13	2,23E-12	5,82E-14	7,96E-12
Cm-247+	6,49E-08	2,15E-08	4,34E-09	2,39E-07
Cm-248	2,80E-13	2,04E-12	4,41E-14	7,45E-12
Bk-249	5,01E-14	1,23E-13	9,11E-14	4,60E-13
Cf-248	1,68E-13	2,02E-12	5,86E-14	7,64E-12
Cf-249	6,35E-08	2,08E-08	4,50E-09	2,36E-07
Cf-250	8,90E-13	3,09E-12	1,78E-14	1,42E-11
Cf-251	1,11E-08	6,67E-09	7,93E-10	6,44E-08
Cf-252	5,58E-13	2,60E-12	1,15E-13	1,08E-11
Cf-254	2,40E-16	6,08E-16	1,81E-16	2,09E-15
Es-254	2,56E-10	1,74E-10	2,00E-11	1,35E-09

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TABLE 4.5: ANNUAL DOSE RATES FROM DOMESTIC USE OF RECYCLED MATERIALS (Sv/y)

NUCLIDE	BULDING (3.5.2.1) EXTERNAL ARC	RADIATOR (3.5.2.2) EXTERNAL ARC
H3	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01
Mn54	4,42E-07	2,59E-07
Fe55	0,00E+01	5,11E-12
Co60	1,48E-06	7,33E-07
Ni59	0,00E+01	2,41E-12
Ni63	0,00E+01	0,00E+01
Zn65	3,32E-08	1,74E-08
Sr90+	6,08E-09	4,84E-09
Nb94	8,18E-08	4,90E-08
Tc99	7,52E-12	1,95E-11
Ru106+	2,53E-08	1,73E-08
Ag108m+	7,64E-07	5,19E-07
Ag110m+	1,47E-06	8,38E-07
Sb125+	1,81E-07	1,34E-07
Cs134	7,77E-10	4,90E-10
Cs137+	2,74E-10	1,79E-10
Pm147	1,30E-14	4,82E-14
Sm151	4,24E-32	3,93E-17
Eu152	5,90E-10	3,34E-10
Eu154	6,60E-10	3,66E-10
U234	6,29E-13	1,63E-12
U235+	3,09E-09	4,37E-09
U238+	5,13E-09	4,12E-09
Np237+	5,92E-09	6,26E-09
Pu238	5,77E-14	3,44E-13
Pu239	1,03E-12	1,21E-12
Pu240	6,34E-14	3,60E-13
Pu241	1,46E-14	3,21E-14
Am241	1,36E-11	1,70E-10
Cm244	1,88E-16	1,89E-13
Na-22	1,15E-09	6,63E-10
S-35	2,88E-16	1,72E-15
Cl-36	1,85E-13	2,92E-13
K-40	9,43E-11	4,42E-11
Ca-45	2,39E-25	1,36E-19
Sc-46	1,13E-07	6,10E-08
Mn-53	0,00E+01	0,00E+01
Co-56	2,12E-06	1,00E-06
Co-57	1,93E-08	3,32E-08
Co-58	4,99E-07	3,05E-07
As-73	3,81E-11	6,71E-10
Se-75	1,06E-08	1,16E-08
Se-79	3,02E-14	2,16E-13
Sr-85	2,22E-08	1,62E-08
Y-91	1,89E-10	1,95E-10
Zr-93	1,61E-16	3,40E-13
Zr-95+	7,67E-07	4,69E-07
Nb-93m	2,54E-17	1,17E-12
Mo-93	1,43E-15	6,55E-11
Tc-97	2,45E-16	8,34E-12
Tc-97m	3,37E-12	1,58E-11

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TABLE 4.5 (cont.)		
Pd-107	6,21E-24	4,35E-14
Cd-109	0,00E+01	2,59E-11
Sn-113+	9,71E-09	8,22E-09
Sn-126+	9,32E-08	6,30E-08
Sb-124	1,04E-06	5,48E-07
Te-123m	2,67E-09	3,85E-09
Te-127m+	9,48E-13	2,85E-12
I-125	3,56E-15	1,43E-11
I-129	7,29E-15	1,04E-11
Cs-135	1,10E-17	5,11E-17
Ce-139	2,75E-09	3,93E-09
Ce-144+	2,09E-09	1,34E-09
Sm-147	0,00E+01	0,00E+01
Eu-155	5,05E-12	1,33E-11
Gd-153	6,32E-10	1,89E-09
Tb-160	5,69E-08	3,25E-08
Tm-170	3,18E-11	4,99E-11
Tm-171	7,69E-13	8,81E-12
Ta-182	6,95E-08	3,77E-08
W-181	6,30E-10	5,75E-09
W-185	1,95E-10	4,50E-10
Os-185	3,25E-08	2,16E-08
Ir-192	3,02E-07	2,55E-07
Tl-204	1,56E-11	2,56E-11
Pb-210+	1,10E-12	2,26E-12
Bi-207	7,87E-07	4,63E-07
Po-210	4,47E-13	2,66E-13
Ra-226+	9,50E-08	5,13E-08
Ra-228+	4,87E-08	2,80E-08
Ac-227+	1,18E-08	1,17E-08
Th-228+	8,60E-08	4,14E-08
Th-229+	1,02E-08	9,23E-09
Th-230	3,29E-12	8,48E-12
Th-232	1,01E-12	3,44E-12
Pa-231	8,67E-10	8,90E-10
U-232	2,01E-12	5,09E-12
U-233	2,98E-12	5,83E-12
U-236	2,72E-13	1,92E-12
Pu-236	9,19E-14	1,49E-12
Pu-242	2,65E-14	8,22E-13
Pu-244+	1,60E-08	1,02E-08
Am-242m+	4,18E-13	1,01E-12
Am-243+	3,79E-09	5,79E-09
Cm-242	3,47E-14	1,07E-12
Cm-243	2,75E-09	3,56E-09
Cm-245	9,95E-10	1,83E-09
Cm-246	1,59E-15	6,96E-13
Cm-247+	1,21E-08	1,05E-08
Cm-248	1,52E-14	6,53E-13
Bk-249	3,00E-15	4,18E-14
Cf-248	5,30E-16	6,30E-13
Cf-249	1,18E-08	1,03E-08
Cf-250	1,43E-13	1,10E-12
Cf-251	2,13E-09	3,17E-09
Cf-252	6,56E-14	8,81E-13
Cf-254	1,72E-18	1,93E-16
Es-254	4,44E-11	7,37E-11

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TABLE 4.6: ANNUAL DOSE RATES FROM ARC FURNACE SLAG DISPOSAL SCENARIO (Sv/y)

NUCLIDE	WORKERS EXTERNAL (3.6.1.1)	WORKERS INHALATION (3.6.1.2)	WORKERS INGESTION (3.6.1.3)	PUBLIC (RESIDENCE) (3.6.1.4) ADULT	PUBLIC (RESIDENCE) (3.6.1.4) CHILD	PUBLIC (RESIDENCE) (3.6.1.4) BABY
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	8,83E-07	1,95E-12	4,28E-12	8,02E-12	2,00E-11	4,92E-12
Fe55	7,81E-18	1,49E-13	1,99E-13	2,15E-15	7,45E-15	1,53E-14
Co60	2,72E-07	2,76E-12	2,05E-12	2,18E-09	5,47E-09	1,35E-09
Ni59	5,26E-17	3,57E-14	3,80E-14	1,68E-13	2,96E-13	7,31E-14
Ni63	0,00E+01	8,43E-14	9,04E-14	3,73E-13	7,01E-13	1,68E-13
Zn65	6,27E-07	4,54E-12	2,35E-11	8,10E-13	1,83E-12	4,07E-13
Sr90+	1,01E-07	1,28E-09	1,85E-09	1,15E-07	2,49E-07	1,82E-08
Nb94	1,66E-05	4,05E-10	1,03E-10	4,97E-07	1,24E-06	3,06E-07
Tc99	1,82E-12	5,19E-11	4,70E-11	8,49E-08	1,72E-07	3,19E-08
Ru106+	2,31E-07	5,67E-11	4,22E-11	7,59E-12	1,95E-11	4,47E-12
Ag108m+	1,79E-07	3,08E-12	1,39E-12	5,16E-09	1,28E-08	3,14E-09
Ag110m+	2,90E-07	1,18E-12	1,69E-12	3,51E-13	8,75E-13	2,14E-13
Sb125+	4,05E-09	6,42E-14	7,83E-14	9,86E-12	2,46E-11	6,07E-12
Cs134	1,61E-06	1,56E-11	1,15E-10	1,54E-09	3,84E-09	9,44E-10
Cs137+	5,79E-07	1,09E-11	7,84E-11	1,39E-08	3,45E-08	8,47E-09
Pm147	1,64E-11	5,67E-11	1,57E-11	1,56E-12	3,56E-12	1,70E-12
Sm151	6,32E-13	4,21E-11	5,91E-12	5,20E-12	1,17E-11	6,77E-12
Eu152	1,46E-05	4,38E-10	8,44E-11	2,61E-07	6,52E-07	1,60E-07
Eu154	1,29E-05	5,67E-10	1,21E-10	1,72E-07	4,30E-07	1,06E-07
U234	3,22E-10	1,10E-07	2,95E-09	1,96E-09	6,53E-09	2,55E-09
U235+	9,36E-07	9,89E-08	2,79E-09	2,98E-08	7,60E-08	1,96E-08
U238+	3,06E-07	9,25E-08	2,89E-09	9,86E-09	2,76E-08	6,83E-09
Np237+	1,72E-06	2,43E-07	6,69E-09	5,86E-08	1,51E-07	3,80E-08
Pu238	5,60E-11	4,86E-07	1,39E-08	6,68E-09	3,80E-08	1,10E-08
Pu239	2,23E-10	5,19E-07	1,51E-08	7,88E-09	4,49E-08	1,25E-08
Pu240	6,71E-11	5,19E-07	1,51E-08	7,87E-09	4,49E-08	1,25E-08
Pu241	1,45E-11	9,40E-09	2,83E-10	9,36E-11	5,55E-10	1,10E-10
Am241	3,07E-08	4,38E-07	1,21E-08	7,28E-09	3,93E-08	1,16E-08
Cm244	4,19E-11	2,76E-07	7,24E-09	2,56E-09	1,56E-08	5,65E-09
Na-22	2,30E-06	3,24E-12	1,93E-11	5,01E-09	1,23E-08	3,00E-09
S-35	0,00E+01	1,78E-11	4,64E-11	3,53E-21	7,34E-21	1,25E-21
Cl-36	1,54E-09	8,27E-11	5,61E-11	1,23E-07	2,52E-07	4,18E-08
K-40	1,87E-07	4,86E-12	3,74E-11	2,20E-08	4,84E-08	9,02E-09
Ca-45	2,07E-18	3,73E-11	4,58E-11	2,02E-16	5,13E-16	7,68E-17
Sc-46	2,23E-05	7,78E-11	9,04E-11	5,53E-20	1,38E-19	3,39E-20
Mn-53	0,00E+01	5,84E-14	1,81E-13	7,96E-12	1,73E-11	3,10E-12
Co-56	4,13E-07	7,94E-13	1,51E-12	1,44E-22	3,60E-22	8,86E-23
Co-57	3,62E-09	9,73E-14	1,27E-13	9,56E-15	2,39E-14	5,89E-15
Co-58	9,99E-08	2,76E-13	4,46E-13	9,14E-25	2,29E-24	5,63E-25
As-73	3,01E-12	1,05E-14	1,57E-14	2,18E-27	5,35E-27	1,58E-27
Se-75	2,21E-06	2,76E-11	1,57E-10	9,00E-17	2,16E-16	3,87E-17
Se-79	0,00E+01	5,02E-11	1,75E-10	7,69E-08	3,71E-07	3,74E-08
Sr-85	4,54E-06	9,08E-12	3,38E-11	1,71E-24	4,28E-24	1,04E-24
Y-91	7,22E-08	9,89E-11	1,45E-10	3,78E-28	9,99E-28	2,02E-28
Zr-93	0,00E+01	4,70E-12	1,69E-13	6,20E-14	6,05E-14	6,50E-14
Zr-95+	1,53E-07	8,91E-13	8,80E-13	2,90E-26	7,26E-26	1,79E-26
Nb-93m	4,80E-11	1,39E-11	7,24E-12	2,09E-11	4,76E-11	1,28E-11
Mo-93	2,69E-10	2,27E-11	1,57E-10	3,74E-09	4,84E-09	4,76E-10
Tc-97	3,56E-10	2,59E-12	5,00E-12	9,03E-09	1,86E-08	3,26E-09
Tc-97m	9,50E-10	4,38E-11	3,98E-11	3,38E-20	6,76E-20	1,26E-20

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TABLE 4.6 (cont.)						
Pd-107	0,00E+01	4,70E-14	2,23E-14	1,97E-13	4,34E-13	9,77E-14
Cd-109	1,21E-10	1,56E-11	1,21E-11	9,08E-12	1,59E-11	2,19E-12
Sn-113+	2,04E-07	3,13E-12	4,57E-12	1,74E-18	4,34E-18	1,06E-18
Sn-126+	1,89E-06	3,00E-11	3,06E-11	5,73E-08	1,43E-07	3,50E-08
Sb-124	2,06E-08	7,62E-14	1,51E-13	3,53E-28	8,84E-28	2,18E-28
Te-123m	5,45E-07	5,51E-11	8,44E-11	1,09E-17	2,72E-17	6,75E-18
Te-127m+	4,31E-08	1,03E-10	1,49E-10	1,16E-19	2,93E-19	8,13E-20
I-125	6,71E-09	1,18E-10	9,04E-10	4,71E-27	9,78E-27	1,20E-27
I-129	4,82E-09	8,27E-10	6,63E-09	5,87E-08	1,02E-07	7,70E-09
Cs-135	0,00E+01	1,60E-12	1,21E-11	3,11E-11	2,68E-11	3,72E-12
Ce-139	5,69E-07	2,27E-11	1,57E-11	1,77E-16	4,42E-16	1,09E-16
Ce-144+	6,32E-07	4,71E-10	3,17E-10	2,25E-12	6,17E-12	1,23E-12
Sm-147	0,00E+01	9,93E-08	2,97E-09	3,27E-09	7,58E-09	2,56E-09
Eu-155	9,70E-08	7,62E-11	1,93E-11	7,23E-10	1,81E-09	4,48E-10
Gd-153	1,34E-07	4,05E-11	1,63E-11	1,14E-13	2,86E-13	7,08E-14
Tb-160	1,13E-05	8,75E-11	9,65E-11	2,13E-22	5,32E-22	1,31E-22
Tm-170	1,02E-08	8,43E-11	7,84E-11	1,00E-18	2,67E-18	6,83E-19
Tm-171	4,07E-10	1,47E-11	6,63E-12	5,73E-13	1,35E-12	4,63E-13
Ta-182	1,37E-05	1,20E-10	9,04E-11	1,07E-16	2,67E-16	6,58E-17
W-181	2,71E-08	6,97E-13	4,58E-12	6,86E-19	1,70E-18	4,15E-19
W-185	9,44E-11	3,57E-12	2,65E-11	5,81E-25	1,28E-24	2,84E-25
Os-185	6,56E-07	2,27E-12	3,08E-12	3,44E-20	8,61E-20	2,12E-20
Ir-192	6,32E-08	7,94E-13	8,44E-13	2,83E-24	7,07E-24	1,74E-24
Tl-204	1,84E-09	1,00E-11	7,84E-11	1,53E-09	3,20E-09	5,56E-10
Pb-210+	1,31E-09	1,88E-09	4,11E-09	1,36E-08	3,75E-08	5,70E-09
Bi-207	1,57E-08	5,19E-14	7,84E-14	3,86E-10	9,63E-10	2,36E-10
Po-210	8,92E-11	3,57E-08	1,45E-08	9,80E-17	2,31E-16	8,44E-16
Ra-226+	1,91E-05	3,61E-08	1,69E-08	6,39E-07	1,63E-06	3,67E-07
Ra-228+	9,66E-06	2,80E-08	4,04E-08	1,42E-07	5,30E-07	9,03E-08
Ac-227+	2,60E-06	1,04E-05	7,28E-08	1,05E-07	3,80E-07	1,17E-07
Th-228+	1,67E-05	5,59E-07	8,51E-09	1,34E-08	3,39E-08	8,59E-09
Th-229+	2,10E-06	1,30E-06	3,61E-08	8,70E-08	2,88E-07	8,44E-08
Th-230	7,43E-10	4,54E-07	1,27E-08	9,19E-09	4,42E-08	1,27E-08
Th-232	2,40E-10	4,74E-07	1,34E-08	1,01E-08	5,26E-08	1,41E-08
Pa-231	1,83E-07	1,44E-06	4,28E-08	7,68E-07	1,05E-06	9,33E-08
U-232	4,52E-10	4,21E-07	1,99E-08	1,05E-08	2,90E-08	1,10E-08
U-233	5,50E-10	1,12E-07	3,01E-09	2,03E-09	6,66E-09	2,69E-09
U-236	8,25E-11	1,02E-07	2,77E-09	1,85E-09	6,03E-09	2,45E-09
Pu-236	5,40E-11	2,11E-07	5,19E-09	2,32E-10	1,45E-09	5,38E-10
Pu-242	2,71E-11	5,02E-07	1,45E-08	7,25E-09	4,49E-08	1,19E-08
Pu-244+	3,27E-06	4,86E-07	1,45E-08	1,05E-07	2,89E-07	7,17E-08
Am-242m+	5,99E-08	3,89E-07	1,15E-08	7,64E-09	3,80E-08	9,94E-09
Am-243+	7,79E-07	4,38E-07	1,21E-08	2,97E-08	9,57E-08	2,51E-08
Cm-242	3,72E-11	6,00E-08	7,24E-10	7,19E-17	5,71E-16	2,91E-16
Cm-243	5,64E-07	3,24E-07	9,04E-09	1,68E-08	5,45E-08	1,56E-08
Cm-245	1,88E-07	4,38E-07	1,27E-08	1,21E-08	5,15E-08	1,47E-08
Cm-246	2,25E-11	4,38E-07	1,27E-08	6,46E-09	3,74E-08	1,12E-08
Cm-247+	2,53E-06	4,05E-07	1,15E-08	8,14E-08	2,24E-07	5,67E-08
Cm-248	2,24E-11	1,54E-06	4,64E-08	2,38E-08	1,39E-07	4,10E-08
Bk-249	0,00E+01	1,62E-09	5,85E-11	3,27E-14	6,66E-14	1,85E-14
Cf-248	2,21E-11	9,89E-08	1,69E-09	1,43E-12	5,11E-12	1,72E-12
Cf-249	2,47E-06	7,29E-07	2,11E-08	1,04E-07	2,47E-07	6,15E-08
Cf-250	4,92E-11	3,57E-07	9,65E-09	8,87E-09	2,01E-08	6,53E-09
Cf-251	4,26E-07	7,46E-07	2,17E-08	4,59E-08	9,91E-08	2,51E-08
Cf-252	3,56E-11	2,11E-07	5,43E-09	6,17E-10	1,97E-09	7,32E-10
Cf-254	8,78E-15	3,57E-07	2,41E-08	2,59E-26	6,96E-26	2,96E-26
Es-254	1,01E-08	9,73E-08	1,69E-09	3,19E-13	1,08E-12	3,64E-13

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TABLE 4.7: ANNUAL DOSE RATES FROM INDUCTION FURNACE SLAG DISPOSAL SCENARIO (Sv/y)

NUCLIDE	WORKERS EXTERNAL (3.6.1.1)	WORKERS INHALATION (3.6.1.2)	WORKERS INGESTION (3.6.1.3)	PUBLIC (RESIDENCE) (3.6.1.4) ADULT	PUBLIC (RESIDENCE) (3.6.1.4) CHILD	PUBLIC (RESIDENCE) (3.6.1.4) BABY
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	1,32E-06	2,90E-12	6,39E-12	1,20E-11	2,99E-11	7,34E-12
Fe55	1,17E-17	2,23E-13	2,97E-13	3,21E-15	1,11E-14	2,28E-14
Co60	4,06E-07	4,11E-12	3,06E-12	3,26E-09	8,16E-09	2,01E-09
Ni59	7,85E-17	5,32E-14	5,67E-14	2,51E-13	4,41E-13	1,09E-13
Ni63	0,00E+01	1,26E-13	1,35E-13	5,57E-13	1,05E-12	2,51E-13
Zn65	9,36E-07	6,77E-12	3,51E-11	1,21E-12	2,74E-12	6,07E-13
Sr90+	1,51E-07	1,90E-09	2,76E-09	1,72E-07	3,72E-07	2,72E-08
Nb94	2,48E-05	6,05E-10	1,53E-10	7,42E-07	1,86E-06	4,57E-07
Tc99	2,71E-12	7,74E-11	7,02E-11	1,27E-07	2,57E-07	4,76E-08
Ru106+	3,45E-07	8,47E-11	6,30E-11	1,13E-11	2,91E-11	6,67E-12
Ag108m+	2,66E-07	4,60E-12	2,07E-12	7,71E-09	1,92E-08	4,68E-09
Ag110m+	4,33E-07	1,77E-12	2,52E-12	5,24E-13	1,31E-12	3,20E-13
Sb125+	6,05E-09	9,58E-14	1,17E-13	1,47E-11	3,68E-11	9,06E-12
Cs134	2,40E-06	2,32E-11	1,71E-10	2,30E-09	5,73E-09	1,41E-09
Cs137+	8,64E-07	1,62E-11	1,17E-10	2,07E-08	5,14E-08	1,26E-08
Pm147	2,46E-11	8,47E-11	2,34E-11	2,32E-12	5,31E-12	2,54E-12
Sm151	9,43E-13	6,29E-11	8,82E-12	7,76E-12	1,75E-11	1,01E-11
Eu152	2,17E-05	6,53E-10	1,26E-10	3,89E-07	9,73E-07	2,40E-07
Eu154	1,92E-05	8,47E-10	1,80E-10	2,56E-07	6,42E-07	1,58E-07
U234	4,81E-10	1,65E-07	4,41E-09	2,92E-09	9,74E-09	3,80E-09
U235+	1,40E-06	1,48E-07	4,17E-09	4,45E-08	1,13E-07	2,93E-08
U238+	4,57E-07	1,38E-07	4,31E-09	1,47E-08	4,13E-08	1,02E-08
Np237+	2,56E-06	3,63E-07	9,98E-09	8,74E-08	2,25E-07	5,67E-08
Pu238	8,35E-11	7,26E-07	2,07E-08	9,96E-09	5,67E-08	1,64E-08
Pu239	3,33E-10	7,74E-07	2,25E-08	1,18E-08	6,70E-08	1,87E-08
Pu240	1,00E-10	7,74E-07	2,25E-08	1,17E-08	6,70E-08	1,87E-08
Pu241	2,16E-11	1,40E-08	4,23E-10	1,40E-10	8,29E-10	1,65E-10
Am241	4,59E-08	6,53E-07	1,80E-08	1,09E-08	5,86E-08	1,73E-08
Cm244	6,25E-11	4,11E-07	1,08E-08	3,83E-09	2,33E-08	8,43E-09
Na-22	3,43E-06	4,84E-12	2,88E-11	7,47E-09	1,84E-08	4,47E-09
S-35	0,00E+01	2,66E-11	6,93E-11	5,27E-21	1,10E-20	1,87E-21
Cl-36	2,30E-09	1,23E-10	8,37E-11	1,84E-07	3,76E-07	6,25E-08
K-40	2,79E-07	7,25E-12	5,58E-11	3,28E-08	7,23E-08	1,35E-08
Ca-45	3,10E-18	5,56E-11	6,84E-11	3,02E-16	7,65E-16	1,15E-16
Sc-46	3,33E-05	1,16E-10	1,35E-10	8,26E-20	2,06E-19	5,05E-20
Mn-53	0,00E+01	8,71E-14	2,70E-13	1,19E-11	2,58E-11	4,62E-12
Co-56	6,16E-07	1,19E-12	2,25E-12	2,15E-22	5,37E-22	1,32E-22
Co-57	5,41E-09	1,45E-13	1,89E-13	1,43E-14	3,57E-14	8,79E-15
Co-58	1,49E-07	4,11E-13	6,66E-13	1,36E-24	3,41E-24	8,41E-25
As-73	4,49E-12	1,57E-14	2,34E-14	3,25E-27	7,98E-27	2,36E-27
Se-75	3,30E-06	4,11E-11	2,34E-10	1,34E-16	3,23E-16	5,78E-17
Se-79	0,00E+01	7,50E-11	2,61E-10	1,15E-07	5,54E-07	5,58E-08
Sr-85	6,78E-06	1,35E-11	5,04E-11	2,55E-24	6,38E-24	1,55E-24
Y-91	1,08E-07	1,48E-10	2,16E-10	5,65E-28	1,49E-27	3,01E-28
Zr-93	0,00E+01	7,02E-12	2,52E-13	9,25E-14	9,02E-14	9,71E-14
Zr-95+	2,29E-07	1,33E-12	1,31E-12	4,33E-26	1,08E-25	2,67E-26
Nb-93m	7,16E-11	2,08E-11	1,08E-11	3,12E-11	7,11E-11	1,91E-11
Mo-93	4,01E-10	3,39E-11	2,34E-10	5,59E-09	7,23E-09	7,10E-10
Tc-97	5,32E-10	3,87E-12	7,47E-12	1,35E-08	2,78E-08	4,87E-09
Tc-97m	1,42E-09	6,53E-11	5,94E-11	5,04E-20	1,01E-19	1,88E-20

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TABLE 4.7 (cont.)						
Pd-107	0,00E+01	7,02E-14	3,33E-14	2,94E-13	6,48E-13	1,46E-13
Cd-109	1,80E-10	2,32E-11	1,80E-11	1,35E-11	2,37E-11	3,27E-12
Sn-113+	3,04E-07	4,67E-12	6,82E-12	2,59E-18	6,47E-18	1,58E-18
Sn-126+	2,82E-06	4,47E-11	4,56E-11	8,56E-08	2,14E-07	5,22E-08
Sb-124	3,07E-08	1,14E-13	2,25E-13	5,27E-28	1,32E-27	3,25E-28
Te-123m	8,14E-07	8,23E-11	1,26E-10	1,63E-17	4,07E-17	1,01E-17
Te-127m+	6,44E-08	1,54E-10	2,22E-10	1,73E-19	4,38E-19	1,21E-19
I-125	1,00E-08	1,77E-10	1,35E-09	7,02E-27	1,46E-26	1,80E-27
I-129	7,20E-09	1,23E-09	9,90E-09	8,76E-08	1,52E-07	1,15E-08
Cs-135	0,00E+01	2,40E-12	1,80E-11	4,64E-11	4,00E-11	5,56E-12
Ce-139	8,50E-07	3,39E-11	2,34E-11	2,64E-16	6,60E-16	1,63E-16
Ce-144+	9,43E-07	7,02E-10	4,72E-10	3,35E-12	9,21E-12	1,84E-12
Sm-147	0,00E+01	1,48E-07	4,43E-09	4,88E-09	1,13E-08	3,82E-09
Eu-155	1,45E-07	1,14E-10	2,88E-11	1,08E-09	2,70E-09	6,69E-10
Gd-153	2,00E-07	6,05E-11	2,43E-11	1,71E-13	4,27E-13	1,06E-13
Tb-160	1,68E-05	1,31E-10	1,44E-10	3,17E-22	7,94E-22	1,96E-22
Tm-170	1,52E-08	1,26E-10	1,17E-10	1,49E-18	3,99E-18	1,02E-18
Tm-171	6,07E-10	2,20E-11	9,90E-12	8,55E-13	2,01E-12	6,92E-13
Ta-182	2,05E-05	1,79E-10	1,35E-10	1,59E-16	3,99E-16	9,83E-17
W-181	4,04E-08	1,04E-12	6,84E-12	1,02E-18	2,54E-18	6,20E-19
W-185	1,41E-10	5,32E-12	3,96E-11	8,68E-25	1,92E-24	4,24E-25
Os-185	9,79E-07	3,39E-12	4,59E-12	5,14E-20	1,29E-19	3,16E-20
Ir-192	9,43E-08	1,19E-12	1,26E-12	4,22E-24	1,06E-23	2,60E-24
Tl-204	2,74E-09	1,50E-11	1,17E-10	2,29E-09	4,78E-09	8,30E-10
Pb-210+	1,95E-09	2,81E-09	6,13E-09	2,02E-08	5,59E-08	8,51E-09
Bi-207	2,34E-08	7,74E-14	1,17E-13	5,76E-10	1,44E-09	3,52E-10
Po-210	1,33E-10	5,32E-08	2,16E-08	1,46E-16	3,45E-16	1,26E-15
Ra-226+	2,85E-05	5,38E-08	2,52E-08	9,54E-07	2,44E-06	5,48E-07
Ra-228+	1,44E-05	4,18E-08	6,03E-08	2,12E-07	7,92E-07	1,35E-07
Ac-227+	3,88E-06	1,56E-05	1,09E-07	1,57E-07	5,68E-07	1,75E-07
Th-228+	2,50E-05	8,34E-07	1,27E-08	2,00E-08	5,07E-08	1,28E-08
Th-229+	3,13E-06	1,94E-06	5,39E-08	1,30E-07	4,31E-07	1,26E-07
Th-230	1,11E-09	6,77E-07	1,89E-08	1,37E-08	6,59E-08	1,90E-08
Th-232	3,58E-10	7,07E-07	1,99E-08	1,51E-08	7,86E-08	2,10E-08
Pa-231	2,73E-07	2,15E-06	6,39E-08	1,15E-06	1,56E-06	1,39E-07
U-232	6,75E-10	6,29E-07	2,97E-08	1,56E-08	4,33E-08	1,64E-08
U-233	8,21E-10	1,67E-07	4,50E-09	3,03E-09	9,94E-09	4,02E-09
U-236	1,23E-10	1,52E-07	4,14E-09	2,76E-09	9,00E-09	3,66E-09
Pu-236	8,06E-11	3,14E-07	7,74E-09	3,46E-10	2,16E-09	8,02E-10
Pu-242	4,05E-11	7,50E-07	2,16E-08	1,08E-08	6,70E-08	1,78E-08
Pu-244+	4,88E-06	7,26E-07	2,17E-08	1,56E-07	4,31E-07	1,07E-07
Am-242m+	8,93E-08	5,81E-07	1,71E-08	1,14E-08	5,68E-08	1,48E-08
Am-243+	1,16E-06	6,53E-07	1,81E-08	4,43E-08	1,43E-07	3,75E-08
Cm-242	5,56E-11	8,95E-08	1,08E-09	1,07E-16	8,52E-16	4,34E-16
Cm-243	8,42E-07	4,84E-07	1,35E-08	2,51E-08	8,13E-08	2,33E-08
Cm-245	2,81E-07	6,53E-07	1,89E-08	1,81E-08	7,68E-08	2,19E-08
Cm-246	3,36E-11	6,53E-07	1,89E-08	9,64E-09	5,58E-08	1,67E-08
Cm-247+	3,77E-06	6,05E-07	1,71E-08	1,22E-07	3,34E-07	8,46E-08
Cm-248	3,35E-11	2,30E-06	6,93E-08	3,55E-08	2,07E-07	6,12E-08
Bk-249	0,00E+01	2,42E-09	8,73E-11	4,88E-14	9,94E-14	2,76E-14
Cf-248	3,30E-11	1,48E-07	2,52E-09	2,13E-12	7,63E-12	2,57E-12
Cf-249	3,69E-06	1,09E-06	3,15E-08	1,56E-07	3,69E-07	9,18E-08
Cf-250	7,34E-11	5,32E-07	1,44E-08	1,32E-08	3,00E-08	9,75E-09
Cf-251	6,35E-07	1,11E-06	3,24E-08	6,85E-08	1,48E-07	3,74E-08
Cf-252	5,31E-11	3,14E-07	8,10E-09	9,21E-10	2,94E-09	1,09E-09
Cf-254	1,31E-14	5,32E-07	3,60E-08	3,86E-26	1,04E-25	4,41E-26
Es-254	1,50E-08	1,45E-07	2,52E-09	4,77E-13	1,60E-12	5,43E-13

Appendix A

TABLE 4.8: ANNUAL DOSE RATES FROM ARC FURNACE DUST DISPOSAL SCENARIO (Sv/y)

NUCLIDE	WORKERS			PUBLIC (RESIDENCE) (3.6.1.4)		
	EXTERNAL (3.6.1.1)	INHALATION (3.6.1.2)	INGESTION (3.6.1.3)	ADULT	CHILD	BABY
H3	0,00E+01	8,75E-13	3,26E-12	1,32E-09	1,69E-09	1,76E-10
C14	0,00E+01	2,82E-11	1,05E-10	6,41E-08	8,85E-08	8,88E-09
Mn54	1,32E-06	2,92E-12	6,42E-12	1,10E-18	2,74E-18	6,73E-19
Fe55	1,17E-17	2,24E-13	2,98E-13	1,83E-17	6,34E-17	1,30E-16
Co60	4,08E-07	4,13E-12	3,08E-12	2,36E-10	5,91E-10	1,45E-10
Ni59	1,58E-17	1,07E-14	1,14E-14	5,05E-14	8,87E-14	2,19E-14
Ni63	0,00E+01	2,53E-14	2,71E-14	9,69E-14	1,82E-13	4,37E-14
Zn65	1,88E-05	1,36E-10	7,06E-10	2,37E-20	5,36E-20	1,19E-20
Sr90+	3,04E-08	3,83E-10	5,55E-10	2,11E-08	4,57E-08	3,34E-09
Nb94	4,99E-08	1,22E-12	3,08E-13	1,49E-09	3,73E-09	9,18E-10
Tc99	5,46E-15	1,56E-13	1,41E-13	2,55E-10	5,17E-10	9,56E-11
Ru106+	6,94E-06	1,70E-09	1,27E-09	2,86E-16	7,34E-16	1,68E-16
Ag108m+	5,36E-06	9,24E-11	4,16E-11	1,39E-07	3,46E-07	8,44E-08
Ag110m+	8,71E-06	3,55E-11	5,07E-11	1,67E-20	4,16E-20	1,02E-20
Sb125+	1,22E-07	1,93E-12	2,35E-12	1,95E-12	4,87E-12	1,20E-12
Cs134	4,83E-05	4,67E-10	3,44E-09	4,68E-11	1,17E-10	2,87E-11
Cs137+	1,74E-05	3,26E-10	2,35E-09	2,62E-07	6,51E-07	1,60E-07
Pm147	4,93E-14	1,70E-13	4,70E-14	2,35E-17	5,38E-17	2,57E-17
Sm151	1,90E-15	1,26E-13	1,77E-14	1,34E-14	3,01E-14	1,74E-14
Eu152	4,37E-08	1,31E-12	2,53E-13	2,80E-10	7,00E-10	1,72E-10
Eu154	3,87E-08	1,70E-12	3,62E-13	1,03E-10	2,57E-10	6,33E-11
U234	9,67E-13	3,31E-10	8,86E-12	5,87E-12	1,96E-11	7,64E-12
U235+	2,81E-09	2,97E-10	8,38E-12	8,94E-11	2,28E-10	5,89E-11
U238+	9,19E-10	2,77E-10	8,67E-12	2,96E-11	8,29E-11	2,05E-11
Np237+	5,15E-09	7,30E-10	2,01E-11	1,76E-10	4,53E-10	1,14E-10
Pu238	1,68E-13	1,46E-09	4,16E-11	1,71E-11	9,73E-11	2,82E-11
Pu239	6,70E-13	1,56E-09	4,52E-11	2,36E-11	1,35E-10	3,76E-11
Pu240	2,01E-13	1,56E-09	4,52E-11	2,36E-11	1,34E-10	3,75E-11
Pu241	4,34E-14	2,82E-11	8,50E-13	1,07E-13	6,36E-13	1,27E-13
Am241	9,22E-11	1,31E-09	3,62E-11	2,12E-11	1,14E-10	3,37E-11
Cm244	1,26E-13	8,27E-10	2,17E-11	3,58E-12	2,17E-11	7,88E-12
Na-22	6,89E-05	9,73E-11	5,79E-10	7,27E-10	1,79E-09	4,35E-10
S-35	0,00E+01	5,35E-12	1,39E-11	8,81E-47	1,83E-46	3,12E-47
Cl-36	4,62E-09	2,48E-10	1,68E-10	3,70E-07	7,56E-07	1,26E-07
K-40	5,61E-06	1,46E-10	1,12E-09	6,60E-07	1,45E-06	2,71E-07
Ca-45	6,22E-19	1,12E-11	1,37E-11	1,93E-30	4,91E-30	7,35E-31
Sc-46	6,69E-06	2,33E-11	2,71E-11	1,12E-46	2,79E-46	6,85E-47
Mn-53	0,00E+01	8,75E-14	2,71E-13	1,19E-11	2,59E-11	4,65E-12
Co-56	6,19E-07	1,19E-12	2,26E-12	2,93E-50	7,32E-50	1,80E-50
Co-57	5,43E-09	1,46E-13	1,90E-13	1,11E-22	2,77E-22	6,82E-23
Co-58	1,50E-07	4,13E-13	6,69E-13	1,29E-55	3,22E-55	7,93E-56
As-73	9,03E-11	3,16E-13	4,70E-13	2,84E-53	6,99E-53	2,07E-53
Se-75	6,63E-07	8,27E-12	4,70E-11	1,20E-35	2,89E-35	5,17E-36
Se-79	0,00E+01	1,51E-11	5,25E-11	2,31E-08	1,11E-07	1,12E-08
Sr-85	1,36E-06	2,72E-12	1,01E-11	7,82E-59	1,96E-58	4,77E-59
Y-91	2,17E-08	2,97E-11	4,34E-11	2,72E-66	7,18E-66	1,45E-66
Zr-93	0,00E+01	7,05E-12	2,53E-13	9,30E-14	9,07E-14	9,75E-14
Zr-95+	2,30E-07	1,34E-12	1,32E-12	1,75E-60	4,38E-60	1,08E-60
Nb-93m	1,44E-13	4,18E-14	2,17E-14	2,42E-14	5,53E-14	1,49E-14
Mo-93	8,06E-11	6,81E-12	4,70E-11	1,12E-09	1,45E-09	1,42E-10
Tc-97	1,07E-12	7,78E-15	1,50E-14	2,71E-11	5,58E-11	9,78E-12
Tc-97m	2,85E-12	1,31E-13	1,19E-13	2,17E-47	4,34E-47	8,10E-48

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TABLE 4.8 (cont.)						
Pd-107	0,00E+01	1,41E-14	6,69E-15	5,92E-14	1,30E-13	2,93E-14
Cd-109	3,62E-09	4,67E-10	3,62E-10	4,96E-15	8,68E-15	1,20E-15
Sn-113+	6,11E-06	9,39E-11	1,37E-10	4,06E-36	1,01E-35	2,48E-36
Sn-126+	5,66E-05	8,99E-10	9,18E-10	1,72E-06	4,29E-06	1,05E-06
Sb-124	6,17E-07	2,29E-12	4,52E-12	3,50E-63	8,77E-63	2,16E-63
Te-123m	1,64E-07	1,65E-11	2,53E-11	1,46E-36	3,64E-36	9,01E-37
Te-127m+	1,29E-08	3,10E-11	4,46E-11	2,57E-40	6,50E-40	1,80E-40
I-125	2,01E-08	3,55E-10	2,71E-09	4,67E-63	9,70E-63	1,19E-63
I-129	1,45E-08	2,48E-09	1,99E-08	1,76E-07	3,05E-07	2,31E-08
Cs-135	0,00E+01	4,81E-11	3,62E-10	9,33E-10	8,04E-10	1,12E-10
Ce-139	1,71E-07	6,81E-12	4,70E-12	5,73E-33	1,43E-32	3,53E-33
Ce-144+	1,89E-07	1,41E-10	9,50E-11	1,26E-20	3,47E-20	6,92E-21
Sm-147	0,00E+01	2,98E-10	8,90E-12	9,82E-12	2,27E-11	7,67E-12
Eu-155	2,91E-10	2,29E-13	5,79E-14	1,33E-13	3,31E-13	8,22E-14
Gd-153	4,02E-10	1,22E-13	4,88E-14	2,77E-25	6,94E-25	1,72E-25
Tb-160	3,39E-08	2,63E-13	2,89E-13	2,54E-55	6,34E-55	1,56E-55
Tm-170	3,06E-11	2,53E-13	2,35E-13	2,38E-38	6,37E-38	1,63E-38
Tm-171	1,22E-12	4,42E-14	1,99E-14	1,26E-18	2,96E-18	1,02E-18
Ta-182	4,12E-08	3,60E-13	2,71E-13	2,17E-38	5,42E-38	1,34E-38
W-181	8,12E-09	2,09E-13	1,37E-12	1,34E-37	3,33E-37	8,14E-38
W-185	2,83E-11	1,07E-12	7,96E-12	1,05E-54	2,32E-54	5,13E-55
Os-185	1,97E-05	6,81E-11	9,23E-11	3,17E-42	7,93E-42	1,95E-42
Ir-192	9,48E-08	1,19E-12	1,27E-12	9,46E-54	2,36E-53	5,82E-54
Tl-204	5,52E-10	3,01E-12	2,35E-11	1,18E-11	2,46E-11	4,26E-12
Pb-210+	3,92E-08	5,64E-08	1,23E-07	2,19E-07	6,04E-07	9,19E-08
Bi-207	4,70E-07	1,56E-12	2,35E-12	7,65E-09	1,91E-08	4,68E-09
Po-210	2,68E-11	1,07E-08	4,34E-09	3,86E-33	9,09E-33	3,32E-32
Ra-226+	5,73E-06	1,08E-08	5,07E-09	1,90E-07	4,86E-07	1,09E-07
Ra-228+	2,90E-06	8,41E-09	1,21E-08	3,82E-09	1,43E-08	2,43E-09
Ac-227+	7,80E-07	3,13E-06	2,18E-08	1,67E-08	6,04E-08	1,87E-08
Th-228+	5,02E-08	1,68E-09	2,55E-11	2,83E-14	7,18E-14	1,82E-14
Th-229+	6,30E-09	3,91E-09	1,08E-10	2,61E-10	8,64E-10	2,53E-10
Th-230	2,23E-12	1,36E-09	3,80E-11	2,76E-11	1,32E-10	3,81E-11
Th-232	7,19E-13	1,42E-09	4,01E-11	3,04E-11	1,58E-10	4,22E-11
Pa-231	5,48E-10	4,33E-09	1,28E-10	2,30E-09	3,14E-09	2,80E-10
U-232	1,36E-12	1,26E-09	5,97E-11	2,59E-11	7,17E-11	2,72E-11
U-233	1,65E-12	3,36E-10	9,04E-12	6,09E-12	2,00E-11	8,07E-12
U-236	2,47E-13	3,06E-10	8,32E-12	5,55E-12	1,81E-11	7,35E-12
Pu-236	1,62E-13	6,32E-10	1,56E-11	5,37E-15	3,36E-14	1,25E-14
Pu-242	8,13E-14	1,51E-09	4,34E-11	2,17E-11	1,35E-10	3,57E-11
Pu-244+	9,82E-09	1,46E-09	4,36E-11	3,14E-10	8,67E-10	2,15E-10
Am-242m+	1,80E-10	1,17E-09	3,44E-11	2,09E-11	1,04E-10	2,72E-11
Am-243+	2,34E-09	1,31E-09	3,63E-11	8,89E-11	2,87E-10	7,51E-11
Cm-242	1,12E-13	1,80E-10	2,17E-12	7,38E-33	5,86E-32	2,99E-32
Cm-243	1,69E-09	9,73E-10	2,71E-11	3,10E-11	1,01E-10	2,88E-11
Cm-245	5,64E-10	1,31E-09	3,80E-11	3,64E-11	1,54E-10	4,39E-11
Cm-246	6,74E-14	1,31E-09	3,80E-11	1,93E-11	1,12E-10	3,35E-11
Cm-247+	7,58E-09	1,22E-09	3,44E-11	2,44E-10	6,72E-10	1,70E-10
Cm-248	6,73E-14	4,62E-09	1,39E-10	7,13E-11	4,16E-10	1,23E-10
Bk-249	0,00E+01	4,86E-12	1,75E-13	1,34E-23	2,74E-23	7,59E-24
Cf-248	6,63E-14	2,97E-10	5,07E-12	1,11E-21	3,98E-21	1,34E-21
Cf-249	7,42E-09	2,19E-09	6,33E-11	3,01E-10	7,13E-10	1,77E-10
Cf-250	1,48E-13	1,07E-09	2,89E-11	9,23E-12	2,10E-11	6,80E-12
Cf-251	1,28E-09	2,24E-09	6,51E-11	1,36E-10	2,93E-10	7,40E-11
Cf-252	1,07E-13	6,32E-10	1,63E-11	9,71E-15	3,10E-14	1,15E-14
Cf-254	2,63E-17	1,07E-09	7,24E-11	4,26E-65	1,15E-64	4,86E-65
Es-254	3,02E-11	2,92E-10	5,07E-12	1,02E-23	3,43E-23	1,16E-23

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TABLE 4.9: ANNUAL DOSE RATES FROM INDUCTION FURNACE DUST DISPOSAL SCENARIO (Sv/y)

NUCLIDE	WORKERS EXTERNAL (3.6.1.1)	WORKERS INHALATION (3.6.1.2)	WORKERS INGESTION (3.6.1.3)	PUBLIC (RESIDENCE) (3.6.1.4) ADULT	PUBLIC (RESIDENCE) (3.6.1.4) CHILD	PUBLIC (RESIDENCE) (3.6.1.4) BABY
H3	0,00E+01	4,38E-13	1,63E-12	6,61E-10	8,44E-10	8,82E-11
C14	0,00E+01	1,41E-11	5,25E-11	3,21E-08	4,42E-08	4,44E-09
Mn54	6,62E-07	1,46E-12	3,21E-12	5,48E-19	1,37E-18	3,36E-19
Fe55	5,86E-18	1,12E-13	1,49E-13	9,17E-18	3,17E-17	6,50E-17
Co60	2,04E-07	2,07E-12	1,54E-12	1,18E-10	2,95E-10	7,27E-11
Ni59	7,89E-18	5,35E-15	5,70E-15	2,53E-14	4,44E-14	1,10E-14
Ni63	0,00E+01	1,26E-14	1,36E-14	4,85E-14	9,10E-14	2,19E-14
Zn65	9,41E-06	6,81E-11	3,53E-10	1,18E-20	2,68E-20	5,95E-21
Sr90+	1,52E-08	1,91E-10	2,78E-10	1,06E-08	2,29E-08	1,67E-09
Nb94	2,50E-08	6,08E-13	1,54E-13	7,46E-10	1,86E-09	4,59E-10
Tc99	2,73E-15	7,78E-14	7,06E-14	1,27E-10	2,59E-10	4,78E-11
Ru106+	3,47E-06	8,51E-10	6,33E-10	1,43E-16	3,67E-16	8,42E-17
Ag108m+	2,68E-06	4,62E-11	2,08E-11	6,95E-08	1,73E-07	4,22E-08
Ag110m+	4,36E-06	1,77E-11	2,53E-11	8,34E-21	2,08E-20	5,09E-21
Sb125+	6,08E-08	9,63E-13	1,17E-12	9,75E-13	2,44E-12	6,00E-13
Cs134	2,42E-05	2,33E-10	1,72E-09	2,34E-11	5,83E-11	1,43E-11
Cs137+	8,68E-06	1,63E-10	1,18E-09	1,31E-07	3,26E-07	8,00E-08
Pm147	2,47E-14	8,51E-14	2,35E-14	1,18E-17	2,69E-17	1,29E-17
Sm151	9,48E-16	6,32E-14	8,86E-15	6,69E-15	1,50E-14	8,71E-15
Eu152	2,19E-08	6,56E-13	1,27E-13	1,40E-10	3,50E-10	8,62E-11
Eu154	1,93E-08	8,51E-13	1,81E-13	5,13E-11	1,28E-10	3,16E-11
U234	4,83E-13	1,65E-10	4,43E-12	2,93E-12	9,79E-12	3,82E-12
U235+	1,40E-09	1,48E-10	4,19E-12	4,47E-11	1,14E-10	2,95E-11
U238+	4,60E-10	1,39E-10	4,33E-12	1,48E-11	4,15E-11	1,02E-11
Np237+	2,58E-09	3,65E-10	1,00E-11	8,79E-11	2,27E-10	5,70E-11
Pu238	8,39E-14	7,29E-10	2,08E-11	8,54E-12	4,87E-11	1,41E-11
Pu239	3,35E-13	7,78E-10	2,26E-11	1,18E-11	6,73E-11	1,88E-11
Pu240	1,01E-13	7,78E-10	2,26E-11	1,18E-11	6,71E-11	1,87E-11
Pu241	2,17E-14	1,41E-11	4,25E-13	5,36E-14	3,18E-13	6,33E-14
Am241	4,61E-11	6,56E-10	1,81E-11	1,06E-11	5,70E-11	1,69E-11
Cm244	6,28E-14	4,13E-10	1,09E-11	1,79E-12	1,09E-11	3,94E-12
Na-22	3,44E-05	4,86E-11	2,89E-10	3,64E-10	8,96E-10	2,18E-10
S-35	0,00E+01	2,67E-12	6,96E-12	4,40E-47	9,15E-47	1,56E-47
Cl-36	2,31E-09	1,24E-10	8,41E-11	1,85E-07	3,78E-07	6,28E-08
K-40	2,81E-06	7,29E-11	5,60E-10	3,30E-07	7,26E-07	1,35E-07
Ca-45	3,11E-19	5,59E-12	6,87E-12	9,67E-31	2,45E-30	3,67E-31
Sc-46	3,34E-06	1,17E-11	1,36E-11	5,60E-47	1,40E-46	3,43E-47
Mn-53	0,00E+01	4,38E-14	1,36E-13	5,97E-12	1,29E-11	2,32E-12
Co-56	3,10E-07	5,96E-13	1,13E-12	1,46E-50	3,66E-50	9,02E-51
Co-57	2,72E-09	7,29E-14	9,50E-14	5,53E-23	1,39E-22	3,41E-23
Co-58	7,49E-08	2,07E-13	3,35E-13	6,44E-56	1,61E-55	3,97E-56
As-73	4,52E-11	1,58E-13	2,35E-13	1,42E-53	3,50E-53	1,04E-53
Se-75	3,31E-07	4,13E-12	2,35E-11	6,01E-36	1,44E-35	2,58E-36
Se-79	0,00E+01	7,54E-12	2,62E-11	1,15E-08	5,57E-08	5,60E-09
Sr-85	6,81E-07	1,36E-12	5,07E-12	3,91E-59	9,79E-59	2,38E-59
Y-91	1,08E-08	1,48E-11	2,17E-11	1,36E-66	3,59E-66	7,25E-67
Zr-93	0,00E+01	3,53E-12	1,27E-13	4,65E-14	4,53E-14	4,88E-14
Zr-95+	1,15E-07	6,68E-13	6,60E-13	8,75E-61	2,19E-60	5,39E-61
Nb-93m	7,19E-14	2,09E-14	1,09E-14	1,21E-14	2,77E-14	7,43E-15
Mo-93	4,03E-11	3,40E-12	2,35E-11	5,59E-10	7,23E-10	7,11E-11
Tc-97	5,35E-13	3,89E-15	7,51E-15	1,35E-11	2,79E-11	4,89E-12
Tc-97m	1,43E-12	6,56E-14	5,97E-14	1,08E-47	2,17E-47	4,05E-48

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TABLE 4.9 (cont.)						
Pd-107	0,00E+01	7,05E-15	3,35E-15	2,96E-14	6,51E-14	1,47E-14
Cd-109	1,81E-09	2,33E-10	1,81E-10	2,48E-15	4,34E-15	5,99E-16
Sn-113+	3,05E-06	4,70E-11	6,86E-11	2,03E-36	5,06E-36	1,24E-36
Sn-126+	2,83E-05	4,49E-10	4,59E-10	8,60E-07	2,15E-06	5,25E-07
Sb-124	3,08E-07	1,14E-12	2,26E-12	1,75E-63	4,38E-63	1,08E-63
Te-123m	8,18E-08	8,27E-12	1,27E-11	7,28E-37	1,82E-36	4,51E-37
Te-127m+	6,47E-09	1,55E-11	2,23E-11	1,29E-40	3,25E-40	9,01E-41
I-125	1,01E-08	1,77E-10	1,36E-09	2,33E-63	4,85E-63	5,97E-64
I-129	7,24E-09	1,24E-09	9,95E-09	8,80E-08	1,52E-07	1,15E-08
Cs-135	0,00E+01	2,41E-11	1,81E-10	4,66E-10	4,02E-10	5,59E-11
Ce-139	8,54E-08	3,40E-12	2,35E-12	2,87E-33	7,17E-33	1,77E-33
Ce-144+	9,47E-08	7,06E-11	4,75E-11	6,32E-21	1,74E-20	3,46E-21
Sm-147	0,00E+01	1,49E-10	4,45E-12	4,91E-12	1,14E-11	3,84E-12
Eu-155	1,45E-10	1,14E-13	2,89E-14	6,63E-14	1,66E-13	4,11E-14
Gd-153	2,01E-10	6,08E-14	2,44E-14	1,39E-25	3,47E-25	8,58E-26
Tb-160	1,69E-08	1,31E-13	1,45E-13	1,27E-55	3,17E-55	7,81E-56
Tm-170	1,53E-11	1,26E-13	1,18E-13	1,19E-38	3,18E-38	8,13E-39
Tm-171	6,10E-13	2,21E-14	9,95E-15	6,30E-19	1,48E-18	5,09E-19
Ta-182	2,06E-08	1,80E-13	1,36E-13	1,08E-38	2,71E-38	6,68E-39
W-181	4,06E-09	1,05E-13	6,87E-13	6,71E-38	1,67E-37	4,07E-38
W-185	1,42E-11	5,35E-13	3,98E-12	5,25E-55	1,16E-54	2,57E-55
Os-185	9,84E-06	3,40E-11	4,61E-11	1,59E-42	3,96E-42	9,75E-43
Ir-192	4,74E-08	5,96E-13	6,33E-13	4,73E-54	1,18E-53	2,91E-54
Tl-204	2,76E-10	1,51E-12	1,18E-11	5,89E-12	1,23E-11	2,13E-12
Pb-210+	1,96E-08	2,82E-08	6,16E-08	1,09E-07	3,02E-07	4,60E-08
Bi-207	2,35E-07	7,78E-13	1,18E-12	3,82E-09	9,54E-09	2,34E-09
Po-210	1,34E-11	5,35E-09	2,17E-09	1,93E-33	4,54E-33	1,66E-32
Ra-226+	2,86E-06	5,41E-09	2,53E-09	9,50E-08	2,43E-07	5,46E-08
Ra-228+	1,45E-06	4,20E-09	6,06E-09	1,91E-09	7,14E-09	1,22E-09
Ac-227+	3,90E-07	1,56E-06	1,09E-08	8,35E-09	3,02E-08	9,33E-09
Th-228+	2,51E-08	8,38E-10	1,28E-11	1,42E-14	3,59E-14	9,09E-15
Th-229+	3,15E-09	1,95E-09	5,42E-11	1,30E-10	4,32E-10	1,26E-10
Th-230	1,11E-12	6,81E-10	1,90E-11	1,38E-11	6,62E-11	1,91E-11
Th-232	3,59E-13	7,10E-10	2,00E-11	1,52E-11	7,90E-11	2,11E-11
Pa-231	2,74E-10	2,16E-09	6,42E-11	1,15E-09	1,57E-09	1,40E-10
U-232	6,78E-13	6,32E-10	2,98E-11	1,30E-11	3,59E-11	1,36E-11
U-233	8,25E-13	1,68E-10	4,52E-12	3,05E-12	9,99E-12	4,04E-12
U-236	1,24E-13	1,53E-10	4,16E-12	2,78E-12	9,04E-12	3,68E-12
Pu-236	8,10E-14	3,16E-10	7,78E-12	2,69E-15	1,68E-14	6,23E-15
Pu-242	4,07E-14	7,54E-10	2,17E-11	1,09E-11	6,73E-11	1,79E-11
Pu-244+	4,91E-09	7,29E-10	2,18E-11	1,57E-10	4,33E-10	1,08E-10
Am-242m+	8,98E-11	5,84E-10	1,72E-11	1,05E-11	5,21E-11	1,36E-11
Am-243+	1,17E-09	6,56E-10	1,82E-11	4,45E-11	1,43E-10	3,76E-11
Cm-242	5,59E-14	9,00E-11	1,09E-12	3,69E-33	2,93E-32	1,49E-32
Cm-243	8,47E-10	4,86E-10	1,36E-11	1,55E-11	5,03E-11	1,44E-11
Cm-245	2,82E-10	6,56E-10	1,90E-11	1,82E-11	7,71E-11	2,20E-11
Cm-246	3,37E-14	6,56E-10	1,90E-11	9,66E-12	5,59E-11	1,67E-11
Cm-247+	3,79E-09	6,08E-10	1,72E-11	1,22E-10	3,36E-10	8,50E-11
Cm-248	3,36E-14	2,31E-09	6,96E-11	3,56E-11	2,08E-10	6,15E-11
Bk-249	0,00E+01	2,43E-12	8,77E-14	6,72E-24	1,37E-23	3,79E-24
Cf-248	3,31E-14	1,48E-10	2,53E-12	5,57E-22	1,99E-21	6,71E-22
Cf-249	3,71E-09	1,09E-09	3,17E-11	1,50E-10	3,57E-10	8,87E-11
Cf-250	7,38E-14	5,35E-10	1,45E-11	4,62E-12	1,05E-11	3,40E-12
Cf-251	6,39E-10	1,12E-09	3,26E-11	6,78E-11	1,46E-10	3,70E-11
Cf-252	5,33E-14	3,16E-10	8,14E-12	4,86E-15	1,55E-14	5,76E-15
Cf-254	1,32E-17	5,35E-10	3,62E-11	2,13E-65	5,73E-65	2,43E-65
Es-254	1,51E-11	1,46E-10	2,53E-12	5,10E-24	1,72E-23	5,81E-24

Appendix A

TABLE 4.10: ANNUAL DOSE RATES FROM FOOTBALL PITCH MADE OF SLAG (Sv/y)

NUCLIDE	SPORTMAN (3.6.2.1.1) INHALATION		SPECTATOR (3.6.2.1.2) INHALATION	
	ARC	INDUCTION	ARC	INDUCTION
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	6,77E-12	5,05E-11	5,02E-13	3,75E-12
Fe55	3,47E-13	2,59E-12	2,58E-14	1,92E-13
Co60	1,40E-11	1,04E-10	1,04E-12	7,75E-12
Ni59	1,98E-13	1,48E-12	1,47E-14	1,10E-13
Ni63	5,86E-13	4,38E-12	4,35E-14	3,25E-13
Zn65	9,92E-12	7,41E-11	7,37E-13	5,50E-12
Sr90+	7,28E-09	5,44E-08	5,41E-10	4,04E-09
Nb94	2,21E-09	1,65E-08	1,64E-10	1,23E-09
Tc99	5,86E-10	4,38E-09	4,36E-11	3,25E-10
Ru106+	2,98E-10	2,22E-09	2,21E-11	1,65E-10
Ag108m+	1,67E-11	1,25E-10	1,24E-12	9,25E-12
Ag110m+	5,41E-12	4,04E-11	4,02E-13	3,00E-12
Sb125+	5,84E-13	4,36E-12	4,34E-14	3,24E-13
Cs134	9,02E-11	6,73E-10	6,70E-12	5,00E-11
Cs137+	1,76E-10	1,31E-09	1,31E-11	9,75E-11
Pm147	2,26E-10	1,68E-09	1,67E-11	1,25E-10
Sm151	1,80E-10	1,35E-09	1,34E-11	10,00E-11
Eu152	1,89E-09	1,41E-08	1,41E-10	1,05E-09
Eu154	2,39E-09	1,78E-08	1,78E-10	1,32E-09
U234	4,24E-07	3,16E-06	3,15E-08	2,35E-07
U235+	3,83E-07	2,86E-06	2,85E-08	2,13E-07
U238+	3,61E-07	2,70E-06	2,68E-08	2,00E-07
Np237+	2,26E-06	1,68E-05	1,68E-07	1,25E-06
Pu238	4,96E-06	3,70E-05	3,68E-07	2,75E-06
Pu239	5,41E-06	4,04E-05	4,02E-07	3,00E-06
Pu240	5,41E-06	4,04E-05	4,02E-07	3,00E-06
Pu241	1,04E-07	7,74E-07	7,70E-09	5,75E-08
Am241	4,33E-06	3,23E-05	3,22E-07	2,40E-06
Cm244	2,57E-06	1,92E-05	1,91E-07	1,42E-06
Na-22	5,86E-12	4,38E-11	4,35E-13	3,25E-12
S-35	8,57E-11	6,40E-10	6,36E-12	4,75E-11
Cl-36	3,29E-10	2,46E-09	2,45E-11	1,83E-10
K-40	9,47E-12	7,06E-11	7,03E-13	5,25E-12
Ca-45	1,67E-10	1,25E-09	1,24E-11	9,25E-11
Sc-46	3,07E-10	2,29E-09	2,28E-11	1,70E-10
Mn-53	2,44E-13	1,82E-12	1,81E-14	1,35E-13
Co-56	3,02E-12	2,26E-11	2,24E-13	1,67E-12
Co-57	4,51E-13	3,37E-12	3,35E-14	2,50E-13
Co-58	9,47E-13	7,07E-12	7,03E-14	5,25E-13
As-73	4,51E-14	3,37E-13	3,35E-15	2,50E-14
Se-75	5,86E-11	4,38E-10	4,35E-12	3,25E-11
Se-79	3,07E-10	2,29E-09	2,28E-11	1,70E-10
Sr-85	3,65E-11	2,73E-10	2,71E-12	2,02E-11
Y-91	4,01E-10	3,00E-09	2,98E-11	2,22E-10
Zr-93	1,13E-11	8,41E-11	8,37E-13	6,25E-12
Zr-95+	3,47E-12	2,59E-11	2,58E-13	1,92E-12
Nb-93m	8,12E-11	6,06E-10	6,03E-12	4,50E-11
Mo-93	1,04E-10	7,74E-10	7,70E-12	5,75E-11
Tc-97	8,12E-11	6,06E-10	6,03E-12	4,50E-11
Tc-97m	1,85E-10	1,38E-09	1,37E-11	1,02E-10

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TABLE 4.10 (cont.)				
Pd-107	2,66E-13	1,99E-12	1,98E-14	1,47E-13
Cd-109	3,65E-11	2,73E-10	2,71E-12	2,02E-11
Sn-113+	1,23E-11	9,16E-11	9,11E-13	6,80E-12
Sn-126+	1,28E-10	9,58E-10	9,54E-12	7,12E-11
Sb-124	3,88E-13	2,89E-12	2,88E-14	2,15E-13
Te-123m	2,30E-10	1,72E-09	1,71E-11	1,27E-10
Te-127m+	4,48E-10	3,34E-09	3,33E-11	2,48E-10
I-125	2,30E-10	1,72E-09	1,71E-11	1,27E-10
I-129	1,62E-09	1,21E-08	1,21E-10	9,00E-10
Cs-135	3,88E-11	2,89E-10	2,88E-12	2,15E-11
Ce-139	8,57E-11	6,40E-10	6,36E-12	4,75E-11
Ce-144+	2,39E-09	1,78E-08	1,78E-10	1,33E-09
Sm-147	4,35E-07	3,24E-06	3,23E-08	2,41E-07
Eu-155	3,11E-10	2,32E-09	2,31E-11	1,72E-10
Gd-153	9,47E-11	7,07E-10	7,03E-12	5,25E-11
Tb-160	3,16E-10	2,36E-09	2,34E-11	1,75E-10
Tm-170	3,16E-10	2,36E-09	2,34E-11	1,75E-10
Tm-171	6,31E-11	4,71E-10	4,69E-12	3,50E-11
Ta-182	4,51E-10	3,37E-09	3,35E-11	2,50E-10
W-181	1,22E-12	9,09E-12	9,04E-14	6,75E-13
W-185	5,41E-12	4,04E-11	4,02E-13	3,00E-12
Os-185	7,22E-12	5,39E-11	5,36E-13	4,00E-12
Ir-192	2,98E-12	2,22E-11	2,21E-13	1,65E-12
Tl-204	1,76E-11	1,31E-10	1,31E-12	9,75E-12
Pb-210+	2,57E-08	1,92E-07	1,91E-09	1,42E-08
Bi-207	2,53E-13	1,88E-12	1,88E-14	1,40E-13
Po-210	1,94E-07	1,45E-06	1,44E-08	1,07E-07
Ra-226+	4,30E-07	3,21E-06	3,19E-08	2,38E-07
Ra-228+	7,23E-07	5,39E-06	5,37E-08	4,01E-07
Ac-227+	2,56E-05	1,91E-04	1,90E-06	1,42E-05
Th-228+	1,97E-06	1,47E-05	1,46E-07	1,09E-06
Th-229+	1,16E-05	8,62E-05	8,58E-07	6,41E-06
Th-230	4,51E-06	3,37E-05	3,35E-07	2,50E-06
Th-232	5,00E-06	3,73E-05	3,71E-07	2,77E-06
Pa-231	6,31E-06	4,71E-05	4,69E-07	3,50E-06
U-232	1,67E-06	1,25E-05	1,24E-07	9,25E-07
U-233	4,33E-07	3,23E-06	3,22E-08	2,40E-07
U-236	3,92E-07	2,93E-06	2,91E-08	2,18E-07
Pu-236	1,80E-06	1,35E-05	1,34E-07	10,00E-07
Pu-242	4,96E-06	3,70E-05	3,69E-07	2,75E-06
Pu-244+	4,96E-06	3,70E-05	3,68E-07	2,75E-06
Am-242m+	4,15E-06	3,10E-05	3,08E-07	2,30E-06
Am-243+	4,33E-06	3,23E-05	3,22E-07	2,40E-06
Cm-242	2,66E-07	1,99E-06	1,98E-08	1,47E-07
Cm-243	3,11E-06	2,32E-05	2,31E-07	1,72E-06
Cm-245	4,47E-06	3,33E-05	3,32E-07	2,48E-06
Cm-246	4,42E-06	3,30E-05	3,28E-07	2,45E-06
Cm-247+	4,06E-06	3,03E-05	3,01E-07	2,25E-06
Cm-248	1,62E-05	1,21E-04	1,21E-06	9,00E-06
Bk-249	7,22E-09	5,39E-08	5,36E-10	4,00E-09
Cf-248	3,97E-07	2,96E-06	2,95E-08	2,20E-07
Cf-249	3,16E-06	2,36E-05	2,35E-07	1,75E-06
Cf-250	1,53E-06	1,14E-05	1,14E-07	8,50E-07
Cf-251	3,20E-06	2,39E-05	2,38E-07	1,78E-06
Cf-252	9,02E-07	6,73E-06	6,70E-08	5,00E-07
Cf-254	1,85E-06	1,38E-05	1,37E-07	1,02E-06
Es-254	3,88E-07	2,89E-06	2,88E-08	2,15E-07

Appendix A

TABLE 4.11 MAXIMUM ANNUAL DOSES DUE TO ARC FURNACE SCENARIOS (μSv/y per Bq/g)

NUCLIDE	MAXIMUM DOSES
H3	7,30E-03
C14	8,85E-02
Mn54	6,12E-00
Fe55	5,54E-05
Co60	1,74E+01
Ni59	2,60E-05
Ni63	1,12E-05
Zn65	1,88E+01
Sr90+	3,07E-01
Nb94	1,66E+01
Tc99	1,72E-01
Ru106+	6,94E-00
Ag108m+	1,22E+01
Ag110m+	1,98E+01
Sb125+	3,11E-00
Cs134	4,83E+01
Cs137+	1,74E+01
Pm147	2,26E-04
Sm151	1,80E-04
Eu152	1,46E+01
Eu154	1,29E+01
U234	4,24E-01
U235+	9,36E-01
U238+	3,61E-01
Np237+	2,26E-00
Pu238	4,96E-00
Pu239	5,41E-00
Pu240	5,41E-00
Pu241	1,04E-01
Am241	4,33E-00
Cm244	2,57E-00
Na-22	6,89E+01
S-35	1,74E-03
Cl-36	7,56E-01
K-40	5,61E-00
Ca-45	1,72E-03
Sc-46	2,23E+01
Mn-53	3,39E-05
Co-56	2,37E+01
Co-57	6,47E-01
Co-58	7,21E-00
As-73	7,33E-03
Se-75	2,21E-00
Se-79	3,71E-01
Sr-85	4,54E-00
Y-91	1,06E-01
Zr-93	6,26E-04
Zr-95+	1,11E+01
Nb-93m	8,12E-05
Mo-93	5,88E-03
Tc-97	1,86E-02
Tc-97m	9,50E-04

Appendix A

TABLE 4.11 (cont.)	
Pd-107	6,26E-06
Cd-109	4,52E-02
Sn-113+	6,11E-00
Sn-126+	5,66E+01
Sb-124	1,29E+01
Te-123m	5,45E-01
Te-127m+	4,31E-02
I-125	3,39E-01
I-129	2,49E-00
Cs-135	4,52E-02
Ce-139	5,69E-01
Ce-144+	6,32E-01
Sm-147	4,35E-01
Eu-155	9,70E-02
Gd-153	1,34E-01
Tb-160	1,13E+01
Tm-170	1,45E-02
Tm-171	4,07E-04
Ta-182	1,37E+01
W-181	6,55E-02
W-185	7,35E-03
Os-185	1,97E+01
Ir-192	5,89E-00
Tl-204	6,63E-03
Pb-210+	1,54E+01
Bi-207	1,08E+01
Po-210	5,43E-01
Ra-226+	1,91E+01
Ra-228+	9,66E-00
Ac-227+	1,40E+02
Th-228+	1,67E+01
Th-229+	1,16E+01
Th-230	4,51E-00
Th-232	5,00E-00
Pa-231	6,31E-00
U-232	1,67E-00
U-233	4,33E-01
U-236	3,92E-01
Pu-236	1,80E-00
Pu-242	4,96E-00
Pu-244+	4,96E-00
Am-242m+	4,15E-00
Am-243+	4,33E-00
Cm-242	2,66E-01
Cm-243	3,11E-00
Cm-245	4,47E-00
Cm-246	4,42E-00
Cm-247+	4,06E-00
Cm-248	1,62E+01
Bk-249	7,22E-03
Cf-248	3,97E-01
Cf-249	3,16E-00
Cf-250	1,53E-00
Cf-251	3,20E-00
Cf-252	9,02E-01
Cf-254	1,85E-00
Es-254	3,88E-01

Appendix A

TABLE 4.12 MAXIMUM ANNUAL DOSES DUE TO INDUCTION FURNACE SCENARIOS (µSv/y per Bq/g)

RADIONUCLIDE	MAXIMUM DOSES
H3	4,07E-03
C14	1,31E-01
Mn54	2,51E-00
Fe55	3,73E-04
Co60	8,66E-00
Ni59	1,42E-05
Ni63	3,39E-05
Zn65	9,41E-00
Sr90+	6,94E-01
Nb94	2,48E+01
Tc99	2,57E-01
Ru106+	3,47E-00
Ag108m+	4,21E-00
Ag110m+	8,35E-00
Sb125+	9,75E-01
Cs134	2,42E+01
Cs137+	8,68E-00
Pm147	1,68E-03
Sm151	1,35E-03
Eu152	2,17E+01
Eu154	1,92E+01
U234	3,16E-00
U235+	2,86E-00
U238+	2,70E-00
Np237+	1,68E+01
Pu238	3,70E+01
Pu239	4,04E+01
Pu240	4,04E+01
Pu241	7,74E-01
Am241	3,23E+01
Cm244	1,92E+01
Na-22	3,44E+01
S-35	1,74E-02
Cl-36	3,78E-01
K-40	2,81E-00
Ca-45	1,72E-02
Sc-46	3,33E+01
Mn-53	3,39E-04
Co-56	1,25E+01
Co-57	7,00E-02
Co-58	2,81E-00
As-73	2,00E-03
Se-75	3,30E-00
Se-79	5,54E-01
Sr-85	6,78E-00
Y-91	1,08E-01
Zr-93	1,26E-03
Zr-95+	4,30E-00
Nb-93m	6,06E-04
Mo-93	5,88E-02
Tc-97	2,78E-02
Tc-97m	1,42E-03

Appendix A

TABLE 4.12 (cont.)	
Pd-107	8,37E-06
Cd-109	4,52E-01
Sn-113+	3,05E-00
Sn-126+	2,83E+01
Sb-124	6,05E-00
Te-123m	8,14E-01
Te-127m+	6,44E-02
I-125	3,39E-00
I-129	2,49E+01
Cs-135	4,52E-01
Ce-139	8,50E-01
Ce-144+	9,43E-01
Sm-147	3,24E-00
Eu-155	1,45E-01
Gd-153	2,00E-01
Tb-160	1,68E+01
Tm-170	1,52E-02
Tm-171	6,07E-04
Ta-182	2,05E+01
W-181	4,04E-02
W-185	9,95E-03
Os-185	9,84E-00
Ir-192	1,59E-00
Tl-204	2,94E-02
Pb-210+	1,54E+02
Bi-207	4,47E-00
Po-210	5,43E-00
Ra-226+	2,85E+01
Ra-228+	1,52E+01
Ac-227+	5,58E+02
Th-228+	2,50E+01
Th-229+	8,62E+01
Th-230	3,37E+01
Th-232	3,73E+01
Pa-231	4,71E+01
U-232	1,25E+01
U-233	3,23E-00
U-236	2,93E-00
Pu-236	1,35E+01
Pu-242	3,70E+01
Pu-244+	3,70E+01
Am-242m+	3,10E+01
Am-243+	3,23E+01
Cm-242	1,99E-00
Cm-243	2,32E+01
Cm-245	3,33E+01
Cm-246	3,30E+01
Cm-247+	3,03E+01
Cm-248	1,21E+02
Bk-249	5,39E-02
Cf-248	2,96E-00
Cf-249	2,36E+01
Cf-250	1,14E+01
Cf-251	2,39E+01
Cf-252	6,73E-00
Cf-254	1,38E+01
Es-254	2,89E-00

5 Comparison of the results for the two types of steel

Tables 4.11 and 4.12 show the results obtained for carbon steel (arc furnace) exposure scenarios and special or stainless steel (induction furnace) exposure scenarios.

The dominant scenario for each radionuclide is not always due to the same type of steel and the variation between the two types of steel is not the same for all the radionuclides. Therefore it is important to study both processes and both types of steel.

The maximum dose from both types of steel is given in Table 6.8 of reference 1. The rounded and unrounded clearance levels for steel are given in Tables 3.1 and 7.2 of reference 1, respectively.

6 References

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APPENDIX B

Exposure Scenarios and Parameters Used to Calculate Doses Arising from the Recycling of Copper and Aluminium

Contents

Appendix B

1 Introduction

This appendix describes the methodology and models used to calculate the doses arising from the recycling of copper and aluminium contaminated with radionuclides. These doses were then used to derive the associated clearance levels. Section 2 describes the methodology and gives a general discussion on parameters. Section 3 describes the scenarios, formulae and parameters used to calculate doses and Section 4 gives tables of doses from the scenarios. In many cases the formulae are the same as those used for the recycling of steel (Appendix A) and are therefore not repeated here. The radionuclide dependent factors are all given in Appendix D.

2 Methodology and general discussion

2.1 Methodology

The methodology adopted comprises the following stages

- selection of a source term and physical, chemical and radioactive characterisation of the source,
- description of the processes to be undergone by the materials (all treatments applied to the materials themselves and to the treatment residues),
- description of scenarios which, during processing or the use of recycled products, could involve exposure of persons,
- options regarding characteristic parameters for these scenarios,
- calculation of annual individual doses,
- comparison of results with acceptable dose levels,
- proposal of derived clearance levels.

The first five stages are described in this Appendix; the remaining two stages are addressed in ref. 4.

2.2 Quantities of very low level copper and aluminium recovered from dismantling

The quantities of copper and aluminium liable to be recycled yearly were assessed on the same basis as that adopted for the European Community survey, i.e. the dismantling of two reactors per year, yielding 200 tonnes of copper waste and 40 tonnes of aluminium waste. The aluminium from reactors is referred to as AL(PWR) in this Appendix. The other type of aluminium considered here comes from the dismantling uranium enrichment plants and is referred to as AL(AG3). A value of 1500 tonnes per year of AL(AG3) was considered here.

2.3 Choice of parameters and its influence on results

2.3.1 Radionuclide distribution

For each radionuclide it is necessary to know the fraction of the activity present in the copper or aluminium waste which may be transferred to the ingots, slag and dust after refining. The method used in Appendix A was used and the values are given in Table 3.1 of Appendix D.

2.3.2 Specific concentration factor

This is the ratio of the mass of material processed, (dismantled copper or aluminium) to the mass of post refining by-products (dust or slag). The values are given in Table 2.1.

TABLE 2.1 Quantities of steel and waste products assumed in copper and

aluminium smelting operations

Type of metal	Amount of VLL activity metal dismantled t y^{-1}	Amount of total metal smelted t y^{-1}	Total dust produced for total metal smelted t y^{-1}	Specific concentration factor for dust	Total slag produced for total metal smelted t y^{-1}	Specific concentration factor for slag
Copper	200	20,000	200	100	8,800	2.3
Aluminium (PWR)	40	14,330	30	480	3,300	4.4
Uranium - contaminated aluminium (AG3)	1500	14,330	30	480	3,300	4.4

2.3.3 Atmospheric concentrations

The values selected are based on experimental results when possible (see Appendix A) and are estimated in other cases.

2.3.4 Radiological data

Radiological data are given in Appendix D.

2.3.5 Fraction of very low level waste (VLLW)

The values of the ratio of the quantity of material from VLLW waste to the total quantity of material constituting the substance investigated are easily assessed for scenarios located in the metal refineries. These can be calculated from the ratio of the mass of dismantled VLLW metal to the total annual metal smelted using the values given in Table 2.1. Note that for aluminium (PWR) the value has been rounded up to 0.01.

2.3.6 Radioactive decay

In general no radioactive decay is taken into account during the scenario. However for the public residence scenario (3.7.2) the waste is assumed to decay for the period before residence is assumed to occur i.e. 30 years. Radioactive decay over the crop growing period is also taken into account in scenario 3.3.4.

2.3.7 Human habit data

The discussion given in section 2.3.7 of Appendix A is also relevant to copper and aluminium recycling. It should be noted that the scenarios are generic.

Appendix B

3 Description of scenarios and formulae used in the calculation of doses to the critical group

The scenarios described enable calculation of the dose received by an individual in the critical group from a waste product having an activity concentration of one unit (1 Bq g^{-1}) upon leaving the nuclear installation, taking into account the waste processing undergone in the metal recovery industry.

In the following text, unless otherwise stated the word ”dose” will be used in place of effective dose for external exposures and committed effective dose for ingestion and inhalation scenarios.

The scenarios considered are:

1 Exposure in a scrapyard (transport: external irradiation)
2 Exposure in the refinery (scrap heap: external)
3 Exposure from metal smelting (inhalation of dust, ingestion of dust, external irradiation, atmospheric emissions)
4 Exposure from treatment of by-products (inhalation during compaction, inhalation during treatment, external irradiation)
5 Exposure from purification treatments (external from vats)
6 Exposure from manufacture of products (inhalation)
7 Exposure from disposal or storage of by-products (waste unloading, analysis, handling, residence: inhalation, ingestion, external irradiation, contamination)
8 Exposure from use of by-products (football field: inhalation; concrete: external irradiation)
9 Exposure to objects made of recycled metal (laboratory, office, boat, musical instrument, kitchen, radiator, car: external irradiation; food, saucepan: ingestion)

These scenarios and the parameter values are discussed in turn.

3.1 Exposure in the scrap yard

The main exposures in a scrap yard are external irradiation from transporting scrap. Exposure via inhalation from cutting scrap is not considered.

3.1.1 External exposure during scrap transport

This scenario represents exposure of a driver as discussed in Appendix A (3.1.1). The source is represented by a cylindrical or thick disk source of 0.8 m in thickness and 0.2 m in diameter. Exposure of the worker is assumed to occur at 1.2 m distance with shielding by 0.5 cm of copper or aluminium. It should be noted that there is no dilution of copper or aluminium from the nuclear facility.

The dose is expressed by formula (1) in Appendix A, using the density of metals given below in the Table 3.1. The radionuclide dependent data can be found in Appendix D. It should be noted that there are separate values of DF_{ST} and $Brem_{ST}$ for copper and aluminium. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.1.

TABLE 3.1 Data for external exposure from transport of scrap metal

Parameter	Copper	Aluminium
Source	Thick disk or cylinder	
Diameter (cm)	200	200
Thickness (cm)	800	800
Distance (cm)	120	120
Time of exposure (h y^{-1})	100	100
Fraction of VLLW	1	1
Shield thickness (cm)	0.5	0.5
Density of metal, ρm (g cm^{-3})	8.9	2.7

3.2 Exposure in the refinery

Scenarios for exposure in the refinery are similar to those considered in Section 3.2 of Appendix A (Exposure in a foundry).

Occupational exposure in the refinery may arise from the metal waste and the various treatments it undergoes (irradiation from nearby scrap metal heap in a storage area, inhalation of dust generated by metal refining processes, irradiation from proximity to ingots and finished products in a warehouse) and to by-product processing and removal (inhalation of metal refining dust during its compaction for transport, exposure to slag during processing and loading operations).

3.2.1 External exposure to a scrap metal heap in a refinery storage area

When the scrap metal is transferred to a metal recovery plant, it is first stored, frequently in the open air, before undergoing treatment in the plant. This scenario represents the exposure of a worker positioned 1.5 m from a right circular cone. The dose is given by formula (15) in Appendix A using the appropriate density of metal (Table 3.2).

The radionuclide dependent data can be found in Appendix D. It should be noted that there are separate values of DF_{SC} and $Brem_{SC}$ for copper and aluminium.

The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.2.

TABLE 3.2 Data for external exposure to a scrap metal heap in a refinery storage area

Parameter	Copper	AL(PWR)[1]	AL(AG3)[2]
Source (gamma)		Right circular cone	
Distance (m)	1.5	1.5	1.5
Apparent diameter (m)	1.5	1.5	1.5
Factor G (see formula (45))			
Time of exposure (h y^{-1})	1800	1800	1800
Fraction of VVLW	10^{-2}	10^{-2}	10^{-1}
Density of metal, ρ (g cm^{-3})	8.9	2.7	2.7

Notes
(1) Aluminium from PWR electric cables.
(2) Aluminium from uranium isotopic enrichment plant.

3.3 Metal smelting

3.3.1 Exposure by dust inhalation during metal refining (worker exposure)

During copper or aluminium refining, the furnaces gives off fumes most of which are collected by filtration as they exit the furnaces. Remaining dust is dispersed in the refining bay atmosphere. Experiments conducted in copper and aluminium refineries have enabled these parameters to be measured. Workers are exposed to dust generated when the furnaces are charged, during the refining processes, during the metal pouring and during the slag tapping.

The generic inhalation exposure scenario is represented by a work station located in the refining bay, where a worker is permanently exposed to the mean dust concentration measured in the bay.

The dose is given by equation (17) in Appendix A, using the parameter values for copper, AL(PWR) and AL(AG3) from Table 3.3 below. The radionuclide dependent factors can be found in Appendix D. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.3 for copper and Table 4.4 for aluminium.

TABLE 3.3 Data for dust inhalation during melting in a refinery

Parameter	Copper	AL(PWR)	AL(AG3)
Mean breathing rate ($m^3 h^{-1}$)	1.2	1.2	1.2
Inhalable particle conc. in the atmosphere ($g m^{-3}$)	$3 \ 10^{-3}$	$3 \ 10^{-3}$	$3 \ 10^{-3}$
Time of exposure ($h y^{-1}$)	1800	1800	1800
Fraction of VLLW	10^{-2}	10^{-2}	10^{-1}
Specific concentration factor in the dust	100	480	480

3.3.2 Exposure by ingestion during metal refining

During metal refining, the workers collect dust particles on the hands and the face. When they clean their face, smoke or touch their lips with their hands a fraction of dust is deposited on the lips and may be ingested. In this scenario a worker is assumed to ingest 0.02 g of copper dust per day and 0.0075 g per day of aluminium dust.

The dose is expressed by equation (19) in Appendix A, using the parameter values for copper, AL(PWR) and AL(AG3) from Table 3.4 below. The radionuclide dependent factors can be found in Appendix D. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.3 for copper and Table 4.4 for aluminium.

TABLE 3.4 Data for ingestion during melting in a refinery

Parameter	Copper	AL(PWR)	AL(AG3)
Surface area of the deposit (cm^2)	2	2	2
Thickness of the deposit (cm)	$3 \ 10^{-4}$	$3 \ 10^{-4}$	$3 \ 10^{-4}$
Number of times per day the deposit is ingested	5	5	5
Number of days per year	225	225	225
Apparent density ($g cm^{-3}$)	7	2.5	2.5
Daily absorbed dust quantity (g)	$2.1 \ 10^{-2}$	$7.5 \ 10^{-3}$	$7.5 \ 10^{-3}$
Fraction of VVLW	10^{-2}	10^{-2}	10^{-1}
Radionuclide concentration factor in the dust	100	480	480

3.3.3 External exposure to the ingots and products fabricated in a refinery (worker exposure)

This exposure pathway is similar to 3.4.1.1 in Appendix A.

After refining, the metal is cast into ingots or elements of different shapes which are loaded onto transport pallets and placed in storage prior to dispatch to customers. The scenario considers a worker responsible for arranging the pallets in the storage room. He is exposed to the ingots fabricated from VLL metal waste whilst he conveys them by means of a fork lift-truck to the storage room. The mass of ingots on a transport pallet is represented by a truncated slab source or right circular cone with a visible surface of 2 m in diameter at a mean distance of 1.5 m from the operator.

The dose is expressed by formula (35) in Appendix A using the density of metals given in the Table 3.5 below. The radionuclide dependent data can be found in Appendix D. It should be noted that these are separate values of DF_I and $Brem_I$ for copper and aluminium.

The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.3 for copper and Table 4.4 for aluminium.

TABLE 3.5 Data for occupational external exposure to the ingots

Parameter	Copper	AL(PWR)	AL(AG3)
Source (gamma)		Right circular cone	
Distance (m)	1.5	1.5	1.5
Apparent diameter (m)	2	2	2
Source geometry factor G	0.17	0.17	0.17
Time of exposure (h y^{-1})	1800	1800	1800
Fraction of VVLW	10^{-2}	10^{-2}	10^{-1}
Density of metal, (g cm^{-3})	8.9	2.7	2.7
Cone angle α (radians)	0.588	0.588	0.588

3.3.4 Atmospheric emission in the refinery

The impact of atmospheric emission of dust and gas in the environment of the copper or aluminium refinery is considered here. The pathways taken into account are the same as those in Appendix A for steel: inhalation of dust or gas, external exposure to dust deposit on the ground and ingestion of food cultivated on the ground nearby the refinery. The fraction of dust emitted outside is estimated after filtration to be 1% of the total dust generated. An individual is assumed to live at about 100 m from the plant and to spend 1100 hours per year (3 hours per day) outside. Note doses for H-3 and C-14 were not calculated using the complex formulae specific to these nuclides given in section 3.3.4 of Appendix A. Instead, the following formulae from Appendix A were used: Formula (21) for inhalation doses; formula (22) for external doses; and formula (23) for ingestion doses. All the parameter values are given in Table 3.6, with the radionuclide dependent factors in Appendix D. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.3 for copper and Table 4.4. for aluminium.

TABLE 3.6 Data for exposure by atmospheric emission in the environment

Parameter	Value		
Total mass of dust generated (kg)	$2\ 10^5$ (copper)	$2.8\ 10^4$ (AL(PWR))	$2.8\ 10^4$ (AL(AG3))
Emitted dust ratio after filtration	0.01		
Atmosphere transfer coef. (Bq m^{-3}/Bq s^{-1})	$1.2\ 10^{-5}$		
Occupancy factor	0.8		
Fraction of VLLW	10^{-2}		
Specific concentration factor in dust	100		
<u>Parameters specific to inhalation</u>			
Breathing rate ($m^3\ h^{-1}$)	1		
<u>Parameter specific to ground deposit (external)</u>			
Deposition velocity (m s^{-1})	$5\ 10^{-3}$		
Deposition duration (h)	8760		
Spent time outside (h)	1100		
<u>Parameters specific to foodstuff (ingestion)</u>			
Absorption ratio	0.25		
Biological half-life (d)	30		
Growing time of crops (d)	30		
Agricultural yield (kg m^{-2})	2		
Annual quantity ingested (kg y^{-1})	50		

3.4 Treatment of by-products

3.4.1 Exposure by inhalation during copper refining dust compacting

The generic scenario for exposure by inhalation represents a dust compacting work station, where a worker is permanently exposed to the inhalable particle concentration measured at this station. The dose is expressed by equation (17) in Appendix A, using the parameter values given in Table 3.7 below. The radionuclide dependent factors can be found in Appendix D. The doses resulting from exposure to 1 Bq g^{-1} of each radionuclide are presented in Table 4.5.

TABLE 3.7 Data for inhalation during copper refining dust compacting

Parameter	Copper
Mean breathing rate ($m^3\ h^{-1}$)	1.2
Inhalable particle concentration in the atmosphere (g m^{-3})	$6\ 10^{-4}$
Time of exposure (h y^{-1})	1800
Fraction of VLLW	10^{-2}
Specific concentration factor in the dust	100

3.4.2 Exposure by inhalation during copper treatment for recovering the zinc

The generic scenario for exposure by inhalation in a plant processing copper refinery dust to recover the zinc represents a worker in the processing bay who is exposed to the inhalable particle concentration.

The dose is expressed by equation (17) in Appendix A, using the parameter values given in Table 3.8 below. The radionuclide dependent factors can be found in Appendix D. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.5.

TABLE 3.8 Data for inhalation during copper dust treatment for recovering the zinc

Parameter	Copper
Mean breathing rate (m^3 h^{-1})	1.2
Inhalable particle concentration in the atmosphere (g m^{-3})	5 10^{-3}
Time of exposure (h y^{-1})	1800
Fraction of VLLW	4 10^{-4}
Mass concentration factor in the dust	100

3.4.3 Exposure during slag processing

In copper and aluminium refineries, slag is run off into tanks either before or after the metal is tapped, depending on the type of furnace The slag is then placed in a storage area in the open.

Copper refining slag is then removed without further treatment. The generic scenario concerns external exposure to a volume source, represented by a right circular cone, during slag loading for disposal.

Aluminium refining slag contains numerous metal inclusions which are recovered either by crushing the slag or by means of a pneumatic hammer. A conservative scenario corresponds to a worker using a pneumatic hammer on the slag who is exposed to external radiation from a right circular cone source and to inhalation of the dust generated.

The dose from external exposure is expressed by the equation below. Note that the density of slag is taken into account.

The external dose from a semi-infinite volume slag source is given by the following equation:

$$H = Am \cdot \rho m \cdot (DF_{SL} + Brem_{SL}) \cdot F \cdot t \cdot r \cdot c_m \quad (Sv\ y^{-1}) \qquad (68)$$

where:

- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
- ρm: density of source material (g cm^{-3}), (= 2.8 g cm^{-3} for copper slag; 1.5 g cm^{-3} for aluminium slag),
- DF_{SL}: dose factor per unit volume activity concentration from external exposure to gamma radiation from a slag volume, represented by a right circular cone at 0 m (Sv h^{-1} per Bq cm^{-3}), (along axial direction); (this is based on equations (2), (3) and (15) in Appendix A, assuming $\alpha = 1.3$ radians).

$Brem_{SL}$: bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}), (Table 3.2 in Appendix D),
F: fraction of VLL metal waste,
t: annual time of exposure h y^{-1},
r: radionuclide distribution factor in the slag, during melting, (Table 3.1 in Appendix D),
c_m: specific concentration factor in the slag waste.

The inhalation dose is expressed by equation (17) in Appendix A, except the values of r and c_m are for slag.

All parameter values are given in Table 3.9 and the radionuclide dependent factors are given in Appendix D. The external dose resulting from 1 Bq g^{-1} of each radionuclide for copper is given in Table 4.5 and both external and inhalation doses for aluminium are given in Table 4.6.

TABLE 3.9 Data for inhalation and external exposure during the treatment of copper and aluminium slags

Parameter	Copper External exposure	AL(PWR) Ext. exp,+inh. dust	AL(AG3) Ext.exp.+inh. dust
Source			
-For beta radiation	Semi-infinite volume		
-For gamma radiation	Right circular cone		
Distance	0 m	0 m	0 m
Geometry factor	0.8	0.8	0.8
Mean breathing rate (m^3 h^{-1})	-	1.2	1.2
Inhalable particle concentration in the atmosphere (g m^{-3})	-	1 10^{-3}	1 10^{-3}
Time of exposure (h y^{-1})	180	1800	1800
Fraction of VLLW	10^{-2}	10^{-2}	10^{-1}
Specific concentration factor in the slags	2.3	4.4	4.4

3.5 Purification treatments

3.5.1 External exposure in electro-refining facility

Copper cathodes are manufactured by immersing copper in a vat containing a solution of copper sulphate and sulphuric acid at 60°C. A train of 23 anodes is connected to the generator positive pole and a train of 24 cathode outgoing foil strips connected to the negative pole. The anode is dissolved by the current, the cathode forms and the electrolytic solution is charged with copper. Electrolysis operations are regularly monitored by an operator, positioned directly over the vats. The anodes were refined in a reverberatory furnace loaded with 50% blister copper and 50% scrap metal. Each anode weighs 235 kg and contains 99% copper. The generic scenario represents a worker subjected to external exposure from the electrolysis vats. The vats are represented by a right circular cone source of mean density 3 t m^{-3}.

The dose is expressed by formula (35) in Appendix A using the density of electrolyte from the Table of parameter values (Table 3.10). Note that the value for DF and bremsstrahlung will be for an electrolyte (DF_E and $Brem_E$) as given in the radionuclide dependent data in Table 3.2 of Appendix D. Other nuclide dependent parameters can also be found in Appendix D.

The dose from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.7.

TABLE 3.10 Data for external exposure in electro-refining facility

Parameter	Copper
Source (gamma)	Right circular cone
Distance	0 m
Time of exposure	1800
Fraction of VVLW	4 10^{-3}
Electrolyte density (g cm^{-3})	3
Cone angle α (radians)	1.3

3.6 Manufacture of products made of recycled metal

During the various processes involved in transforming the ingots and by-products into manufactured products, dust could be generated in the work area in non negligible concentrations.

The scenario represents metal part machining. The ingots or by-products cast after refining, come from charges containing different batches of scrap metal containing variable amounts of very low level waste. They consequently contain a variable proportion of the initial radioactivity expressed by dilution factors. These dilution factors vary considerably, depending on, for example, the size of the receiving plant, on the degree of specialisation of the plant and the type of alloys.

For copper, the dilution factor is estimated at 10% in the processing and melting plant. A dilution factor of 10% is also used for aluminium from the enrichment plant, but 1% is taken for the aluminium scrap from reactors.

The dose is expressed by formula (36) in Appendix A using the parameter values given in Table 3.11 below. The radionuclide dependent factors are given in Appendix D. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.8.

TABLE 3.11 Data for inhalation during manufacture of products made of recycled metal

Parameter	Copper	AL(PWR)	AL (AG3)
Mean breathing rate (m^3 h^{-1})	1.2	1.2	1.2
Inhalable particle concentration in the atmosphere (g m^{-3})	1 10^{-3}	1 10^{-3}	1 10^{-3}
Time of exposure (h y^{-1})	1800	1800	1800
Fraction of VLLW	10^{-1}	10^{-2}	10^{-1}

3.7 Disposal or storage of by-products

These scenarios are similar to those in section 3.6.1 of Appendix A.

The disposal dumps are classified according to their capacity to deal with waste classed as inert, innocuous or special (liable to have harmful effects). In France, the following classification is adopted:

- Class 1: industrial waste
- Class 2: innocuous waste (e.g. household refuse)
- Class 3: inert waste

In this study a Class 1 dump is considered because it is very improbable that refinery slag would be disposed of as innocuous waste. The generic Class 1 disposal dump capacity is assumed to be 50,000 tonnes per year.

The quantity of slag arising from smelting of copper and aluminium which is considered to be disposed of at such a landfill is 8,800 tonnes for copper and 3,300 tonnes for aluminium, ie, the total annual production.

Exposure hazards related to disposal of refinery slag at the landfill sites are as follows:

Occupational exposure: (Adult)

- exposure of the hands due to dust generated by unloading the trucks
- exposure of the hands during waste analysis
- exposure of the face due to dust generated by unloading the trucks
- exposure by ingestion of dust particles during waste handling
- exposure by inhalation of dust during waste handling
- external exposure from the landfill during waste handling

Public exposure: (Adult, 10 y old children, 1 y old babies)

- exposure of the public after closure of the site and its reuse for residence

(external exposure, inhalation, ingestion of produce grown on the site).

3.7.1 Occupational exposure

These scenarios model the work of a truck driver in the transport and manipulation of slags in the landfill and a chemist who takes samples of slag for analysis at the entrance to the landfill.

Appendix B

3.7.1.a Contamination of hands by waste manipulation

It is assumed that dust from the landfill on the palm of the hands results in a skin dose as calculated by the following formula:

$$H_{skin} = As \cdot (DF_{\beta c40} + DF_{\gamma c}) \cdot t \cdot s \qquad (69)$$

where:

- As: surface activity of the deposit ($Bq\ cm^{-2}$),
- $DF_{\beta c40}$: skin equivalent dose rate to the basal layer of the skin epidermis for beta irradiation, (at 40 mg cm^{-2} depth) ($Sv\ h^{-1}$ per $Bq\ cm^{-2}$),
- $DF_{\gamma c}$: skin equivalent dose rate to the basal layer of the skin epidermis for gamma irradiation, (at 7 mg cm^{-2} depth) ($Sv\ h^{-1}$ per $Bq\ cm^{-2}$),
- t: annual time of exposure ($h\ y^{-1}$),
- s: surface area over which dose is calculated (cm^2) (= 1 cm^2)[1].

The surface activity of the deposit is expressed by:

$$As = Am \cdot r \cdot c_m \cdot e \cdot \rho \cdot F \cdot FL \quad (Bq\ g^{-1}) \qquad (70)$$

where :

- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation ($Bq\ g^{-1}$),
- r: radionuclide distribution factor in the slag during melting (Table 3.1 in Appendix D),
- c_m: specific concentration factor in the slag dust = ratio of the mass of products processed to the mass of post-melting by-products obtained,
- e: thickness of the deposit (cm),
- ρ: apparent density of the deposit ($g\ cm^{-3}$),
- F: fraction of VLL metal waste,
- FL: fraction of slag in the landfill. This is a dilution factor which gives the ratio of the mass of the slag to the mass of waste disposed of in the landfill.

The annual time of exposure is expressed by:

$$t = n\ dc \quad (h\ y^{-1})$$

where:

- n: number of contaminations per year (y^{-1}),
- dc: duration of each contamination (h).

Radionuclide dependent factors are given in Appendix D and the other parameter values are given in Table 3.12. The skin dose resulting from exposure to 1 $Bq\ g^{-1}$ of each radionuclide is presented in Table 4.9 for copper and Tables 4.10 and 4.11 for aluminium.

TABLE 3.12 Data for contamination of hands by waste manipulation

Parameter	Copper	AL(PWR)	AL(AG3)
Skin epidermis thickness (mg cm^{-2}) for β	40	40	40
Number of contaminations per year	450	450	450
Duration of each contamination (h)	4	4	4
Deposit thickness (cm)	1 10^{-2}	1 10^{-2}	1 10^{-2}
Density of the deposit (g cm^{-3})	1.4	1.4	1.4
Fraction of VLLW	10^{-2}	10^{-2}	10^{-2}
Fraction of slags in the landfill	1.8 10^{-1}	6.7 10^{-2}	6.7 10^{-2}
Specific concentration factor in slag	2.3	4.4	4.4
Area of skin contamination (cm^{2})	1	1	1

3.7.1.b Contamination of hands during waste analysis

The dose is expressed by equation (69), using the parameter values given in Table 3.13. The radionuclide dependent factors can be found in Appendix D. The skin dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.9 for copper, and Tables 4.10 and 4.11 for aluminium.

TABLE 3.13 Data for contamination of hands during waste analysis

Parameter	Copper	AL(PWR)	AL(AG3)
Skin epidermis thickness (mg cm^{-2}) for β	40	40	40
Number of contaminations per year	9	9	9
Duration of each contamination (h)	0.5	0.5	0.5
Deposit thickness (cm)	1 10^{-3}	1 10^{-3}	1 10^{-3}
Density of the deposit (g/cm$^{3)}$	1.4	1.4	1.4
Fraction of VLLW	10^{-2}	10^{-2}	10^{-1}
Fraction of slags in the landfill	1.8 10^{-1}	6.7 10^{-2}	6.7 10^{-2}
Specific concentration factor in slag	2.3	4.4	4.4

Appendix B

3.7.1.c Contamination of face by waste manipulation

It is assumed that dust from the landfill deposits on the face and results in a skin dose which is calculated by the following formula:

$$H_{skin} = As \cdot (DF_{\beta c4} + DF_{\gamma c}) \cdot t \cdot s \qquad (71)$$

where:

- As: surface activity of the deposit (Bq cm^{-2}),
- $DF_{\beta c4}$: skin equivalent dose rate to the basal layer of the skin epidermis for beta irradiation (at 4 mg cm^{-2} depth) (Sv h^{-1} per Bq cm^{-2}),
- $DF_{\gamma c}$: skin equivalent dose rate to the basal layer of the skin epidermis (at 7 mg cm^{-2} depth) (Sv h^{-1} per Bq cm^{-2}),
- t: annual time of exposure (h y^{-1}),
- s: surface area over which dose is calculated (cm^2) (= 1 cm^2)[1].

The surface radioactivity of the deposit is expressed by:

$$As = Am \cdot r \cdot c_m \cdot e \cdot \rho \cdot F \cdot FL \quad (Bq\ g^{-1}) \qquad (72)$$

where :

- Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1}),
- r: radionuclide distribution factor in the slag during melting (Table 3.1 in Appendix D),
- c_m: specific concentration factor in the slag dust = ratio of the mass of products processed to the mass of post-melting by-products obtained,
- e: thickness of the deposit (cm),
- ρ: apparent density of the deposit (g cm^{-3}),
- F: fraction of VLL metal waste,
- FL: fraction of slag in the landfill. This is a dilution factor which gives the ratio of the mass of slag to the mass of disposed waste in the landfill.

The annual time of exposure is expressed by:

$$t = n\ dc \quad (h\ y^{-1})$$

where:

- n: number of contaminations per year (y^{-1}),
- dc: duration of each contamination (h).

The radionuclide dependent factors are given in Appendix D and the other parameter values are given in Table 3.14. The skin dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Tables 4.8 for copper and in Tables 4.9 and 4.10 for aluminium.

TABLE 3.14 Data for contamination of face by waste manipulation

Parameter	Copper	AL(PWR)	AL(AG3)
Skin epidermis thickness (mg cm^{-2})	4	4	4
Number of contamination per year	225	225	225
Duration of each contamination (h)	8	8	8
Deposit thickness (cm)	$5\ 10^{-3}$	$5\ 10^{-3}$	$5\ 10^{-3}$
Density of the deposit (g cm^{-3})	1.4	1.4	1.4
Fraction of VLLW	10^{-2}	10^{-2}	10^{-1}
Fraction of slags in the landfill	$1.8\ 10^{-1}$	$6.7\ 10^{-2}$	$6.7\ 10^{-2}$
Specific concentration factor in slag	2.3	4.4	4.4

3.7.1.d Dust ingestion

The ingestion dose is expressed by equation (49) in Appendix A, except the values of r and c_m are for slag only. Radionuclide dependent factors are given in Appendix D and the other parameter values are given in Table 3.15. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Tables 4.9 for copper and in Tables 4.10 and 4.11 for aluminium.

TABLE 3.15 Data for dust ingestion following hand contamination

Parameter	Copper	AL(PWR)	AL(AG3)
Size of the dusty surface (cm)	2	2	2
Density of the deposit (g cm^{-3})	1.4	1.4	1.4
Deposit thickness (cm)	$5\ 10^{-3}$	$5\ 10^{-3}$	$5\ 10^{-3}$
Number of times per day the dust is ingested	5	5	5
Number of work days	225	225	225
Dust dilution on the site	1	1	1
Fraction of VLLW	10^{-2}	10^{-2}	10^{-1}
Fraction of slags in the landfill	$1.8\ 10^{-1}$	$6.7\ 10^{-2}$	$6.7\ 10^{-2}$
Specific concentration factor in slag	2.3	4.4	4.4

3.7.1.e Dust inhalation by waste manipulation

The inhalation dose is given by equation (47) in Appendix A, the values of r and c_m are for slag only. All parameter values are given in Table 3.16 and radionuclide dependent factors are given in Appendix D. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Tables 4.9 for copper and in Tables 4.10 and 4.11 for aluminium.

TABLE 3.16 Data for dust inhalation by waste manipulation

Parameter	Copper	AL(PWR)	AL(AG3)
Breathing rate (m^3 h^{-1})	1.2	1.2	1.2
Inhalable dust concentration			
- inside a cabin (g m^{-3})	2 10^{-4}	2 10^{-4}	2 10^{-4}
- outside (g m^{-3})	1 10^{-3}	1 10^{-3}	1 10^{-3}
Time of exposure (h y^{-1}):			
- inside	1620	1620	1620
- outside	180	180	180
Dust dilution on the site	1	1	1
Fraction of VLLW	10^{-2}	10^{-2}	10^{-1}
Fraction of slags in the landfill	1.8 10^{-1}	6.7 10^{-2}	6.7 10^{-2}
Specific concentration factor in slag	2.3	4.4	4.4

3.7.1.f External exposure to waste in a rubbish tip

The external dose is expressed by equation (45) in Appendix A, except that the values for r and c_m are for slag only. The radionuclide dependent factors are given in Appendix D and all other parameter values are given in Table 3.17. The dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.9 for copper and in Tables 4.10 and 4.11 for aluminium.

TABLE 3.17 Data for external exposure to waste in a rubbish tip

Parameter	Copper	AL(PWR)	AL(AG3)
Geometry factor (semi-infinite source)	1	1	1
Time of exposure (h y^{-1})	1800	1800	1800
Fraction of VLLW	10^{-2}	10^{-2}	10^{-1}
Fraction of slags in the landfill	1.8 10^{-1}	6.7 10^{-2}	6.7 10^{-2}
Specific concentration factor in slag	2.3	4.4	4.4

3.7.2 Public exposure

This scenario includes the different exposure pathways that could arise following residence of an individual at an old landfill site. The pathways include external exposure, inhalation of dust and ingestion of locally grown vegetables. Three age groups are considered, an adult, a 10 year old child and a 1 year old baby.

The site of an industrial landfill will not be reused before 30 years after closure. Radioactive decay over this period is taken into account. It is assumed that all slags will be deposited in an industrial landfill. All scenarios are similar to the scenarios in Section 3.6.1.4 of Appendix A.

The exposure scenarios represent external exposure, inhalation of dust, ingestion of grown vegetables and inadvertent ingestion of soil, for adults, 10 y children and 1 y old babies. Doses are calculated for slags from copper (3.7.2.a), AL(PWR) (3.7.2.b) and AL(AG3) (3.7.2.c). The formulae used to calculate the doses are (51) to (63) in Appendix A, using the parameter values listed in Table 3.18 below. The radionuclide dependent factors are given in Appendix D and the doses resulting from disposal of slags arising from metals containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.9 for copper and in Tables 4.10 and 4.11 for aluminium.

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TABLE 3.18 Data for residence scenario

Parameter	Copper	AL(PWR)	AL(AG3)
Time before scenario (y):			
- ordinary landfill	10	10	10
- industrial landfill	30	30	30
Dust concentration in the garden (g cm^{-3})	2 10^{-5}	2 10^{-5}	2 10^{-5}
Dust concentration in the house (g cm^{-3})	1 10^{-5}	1 10^{-5}	1 10^{-5}
Dust concentration on excavated (cuts and fills) material (g cm^{-3})	2 10^{-4}	2 10^{-4}	2 10^{-4}
Dilution of waste in the garden soil	0.03	0.03	0.03
Dilution of waste on excavated material (cuts and fills)	1	1	1
Indoor radiation reduction (shielding)	0.1	0.1	0.1
Age of the individual:			
- adult	30	30	30
- child	10	10	10
- baby	1	1	1
Breathing rate (m^3 h^{-1}):			
- adult: in activity	1	1	1
resting	0.45	0.45	0.45
- child: in activity	0.6	0.6	0.6
resting	0.27	0.27	0.27
- baby: in activity	0.25	0.25	0.25
resting	0.09	0.09	0.09
Consumption of soil (g):			
- adult	2	2	2
- child	2	2	2
- baby	10	10	10
Time spent on excavated material (cuts and fills) (h y^{-1}):	0	0	0
- adult	100	100	100
- child	0	0	0
- baby			
Time spent in the garden (h y^{-1}):			
- adult	1100	1100	1100
- child	500	500	500
- baby	300	300	300
Time spent in the house not resting (h y^{-1}):			
- adult	4000	4000	4000
- child	3145	3145	3145
- baby	3350	3350	3350
Time spent resting inside (h y^{-1}):			
- adult	2920	2920	2920
- child	3350	3350	3350
- baby	4690	4690	4690
Fraction of VLLW	10^{-2}	10^{-2}	10^{-1}
Fraction of slags	1.8 10^{-1}	6.7 10^{-2}	6.7 10^{-2}
Mass concentration factor in slag	2.3	4.4	4.4

3.8 Use of by-products

3.8.1 Exposure to dust from a football field made of copper slag

In Germany, football fields may be coated with materials containing slag. A generic scenario represents a person exposed to the dust created by the players during training or a game. It is assumed that 1% of the dust comes from the copper slag.

Both players and spectators are considered. The player trains for 4 h per week and plays one match per week (average exposure time of 5 h 30 min per week).

The spectator attends the football matches; the cumulative duration is taken to be 50h per year.

The doses to a football player from inhalation are calculated using formula (64) in Appendix A and for inhalation by a spectator using formula (66) in Appendix A. The parameters used for both calculations are given in Table 3.19. The radionuclide dependent factors are given in Appendix D and the doses resulting from slags arising from metals containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.12.

TABLE 3.19 Data for dust inhalation on a football field

Parameter	Player	Spectator
Breathing rate (m^3 h^{-1})		
- high activity	1.8	
- intermediate activity	1.5	1
Inhalable dust concentration: (g cm^{-3})		
- high activity	2 10^{-3}	
- intermediate activity	1 10^{-3}	1 10^{-3}
Time of exposure (h y^{-1}):		
- high activity	132	
- intermediate activity	132	50
General dilution of VLLW		
(dust dilution on the site)	10^{-2}	10^{-2}
Specific concentration factor in slag	2.3	2.3

3.8.2 External exposure to a plate of concrete containing aluminium slag

This scenario models the potential use of aluminium slags mixed in concrete. It is assumed that the concrete is used for a wall in a room, for instance a bedroom, where an individual spends 8 hours per day for 330 days per year (11 months). The wall is taken to be a disc of 3.8 m diameter and 10 cm thick. An individual stands in the room at a mean distance of 1 m from the source.

The amount of cement in 1 m^3 of concrete is 350 kg and the corresponding amount of slag is 7 kg assuming that the fraction of slags in concrete is 2 10^{-2}. A density for cement of 0.35 g cm^{-3} is used.

The doses are calculated by the following formula:

$$H = Am \cdot \rho m \cdot (DF_{CS} + Brem_{CS}) \cdot F \cdot Fc \cdot t \cdot c_m \cdot r \quad (Sv\ y^{-1}) \qquad (73)$$

where:

Am:	activity concentration of the VLL waste metal when it leaves the nuclear installation (Bq g^{-1}),
ρm:	density of the source material (g cm^{-3}) (= 0.35 g cm^{-3} for cement),
DF_{CS}:	dose factor per unit volume activity concentration from external exposure to gamma radiation from a plate of concrete, represented by a thick disk or cylindrical volume 10 cm thick and at 1 m, (along axial direction); (this is based on formulae (2), (3) and (4) in Appendix A), (Sv h^{-1} per Bq cm^{-3}),
$Brem_{CS}$:	bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}), (Table 3.2 in Appendix D),
F:	fraction of VLLW,
Fc:	fraction of slags in the concrete,
t:	annual time of exposure (h y^{-1}),
c_m:	specific concentration factor in slag,
r:	radionuclide distribution factor in slag during melting (Table 3.1 in Appendix D).

All parameters are given in Table 3.20. The dose resulting from exposure of 1 Bq g^{-1} of each radionuclide is presented in Table 4.12.

TABLE 3.20 External exposure to a plate of concrete with aluminium

Parameter	AL(PWR) and AL(AG3)
Source	Thick disk
Time of exposure (h y^{-1})	2640
Thickness (cm)	10
Fraction of VLLW	10^{-1}
Cement density (g cm^{-3})	0.35
Fraction of slags in the concrete	2 10^{-2}
Specific concentration factor in slag	4.4

3.9 Exposure to objects made from recycled metal

Copper and aluminium alloys have a wide range of applications and a generic scenario is used to represent them. The scenario is based on a geometrically simple solid thick disc source, the dimensions of which will vary according to the dimensions of the actual source being represented. For these scenarios, the dilution factor is assumed to be 30% for copper and 20% for aluminium.

3.9.1 Occupational exposures

3.9.1.a External exposure to a copper alloy (brass) laboratory object and aluminium office furniture

For copper alloy, a laboratory sink fitting is considered. These usually consist of two taps on either side of a spout. For a generic scenario, such an assembly is represented by a thick solid disc source of 0.2 m in diameter and 2 cm in thickness.

The exposed individual is assumed to work permanently near a laboratory bench at a mean distance of 1 m away from taps or fittings with an annual exposure time of 1800 h.

In the case of use of aluminium fittings, occupational exposure in an office fitted with aluminium sections is considered. These are located in different parts of the room and can be at a minimum distance of 0.5 m from the individual sitting at his desk. The source geometry (comprising all the aluminium fittings in the room) is complex. However, the generic scenario represents external exposure of an individual at 0.5 m from a solid disc source.

The doses are calculated by formula (35) in Appendix A using the density of brass and aluminium given in Table 3.21 below and the appropriate dose factors substituted in place of DF_I and $Brem_I$ which are given in Table 3.2 in Appendix D (DF_{LAB}, $Brem_{LAB}$ for copper alloy and DF_{FU}, $Brem_{FU}$ for aluminium).

The radionuclide dependent factors are given in Appendix D and the remaining scenario parameters are given in Table 3.21.

The doses resulting from exposure to 1 Bq g^{-1} of each radionuclide for brass and aluminium are given in Tables 4.13 and Table 4.14 respectively.

TABLE 3.21 Data for external exposure to a copper alloy laboratory object and aluminium and office furniture

Parameter	Copper	AL(PWR) and AL(AG3)
Time of exposure (h y^{-1})	1800	1800
Fraction of VLLW	0.3	0.2
Mean distance to the object (m)	1	0.5
Diameter of the disc source (m)	0.2	0.5
Thickness of the disc source (cm)	2	1
Density of the metal (g cm^{-3})	8.2 (brass)	2.7

3.9.1.b External exposure in a fishing boat

Aluminium alloys may be used in ship-building, including the construction of fishing boat hulls. The generic scenario concerns an individual who is a fisherman by trade, employed on a medium- sized trawler. Trawlers boats of this type generally spend 2 or 3 day periods at sea, interspersed with 1 to 2 day periods ashore. In general, fishermen spend about 5,000 hours per year aboard ship. In the generic scenario, the trawler boat is considered to be a thick disc source of 3 m in diameter and 0.5 cm thick. The fisherman is assumed to be exposed to the source at a mean distance of 1.5 m.

The doses are calculated by formula (35) in Appendix A using the density of aluminium given in Table 3.22 and the appropriate dose factor substituted in place of DF_I and $Brem_I$ as given in Appendix D (DF_{FB} and $Brem_{FB}$). The remaining parameters are given in Table 3.22 and radionuclide dependent parameters are given in Appendix D. The doses resulting from exposure to 1 Bq g^{-1} are given in Table 4.14.

TABLE 3.22 Data for external exposure in a fishing boat

Parameter	AL(PWR) and AL(AG3)
Time of exposure (h y^{-1})	5000
Fraction of VLLW	0.2
Diameter of the disc source (m)	3
Mean distance to the object (m)	1.5
Thickness of the disc source (cm)	0.5
Density (g cm^{-3})	2.7

3.9.1.c External exposure to a large object in copper or in aluminium

Large copper object

An individual is assumed to work 8 hours per day during 225 days per year in a place where there is a modern decoration made in copper. The decorative object is assumed to be represented by a disc with a diameter of 4 m and a thickness of 0.2 cm. The mean distance between the exposed person and the object is about 1.5 m.

Large aluminium object

An individual is assumed to spend 8 hours per day during 225 days per year in a office room where the ceiling is constructed from sheet aluminium. The source is considered to be a disc of area 12.25 m^2 (3.50 m x 3.50 m). The individual is assumed to be located 1.5 m under the source.

The doses are calculated by formula (35) in Appendix A using the parameter values given in Table 3.23 and the appropriate dose factors in place of DF_I and $Brem_I$ as given in Appendix D (DF_{LCO} and $Brem_{LCO}$ for copper and DF_{LAO} and $Brem_{LAO}$ for aluminium). Radionuclide dependent parameters are given in Appendix D.

The doses resulting from exposure to 1 Bq g^{-1} of each radionuclide for copper and aluminium are given in Tables 4.13 and Tables 4.14 respectively.

TABLE 3.23 Data for external exposure from a large object in copper and in aluminium

Parameter	Copper	AL(PWR) and AL(AG3)
Time of exposure (h y^{-1})	1800	1800
Fraction of VLLW	0.3	0.2
Diameter of the disc source (m)	4	4
Mean distance to the object (m)	1.5	1.5
Thickness of the disc source (cm)	0.2	0.2
Density of the metal (g cm^{-3})	8.9	2.7

3.9.1.d External exposure to a musical instrument in copper alloy (brass)

The individual is assumed to be a professional french horn player and to be exposed for 1622 hours per year[2].

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The external dose to the whole body (excluding effective dose from skin exposures), was calculated assuming a distance of 0 m from a source of similar dimensions to the french horn (see Table 3.24), represented by a thick cylinder along the axial direction.

The skin doses from contact of the french horn are calculated for the palm of the left hand, back of the right hand and lips. These are added together to calculate the total skin dose. The total effective dose is therefore the sum of the effective dose from the gamma dose from the cylindrical wall geometry and the total skin effective dose.

The effective gamma dose from a french horn assuming a cylindrical wall geometry is calculated by the equation below and the parameter values for this scenario are given in Table 3.24.

$$H = Am \cdot \rho m \cdot (DF_{MI} + Brem_{MI}) \cdot F \cdot t \cdot r \qquad (Sv\ y^{-1}) \qquad (74)$$

where:

- Am: Activity concentration of the VLL metal waste, when it leaves the nuclear installation (Bqg^{1}),
- ρm: density of the source material ($g\ cm^{-3}$), (= 8.2 $g\ cm^{-3}$ for brass),
- DF_{MI}: dose factor per unit volume activity concentration due to external exposure to gamma radiation from a musical instrument, represented by a thick cylindrical wall source at 0 m, (along axial direction) ($Sv\ h^{-1}$ per $Bq\ cm^{-3}$),
- $Brem_{MI}$: bremsstrahlung radiation ($Sv\ h^{-1}$ per $Bq\ cm^{-3}$), (Table 3.2 in Appendix D),
- F: fraction of VLL metal waste,
- t: annual time of exposure $h\ y^{-1}$,
- r: radionuclide distribution factor in the ingot during melting (Table 3.1 in Appendix D),

The term DF is derived from equation (2) in Appendix A.

where: φ is the flux per unit volume activity concentration for a thick cylindrical wall in the axial direction (see Figure 1):

$$\phi = 1/2 \cdot \int_{O}^{L} dx \int_{Ri}^{Re} B \cdot \frac{\exp(-((\mu \cdot (r - R_i)/\sin\alpha) + \mu_s \cdot \delta/\cos\alpha))}{r^2 + (x + d)^2} \cdot r\ dr \qquad (75)$$

where:

- B: build up fraction,
- R_i, R_e: internal and external radii, respectively (cm),
- Cone angle α = current variable,
- μ, μ_s: attenuation coefficients of the source and shield materials (cm^{-1}).

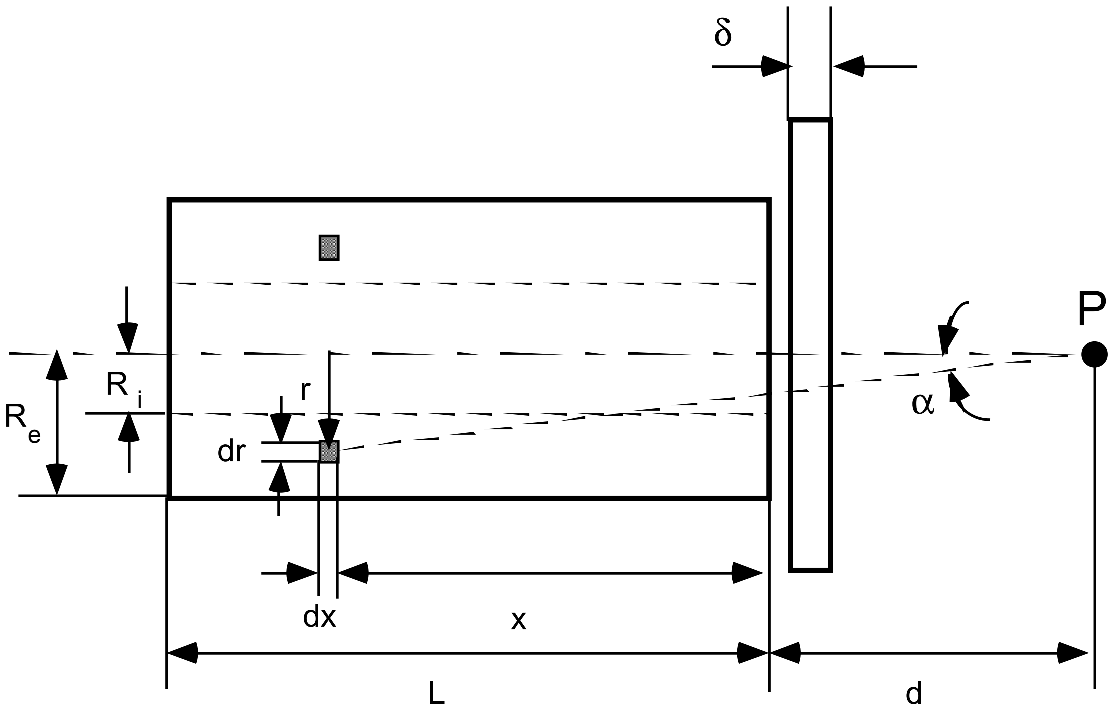

FIGURE 1 Diagram showing geometry for thick cylindrical wall axial direction

The skin dose from handling a french horn is calculated by the formula below and the parameter values for this scenario are given in Table 3.24:

For exposure to lips:

$H_{skinLIPS} = As \cdot (DF_{\beta c4} + DF_{\gamma c}) \cdot t \cdot s$ (76)

For exposure to hands:

$H_{skinLH} = As \cdot (DF_{\beta c40} + DF_{\gamma c}) \cdot t \cdot s$ (77)

$H_{skinRH} = As \cdot (DF_{\beta c4} + DF_{\gamma c}) \cdot t \cdot s$ (78)

where:

As: surface radioactivity of musical instrument (Bq cm^{-2})

$DF_{\beta c40}$: skin equivalent dose rate to the basal layer of the skin epidermis for beta irradiation, (at 40 mg cm^{-2} depth), (Sv h^{-1} per Bq cm^{-2}), (Table 3.2 in Appendix D),

$DF\beta c4$: skin equivalent dose rate to the basal layer of the skin epidermis for beta irradiation , (at 4 mg cm^{-2} depth), (Sv h^{-1} per Bq cm^{-2}), (Table 3.2 in Appendix D),

$DF\gamma c$: skin equivalent dose rate to the basal layer of the skin epidermis for gamma irradiation, (at 7 mg cm^{-2} depth) (Sv h^{-1} per Bq cm^{-2}), (Table 3.2 in Appendix D),

t: annual time of exposure (h y^{-1}),

s: surface over which dose is calculated (cm^2) (= 1 cm^2).

The radioactivity is per unit surface area expressed by:

$$As = Am \cdot r \cdot e \cdot \rho \cdot F \quad (Bq\ cm^{-2}) \qquad (79)$$

where:

Am: activity concentration of the VLL metal waste when it leaves the nuclear installation (Bq g^{-1})

r: radionuclide distribution factor in the ingot during melting (Table 3.1 in Appendix D),

e: thickness of musical instrument (cm),

ρ: density of brass (g cm^{-3}),

F: fraction of VLL metal waste.

The total skin dose is given by equation (80) below.
The total skin dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.13.

$$H_{skin\ total} = H_{skinLIPS} + H_{skinLH} + H_{skinRH} \qquad (80)$$

The effective skin dose is calculated from the formula given below and the parameter values for the scenarios are given in Table 3.24.

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$$H_{effskin} = H_{skin\,LIPS} \cdot W_{skin} \cdot \frac{CONTACT_{LIPS}}{BODY} + H_{skinLH} \cdot W_{skin} \cdot \frac{CONTACT_{LH}}{BODY} + H_{skinRH} \cdot W_{skin} \cdot \frac{CONTACT_{RH}}{BODY} \quad (81)$$

where:

W_{skin}: The tissue weighting factor for skin[1].

CONTACT: Area of skin in contact with contaminated object (for lips, left hand LH, right hand RH)[2].

BODY: The total skin area of the body = 10,000 cm^2

The total effective dose is given by the equation below. The total effective dose resulting from exposure to 1 Bq g^{-1} of each radionuclide is presented in Table 4.13.

$$H_{eff\,total} = H + H_{effskin} \quad (82)$$

TABLE 3.24 Data for handling a musical instrument (french horn) made from brass

Parameter	Value	Remarks
Parameters for external effective dose		
Source	Thick cylindrical wall geometry	Axial direction at 0 m distance
Time of exposure (h y^{-1})	1622	
Inner diameter (cm)	2.8	
External diameter (cm)	3.2	
Length (cm)	50	
Distance from end of source (cm)	0	
Density of source (brass) (g cm^{-3})	8.2	
Fraction of VLLW	0.3	
Parameters for skin dose and effective skin dose		
Time of exposure (h y^{-1})	1622	
Skin epidermis thickness (mg cm^{-2})	4	(for lips and back of right hand)
	40	(for palm of left hand)
Thickness of source (cm)	6.6 10^{-2}	
Fraction of VLLW	0.3	
Area of skin in contact with source (cm^2)		
$CONTACT_{LIPS}$	1	
$CONTACT_{LH}$	20.75	
$CONTACT_{RH}$	47	
Skin weighting factor	10^{-2}	

3.9.2 Public exposures

External exposure scenarios

3.9.2.a External exposure to a kitchen fitting in copper alloy

In this case, we have assumed an individual who spends about 1 hour per day (400 h per year), in a kitchen, near a brass fitting. The diameter is 0.2 m the thickness is 0.2 cm and the exposure distance is 0.5 m.

The doses are calculated by formula (35) in Appendix A using the density of brass given in Table 3.25 below and the appropriate dose factors substituted in place of DF_I and $Brem_I$ (Table 3.2 in Appendix D, DF_{SAN} and $Brem_{SAN}$). The radionuclide dependent parameters are given in Appendix D and the remaining parameters are given in Table 3.25. The doses resulting from exposure to 1 Bq g^{-1} of each radionuclide for brass are given in Table 4.13.

TABLE 3.25 Data for external exposure from a kitchen fitting in copper alloy

Parameter	Copper
Time of exposure (h y^{-1})	400
Fraction of VLLW	0.3
Mean distance to the object (m)	0.5
Diameter of the disc source (m)	0.2
Thickness of the disc source (cm)	0.2
Density of the metal (brass) (g cm^{-3})	8.2

3.9.2.b External exposure to an aluminium radiator

The scenario considers a radiator made from aluminium and situated in a room (such as a bedroom) where an individual spends 8 hours per day, and 11 months per year (330 days). The radiator is 80 cm high, 50 cm long and 12 kg in weight. The source is considered to be a disc of a diameter of 0.7 m giving a similar surface area to the radiator (400 cm^2). The distance to the radiator is about 1.5 m.

The doses are calculated by formula (35) in Appendix A using the density of aluminium given in Table 3.26 and the appropriate dose factors substituted in place of DF_I and $Brem_I$ (Table 3.2 in Appendix D (DF_{RAL} and $Brem_{RAL}$)). The radionuclide dependent parameters are given in Appendix D and the remaining scenario parameters are given in Table 3.26.

The doses resulting from exposure to 1 Bq g^{-1} of each radionuclide for aluminium are given in Table 4.14.

TABLE 3.26 Data for external exposure from a radiator in aluminium

Parameter	AL(PWR) and AL(AG3)
Time of exposure (h y^{-1})	2640
Fraction of VLLW	0.2
Diameter of the disc source (m)	0.70
Mean distance to the object (m)	1.5
Thickness of the disk source (cm)	1
Density of the metal (g cm^{-3})	2.7

3.9.2c External exposure to a car engine in aluminium

Recycled aluminium is assumed to be used in the engine of a car. The individual is assumed to be a taxi-driver who spends 1800 hours per year in his vehicle. The car engine is modelled as a disc source with a diameter of 0.5 m and a thickness of 20 cm. The mean distance between the engine and the individual is 1 m.

The doses are calculated by formula (35) in Appendix A using the density given in Table 3.27 below and the appropriate dose factors substituted in place of DF_I and $Brem_I$ (Table 3.2 in Appendix D (DF_{CE} and $Brem_{CE}$)). The radionuclide dependent parameters are given in Appendix D and the remaining parameters are given in Table 3.27.

The doses resulting from exposure to 1 Bq g^{-1} of each radionuclide for aluminium are given in Table 4.14.

TABLE 3.27 Data for external exposure from a car engine

Parameter	AL(PWR) and AL(AG3)
Time of exposure (h y^{-1})	1800
Fraction of VLLW	0.2
Mean distance to the object (m)	1.0
Diameter of the disc source (m)	0.5
Thickness of the disk source (cm)	20
Apparent density (g cm^{-3})	2

Ingestion exposure scenarios

3.9.2d Consumption of pig meat

Copper is included in foodstuffs for animals in various forms. Most of the copper intended for this purpose is used in the preparation of pig food, which is supplemented by the addition of oligo-elements stimulating growth. Among these additives are copper compounds, such as sulfates and acetates. Official regulations relating to the use of additives in foodstuffs for animals authorize a maximum of 175 mg kg^{-1} at the beginning of growth and 35 mg kg^{-1} at the end of growth, giving a mean amount of 42 g of copper for a 7 months growth (0.23 g of copper per day during the life of an animal intended for human consumption).

The generic scenario for exposure by ingestion of pig meat is represented by the mean consumption of a European citizen.

The dose is given by equation (83) below and the parameter values for this scenario are given in Table 3.28. The doses corresponding to waste containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.13.

The annual dose for exposure by ingestion of pig meat containing copper is given by the following equation:

$$H = Am \cdot M_{CU} \cdot Mv \cdot F \cdot DF_{ing} \cdot FT \cdot r \qquad (83)$$

where:

Am: activity concentration of the VLLW metal waste when it leaves the nuclear installation (Bq g^{-1}),

M_{CU}: mass of daily copper intake by the pig (g d^{-1}),

Mv: mass of annual intake of pig met ingested by an European citizen (kg y^{-1}),
F: fraction of VLL metal waste,
DF_{ing}: public dose coefficient for ingestion (Sv Bq^{-1}),
(Table 3.3 in Appendix D),
FT: animal transfer rate for pig meat (Bq kg^{-1} per Bq d^{-1}),
(Table 3.4 in Appendix D),
r: radionuclide distribution factor in the ingot during melting,
(Table 3.1 Appendix D).

TABLE 3.28 Data for ingestion of the meat of a pig fed with food containing copper

Parameter	Copper
Mass of daily copper intake by the pig (g d^{-1})	0.23
Mass of annual intake of pig meat by an European citizen (kg y^{-1})	38
Fraction of VVLW	0.2

3.9.2.e Ingestion of aluminium metal particles from a saucepan

Various aluminium alloys may be used in the manufacture of cooking utensils, such as saucepans and frying pans. When food is cooked in salt water, the surface of the saucepan can be corroded. If the food is not washed after cooking (which is the case for soups, potatoes, etc) the corroded metal will be consumed with the food. The generic scenario represents corrosion of the effective area of the utensil. The saucepan has a 28 cm diameter and the thickness of the corroded metal layer is 1 µm.

The dose is expressed by equation (84) below and the parameter values for this scenario are given in Table 3.29. The doses corresponding to waste containing 1 Bq g^{-1} of each radionuclide are presented in Table 4.14.

The annual dose for exposure by ingestion of aluminium corroded from a saucepan is given by the following equation:

$$H = Am \cdot e \cdot a \cdot \rho \cdot DF_{ing} \cdot F \cdot r \qquad (84)$$

where:

Am: activity concentration of the VLLW metal waste when it leaves the nuclear installation (Bq g^{-1}),
e: thickness of aluminium removed in a year (cm y^{-1}),
a: area of the saucepan over which corrosion takes place (cm^2),
ρ: density of aluminium (g cm^{-3}),
DF_{ing}: public dose coefficient for ingestion (Sv Bq^{-1}),
(Table 3.3 in Appendix D),
F: fraction of VLL metal waste,
r: radionuclide distribution factor in the ingot during melting,
(Table 3.1 in Appendix D).

TABLE 3.29 Data for ingestion of aluminium metal particles from a saucepan

Parameter	Aluminium
Area of the saucepan over which corrosion takes place (cm^2)	640
Thickness removed ($cm\ y^{-1}$)	10^{-4}
Fraction of VVLW	0.2
Density ($g\ cm^{-3}$)	2.7

Section 4

Tables of Doses

Appendix B

TABLE 4.1 ANNUAL INDIVIDUAL DOSE RATES AT A SCRAP YARD (WORKERS) (Sv/y)

NUCLIDE	(3.1) EXTERNAL COPPER	(3.1) EXTERNAL ALUMINIUM
H3	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01
Mn54	2,49E-06	2,61E-06
Fe55	0,00E+01	0,00E+01
Co60	8,66E-06	8,53E-06
Ni59	0,00E+01	0,00E+01
Ni63	0,00E+01	0,00E+01
Zn65	1,92E-06	1,93E-06
Sr90+	3,35E-07	1,27E-07
Nb94	4,58E-06	4,86E-06
Tc99	1,28E-10	1,95E-10
Ru106+	1,43E-06	8,91E-07
Ag108m+	4,11E-06	4,64E-06
Ag110m+	8,33E-06	8,67E-06
Sb125+	9,52E-07	8,67E-07
Cs134	4,31E-06	4,67E-06
Cs137+	1,50E-06	1,66E-06
Pm147	1,54E-11	3,24E-11
Sm151	2,40E-50	2,52E-49
Eu152	3,36E-06	3,48E-06
Eu154	3,77E-06	3,84E-06
U234	7,84E-12	6,78E-12
U235+	8,46E-08	2,17E-07
U238+	2,79E-07	1,21E-07
Np237+	1,25E-07	4,81E-08
Pu238	5,05E-13	6,26E-13
Pu239	2,05E-11	8,26E-12
Pu240	6,05E-13	6,91E-13
Pu241	1,75E-13	1,57E-13
Am241	1,03E-11	4,67E-11
Cm244	1,57E-18	1,23E-17
Na-22	6,57E-06	6,94E-06
S-35	2,08E-12	5,67E-12
Cl-36	7,58E-09	5,83E-09
K-40	5,59E-07	5,45E-07
Ca-45	5,00E-25	2,00E-24
Sc-46	6,48E-06	6,56E-06
Mn-53	0,00E+01	0,00E+01
Co-56	1,25E-05	1,21E-05
Co-57	4,39E-08	1,08E-07
Co-58	2,80E-06	3,05E-06
As-73	3,96E-13	5,02E-12
Se-75	4,74E-07	6,99E-07
Se-79	2,38E-12	6,74E-12
Sr-85	1,19E-06	1,44E-06
Y-91	1,13E-07	5,71E-08
Zr-93	1,13E-18	5,79E-18
Zr-95+	4,29E-06	4,72E-06
Nb-93m	5,31E-17	2,13E-16
Mo-93	2,98E-16	1,19E-15
Tc-97	5,13E-16	2,05E-15
Tc-97m	3,85E-11	1,40E-10

Appendix B

TABLE 4.1 (cont.)		
Pd-107	6,63E-35	3,24E-34
Cd-109	0,00E+01	0,00E+01
Sn-113+	5,06E-07	6,45E-07
Sn-126+	5,11E-06	5,86E-06
Sb-124	6,03E-06	6,16E-06
Te-123m	8,72E-08	1,71E-07
Te-127m+	1,37E-08	1,20E-08
I-125	7,19E-14	2,89E-13
I-129	4,21E-14	1,69E-13
Cs-135	1,37E-11	2,94E-11
Ce-139	9,52E-08	1,80E-07
Ce-144+	1,13E-07	1,20E-07
Sm-147	0,00E+01	0,00E+01
Eu-155	5,83E-09	2,06E-08
Gd-153	7,92E-09	2,73E-08
Tb-160	3,24E-06	3,35E-06
Tm-170	1,47E-08	1,39E-09
Tm-171	9,08E-13	5,83E-12
Ta-182	4,01E-06	4,00E-06
W-181	1,74E-10	6,48E-10
W-185	5,45E-10	6,18E-10
Os-185	1,80E-06	2,02E-06
Ir-192	1,57E-06	2,00E-06
Tl-204	6,64E-09	4,70E-09
Pb-210+	2,82E-08	1,54E-08
Bi-207	4,46E-06	4,67E-06
Po-210	2,51E-11	2,70E-11
Ra-226+	5,47E-06	5,59E-06
Ra-228+	2,76E-06	2,89E-06
Ac-227+	5,74E-07	7,67E-07
Th-228+	5,01E-06	4,91E-06
Th-229+	5,12E-07	6,35E-07
Th-230	8,68E-11	1,71E-10
Th-232	1,87E-11	4,82E-11
Pa-231	4,14E-08	5,78E-08
U-232	5,20E-11	1,14E-10
U-233	5,42E-11	1,55E-10
U-236	6,86E-13	4,13E-12
Pu-236	9,08E-14	6,21E-13
Pu-242	8,48E-15	7,34E-14
Pu-244+	8,99E-07	9,94E-07
Am-242m+	1,20E-08	1,37E-08
Am-243+	1,36E-07	2,25E-07
Cm-242	2,46E-14	1,77E-13
Cm-243	1,08E-07	1,73E-07
Cm-245	2,15E-08	5,35E-08
Cm-246	7,65E-16	3,43E-15
Cm-247+	6,24E-07	7,96E-07
Cm-248	4,51E-15	4,00E-14
Bk-249	2,36E-13	6,28E-13
Cf-248	2,68E-16	1,13E-15
Cf-249	6,07E-07	7,86E-07
Cf-250	6,61E-13	3,40E-12
Cf-251	6,85E-08	1,29E-07
Cf-252	1,65E-13	9,94E-13
Cf-254	8,70E-19	3,67E-18
Es-254	1,92E-09	2,83E-09

Appendix B

TABLE 4.2 ANNUAL INDIVIDUAL DOSE RATES FROM EXTERNAL EXPOSURE IN THE REFINERY (WORKERS) (Sv/y)

NUCLIDE	SCRAP HEAP (3.2.1) EXTERNAL COPPER	SCRAP HEAP (3.2.1) EXTERNAL ALUMINIUM (PWR)	SCRAP HEAP (3.2.1) EXTERNAL ALUMINIUM (AG3)
H3	0,00E+01	0,00E+01	
C14	0,00E+01	0,00E+01	
Mn54	2,80E-07	3,10E-07	
Fe55	5,66E-13	5,39E-13	
Co60	9,24E-07	9,67E-07	
Ni59	8,44E-13	7,44E-13	
Ni63	0,00E+01	0,00E+01	
Zn65	2,08E-07	2,22E-07	
Sr90+	1,53E-08	2,85E-09	
Nb94	5,19E-07	5,78E-07	
Tc99	3,40E-11	2,51E-11	
Ru106+	9,60E-08	7,80E-08	
Ag108m+	4,84E-07	5,73E-07	
Ag110m+	9,28E-07	1,02E-06	
Sb125+	1,14E-07	1,05E-07	
Cs134	4,95E-07	5,69E-07	
Cs137+	1,76E-07	2,03E-07	
Pm147	7,10E-12	8,30E-12	
Sm151	4,15E-15	4,35E-14	
Eu152	3,70E-07	4,13E-07	
Eu154	4,11E-07	4,53E-07	
U234	2,71E-12	3,89E-12	3,89E-11
U235+	1,45E-08	4,04E-08	4,04E-07
U238+	1,25E-08	5,93E-09	5,93E-08
Np237+	1,68E-08	7,39E-09	
Pu238	4,21E-13	2,20E-12	
Pu239	2,95E-12	2,26E-12	
Pu240	4,47E-13	3,71E-12	
Pu241	5,24E-14	5,20E-14	
Am241	1,75E-10	7,68E-10	
Cm244	1,97E-13	1,96E-12	
Na-22	7,31E-07	8,16E-07	
S-35	2,22E-12	3,94E-12	
Cl-36	7,73E-10	2,74E-10	
K-40	5,88E-08	6,07E-08	
Ca-45	0,00E+01	2,33E-18	
Sc-46	7,08E-07	7,58E-07	
Mn-53	0,00E+01	0,00E+01	
Co-56	1,31E-06	1,36E-06	
Co-57	9,98E-09	2,60E-08	
Co-58	3,17E-07	3,65E-07	
As-73	9,10E-11	6,80E-10	
Se-75	6,74E-08	1,06E-07	
Se-79	2,76E-12	4,92E-12	
Sr-85	1,44E-07	1,80E-07	
Y-91	6,93E-09	2,57E-09	
Zr-93	4,18E-14	1,54E-13	
Zr-95+	4,87E-07	5,64E-07	
Nb-93m	1,62E-12	1,76E-11	
Mo-93	9,07E-12	9,87E-11	
Tc-97	1,57E-11	1,26E-10	
Tc-97m	3,46E-11	1,79E-10	

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TABLE 4.2 (cont.)			
Pd-107	5,11E-15	1,29E-14	
Cd-109	9,87E-11	3,92E-10	
Sn-113+	6,41E-08	8,55E-08	
Sn-126+	5,98E-07	7,24E-07	
Sb-124	6,52E-07	7,10E-07	
Te-123m	1,56E-08	3,20E-08	
Te-127m+	4,88E-11	2,03E-10	
I-125	4,97E-10	2,13E-09	
I-129	3,03E-10	1,51E-09	
Cs-135	7,33E-12	9,08E-12	
Ce-139	1,65E-08	3,35E-08	
Ce-144+	1,27E-08	1,56E-08	
Sm-147	0,00E+01	0,00E+01	
Eu-155	2,60E-09	1,05E-08	
Gd-153	3,80E-09	1,64E-08	
Tb-160	3,59E-07	3,95E-07	
Tm-170	1,25E-09	4,92E-10	
Tm-171	1,20E-11	8,50E-11	
Ta-182	4,36E-07	4,71E-07	
W-181	7,74E-10	5,25E-09	
W-185	9,16E-11	5,47E-11	
Os-185	2,08E-07	2,51E-07	
Ir-192	1,99E-07	2,65E-07	
Tl-204	6,37E-10	3,18E-10	
Pb-210+	4,85E-11	1,10E-10	
Bi-207	4,97E-07	5,59E-07	
Po-210	2,84E-12	3,22E-12	
Ra-226+	5,94E-07	6,51E-07	
Ra-228+	3,06E-07	3,40E-07	
Ac-227+	7,64E-08	1,13E-07	
Th-228+	5,25E-07	5,59E-07	
Th-229+	6,47E-08	9,38E-08	
Th-230	2,08E-11	7,29E-11	
Th-232	6,55E-12	3,20E-11	
Pa-231	5,67E-09	8,55E-09	
U-232	1,24E-11	4,74E-11	
U-233	1,47E-11	4,61E-11	
U-236	2,00E-12	1,93E-11	
Pu-236	1,12E-12	1,79E-11	
Pu-242	4,95E-13	1,08E-11	
Pu-244+	1,03E-07	1,21E-07	
Am-242m+	1,84E-11	8,09E-11	
Am-243+	2,29E-08	4,91E-08	
Cm-242	6,18E-13	1,41E-11	
Cm-243	1,68E-08	3,09E-08	
Cm-245	5,16E-09	1,43E-08	
Cm-246	3,28E-13	1,02E-11	
Cm-247+	7,93E-08	1,08E-07	
Cm-248	3,67E-13	8,85E-12	
Bk-249	5,06E-13	1,31E-12	
Cf-248	3,49E-13	9,28E-12	
Cf-249	7,75E-08	1,05E-07	
Cf-250	1,03E-12	1,26E-11	
Cf-251	1,23E-08	2,61E-08	
Cf-252	7,06E-13	1,08E-11	
Cf-254	3,32E-16	2,37E-15	
Es-254	3,03E-10	7,14E-10	

Appendix B

TABLE 4.3 ANNUAL INDIVIDUAL DOSE RATES FROM EXPOSURE DURING COPPER SMELTING (Sv/y)

NUCLIDE	(3.3.1) DUST INHALATION (WORKER)	(3.3.2) DUST INGESTION (WORKER)	(3.3.3) EXTERNAL (WORKER)	(3.3.4) ATMOSPHERIC EMISSION (PUBLIC)
H3	1,17E-10	8,50E-11	0,00E+01	2,19E-12
C14	3,76E-09	2,74E-09	0,00E+01	5,67E-11
Mn54	3,89E-10	1,68E-10	4,44E-09	1,59E-11
Fe55	2,98E-10	7,80E-11	8,99E-15	9,43E-13
Co60	2,20E-08	3,21E-09	7,35E-08	2,13E-10
Ni59	2,85E-10	5,95E-11	6,70E-14	1,06E-12
Ni63	6,74E-10	1,42E-10	0,00E+01	2,72E-12
Zn65	9,07E-09	9,21E-09	3,32E-09	1,83E-10
Sr90+	5,10E-08	1,45E-08	2,50E-08	2,27E-10
Nb94	1,62E-07	8,03E-09	8,23E-07	8,63E-10
Tc99	2,07E-11	3,69E-12	5,43E-12	9,78E-14
Ru106+	2,27E-07	3,31E-08	1,54E-08	7,85E-10
Ag108m+	1,23E-08	1,09E-09	7,67E-07	8,51E-11
Ag110m+	4,73E-09	1,32E-09	1,47E-06	1,07E-10
Sb125+	5,13E-09	1,23E-09	1,83E-07	5,49E-11
Cs134	6,22E-08	8,98E-08	7,85E-08	1,47E-09
Cs137+	4,34E-08	6,14E-08	2,79E-08	9,80E-10
Pm147	2,27E-11	1,23E-12	1,13E-14	3,82E-14
Sm151	1,68E-11	4,63E-13	6,58E-18	2,57E-14
Eu152	1,75E-10	6,61E-12	2,93E-07	6,56E-13
Eu154	2,27E-10	9,45E-12	3,27E-07	7,75E-13
U234	4,41E-08	2,32E-10	4,07E-12	5,23E-11
U235+	3,95E-08	2,19E-10	2,29E-08	4,75E-11
U238+	3,70E-08	2,26E-10	2,48E-08	4,49E-11
Np237+	9,72E-08	5,24E-10	2,74E-08	2,72E-10
Pu238	1,94E-07	1,09E-09	6,63E-13	5,97E-10
Pu239	2,07E-07	1,18E-09	4,77E-12	6,51E-10
Pu240	2,07E-07	1,18E-09	7,11E-13	6,51E-10
Pu241	3,76E-09	2,22E-11	8,38E-14	1,25E-11
Am241	1,75E-07	9,45E-10	2,77E-10	5,21E-10
Cm244	1,10E-07	5,67E-10	3,14E-13	3,09E-10
Na-22	1,30E-08	1,51E-08	1,16E-07	8,40E-10
S-35	7,13E-10	3,64E-10	3,55E-16	4,44E-12
Cl-36	3,30E-08	4,39E-09	1,25E-13	8,30E-11
K-40	1,94E-08	2,93E-08	9,35E-09	3,50E-10
Ca-45	1,49E-09	3,59E-10	0,00E+01	5,13E-12
Sc-46	3,11E-09	7,09E-10	1,13E-06	7,42E-11
Mn-53	1,17E-11	7,09E-12	0,00E+01	8,40E-14
Co-56	6,35E-09	2,36E-09	1,04E-07	2,47E-10
Co-57	7,78E-10	1,98E-10	7,95E-10	1,24E-11
Co-58	2,20E-09	6,99E-10	2,52E-08	7,39E-11
As-73	8,42E-10	2,46E-10	1,46E-10	4,04E-12
Se-75	1,10E-10	1,23E-10	1,07E-07	2,65E-12
Se-79	2,01E-10	1,37E-10	4,38E-12	1,65E-12
Sr-85	3,63E-10	2,65E-10	2,29E-07	2,05E-11
Y-91	3,95E-09	1,13E-09	1,12E-08	1,82E-11
Zr-93	1,88E-07	1,32E-09	6,65E-14	1,82E-10
Zr-95+	3,56E-08	6,90E-09	7,75E-07	6,12E-10
Nb-93m	5,57E-09	5,67E-10	2,39E-12	1,53E-11
Mo-93	9,07E-10	1,23E-09	1,34E-12	1,52E-11
Tc-97	1,04E-12	3,92E-13	2,35E-12	1,48E-14
Tc-97m	1,75E-11	3,12E-12	5,35E-12	4,82E-14

Appendix B

TABLE 4.3 (cont.)				
Pd-107	3,76E-10	3,50E-11	2,03E-17	9,58E-13
Cd-109	3,11E-08	4,72E-09	1,54E-12	6,77E-11
Sn-113+	1,25E-08	3,58E-09	1,02E-08	1,43E-10
Sn-126+	1,20E-07	2,40E-08	9,50E-08	1,08E-09
Sb-124	6,09E-09	2,36E-09	1,04E-06	1,50E-10
Te-123m	2,20E-10	6,61E-11	2,48E-08	1,43E-12
Te-127m+	4,13E-10	1,17E-10	7,89E-11	1,69E-12
I-125	4,73E-08	7,09E-08	7,98E-12	7,03E-10
I-129	3,30E-07	5,20E-07	4,92E-12	5,09E-09
Cs-135	6,42E-09	9,45E-09	1,17E-13	1,35E-10
Ce-139	9,07E-12	1,23E-12	2,63E-08	8,00E-14
Ce-144+	1,88E-10	2,48E-11	2,02E-08	5,81E-13
Sm-147	3,97E-08	2,32E-10	0,00E+01	5,34E-11
Eu-155	3,05E-11	1,51E-12	2,07E-09	7,46E-14
Gd-153	1,62E-11	1,28E-12	3,04E-09	6,50E-14
Tb-160	3,50E-11	7,56E-12	5,70E-07	4,61E-13
Tm-170	3,37E-11	6,14E-12	5,07E-10	1,05E-13
Tm-171	5,90E-12	5,20E-13	9,61E-12	1,26E-14
Ta-182	4,80E-08	7,09E-09	6,94E-07	5,26E-10
W-181	2,79E-11	3,59E-11	1,24E-10	1,89E-12
W-185	1,43E-10	2,08E-10	1,47E-12	2,02E-12
Os-185	9,07E-09	2,41E-09	3,30E-08	2,72E-10
Ir-192	6,35E-09	1,32E-09	1,58E-08	7,69E-11
Tl-204	4,02E-10	6,14E-10	1,03E-11	6,26E-12
Pb-210+	7,52E-06	3,22E-06	7,86E-13	6,11E-08
Bi-207	4,15E-09	1,23E-09	7,91E-07	1,18E-10
Po-210	1,43E-07	1,13E-08	4,50E-12	7,63E-10
Ra-226+	1,44E-06	1,32E-07	9,47E-07	6,39E-09
Ra-228+	1,12E-06	3,17E-07	4,87E-07	1,16E-08
Ac-227+	4,17E-04	5,71E-07	1,21E-07	3,09E-07
Th-228+	2,23E-07	6,67E-10	8,36E-07	2,40E-10
Th-229+	5,21E-07	2,83E-09	1,03E-07	1,39E-09
Th-230	1,81E-07	9,92E-10	3,33E-11	5,43E-10
Th-232	1,89E-07	1,05E-09	1,04E-11	5,97E-10
Pa-231	5,77E-07	3,35E-09	9,04E-09	7,78E-10
U-232	1,68E-07	1,56E-09	1,99E-11	2,12E-10
U-233	4,47E-08	2,36E-10	2,34E-11	5,35E-11
U-236	4,08E-08	2,17E-10	3,20E-12	4,85E-11
Pu-236	8,42E-08	4,06E-10	1,76E-12	2,17E-10
Pu-242	2,01E-07	1,13E-09	7,74E-13	5,97E-10
Pu-244+	1,94E-07	1,14E-09	1,63E-07	5,97E-10
Am-242m+	1,56E-07	8,99E-10	2,95E-11	4,99E-10
Am-243+	1,75E-07	9,49E-10	3,65E-08	5,21E-10
Cm-242	2,40E-08	5,67E-11	9,37E-13	3,20E-11
Cm-243	1,30E-07	7,09E-10	2,68E-08	3,75E-10
Cm-245	1,75E-07	9,92E-10	8,20E-09	5,37E-10
Cm-246	1,75E-07	9,92E-10	4,87E-13	5,32E-10
Cm-247+	1,62E-07	8,98E-10	1,26E-07	4,89E-10
Cm-248	6,16E-07	3,64E-09	5,54E-13	1,95E-09
Bk-249	6,48E-10	4,58E-12	8,03E-13	8,96E-13
Cf-248	3,95E-08	1,32E-10	5,03E-13	4,82E-11
Cf-249	2,92E-07	1,65E-09	1,23E-07	3,89E-10
Cf-250	1,43E-07	7,56E-10	1,59E-12	1,88E-10
Cf-251	2,98E-07	1,70E-09	1,95E-08	3,95E-10
Cf-252	8,42E-08	4,25E-10	1,07E-12	1,11E-10
Cf-254	1,43E-07	1,89E-09	5,40E-16	2,36E-10
Es-254	3,89E-08	1,32E-10	4,81E-10	4,71E-11

Appendix B

TABLE 4.4 ANNUAL INDIVIDUAL DOSE RATES FROM EXPOSURE DURING ALUMINIUM SMELTING (Sv/y)

NUCLIDE	(3.3.1) DUST INHALATION (WORKERS)	(3.3.2) DUST INGESTION (WORKERS)	(3.3.3) EXTERNAL (WORKERS)	(3.3.4) ATMOSPHERIC EMISSION (PUBLIC)
PWR				
H3	5,60E-10	1,46E-10	0,00E+01	1,47E-12
C14	1,80E-08	4,70E-09	0,00E+01	3,81E-11
Mn54	1,87E-10	2,88E-11	4,91E-07	1,07E-12
Fe55	1,43E-10	1,34E-11	8,55E-13	6,34E-14
Co60	5,29E-10	2,75E-11	1,54E-06	7,17E-13
Ni59	3,42E-11	2,55E-12	1,18E-12	1,78E-14
Ni63	8,09E-11	6,07E-12	0,00E+01	4,57E-14
Zn65	4,35E-10	1,58E-10	3,52E-07	1,23E-12
Sr90+	2,45E-07	2,49E-08	4,68E-09	1,52E-10
Nb94	7,78E-07	1,38E-08	9,23E-07	5,80E-10
Tc99	9,95E-11	6,32E-12	4,11E-12	6,57E-14
Ru106+	1,09E-06	5,67E-08	1,25E-08	5,27E-10
Ag108m+	5,91E-10	1,86E-11	9,14E-07	5,72E-13
Ag110m+	2,27E-10	2,27E-11	1,62E-06	7,22E-13
Sb125+	2,46E-10	2,10E-11	1,71E-07	3,69E-13
Cs134	2,99E-07	1,54E-07	8,99E-09	9,90E-10
Cs137+	2,08E-07	1,05E-07	3,23E-09	6,59E-10
Pm147	1,09E-10	2,11E-12	1,35E-14	2,57E-14
Sm151	8,09E-11	7,94E-13	6,90E-17	1,73E-14
Eu152	8,40E-10	1,13E-11	3,28E-07	4,41E-13
Eu154	1,09E-09	1,62E-11	3,60E-07	5,21E-13
U234	2,12E-07	3,97E-10	1,26E-11	3,52E-11
U235+	1,90E-07	3,75E-10	3,21E-08	3,19E-11
U238+	1,77E-07	3,88E-10	4,83E-09	3,02E-11
Np237+	4,67E-07	8,98E-10	6,07E-09	1,83E-10
Pu238	9,33E-07	1,86E-09	2,79E-12	4,01E-10
Pu239	9,95E-07	2,03E-09	1,84E-12	4,38E-10
Pu240	9,95E-07	2,02E-09	1,80E-12	4,38E-10
Pu241	1,80E-08	3,81E-11	4,28E-14	8,39E-12
Am241	8,40E-07	1,62E-09	6,29E-10	3,50E-10
Cm244	5,29E-07	9,72E-10	1,56E-12	2,08E-10
AG3				
U234	2,12E-06	3,97E-09	1,26E-10	3,52E-10
U235+	1,90E-06	3,75E-09	3,21E-07	3,19E-10
U238+	1,77E-06	3,88E-09	4,83E-08	3,02E-10
PWR				
Na-22	6,22E-09	2,59E-09	1,31E-07	5,64E-11
S-35	3,42E-09	6,24E-10	6,39E-14	2,98E-12
Cl-36	1,59E-08	7,53E-10	4,47E-12	5,58E-12
K-40	9,32E-09	5,02E-09	9,71E-09	2,35E-11
Ca-45	7,15E-09	6,16E-10	4,82E-19	3,45E-12
Sc-46	1,49E-08	1,21E-09	1,21E-06	4,99E-11
Mn-53	5,60E-12	1,21E-12	0,00E+01	5,64E-15
Co-56	1,52E-10	2,02E-11	2,17E-06	8,30E-13
Co-57	1,87E-11	1,70E-12	4,17E-08	4,16E-14
Co-58	5,29E-11	5,99E-12	5,83E-07	2,48E-13
As-73	4,04E-11	4,21E-12	1,10E-09	2,72E-14
Se-75	5,29E-09	2,11E-09	1,72E-08	1,78E-11
Se-79	9,64E-09	2,35E-09	7,99E-14	1,11E-11
Sr-85	1,74E-09	4,54E-10	2,90E-07	1,37E-11
Y-91	1,90E-08	1,94E-09	4,15E-09	1,22E-11
Zr-93	9,02E-07	2,27E-09	2,45E-13	1,22E-10
Zr-95+	1,71E-07	1,18E-08	9,04E-07	4,11E-10
Nb-93m	2,67E-08	9,72E-10	3,00E-11	1,03E-11
Mo-93	4,35E-09	2,11E-09	1,68E-11	1,02E-11
Tc-97	4,98E-12	6,72E-13	2,13E-11	9,97E-15
Tc-97m	8,40E-11	5,35E-12	2,96E-11	3,24E-14

Appendix B

TABLE 4.4 (cont.)				
Pd-107	4,51E-11	1,50E-12	2,05E-14	1,61E-14
Cd-109	1,49E-09	8,10E-11	6,51E-10	4,55E-13
Sn-113+	6,01E-08	6,14E-09	1,38E-08	9,63E-11
Sn-126+	5,75E-07	4,11E-08	1,16E-07	7,29E-10
Sb-124	2,92E-10	4,05E-11	1,13E-06	1,01E-12
Te-123m	1,06E-08	1,13E-09	5,15E-09	9,62E-12
Te-127m+	1,98E-08	2,00E-09	3,24E-12	1,13E-11
I-125	2,27E-08	1,21E-08	3,48E-10	4,72E-11
I-129	1,59E-07	8,91E-08	2,46E-10	3,42E-10
Cs-135	3,08E-08	1,62E-08	1,48E-15	9,06E-11
Ce-139	4,35E-11	2,11E-12	2,70E-08	5,38E-14
Ce-144+	9,03E-10	4,25E-11	2,49E-08	3,91E-13
Sm-147	1,90E-07	3,98E-10	0,00E+01	3,59E-11
Eu-155	1,46E-10	2,59E-12	8,46E-09	5,01E-14
Gd-153	7,78E-11	2,19E-12	1,33E-08	4,37E-14
Tb-160	1,68E-10	1,30E-11	3,16E-07	3,10E-13
Tm-170	1,62E-10	1,05E-11	2,01E-10	7,05E-14
Tm-171	2,83E-11	8,91E-13	6,85E-11	8,48E-15
Ta-182	2,30E-07	1,21E-08	7,53E-07	3,53E-10
W-181	1,34E-10	6,16E-11	8,50E-10	1,27E-12
W-185	6,84E-10	3,56E-10	8,92E-13	1,36E-12
Os-185	4,35E-08	4,13E-09	4,03E-08	1,83E-10
Ir-192	1,52E-10	1,13E-11	4,26E-07	2,59E-13
Tl-204	1,93E-09	1,05E-09	5,15E-10	4,20E-12
Pb-210+	3,61E-05	5,52E-06	1,75E-12	4,11E-08
Bi-207	1,99E-10	2,11E-11	8,94E-07	7,96E-13
Po-210	6,84E-06	1,94E-07	5,15E-13	5,13E-09
Ra-226+	6,92E-06	2,27E-07	1,04E-06	4,29E-09
Ra-228+	5,38E-06	5,43E-07	5,44E-07	7,83E-09
Ac-227+	2,00E-03	9,78E-07	1,82E-07	2,07E-07
Th-228+	1,07E-06	1,14E-09	4,42E-07	1,61E-10
Th-229+	2,50E-06	4,85E-09	7,51E-08	9,37E-10
Th-230	8,71E-07	1,70E-09	6,00E-11	3,65E-10
Th-232	9,09E-07	1,80E-09	2,69E-11	4,01E-10
Pa-231	2,77E-06	5,75E-09	6,88E-09	5,23E-10
U-232	8,09E-07	2,67E-09	3,99E-11	1,42E-10
U-233	2,15E-07	4,05E-10	3,77E-11	3,59E-11
U-236	1,96E-07	3,73E-10	1,70E-11	3,26E-11
Pu-236	4,04E-07	6,97E-10	1,63E-11	1,46E-10
Pu-242	9,64E-07	1,94E-09	9,96E-12	4,01E-10
Pu-244+	9,33E-07	1,95E-09	9,67E-08	4,01E-10
Am-242m+	7,47E-07	1,54E-09	3,23E-11	3,35E-10
Am-243+	8,40E-07	1,63E-09	3,96E-08	3,50E-10
Cm-242	1,15E-07	9,72E-11	1,28E-11	2,15E-11
Cm-243	6,22E-07	1,21E-09	2,48E-08	2,52E-10
Cm-245	8,40E-07	1,70E-09	1,15E-08	3,61E-10
Cm-246	8,40E-07	1,70E-09	9,36E-12	3,58E-10
Cm-247+	7,78E-07	1,54E-09	8,70E-08	3,28E-10
Cm-248	2,95E-06	6,24E-09	8,02E-12	1,31E-09
Bk-249	3,11E-09	7,86E-12	5,30E-13	6,02E-13
Cf-248	1,90E-07	2,27E-10	8,31E-12	3,24E-11
Cf-249	1,40E-06	2,84E-09	8,43E-08	2,61E-10
Cf-250	6,84E-07	1,30E-09	1,10E-11	1,27E-10
Cf-251	1,43E-06	2,92E-09	2,11E-08	2,65E-10
Cf-252	4,04E-07	7,29E-10	9,45E-12	7,44E-11
Cf-254	6,84E-07	3,24E-09	1,92E-15	1,59E-10
Es-254	1,87E-07	2,27E-10	5,86E-10	3,17E-11

Appendix B

TABLE 4.5 ANNUAL INDIVIDUAL DOSE RATES FROM EXPOSURE DURING TREATMENT OF COPPER BY-PRODUCTS (WORKERS) (Sv/y)

NUCLIDE	DUST COMPACTING (2.3.1) INHALATION	RECOVERY OF ZINC (2.3.2) INHALATION	SLAG PROCESSING (2.3.3) EXTERNAL
H3	2,33E-11	7,78E-12	0,00E+01
C14	7,52E-10	2,51E-10	0,00E+01
Mn54	7,78E-11	2,59E-11	4,45E-07
Fe55	5,96E-11	1,99E-11	9,02E-13
Co60	4,41E-09	1,47E-09	1,47E-06
Ni59	5,70E-11	1,90E-11	1,34E-12
Ni63	1,35E-10	4,49E-11	0,00E+01
Zn65	1,81E-09	6,05E-10	3,32E-07
Sr90+	1,02E-08	3,40E-09	1,43E-08
Nb94	3,24E-08	1,08E-08	8,27E-07
Tc99	4,15E-12	1,38E-12	4,36E-11
Ru106+	4,54E-08	1,51E-08	1,29E-08
Ag108m+	2,46E-09	8,21E-10	7,69E-07
Ag110m+	9,46E-10	3,15E-10	1,47E-06
Sb125+	1,03E-09	3,42E-10	3,29E-08
Cs134	1,24E-08	4,15E-09	7,87E-07
Cs137+	8,68E-09	2,89E-09	2,79E-07
Pm147	4,54E-12	1,51E-12	9,96E-12
Sm151	3,37E-12	1,12E-12	6,61E-15
Eu152	3,50E-11	1,17E-11	5,89E-07
Eu154	4,54E-11	1,51E-11	6,55E-07
U234	8,81E-09	2,94E-09	3,28E-12
U235+	7,91E-09	2,64E-09	2,31E-08
U238+	7,40E-09	2,47E-09	1,59E-08
Np237+	1,94E-08	6,48E-09	1,61E-08
Pu238	3,89E-08	1,30E-08	6,16E-13
Pu239	4,15E-08	1,38E-08	9,13E-12
Pu240	4,15E-08	1,38E-08	6,51E-13
Pu241	7,52E-10	2,51E-10	6,65E-14
Am241	3,50E-08	1,17E-08	2,77E-10
Cm244	2,20E-08	7,34E-09	3,15E-13
Na-22	2,59E-09	8,64E-10	1,17E-06
S-35	1,43E-10	4,75E-11	3,33E-12
Cl-36	6,61E-09	2,20E-09	8,26E-12
K-40	3,89E-09	1,30E-09	9,26E-08
Ca-45	2,98E-10	9,94E-11	1,19E-19
Sc-46	6,22E-10	2,07E-10	1,14E-06
Mn-53	2,33E-12	7,78E-13	0,00E+01
Co-56	1,27E-09	4,23E-10	2,05E-06
Co-57	1,56E-10	5,18E-11	1,63E-08
Co-58	4,41E-10	1,47E-10	5,17E-07
As-73	1,68E-10	5,62E-11	2,64E-11
Se-75	2,20E-11	7,34E-12	1,12E-08
Se-79	4,02E-11	1,34E-11	4,16E-14
Sr-85	7,26E-11	2,42E-11	2,36E-07
Y-91	7,91E-10	2,64E-10	7,42E-09
Zr-93	3,76E-08	1,25E-08	6,92E-14
Zr-95+	7,12E-09	2,37E-09	7,94E-07
Nb-93m	1,11E-09	3,72E-10	6,06E-12
Mo-93	1,81E-10	6,05E-11	3,40E-11
Tc-97	2,07E-13	6,91E-14	4,60E-11
Tc-97m	3,50E-12	1,17E-12	7,09E-11

Appendix B

TABLE 4.5 (cont.)			
Pd-107	7,52E-11	2,51E-11	9,37E-15
Cd-109	6,22E-09	2,07E-09	1,54E-10
Sn-113+	2,50E-09	8,35E-10	1,06E-08
Sn-126+	2,40E-08	7,98E-09	9,77E-08
Sb-124	1,22E-09	4,06E-10	2,07E-07
Te-123m	4,41E-11	1,47E-11	2,57E-09
Te-127m+	8,26E-11	2,75E-11	5,99E-13
I-125	9,46E-09	3,15E-09	5,81E-11
I-129	6,61E-08	2,20E-08	3,42E-11
Cs-135	1,28E-09	4,28E-10	1,04E-11
Ce-139	1,81E-12	6,05E-13	2,71E-08
Ce-144+	3,76E-11	1,25E-11	2,01E-08
Sm-147	7,94E-09	2,65E-09	0,00E+01
Eu-155	6,09E-12	2,03E-12	4,16E-09
Gd-153	3,24E-12	1,08E-12	5,89E-09
Tb-160	7,00E-12	2,33E-12	5,77E-07
Tm-170	6,74E-12	2,25E-12	1,30E-09
Tm-171	1,18E-12	3,93E-13	1,77E-11
Ta-182	9,59E-09	3,20E-09	6,97E-07
W-181	5,57E-12	1,86E-12	1,16E-09
W-185	2,85E-11	9,50E-12	1,08E-10
Os-185	1,81E-09	6,05E-10	3,40E-08
Ir-192	1,27E-09	4,23E-10	3,27E-07
Tl-204	8,04E-11	2,68E-11	6,67E-10
Pb-210+	1,50E-06	5,01E-07	5,30E-13
Bi-207	8,29E-10	2,76E-10	1,60E-07
Po-210	2,85E-08	9,50E-09	4,60E-13
Ra-226+	2,88E-07	9,62E-08	9,45E-07
Ra-228+	2,24E-07	7,47E-08	4,94E-07
Ac-227+	8,33E-05	2,78E-05	1,26E-07
Th-228+	4,47E-08	1,49E-08	8,14E-07
Th-229+	1,04E-07	3,47E-08	1,06E-07
Th-230	3,63E-08	1,21E-08	3,41E-11
Th-232	3,79E-08	1,26E-08	1,07E-11
Pa-231	1,15E-07	3,84E-08	9,39E-09
U-232	3,37E-08	1,12E-08	2,10E-11
U-233	8,94E-09	2,98E-09	2,43E-11
U-236	8,16E-09	2,72E-09	3,79E-12
Pu-236	1,68E-08	5,62E-09	3,19E-12
Pu-242	4,02E-08	1,34E-08	1,79E-12
Pu-244+	3,89E-08	1,30E-08	1,67E-07
Am-242m+	3,11E-08	1,04E-08	2,71E-11
Am-243+	3,50E-08	1,17E-08	3,78E-08
Cm-242	4,80E-09	1,60E-09	2,97E-12
Cm-243	2,59E-08	8,64E-09	2,78E-08
Cm-245	3,50E-08	1,17E-08	8,45E-09
Cm-246	3,50E-08	1,17E-08	2,09E-12
Cm-247+	3,24E-08	1,08E-08	1,31E-07
Cm-248	1,23E-07	4,10E-08	1,83E-12
Bk-249	1,30E-10	4,32E-11	7,94E-13
Cf-248	7,91E-09	2,64E-09	2,36E-12
Cf-249	5,83E-08	1,94E-08	1,29E-07
Cf-250	2,85E-08	9,50E-09	3,45E-12
Cf-251	5,96E-08	1,99E-08	2,02E-08
Cf-252	1,68E-08	5,62E-09	2,79E-12
Cf-254	2,85E-08	9,50E-09	4,31E-16
Es-254	7,78E-09	2,59E-09	5,22E-10

Appendix B

TABLE 4.6 ANNUAL INDIVIDUAL DOSE RATES FROM EXPOSURE DURING TREATMENT OF ALUMINIUM BY-PRODUCTS (WORKERS) (Sv/y)

NUCLIDE	SLAG PROCESSING (3.4.3)	
	EXTERNAL	INHALATION
PWR		
H3	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01
Mn54	1,89E-06	2,28E-11
Fe55	3,28E-12	1,75E-11
Co60	2,96E-06	1,62E-10
Ni59	4,54E-12	4,18E-12
Ni63	0,00E+01	9,88E-12
Zn65	3,38E-07	1,33E-11
Sr90+	8,20E-08	7,48E-09
Nb94	1,77E-05	2,38E-09
Tc99	7,20E-10	3,04E-10
Ru106+	2,37E-07	3,33E-10
Ag108m+	8,73E-07	9,03E-11
Ag110m+	1,56E-06	3,47E-11
Sb125+	2,96E-06	3,76E-10
Cs134	1,72E-05	9,12E-10
Cs137+	6,19E-06	6,37E-10
Pm147	2,38E-10	3,33E-10
Sm151	1,32E-12	2,47E-10
Eu152	1,26E-05	2,57E-09
Eu154	1,38E-05	3,33E-09
U234	1,11E-10	6,46E-07
U235+	1,24E-06	5,80E-07
U238+	1,70E-07	5,42E-07
Np237+	2,13E-07	1,43E-06
Pu238	6,53E-11	2,85E-06
Pu239	6,58E-11	3,04E-06
Pu240	6,63E-11	3,04E-06
Pu241	1,50E-12	5,51E-08
Am241	2,17E-08	2,57E-06
Cm244	5,88E-11	1,62E-06
AG3		
U234	1,11E-09	6,46E-06
U235+	1,24E-05	5,80E-06
U238+	1,70E-06	5,42E-06
PWR		
Na-22	2,53E-05	1,90E-10
S-35	1,13E-10	1,05E-10
Cl-36	7,97E-09	4,85E-10
K-40	1,85E-06	2,85E-10
Ca-45	1,19E-16	2,19E-10
Sc-46	2,34E-05	4,56E-10
Mn-53	0,00E+01	6,84E-13
Co-56	4,13E-06	4,66E-11
Co-57	8,24E-08	5,70E-12
Co-58	1,14E-06	1,62E-11
As-73	2,17E-08	6,18E-11
Se-75	3,37E-06	1,62E-10
Se-79	1,41E-10	2,95E-10
Sr-85	5,68E-06	5,32E-11
Y-91	7,64E-08	5,80E-10
Zr-93	4,60E-12	2,76E-09
Zr-95+	1,76E-05	5,22E-10
Nb-93m	6,64E-10	8,17E-11
Mo-93	3,72E-09	1,33E-10

Appendix B

TABLE 4.6 (cont.)		
Tc-97	4,61E-09	1,52E-11
Tc-97m	6,17E-09	2,57E-10
Pd-107	1,64E-14	5,51E-12
Cd-109	6,71E-10	4,56E-11
Sn-113+	2,71E-06	1,84E-10
Sn-126+	2,27E-05	1,76E-09
Sb-124	2,17E-05	4,47E-10
Te-123m	1,02E-06	3,23E-10
Te-127m+	6,04E-09	6,06E-10
I-125	7,00E-08	6,94E-10
I-129	4,92E-08	4,85E-09
Cs-135	2,61E-10	9,41E-11
Ce-139	1,06E-06	1,33E-10
Ce-144+	4,79E-07	2,76E-09
Sm-147	0,00E+01	5,82E-07
Eu-155	3,34E-07	4,47E-10
Gd-153	5,25E-07	2,38E-10
Tb-160	1,22E-05	5,13E-10
Tm-170	1,41E-08	4,94E-10
Tm-171	2,71E-09	8,65E-11
Ta-182	1,45E-05	7,03E-10
W-181	1,68E-07	4,09E-12
W-185	1,59E-09	2,09E-11
Os-185	7,86E-07	1,33E-11
Ir-192	8,35E-07	4,66E-11
Tl-204	9,37E-11	5,89E-12
Pb-210+	3,32E-09	1,10E-07
Bi-207	1,73E-05	3,04E-10
Po-210	1,00E-10	2,09E-07
Ra-226+	2,00E-05	2,12E-07
Ra-228+	1,05E-05	1,64E-07
Ac-227+	3,58E-06	6,11E-05
Th-228+	1,68E-05	3,28E-06
Th-229+	2,95E-06	7,64E-06
Th-230	2,42E-09	2,66E-06
Th-232	1,12E-09	2,78E-06
Pa-231	2,71E-07	8,46E-06
U-232	1,66E-09	2,47E-06
U-233	1,52E-09	6,56E-07
U-236	7,46E-10	5,99E-07
Pu-236	7,46E-10	1,24E-06
Pu-242	4,66E-10	2,95E-06
Pu-244+	3,77E-06	2,85E-06
Am-242m+	2,37E-09	2,28E-06
Am-243+	1,56E-06	2,57E-06
Cm-242	5,99E-10	3,52E-07
Cm-243	9,81E-07	1,90E-06
Cm-245	4,55E-07	2,57E-06
Cm-246	4,42E-10	2,57E-06
Cm-247+	3,41E-06	2,38E-06
Cm-248	3,74E-10	9,03E-06
Bk-249	3,80E-11	9,50E-09
Cf-248	3,88E-10	5,80E-07
Cf-249	3,31E-06	4,28E-06
Cf-250	4,92E-10	2,09E-06
Cf-251	8,32E-07	4,37E-06
Cf-252	4,28E-10	1,24E-06
Cf-254	7,60E-14	2,09E-06
Es-254	2,39E-08	5,70E-07

Appendix B

TABLE 4.7 ANNUAL INDIVIDUAL DOSE RATES FROM EXPOSURE DURING ELECTRO-REFINING OF COPPER (WORKERS) (Sv/y)

NUCLIDE	(3.5.1) EXTERNAL
H3	0,00E+01
C14	0,00E+01
Mn54	7,75E-09
Fe55	1,57E-14
Co60	1,29E-07
Ni59	1,17E-13
Ni63	0,00E+01
Zn65	5,77E-09
Sr90+	2,64E-08
Nb94	1,44E-06
Tc99	7,75E-12
Ru106+	2,27E-08
Ag108m+	1,34E-06
Ag110m+	2,57E-06
Sb125+	2,92E-07
Cs134	1,37E-07
Cs137+	4,86E-08
Pm147	1,76E-14
Sm151	1,15E-17
Eu152	5,12E-07
Eu154	5,70E-07
U234	5,85E-12
U235+	4,00E-08
U238+	2,90E-08
Np237+	2,96E-08
Pu238	1,08E-12
Pu239	1,60E-11
Pu240	1,15E-12
Pu241	1,19E-13
Am241	4,82E-10
Cm244	5,49E-13
Na-22	2,05E-07
S-35	5,90E-16
Cl-36	1,51E-13
K-40	1,63E-08
Ca-45	1,65E-20
Sc-46	2,00E-06
Mn-53	0,00E+01
Co-56	1,80E-07
Co-57	1,43E-09
Co-58	4,51E-08
As-73	2,33E-10
Se-75	1,94E-07
Se-79	7,32E-12
Sr-85	4,13E-07
Y-91	1,35E-08
Zr-93	1,19E-13
Zr-95+	1,39E-06
Nb-93m	1,02E-11
Mo-93	5,70E-12
Tc-97	7,82E-12
Tc-97m	1,22E-11

Appendix B

TABLE 4.7 (cont.)	
Pd-107	3,93E-17
Cd-109	2,72E-12
Sn-113+	1,84E-08
Sn-126+	1,70E-07
Sb-124	1,82E-06
Te-123m	4,47E-08
Te-127m+	1,08E-10
I-125	1,05E-11
I-129	6,18E-12
Cs-135	1,84E-13
Ce-139	4,73E-08
Ce-144+	3,52E-08
Sm-147	0,00E+01
Eu-155	3,62E-09
Gd-153	5,14E-09
Tb-160	1,01E-06
Tm-170	5,94E-10
Tm-171	1,56E-11
Ta-182	1,22E-06
W-181	2,04E-10
W-185	1,95E-12
Os-185	5,92E-08
Ir-192	2,85E-08
Tl-204	1,23E-11
Pb-210+	9,66E-13
Bi-207	1,40E-06
Po-210	8,04E-12
Ra-226+	1,66E-06
Ra-228+	8,64E-07
Ac-227+	2,20E-07
Th-228+	1,43E-06
Th-229+	1,84E-07
Th-230	5,92E-11
Th-232	1,85E-11
Pa-231	1,63E-08
U-232	3,63E-11
U-233	4,23E-11
U-236	6,46E-12
Pu-236	5,27E-12
Pu-242	2,92E-12
Pu-244+	2,92E-07
Am-242m+	4,77E-11
Am-243+	6,59E-08
Cm-242	4,84E-12
Cm-243	4,84E-08
Cm-245	1,47E-08
Cm-246	3,37E-12
Cm-247+	2,29E-07
Cm-248	2,98E-12
Bk-249	1,39E-12
Cf-248	3,84E-12
Cf-249	2,22E-07
Cf-250	5,75E-12
Cf-251	3,52E-08
Cf-252	4,62E-12
Cf-254	7,67E-16
Es-254	9,05E-10

Appendix B

TABLE 4.8 ANNUAL INDIVIDUAL DOSE RATES DURING THE MANUFACTURE OF PRODUCTS MADE OF RECYCLED METAL (WORKERS) (Sv/y)

NUCLIDE	(3.6) INHALATION COPPER	(3.6) INHALATION ALUMINIUM (PWR)	(3.6) INHALATION ALUMINIUM (AG3)
H3	0,00E+01	0,00E+01	
C14	0,00E+01	0,00E+01	
Mn54	2,59E-12	2,59E-11	
Fe55	1,99E-12	1,99E-11	
Co60	1,84E-10	3,67E-10	
Ni59	2,38E-12	4,75E-12	
Ni63	5,62E-12	1,12E-11	
Zn65	6,05E-12	6,05E-11	
Sr90+	1,70E-08	1,70E-09	
Nb94	5,40E-09	5,40E-10	
Tc99	6,91E-11	6,91E-12	
Ru106+	7,56E-10	7,56E-11	
Ag108m+	4,10E-09	4,10E-10	
Ag110m+	1,58E-09	1,58E-10	
Sb125+	8,56E-10	8,56E-11	
Cs134	2,07E-10	2,07E-12	
Cs137+	1,45E-10	1,45E-12	
Pm147	7,56E-13	7,56E-14	
Sm151	5,62E-13	5,62E-14	
Eu152	2,92E-09	2,92E-10	
Eu154	3,78E-09	3,78E-10	
U234	1,47E-06	7,34E-08	7,34E-07
U235+	1,32E-06	6,59E-08	6,59E-07
U238+	1,23E-06	6,16E-08	6,16E-07
Np237+	3,24E-06	1,62E-07	
Pu238	6,48E-06	3,24E-07	
Pu239	6,91E-06	3,46E-07	
Pu240	6,91E-06	3,46E-07	
Pu241	1,25E-07	6,26E-09	
Am241	5,83E-06	2,92E-07	
Cm244	3,67E-06	1,84E-07	
Na-22	4,32E-11	4,32E-12	
S-35	2,38E-12	2,38E-12	
Cl-36	1,10E-11	1,10E-11	
K-40	6,48E-11	6,48E-12	
Ca-45	4,97E-11	4,97E-12	
Sc-46	1,04E-09	1,04E-10	
Mn-53	7,78E-14	7,78E-13	
Co-56	5,29E-11	1,06E-10	
Co-57	6,48E-12	1,30E-11	
Co-58	1,84E-11	3,67E-11	
As-73	1,40E-10	1,40E-11	
Se-75	3,67E-10	3,67E-12	
Se-79	6,70E-10	6,70E-12	
Sr-85	1,21E-10	1,21E-11	
Y-91	1,32E-09	1,32E-10	
Zr-93	6,26E-09	6,26E-10	
Zr-95+	1,19E-09	1,19E-10	
Nb-93m	1,86E-10	1,86E-11	
Mo-93	3,02E-11	3,02E-12	
Tc-97	3,46E-12	3,46E-13	
Tc-97m	5,83E-11	5,83E-12	

Appendix B

TABLE 4.8 (cont.)			
Pd-107	3,13E-12	6,26E-12	
Cd-109	2,07E-11	2,07E-10	
Sn-113+	4,17E-11	4,17E-12	
Sn-126+	3,99E-10	3,99E-11	
Sb-124	1,02E-09	1,02E-10	
Te-123m	7,34E-10	7,34E-12	
Te-127m+	1,38E-09	1,38E-11	
I-125	1,58E-11	1,58E-11	
I-129	1,10E-10	1,10E-10	
Cs-135	2,14E-11	2,14E-13	
Ce-139	3,02E-10	1,51E-11	
Ce-144+	6,27E-09	6,27E-10	
Sm-147	1,32E-09	1,32E-10	
Eu-155	5,08E-10	5,08E-11	
Gd-153	2,70E-10	2,70E-11	
Tb-160	1,17E-09	5,83E-11	
Tm-170	5,62E-10	5,62E-11	
Tm-171	9,83E-11	9,83E-12	
Ta-182	1,60E-09	1,60E-10	
W-181	9,29E-13	9,29E-14	
W-185	4,75E-12	4,75E-13	
Os-185	3,02E-11	3,02E-12	
Ir-192	5,29E-11	1,06E-10	
Tl-204	1,34E-11	1,34E-11	
Pb-210+	2,51E-08	2,51E-09	
Bi-207	6,91E-10	6,91E-11	
Po-210	4,75E-07	4,75E-09	
Ra-226+	4,81E-07	4,81E-08	
Ra-228+	3,73E-07	3,73E-08	
Ac-227+	1,39E-04	1,39E-05	
Th-228+	7,45E-06	3,72E-07	
Th-229+	1,74E-05	8,68E-07	
Th-230	6,05E-06	3,02E-07	
Th-232	6,31E-06	3,16E-07	
Pa-231	1,92E-05	9,61E-07	
U-232	5,62E-06	2,81E-07	
U-233	1,49E-06	7,45E-08	
U-236	1,36E-06	6,80E-08	
Pu-236	2,81E-06	1,40E-07	
Pu-242	6,70E-06	3,35E-07	
Pu-244+	6,48E-06	3,24E-07	
Am-242m+	5,19E-06	2,59E-07	
Am-243+	5,83E-06	2,92E-07	
Cm-242	7,99E-07	4,00E-08	
Cm-243	4,32E-06	2,16E-07	
Cm-245	5,83E-06	2,92E-07	
Cm-246	5,83E-06	2,92E-07	
Cm-247+	5,40E-06	2,70E-07	
Cm-248	2,05E-05	1,03E-06	
Bk-249	2,16E-08	1,08E-09	
Cf-248	1,32E-06	6,59E-08	
Cf-249	9,72E-06	4,86E-07	
Cf-250	4,75E-06	2,38E-07	
Cf-251	9,94E-06	4,97E-07	
Cf-252	2,81E-06	1,40E-07	
Cf-254	4,75E-06	2,38E-07	
Es-254	1,30E-06	6,48E-08	

Appendix B

TABLE 4.9 ANNUAL DOSE RATES DURING DISPOSAL OF COPPER SLAGS IN A LANDFILL (Sv/y)

NUCLIDE	OCCUPATIONAL (WORKERS) *skin dose						PUBLIC (RESIDENCE)		
	WASTE MANIP.* (3.7.1.a) EXTERNAL HANDS	WASTE ANALYSIS* (3.7.1.b) EXTERNAL HANDS	WASTE MANIP.* (3.7.1.c) EXTERNAL FACE	WASTE HANDLING (3.7.1.d) ING. DUST	WASTE HANDLING (3.7.1.e) INH. DUST	WASTE HANDLING (3.7.1.f) EXTERNAL	(3.7.2) ADULT	(3.7.2) CHILD	(3.7.2) BABY
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	6,36E-09	1,59E-12	3,18E-09	4,63E-11	3,00E-12	1,36E-06	1,13E-18	2,82E-18	6,93E-19
Fe55	1,67E-09	4,17E-13	8,35E-10	2,15E-11	2,30E-12	1,21E-16	1,89E-16	6,51E-16	1,33E-15
Co60	1,65E-08	4,13E-12	1,02E-07	2,22E-10	4,26E-11	4,20E-06	2,43E-09	6,09E-09	1,50E-09
Ni59	6,67E-09	1,67E-12	3,33E-09	4,11E-12	5,51E-13	8,12E-16	2,60E-12	4,57E-12	1,12E-12
Ni63	0,00E+01	0,00E+01	9,55E-10	9,78E-12	1,30E-12	0,00E+01	4,99E-12	9,37E-12	2,23E-12
Zn65	5,34E-09	1,33E-12	4,57E-09	2,54E-10	7,01E-12	9,54E-07	1,21E-21	2,73E-21	6,05E-22
Sr90+	1,84E-07	4,59E-11	2,68E-07	2,00E-09	1,97E-10	1,56E-08	1,09E-08	2,35E-08	1,72E-09
Nb94	2,95E-08	7,38E-12	1,18E-07	1,11E-10	6,26E-11	2,57E-06	7,68E-08	1,92E-07	4,73E-08
Tc99	1,43E-09	3,57E-13	8,35E-08	5,09E-11	8,01E-12	2,81E-13	1,31E-08	2,66E-08	4,92E-09
Ru106+	1,68E-08	4,20E-12	1,49E-08	4,56E-11	8,76E-12	3,58E-08	1,47E-18	3,78E-18	8,67E-19
Ag108m+	2,54E-08	6,34E-12	2,11E-08	1,50E-10	4,76E-11	2,76E-06	7,15E-08	1,78E-07	4,35E-08
Ag110m+	2,63E-08	6,57E-12	5,08E-08	1,83E-10	1,83E-11	4,49E-06	8,59E-21	2,14E-20	5,24E-21
Sb125+	2,52E-09	6,30E-13	2,18E-08	1,69E-11	1,98E-12	1,25E-07	2,01E-12	5,02E-12	1,24E-12
Cs134	4,13E-08	1,03E-11	1,00E-07	1,24E-09	2,40E-11	2,49E-06	2,41E-12	6,00E-12	1,48E-12
Cs137+	4,43E-08	1,11E-11	1,34E-07	8,48E-10	1,68E-11	8,94E-07	1,35E-08	3,35E-08	8,24E-09
Pm147	4,29E-11	1,07E-14	6,57E-08	1,70E-11	8,76E-12	2,54E-12	1,21E-15	2,76E-15	1,29E-15
Sm151	6,68E-13	1,67E-16	1,49E-09	6,39E-12	6,51E-12	9,76E-14	6,89E-13	1,54E-12	8,54E-13
Eu152	3,02E-08	7,54E-12	8,96E-08	9,13E-11	6,76E-11	2,25E-06	1,44E-08	3,61E-08	8,88E-09
Eu154	4,87E-08	1,22E-11	1,83E-07	1,30E-10	8,76E-11	1,99E-06	5,29E-09	1,32E-08	3,26E-09
U234	2,82E-10	7,04E-14	5,28E-10	3,20E-09	1,70E-08	4,98E-11	3,02E-10	9,72E-10	2,40E-10
U235+	6,68E-09	1,67E-12	1,34E-07	3,02E-09	1,53E-08	1,45E-07	4,60E-09	1,17E-08	2,90E-09
U238+	1,32E-07	3,31E-11	2,00E-07	3,12E-09	1,43E-08	4,73E-08	1,52E-09	4,24E-09	9,22E-10
Np237+	1,37E-08	3,42E-12	1,82E-07	7,23E-09	3,76E-08	2,65E-07	9,05E-09	2,32E-08	5,37E-09
Pu238	2,82E-10	7,04E-14	1,41E-10	1,50E-08	7,51E-08	8,64E-12	8,80E-10	4,75E-09	6,56E-10
Pu239	1,04E-10	2,61E-14	7,48E-11	1,63E-08	8,01E-08	3,45E-11	1,22E-09	6,57E-09	8,75E-10
Pu240	2,71E-10	6,78E-14	1,36E-10	1,63E-08	8,01E-08	1,04E-11	1,21E-09	6,55E-09	8,72E-10
Pu241	3,44E-13	8,61E-17	1,72E-13	3,06E-10	1,45E-09	2,24E-12	5,52E-12	3,10E-11	2,89E-12
Am241	1,77E-09	4,43E-13	3,75E-09	1,30E-08	6,76E-08	4,75E-09	1,09E-09	5,58E-09	8,26E-10
Cm244	2,30E-10	5,74E-14	1,15E-10	7,82E-09	4,26E-08	6,47E-12	1,84E-10	1,06E-09	1,87E-10

Appendix B

Na-22	5,19E-08	1,30E-11	1,31E-07	2,09E-10	5,01E-12	3,55E-06	3,74E-11	9,23E-11	2,24E-11
S-35	0,00E+01	0,00E+01	4,71E-08	5,02E-11	2,75E-12	0,00E+01	4,53E-47	9,42E-47	1,61E-47
Cl-36	5,53E-09	1,38E-12	1,31E-08	6,06E-12	1,28E-12	2,38E-11	1,91E-09	3,90E-09	6,46E-10
K-40	9,99E-08	2,50E-11	1,26E-07	4,04E-10	7,51E-12	2,89E-07	3,40E-08	7,48E-08	1,39E-08
Ca-45	3,81E-10	9,52E-14	8,35E-08	4,96E-11	5,76E-12	3,20E-19	9,96E-31	2,53E-30	3,78E-31
Sc-46	1,92E-08	4,79E-12	1,08E-07	9,78E-11	1,20E-11	3,44E-06	5,77E-47	1,44E-46	3,53E-47
Mn-53	8,70E-12	2,18E-15	4,35E-12	1,96E-12	9,01E-14	0,00E+01	1,23E-11	2,67E-11	4,78E-12
Co-56	4,36E-08	1,09E-11	7,36E-08	1,63E-10	1,23E-11	6,38E-06	3,02E-49	7,54E-49	1,86E-49
Co-57	4,17E-09	1,04E-12	7,82E-09	1,37E-11	1,50E-12	5,60E-08	1,14E-21	2,85E-21	7,02E-22
Co-58	1,25E-08	3,14E-12	2,51E-08	4,83E-11	4,26E-12	1,54E-06	1,33E-54	3,32E-54	8,17E-55
As-73	2,54E-09	6,36E-13	6,30E-09	3,39E-12	3,26E-13	9,30E-11	2,93E-53	7,20E-53	2,13E-53
Se-75	4,73E-10	1,18E-13	1,11E-09	1,70E-11	4,26E-13	3,41E-08	6,19E-37	1,49E-36	2,66E-37
Se-79	0,00E+01	0,00E+01	5,95E-09	1,89E-11	7,76E-13	0,00E+01	1,19E-09	5,74E-09	5,77E-10
Sr-85	5,77E-09	1,44E-12	3,34E-09	3,65E-11	1,40E-12	7,01E-07	4,03E-59	1,01E-58	2,45E-59
Y-91	1,18E-07	2,95E-11	1,37E-07	1,56E-10	1,53E-11	1,12E-08	1,40E-66	3,70E-66	7,46E-67
Zr-93	1,20E-11	3,00E-15	2,50E-08	1,83E-11	7,26E-11	0,00E+01	9,57E-13	9,05E-13	9,71E-13
Zr-95+	1,32E-08	3,30E-12	1,03E-07	9,52E-11	1,38E-11	2,37E-06	1,80E-59	4,51E-59	1,11E-59
Nb-93m	1,20E-11	3,00E-15	6,00E-12	7,82E-12	2,15E-12	7,41E-12	1,25E-12	2,85E-12	7,57E-13
Mo-93	6,70E-11	1,67E-14	3,35E-11	1,70E-10	3,51E-12	4,15E-11	5,76E-10	7,45E-10	7,32E-11
Tc-97	7,14E-11	1,78E-14	2,94E-09	5,41E-12	4,01E-13	5,51E-11	1,40E-09	2,87E-09	5,04E-10
Tc-97m	1,82E-08	4,55E-12	4,53E-08	4,30E-11	6,76E-12	1,47E-10	1,12E-45	2,23E-45	4,17E-46
Pd-107	0,00E+01	0,00E+01	0,00E+01	2,41E-12	7,26E-13	0,00E+01	3,05E-12	6,70E-12	1,50E-12
Cd-109	1,77E-09	4,43E-13	8,87E-10	1,30E-10	2,40E-11	1,86E-10	2,55E-16	4,47E-16	6,17E-17
Sn-113+	1,25E-10	3,13E-14	6,26E-11	4,94E-12	4,84E-13	3,14E-08	2,09E-38	5,21E-38	1,27E-38
Sn-126+	4,28E-10	1,07E-13	9,75E-09	3,31E-11	4,63E-12	2,92E-07	8,86E-09	2,21E-08	5,41E-09
Sb-124	1,51E-08	3,77E-12	2,60E-08	3,26E-11	2,35E-12	6,35E-07	3,61E-63	9,03E-63	2,22E-63
Te-123m	1,25E-10	3,13E-14	1,20E-08	9,13E-12	8,51E-13	8,42E-09	7,49E-38	1,87E-37	4,64E-38
Te-127m+	1,19E-10	2,97E-14	9,55E-09	1,61E-11	1,60E-12	6,66E-10	1,33E-41	3,35E-41	9,27E-42
I-125	2,19E-10	5,48E-14	1,10E-10	9,78E-11	1,83E-12	1,04E-10	2,40E-65	4,99E-65	6,15E-66
I-129	1,01E-10	2,53E-14	3,45E-09	7,17E-10	1,28E-11	7,45E-11	9,07E-10	1,57E-09	1,19E-10
Cs-135	5,96E-12	1,49E-15	5,74E-08	1,30E-10	2,48E-12	0,00E+01	4,80E-11	4,13E-11	5,63E-12
Ce-139	9,41E-09	2,35E-12	1,96E-08	1,70E-11	3,51E-12	8,79E-08	2,95E-33	7,38E-33	1,82E-33
Ce-144+	1,57E-07	3,92E-11	2,32E-07	3,42E-10	7,27E-11	9,76E-08	6,51E-21	1,79E-20	3,56E-21
Sm-147	0,00E+01	0,00E+01	0,00E+01	3,21E-09	1,53E-08	0,00E+01	5,05E-10	1,14E-09	2,73E-10
Eu-155	3,95E-10	9,89E-14	4,55E-08	2,09E-11	1,18E-11	1,50E-08	6,83E-12	1,71E-11	4,23E-12
Gd-153	6,57E-10	1,64E-13	2,12E-08	1,76E-11	6,26E-12	2,07E-08	1,43E-23	3,57E-23	8,83E-24
Tb-160	5,10E-08	1,28E-11	1,82E-07	1,04E-10	1,35E-11	1,74E-06	1,31E-53	3,27E-53	8,05E-54
Tm-170	6,91E-08	1,73E-11	1,20E-07	8,48E-11	1,30E-11	1,57E-09	1,23E-36	3,28E-36	8,34E-37
Tm-171	4,07E-12	1,02E-15	1,34E-08	7,17E-12	2,28E-12	6,28E-11	6,48E-17	1,52E-16	5,18E-17
Ta-182	5,23E-08	1,31E-11	1,24E-07	9,78E-11	1,85E-11	2,12E-06	1,12E-36	2,79E-36	6,88E-37

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W-181	2,52E-10	6,31E-14	5,81E-09	4,96E-12	1,08E-13	4,18E-09	6,91E-38	1,72E-37	4,19E-38
W-185	2,56E-08	6,39E-12	6,62E-08	2,87E-11	5,51E-13	1,46E-11	5,41E-55	1,20E-54	2,64E-55
Os-185	5,80E-10	1,45E-13	5,40E-10	3,33E-12	3,51E-13	1,01E-07	1,63E-44	4,08E-44	1,00E-44
Ir-192	4,56E-08	1,14E-11	1,40E-07	9,13E-11	1,23E-11	9,76E-07	9,74E-53	2,44E-52	5,99E-53
Tl-204	5,96E-08	1,49E-11	1,25E-07	8,48E-11	1,55E-12	2,84E-10	6,06E-12	1,26E-11	2,19E-12
Pb-210+	8,90E-09	2,23E-12	1,38E-08	4,44E-09	2,90E-10	2,02E-10	1,13E-09	3,11E-09	4,69E-10
Bi-207	6,77E-09	1,69E-12	1,31E-08	1,70E-11	1,60E-12	4,84E-07	7,88E-09	1,96E-08	4,81E-09
Po-210	5,01E-15	1,25E-18	2,50E-15	1,56E-09	5,51E-10	1,38E-12	1,99E-34	4,65E-34	1,70E-33
Ra-226+	2,72E-07	6,80E-11	4,51E-07	1,83E-08	5,57E-09	2,95E-06	9,79E-08	2,50E-07	5,61E-08
Ra-228+	8,10E-08	2,03E-11	1,64E-07	4,37E-08	4,33E-09	1,49E-06	1,97E-09	7,36E-09	1,25E-09
Ac-227+	0,00E+01	0,00E+01	0,00E+01	7,87E-08	1,61E-06	4,02E-07	8,60E-09	3,02E-08	6,23E-09
Th-228+	1,38E-07	3,44E-11	3,36E-07	9,20E-09	8,63E-08	2,58E-06	1,46E-12	3,70E-12	9,21E-13
Th-229+	1,11E-07	2,76E-11	3,32E-07	3,91E-08	2,01E-07	3,24E-07	1,34E-08	4,35E-08	1,01E-08
Th-230	3,96E-10	9,91E-14	5,62E-09	1,37E-08	7,01E-08	1,15E-10	1,42E-09	6,49E-09	9,03E-10
Th-232	2,21E-07	5,53E-11	5,06E-07	1,45E-08	7,32E-08	3,70E-11	1,57E-09	7,73E-09	9,98E-10
Pa-231	8,35E-10	2,09E-13	7,87E-09	4,63E-08	2,23E-07	2,82E-08	1,19E-07	1,61E-07	1,32E-08
U-232	1,37E-07	3,43E-11	3,38E-07	2,15E-08	6,51E-08	6,98E-11	1,33E-09	3,60E-09	1,02E-09
U-233	1,77E-10	4,43E-14	3,63E-10	3,26E-09	1,73E-08	8,50E-11	3,14E-10	9,92E-10	2,57E-10
U-236	9,83E-12	2,46E-15	2,43E-10	3,00E-09	1,58E-08	1,27E-11	2,86E-10	8,98E-10	2,36E-10
Pu-236	1,30E-11	3,26E-15	6,52E-12	5,61E-09	3,26E-08	8,35E-12	2,77E-13	1,64E-12	3,00E-13
Pu-242	9,01E-12	2,25E-15	4,51E-12	1,56E-08	7,76E-08	4,19E-12	1,12E-09	6,57E-09	8,32E-10
Pu-244+	7,64E-12	1,91E-15	3,82E-12	1,57E-08	7,51E-08	5,05E-07	1,61E-08	4,43E-08	1,01E-08
Am-	3,11E-08	7,78E-12	1,01E-07	1,24E-08	6,01E-08	9,25E-09	1,08E-09	5,11E-09	7,08E-10
Am-243+	1,57E-08	3,93E-12	2,22E-07	1,31E-08	6,76E-08	1,20E-07	4,58E-09	1,45E-08	2,97E-09
Cm-242	2,50E-10	6,26E-14	1,25E-10	7,82E-10	9,26E-09	5,75E-12	3,80E-31	2,86E-30	8,34E-31
Cm-243	4,41E-09	1,10E-12	1,02E-07	9,78E-09	5,01E-08	8,72E-08	1,60E-09	5,07E-09	1,10E-09
Cm-245	9,96E-09	2,49E-12	5,62E-08	1,37E-08	6,76E-08	2,91E-08	1,87E-09	7,63E-09	1,31E-09
Cm-246	1,58E-10	3,94E-14	7,88E-11	1,37E-08	6,76E-08	3,47E-12	9,95E-10	5,45E-09	7,74E-10
Cm-247+	3,87E-09	9,68E-13	9,33E-09	1,24E-08	6,26E-08	3,91E-07	1,26E-08	3,43E-08	7,90E-09
Cm-248	7,26E-12	1,82E-15	3,63E-12	5,02E-08	2,38E-07	3,47E-12	3,67E-09	2,03E-08	2,89E-09
Bk-249	0,00E+01	0,00E+01	0,00E+01	6,32E-11	2,50E-10	0,00E+01	6,92E-22	1,38E-21	3,02E-22
Cf-248	8,14E-12	2,03E-15	3,11E-09	1,83E-09	1,53E-08	3,41E-12	5,73E-20	1,99E-19	4,67E-20
Cf-249	3,76E-09	9,39E-13	1,77E-08	2,28E-08	1,13E-07	3,82E-07	1,55E-08	3,65E-08	8,39E-09
Cf-250	7,76E-12	1,94E-15	2,54E-10	1,04E-08	5,51E-08	7,60E-12	4,75E-10	1,05E-09	2,44E-10
Cf-251	4,17E-08	1,04E-11	1,03E-07	2,35E-08	1,15E-07	6,58E-08	6,98E-09	1,48E-08	3,04E-09
Cf-252	1,36E-10	3,39E-14	2,70E-10	5,87E-09	3,26E-08	5,49E-12	5,00E-13	1,56E-12	4,18E-13
Cf-254	1,76E-06	4,40E-10	2,65E-06	2,61E-08	5,51E-08	1,36E-15	2,19E-63	5,81E-63	2,10E-63
Es-254	1,47E-08	3,68E-12	3,66E-08	1,83E-09	1,50E-08	1,56E-09	5,25E-22	1,73E-21	4,18E-22

TABLE 4.10 ANNUAL DOSE RATES DURING DISPOSAL OF ALUMINIUM SLAGS IN A LANDFILL (PWR) (Sv/y)

Appendix B

NUCLIDE	OCCUPATIONAL (WORKERS) *skin dose						PUBLIC (RESIDENCE)		
	WASTE MANIP.* (3.7.1.a) EXTERNAL	WASTE (3.7.1.b) EXTERNAL	WASTE MANIP.* (3.7.1.c) EXTERNAL	WASTE HANDLING (3.7.1.d) ING. DUST	(3.7.1.e) INH. DUST	(3.7.1.f) EXTERNAL	(3.7.2) ADULT	(3.7.2) CHILD	(3.7.2) BABY
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	9,06E-10	2,27E-13	4,53E-10	6,59E-12	4,28E-13	1,94E-07	1,61E-19	4,02E-19	9,86E-20
Fe55	2,38E-10	5,94E-14	1,19E-10	3,06E-12	3,28E-13	1,72E-17	2,69E-17	9,28E-17	1,90E-16
Co60	1,18E-09	2,94E-13	7,28E-09	1,58E-11	3,03E-12	2,99E-07	1,73E-10	4,33E-10	1,07E-10
Ni59	9,49E-10	2,37E-13	4,75E-10	5,85E-13	7,84E-14	1,16E-16	3,70E-13	6,50E-13	1,60E-13
Ni63	0,00E+01	0,00E+01	1,36E-10	1,39E-12	1,85E-13	0,00E+01	7,11E-13	1,33E-12	3,18E-13
Zn65	1,90E-10	4,75E-14	1,63E-10	9,05E-12	2,50E-13	3,40E-08	4,30E-23	9,71E-23	2,15E-23
Sr90+	1,31E-07	3,27E-11	1,91E-07	1,43E-09	1,40E-10	1,11E-08	7,74E-09	1,68E-08	1,22E-09
Nb94	2,10E-08	5,26E-12	8,43E-08	7,89E-11	4,46E-11	1,83E-06	5,47E-08	1,37E-07	3,37E-08
Tc99	1,02E-09	2,54E-13	5,94E-08	3,62E-11	5,71E-12	2,00E-13	9,34E-09	1,90E-08	3,51E-09
Ru106+	1,20E-08	2,99E-12	1,06E-08	3,25E-11	6,24E-12	2,55E-08	1,05E-18	2,69E-18	6,17E-19
Ag108m+	9,03E-10	2,26E-13	7,50E-10	5,34E-12	1,69E-12	9,82E-08	2,55E-09	6,33E-09	1,55E-09
Ag110m+	9,36E-10	2,34E-13	1,81E-09	6,50E-12	6,51E-13	1,60E-07	3,06E-22	7,62E-22	1,87E-22
Sb125+	8,97E-09	2,24E-12	7,75E-08	6,03E-11	7,06E-12	4,46E-07	7,15E-12	1,79E-11	4,40E-12
Cs134	2,94E-08	7,35E-12	7,12E-08	8,82E-10	1,71E-11	1,77E-06	1,72E-12	4,27E-12	1,05E-12
Cs137+	3,16E-08	7,90E-12	9,56E-08	6,04E-10	1,19E-11	6,37E-07	9,62E-09	2,39E-08	5,87E-09
Pm147	3,06E-11	7,64E-15	4,68E-08	1,21E-11	6,24E-12	1,81E-12	8,63E-16	1,97E-15	9,19E-16
Sm151	4,75E-13	1,19E-16	1,06E-09	4,55E-12	4,64E-12	6,95E-14	4,91E-13	1,10E-12	6,08E-13
Eu152	2,15E-08	5,37E-12	6,38E-08	6,50E-11	4,81E-11	1,60E-06	1,03E-08	2,57E-08	6,32E-09
Eu154	3,47E-08	8,68E-12	1,30E-07	9,29E-11	6,24E-11	1,42E-06	3,76E-09	9,42E-09	2,32E-09
U234	2,01E-10	5,01E-14	3,76E-10	2,28E-09	1,21E-08	3,54E-11	2,15E-10	6,92E-10	1,71E-10
U235+	4,75E-09	1,19E-12	9,56E-08	2,15E-09	1,09E-08	1,03E-07	3,28E-09	8,34E-09	2,06E-09
U238+	9,43E-08	2,36E-11	1,43E-07	2,22E-09	1,02E-08	3,37E-08	1,08E-09	3,02E-09	6,57E-10
Np237+	9,75E-09	2,44E-12	1,30E-07	5,15E-09	2,67E-08	1,89E-07	6,44E-09	1,65E-08	3,83E-09
Pu238	2,01E-10	5,01E-14	1,00E-10	1,07E-08	5,35E-08	6,16E-12	6,27E-10	3,38E-09	4,67E-10
Pu239	7,43E-11	1,86E-14	5,33E-11	1,16E-08	5,71E-08	2,46E-11	8,67E-10	4,68E-09	6,23E-10
Pu240	1,93E-10	4,83E-14	9,66E-11	1,16E-08	5,71E-08	7,38E-12	8,64E-10	4,67E-09	6,21E-10
Pu241	2,45E-13	6,13E-17	1,23E-13	2,18E-10	1,03E-09	1,59E-12	3,93E-12	2,21E-11	2,06E-12
Am241	1,26E-09	3,16E-13	2,67E-09	9,29E-09	4,81E-08	3,38E-09	7,76E-10	3,98E-09	5,88E-10
Cm244	1,63E-10	4,09E-14	8,17E-11	5,57E-09	3,03E-08	4,61E-12	1,31E-10	7,55E-10	1,33E-10
Na-22	3,69E-08	9,23E-12	9,36E-08	1,49E-10	3,57E-12	2,53E-06	2,67E-11	6,57E-11	1,60E-11

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S-35	0,00E+01	0,00E+01	3,35E-08	3,58E-11	1,96E-12	0,00E+01	3,23E-47	6,71E-47	1,14E-47
Cl-36	3,94E-08	9,84E-12	9,32E-08	4,32E-11	9,09E-12	1,69E-10	1,36E-08	2,77E-08	4,60E-09
K-40	7,11E-08	1,78E-11	8,94E-08	2,88E-10	5,35E-12	2,06E-07	2,42E-08	5,33E-08	9,92E-09
Ca-45	2,71E-10	6,78E-14	5,94E-08	3,53E-11	4,10E-12	2,28E-19	7,09E-31	1,80E-30	2,69E-31
Sc-46	1,37E-08	3,41E-12	7,66E-08	6,96E-11	8,56E-12	2,45E-06	4,11E-47	1,02E-46	2,51E-47
Mn-53	1,24E-12	3,10E-16	6,20E-13	2,79E-13	1,28E-14	0,00E+01	1,75E-12	3,80E-12	6,81E-13
Co-56	3,11E-09	7,76E-13	5,24E-09	1,16E-11	8,74E-13	4,54E-07	2,15E-50	5,37E-50	1,32E-50
Co-57	2,97E-10	7,43E-14	5,57E-10	9,75E-13	1,07E-13	3,99E-09	8,12E-23	2,03E-22	5,00E-23
Co-58	8,93E-10	2,23E-13	1,79E-09	3,44E-12	3,03E-13	1,10E-07	9,44E-56	2,36E-55	5,82E-56
As-73	9,06E-09	2,27E-12	2,24E-08	1,21E-11	1,16E-12	3,31E-10	1,04E-52	2,56E-52	7,58E-53
Se-75	3,37E-09	8,42E-13	7,91E-09	1,21E-10	3,03E-12	2,43E-07	4,41E-36	1,06E-35	1,89E-36
Se-79	0,00E+01	0,00E+01	4,23E-08	1,35E-10	5,53E-12	0,00E+01	8,46E-09	4,08E-08	4,11E-09
Sr-85	4,11E-09	1,03E-12	2,38E-09	2,60E-11	9,98E-13	4,99E-07	2,87E-59	7,18E-59	1,75E-59
Y-91	8,40E-08	2,10E-11	9,77E-08	1,11E-10	1,09E-11	7,95E-09	9,97E-67	2,63E-66	5,31E-67
Zr-93	8,54E-12	2,14E-15	1,78E-08	1,30E-11	5,17E-11	0,00E+01	6,82E-13	6,44E-13	6,91E-13
Zr-95+	9,40E-09	2,35E-12	7,36E-08	6,78E-11	9,80E-12	1,69E-06	1,28E-59	3,21E-59	7,91E-60
Nb-93m	8,54E-12	2,14E-15	4,27E-12	5,57E-12	1,53E-12	5,27E-12	8,89E-13	2,03E-12	5,39E-13
Mo-93	4,77E-11	1,19E-14	2,38E-11	1,21E-10	2,50E-12	2,96E-11	4,10E-10	5,31E-10	5,21E-11
Tc-97	5,08E-11	1,27E-14	2,09E-09	3,85E-12	2,85E-13	3,92E-11	9,93E-10	2,05E-09	3,59E-10
Tc-97m	1,30E-08	3,24E-12	3,23E-08	3,06E-11	4,81E-12	1,05E-10	7,96E-46	1,59E-45	2,97E-46
Pd-107	0,00E+01	0,00E+01	0,00E+01	3,44E-13	1,03E-13	0,00E+01	4,34E-13	9,54E-13	2,13E-13
Cd-109	6,31E-11	1,58E-14	3,16E-11	4,64E-12	8,56E-13	6,63E-12	9,09E-18	1,59E-17	2,20E-18
Sn-113+	8,91E-10	2,23E-13	4,46E-10	3,52E-11	3,44E-12	2,24E-07	1,49E-37	3,71E-37	9,08E-38
Sn-126+	3,05E-09	7,62E-13	6,94E-08	2,35E-10	3,30E-11	2,08E-06	6,31E-08	1,57E-07	3,85E-08
Sb-124	5,37E-08	1,34E-11	9,27E-08	1,16E-10	8,38E-12	2,26E-06	1,29E-62	3,21E-62	7,91E-63
Te-123m	8,91E-10	2,23E-13	8,51E-08	6,50E-11	6,06E-12	6,00E-08	5,34E-37	1,33E-36	3,30E-37
Te-127m+	8,45E-10	2,11E-13	6,80E-08	1,14E-10	1,14E-11	4,74E-09	9,44E-41	2,38E-40	6,60E-41
I-125	1,56E-09	3,90E-13	7,80E-10	6,96E-10	1,30E-11	7,38E-10	1,71E-64	3,56E-64	4,38E-65
I-129	7,21E-10	1,80E-13	2,45E-08	5,11E-09	9,09E-11	5,31E-10	6,46E-09	1,12E-08	8,47E-10
Cs-135	4,24E-12	1,06E-15	4,09E-08	9,29E-11	1,77E-12	0,00E+01	3,42E-11	2,94E-11	4,01E-12
Ce-139	6,70E-09	1,68E-12	1,39E-08	1,21E-11	2,50E-12	6,26E-08	2,10E-33	5,26E-33	1,30E-33
Ce-144+	1,12E-07	2,79E-11	1,65E-07	2,44E-10	5,18E-11	6,95E-08	4,64E-21	1,27E-20	2,53E-21
Sm-147	0,00E+01	0,00E+01	0,00E+01	2,28E-09	1,09E-08	0,00E+01	3,60E-10	8,10E-10	1,94E-10
Eu-155	2,82E-10	7,04E-14	3,24E-08	1,49E-11	8,38E-12	1,07E-08	4,86E-12	1,21E-11	3,01E-12
Gd-153	4,68E-10	1,17E-13	1,51E-08	1,25E-11	4,46E-12	1,48E-08	1,02E-23	2,54E-23	6,29E-24
Tb-160	3,63E-08	9,09E-12	1,30E-07	7,43E-11	9,63E-12	1,24E-06	9,30E-54	2,33E-53	5,73E-54
Tm-170	4,92E-08	1,23E-11	8,54E-08	6,04E-11	9,27E-12	1,12E-09	8,73E-37	2,33E-36	5,94E-37
Tm-171	2,90E-12	7,24E-16	9,51E-09	5,11E-12	1,62E-12	4,47E-11	4,62E-17	1,09E-16	3,69E-17

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Ta-182	3,72E-08	9,31E-12	8,83E-08	6,96E-11	1,32E-11	1,51E-06	7,95E-37	1,99E-36	4,90E-37
W-181	1,80E-10	4,49E-14	4,14E-09	3,53E-12	7,67E-14	2,98E-09	4,92E-38	1,22E-37	2,98E-38
W-185	1,82E-08	4,55E-12	4,72E-08	2,04E-11	3,92E-13	1,04E-11	3,85E-55	8,51E-55	1,88E-55
Os-185	4,13E-10	1,03E-13	3,84E-10	2,37E-12	2,50E-13	7,22E-08	1,16E-44	2,91E-44	7,15E-45
Ir-192	3,25E-09	8,12E-13	9,95E-09	6,50E-12	8,74E-13	6,95E-08	6,94E-54	1,73E-53	4,27E-54
Tl-204	4,24E-09	1,06E-12	8,92E-09	6,04E-12	1,11E-13	2,02E-11	4,32E-13	9,01E-13	1,56E-13
Pb-210+	6,34E-08	1,58E-11	9,80E-08	3,16E-08	2,07E-09	1,44E-09	8,02E-09	2,21E-08	3,34E-09
Bi-207	2,41E-08	6,02E-12	4,65E-08	6,04E-11	5,71E-12	1,72E-06	2,80E-08	6,99E-08	1,71E-08
Po-210	3,57E-14	8,91E-18	1,78E-14	1,11E-08	3,92E-09	9,82E-12	1,41E-33	3,31E-33	1,21E-32
Ra-226+	1,94E-07	4,84E-11	3,21E-07	1,30E-08	3,97E-09	2,10E-06	6,97E-08	1,78E-07	3,99E-08
Ra-228+	5,77E-08	1,44E-11	1,17E-07	3,11E-08	3,08E-09	1,06E-06	1,40E-09	5,24E-09	8,87E-10
Ac-227+	0,00E+01	0,00E+01	0,00E+01	5,61E-08	1,15E-06	2,86E-07	6,12E-09	2,15E-08	4,43E-09
Th-228+	9,81E-08	2,45E-11	2,39E-07	6,55E-09	6,15E-08	1,84E-06	1,04E-12	2,63E-12	6,56E-13
Th-229+	7,87E-08	1,97E-11	2,36E-07	2,78E-08	1,43E-07	2,31E-07	9,56E-09	3,10E-08	7,18E-09
Th-230	2,82E-10	7,06E-14	4,00E-09	9,75E-09	4,99E-08	8,17E-11	1,01E-09	4,62E-09	6,43E-10
Th-232	1,58E-07	3,94E-11	3,60E-07	1,03E-08	5,21E-08	2,64E-11	1,12E-09	5,51E-09	7,11E-10
Pa-231	5,94E-10	1,49E-13	5,60E-09	3,30E-08	1,59E-07	2,01E-08	8,45E-08	1,15E-07	9,39E-09
U-232	9,76E-08	2,44E-11	2,40E-07	1,53E-08	4,64E-08	4,97E-11	9,51E-10	2,56E-09	7,24E-10
U-233	1,26E-10	3,16E-14	2,58E-10	2,32E-09	1,23E-08	6,05E-11	2,23E-10	7,06E-10	1,83E-10
U-236	7,00E-12	1,75E-15	1,73E-10	2,14E-09	1,12E-08	9,07E-12	2,04E-10	6,39E-10	1,68E-10
Pu-236	9,29E-12	2,32E-15	4,64E-12	3,99E-09	2,32E-08	5,94E-12	1,97E-13	1,17E-12	2,13E-13
Pu-242	6,42E-12	1,60E-15	3,21E-12	1,11E-08	5,53E-08	2,98E-12	7,97E-10	4,68E-09	5,93E-10
Pu-244+	5,44E-12	1,36E-15	2,72E-12	1,12E-08	5,35E-08	3,60E-07	1,15E-08	3,15E-08	7,17E-09
Am-242m+	2,22E-08	5,54E-12	7,21E-08	8,84E-09	4,28E-08	6,58E-09	7,67E-10	3,64E-09	5,04E-10
Am-243+	1,12E-08	2,80E-12	1,58E-07	9,32E-09	4,81E-08	8,57E-08	3,26E-09	1,03E-08	2,12E-09
Cm-242	1,78E-10	4,46E-14	8,91E-11	5,57E-10	6,60E-09	4,10E-12	2,71E-31	2,04E-30	5,94E-31
Cm-243	3,14E-09	7,84E-13	7,24E-08	6,96E-09	3,57E-08	6,21E-08	1,14E-09	3,61E-09	7,83E-10
Cm-245	7,09E-09	1,77E-12	4,00E-08	9,75E-09	4,81E-08	2,07E-08	1,33E-09	5,44E-09	9,32E-10
Cm-246	1,12E-10	2,80E-14	5,61E-11	9,75E-09	4,81E-08	2,47E-12	7,09E-10	3,88E-09	5,51E-10
Cm-247+	2,76E-09	6,89E-13	6,64E-09	8,83E-09	4,46E-08	2,78E-07	8,96E-09	2,44E-08	5,63E-09
Cm-248	5,17E-12	1,29E-15	2,59E-12	3,58E-08	1,69E-07	2,47E-12	2,61E-09	1,44E-08	2,06E-09
Bk-249	0,00E+01	0,00E+01	0,00E+01	4,50E-11	1,78E-10	0,00E+01	4,93E-22	9,84E-22	2,15E-22
Cf-248	5,79E-12	1,45E-15	2,22E-09	1,30E-09	1,09E-08	2,43E-12	4,08E-20	1,42E-19	3,33E-20
Cf-249	2,67E-09	6,69E-13	1,26E-08	1,63E-08	8,02E-08	2,72E-07	1,10E-08	2,60E-08	5,97E-09
Cf-250	5,53E-12	1,38E-15	1,81E-10	7,43E-09	3,92E-08	5,41E-12	3,39E-10	7,50E-10	1,74E-10
Cf-251	2,97E-08	7,43E-12	7,31E-08	1,67E-08	8,20E-08	4,68E-08	4,97E-09	1,06E-08	2,16E-09
Cf-252	9,66E-11	2,41E-14	1,92E-10	4,18E-09	2,32E-08	3,91E-12	3,56E-13	1,11E-12	2,98E-13
Cf-254	1,25E-06	3,13E-10	1,89E-06	1,86E-08	3,92E-08	9,66E-16	1,56E-63	4,14E-63	1,49E-63
Es-254	1,05E-08	2,62E-12	2,61E-08	1,30E-09	1,07E-08	1,11E-09	3,74E-22	1,23E-21	2,97E-22

Appendix B

TABLE 4.11 ANNUAL DOSE RATES DURING DISPOSAL OF ALUMINIUM SLAGS IN A LANDFILL (AG3) (Sv/y)

NUCLIDE	OCCUPATIONAL (WORKERS)						PUBLIC (RESIDENCE)		
	WASTE MANIP.*	WASTE ANALYSIS*	WASTE MANIP.*	WASTE HANDLING					
	(3.7.1.a)	(3.7.1.b)	(3.7.1.c)	(3.7.1.d)	(3.7.1.e)	(3.7.1.f)	(3.7.2)	(3.7.2)	(3.7.2)
	EXTERNAL HANDS	EXTERNAL HANDS	EXTERNAL FACE	ING. DUST	INH. DUST	EXTERNAL	ADULT	CHILD	BABY
H3									
C14									
Mn54									
Fe55									
Co60									
Ni59									
Ni63									
Zn65									
Sr90+									
Nb94									
Tc99									
Ru106+									
Ag108m+									
Ag110m+									
Sb125+									
Cs134									
Cs137+									
Pm147									
Sm151									
Eu152									
Eu154									
U234	2,01E-09	5,01E-13	3,76E-09	2,28E-08	1,21E-07	3,54E-10	2,15E-09	6,92E-09	1,71E-09
U235+	4,75E-08	1,19E-11	9,56E-07	2,15E-08	1,09E-07	1,03E-06	3,28E-08	8,34E-08	2,06E-08
U238+	9,43E-07	2,36E-10	1,43E-06	2,22E-08	1,02E-07	3,37E-07	1,08E-08	3,02E-08	6,57E-09
Np237+									
Pu238									
Pu239									
Pu240									
Pu241									
Am241									
Cm244									

* skin doses

Appendix B

TABLE 4.12 ANNUAL INDIVIDUAL DOSE RATES FROM USE OF COPPER AND ALUMINIUM BY-PRODUCTS (PUBLIC) (Sv/y)

NUCLIDE	FOOTBALL PLAYER (3.8.1) INHALATION COPPER	FOOTBALL SPECTATOR (3.8.1) INHALATION COPPER	CONCRETE PLATE (3.8.2) EXTERNAL ALUMINIUM
H3	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01
Mn54	2,32E-11	1,72E-12	4,11E-08
Fe55	1,19E-11	8,85E-13	1,19E-13
Co60	4,80E-10	3,56E-11	5,95E-08
Ni59	6,81E-12	5,06E-13	1,57E-13
Ni63	2,01E-11	1,49E-12	0,00E+01
Zn65	3,41E-11	2,53E-12	6,99E-09
Sr90+	2,50E-09	1,86E-10	3,21E-09
Nb94	7,59E-10	5,64E-11	3,89E-07
Tc99	2,01E-10	1,50E-11	2,72E-11
Ru106+	1,02E-10	7,59E-12	5,72E-09
Ag108m+	5,73E-10	4,25E-11	2,02E-08
Ag110m+	1,86E-10	1,38E-11	3,35E-08
Sb125+	4,01E-11	2,98E-12	1,63E-08
Cs134	3,10E-10	2,30E-11	3,87E-07
Cs137+	6,04E-10	4,48E-11	1,41E-07
Pm147	7,74E-11	5,75E-12	8,78E-12
Sm151	6,19E-11	4,60E-12	4,10E-14
Eu152	6,50E-10	4,83E-11	2,68E-07
Eu154	8,21E-10	6,09E-11	2,91E-07
U234	1,46E-07	1,08E-08	4,29E-12
U235+	1,32E-07	9,78E-09	3,27E-08
U238+	1,24E-07	9,21E-09	3,12E-09
Np237+	7,74E-07	5,75E-08	8,38E-09
Pu238	1,70E-06	1,26E-07	2,16E-12
Pu239	1,86E-06	1,38E-07	2,43E-12
Pu240	1,86E-06	1,38E-07	2,22E-12
Pu241	3,56E-08	2,64E-09	5,88E-14
Am241	1,49E-06	1,10E-07	8,29E-10
Cm244	8,83E-07	6,55E-08	1,87E-12
Na-22	2,01E-11	1,49E-12	5,40E-07
S-35	2,94E-11	2,18E-12	3,94E-12
Cl-36	1,13E-11	8,40E-13	2,77E-10
K-40	3,25E-11	2,41E-12	3,62E-08
Ca-45	5,73E-11	4,25E-12	2,72E-18
Sc-46	1,05E-10	7,82E-12	4,90E-07
Mn-53	8,36E-13	6,21E-14	0,00E+01
Co-56	1,04E-10	7,70E-12	8,07E-08
Co-57	1,55E-11	1,15E-12	2,20E-09
Co-58	3,25E-11	2,41E-12	2,49E-08
As-73	3,10E-12	2,30E-13	5,86E-10
Se-75	2,01E-12	1,49E-13	8,54E-08
Se-79	1,05E-11	7,82E-13	4,95E-12
Sr-85	1,25E-11	9,31E-13	1,32E-07
Y-91	1,38E-10	1,02E-11	2,10E-09
Zr-93	3,87E-10	2,87E-11	1,33E-13
Zr-95+	1,19E-10	8,85E-12	3,85E-07
Nb-93m	2,79E-11	2,07E-12	1,65E-11
Mo-93	3,56E-11	2,64E-12	9,27E-11
Tc-97	2,79E-11	2,07E-12	1,16E-10
Tc-97m	6,35E-11	4,71E-12	1,60E-10

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TABLE 4.12 (cont.)			
Pd-107	9,14E-12	6,78E-13	2,92E-16
Cd-109	1,25E-10	9,31E-12	1,77E-11
Sn-113+	4,21E-12	3,13E-13	6,55E-08
Sn-126+	4,41E-11	3,27E-12	5,11E-07
Sb-124	2,66E-11	1,98E-12	4,46E-07
Te-123m	7,90E-12	5,86E-13	2,67E-08
Te-127m+	1,54E-11	1,14E-12	1,88E-10
I-125	7,90E-12	5,86E-13	1,85E-09
I-129	5,57E-11	4,14E-12	1,30E-09
Cs-135	1,33E-10	9,89E-12	9,32E-12
Ce-139	2,94E-11	2,18E-12	2,79E-08
Ce-144+	8,21E-10	6,10E-11	1,02E-08
Sm-147	1,49E-07	1,11E-08	0,00E+01
Eu-155	1,07E-10	7,93E-12	9,03E-09
Gd-153	3,25E-11	2,41E-12	1,41E-08
Tb-160	1,08E-10	8,05E-12	2,60E-07
Tm-170	1,08E-10	8,05E-12	5,31E-10
Tm-171	2,17E-11	1,61E-12	7,32E-11
Ta-182	1,55E-10	1,15E-11	3,01E-07
W-181	4,18E-13	3,10E-14	4,55E-09
W-185	1,86E-12	1,38E-13	5,65E-11
Os-185	2,48E-12	1,84E-13	1,76E-08
Ir-192	1,02E-10	7,59E-12	2,01E-08
Tl-204	6,04E-12	4,48E-13	3,16E-12
Pb-210+	8,81E-09	6,55E-10	7,24E-11
Bi-207	1,73E-11	1,29E-12	3,72E-07
Po-210	6,66E-09	4,94E-10	2,17E-12
Ra-226+	1,48E-07	1,10E-08	4,13E-07
Ra-228+	2,48E-07	1,84E-08	2,24E-07
Ac-227+	8,80E-06	6,54E-07	8,86E-08
Th-228+	6,75E-07	5,02E-08	3,26E-07
Th-229+	3,97E-06	2,95E-07	7,03E-08
Th-230	1,55E-06	1,15E-07	6,37E-11
Th-232	1,72E-06	1,27E-07	2,91E-11
Pa-231	2,17E-06	1,61E-07	6,80E-09
U-232	5,73E-07	4,25E-08	4,28E-11
U-233	1,49E-07	1,10E-08	4,02E-11
U-236	1,35E-07	1,00E-08	1,86E-11
Pu-236	6,19E-07	4,60E-08	1,80E-11
Pu-242	1,70E-06	1,27E-07	1,11E-11
Pu-244+	1,70E-06	1,26E-07	8,29E-08
Am-242m+	1,42E-06	1,06E-07	3,29E-11
Am-243+	1,49E-06	1,10E-07	4,07E-08
Cm-242	9,14E-08	6,78E-09	1,42E-11
Cm-243	1,07E-06	7,93E-08	2,54E-08
Cm-245	1,53E-06	1,14E-07	1,21E-08
Cm-246	1,52E-06	1,13E-07	1,04E-11
Cm-247+	1,39E-06	1,03E-07	8,29E-08
Cm-248	5,57E-06	4,14E-07	8,86E-12
Bk-249	2,48E-09	1,84E-10	1,27E-12
Cf-248	1,36E-07	1,01E-08	9,27E-12
Cf-249	1,08E-06	8,05E-08	8,05E-08
Cf-250	5,26E-07	3,91E-08	1,20E-11
Cf-251	1,10E-06	8,17E-08	2,18E-08
Cf-252	3,10E-07	2,30E-08	1,04E-11
Cf-254	6,35E-07	4,71E-08	2,03E-15
Es-254	1,33E-07	9,89E-09	6,07E-10

Appendix B

TABLE 4.13 ANNUAL DOSE RATES FROM EXPOSURE TO OBJECTS IN RECYCLED COPPER (Sv/y)

NUCLIDE	OCCUPATIONAL (WORKERS) LABORATORY BENCH (3.9.1.a) EXTERNAL	DECORATIVE OBJECT (3.9.1.c) EXTERNAL	MUSIC INSTRUMENT (3.9.1.d) EXTERNAL*	MUSIC INSTRUMENT (3.9.1.d) EXTERNAL**	PUBLIC KITCHEN FITTING (3.9.2.a) EXTERNAL	PIG MEAT (3.9.2.d) INGESTION
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	1,80E-09	2,38E-08	4,82E-07	5,87E-08	1,88E-10	4,47E-14
Fe55	7,97E-15	6,44E-13	1,26E-07	4,29E-12	6,93E-15	1,50E-13
Co60	2,59E-08	3,36E-07	5,37E-05	8,29E-07	2,65E-09	5,05E-11
Ni59	5,93E-14	4,78E-12	2,52E-06	6,82E-11	5,17E-14	1,65E-14
Ni63	0,00E+01	0,00E+01	4,82E-07	1,16E-11	0,00E+01	3,93E-14
Zn65	1,22E-09	1,60E-08	5,97E-07	3,92E-08	1,26E-10	1,02E-11
Sr90+	3,17E-08	5,05E-07	3,17E-03	1,12E-06	4,03E-09	2,09E-09
Nb94	3,40E-07	4,52E-06	1,27E-03	1,11E-05	3,56E-08	2,97E-11
Tc99	5,18E-12	2,22E-10	8,46E-05	2,49E-09	2,01E-12	1,12E-10
Ru106+	1,19E-08	1,71E-07	1,93E-04	3,81E-07	1,35E-09	1,22E-11
Ag108m+	3,48E-07	4,73E-06	2,77E-04	1,17E-05	3,72E-08	2,21E-11
Ag110m+	5,84E-07	7,69E-06	5,79E-04	1,89E-05	6,07E-08	2,69E-11
Sb125+	8,81E-08	1,23E-06	1,13E-03	2,59E-06	9,66E-09	2,27E-11
Cs134	3,37E-08	4,51E-07	1,11E-04	1,11E-06	3,55E-09	8,30E-10
Cs137+	1,23E-08	1,64E-07	1,47E-04	4,06E-07	1,29E-09	5,68E-10
Pm147	1,03E-14	5,66E-13	6,64E-07	1,71E-11	5,36E-15	4,54E-13
Sm151	5,84E-18	4,70E-16	1,50E-08	3,61E-13	5,08E-18	1,71E-13
Eu152	1,13E-07	1,54E-06	4,90E-04	3,76E-06	1,22E-08	1,22E-11
Eu154	1,25E-07	1,69E-06	9,86E-04	4,16E-06	1,34E-08	1,75E-11
U234	3,76E-12	1,64E-10	6,04E-06	4,86E-10	1,48E-12	3,43E-09
U235+	1,79E-08	4,08E-07	1,37E-03	9,79E-07	3,30E-09	3,31E-09
U238+	2,63E-08	4,23E-07	2,36E-03	9,35E-07	3,41E-09	3,42E-09
Np237+	3,35E-08	5,82E-07	1,87E-03	1,25E-06	4,69E-09	9,69E-10
Pu238	5,89E-13	3,79E-11	2,13E-06	1,29E-10	3,79E-13	4,02E-11
Pu239	5,71E-12	1,16E-10	1,02E-06	2,65E-10	9,75E-13	4,37E-11
Pu240	6,33E-13	3,98E-11	2,05E-06	1,32E-10	3,97E-13	4,37E-11
Pu241	7,84E-14	3,16E-12	2,61E-09	6,56E-12	2,71E-14	8,39E-13
Am241	2,45E-10	1,92E-08	4,23E-05	4,21E-08	1,98E-10	6,99E-11
Cm244	2,79E-13	2,24E-11	1,74E-06	8,85E-11	2,42E-13	2,10E-09
Na-22	4,56E-08	6,10E-07	1,46E-04	1,50E-06	4,80E-09	4,47E-11
S-35	3,15E-16	2,12E-14	4,75E-06	1,14E-10	2,09E-16	1,35E-12
Cl-36	1,35E-13	3,11E-12	1,46E-05	3,50E-10	2,59E-14	1,30E-12
K-40	3,13E-09	4,07E-08	1,52E-04	1,04E-07	3,21E-10	2,17E-11
Ca-45	3,53E-20	2,01E-18	8,44E-05	2,02E-09	1,88E-20	1,24E-13
Sc-46	4,26E-07	5,57E-06	1,13E-03	1,38E-05	4,41E-08	5,24E-11
Mn-53	0,00E+01	0,00E+01	6,59E-10	1,51E-14	0,00E+01	1,89E-15
Co-56	3,52E-08	4,61E-07	4,26E-05	1,13E-06	3,64E-09	3,71E-11
Co-57	6,44E-10	1,57E-08	4,48E-06	3,66E-08	1,26E-10	3,12E-12
Co-58	1,05E-08	1,40E-07	1,42E-05	3,43E-07	1,10E-09	1,10E-11
As-73	9,79E-11	7,69E-09	3,50E-04	2,54E-08	7,76E-11	9,09E-13
Se-75	6,60E-08	1,08E-06	1,24E-04	2,59E-06	8,51E-09	9,09E-11
Se-79	3,89E-12	2,65E-10	6,00E-04	1,47E-08	2,62E-12	1,01E-10
Sr-85	1,09E-07	1,49E-06	4,83E-05	3,65E-06	1,17E-08	3,82E-11
Y-91	1,19E-08	2,02E-07	1,68E-03	2,74E-07	1,63E-09	4,20E-12
Zr-93	5,77E-14	5,02E-12	2,53E-04	6,08E-09	5,41E-14	3,85E-11
Zr-95+	3,25E-07	4,32E-06	1,08E-03	1,06E-05	3,40E-08	5,35E-11
Nb-93m	2,06E-12	1,49E-10	9,09E-08	3,49E-10	1,54E-12	2,10E-12
Mo-93	1,16E-12	8,36E-11	5,07E-08	1,95E-10	8,60E-13	3,79E-12
Tc-97	1,44E-12	1,06E-10	2,99E-06	3,17E-10	1,09E-12	1,19E-11
Tc-97m	3,46E-12	1,76E-10	5,03E-05	1,60E-09	1,67E-12	9,61E-11

Appendix B

TABLE 4.13 (cont.)						
Pd-107	1,67E-17	1,74E-15	0,00E+01	2,10E-15	1,88E-17	1,29E-14
Cd-109	4,28E-13	3,28E-11	1,34E-07	7,85E-11	3,46E-13	1,40E-14
Sn-113+	5,36E-09	7,59E-08	9,48E-07	1,85E-07	5,99E-10	1,06E-11
Sn-126+	4,24E-08	5,77E-07	9,95E-05	1,42E-06	4,57E-09	7,09E-11
Sb-124	3,81E-07	5,05E-06	1,50E-03	1,24E-05	3,97E-08	4,37E-11
Te-123m	1,87E-08	3,60E-07	1,21E-03	8,83E-07	2,87E-09	1,96E-10
Te-127m+	8,48E-11	3,29E-09	9,67E-04	2,71E-08	3,21E-11	3,45E-10
I-125	2,17E-12	1,73E-10	1,66E-07	3,99E-10	1,85E-12	2,62E-12
I-129	1,54E-12	1,24E-10	3,51E-06	3,66E-10	1,33E-12	1,92E-11
Cs-135	1,06E-13	6,06E-12	5,79E-05	1,40E-09	5,78E-14	8,74E-11
Ce-139	1,94E-08	3,69E-07	2,21E-04	8,83E-07	2,97E-09	9,09E-13
Ce-144+	7,97E-09	1,24E-07	2,74E-03	3,65E-07	9,94E-10	1,84E-11
Sm-147	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	8,57E-11
Eu-155	1,69E-09	6,61E-08	2,30E-04	1,54E-07	5,61E-10	1,40E-12
Gd-153	2,32E-09	9,64E-08	1,08E-04	2,20E-07	8,56E-10	9,44E-13
Tb-160	2,23E-07	2,99E-06	1,97E-03	7,39E-06	2,36E-08	1,40E-11
Tm-170	5,78E-10	1,32E-08	6,93E-04	3,16E-08	1,11E-10	5,68E-12
Tm-171	6,62E-12	4,97E-10	6,74E-05	2,72E-09	4,90E-12	4,81E-13
Ta-182	2,55E-07	3,47E-06	1,38E-03	8,53E-06	2,76E-08	1,31E-09
W-181	8,86E-11	6,39E-09	5,93E-06	1,43E-08	6,18E-11	5,31E-13
W-185	1,48E-12	4,98E-11	7,33E-05	1,80E-09	4,32E-13	3,08E-12
Os-185	1,44E-08	1,99E-07	6,92E-06	4,87E-07	1,58E-09	3,57E-11
Ir-192	8,24E-09	1,18E-07	7,63E-05	2,89E-07	9,25E-10	2,45E-13
Tl-204	1,15E-11	2,73E-10	1,41E-04	3,66E-09	2,29E-12	8,39E-12
Pb-210+	8,88E-13	2,48E-11	1,61E-04	3,83E-09	2,27E-13	4,83E-11
Bi-207	3,14E-07	4,27E-06	7,45E-04	1,05E-05	3,38E-08	4,54E-11
Po-210	1,85E-12	2,45E-11	3,79E-10	6,03E-11	1,93E-13	1,05E-08
Ra-226+	3,53E-07	4,72E-06	5,24E-03	1,17E-05	3,73E-08	4,41E-10
Ra-228+	1,92E-07	2,57E-06	1,86E-03	6,35E-06	2,03E-08	1,09E-09
Ac-227+	6,77E-08	1,09E-06	0,00E+01	2,61E-06	8,66E-09	1,27E-07
Th-228+	2,81E-07	3,82E-06	3,74E-03	9,43E-06	3,01E-08	5,01E-11
Th-229+	5,18E-08	8,65E-07	3,63E-03	2,15E-06	6,93E-09	2,14E-10
Th-230	2,57E-11	8,75E-10	5,78E-05	3,36E-09	7,62E-12	7,34E-11
Th-232	9,01E-12	3,71E-10	5,62E-03	1,34E-07	3,35E-12	8,04E-11
Pa-231	5,27E-09	8,27E-08	8,16E-05	2,01E-07	6,58E-10	6,21E-09
U-232	1,67E-11	5,33E-10	3,76E-03	9,02E-08	4,71E-12	2,31E-08
U-233	2,01E-11	5,62E-10	4,11E-06	1,40E-09	4,59E-12	3,57E-09
U-236	3,52E-12	2,21E-10	2,48E-06	5,54E-10	2,04E-12	3,29E-09
Pu-236	2,76E-12	1,83E-10	9,88E-08	4,21E-10	1,77E-12	1,52E-11
Pu-242	1,58E-12	1,04E-10	6,83E-08	2,42E-10	1,02E-12	4,20E-11
Pu-244+	7,00E-08	9,42E-07	5,78E-08	2,31E-06	7,42E-09	4,21E-11
Am-242m+	2,75E-11	1,04E-09	1,10E-03	2,74E-08	9,43E-12	6,65E-11
Am-243+	2,44E-08	5,53E-07	2,28E-03	1,35E-06	4,54E-09	7,02E-11
Cm-242	2,02E-12	1,35E-10	1,90E-06	3,55E-10	1,33E-12	2,10E-10
Cm-243	1,76E-08	3,35E-07	1,04E-03	8,19E-07	2,68E-09	2,62E-09
Cm-245	6,60E-09	1,75E-07	5,93E-04	4,17E-07	1,42E-09	3,67E-09
Cm-246	1,37E-12	9,08E-11	1,19E-06	2,39E-10	9,08E-13	3,67E-09
Cm-247+	6,64E-08	9,71E-07	1,04E-04	2,36E-06	7,69E-09	3,32E-09
Cm-248	1,24E-12	8,31E-11	5,50E-08	1,93E-10	8,22E-13	1,35E-08
Bk-249	7,03E-13	5,31E-11	0,00E+01	6,31E-11	5,48E-13	3,39E-13
Cf-248	1,20E-12	8,17E-11	3,15E-05	9,46E-10	8,25E-13	9,79E-12
Cf-249	6,60E-08	9,42E-07	1,89E-04	2,30E-06	7,44E-09	1,22E-10
Cf-250	2,11E-12	1,28E-10	2,58E-06	3,56E-10	1,22E-12	5,59E-11
Cf-251	1,42E-08	3,00E-07	1,14E-03	7,29E-07	2,40E-09	1,26E-10
Cf-252	1,62E-12	1,07E-10	3,07E-06	3,17E-10	1,03E-12	3,15E-11
Cf-254	2,78E-16	2,27E-14	3,12E-02	7,35E-07	2,41E-16	1,40E-10
Es-254	3,14E-10	7,50E-09	4,07E-04	2,71E-08	6,49E-11	9,79E-12

* SKIN DOSES
** TOTAL EFFECTIVE

Appendix B

TABLE 4.14 ANNUAL DOSE RATES FROM EXPOSURE TO OBJECTS IN RECYCLED ALUMINIUM (Sv/y)

NUCLIDE	OCCUPATIONAL (WORKERS) OFFICE FURNITURE (3.9.1.a) EXTERNAL	FISHING BOAT (3.9.1.b) EXTERNAL	OFFICE CEILING (3.9.1.c) EXTERNAL	RADIATOR (3.9.2.b) EXTERNAL	PUBLIC CAR ENGINE (3.9.2.c) EXTERNAL	SAUCEPAN (3.9.2.e) INGESTION
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	5,16E-07	2,28E-06	4,88E-07	1,82E-07	1,22E-06	2,45E-11
Fe55	1,07E-11	8,26E-11	4,06E-11	3,89E-12	3,03E-12	1,14E-11
Co60	1,46E-06	6,45E-06	1,38E-06	5,15E-07	3,54E-06	1,18E-10
Ni59	1,49E-11	1,14E-10	5,63E-11	5,40E-12	4,20E-12	2,18E-12
Ni63	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	5,18E-12
Zn65	3,46E-07	1,53E-06	3,27E-07	1,22E-07	1,09E-06	1,35E-10
Sr90+	5,59E-08	2,47E-07	5,32E-08	1,97E-08	2,22E-08	1,06E-09
Nb94	9,82E-07	4,32E-06	9,24E-07	3,45E-07	2,30E-06	5,88E-11
Tc99	4,94E-11	2,37E-10	5,62E-11	1,75E-11	1,86E-11	2,21E-12
Ru106+	2,47E-08	1,09E-07	2,32E-08	8,70E-09	3,43E-08	2,42E-11
Ag108m+	1,04E-06	4,59E-06	9,82E-07	3,68E-07	2,38E-06	7,95E-11
Ag110m+	1,67E-06	7,37E-06	1,57E-06	5,90E-07	3,95E-06	9,68E-11
Sb125+	2,85E-07	1,29E-06	2,86E-07	1,01E-07	1,12E-07	4,49E-11
Cs134	9,82E-09	4,32E-08	9,21E-09	3,45E-09	2,28E-08	6,57E-12
Cs137+	3,58E-09	1,58E-08	3,37E-09	1,26E-09	8,28E-09	4,49E-12
Pm147	1,64E-13	8,25E-13	2,08E-13	5,83E-14	6,22E-14	8,99E-15
Sm151	8,64E-16	6,59E-15	2,76E-15	3,15E-16	2,45E-16	3,39E-15
Eu152	3,44E-07	1,53E-06	3,27E-07	1,21E-07	7,92E-07	2,42E-11
Eu154	3,71E-07	1,63E-06	3,50E-07	1,31E-07	8,61E-07	3,46E-11
U234	3,82E-11	1,71E-10	3,66E-11	1,35E-11	1,48E-11	8,47E-10
U235+	5,20E-08	2,25E-07	4,74E-08	1,84E-08	9,50E-08	8,18E-10
U238+	2,71E-08	1,20E-07	2,56E-08	9,54E-09	1,08E-08	8,45E-10
Np237+	7,24E-08	3,16E-07	6,71E-08	2,54E-08	2,91E-08	1,92E-09
Pu238	2,18E-11	1,46E-10	5,64E-11	7,84E-12	6,77E-12	3,97E-09
Pu239	2,23E-11	1,17E-10	3,43E-11	7,91E-12	8,17E-12	4,32E-09
Pu240	2,22E-11	1,46E-10	5,49E-11	7,98E-12	6,95E-12	4,32E-09
Pu241	5,10E-13	2,20E-12	4,66E-13	1,79E-13	2,06E-13	8,29E-11
Am241	7,53E-09	3,47E-08	7,53E-09	2,67E-09	2,84E-09	3,46E-09
Cm244	1,94E-11	1,40E-10	5,54E-11	7,06E-12	5,69E-12	2,07E-09
Na-22	1,34E-07	5,91E-07	1,25E-07	4,73E-08	3,19E-07	1,11E-11
S-35	7,74E-13	4,13E-12	1,11E-12	2,77E-13	2,71E-13	2,66E-12
Cl-36	4,44E-11	2,00E-10	4,39E-11	1,57E-11	1,93E-11	3,21E-12
K-40	8,82E-09	3,91E-08	8,32E-09	3,11E-09	2,16E-08	2,14E-11
Ca-45	2,83E-18	2,21E-17	1,05E-17	1,03E-18	1,07E-18	2,45E-12
Sc-46	1,22E-06	5,37E-06	1,15E-06	4,29E-07	2,91E-06	5,18E-11
Mn-53	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	1,04E-12
Co-56	2,00E-06	8,86E-06	1,89E-06	7,04E-07	4,82E-06	8,64E-11
Co-57	7,71E-08	3,32E-07	6,87E-08	2,71E-08	1,29E-07	7,26E-12
Co-58	6,19E-07	2,73E-06	5,75E-07	2,18E-07	1,47E-06	2,56E-11
As-73	4,24E-09	1,85E-08	3,89E-09	1,50E-09	3,61E-09	8,99E-12
Se-75	2,52E-08	1,09E-07	2,26E-08	8,84E-09	5,00E-08	8,99E-12
Se-79	9,70E-13	5,14E-12	1,37E-12	3,46E-13	3,40E-13	1,00E-11
Sr-85	3,35E-07	1,47E-06	3,10E-07	1,18E-07	7,70E-07	1,94E-11
Y-91	2,45E-08	1,09E-07	2,34E-08	8,65E-09	1,41E-08	8,29E-11
Zr-93	3,07E-12	2,14E-11	8,12E-12	1,12E-12	9,01E-13	3,80E-11
Zr-95+	9,55E-07	4,18E-06	8,86E-07	3,35E-07	2,27E-06	5,29E-11
Nb-93m	3,18E-10	2,45E-09	1,01E-09	1,15E-10	9,50E-11	4,15E-12
Mo-93	1,78E-10	1,37E-09	5,68E-10	6,47E-11	5,32E-11	1,07E-11
Tc-97	2,31E-10	1,77E-09	6,93E-10	8,43E-11	6,86E-11	2,35E-13
Tc-97m	2,42E-10	1,77E-09	6,41E-10	8,78E-11	9,50E-11	1,90E-12

TABLE 4.14 (cont.)						
Pd-107	2,68E-13	2,05E-12	9,97E-13	9,76E-14	7,59E-14	1,28E-12
Cd-109	7,62E-09	5,48E-08	1,68E-08	2,78E-09	2,15E-09	6,91E-11
Sn-113+	1,87E-08	8,50E-08	1,86E-08	6,59E-09	3,83E-08	2,62E-12
Sn-126+	1,30E-07	5,72E-07	1,21E-07	4,59E-08	3,01E-07	1,75E-11
Sb-124	1,10E-06	4,86E-06	1,03E-06	3,88E-07	2,65E-06	8,64E-11
Te-123m	9,61E-09	4,32E-08	9,19E-09	3,39E-09	1,57E-08	4,84E-12
Te-127m+	3,81E-11	2,49E-10	7,82E-11	1,38E-11	1,19E-11	8,52E-12
I-125	3,47E-09	1,99E-08	4,87E-09	1,25E-09	1,17E-09	5,18E-11
I-129	2,14E-09	1,11E-08	2,48E-09	7,64E-10	8,28E-10	3,80E-10
Cs-135	1,79E-14	9,03E-14	2,29E-14	6,36E-15	6,47E-15	6,91E-13
Ce-139	5,35E-08	2,35E-07	4,86E-08	1,88E-08	8,21E-08	4,49E-12
Ce-144+	3,08E-08	1,36E-07	2,85E-08	1,09E-08	6,11E-08	1,81E-10
Sm-147	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	1,69E-12
Eu-155	2,12E-08	9,19E-08	1,89E-08	7,48E-09	2,69E-08	5,53E-12
Gd-153	4,37E-08	1,93E-07	3,98E-08	1,54E-08	4,28E-08	4,67E-12
Tb-160	3,32E-07	1,46E-06	3,10E-07	1,17E-07	7,70E-07	2,76E-11
Tm-170	2,40E-09	1,08E-08	2,32E-09	8,49E-10	9,42E-10	2,25E-11
Tm-171	2,50E-10	1,08E-09	2,21E-10	8,77E-11	2,26E-10	1,90E-12
Ta-182	7,77E-07	3,43E-06	7,26E-07	2,74E-07	1,79E-06	5,18E-11
W-181	2,86E-09	1,23E-08	2,51E-09	1,01E-09	2,79E-09	2,63E-13
W-185	9,41E-12	4,39E-11	1,00E-11	3,33E-12	3,90E-12	1,52E-12
Os-185	4,58E-08	2,00E-07	4,23E-08	1,61E-08	1,04E-07	1,76E-12
Ir-192	5,38E-07	2,33E-06	4,88E-07	1,90E-07	1,17E-06	4,84E-11
Tl-204	4,41E-09	1,97E-08	4,30E-09	1,55E-09	2,13E-09	4,15E-11
Pb-210+	1,40E-11	7,10E-11	1,77E-11	4,99E-12	4,93E-12	2,39E-09
Bi-207	9,50E-07	4,16E-06	8,84E-07	3,34E-07	2,20E-06	4,49E-11
Po-210	5,38E-13	2,37E-12	5,02E-13	1,90E-13	1,28E-12	4,15E-09
Ra-226+	1,04E-06	4,59E-06	9,72E-07	3,66E-07	2,46E-06	9,69E-09
Ra-228+	5,66E-07	2,49E-06	5,29E-07	2,00E-07	1,32E-06	2,39E-08
Ac-227+	2,59E-07	1,12E-06	2,34E-07	9,10E-08	5,18E-07	4,17E-08
Th-228+	4,20E-07	1,85E-06	3,94E-07	1,48E-07	9,79E-07	2,48E-09
Th-229+	1,07E-07	4,68E-07	9,87E-08	3,78E-08	2,07E-07	1,06E-08
Th-230	1,59E-10	7,94E-10	2,28E-10	5,65E-11	1,84E-10	3,63E-09
Th-232	8,96E-11	4,94E-10	1,66E-10	3,19E-11	8,12E-11	3,97E-09
Pa-231	1,08E-08	4,91E-08	1,09E-08	3,81E-09	1,98E-08	1,23E-08
U-232	1,34E-10	7,82E-10	2,83E-10	4,78E-11	1,19E-10	5,70E-09
U-233	8,60E-11	4,36E-10	1,30E-10	3,04E-11	1,15E-10	8,81E-10
U-236	7,58E-11	4,95E-10	2,04E-10	2,72E-11	4,90E-11	8,12E-10
Pu-236	9,72E-11	6,97E-10	3,08E-10	3,51E-11	4,54E-11	1,50E-09
Pu-242	6,42E-11	4,71E-10	2,12E-10	2,32E-11	2,72E-11	4,15E-09
Pu-244+	1,05E-07	4,63E-07	9,91E-08	3,71E-08	2,45E-07	4,17E-09
Am-	1,62E-10	1,00E-09	3,72E-10	5,81E-11	5,31E-11	3,29E-09
Am-243+	7,24E-08	3,15E-07	6,66E-08	2,55E-08	1,20E-07	3,47E-09
Cm-242	9,53E-11	7,17E-10	3,25E-10	3,45E-11	3,64E-11	2,07E-10
Cm-243	4,07E-08	1,77E-07	3,76E-08	1,43E-08	7,42E-08	2,59E-09
Cm-245	2,23E-08	9,73E-08	2,10E-08	7,84E-09	3,56E-08	3,63E-09
Cm-246	7,48E-11	5,67E-10	2,58E-10	2,72E-11	2,61E-11	3,63E-09
Cm-247+	1,12E-07	4,87E-07	1,02E-07	3,94E-08	2,42E-07	3,28E-09
Cm-248	6,03E-11	4,52E-10	2,05E-10	2,17E-11	2,26E-11	1,33E-08
Bk-249	6,38E-12	3,67E-11	1,08E-11	2,29E-12	2,13E-12	1,68E-11
Cf-248	7,48E-11	5,74E-10	2,59E-10	2,72E-11	2,43E-11	4,84E-10
Cf-249	1,08E-07	4,70E-07	9,87E-08	3,80E-08	2,35E-07	6,05E-09
Cf-250	7,87E-11	5,87E-10	2,60E-10	2,86E-11	3,28E-11	2,76E-09
Cf-251	3,69E-08	1,61E-07	3,43E-08	1,30E-08	6,41E-08	6,22E-09
Cf-252	7,24E-11	5,43E-10	2,42E-10	2,62E-11	2,82E-11	1,56E-09
Cf-254	1,04E-14	4,71E-14	9,72E-15	3,70E-15	6,41E-15	6,91E-09
Es-254	1,93E-09	1,17E-08	4,26E-09	6,90E-10	1,76E-09	4,84E-10

5 References

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2 NRPB personal communication.

3 European Commission. Principals and Methods for Establishing Concentrations and Quantities (Exemption Values) Below which Reporting is not Required in the European Directive. Radiation Protection 65, Luxembourg (1993).

4 European Commission. Recommended radiological protection criteria for the recycling of metals from the dismantling of nuclear installations. Radiation Protection 89, Luxembourg (1998).

APPENDIX C

Collective Doses Arising from

Recycled Steel, Copper and Aluminium

Contents

1 Introduction

This Appendix describes the methodology and the formulae used to calculate the collective doses arising from recycled steel, copper and aluminium which has been contaminated by radionuclides. Individual doses were taken from a selection of scenarios expected to cover the main part of the total collective dose and which are described in Appendix A for steel, and Appendix B for copper and aluminium. Section 2 describes the scenarios and covers in detail the formulae and parameters used. Section 3 contains the collective doses for workers and public arising from contaminated steel, copper and aluminium.

2 Description of formulae and parameters used in the collective dose calculations

The scenarios described enable calculation of the collective dose received by either a member of the public or by a worker. These collective doses arise from steel, copper or aluminium having an activity concentration of 1 Bq g^{-1} prior to any recycling activities, but taking into account any processing subsequently undergone in the metal recovery industry.

2.1 Collective doses to workers

The total collective dose for each pathway is given by the generic workers formula: ·

$$CD = \frac{D_1 \cdot N}{1 - i \cdot r \cdot e^{-\lambda \cdot T}} \qquad (85)$$

where:

CD:	the collective dose for one year for the scenario (manSv),
D_1:	the individual dose in the scenario (Sv y^{-1}),
N:	the number of workers in the scenario,
i :	fraction of the radionuclides transferred to the ingot (Table 3.1 in Appendix D),
r:	fraction of metal that is recycled,
λ:	decay constant for a particular radionuclide (y^{-1}) (see Table 3.1 in Appendix D for half-life),
T:	average time between recyclings (y).

The collective dose scenarios were based on scenarios selected from Appendices A and B. The scenarios and parameter values are described in the following sections.

2.1.1 Steel

The number of exposed workers in the steel works is assumed to be equal to the number of those actually working in the typical plant used for the calculation of the occupational individual doses, ie, 10 workers for scrap handling and 40 workers for steel smelting. In the case of manufacturing plant a total of 1000 workers is considered. This is based on the number of workers in the French steel-based manufacturing industry and the fraction of the total steel used that is recycled steel. Half of the products are assumed to be recycled after 10 years of use.

Three scenarios were selected from Appendix A. The collective doses were then calculated using equation (85); the relevant parameters values are listed in Table 2.1.1. The corresponding doses are listed in Table 3.1.

Appendix C

Scenarios

a) External exposure from scrap metal heap

This considers external exposure from a scrap metal heap at a foundry storage area. The value of D_1 is taken from Appendix A (section 3.2.1).

b) Inhalation during melting

A dose arises in the foundry from the inhalation of fumes and dust particles. This is considered for induction furnaces. Doses arising from atmospheric emissions are not considered for steel melting. The individual dose is calculated in Appendix A, section 3.2.2.1.

c) Exposure during manufacturing

Exposure will arise during manufacturing of ingots and products. The pathways are external irradiation by the ingots themselves and inhalation of dust. The individual doses for these pathways are taken from section 3.4.1.1 and 3.4.1.2 in Appendix A.

The parameter values for the recycling of steel are listed in Table 2.1.1 below.

Table 2.1.1 Parameter values used in the calculation of collective doses to workers from steel recycling

Parameter	Scrap heap	Melting plant	Manufacturing
Number of workers, N	10	40	1000
Fraction of metal recycled, r	0.5	0.5	0.5
Average time between recyclings, T (y)	10	10	10

2.1.2 Copper

Five scenarios were selected from Appendix B. The collective doses were then calculated using equation (85); the relevant parameter values are listed in Table 2.1.2. The resulting doses are listed in Table 3.2.

Scenarios

a) External exposure from scrap metal heap

This considers external exposure from a pile of scrap metal at a foundry storage area. The value of D_1 is taken from Appendix B (section 3.2.1).

b) Doses during melting

A dose arises in the foundry from the inhalation and ingestion of fumes and dust particles arising from furnaces and from external irradiation by the ingots. The individual dose from these pathways is calculated in Appendix B, section 3.3.

c) Treatment of by-products

Copper dust may be treated to recover zinc or the dust may be compacted. These scenarios lead to a dose through inhalation of the dust. The individual doses for both pathways are calculated in Appendix B, section 3.4.1 and 3.4.2, and both pathways are used to calculate collective dose.

d) Purification of metal

Ultra pure copper is manufactured by electro-refining. The electrolysis vats will give rise to an external dose to a worker. This dose is calculated in Appendix B, section 3.5.1.

e) Exposure during manufacturing

Exposure will arise during manufacturing of ingots and products. The pathway is inhalation of dust during the product's manufacturing process. The individual doses for these pathways are taken from section 3.6 in Appendix B.

The parameter values for the recycling of copper are listed in Table 2.1.2 below.

Table 2.1.2 Parameter values used in the calculation of collective doses to workers from copper recycling

Parameter	Scrap heap	Melting plant	Purification treatment	Treatment (by-products)	Manufacturing
Number of workers, N	10	40	10	10	100
Fraction of metal recycled, r	0.5	0.5	0.5	0.5	0.5
Average time between recyclings, T (y)	10	10	10	10	10

2.1.3 Aluminium

Four scenarios were selected from Appendix B. The collective doses were calculated using the generic workers formula (equation (85)); the relevant parameter values are listed in Table 2.1.3. The corresponding doses are listed in Table 3.3. Most of the VLLW aluminium is assumed to come from PWR electrical cabling, however ^{234}U, ^{235}U and ^{238}U are only significantly present in aluminium arising from a uranium isotopic enrichment plant. The latter is referred to as AL(AG3), and is used for collective dose calculations for uranium isotopes in all occupational scenarios unless stated. Aluminium from PWRs is termed AL(PWR) if necessary.

Scenarios

a) External from scrap metal heap

This considers external exposure from a scrap metal heap at a foundry storage area. The value of D_1 is taken from Appendix B (section 3.2.1).

b) Doses during melting

A dose arises in the foundry from the inhalation and ingestion of fumes and dust particles arising from furnaces and from external irradiation by the ingots. Atmospheric emissions by the plant are also considered, the pathways being inhalation of the dust, ingestion of foodstuffs grown near to the plant (within 100 m) and external exposure to the deposited dust. The individual dose from all these exposures is calculated in Appendix B, section 3.3.

c) Treatment of by-products

Aluminium slag contains many metal inclusions which are recovered by crushing the slag with a pneumatic hammer. This leads to a dose through external exposure and inhalation of the dust. The individual dose is calculated in Appendix B, section 3.4.3.

d) Exposure during manufacturing

Exposure will arise during manufacturing of ingots and products. The pathway is inhalation of dust during the product's manufacturing process. The individual doses for this pathway are taken from section 3.6 in Appendix B.

e) Exposure by office ceiling

The individual is exposed to external irradiation from a room with a ceiling constructed from sheet aluminium. The individual dose is given in Appendix B Section 3.9.1c. The number of persons exposed N is calculated by using the following equation (86):

$$N = \frac{M \cdot Fp}{m \cdot F} \cdot n \qquad (86)$$

where:

M: total quantity of very low level waste arising from nuclear power plant dismantling in the EC (40 tonnes),

Fp: fraction of amount of recycled metal used for this practice (0.05),

F: fraction of VLLW (0.2),

m: mass of metal per scenario,

n: number of persons in each exposure situation.

The parameter values for the recycling of aluminium are listed in Table 2.1.3.

Table 2.1.3 Parameter values used in the calculation of collective doses to workers from aluminium recycling

Parameter	Scrap heap	Melting plant	Treatment (by-products)	Manufacturing	Office ceiling
Number of workers, N	10	40	10	100	188
Fraction of metal recycled, r	0.5	0.5	0.5	0.5	0.5
Ave. time between recycling, T (y)	10	10	10	10	30

2.2 Collective doses to the public

The collective dose for each radionuclide and each exposure pathway may be calculated using the generic public formula:

$$CD = \frac{1 - e^{-\lambda \cdot T}}{\lambda} \cdot \frac{D_1 \cdot N}{1 - i \cdot r \cdot e^{-\lambda \cdot T}} \qquad (87)$$

where:

- CD; collective dose arising from the scenario (manSv),
- D_1: individual dose for one year for the scenario (Sv y^{-1}),
- N: number of people exposed
- λ: decay constant for a particular radionuclide (y^{-1}) (see Table 3.1 in Appendix D for half-life),
- T: average time between two recyclings (y),
- i: fraction of the radionuclides transferred to the ingot (Table 3.1 in Appendix D),
- r: fraction of metal recycled.

The collective dose scenarios were based on scenarios selected from Appendices A and B. The scenarios and parameter values are described below.

2.2.1 Steel

The working group considered three scenarios for exposure of the public at large, these being exposure to radiators, exposure from the use of recycled carbon steel as building reinforcement bars and exposure through residence of adults on a landfill. The total amount of steel recycled per year was taken as 10^4 tonnes. The individual doses are taken from Appendix A, and the resulting collective doses for each scenario are shown in Table 3.4. Equation 2.2 is used throughout to calculate the collective doses.

Scenarios

a) Exposure from landfill

The following assumptions are used for the exposure of families residing on a landfill which has been used for the disposal of slag from arc and induction furnaces. The individual dose is taken from Appendix A, section 3.6.1.4. The number of persons exposed is calculated using the method shown below, and assuming 100% of the slag is disposed of on a landfill, and all landfills are used as a residential areas. Table 2.2.1a contains all relevant parameter values.

The number of persons exposed is calculated by finding the area of contaminated landfill ($M_L/\{Rho_L \cdot d\}$) and dividing by the area occupied by a family (A), then multiplying by the number of people in that family. With the above assumptions the equation is:·

$$N = \frac{M_L}{Rho_L \cdot d} \cdot \frac{1}{A} \cdot N_F \qquad (88)$$

where:

- N: number of persons exposed,
- M_L: capacity of landfill (t),
- Rho_L: density of the landfill (t m^{-3}),
- d: depth of landfill (m),
- A: average residential area per family (m^2),
- N_F : number of persons per family (4).

Rho_L, d, A take the values shown in Table 2.2.1a. The capacity of the landfill can be calculated by:

$$M_L = \frac{M_s}{F \cdot F_s} \qquad (89)$$

where:

M_L: capacity of landfill (t),

M_s: mass of slag containing VLLW that is disposed of by landfill (t),

F: fraction of metal in slag that is VLLW,

F_s: fraction of landfill capacity that is slag.

Giving $M_L = 3.5\ 10^5$ tonnes for arc furnace slag.

The mass of slag containing VLLW is simply the amount of slag produced per tonne of recycled material multiplied by the amount of recycled material, ie:

$$M_s = C_s \cdot M_{rm} \cdot F_m \qquad (90)$$

where:

C_s: quantity of slag per tonne of recycled material (kg t^{-1}),

M_{rm}: total quantity of very low level metal arising from nuclear power plant dismantling in the EC (t),

F_m: fraction of the recycled metal that is molten in the furnace.

If arc furnace slag is considered, the mass of slag is 1,120 tonnes.

b) Exposure from radiators

A dose arises from large steel surfaces in the house (eg, radiators). The individual dose D_I is given in Appendix A, section 3.5.2.2. The number of persons exposed is calculated by using formula (86).

Other relevant parameter values for the assessment of the collective dose are listed in Table 2.2.1b.

c) Exposure from building reinforcement bars

A dose arises from steel reinforcements in concrete building structures. The individual dose is given in Appendix A, section 3.5.2.1. The number of persons exposed is calculated by using formula (86). The relevant parameter values are listed in Table 2.2.1b.

Table 2.2.1a Parameter values for calculation of collective doses to the public arising from landfills contaminated with recycled steel slag

Scenario	Mass recycled M_{rm} (t)	Conc. of slag, C_s (kg t^{-1})	Fract. of VLLW, F	Fract. of slag, F_s	Density, Rho_L (t m^{-3})	Thickness, d (m)	Area per family, A (m^2)	Fraction molten, F_m	Resid. time, t (y)	No. exposed, N
Landfill	10^4	140 [A] 20 [B]	0.01	0.4 [A] 0.08 [B]	1.5	5	330	0.8 [A] 0.2 [B]	100	453 [A] 81 [B]

Notes
A Arc furnaces
B Induction furnaces

Table 2.2.1b Parameter values for calculation of collective doses to the public arising from radiators and reinforcement bars contaminated with recycled steel

Scenario	Total quantity recycled, M_{rm}(t)	Fraction of recycled metal used, F_p	Fraction of VLLW, F	Mass of metal per family, m (kg)	Time between recyclings, t (y)	No. persons per scenario, n	No. of people exposed, N
Radiator	10^4	0.01	0.1	500	30	4	8,000
Reinforcement bars	10^4	0.03	0.025	2000	100	4	24,000

2.2.2 Copper

Two scenarios for exposure of the public at large are considered, these being exposure through residence on a landfill and from a kitchen fitting. The collective dose was calculated with equation (87). The individual doses are taken from Appendix B, and the resulting collective doses for each scenario are shown in Table 3.5.

Scenarios

a) Exposure by landfill

The following assumptions are used for the exposure of families taking residence on a landfill which has been used for the disposal of copper slag. The individual doses for ingestion, inhalation and external pathways are given in Appendix B, section 3.7.2. The number of persons exposed is calculated using equation (88). Table 2.2.2a contains all relevant parameter values.

b) Exposure from a kitchen fitting

An individual is exposed in the kitchen to external irradiation from a fitting made of brass. The individual dose is given in Appendix B, section 3.9.2a. The number of persons exposed is calculated by using equation (86). Other relevant parameter values are listed in Table 2.2.2b.

Table 2.2.2a Parameter values for calculation of collective doses to the public arising from landfills contaminated with copper recycling slag

Scenario	Mass of slag, M_s (t)	Fract. of VLLW, F	Fract. of slag, F_s	Density, Rho_L (t m^{-3})	Thickness, d(m)	Area per family A (m^2)	Fract. molten, F_m	Resid. time, t (y)	No.exposed, N
Landfill	8800	0.01	0.18	1.5	5	330	1	100	7,900

Table 2.2.2b Parameter values for calculation of collective doses to the public arising from kitchen fittings contaminated with recycled copper

Scenario	Total quantity recycled M_{rm} (t)	Fraction of recycled metal used, F_p	Fraction of VLLW, F	Mass of metal per scenario m (t)	Time between recyclings, t (y)	No. persons per scenario, n	No. of people exposed, N
Sanitary	200 t	0.01	0.3	5.2 10^{-4}	30 y	1	12,820

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2.2.3 Aluminium

Four scenarios for exposure of the public at large are considered, these being exposure through residence on a landfill and external irradiation from a concrete plate, radiator and car engine. Only aluminium arising from PWR electric cables is considered, (AG3 is assumed to be the same). All collective doses are calculated using the generic public formula, equation (87). The individual doses are taken from Appendix B, and the resulting collective doses for each scenario are shown in Table 3.6.

Scenarios

a) Exposure by landfill

The following assumptions are used for the exposure of families taking residence on a landfill which has been used for the disposal of aluminium slag. The individual doses for ingestion, inhalation and external irradiation pathways are given in Appendix B, section 3.7.2. The number of persons exposed is calculated using equation (88). Table 2.2.3a contains all relevant parameter values.

b) Exposure from a concrete plate

The individual is exposed to external irradiation from a room with a concrete wall containing aluminium slag. It is assumed that there is 11.5 t of concrete per (4 person) family. This concrete contains 2% slag. The mass of slag per scenario is thus $(11.5 / 4) \cdot 0.02 = 5.7 \cdot 10^{-2}$ t. The individual dose is given in Appendix B, section 3.8.2. The number of persons exposed is calculated by using equation (86), the relevant parameter values are listed in Table 2.2.3b. The number of persons exposed per scenario (n) is assumed to be 1.

c) Exposure from radiators

A dose arises from large aluminium surfaces in the house (eg, radiators). The individual dose is given in Appendix B, section 3.9.2b. The number of persons exposed is calculated by using equation (86), and the parameter values listed in Table 2.2.3b. The number of persons exposed per scenario (n) is assumed to be 4.

d) Exposure by car engine

The individual is exposed to external irradiation from an aluminium engine when driving a car. The individual dose is given in Appendix B, section 3.9.2c. The number of persons exposed is calculated with equation (86), the relevant parameter values are listed in Table 2.2.3b. The average number of persons exposed per scenario (n) is assumed to be 1.5.

Table 2.2.3a Parameter values for calculation of collective doses to the public arising from landfills contaminated with aluminium recycling slag

Scenario	Mass of slag, M_s (t)	Fract. of VLLW, F	Fract. of slag, F_s	Density, Rho_L (t m^{-3})	Thickness, d (m)	Area per family, A (m^2)	Fract. molten, F_m	Resid. time, t (y)	No. exposed, N
Landfill	3300	0.01	0.067	1.5	5 m	330	1	100 y	7,960

Table 2.2.3b Parameter values for calculation of collective doses to the public arising from scenarios for contaminated recycled aluminium

Scenario	Total quantity recycled, M_{rm} (t)	Fraction of recycled metal used, F_p	Fraction of VLLW, F	Mass per scenario, m (t)	Time between recyclings, t (y)	No. persons per scenario, n	No. of people exposed, N
Wall	40	0.05	0.1	5.75 10^{-2}	30	1	348
Radiator	40	0.05	0.2	0.12	30	4	333
Car engine	40	0.2	0.2	7.9 10^{-2}	10	1.5	759

Section 3

Tables of Doses

Appendix C

TABLE 3.1 COLLECTIVE DOSES FROM STEEL RECYCLING (OCCUPATIONAL) (manSv)

NUCLIDE	SCRAP HEAP (3.2.1) EXTERNAL	STEEL PLANT (3.2.2.1) INHALATION (INDUCTION)	MANUFACT. PLANT (3.4.1) EXTERNAL +INH.	TOTAL
H3	0,00E+01	6,25E-09	0,00E+01	6,25E-09
C14	0,00E+01	2,01E-07	0,00E+01	2,01E-07
Mn54	2,82E-06	2,08E-08	1,37E-04	1,40E-04
Fe55	7,46E-12	1,66E-09	2,10E-08	2,27E-08
Co60	1,07E-05	3,41E-08	5,21E-04	5,32E-04
Ni59	6,77E-12	1,53E-10	9,83E-09	9,99E-09
Ni63	0,00E+01	3,38E-10	2,10E-08	2,13E-08
Zn65	2,09E-06	9,73E-07	1,02E-05	1,32E-05
Sr90+	1,33E-07	2,84E-06	8,07E-07	3,78E-06
Nb94	5,53E-06	9,14E-09	2,70E-05	3,25E-05
Tc99	3,81E-10	1,17E-09	9,11E-09	1,07E-08
Ru106+	9,08E-07	1,22E-05	4,46E-06	1,75E-05
Ag108m+	9,36E-06	1,25E-06	4,57E-04	4,67E-04
Ag110m+	9,36E-06	2,54E-07	4,55E-04	4,65E-04
Sb125+	1,22E-06	1,43E-08	5,95E-05	6,07E-05
Cs134	5,01E-06	3,33E-06	2,45E-07	8,59E-06
Cs137+	1,78E-06	2,33E-06	8,68E-08	4,20E-06
Pm147	8,14E-11	1,22E-09	7,95E-11	1,38E-09
Sm151	5,52E-14	9,03E-10	5,62E-11	9,60E-10
Eu152	3,74E-06	9,38E-09	1,82E-07	3,93E-06
Eu154	4,15E-06	1,22E-08	2,02E-07	4,37E-06
U234	3,72E-11	2,49E-06	1,55E-05	1,79E-05
U235+	1,82E-07	2,23E-06	1,48E-05	1,72E-05
U238+	1,42E-07	2,09E-06	1,37E-05	1,59E-05
Np237+	1,68E-07	5,49E-06	3,49E-05	4,06E-05
Pu238	5,90E-12	1,09E-05	6,79E-05	7,89E-05
Pu239	6,93E-11	1,17E-05	7,28E-05	8,45E-05
Pu240	6,37E-12	1,17E-05	7,28E-05	8,45E-05
Pu241	7,62E-13	2,08E-07	1,29E-06	1,50E-06
Am241	2,53E-09	9,86E-06	6,14E-05	7,12E-05
Cm244	2,75E-12	6,11E-06	3,80E-05	4,41E-05
Na-22	7,36E-06	6,95E-07	3,58E-07	8,41E-06
S-35	2,65E-11	3,82E-08	2,38E-10	3,85E-08
Cl-36	7,16E-09	1,78E-06	1,14E-09	1,79E-06
K-40	5,91E-07	1,04E-06	2,87E-08	1,66E-06
Ca-45	1,56E-19	7,99E-08	4,97E-09	8,49E-08
Sc-46	7,15E-06	1,67E-07	3,47E-05	4,20E-05
Mn-53	0,00E+01	1,25E-09	1,56E-09	2,81E-09
Co-56	1,32E-05	8,51E-09	6,39E-04	6,52E-04
Co-57	1,16E-07	1,04E-09	5,67E-06	5,79E-06
Co-58	3,22E-06	2,95E-09	1,56E-04	1,59E-04
As-73	9,55E-10	2,26E-09	6,04E-08	6,36E-08
Se-75	7,10E-07	5,90E-08	3,46E-06	4,23E-06
Se-79	3,47E-11	1,13E-07	7,07E-09	1,20E-07
Sr-85	1,46E-06	1,95E-08	7,11E-06	8,59E-06
Y-91	1,39E-08	2,12E-07	4,21E-08	2,68E-07
Zr-93	9,26E-13	1,01E-07	1,25E-06	1,35E-06
Zr-95+	4,93E-06	9,55E-09	2,40E-04	2,45E-04
Nb-93m	1,90E-11	3,08E-10	2,01E-09	2,34E-09
Mo-93	2,06E-10	9,71E-08	7,05E-08	1,68E-07
Tc-97	1,47E-10	5,85E-11	1,09E-09	1,29E-09
Tc-97m	3,31E-10	9,38E-10	7,45E-09	8,72E-09

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TABLE 3.1 (cont.)				
Pd-107	1,09E-13	2,01E-10	1,25E-08	1,27E-08
Cd-109	4,68E-10	3,34E-06	2,30E-08	3,36E-06
Sn-113+	6,54E-07	6,71E-07	3,19E-06	4,52E-06
Sn-126+	6,37E-06	6,76E-06	3,09E-05	4,41E-05
Sb-124	6,56E-06	1,63E-08	3,19E-04	3,25E-04
Te-123m	1,75E-07	1,18E-07	8,57E-07	1,15E-06
Te-127m+	5,22E-10	2,21E-07	1,40E-08	2,36E-07
I-125	2,27E-09	2,54E-06	2,67E-09	2,54E-06
I-129	1,58E-09	1,78E-05	1,18E-08	1,78E-05
Cs-135	8,44E-11	3,44E-07	2,14E-11	3,44E-07
Ce-139	1,84E-07	4,86E-08	8,96E-07	1,13E-06
Ce-144+	1,29E-07	1,01E-06	6,90E-07	1,83E-06
Sm-147	0,00E+01	2,13E-06	1,32E-07	2,26E-06
Eu-155	3,10E-08	1,63E-09	1,60E-09	3,43E-08
Gd-153	4,30E-08	8,68E-10	2,15E-07	2,58E-07
Tb-160	3,62E-06	1,88E-09	1,76E-05	2,12E-05
Tm-170	1,15E-08	1,81E-09	1,67E-08	3,00E-08
Tm-171	1,29E-10	3,16E-10	2,60E-09	3,04E-09
Ta-182	4,39E-06	2,57E-09	2,14E-05	2,58E-05
W-181	8,61E-09	1,49E-09	4,19E-07	4,29E-07
W-185	9,20E-10	7,64E-09	4,90E-08	5,76E-08
Os-185	2,11E-06	4,86E-07	1,02E-05	1,28E-05
Ir-192	2,02E-06	8,51E-09	9,87E-05	1,01E-04
Tl-204	5,91E-09	2,17E-08	4,17E-09	3,18E-08
Pb-210+	4,87E-10	4,18E-04	2,60E-06	4,21E-04
Bi-207	8,47E-06	1,87E-08	4,12E-04	4,20E-04
Po-210	2,86E-11	7,64E-05	4,75E-06	8,12E-05
Ra-226+	6,31E-06	8,14E-05	3,56E-05	1,23E-04
Ra-228+	3,15E-06	6,10E-05	1,90E-05	8,32E-05
Ac-227+	8,22E-07	2,32E-02	1,45E-03	2,46E-02
Th-228+	5,29E-06	1,20E-05	1,00E-04	1,17E-04
Th-229+	7,05E-07	2,94E-05	1,86E-04	2,16E-04
Th-230	2,50E-10	1,02E-05	6,37E-05	7,39E-05
Th-232	7,95E-11	1,07E-05	6,64E-05	7,71E-05
Pa-231	6,19E-08	3,25E-05	2,03E-04	2,35E-04
U-232	1,50E-10	9,46E-06	5,88E-05	6,83E-05
U-233	1,85E-10	2,52E-06	1,57E-05	1,82E-05
U-236	2,63E-11	2,30E-06	1,43E-05	1,66E-05
Pu-236	1,59E-11	4,54E-06	2,82E-05	3,27E-05
Pu-242	8,13E-12	1,13E-05	7,05E-05	8,18E-05
Pu-244+	1,09E-06	1,10E-05	7,35E-05	8,56E-05
Am-242m+	2,83E-09	8,76E-06	5,45E-05	6,32E-05
Am-243+	2,63E-07	9,87E-06	6,27E-05	7,28E-05
Cm-242	1,14E-11	1,29E-06	7,99E-06	9,28E-06
Cm-243	1,89E-07	7,23E-06	4,59E-05	5,33E-05
Cm-245	6,35E-08	9,87E-06	6,17E-05	7,16E-05
Cm-246	7,15E-12	9,87E-06	6,14E-05	7,13E-05
Cm-247+	8,56E-07	9,14E-06	6,10E-05	7,10E-05
Cm-248	7,23E-12	3,47E-05	2,16E-04	2,51E-04
Bk-249	6,06E-12	3,47E-08	2,16E-07	2,51E-07
Cf-248	7,36E-12	2,12E-06	1,32E-05	1,53E-05
Cf-249	8,36E-07	1,64E-05	1,06E-04	1,24E-04
Cf-250	1,65E-11	7,87E-06	4,90E-05	5,68E-05
Cf-251	1,44E-07	1,68E-05	1,05E-04	1,22E-04
Cf-252	1,17E-11	4,53E-06	2,82E-05	3,27E-05
Cf-254	2,77E-15	7,64E-06	4,75E-05	5,52E-05
Es-254	3,24E-09	2,08E-06	1,30E-05	1,51E-05

Appendix C

TABLE 3.2 COLLECTIVE DOSES FOR COPPER RECYCLING (OCCUPATIONAL) (manSv)

NUCLIDE	SCRAP HEAP (3.2.1)	SMELTING (3.3)	TREATMENT OF BY-PRODUCTS (3.4)	PURIFICATION TREATMENT (3.5)	MANUFACTURING (3.6)	TOTAL
H3	0,00E+01	8,07E-09	3,11E-10	0,00E+01	0,00E+01	8,38E-09
C14	0,00E+01	2,60E-07	1,00E-08	0,00E+01	0,00E+01	2,70E-07
Mn54	2,80E-06	2,00E-07	4,45E-06	7,75E-08	2,59E-10	7,53E-06
Fe55	5,66E-12	1,50E-08	8,04E-10	1,57E-13	1,99E-10	1,66E-08
Co60	9,31E-06	3,98E-06	1,49E-05	1,29E-06	1,85E-08	2,95E-05
Ni59	8,66E-12	1,41E-08	7,94E-10	1,20E-12	2,44E-10	1,52E-08
Ni63	0,00E+01	3,34E-08	1,84E-09	0,00E+01	5,75E-10	3,58E-08
Zn65	2,08E-06	8,64E-07	3,34E-06	5,77E-08	6,05E-10	6,34E-06
Sr90+	2,51E-07	5,94E-06	4,57E-07	4,33E-07	2,79E-06	9,87E-06
Nb94	1,04E-05	7,94E-05	1,74E-05	2,88E-05	1,08E-06	1,37E-04
Tc99	3,57E-10	1,26E-09	5,17E-10	8,16E-11	7,28E-09	9,49E-09
Ru106+	9,60E-07	1,10E-05	7,34E-07	2,27E-07	7,56E-08	1,30E-05
Ag108m+	9,19E-06	5,93E-05	1,47E-05	2,54E-05	7,79E-07	1,09E-04
Ag110m+	9,28E-06	5,91E-05	1,47E-05	2,57E-05	1,58E-07	1,09E-04
Sb125+	1,19E-06	7,88E-06	3,57E-07	3,04E-06	8,92E-08	1,26E-05
Cs134	4,96E-06	9,23E-06	8,05E-06	1,37E-06	2,08E-08	2,36E-05
Cs137+	1,84E-06	5,53E-06	3,03E-06	5,06E-07	1,51E-08	1,09E-05
Pm147	7,10E-11	9,57E-10	1,60E-10	1,76E-13	7,56E-11	1,26E-09
Sm151	4,15E-14	6,93E-10	4,50E-11	1,15E-16	5,62E-11	7,94E-10
Eu152	4,35E-06	1,38E-05	6,93E-06	6,02E-06	3,43E-07	3,14E-05
Eu154	4,63E-06	1,47E-05	7,37E-06	6,42E-06	4,25E-07	3,36E-05
U234	5,41E-11	3,54E-06	2,35E-07	1,17E-10	2,94E-04	2,98E-04
U235+	2,89E-07	5,01E-06	6,72E-07	7,99E-07	2,64E-04	2,70E-04
U238+	2,51E-07	4,96E-06	5,15E-07	5,80E-07	2,47E-04	2,53E-04
Np237+	3,36E-07	1,00E-05	8,41E-07	5,92E-07	6,48E-04	6,60E-04
Pu238	7,83E-12	1,45E-05	9,63E-07	2,01E-11	1,20E-03	1,22E-03
Pu239	5,89E-11	1,67E-05	1,11E-06	3,20E-10	1,38E-03	1,40E-03
Pu240	8,93E-12	1,67E-05	1,10E-06	2,29E-11	1,38E-03	1,40E-03
Pu241	7,58E-13	2,19E-07	1,45E-08	1,72E-12	1,81E-05	1,84E-05
Am241	3,44E-09	1,39E-05	9,24E-07	9,48E-09	1,15E-03	1,16E-03
Cm244	2,99E-12	6,72E-06	4,46E-07	8,32E-12	5,57E-04	5,64E-04
Na-22	7,33E-06	5,78E-06	1,18E-05	2,06E-06	4,34E-09	2,70E-05
S-35	2,22E-11	4,31E-08	1,93E-09	5,90E-15	2,38E-10	4,53E-08
Cl-36	7,77E-09	1,51E-06	8,87E-08	1,52E-12	1,11E-09	1,60E-06
K-40	6,18E-07	2,44E-06	1,03E-06	1,71E-07	6,82E-09	4,27E-06
Ca-45	0,00E+01	7,40E-08	3,97E-09	1,65E-19	4,97E-09	8,29E-08
Sc-46	7,08E-06	4,53E-05	1,14E-05	2,00E-05	1,04E-07	8,38E-05
Mn-53	0,00E+01	7,54E-10	3,13E-11	0,00E+01	7,82E-12	7,93E-10
Co-56	1,31E-05	4,51E-06	2,05E-05	1,80E-06	5,29E-09	4,00E-05
Co-57	9,98E-08	7,08E-08	1,66E-07	1,43E-08	6,48E-10	3,51E-07
Co-58	3,17E-06	1,13E-06	5,18E-06	4,51E-07	1,84E-09	9,93E-06
As-73	9,10E-10	4,94E-08	2,51E-09	2,33E-09	1,40E-08	6,92E-08
Se-75	6,74E-07	4,30E-06	1,12E-07	1,94E-06	3,67E-08	7,07E-06
Se-79	5,52E-11	2,74E-08	1,07E-09	1,46E-10	1,34E-07	1,63E-07
Sr-85	1,44E-06	9,19E-06	2,37E-06	4,13E-06	1,21E-08	1,71E-05
Y-91	6,93E-08	6,51E-07	8,47E-08	1,35E-07	1,32E-07	1,07E-06
Zr-93	8,36E-13	1,51E-05	1,00E-06	2,38E-12	1,25E-06	1,74E-05
Zr-95+	4,87E-06	3,27E-05	8,04E-06	1,39E-05	1,19E-07	5,96E-05
Nb-93m	2,35E-11	3,57E-07	2,17E-08	1,48E-10	2,70E-08	4,05E-07
Mo-93	9,54E-11	9,00E-08	2,90E-09	6,00E-11	3,18E-09	9,62E-08
Tc-97	1,66E-10	1,59E-10	4,87E-10	8,23E-11	3,64E-10	1,26E-09
Tc-97m	3,46E-10	1,04E-09	7,56E-10	1,22E-10	5,83E-09	8,10E-09

Appendix C

TABLE 3.2 (cont.)						
Pd-107	5,24E-14	1,69E-08	1,03E-09	4,04E-16	3,21E-10	1,82E-08
Cd-109	9,87E-10	1,43E-06	8,45E-08	2,72E-11	2,07E-09	1,52E-06
Sn-113+	6,41E-07	1,05E-06	1,39E-07	1,84E-07	4,17E-09	2,02E-06
Sn-126+	6,29E-06	1,01E-05	1,36E-06	1,79E-06	4,20E-08	1,95E-05
Sb-124	6,52E-06	4,19E-05	2,09E-06	1,82E-05	1,02E-07	6,87E-05
Te-123m	1,56E-07	1,00E-06	2,63E-08	4,47E-07	7,34E-08	1,71E-06
Te-127m+	4,88E-10	2,43E-08	1,11E-09	1,08E-09	1,38E-07	1,65E-07
I-125	4,97E-09	4,73E-06	1,27E-07	1,05E-10	1,58E-09	4,86E-06
I-129	3,04E-09	3,42E-05	8,86E-07	6,21E-11	1,11E-08	3,51E-05
Cs-135	7,72E-11	6,68E-07	1,81E-08	1,94E-12	2,25E-09	6,88E-07
Ce-139	1,65E-07	1,05E-06	2,71E-07	4,73E-07	3,02E-08	1,99E-06
Ce-144+	1,27E-07	8,16E-07	2,01E-07	3,52E-07	6,27E-07	2,12E-06
Sm-147	0,00E+01	1,60E-06	1,06E-07	0,00E+01	1,32E-07	1,84E-06
Eu-155	2,77E-08	8,98E-08	4,44E-08	3,86E-08	5,41E-08	2,55E-07
Gd-153	3,80E-08	1,22E-07	5,89E-08	5,14E-08	2,70E-08	2,97E-07
Tb-160	3,59E-06	2,28E-05	5,77E-06	1,01E-05	1,17E-07	4,24E-05
Tm-170	1,25E-08	2,19E-08	1,30E-08	5,94E-09	5,62E-08	1,10E-07
Tm-171	1,21E-10	6,46E-10	1,94E-10	1,57E-10	9,89E-09	1,10E-08
Ta-182	4,36E-06	2,99E-05	7,09E-06	1,22E-05	1,60E-07	5,38E-05
W-181	7,74E-09	7,52E-09	1,17E-08	2,04E-09	9,29E-11	2,91E-08
W-185	9,16E-10	1,41E-08	1,46E-09	1,95E-11	4,75E-10	1,69E-08
Os-185	2,08E-06	1,78E-06	3,64E-07	5,92E-07	3,02E-09	4,82E-06
Ir-192	1,99E-06	9,38E-07	3,29E-06	2,85E-07	5,29E-09	6,50E-06
Tl-204	6,42E-09	4,14E-08	7,80E-09	1,24E-10	1,35E-09	5,71E-08
Pb-210+	5,04E-10	4,46E-04	2,08E-05	1,00E-11	2,60E-06	4,69E-04
Bi-207	8,37E-06	5,37E-05	2,72E-06	2,36E-05	1,16E-07	8,85E-05
Po-210	2,84E-11	6,16E-06	3,80E-07	8,04E-11	4,75E-05	5,41E-05
Ra-226+	1,18E-05	2,01E-04	2,65E-05	3,30E-05	9,57E-05	3,68E-04
Ra-228+	3,60E-06	9,05E-05	9,32E-06	1,02E-05	4,39E-05	1,58E-04
Ac-227+	1,20E-06	2,62E-02	1,75E-03	3,46E-06	2,18E-02	4,98E-02
Th-228+	5,33E-06	4,30E-05	8,85E-06	1,45E-05	7,55E-04	8,26E-04
Th-229+	1,29E-06	5,01E-05	4,88E-06	3,68E-06	3,47E-03	3,53E-03
Th-230	4,16E-10	1,46E-05	9,68E-07	1,18E-09	1,21E-03	1,23E-03
Th-232	1,31E-10	1,52E-05	1,01E-06	3,70E-10	1,26E-03	1,28E-03
Pa-231	1,13E-07	4,71E-05	3,26E-06	3,27E-07	3,84E-03	3,89E-03
U-232	2,28E-10	1,25E-05	8,23E-07	6,65E-10	1,03E-03	1,04E-03
U-233	2,95E-10	3,60E-06	2,39E-07	8,47E-10	2,98E-04	3,02E-04
U-236	4,00E-11	3,28E-06	2,18E-07	1,29E-10	2,72E-04	2,76E-04
Pu-236	1,17E-11	3,54E-06	2,35E-07	5,51E-11	2,94E-04	2,97E-04
Pu-242	9,90E-12	1,62E-05	1,07E-06	5,83E-11	1,34E-03	1,36E-03
Pu-244+	2,05E-06	2,87E-05	4,38E-06	5,83E-06	1,30E-03	1,34E-03
Am-242m+	3,53E-10	1,20E-05	7,95E-07	9,13E-10	9,93E-04	1,01E-03
Am-243+	4,58E-07	1,70E-05	1,69E-06	1,32E-06	1,17E-03	1,19E-03
Cm-242	6,18E-12	9,61E-07	6,40E-08	4,84E-11	7,99E-05	8,09E-05
Cm-243	2,77E-07	1,03E-05	1,03E-06	7,96E-07	7,11E-04	7,23E-04
Cm-245	1,03E-07	1,47E-05	1,10E-06	2,94E-07	1,17E-03	1,18E-03
Cm-246	6,56E-12	1,41E-05	9,32E-07	6,73E-11	1,16E-03	1,18E-03
Cm-247+	1,59E-06	2,31E-05	3,48E-06	4,58E-06	1,08E-03	1,11E-03
Cm-248	7,34E-12	4,95E-05	3,28E-06	5,96E-11	4,10E-03	4,16E-03
Bk-249	5,06E-12	2,61E-08	1,74E-09	1,39E-11	2,16E-06	2,19E-06
Cf-248	3,49E-12	1,59E-06	1,05E-07	3,85E-11	1,32E-04	1,33E-04
Cf-249	1,52E-06	3,27E-05	4,05E-06	4,36E-06	1,91E-03	1,95E-03
Cf-250	1,47E-11	8,13E-06	5,39E-07	8,15E-11	6,74E-04	6,82E-04
Cf-251	2,43E-07	2,54E-05	1,98E-06	6,99E-07	1,97E-03	2,00E-03
Cf-252	7,33E-12	3,51E-06	2,33E-07	4,80E-11	2,91E-04	2,95E-04
Cf-254	3,32E-15	5,78E-06	3,80E-07	7,67E-15	4,75E-04	4,81E-04
Es-254	3,03E-09	1,58E-06	1,09E-07	9,05E-09	1,30E-04	1,31E-04

Appendix C

TABLE 3.3 COLLECTIVE DOSE FROM ALUMINIUM RECYCLING (OCCUPATIONAL) (manSv)

NUCLIDE	SCRAP HEAP (3.2.1)	SMELTING (3.3)	TREATMENT OF BY-PRODUCTS (3.4)	MANUFACTURING (3.6)	OFFICE CEILING (3.9.1.c)	TOTAL
H3	0,00E+01	2,82E-08	0,00E+01	0,00E+01	0,00E+01	2,82E-08
C14	0,00E+01	9,10E-07	0,00E+01	0,00E+01	0,00E+01	9,10E-07
Mn54	3,10E-06	1,96E-05	1,89E-05	2,59E-09	9,18E-05	1,33E-04
Fe55	5,61E-12	6,54E-09	2,16E-10	2,06E-09	7,64E-09	1,65E-08
Co60	1,12E-05	7,12E-05	3,42E-05	4,24E-08	2,62E-04	3,79E-04
Ni59	1,49E-11	3,04E-09	1,74E-10	9,50E-10	2,12E-08	2,53E-08
Ni63	0,00E+01	6,50E-09	1,85E-10	2,10E-09	0,00E+01	8,79E-09
Zn65	2,22E-06	1,41E-05	3,38E-06	6,05E-09	6,14E-05	8,11E-05
Sr90+	4,67E-08	1,80E-05	1,47E-06	2,79E-07	1,31E-05	3,29E-05
Nb94	1,16E-05	1,37E-04	3,54E-04	1,08E-07	3,47E-04	8,50E-04
Tc99	2,64E-10	4,63E-09	1,08E-08	7,28E-10	1,11E-08	2,75E-08
Ru106+	7,80E-07	4,63E-05	2,37E-06	7,56E-09	4,37E-06	5,38E-05
Ag108m+	1,09E-05	6,95E-05	1,66E-05	7,79E-08	3,21E-04	4,18E-04
Ag110m+	1,02E-05	6,49E-05	1,56E-05	1,58E-08	2,96E-04	3,87E-04
Sb125+	1,10E-06	7,12E-06	3,08E-05	8,92E-09	5,38E-05	9,28E-05
Cs134	5,69E-06	1,85E-05	1,72E-04	2,07E-10	1,73E-06	1,98E-04
Cs137+	2,04E-06	1,27E-05	6,21E-05	1,45E-10	6,36E-07	7,76E-05
Pm147	8,31E-11	4,44E-09	5,71E-09	7,56E-12	3,91E-11	1,03E-08
Sm151	4,35E-13	3,27E-09	2,49E-09	5,62E-12	5,19E-13	5,76E-09
Eu152	4,86E-06	1,55E-05	1,48E-04	3,43E-08	6,49E-05	2,33E-04
Eu154	5,10E-06	1,63E-05	1,55E-04	4,25E-08	6,73E-05	2,44E-04
U234	5,18E-10	1,13E-04	8,62E-05	9,79E-05	9,18E-09	2,97E-04
U235+	5,38E-06	1,19E-04	2,42E-04	8,78E-05	1,19E-05	4,66E-04
U238+	7,91E-07	9,74E-05	9,49E-05	8,22E-05	6,42E-06	2,82E-04
Np237+	9,85E-08	2,53E-05	2,18E-05	2,16E-05	1,68E-05	8,56E-05
Pu238	2,86E-11	4,86E-05	3,71E-05	4,21E-05	1,32E-08	1,28E-04
Pu239	3,01E-11	5,32E-05	4,05E-05	4,61E-05	8,60E-09	1,40E-04
Pu240	4,94E-11	5,32E-05	4,05E-05	4,61E-05	1,38E-08	1,40E-04
Pu241	6,15E-13	8,55E-07	6,52E-07	7,41E-07	9,30E-11	2,25E-06
Am241	1,02E-08	4,47E-05	3,43E-05	3,87E-05	1,86E-06	1,20E-04
Cm244	2,36E-11	2,55E-05	1,95E-05	2,21E-05	1,13E-08	6,72E-05
Na-22	8,19E-06	5,60E-06	2,54E-04	4,34E-10	2,36E-05	2,91E-04
S-35	3,94E-11	1,62E-07	2,17E-09	2,38E-10	2,08E-10	1,64E-07
Cl-36	2,88E-09	7,00E-07	8,90E-08	1,16E-09	8,69E-09	8,02E-07
K-40	6,39E-07	1,01E-06	1,95E-05	6,82E-10	1,65E-06	2,28E-05
Ca-45	2,33E-17	3,11E-07	2,19E-09	4,97E-10	1,97E-15	3,13E-07
Sc-46	7,58E-06	4,92E-05	2,34E-04	1,04E-08	2,16E-04	5,07E-04
Mn-53	0,00E+01	5,45E-10	1,37E-11	1,56E-10	0,00E+01	7,14E-10
Co-56	1,36E-05	8,67E-05	4,13E-05	1,06E-08	3,55E-04	4,96E-04
Co-57	2,60E-07	1,67E-06	8,25E-07	1,30E-09	1,29E-05	1,57E-05
Co-58	3,65E-06	2,33E-05	1,14E-05	3,67E-09	1,08E-04	1,47E-04
As-73	6,80E-09	4,57E-08	2,18E-07	1,40E-09	7,31E-07	1,00E-06
Se-75	1,06E-06	9,82E-07	3,37E-05	3,67E-10	4,26E-06	4,00E-05
Se-79	5,18E-11	5,05E-07	4,59E-09	7,05E-10	2,71E-10	5,11E-07
Sr-85	1,80E-06	1,17E-05	5,68E-05	1,21E-09	5,83E-05	1,29E-04
Y-91	2,57E-08	1,00E-06	7,69E-07	1,32E-08	4,40E-06	6,21E-06
Zr-93	3,08E-12	7,23E-05	5,52E-08	1,25E-07	3,05E-09	7,25E-05
Zr-95+	5,64E-06	4,35E-05	1,76E-04	1,19E-08	1,67E-04	3,92E-04
Nb-93m	2,55E-10	1,61E-06	1,08E-08	2,70E-09	2,16E-07	1,84E-06
Mo-93	1,04E-09	2,73E-07	4,05E-08	3,18E-10	1,12E-07	4,27E-07
Tc-97	1,33E-09	1,13E-09	4,87E-08	3,64E-11	1,37E-07	1,88E-07
Tc-97m	1,79E-09	4,76E-09	6,42E-08	5,83E-10	1,20E-07	1,92E-07

Appendix C

TABLE 3.3 (cont.)						
Pd-107	2,58E-13	3,73E-09	1,11E-10	1,25E-09	3,75E-10	5,47E-09
Cd-109	3,93E-09	8,92E-08	7,18E-09	2,08E-08	3,16E-06	3,28E-06
Sn-113+	8,55E-07	3,20E-06	2,71E-05	4,17E-10	3,49E-06	3,46E-05
Sn-126+	7,62E-06	3,08E-05	2,39E-04	4,20E-09	2,39E-05	3,01E-04
Sb-124	7,10E-06	4,53E-05	2,17E-04	1,02E-08	1,94E-04	4,64E-04
Te-123m	3,20E-07	6,74E-07	1,02E-05	7,34E-10	1,73E-06	1,29E-05
Te-127m+	2,03E-09	8,73E-07	6,65E-08	1,38E-09	1,47E-08	9,58E-07
I-125	2,13E-08	1,41E-06	7,07E-07	1,58E-09	9,16E-07	3,05E-06
I-129	1,59E-08	1,04E-05	5,69E-07	1,16E-08	4,91E-07	1,15E-05
Cs-135	9,13E-11	1,89E-06	3,57E-09	2,15E-11	4,33E-12	1,89E-06
Ce-139	3,35E-07	1,08E-06	1,06E-05	1,51E-09	9,14E-06	2,12E-05
Ce-144+	1,56E-07	1,03E-06	4,82E-06	6,27E-08	5,36E-06	1,14E-05
Sm-147	0,00E+01	7,64E-06	5,82E-06	1,32E-08	0,00E+01	1,35E-05
Eu-155	1,12E-07	3,67E-07	3,56E-06	5,41E-09	3,57E-06	7,62E-06
Gd-153	1,64E-07	5,34E-07	5,25E-06	2,70E-09	7,48E-06	1,34E-05
Tb-160	3,95E-06	1,26E-05	1,22E-04	5,83E-09	5,83E-05	1,97E-04
Tm-170	4,92E-09	1,49E-08	1,46E-07	5,62E-09	4,37E-07	6,08E-07
Tm-171	8,56E-10	3,94E-09	2,81E-08	9,89E-10	4,15E-08	7,54E-08
Ta-182	4,71E-06	3,98E-05	1,45E-04	1,60E-08	1,37E-04	3,26E-04
W-181	5,25E-08	4,18E-08	1,68E-06	9,29E-12	4,72E-07	2,24E-06
W-185	5,47E-10	4,17E-08	1,61E-08	4,75E-11	1,89E-09	6,02E-08
Os-185	2,51E-06	3,52E-06	7,86E-06	3,02E-10	7,95E-06	2,18E-05
Ir-192	2,65E-06	1,70E-05	8,35E-06	1,06E-08	9,18E-05	1,20E-04
Tl-204	3,46E-09	1,52E-07	1,08E-09	1,46E-09	8,11E-07	9,69E-07
Pb-210+	1,14E-09	1,73E-03	1,18E-06	2,60E-07	3,39E-09	1,73E-03
Bi-207	9,41E-06	6,03E-05	2,92E-04	1,16E-08	2,27E-04	5,89E-04
Po-210	3,22E-11	2,81E-04	2,09E-06	4,75E-07	9,43E-11	2,84E-04
Ra-226+	1,30E-05	6,52E-04	4,02E-04	9,57E-06	3,61E-04	1,44E-03
Ra-228+	4,00E-06	3,04E-04	1,26E-04	4,39E-06	1,01E-04	5,39E-04
Ac-227+	1,78E-06	1,26E-01	1,02E-03	2,18E-03	5,46E-05	1,29E-01
Th-228+	5,63E-06	6,10E-05	2,02E-04	3,75E-05	7,41E-05	3,80E-04
Th-229+	1,25E-06	1,37E-04	1,41E-04	1,16E-04	2,47E-05	4,20E-04
Th-230	9,72E-10	4,65E-05	3,55E-05	4,03E-05	5,71E-08	1,22E-04
Th-232	4,26E-10	4,86E-05	3,70E-05	4,21E-05	4,17E-08	1,28E-04
Pa-231	1,14E-07	1,48E-04	1,16E-04	1,28E-04	2,74E-06	3,96E-04
U-232	6,13E-10	4,20E-05	3,20E-05	3,63E-05	6,56E-08	1,10E-04
U-233	6,15E-10	1,15E-05	8,76E-06	9,94E-06	3,25E-08	3,02E-05
U-236	2,57E-10	1,05E-05	7,99E-06	9,07E-06	5,11E-08	2,76E-05
Pu-236	1,83E-10	1,66E-05	1,26E-05	1,44E-05	5,79E-08	4,36E-05
Pu-242	1,44E-10	5,15E-05	3,93E-05	4,46E-05	5,33E-08	1,36E-04
Pu-244+	1,61E-06	5,50E-05	8,82E-05	4,32E-05	2,49E-05	2,13E-04
Am-242m+	1,06E-09	3,93E-05	3,00E-05	3,41E-05	8,95E-08	1,04E-04
Am-243+	6,54E-07	4,70E-05	5,49E-05	3,89E-05	1,67E-05	1,58E-04
Cm-242	1,41E-10	4,61E-06	3,52E-06	4,00E-06	6,11E-08	1,22E-05
Cm-243	3,84E-07	3,22E-05	3,58E-05	2,69E-05	8,04E-06	1,03E-04
Cm-245	1,90E-07	4,55E-05	4,03E-05	3,89E-05	5,27E-06	1,30E-04
Cm-246	1,36E-10	4,49E-05	3,42E-05	3,89E-05	6,46E-08	1,18E-04
Cm-247+	1,44E-06	4,62E-05	7,71E-05	3,60E-05	2,56E-05	1,86E-04
Cm-248	1,18E-10	1,58E-04	1,20E-04	1,37E-04	5,14E-08	4,15E-04
Bk-249	1,31E-11	1,25E-07	9,54E-08	1,08E-07	2,04E-09	3,30E-07
Cf-248	9,28E-11	7,60E-06	5,80E-06	6,59E-06	4,87E-08	2,00E-05
Cf-249	1,39E-06	7,88E-05	1,01E-04	6,44E-05	2,43E-05	2,69E-04
Cf-250	1,48E-10	3,22E-05	2,45E-05	2,79E-05	5,15E-08	8,46E-05
Cf-251	3,48E-07	7,74E-05	6,92E-05	6,61E-05	8,53E-06	2,22E-04
Cf-252	1,10E-10	1,65E-05	1,26E-05	1,43E-05	4,54E-08	4,34E-05
Cf-254	2,37E-14	2,75E-05	2,09E-05	2,38E-05	1,83E-12	7,22E-05
Es-254	7,14E-09	7,50E-06	5,94E-06	6,48E-06	8,01E-07	2,07E-05

Appendix C

TABLE 3.4 COLLECTIVE DOSES FROM STEEL RECYCLING (PUBLIC) (manSv)

NUCLIDE	RADIATOR (3.5.2.2) EXTERNAL (ARC)	BUILDING (3.5.2.1) EXTERNAL (ARC)	RESIDENCE ON A LANDFILL (3.6.1.4) (ARC+INDUC. SLAG)	TOTAL
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	2,56E-03	1,31E-02	5,67E-09	1,56E-02
Fe55	1,58E-07	0,00E+01	4,77E-12	1,58E-07
Co60	4,42E-02	2,69E-01	9,52E-06	3,14E-01
Ni59	1,16E-06	0,00E+01	9,65E-09	1,17E-06
Ni63	0,00E+01	0,00E+01	1,52E-08	1,52E-08
Zn65	1,34E-04	7,69E-04	4,48E-10	9,03E-04
Sr90+	8,41E-04	5,44E-03	2,45E-03	8,73E-03
Nb94	1,24E-02	2,06E-01	2,85E-02	2,47E-01
Tc99	4,93E-06	1,90E-05	4,87E-03	4,89E-03
Ru106+	2,03E-04	8,95E-04	6,41E-09	1,10E-03
Ag108m+	2,00E-01	1,99E-00	2,28E-04	2,19E-00
Ag110m+	6,62E-03	3,47E-02	1,99E-10	4,13E-02
Sb125+	4,26E-03	1,73E-02	2,25E-08	2,16E-02
Cs134	1,14E-05	5,41E-05	2,56E-06	6,80E-05
Cs137+	3,09E-05	2,57E-04	3,10E-04	5,98E-04
Pm147	1,46E-09	1,18E-09	3,37E-09	6,01E-09
Sm151	8,43E-12	7,10E-26	2,08E-07	2,08E-07
Eu152	4,08E-05	2,74E-04	2,89E-03	3,21E-03
Eu154	3,31E-05	1,96E-04	1,22E-03	1,45E-03
U234	4,11E-07	1,59E-06	1,12E-04	1,14E-04
U235+	1,10E-03	7,80E-03	1,71E-03	1,06E-02
U238+	1,04E-03	1,30E-02	5,65E-04	1,46E-02
Np237+	1,58E-03	1,49E-02	3,36E-03	1,99E-02
Pu238	7,65E-08	9,77E-08	2,64E-04	2,64E-04
Pu239	3,06E-07	2,59E-06	4,51E-04	4,54E-04
Pu240	9,09E-08	1,59E-07	4,49E-04	4,49E-04
Pu241	4,13E-09	7,23E-09	1,11E-06	1,12E-06
Am241	4,17E-05	3,16E-05	3,86E-04	4,59E-04
Cm244	2,74E-08	1,15E-10	3,75E-05	3,76E-05
Na-22	1,99E-05	1,04E-04	1,08E-05	1,34E-04
S-35	4,78E-12	2,40E-12	7,01E-19	7,17E-12
Cl-36	7,04E-08	4,47E-07	7,07E-03	7,07E-03
K-40	1,06E-05	2,27E-04	1,26E-03	1,50E-03
Ca-45	7,02E-16	3,69E-21	7,45E-14	7,53E-14
Sc-46	1,62E-04	8,98E-04	1,05E-17	1,06E-03
Mn-53	0,00E+01	0,00E+01	4,56E-07	4,56E-07
Co-56	2,50E-03	1,58E-02	2,57E-20	1,83E-02
Co-57	2,84E-04	4,95E-04	5,86E-12	7,79E-04
Co-58	6,83E-04	3,36E-03	1,47E-22	4,04E-03
As-73	1,70E-06	2,90E-07	3,96E-25	1,99E-06
Se-75	4,39E-05	1,20E-04	2,44E-14	1,64E-04
Se-79	5,46E-08	7,61E-08	4,41E-03	4,41E-03
Sr-85	3,33E-05	1,37E-04	2,51E-22	1,70E-04
Y-91	3,61E-07	1,05E-06	5,01E-26	1,41E-06
Zr-93	1,63E-07	7,75E-10	3,55E-09	1,68E-07
Zr-95+	9,48E-04	4,65E-03	4,20E-24	5,60E-03
Nb-93m	1,51E-07	1,27E-11	2,50E-07	4,01E-07
Mo-93	3,12E-05	6,65E-09	2,12E-04	2,44E-04
Tc-97	2,11E-06	6,20E-10	5,18E-04	5,20E-04
Tc-97m	4,45E-08	2,85E-08	6,82E-18	7,30E-08

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TABLE 3.4 (cont.)				
Pd-107	2,09E-08	2,98E-17	1,13E-08	3,22E-08
Cd-109	3,80E-07	0,00E+01	9,53E-09	3,90E-07
Sn-113+	2,99E-05	1,06E-04	4,53E-16	1,36E-04
Sn-126+	1,59E-02	2,35E-01	3,28E-03	2,55E-01
Sb-124	1,04E-03	5,96E-03	4,82E-26	7,00E-03
Te-123m	1,46E-05	3,03E-05	2,96E-15	4,49E-05
Te-127m+	9,85E-09	9,82E-09	2,87E-17	1,97E-08
I-125	2,72E-08	2,03E-11	6,42E-25	2,72E-08
I-129	2,50E-06	1,76E-08	3,36E-03	3,37E-03
Cs-135	1,23E-11	2,64E-11	1,78E-06	1,78E-06
Ce-139	1,71E-05	3,59E-05	5,51E-14	5,30E-05
Ce-144+	1,20E-05	5,64E-05	1,45E-09	6,84E-05
Sm-147	0,00E+01	0,00E+01	1,88E-04	1,88E-04
Eu-155	7,50E-07	8,67E-07	2,96E-06	4,58E-06
Gd-153	1,44E-05	1,45E-05	6,27E-11	2,89E-05
Tb-160	7,44E-05	3,90E-04	3,48E-20	4,64E-04
Tm-170	2,03E-07	3,88E-07	2,91E-16	5,90E-07
Tm-171	1,95E-07	5,11E-08	9,10E-10	2,47E-07
Ta-182	1,37E-04	7,56E-04	2,78E-14	8,92E-04
W-181	2,20E-05	7,22E-06	1,88E-16	2,92E-05
W-185	1,07E-06	1,39E-06	9,90E-23	2,46E-06
Os-185	6,39E-05	2,88E-04	7,29E-18	3,52E-04
Ir-192	5,98E-04	2,13E-03	4,75E-22	2,72E-03
Tl-204	1,11E-06	2,04E-06	4,80E-06	7,95E-06
Pb-210+	3,61E-07	8,14E-07	2,39E-04	2,40E-04
Bi-207	1,13E-01	8,50E-01	9,33E-06	9,63E-01
Po-210	1,16E-09	5,87E-09	3,07E-14	7,03E-09
Ra-226+	1,29E-02	2,34E-01	3,58E-02	2,83E-01
Ra-228+	1,81E-03	9,69E-03	6,75E-04	1,22E-02
Ac-227+	1,84E-03	8,58E-03	1,82E-03	1,22E-02
Th-228+	9,13E-04	5,69E-03	2,11E-05	6,62E-03
Th-229+	2,33E-03	2,57E-02	4,96E-03	3,30E-02
Th-230	2,14E-06	8,32E-06	5,26E-04	5,37E-04
Th-232	8,70E-07	2,54E-06	5,82E-04	5,85E-04
Pa-231	2,25E-04	2,19E-03	4,40E-02	4,64E-02
U-232	1,10E-06	3,15E-06	3,86E-04	3,90E-04
U-233	1,47E-06	7,54E-06	1,16E-04	1,25E-04
U-236	4,85E-07	6,87E-07	1,06E-04	1,07E-04
Pu-236	4,91E-08	9,07E-09	5,46E-07	6,04E-07
Pu-242	2,08E-07	6,69E-08	4,15E-04	4,16E-04
Pu-244+	2,59E-03	4,05E-02	5,99E-03	4,91E-02
Am-242m+	2,37E-07	8,32E-07	3,51E-04	3,52E-04
Am-243+	1,46E-03	9,53E-03	1,69E-03	1,27E-02
Cm-242	5,51E-09	5,38E-10	2,66E-14	6,05E-09
Cm-243	6,22E-04	2,48E-03	3,61E-04	3,47E-03
Cm-245	4,63E-04	2,50E-03	6,93E-04	3,66E-03
Cm-246	1,75E-07	3,97E-09	3,68E-04	3,68E-04
Cm-247+	2,66E-03	3,06E-02	4,67E-03	3,79E-02
Cm-248	1,65E-07	3,83E-08	1,36E-03	1,36E-03
Bk-249	4,23E-10	9,11E-11	2,37E-11	5,38E-10
Cf-248	6,65E-09	1,68E-11	1,08E-09	7,75E-09
Cf-249	2,51E-03	2,68E-02	5,43E-03	3,47E-02
Cf-250	1,34E-07	6,45E-08	9,56E-05	9,58E-05
Cf-251	7,91E-04	5,16E-03	2,53E-03	8,48E-03
Cf-252	2,69E-08	6,00E-09	1,35E-06	1,38E-06
Cf-254	3,69E-13	9,88E-15	3,55E-24	3,79E-13
Es-254	6,43E-07	1,16E-06	1,99E-10	1,80E-06

Appendix C

TABLE 3.5: COLLECTIVE DOSES FROM COPPER RECYCLING (PUBLIC) (manSv)

NUCLIDE	RESIDENCE ON A LANDFILL (3.7.2)	KITCHEN FITTING (3.9.2.a) EXTERNAL	TOTAL
H3	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01
Mn54	1,10E-14	2,97E-06	2,97E-06
Fe55	5,77E-12	3,43E-10	3,49E-10
Co60	1,46E-04	2,54E-04	4,00E-04
Ni59	2,05E-06	2,04E-08	2,07E-06
Ni63	2,81E-06	0,00E+01	2,81E-06
Zn65	9,19E-18	1,56E-06	1,56E-06
Sr90+	3,19E-03	1,44E-03	4,63E-03
Nb94	6,06E-02	2,74E-02	8,79E-02
Tc99	1,04E-02	8,13E-07	1,04E-02
Ru106+	1,71E-14	2,56E-05	2,56E-05
Ag108m+	4,36E-02	2,29E-02	6,65E-02
Ag110m+	6,70E-17	7,68E-04	7,68E-04
Sb125+	6,32E-08	4,93E-04	4,93E-04
Cs134	5,52E-08	1,32E-04	1,32E-04
Cs137+	4,16E-03	3,67E-04	4,53E-03
Pm147	3,62E-11	2,60E-10	2,96E-10
Sm151	3,80E-07	1,74E-12	3,80E-07
Eu152	2,21E-03	2,52E-03	4,73E-03
Eu154	5,18E-04	1,98E-03	2,50E-03
U234	2,39E-04	1,14E-06	2,40E-04
U235+	3,64E-03	2,54E-03	6,17E-03
U238+	1,20E-03	2,62E-03	3,82E-03
Np237+	7,15E-03	3,61E-03	1,08E-02
Pu238	4,80E-04	2,14E-07	4,80E-04
Pu239	9,60E-04	7,49E-07	9,61E-04
Pu240	9,54E-04	3,04E-07	9,54E-04
Pu241	8,99E-07	6,24E-09	9,06E-07
Am241	7,95E-04	1,42E-04	9,37E-04
Cm244	3,72E-05	6,58E-08	3,72E-05
Na-22	1,11E-06	2,31E-04	2,32E-04
S-35	1,24E-43	9,30E-13	9,30E-13
Cl-36	1,51E-03	1,00E-08	1,51E-03
K-40	2,69E-02	1,30E-04	2,70E-02
Ca-45	5,06E-27	1,55E-16	1,55E-16
Sc-46	1,51E-43	1,88E-04	1,88E-04
Mn-53	9,72E-06	0,00E+01	9,72E-06
Co-56	7,43E-46	1,45E-05	1,45E-05
Co-57	9,64E-18	1,73E-06	1,73E-06
Co-58	2,93E-51	3,96E-06	3,96E-06
As-73	7,35E-50	3,16E-07	3,16E-07
Se-75	2,32E-33	5,16E-05	5,16E-05
Se-79	9,38E-04	2,01E-06	9,40E-04
Sr-85	8,17E-56	3,86E-05	3,86E-05
Y-91	2,55E-63	4,82E-06	4,82E-06
Zr-93	7,56E-07	4,16E-08	7,98E-07
Zr-95+	3,60E-56	1,10E-04	1,10E-04
Nb-93m	2,06E-07	3,58E-07	5,64E-07
Mo-93	4,51E-04	3,47E-07	4,51E-04
Tc-97	1,10E-03	4,42E-07	1,10E-03
Tc-97m	3,11E-42	7,55E-09	7,55E-09

Appendix C

TABLE 3.5 (cont.)			
Pd-107	2,41E-06	7,44E-12	2,41E-06
Cd-109	3,70E-12	8,14E-09	8,14E-09
Sn-113+	7,51E-35	3,49E-06	3,49E-06
Sn-126+	6,99E-03	1,85E-03	8,84E-03
Sb-124	6,79E-60	1,21E-04	1,21E-04
Te-123m	2,80E-34	1,74E-05	1,74E-05
Te-127m+	4,52E-38	1,78E-07	1,78E-07
I-125	4,52E-62	5,65E-09	5,65E-09
I-129	7,16E-04	5,13E-07	7,17E-04
Cs-135	3,79E-05	2,34E-08	3,80E-05
Ce-139	1,27E-29	2,07E-05	2,07E-05
Ce-144+	5,78E-17	1,43E-05	1,43E-05
Sm-147	3,99E-04	0,00E+01	3,99E-04
Eu-155	3,86E-07	5,09E-05	5,13E-05
Gd-153	1,08E-19	1,05E-05	1,05E-05
Tb-160	2,95E-50	8,65E-05	8,65E-05
Tm-170	4,92E-33	7,20E-07	7,20E-07
Tm-171	1,42E-12	1,74E-07	1,74E-07
Ta-182	4,00E-33	1,60E-04	1,60E-04
W-181	2,61E-34	3,78E-07	3,78E-07
W-185	1,27E-51	1,65E-09	1,65E-09
Os-185	4,77E-41	7,50E-06	7,50E-06
Ir-192	2,26E-49	3,47E-06	3,47E-06
Tl-204	2,61E-07	1,59E-07	4,21E-07
Pb-210+	2,73E-04	5,81E-08	2,73E-04
Bi-207	2,62E-03	1,32E-02	1,58E-02
Po-210	8,59E-31	1,35E-09	1,35E-09
Ra-226+	7,57E-02	2,81E-02	1,04E-01
Ra-228+	1,29E-04	2,13E-03	2,26E-03
Ac-227+	2,05E-03	2,66E-03	4,71E-03
Th-228+	3,17E-08	1,06E-03	1,06E-03
Th-229+	1,06E-02	5,31E-03	1,59E-02
Th-230	1,12E-03	5,86E-06	1,13E-03
Th-232	1,24E-03	2,58E-06	1,24E-03
Pa-231	9,37E-02	5,06E-04	9,42E-02
U-232	6,77E-04	2,52E-06	6,80E-04
U-233	2,48E-04	3,53E-06	2,51E-04
U-236	2,26E-04	1,57E-06	2,27E-04
Pu-236	8,99E-09	9,34E-08	1,02E-07
Pu-242	8,85E-04	7,87E-07	8,86E-04
Pu-244+	1,28E-02	5,71E-03	1,85E-02
Am-242m+	6,83E-04	6,01E-06	6,89E-04
Am-243+	3,60E-03	3,47E-03	7,08E-03
Cm-242	1,94E-27	1,10E-08	1,10E-08
Cm-243	4,73E-04	9,63E-04	1,44E-03
Cm-245	1,47E-03	1,09E-03	2,56E-03
Cm-246	7,81E-04	6,94E-07	7,81E-04
Cm-247+	9,94E-03	5,91E-03	1,59E-02
Cm-248	2,90E-03	6,32E-07	2,90E-03
Bk-249	6,92E-18	8,90E-09	8,90E-09
Cf-248	5,97E-16	1,39E-08	1,39E-08
Cf-249	1,11E-02	5,25E-03	1,64E-02
Cf-250	7,07E-05	2,62E-07	7,09E-05
Cf-251	5,31E-03	1,78E-03	7,09E-03
Cf-252	1,51E-08	5,05E-08	6,55E-08
Cf-254	4,15E-60	7,40E-13	7,40E-13
Es-254	4,52E-18	9,07E-07	9,07E-07

Appendix C

TABLE 3.6 COLLECTIVE DOSES FROM ALUMINIUM RECYCLING (PUBLIC) (manSv)

NUCLIDE	RESIDENCE ON A LANDFILL (3.7.2)	CONCRETE PLATE (3.8.2) EXTERNAL	RADIATOR (3.9.2.b) EXTERNAL	CAR ENGINE (3.9.2.c) EXTERNAL	TOTAL
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	1,58E-15	1,77E-05	7,50E-05	4,75E-05	1,40E-04
Fe55	8,28E-13	1,60E-10	5,02E-09	3,56E-10	5,53E-09
Co60	1,05E-05	1,57E-04	1,29E-03	7,19E-04	2,18E-03
Ni59	2,95E-07	5,44E-09	1,08E-07	2,66E-09	4,11E-07
Ni63	4,03E-07	0,00E+01	0,00E+01	0,00E+01	4,03E-07
Zn65	3,30E-19	2,34E-06	3,92E-05	3,32E-05	7,47E-05
Sr90+	2,29E-03	4,15E-05	1,83E-04	1,02E-05	2,52E-03
Nb94	4,34E-02	1,35E-02	6,89E-03	1,45E-03	6,53E-02
Tc99	7,43E-03	9,44E-07	1,85E-07	6,19E-09	7,43E-03
Ru106+	1,23E-14	2,93E-06	4,27E-06	1,60E-06	8,79E-06
Ag108m+	1,56E-03	5,42E-04	5,90E-03	1,39E-03	9,39E-03
Ag110m+	2,40E-18	1,15E-05	1,94E-04	1,23E-04	3,29E-04
Sb125+	2,27E-07	2,26E-05	1,34E-04	1,36E-05	1,70E-04
Cs134	3,96E-08	3,90E-04	3,34E-06	2,03E-06	3,96E-04
Cs137+	2,99E-03	1,91E-03	9,12E-06	2,35E-06	4,91E-03
Pm147	2,60E-11	1,15E-08	7,34E-11	6,91E-12	1,16E-08
Sm151	2,72E-07	9,94E-10	2,81E-12	7,46E-14	2,73E-07
Eu152	1,58E-03	1,80E-03	6,53E-04	2,31E-04	4,27E-03
Eu154	3,71E-04	1,26E-03	5,03E-04	2,11E-04	2,34E-03
U234	1,71E-04	1,49E-07	1,80E-07	6,23E-09	1,72E-04
U235+	2,61E-03	1,14E-03	2,45E-04	4,01E-05	4,03E-03
U238+	8,63E-04	1,09E-04	1,27E-04	4,55E-06	1,10E-03
Np237+	5,13E-03	2,91E-04	3,39E-04	1,23E-05	5,77E-03
Pu238	3,44E-04	5,19E-08	8,69E-08	2,68E-09	3,45E-04
Pu239	6,89E-04	8,44E-08	1,05E-07	3,45E-09	6,89E-04
Pu240	6,84E-04	7,68E-08	1,06E-07	2,93E-09	6,84E-04
Pu241	6,45E-07	4,21E-10	1,01E-09	6,11E-11	6,47E-07
Am241	5,71E-04	2,67E-05	3,43E-05	1,18E-06	6,33E-04
Cm244	2,67E-05	1,66E-08	4,56E-08	1,80E-09	2,67E-05
Na-22	7,96E-07	7,05E-04	5,92E-05	3,54E-05	8,00E-04
S-35	8,90E-44	4,75E-10	3,19E-11	2,97E-12	5,10E-10
Cl-36	1,08E-02	9,63E-06	1,65E-07	6,43E-09	1,08E-02
K-40	1,93E-02	1,26E-03	3,27E-05	7,19E-06	2,06E-02
Ca-45	3,63E-27	6,08E-16	2,20E-16	2,18E-17	8,50E-16
Sc-46	1,08E-43	5,66E-05	4,75E-05	3,06E-05	1,35E-04
Mn-53	1,39E-06	0,00E+01	0,00E+01	0,00E+01	1,39E-06
Co-56	5,33E-47	8,74E-06	7,32E-05	4,76E-05	1,29E-04
Co-57	6,92E-19	8,18E-07	9,67E-06	4,37E-06	1,49E-05
Co-58	2,10E-52	2,42E-06	2,04E-05	1,30E-05	3,58E-05
As-73	2,64E-49	6,47E-08	1,58E-07	3,63E-08	2,59E-07
Se-75	1,66E-32	1,41E-05	1,39E-06	7,48E-07	1,62E-05
Se-79	6,73E-03	1,72E-07	3,64E-09	1,13E-10	6,73E-03
Sr-85	5,86E-56	1,18E-05	1,01E-05	6,26E-06	2,81E-05
Y-91	1,83E-63	1,69E-07	6,65E-07	1,03E-07	9,37E-07
Zr-93	5,43E-07	4,63E-09	2,24E-08	5,70E-10	5,70E-07
Zr-95+	2,58E-56	3,39E-05	2,82E-05	1,81E-05	8,02E-05
Nb-93m	1,48E-07	1,20E-07	7,00E-07	3,48E-08	1,00E-06
Mo-93	3,23E-04	3,19E-06	6,79E-07	1,77E-08	3,27E-04
Tc-97	7,91E-04	4,04E-06	8,87E-07	2,29E-08	7,96E-04
Tc-97m	2,23E-42	1,96E-08	1,03E-08	1,06E-09	3,10E-08

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TABLE 3.6 (cont.)					
Pd-107	3,45E-07	1,02E-11	1,95E-09	4,80E-11	3,48E-07
Cd-109	1,33E-13	1,13E-08	1,70E-06	1,24E-07	1,83E-06
Sn-113+	5,38E-34	1,03E-05	9,98E-07	5,51E-07	1,19E-05
Sn-126+	5,02E-02	1,78E-02	4,83E-04	1,00E-04	6,85E-02
Sb-124	2,44E-59	3,69E-05	3,08E-05	2,00E-05	8,76E-05
Te-123m	2,01E-33	4,39E-06	5,35E-07	2,35E-07	5,16E-06
Te-127m+	3,24E-37	2,82E-08	1,98E-09	1,62E-10	3,04E-08
I-125	3,24E-61	1,54E-07	9,90E-08	8,84E-09	2,61E-07
I-129	5,14E-03	4,53E-05	8,04E-06	2,76E-07	5,19E-03
Cs-135	2,72E-05	3,24E-07	6,39E-11	2,06E-12	2,75E-05
Ce-139	9,10E-30	5,28E-06	3,41E-06	1,41E-06	1,01E-05
Ce-144+	4,15E-17	4,01E-06	4,07E-06	2,17E-06	1,02E-05
Sm-147	2,86E-04	0,00E+01	0,00E+01	0,00E+01	2,86E-04
Eu-155	2,77E-07	2,25E-05	1,77E-05	4,89E-06	4,53E-05
Gd-153	7,74E-20	4,70E-06	4,90E-06	1,30E-06	1,09E-05
Tb-160	2,12E-50	2,59E-05	1,11E-05	6,97E-06	4,40E-05
Tm-170	3,53E-33	9,38E-08	1,44E-07	1,51E-08	2,53E-07
Tm-171	1,02E-12	7,05E-08	8,10E-08	1,94E-08	1,71E-07
Ta-182	2,87E-33	4,74E-05	4,13E-05	2,56E-05	1,14E-04
W-181	1,87E-34	7,55E-07	1,60E-07	4,21E-08	9,57E-07
W-185	9,12E-52	5,84E-09	3,30E-10	3,67E-11	6,20E-09
Os-185	3,42E-41	2,27E-06	1,98E-06	1,21E-06	5,46E-06
Ir-192	1,62E-50	2,05E-06	1,85E-05	1,09E-05	3,14E-05
Tl-204	1,87E-08	6,00E-09	2,82E-06	3,36E-07	3,18E-06
Pb-210+	1,96E-03	7,74E-07	3,31E-08	1,39E-09	1,96E-03
Bi-207	9,41E-03	5,46E-03	3,39E-03	1,06E-03	1,93E-02
Po-210	6,16E-30	4,13E-10	3,46E-11	2,22E-11	4,70E-10
Ra-226+	5,43E-02	1,41E-02	7,19E-03	1,54E-03	7,71E-02
Ra-228+	9,26E-05	6,48E-04	5,44E-04	2,87E-04	1,57E-03
Ac-227+	1,47E-03	9,29E-04	7,26E-04	2,21E-04	3,35E-03
Th-228+	2,28E-08	3,13E-04	1,36E-04	8,37E-05	5,32E-04
Th-229+	7,57E-03	2,43E-03	5,03E-04	8,71E-05	1,06E-02
Th-230	8,04E-04	2,21E-06	7,53E-07	7,76E-08	8,07E-04
Th-232	8,89E-04	1,01E-06	4,25E-07	3,43E-08	8,90E-04
Pa-231	6,72E-02	2,36E-04	5,07E-05	8,37E-06	6,75E-02
U-232	4,86E-04	9,55E-07	5,10E-07	4,64E-08	4,87E-04
U-233	1,78E-04	1,40E-06	4,06E-07	4,86E-08	1,80E-04
U-236	1,62E-04	6,48E-07	3,63E-07	2,07E-08	1,63E-04
Pu-236	6,45E-09	2,57E-08	4,81E-08	5,51E-09	8,57E-08
Pu-242	6,35E-04	3,85E-07	3,10E-07	1,15E-08	6,35E-04
Pu-244+	9,15E-03	2,88E-03	4,94E-04	1,03E-04	1,26E-02
Am-242m+	4,90E-04	9,18E-07	6,95E-07	2,16E-08	4,92E-04
Am-243+	2,58E-03	1,41E-03	3,39E-04	5,04E-05	4,38E-03
Cm-242	1,39E-27	3,19E-09	7,42E-09	7,42E-10	1,14E-08
Cm-243	3,39E-04	3,31E-04	1,16E-04	2,59E-05	8,12E-04
Cm-245	1,06E-03	4,20E-04	1,04E-04	1,50E-05	1,60E-03
Cm-246	5,60E-04	3,59E-07	3,61E-07	1,10E-08	5,61E-04
Cm-247+	7,13E-03	2,88E-03	5,26E-04	1,02E-04	1,06E-02
Cm-248	2,08E-03	3,08E-07	2,90E-07	9,55E-09	2,08E-03
Bk-249	4,96E-18	5,58E-10	9,67E-10	8,54E-11	1,61E-09
Cf-248	4,29E-16	4,25E-09	1,19E-08	1,02E-09	1,72E-08
Cf-249	7,97E-03	2,54E-03	4,83E-04	9,77E-05	1,11E-02
Cf-250	5,07E-05	7,87E-08	1,51E-07	9,44E-09	5,09E-05
Cf-251	3,81E-03	7,30E-04	1,70E-04	2,69E-05	4,73E-03
Cf-252	1,08E-08	1,38E-08	3,33E-08	3,21E-09	6,11E-08
Cf-254	2,98E-60	1,69E-13	2,95E-13	4,86E-14	5,13E-13
Es-254	3,24E-18	2,30E-07	2,51E-07	6,08E-08	5,42E-07

APPENDIX D

Nuclide Dependent Data

Contents

Appendix D

1 Introduction

This appendix gives all the radionuclide dependent dose factors used to calculate the doses given in Appendices A, B and C. It contains tables giving half-lives, radionuclide distribution factors, dose factors, and transfer factors, together with an introductory text containing a description of each parameter. The tables are:

The references for these values are given below.

2 References

1 International Commission on Radiological Protection. Radionuclide Transformations: Energy and intensity of emissions. ICRP Publication 38 (1983).

2 Chapuis, A M, Garbay, H, and Guetat, P. ”How to decrease doses due to radioactive metal recycling”. In Workshop on melting and recycling of radioactive metals from decommissioning of nuclear installations.

3 Decommissioning of nuclear installations. Ed. by Pflugrad K, Bisci, R, Huber B, and Skupinski, E. EUR12690. Elsevier Applied Science, London (1990).

4 Bologna, L, and Mezzanotte, R. Calculations of external exposures for radiation sources of different geometry. Report for European Commission DG XI under Contract No: 94-PR-010 (1994). *

5 Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of health of workers and the general public against dangers arising from ionizing radiation. Official Journal of the European Communities L 159 of 29.6.1996.

* This version also contains doses for low energy gamma emitters and bremsstrahlung.

3. Tables

Table 3.1 Half-lives and radionuclide distribution factors

Table 1 contains data on the half-lives of radionuclides and r, the radionuclide distribution factors for various products and by-products (ingots, slag and dust). The half-lives are taken from ICRP publication 38[1]. These are related to λ, the decay constant, in the following way:

$$\lambda = \frac{\log_e 2}{T_{1/2}}$$

where:

$T_{1/2}$: Half-life of the radionuclide.

The radionuclide dependent distribution factors are calculated for steel, copper and aluminium VLLW[2,3]. The values for all radionuclides and for ingots, slags and dusts are listed in Table 1. The parameters are described briefly below.

Parameter	Description
Nuclide	The radionuclide the other parameters are associated to. If denoted by a ”+” the nuclide is assumed to be in secular equilibrium with its short lived daughter(s), eg. “Sr90+” is ^{90}Sr in equilibrium with ^{90}Y.
Half-life	The radioactive half-life of the nuclide.
r	Radionuclide distribution factor in an ingot during melting. Radionuclide distribution factor in slag. Radionuclide distribution factor in the dust.

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TABLE 3.1: HALF-LIVES AND RADIONUCLIDE DISTRIBUTION FACTORS

NUCLIDE	HALF-LIFE (y)	RADIONUCLIDE DISTRIBUTION FACTOR								
		r (STEEL)			r (COPPER)			r (ALUMINIUM)		
		Ingot	Slag	Dust	Ingot	Slag	Dust	Ingot	Slag	Dust
H3	1,23E+01	0,00E+01	0,00E+01	1,00E-00	0,00E+01	0,00E+01	1,00E-00	0,00E+01	0,00E+01	1,00E-00
C14	5,73E+03	0,00E+01	0,00E+01	1,00E-00	0,00E+01	0,00E+01	1,00E-00	0,00E+01	0,00E+01	1,00E-00
Mn54	8,55E-01	1,00E-00	1,00E-01	5,00E-02	1,00E-02	1,00E-00	5,00E-02	1,00E-00	2,00E-01	5,00E-03
Fe55	2,68E-00	1,00E-00	1,00E-02	5,00E-03	1,00E-02	1,00E-00	5,00E-02	1,00E-00	2,00E-01	5,00E-03
Co60	5,27E-00	1,00E-00	1,00E-02	5,00E-03	5,00E-02	1,00E-00	2,00E-01	1,00E-00	1,00E-01	1,00E-03
Ni59	7,50E+04	1,00E-00	1,00E-02	1,00E-03	5,00E-02	1,00E-00	2,00E-01	1,00E-00	2,00E-01	5,00E-03
Ni63	9,60E+01	1,00E-00	1,00E-02	1,00E-03	5,00E-02	1,00E-00	2,00E-01	1,00E-00	2,00E-01	5,00E-03
Zn65	6,68E-01	1,00E-01	1,00E-01	1,00E-00	1,00E-02	1,00E-00	5,00E-01	1,00E-00	5,00E-02	5,00E-03
Sr90+	2,81E+01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01
Nb94	2,03E+04	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-00	1,00E-00	1,00E-00	1,00E-00
Tc99	2,14E+05	1,00E-01	1,00E-00	1,00E-03	1,00E-01	1,00E-00	1,00E-03	1,00E-01	1,00E-00	1,00E-03
Ru106+	1,02E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00
Ag108m+	1,27E+02	1,00E-00	1,00E-02	1,00E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-00	5,00E-02	1,00E-03
Ag110m+	6,84E-01	1,00E-00	1,00E-02	1,00E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-00	5,00E-02	1,00E-03
Sb125+	2,76E-00	1,00E-00	1,00E-03	1,00E-02	1,00E-00	2,00E-01	2,00E-01	1,00E-00	1,00E-00	2,00E-03
Cs134	2,01E-00	1,00E-03	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-02	1,00E-00	1,00E-00
Cs137+	3,00E+01	1,00E-03	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-02	1,00E-00	1,00E-00
Pm147	2,62E-00	1,00E-03	1,00E-00	1,00E-03	1,00E-03	1,00E-00	1,00E-03	1,00E-03	1,00E-00	1,00E-03
Sm151	9,00E+01	1,00E-03	1,00E-00	1,00E-03	1,00E-03	1,00E-00	1,00E-03	1,00E-03	1,00E-00	1,00E-03
Eu152	1,35E+01	1,00E-03	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Eu154	8,59E-00	1,00E-03	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
U234	2,45E+05	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
U235+	7,04E+08	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
U238+	4,47E+09	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Np237+	2,14E+06	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Pu238	8,74E+01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Pu239	2,41E+04	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Pu240	6,56E+03	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Pu241	1,44E+01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Am241	4,32E+02	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cm244	1,81E+01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Na-22	2,60E-00	1,00E-03	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-00	1,00E-01
S-35	2,40E-01	1,00E-02	1,00E-00	1,00E-01	1,00E-02	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01

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Cl-36	3,01E+05	1,00E-02	1,00E-00	1,00E-00	1,00E-02	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-01
K-40	1,28E+09	1,00E-03	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-00	1,00E-01
Ca-45	4,46E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01
Sc-46	2,30E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01
Mn-53	3,70E+06	1,00E-00	1,00E-01	5,00E-02	1,00E-02	1,00E-00	5,00E-02	1,00E-00	2,00E-01	5,00E-03
Co-56	2,16E-01	1,00E-00	1,00E-02	5,00E-03	5,00E-02	1,00E-00	2,00E-01	1,00E-00	1,00E-01	1,00E-03
Co-57	7,42E-01	1,00E-00	1,00E-02	5,00E-03	5,00E-02	1,00E-00	2,00E-01	1,00E-00	1,00E-01	1,00E-03
Co-58	1,94E-01	1,00E-00	1,00E-02	5,00E-03	5,00E-02	1,00E-00	2,00E-01	1,00E-00	1,00E-01	1,00E-03
As-73	2,20E-01	1,00E-00	1,00E-03	1,00E-02	1,00E-00	2,00E-01	2,00E-01	1,00E-00	1,00E-00	2,00E-03
Se-75	3,28E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-01	1,00E-02	1,00E-01	1,00E-00	1,00E-01
Se-79	6,50E+04	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-01	1,00E-02	1,00E-01	1,00E-00	1,00E-01
Sr-85	1,78E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01
Y-91	1,60E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01
Zr-93	1,53E+06	1,00E-00	1,00E-02	5,00E-03	1,00E-00	1,00E-00	1,00E-00	1,00E-00	1,00E-00	1,00E-00
Zr-95+	1,75E-01	1,00E-00	1,00E-02	5,00E-03	1,00E-00	1,00E-00	1,00E-00	1,00E-00	1,00E-00	1,00E-00
Nb-93m	1,46E+01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-00	1,00E-00	1,00E-00	1,00E-00
Mo-93	3,50E+03	1,00E-00	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01
Tc-97	2,60E+06	1,00E-01	1,00E-00	1,00E-03	1,00E-01	1,00E-00	1,00E-03	1,00E-01	1,00E-00	1,00E-03
Tc-97m	2,44E-01	1,00E-01	1,00E-00	1,00E-03	1,00E-01	1,00E-00	1,00E-03	1,00E-01	1,00E-00	1,00E-03
Pd-107	6,50E+06	1,00E-00	1,00E-02	1,00E-03	5,00E-02	1,00E-00	2,00E-01	1,00E-00	2,00E-01	5,00E-03
Cd-109	1,27E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-02	1,00E-00	5,00E-01	1,00E-00	5,00E-02	5,00E-03
Sn-113+	3,15E-01	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00
Sn-126+	1,00E+05	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00
Sb-124	1,65E-01	1,00E-00	1,00E-03	1,00E-02	1,00E-00	2,00E-01	2,00E-01	1,00E-00	1,00E-00	2,00E-03
Te-123m	3,28E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-01	1,00E-02	1,00E-01	1,00E-00	1,00E-01
Te-127m+	2,99E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-01	1,00E-02	1,00E-01	1,00E-00	1,00E-01
I-125	1,65E-01	1,00E-02	1,00E-00	1,00E-00	1,00E-02	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-01
I-129	1,57E+07	1,00E-02	1,00E-00	1,00E-00	1,00E-02	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-01
Cs-135	2,30E+06	1,00E-03	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-02	1,00E-00	1,00E-00
Ce-139	3,77E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Ce-144+	7,79E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03
Sm-147	6,90E+09	1,00E-03	1,00E-00	1,00E-03	1,00E-03	1,00E-00	1,00E-03	1,00E-03	1,00E-00	1,00E-03
Eu-155	4,96E-00	1,00E-03	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Gd-153	6,62E-01	1,00E-01	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Tb-160	1,98E-01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Tm-170	3,52E-01	1,00E-01	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Tm-171	1,92E-00	1,00E-01	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Ta-182	3,14E-01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-00	1,00E-00	1,00E-00	1,00E-00
W-181	3,31E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01
W-185	2,06E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01

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Os-185	2,56E-01	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00
Ir-192	2,03E-01	1,00E-00	1,00E-02	5,00E-03	5,00E-02	1,00E-00	2,00E-01	1,00E-00	1,00E-01	1,00E-03
Tl-204	3,78E-00	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-01	1,00E-01
Pb-210+	2,23E+01	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00
Bi-207	3,34E+01	1,00E-00	1,00E-03	1,00E-02	1,00E-00	2,00E-01	2,00E-01	1,00E-00	1,00E-00	2,00E-03
Po-210	3,79E-01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-01	1,00E-02	1,00E-01	1,00E-00	1,00E-01
Ra-226+	1,60E+03	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01
Ra-228+	5,75E-00	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01
Ac-227+	2,18E+01	1,00E-01	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01	1,00E-00	1,00E-00	1,00E-01
Th-228+	1,91E-00	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Th-229+	7,34E+03	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Th-230	7,70E+04	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Th-232	1,40E+10	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Pa-231	3,28E+04	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
U-232	7,20E+01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
U-233	1,59E+05	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
U-236	3,42E+06	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Pu-236	2,85E-00	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Pu-242	3,76E+05	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Pu-244+	8,26E+07	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Am-242m+	1,52E+02	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Am-243+	7,38E+03	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cm-242	4,47E-01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cm-243	2,85E+01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cm-245	8,50E+03	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cm-246	4,75E+03	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cm-247+	1,56E+07	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cm-248	3,39E+05	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Bk-249	8,77E-01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cf-248	9,14E-01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cf-249	3,51E+02	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cf-250	1,31E+01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cf-251	9,00E+02	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cf-252	2,64E-00	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Cf-254	1,66E-01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03
Es-254	7,55E-01	1,00E-01	1,00E-00	1,00E-03	1,00E-00	1,00E-00	1,00E-03	5,00E-01	1,00E-00	1,00E-03

Appendix D

Table 3.2 Gamma and beta dose factors

Table 3.2.1 to 3.2.4 contain the nuclide dependent external exposure dose factors for gamma and beta irradiation used throughout the document. The table gives values for all relevant radionuclides. Dose factor column headings have the format:

[Description]	eg.	Scrap transport
[Scenario ref.]*		(3.1.1)
[Name of dose factor]		DF_{ST}
[Unit]		Sv h^{-1} per Bq cm^{-3}

* Only if the dose factor relates to a specific scenario.

Listed firstly are the generic dose factors in Table 3.2.1. These are produced for common geometric conditions, such as an semi-infinite slab, point source or a skin dose. These may be applied to the steel, copper or aluminium scenarios with equal validity.

Secondly, scenario specific dose factors have been calculated by Bologna and Mezzanotte[4] for specific shapes and geometries, and taking into account factors associated with the particular type of contaminated material. These are termed scenario dependent dose factors. The geometric assumptions are specific, whereas the type of source (thick disk, disk or cylindrical wall etc) are general. Each scenario specific factor is different for the different metal types ie steel (Table 3.2.2), copper (Table 3.2.3) and aluminium (Table 3.2.4).

Listed below is a brief description of each external exposure dose factor. Where the parameters are given in brackets, these refer to the name given in the equations in Appendix A or Appendix B.

Parameter	Description
Nuclide	The radionuclide the other parameters are associated to. If denoted by a "+" the nuclide is assumed to be in secular equilibrium with its short lived daughter(s), eg. "Sr90+" is ^{90}Sr in equilibrium with ^{90}Y.

Generic dose factors (Table 3.2.1)

DF_{BC4} ($DF_{\beta 4}$)	Skin equivalent dose rate to the basal layer of the epidermis (4 mg cm^{-2}), for beta irradiation (Sv h^{-1} per Bq cm^{-2}).
DF_{BC40} ($DF_{\beta 40}$)	Skin equivalent dose rate to the basal layer of the epidermis (40 mg cm^{-2}), for beta irradiation (Sv h^{-1} per Bq cm^{-2}).
DF_{GC} ($DF_{\gamma c}$)	Skin equivalent dose rate to the basal layer of the epidermis (7 mg cm^{-2}), for gamma irradiation (Sv h^{-1} per Bq cm^{-2}).
DF_{VB} ($DF_{V\beta}$)	Dose factor per unit mass activity concentration due to external exposure to beta radiation 1 m from a semi-infinite slab source (Sv h^{-1} per Bq g^{-1}).
DF_{VG} ($DF_{V\gamma}$)	Dose factor per unit mass activity concentration due to external exposure to gamma radiation 1 m from an infinite slab source (Sv h^{-1} per Bq g^{-1}).
DF_{BGS} ($DF_{\beta\gamma S}$)	Dose factor per unit surface activity due to external exposure to an infinite surface source, emitting beta- and gamma-radiations (Sv h^{-1} per Bq m^{-2}).

Appendix D

Scenario specific dose factors (Tables 3.2.2 – 3.2.4)

DF_{ST} — The dose factor per unit volume activity concentration due to external exposure to gamma radiation from scrap transport, for steel, copper and aluminium (Sv h^{-1} per Bq cm^{-3}).

DF_{SC} — The dose factor per unit volume activity concentration due to external exposure to gamma radiation from a scrap heap, for steel copper and aluminium (Sv h^{-1} per Bq cm^{-3}).

DF_{I} — The dose factor per unit volume activity concentration due to external exposure to gamma radiation from an ingot, for steel, copper and aluminium (Sv h^{-1} per Bq cm^{-3}).

DF_{M} — The dose factor per unit volume activity concentration due to external exposure from gamma radiation from a large machine, represented by a thick disk or cylindrical volume, diameter 1 m and thickness 50 cm at distance 1 m, for steel (Sv h^{-1} per Bq cm^{-3}).

DF_{K} — The dose factor per unit volume activity concentration due to external exposure from gamma radiation in a kitchen, represented by a thick disk or cylindrical volume, diameter 1.2 m and thickness 0.3 cm at distance 1 m, for steel (Sv h^{-1} per Bq cm^{-3}).

DF_{P} — The dose factor per unit volume activity concentration due to external exposure from gamma radiation from a process vessel, represented by a cylindrical wall (height 2 m, external diameter 1 m, thickness 1 cm) source at 1 m (lateral direction), for steel (Sv h^{-1} per Bq cm^{-3}).

DF_{S} — The dose factor per unit volume activity concentration due to external exposure from gamma radiation from a ship, represented by a thick disk or cylindrical volume, diameter 2 m and thickness 1 cm at distance 1 m, for steel (Sv h^{-1} per Bq cm^{-3}).

DF_{F},DF_{W} — The dose factor per unit volume activity concentration due to external exposure from gamma radiation from a floor or wall, represented by a thick disk or cylindrical volume, apparent diameter 1.8 m/1.4 m and thickness 0.5 cm at distance 1 m (axial direction), for steel (Sv h^{-1} per Bq cm^{-3}). Both include shielding for 5 m concrete.

DF_{R} — The dose factor per unit volume activity concentration due to external exposure from gamma radiation from a radiator, represented by a thick disk or cylindrical volume, diameter 1 m and thickness 0.5 cm at distance 1.5 m (axial direction), for steel (Sv h^{-1} per Bq cm^{-3}).

DF_{SL} — The dose factor per unit volume activity concentration due to external exposure to gamma radiation from a slag volume, represented by a right circular cone, at 0 m distance, for copper and aluminium (Sv h^{-1} per Bq cm^{-3}).

DF_{E} — The dose factor per unit volume activity concentration due to external exposure to gamma radiation from a vat of electrolyte, represented by a right circular cone, at 0 m distance, for copper
(Sv h^{-1} per Bq cm^{-3}).

DF_{LCO} — The dose factor per unit volume activity concentration due to external exposure from gamma radiation from a large copper object, represented by a thick disk of 4 m diameter and 0.2 cm thick, at 1.5 m (Sv h^{-1} per Bq cm^{-3}).

DF_{LAB} — The dose factor per unit volume activity concentration due to external exposure from gamma radiation from a laboratory instrument in brass, represented by a thick disk of 20 cm diameter and 2 cm thick, at 1 m (Sv h^{-1} per Bq cm^{-3}).

DF_{MI} — The dose factor per unit volume activity concentration due to external exposure from gamma radiation from a musical instrument, represented by a cylindrical wall source at 0 m (axial direction) (Sv h^{-1} per Bq cm^{-3}).

DF_{SAN}	The dose factor per unit volume activity concentration due to external exposure from gamma radiation from a copper alloy (brass) kitchen fitting, represented by a thick disk of 0.2 m diameter and 0.2 cm thick, at 0.5 m distance (Sv h^{-1} per Bq cm^{-3}).
DF_{CS}	The dose factor per unit volume activity concentration due to external exposure from gamma radiation from a plate of concrete, represented by a thick disk of 3.8 m diameter and 10 cm thick, at 1 m, for aluminium (Sv h^{-1} per Bq cm^{-3}).
DF_{FU}	The dose factor per unit volume activity concentration due to external exposure from gamma radiation from aluminium furniture, represented by a thick disk of 0.5 m diameter and 1 cm thick, at 0.5 m (Sv h^{-1} per Bq cm^{-3}).
DF_{FB}	The dose factor per unit volume activity concentration due to external exposure from gamma radiation from an aluminium hulled fishing boat, represented by a thick disk of 3 m diameter and 0.5 cm thick, at 1.5 m (Sv h^{-1} per Bq cm^{-3}).
DF_{LAO}	The dose factor per unit volume activity concentration due to external exposure from gamma radiation from a large aluminium object, represented by a disk of 4 m diameter at 1.5 m distance (Sv h^{-1} per Bq cm^{-3}).
DF_{RAL}	The dose factor per unit volume activity concentration due to external exposure from gamma radiation from an aluminium radiator, represented by a thick disk of 0.7 m diameter and 1 cm thick, at 1.5 m (Sv h^{-1} per Bq cm^{-3}).
DF_{CE}	The dose factor per unit volume activity concentration due to external exposure from gamma radiation from an aluminium car engine, represented by a thick disk of 0.5 m diameter and 20 cm thickness, at 1 m (Sv h^{-1} per Bq cm^{-3}).
$BREM_*$	The dose factor per unit volume activity concentration due to external exposure from bremsstrahlung radiation (Sv h^{-1} per Bq cm^{-3}). This is different for each scenario, the " * " refers to the same suffix as DF. The values of DF_* and $BREM_*$ are added for the same scenario and given in Tables 3.2.1 – 3.2.4.

Appendix D

TABLE 3.2.1: GENERIC GAMMA AND BETA DOSE FACTORS

NUCLIDE	Beta Skin DF_{BC4}	Beta Skin DF_{BC40}	Gamma Skin DF_{GC}	Beta Semi inf. slab DF_{VB}	Gamma Inf. slab DF_{VG}	Beta & Gamma Plane DF_{BGS}
		(Sv h^{-1} per Bq cm^{-2})		(Sv h^{-1} per Bq g^{-1})		(Sv h^{-1} per Bq m^{-2})
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	9,02E-07	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	0,00E+01	0,00E+01	6,10E-08	3,08E-14	1,83E-07	2,64E-12
Fe55	0,00E+01	0,00E+01	1,60E-08	0,00E+01	1,62E-17	7,64E-16
Co60	1,83E-06	2,85E-08	1,30E-07	7,19E-13	5,64E-07	7,11E-12
Ni59	0,00E+01	0,00E+01	6,39E-08	0,00E+01	1,09E-16	1,44E-15
Ni63	1,83E-08	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Zn65	3,77E-08	1,14E-09	5,00E-08	4,60E-14	1,28E-07	1,71E-12
Sr90+	5,14E-06	1,76E-06	2,40E-12	2,10E-09	2,16E-16	3,88E-13
Nb94	2,17E-06	1,83E-07	1,00E-07	1,99E-13	3,45E-07	4,98E-12
Tc99	1,60E-06	1,37E-08	2,49E-14	0,00E+01	3,77E-14	1,95E-19
Ru106+	2,85E-06	1,60E-06	1,20E-08	5,78E-09	4,22E-08	1,15E-12
Ag108m+	2,76E-07	1,15E-07	1,28E-07	8,69E-11	3,70E-07	5,22E-12
Ag110m+	8,24E-07	1,02E-07	1,50E-07	5,06E-11	6,02E-07	8,39E-12
Sb125+	2,05E-06	8,56E-08	3,51E-08	1,22E-13	8,40E-08	1,40E-12
Cs134	1,83E-06	3,08E-07	8,80E-08	6,67E-12	3,34E-07	4,94E-12
Cs137+	2,54E-06	3,92E-07	3,31E-08	1,53E-11	1,20E-07	1,84E-12
Pm147	1,26E-06	4,11E-10	4,90E-13	0,00E+01	3,41E-13	1,28E-17
Sm151	2,85E-08	0,00E+01	6,40E-12	0,00E+01	1,31E-14	1,69E-17
Eu152	1,60E-06	1,71E-07	1,18E-07	4,62E-11	3,02E-07	3,50E-12
Eu154	3,42E-06	3,77E-07	9,02E-08	1,32E-10	2,67E-07	3,82E-12
U234	7,42E-09	0,00E+01	2,70E-09	0,00E+01	6,68E-12	2,68E-15
U235+	2,52E-06	1,09E-08	5,31E-08	0,00E+01	1,94E-08	5,96E-13
U238+	3,83E-06	1,26E-06	9,23E-09	2,07E-09	4,28E-09	4,22E-13
Np237+	3,46E-06	9,93E-08	3,20E-08	1,11E-13	3,56E-08	8,40E-13
Pu238	0,00E+01	0,00E+01	2,70E-09	0,00E+01	1,16E-12	2,87E-15
Pu239	4,34E-10	0,00E+01	1,00E-09	0,00E+01	4,63E-12	1,26E-15
Pu240	0,00E+01	0,00E+01	2,60E-09	0,00E+01	1,39E-12	2,82E-15
Pu241	0,00E+01	0,00E+01	3,30E-12	0,00E+01	3,00E-13	1,24E-17
Am241	5,48E-08	0,00E+01	1,70E-08	0,00E+01	6,37E-10	9,43E-14
Cm244	0,00E+01	0,00E+01	2,20E-09	0,00E+01	8,68E-13	2,76E-15
Na-22	2,40E-06	3,77E-07	1,20E-07	4,02E-12	4,76E-07	6,54E-12
S-35	9,02E-07	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Cl-36	2,51E-06	5,30E-07	1,10E-11	3,19E-11	0,00E+01	2,55E-14
K-40	2,40E-06	9,50E-07	8,00E-09	4,24E-10	3,84E-08	6,00E-13
Ca-45	1,60E-06	3,65E-09	2,10E-13	0,00E+01	4,30E-20	7,24E-22
Sc-46	1,94E-06	6,28E-08	1,21E-07	1,49E-13	4,62E-07	6,05E-12
Mn-53	0,00E+01	0,00E+01	8,34E-11	0,00E+01	0,00E+01	5,46E-16
Co-56	1,24E-06	2,48E-07	1,70E-07	2,74E-13	8,56E-07	1,03E-11
Co-57	1,10E-07	0,00E+01	4,00E-08	0,00E+01	7,51E-09	4,47E-13
Co-58	4,11E-07	5,02E-08	7,00E-08	0,00E+01	2,07E-07	3,08E-12
As-73	6,03E-07	1,21E-07	9,66E-10	0,00E+01	6,24E-11	3,15E-14
Se-75	1,71E-07	3,31E-09	4,20E-08	0,00E+01	4,58E-08	1,35E-12
Se-79	1,14E-06	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Sr-85	1,71E-08	8,33E-09	4,70E-08	0,00E+01	9,41E-08	1,66E-12
Y-91	2,63E-06	1,13E-06	1,90E-10	6,34E-10	8,63E-10	2,63E-13
Zr-93	4,80E-07	0,00E+01	1,15E-10	0,00E+01	0,00E+01	0,00E+01
Zr-95+	1,94E-06	8,45E-08	4,20E-08	1,28E-12	3,18E-07	4,76E-12
Nb-93m	0,00E+01	0,00E+01	1,15E-10	0,00E+01	9,94E-13	3,39E-15
Mo-93	0,00E+01	0,00E+01	6,42E-10	0,00E+01	5,57E-12	1,89E-14
Tc-97	5,57E-08	0,00E+01	6,84E-10	0,00E+01	7,39E-12	2,09E-14
Tc-97m	8,68E-07	1,74E-07	5,75E-10	0,00E+01	1,97E-11	1,80E-14

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TABLE 3.2.1 (cont.)						
Pd-107	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Cd-109	0,00E+01	0,00E+01	1,70E-08	0,00E+01	2,50E-11	3,03E-14
Sn-113+	0,00E+01	0,00E+01	1,20E-08	5,77E-13	4,22E-08	9,00E-13
Sn-126+	1,83E-06	2,05E-09	3,90E-08	1,42E-09	3,90E-07	6,70E-12
Sb-124	2,40E-06	6,28E-07	9,50E-08	2,42E-10	4,26E-07	5,62E-12
Te-123m	2,28E-06	0,00E+01	1,20E-08	0,00E+01	1,13E-08	5,08E-13
Te-127m+	1,83E-06	1,07E-08	6,72E-10	6,08E-11	8,33E-10	5,56E-14
I-125	0,00E+01	0,00E+01	2,10E-08	0,00E+01	1,39E-10	7,83E-14
I-129	6,51E-07	0,00E+01	9,70E-09	0,00E+01	1,00E-10	6,93E-14
Cs-135	1,10E-06	5,71E-11	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Ce-139	3,56E-07	7,12E-08	1,90E-08	0,00E+01	1,18E-08	5,52E-13
Ce-144+	4,45E-06	1,50E-06	4,10E-09	4,67E-09	8,42E-09	6,16E-13
Sm-147	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Eu-155	8,68E-07	3,20E-10	3,47E-09	0,00E+01	2,01E-09	2,23E-13
Gd-153	4,00E-07	0,00E+01	6,30E-09	0,00E+01	2,78E-09	3,96E-13
Tb-160	3,42E-06	4,22E-07	6,72E-08	2,03E-11	2,34E-07	3,34E-12
Tm-170	2,30E-06	6,62E-07	3,11E-10	9,92E-11	1,12E-10	9,22E-14
Tm-171	2,56E-07	0,00E+01	3,90E-11	0,00E+01	8,43E-12	2,49E-15
Ta-182	2,30E-06	4,24E-07	7,74E-08	0,00E+01	2,85E-07	3,84E-12
W-181	1,09E-07	0,00E+01	2,42E-09	0,00E+01	5,61E-10	1,46E-13
W-185	1,27E-06	2,45E-07	3,33E-12	3,17E-13	1,64E-12	1,33E-16
Os-185	6,05E-08	1,26E-08	4,30E-08	0,00E+01	1,36E-07	2,28E-12
Ir-192	2,63E-06	3,88E-07	4,90E-08	7,25E-12	1,31E-07	2,72E-12
Tl-204	2,40E-06	5,71E-07	3,20E-10	1,37E-11	2,44E-11	6,75E-14
Pb-210+	2,63E-06	8,45E-07	8,30E-09	2,52E-10	1,85E-11	1,32E-13
Bi-207	1,16E-06	2,32E-07	9,24E-08	1,84E-13	3,25E-07	4,78E-12
Po-210	0,00E+01	0,00E+01	4,80E-13	0,00E+01	1,85E-12	2,69E-17
Ra-226+	8,53E-06	2,49E-06	1,18E-07	6,66E-09	3,89E-07	5,51E-12
Ra-228+	3,08E-06	7,19E-07	5,78E-08	3,28E-10	2,00E-07	2,96E-12
Ac-227+	0,00E+01	0,00E+01	0,00E+01	2,79E-09	5,11E-08	1,70E-12
Th-228+	6,34E-06	1,22E-06	1,00E-07	1,88E-09	3,45E-07	4,79E-12
Th-229+	6,29E-06	9,87E-07	7,30E-08	3,13E-10	4,32E-08	1,04E-12
Th-230	1,04E-07	0,00E+01	3,80E-09	0,00E+01	1,54E-11	2,97E-15
Th-232	9,46E-06	1,94E-06	1,65E-07	0,00E+01	4,93E-12	2,20E-15
Pa-231	1,48E-07	5,14E-09	2,86E-09	0,00E+01	3,79E-09	1,13E-13
U-232	6,38E-06	1,22E-06	9,36E-08	0,00E+01	9,37E-12	3,41E-15
U-233	5,25E-09	0,00E+01	1,70E-09	0,00E+01	1,14E-11	1,62E-15
U-236	4,57E-09	0,00E+01	9,42E-11	0,00E+01	1,71E-12	2,44E-15
Pu-236	0,00E+01	0,00E+01	1,25E-10	0,00E+01	1,12E-12	3,31E-15
Pu-242	0,00E+01	0,00E+01	8,64E-11	0,00E+01	5,62E-13	2,28E-15
Pu-244+	0,00E+01	0,00E+01	7,32E-11	8,33E-10	6,70E-08	1,51E-14
Am242m+	1,94E-06	2,97E-07	1,40E-09	1,09E-11	1,23E-09	8,25E-14
Am-243+	4,24E-06	1,37E-07	1,38E-08	5,50E-11	1,61E-08	8,06E-13
Cm-242	0,00E+01	0,00E+01	2,40E-09	0,00E+01	7,72E-13	3,10E-15
Cm-243	1,94E-06	3,42E-08	8,04E-09	4,99E-13	1,17E-08	4,56E-13
Cm-245	9,82E-07	0,00E+01	9,55E-08	0,00E+01	3,90E-09	2,68E-13
Cm-246	0,00E+01	0,00E+01	1,51E-09	0,00E+01	4,66E-13	2,44E-15
Cm-247+	1,60E-07	1,83E-08	1,88E-08	3,79E-12	5,24E-08	1,14E-12
Cm-248	0,00E+01	0,00E+01	6,96E-11	0,00E+01	4,65E-13	1,96E-15
Bk-249	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Cf-248	5,96E-08	0,00E+01	7,80E-11	0,00E+01	4,58E-13	2,22E-15
Cf-249	3,20E-07	1,60E-08	2,00E-08	3,88E-11	5,12E-08	1,10E-12
Cf-250	4,79E-09	0,00E+01	7,44E-11	0,00E+01	1,02E-12	2,27E-15
Cf-251	1,96E-06	3,92E-07	7,86E-09	4,28E-12	8,82E-09	4,25E-13
Cf-252	3,88E-09	0,00E+01	1,30E-09	0,00E+01	7,37E-13	2,10E-15
Cf-254	5,00E-05	1,60E-05	8,70E-07	0,00E+01	1,82E-16	7,36E-20
Es-254	7,01E-07	1,40E-07	1,15E-09	0,00E+01	2,09E-10	3,78E-14

Appendix D

TABLE 3.2.2: GAMMA AND BETA DOSE FACTORS FOR STEEL SCENARIOS

NUCLIDE	OCCUPATIONAL (STEEL)							PUBLIC (STEEL)		
	Scrap transport	Scrap heap	Manufacture of ingots	Large machine	Professional kitchen	Process vessel	Ship structure	Reinforcement bars (floor)	Reinforcement bars (wall)	Radiator
	(3.1.1)	(3.2.1)	(3.4.1.1)	(3.5.1.1)	(3.5.1.2)	(3.5.1.3)	(3.5.1.4)	(3.5.2.1)	(3.5.2.1)	(3.5.2.2)
	$DF_{ST}+Brem_{ST}$	$DF_{SC}+Brem_{SC}$	$DF_{I}+Brem_{I}$	$DF_{M}+Brem_{M}$	$DF_{K}+Brem_{K}$	$DF_{P}+Brem_{P}$	$DF_{S}+Brem_{S}$	$DF_{F}+Brem_{F}$	$DF_{W}+Brem_{W}$	$DF_{R}+Brem_{R}$
	(Sv h^{-1} per Bq cm^{-3})							(Sv h^{-1} per Bq cm^{-3})		
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	3,22E-09	2,01E-09	9,79E-10	1,92E-09	2,23E-10	1,60E-09	1,57E-09	2,79E-10	1,96E-10	1,26E-10
Fe55	0,00E+01	5,11E-15	2,48E-15	5,10E-15	6,89E-15	8,74E-15	1,42E-14	0,00E+01	0,00E+01	2,48E-15
Co60	1,11E-08	6,61E-09	3,21E-09	6,25E-09	6,31E-10	4,37E-09	4,45E-09	9,33E-10	6,52E-10	3,56E-10
Ni59	0,00E+01	2,41E-15	1,17E-15	2,40E-15	3,24E-15	4,11E-15	6,67E-15	0,00E+01	0,00E+01	1,17E-15
Ni63	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Zn65	2,47E-09	1,49E-09	7,25E-10	1,42E-09	1,50E-10	1,11E-09	1,05E-09	2,10E-10	1,47E-10	8,44E-11
Sr90+ *	3,94E-10	9,08E-11	4,31E-11	2,33E-10	4,29E-11	2,80E-10	2,73E-10	3,83E-11	2,72E-11	2,35E-11
Nb94	5,94E-09	3,74E-09	1,82E-09	3,57E-09	4,23E-10	3,02E-09	2,97E-09	5,16E-10	3,63E-10	2,38E-10
Tc99 *	1,80E-13	2,58E-13	1,24E-13	3,06E-13	2,07E-13	5,11E-13	7,34E-13	4,67E-14	3,51E-14	9,47E-14
Ru106+ *	1,73E-09	6,47E-10	3,12E-10	9,99E-10	1,50E-10	1,07E-09	1,01E-09	1,60E-10	1,13E-10	8,38E-11
Ag108m+	5,40E-09	3,51E-09	1,71E-09	3,39E-09	4,47E-10	3,09E-09	3,12E-09	4,81E-10	3,41E-10	2,52E-10
Ag110m+	1,07E-08	6,67E-09	3,24E-09	6,35E-09	7,22E-10	5,36E-09	5,07E-09	9,25E-10	6,50E-10	4,07E-10
Sb125+	1,25E-09	8,36E-10	4,06E-10	7,27E-10	1,16E-10	7,90E-10	7,97E-10	1,14E-10	8,10E-11	6,50E-11
Cs134	5,59E-09	3,57E-09	1,74E-09	3,42E-09	4,22E-10	3,02E-09	2,95E-09	4,90E-10	3,46E-10	2,38E-10
Cs137+	1,97E-09	1,27E-09	6,17E-10	1,22E-09	1,54E-10	1,08E-09	1,08E-09	1,73E-10	1,22E-10	8,67E-11
Pm147 *	2,25E-14	5,80E-14	2,81E-14	6,23E-14	5,45E-14	1,06E-13	1,62E-13	8,07E-15	6,15E-15	2,34E-14
Sm151	4,11E-53	3,93E-17	1,91E-17	3,93E-17	5,30E-17	5,50E-17	1,09E-16	2,44E-32	2,44E-32	1,91E-17
Eu152	4,32E-09	2,66E-09	1,29E-09	2,53E-09	2,89E-10	2,21E-09	2,00E-09	3,73E-10	2,61E-10	1,62E-10
Eu154 *	4,84E-09	2,96E-09	1,43E-09	2,82E-09	3,17E-10	2,37E-09	2,19E-09	4,17E-10	2,92E-10	1,78E-10
U234	1,38E-14	2,52E-14	1,22E-14	2,50E-14	1,70E-14	3,43E-14	6,22E-14	3,91E-15	2,94E-15	7,90E-15
U235+	1,29E-10	1,23E-10	6,00E-11	1,21E-10	3,93E-11	1,59E-10	2,21E-10	1,93E-11	1,41E-11	2,12E-11
U238+ *	3,34E-10	9,60E-11	4,58E-11	1,96E-10	3,67E-11	2,38E-10	2,30E-10	3,23E-11	2,30E-11	2,00E-11
Np237+	3,48E-10	1,14E-10	5,43E-11	2,51E-10	5,58E-11	2,96E-10	3,42E-10	3,71E-11	2,68E-11	3,04E-11
Pu238	8,60E-16	4,01E-15	1,95E-15	3,99E-15	4,14E-15	5,60E-15	1,08E-14	3,57E-16	2,72E-16	1,67E-15
Pu239	5,91E-14	4,69E-14	2,28E-14	4,32E-14	1,14E-14	5,10E-14	6,13E-14	6,43E-15	4,64E-15	5,88E-15
Pu240	1,05E-15	4,31E-15	2,09E-15	4,29E-15	4,35E-15	6,01E-15	1,15E-14	3,93E-16	2,99E-16	1,75E-15
Pu241	3,17E-16	5,26E-16	2,56E-16	5,21E-16	3,18E-16	7,33E-16	1,27E-15	9,07E-17	6,84E-17	1,56E-16
Am241	1,83E-14	1,71E-12	8,33E-13	1,71E-12	2,19E-12	2,41E-12	4,74E-12	8,30E-14	6,77E-14	8,24E-13
Cm244	2,76E-21	1,89E-15	9,19E-16	1,89E-15	2,55E-15	2,64E-15	5,24E-15	1,12E-18	9,84E-19	9,17E-16

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Na-22 **	8,45E-09	5,24E-09	2,55E-09	4,98E-09	5,75E-10	4,15E-12	4,01E-09	7,27E-10	5,10E-10	3,22E-10
S-35 *	3,17E-15	1,89E-14	9,17E-17	1,92E-16	2,10E-16	2,76E-16	5,26E-16	1,78E-17	1,38E-17	8,38E-17
Cl-36 *	1,02E-11	5,07E-12	2,43E-14	8,63E-14	2,74E-14	1,09E-13	1,43E-13	1,34E-14	4,11E-15	1,42E-14
K-40 **	7,19E-10	4,21E-10	2,04E-10	3,98E-10	3,84E-11	3,68E-13	2,70E-10	5,97E-11	4,16E-11	2,15E-11
Ca-45	8,87E-28	1,11E-22	6,29E-23	0,00E+01	1,87E-21	1,05E-20	2,94E-21	1,44E-27	1,22E-27	6,62E-22
Sc-46 **	8,31E-09	5,09E-09	2,47E-09	4,82E-09	5,27E-10	3,89E-10	3,70E-09	7,12E-10	4,99E-10	2,96E-10
Mn-53	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Co-56 **	1,60E-08	9,37E-09	4,55E-09	8,87E-09	8,69E-10	6,99E-09	6,08E-09	1,34E-09	9,31E-10	4,87E-10
Co-57	6,44E-11	8,29E-11	4,03E-11	8,13E-11	2,99E-11	7,42E-11	1,66E-10	1,20E-11	8,91E-12	1,61E-11
Co-58 **	3,60E-09	2,29E-09	1,11E-09	2,17E-09	2,64E-10	1,91E-09	1,85E-09	3,15E-10	2,22E-10	1,48E-10
As-73	1,80E-16	6,80E-13	3,30E-13	6,91E-13	8,54E-13	4,98E-13	1,88E-12	2,31E-14	1,91E-14	3,26E-13
Se-75	6,30E-10	5,06E-10	2,46E-10	4,89E-10	1,02E-10	5,02E-11	6,57E-10	6,64E-11	4,80E-11	5,63E-11
Se-79 *	3,64E-15	2,35E-14	1,14E-15	2,38E-15	2,60E-15	3,42E-15	6,54E-15	2,17E-16	7,09E-17	1,05E-15
Sr-85	1,54E-09	1,04E-09	5,06E-10	9,94E-10	1,41E-10	9,43E-11	9,74E-10	1,40E-10	9,93E-11	7,88E-11
Y-91 *	1,36E-10	9,90E-12	2,06E-12	8,74E-12	1,74E-12	9,90E-12	1,07E-11	1,37E-12	4,13E-13	9,48E-13
Zr-93 *	8,29E-22	3,30E-16	1,60E-16	3,04E-16	4,62E-16	2,96E-16	8,87E-16	1,15E-19	4,15E-20	1,65E-16
Zr-95+ **	5,51E-09	3,51E-09	1,71E-09	3,33E-09	4,07E-10	2,28E-09	2,85E-09	4,84E-10	3,41E-10	2,28E-10
Nb-93m	9,43E-20	1,31E-14	6,47E-15	5,29E-15	1,60E-14	7,59E-16	3,80E-14	1,53E-19	1,30E-19	5,67E-15
Mo-93	5,28E-19	7,34E-14	3,62E-14	2,96E-14	8,97E-14	4,22E-14	2,13E-13	8,59E-19	7,29E-19	3,18E-14
Tc-97	9,09E-19	9,98E-14	4,90E-14	5,13E-14	1,14E-13	5,32E-15	2,68E-13	1,48E-18	1,25E-18	4,05E-14
Tc-97m	5,95E-14	2,36E-13	1,15E-13	1,97E-13	1,82E-13	1,61E-14	5,89E-13	2,09E-14	1,58E-14	7,67E-14
Pd-107 *	9,62E-38	3,89E-17	1,89E-17	2,85E-17	5,98E-16	3,03E-18	1,08E-16	4,33E-27	1,79E-27	2,11E-17
Cd-109	0,00E+01	3,33E-13	1,61E-13	3,12E-13	3,56E-13	1,20E-13	7,84E-13	0,00E+01	0,00E+01	1,26E-13
Sn-113+	6,58E-10	4,66E-10	2,27E-10	4,47E-10	7,16E-11	7,39E-13	4,87E-10	6,10E-11	4,37E-11	3,99E-11
Sn-126+ **	6,58E-09	4,31E-09	2,09E-09	4,11E-09	5,47E-10	5,36E-12	3,77E-09	5,87E-10	4,16E-10	3,06E-10
Sb-124 **	7,76E-09	4,67E-09	2,27E-09	4,43E-09	4,74E-10	3,59E-09	3,32E-09	6,59E-10	4,61E-10	2,66E-10
Te-123m	1,25E-10	1,25E-10	6,05E-11	1,21E-10	3,42E-11	1,19E-11	2,09E-10	1,67E-11	1,22E-11	1,87E-11
Te-127m+ *	1,83E-11	3,72E-13	1,85E-14	6,00E-14	3,35E-14	7,52E-14	1,06E-13	6,88E-15	2,09E-15	1,39E-14
I-125	1,28E-16	1,62E-12	7,82E-13	1,80E-12	1,95E-12	8,64E-15	4,11E-12	2,14E-16	1,83E-16	6,93E-13
I-129 **	7,47E-17	1,12E-12	5,45E-13	1,24E-12	1,41E-12	6,82E-15	2,94E-12	4,35E-16	3,82E-16	5,04E-13
Cs-135 *	2,01E-14	6,01E-14	2,91E-17	6,39E-17	5,85E-17	9,15E-17	1,68E-16	7,93E-18	2,55E-18	2,48E-17
Ce-139	1,35E-10	1,31E-10	6,36E-11	1,28E-10	3,52E-11	1,25E-11	2,13E-10	1,72E-11	1,26E-11	1,91E-11
Ce-144+ **	1,47E-10	9,22E-11	4,47E-11	8,78E-11	1,18E-11	1,10E-12	7,59E-11	1,32E-11	9,25E-12	6,49E-12
Sm-147	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Eu-155	8,92E-12	2,21E-11	1,07E-11	2,19E-11	1,31E-11	1,81E-14	5,45E-11	3,13E-12	2,37E-12	6,46E-12
Gd-153	1,22E-11	3,06E-11	1,49E-11	3,05E-11	1,96E-11	2,32E-12	7,53E-11	3,92E-12	2,96E-12	9,16E-12
Tb-160 **	4,16E-09	2,58E-09	1,25E-09	2,45E-09	2,82E-10	2,19E-10	1,96E-09	3,59E-10	2,52E-10	1,58E-10
Tm-170 *	1,86E-11	8,18E-12	3,91E-13	1,51E-12	4,73E-13	1,89E-12	2,41E-12	2,30E-13	7,07E-14	2,42E-13
Tm-171	1,29E-15	9,21E-14	4,47E-14	9,32E-14	1,09E-13	6,25E-15	2,54E-13	4,69E-15	3,79E-15	4,28E-14
Ta-182 **	5,15E-09	3,13E-09	1,52E-09	2,96E-09	3,29E-10	2,30E-10	2,24E-09	4,39E-10	3,07E-10	1,83E-10

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W-181	2,50E-13	6,13E-12	2,98E-12	6,18E-12	6,90E-12	4,50E-12	1,68E-11	3,85E-13	3,09E-13	2,79E-12
W-185 *	7,35E-13	6,55E-13	3,15E-13	8,91E-13	4,54E-13	1,22E-12	1,89E-12	1,41E-13	4,42E-14	2,18E-13
Os-185	2,31E-09	1,50E-09	7,28E-10	1,43E-09	1,89E-10	1,37E-10	1,28E-09	2,05E-10	1,45E-10	1,05E-10
Ir-192 **	2,04E-09	1,44E-09	7,02E-10	1,38E-09	2,22E-10	1,46E-09	1,51E-09	1,90E-10	1,36E-10	1,24E-10
Tl-204 *	8,50E-12	4,18E-12	2,00E-13	7,32E-13	2,43E-13	9,30E-13	1,23E-12	1,13E-13	3,47E-14	1,24E-13
Pb-210+ *	3,49E-11	3,34E-13	1,60E-14	5,95E-14	2,43E-14	7,38E-14	9,71E-14	7,97E-15	2,43E-15	1,10E-14
Bi-207 **	5,73E-09	3,58E-09	1,74E-09	3,39E-09	4,03E-10	2,97E-09	2,77E-09	4,97E-10	3,49E-10	2,25E-10
Po-210	3,23E-14	2,04E-14	9,90E-15	1,93E-14	2,31E-15	1,66E-15	1,61E-14	2,82E-15	1,99E-15	1,29E-15
Ra-226+ **	7,04E-09	4,27E-09	2,07E-09	4,05E-09	4,46E-10	7,08E-13	3,09E-09	6,00E-10	4,20E-10	2,49E-10
Ra-228+ **	3,55E-09	2,21E-09	1,07E-09	2,09E-09	2,42E-10	2,25E-13	1,68E-09	3,07E-10	2,16E-10	1,36E-10
Ac-227+ **	7,51E-10	5,64E-10	2,74E-10	5,43E-10	1,03E-10	1,72E-12	6,57E-10	7,43E-11	5,34E-11	5,67E-11
Th-228+ **	6,47E-09	3,76E-09	1,82E-09	3,57E-09	3,60E-10	2,05E-13	2,48E-09	5,44E-10	3,78E-10	2,01E-10
Th-229+ **	6,66E-10	4,77E-10	2,32E-10	4,57E-10	8,23E-11	4,95E-12	5,10E-10	6,43E-11	4,59E-11	4,48E-11
Th-230	1,23E-13	1,69E-13	8,23E-14	1,66E-13	8,73E-14	1,56E-14	3,41E-13	2,05E-14	1,53E-14	4,12E-14
Th-232	2,74E-14	5,34E-14	2,60E-14	5,27E-14	3,73E-14	5,31E-15	1,27E-13	6,21E-15	4,67E-15	1,66E-14
Pa-231	5,44E-11	4,19E-11	2,04E-11	4,04E-11	7,84E-12	9,00E-12	5,09E-11	5,44E-12	3,92E-12	4,32E-12
U-232	7,55E-14	1,02E-13	4,97E-14	9,92E-14	5,34E-14	1,22E-14	2,13E-13	1,25E-14	9,31E-15	2,47E-14
U-233	8,15E-14	1,25E-13	6,09E-14	1,23E-13	5,39E-14	2,73E-14	2,77E-13	1,86E-14	1,38E-14	2,83E-14
U-236	1,02E-15	1,78E-14	8,69E-15	1,68E-14	2,24E-14	1,90E-15	5,71E-14	1,67E-15	1,32E-15	9,33E-15
Pu-236	1,25E-16	1,13E-14	5,58E-15	8,69E-15	1,90E-14	1,62E-15	4,20E-14	5,61E-16	4,52E-16	7,25E-15
Pu-242	9,27E-18	5,50E-15	2,72E-15	3,65E-15	1,08E-14	9,83E-16	2,27E-14	1,61E-16	1,32E-16	3,99E-15
Pu-244+ **	1,15E-09	7,39E-10	3,59E-10	7,03E-10	8,87E-11	2,37E-15	6,17E-10	1,01E-10	7,15E-11	4,97E-11
Am-242m+	1,56E-11	1,92E-12	7,78E-15	1,91E-14	1,07E-14	2,58E-14	3,98E-14	3,02E-15	9,35E-16	4,92E-15
Am-243+ **	1,83E-10	1,78E-10	8,65E-11	1,73E-10	5,35E-11	1,21E-12	2,85E-10	2,37E-11	1,74E-11	2,81E-11
Cm-242	3,24E-17	8,13E-15	4,04E-15	4,15E-15	1,41E-14	1,20E-15	3,13E-14	2,12E-16	1,71E-16	5,19E-15
Cm-243	1,45E-10	1,29E-10	6,27E-11	1,25E-10	3,18E-11	1,30E-11	1,91E-10	1,72E-11	1,25E-11	1,73E-11
Cm-245	3,15E-11	4,30E-11	2,09E-11	4,22E-11	1,67E-11	4,76E-12	8,85E-11	6,20E-12	4,61E-12	8,91E-12
Cm-246	1,30E-18	4,84E-15	2,42E-15	1,70E-15	9,53E-15	7,46E-16	2,04E-14	9,52E-18	8,19E-18	3,38E-15
Cm-247+ **	8,10E-10	5,79E-10	2,81E-10	5,55E-10	9,18E-11	5,56E-11	6,14E-10	7,61E-11	5,44E-11	5,11E-11
Cm-248	4,80E-18	4,89E-15	2,43E-15	2,39E-15	8,71E-15	5,65E-16	1,91E-14	9,23E-17	7,55E-17	3,17E-15
Bk-249 *	2,88E-16	4,32E-15	2,06E-16	4,28E-16	5,26E-16	1,17E-15	1,18E-15	2,15E-17	7,15E-18	2,03E-16
Cf-248	4,66E-19	5,24E-15	2,62E-15	1,44E-15	8,65E-15	7,52E-16	1,96E-14	3,17E-18	2,76E-18	3,06E-15
Cf-249	7,89E-10	5,66E-10	2,75E-10	5,43E-10	8,90E-11	5,77E-11	6,06E-10	7,41E-11	5,31E-11	4,98E-11
Cf-250	1,01E-15	1,14E-14	5,62E-15	7,61E-15	1,32E-14	2,28E-16	3,63E-14	8,81E-16	6,82E-16	5,34E-15
Cf-251	9,55E-11	9,74E-11	4,73E-11	9,49E-11	2,85E-11	1,02E-11	1,65E-10	1,33E-11	9,77E-12	1,54E-11
Cf-252	2,45E-16	8,28E-15	4,09E-15	4,77E-15	1,11E-14	1,47E-15	2,76E-14	4,03E-16	3,18E-16	4,28E-15
Cf-254	1,51E-21	1,97E-18	9,58E-19	2,05E-18	2,60E-18	2,33E-18	5,37E-18	1,03E-20	8,91E-21	9,35E-19
Es-254	2,55E-12	2,31E-12	1,13E-12	2,19E-12	7,45E-13	2,57E-13	3,45E-12	2,78E-13	2,02E-13	3,58E-13

* Bremsstrahlung included for all scenarios for these nuclides

** Bremsstrahlung included for process vessel scenario (3.5.1.3) for these additional nuclides

Appendix D

TABLE 3.2.3: GAMMA AND BETA DOSE FACTORS FOR COPPER SCENARIOS

NUCLIDE	OCCUPATIONAL (COPPER) Scrap transport (3.1.1) $DF_{ST}+Brem_{ST}$	Scrap heap (3.2.1) $DF_{SC}+Brem_{SC}$	Manufacture of ingots (3.3.3) $DF_{I}+Brem_{I}$	Slag treatment (3.4.3) $DF_{SL}+Brem_{SL}$ (Sv h^{-1} per Bq cm^{-3})	Electo refining (3.5.1) $DF_{E}+Brem_{E}$	Laboratory fitting (3.9.1.a) $DF_{LAB}+Brem_{LAB}$	Large object (3.9.1.c) $DF_{LCO}+Brem_{LCO}$	Musical instrument (3.9.1.d) $DF_{MI}+Brem_{MI}$	PUBLIC (COPPER) Sanitary plate (3.9.2.a) $DF_{SAN}+Brem_{SAN}$ (Sv h^{-1} per Bq cm^{-3})
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	2,80E-09	1,75E-09	2,77E-09	3,84E-08	3,59E-08	4,06E-11	4,96E-10	1,47E-09	1,91E-11
Fe55	0,00E+01	3,53E-15	5,61E-15	7,78E-14	7,26E-14	1,8E-16	1,34E-14	3,49E-14	7,04E-16
Co60	9,73E-09	5,77E-09	9,18E-09	1,27E-07	1,19E-07	1,17E-10	1,40E-09	4,15E-09	5,39E-11
Ni59	0,00E+01	5,27E-15	8,37E-15	1,16E-13	1,08E-13	2,68E-16	1,99E-14	5,21E-14	1,05E-15
Ni63	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Zn65	2,16E-09	1,30E-09	2,07E-09	2,86E-08	2,67E-08	2,76E-11	3,32E-10	9,83E-10	1,28E-11
Sr90+ *	3.76E-10	9,54E-11	1,56E-10	1,23E-09	1,22E-09	7,15E-12	1,05E-10	2,62E-10	4,1E-12
Nb94	5,15E-09	3,24E-09	5,14E-09	7,13E-08	6,66E-08	7,68E-11	9,40E-10	2,78E-09	3,62E-11
Tc99 *	1,44E-13	2,12E-13	3,39E-13	3,76E-12	3,59E-12	1,17E-14	4,62E-13	1,16E-12	2,04E-14
Ru106+ *	1,61E-09	5,99E-10	9,62E-10	1,11E-08	1,05E-08	2,69E-11	3,55E-10	9,44E-10	1,38E-11
Ag108m+	4,62E-09	3,02E-09	4,79E-09	6,63E-08	6,19E-08	7,86E-11	9,84E-10	2,93E-09	3,78E-11
Ag110m+	9,36E-09	5,79E-09	9,19E-09	1,27E-07	1,19E-07	1,32E-10	1,60E-09	4,74E-09	6,17E-11
Sb125+	1,07E-09	7,14E-10	1,14E-09	1,42E-08	1,35E-08	1,99E-11	2,56E-10	6,42E-10	9,82E-12
Cs134	4,84E-09	3,09E-09	4,90E-09	6,79E-08	6,34E-08	7,60E-11	9,38E-10	2,77E-09	3,61E-11
Cs137+	1,69E-09	1,10E-09	1,74E-09	2,41E-08	2,25E-08	2,77E-11	3,42E-10	1,01E-09	1,31E-11
Pm147 *	1,73E-14	4,43E-14	7,08E-14	8,60E-13	8,15E-13	2,33E-15	1,18E-13	2,98E-13	5,45E-15
Sm151	2,70E-53	2,59E-17	4,11E-17	5,70E-16	5,32E-16	1,32E-18	9,78E-17	2,56E-16	5,16E-18
Eu152	3,77E-09	2,31E-09	3,66E-09	5,08E-08	4,74E-08	5,11E-11	6,39E-10	1,88E-09	2,47E-11
Eu154 *	4,23E-09	2,57E-09	4,07E-09	5,65E-08	5,28E-08	5,64E-11	7,03E-10	2,07E-09	2,71E-11
U234	8,81E-15	1,69E-14	2,54E-14	2,83E-13	2,71E-13	8,49E-16	3,42E-14	8,60E-14	1,50E-15
U235+	9,51E-11	9,03E-11	1,43E-10	1,99E-09	1,85E-09	4,05E-12	8,49E-11	2,37E-10	3,35E-12
U238+ *	3,14E-10	7,83E-11	1,55E-10	1,37E-09	1,34E-09	5,93E-12	8,81E-11	2,20E-10	3,46E-12
Np237+	1,41E-10	1,05E-10	1,71E-10	1,39E-09	1,37E-09	7,56E-12	1,21E-10	3,03E-10	4,77E-12
Pu238	5,67E-16	2,63E-15	4,14E-15	5,31E-14	5,01E-14	1,33E-16	7,89E-15	2,02E-14	3,85E-16
Pu239	2,30E-14	1,84E-14	2,98E-14	7,88E-13	7,42E-13	1,29E-15	2,42E-14	6,06E-14	9,91E-16
Pu240	6,80E-16	2,79E-15	4,44E-15	5,62E-14	5,31E-14	1,43E-16	8,28E-15	2,12E-14	4,03E-16
Pu241	1,97E-16	3,27E-16	5,23E-16	5,74E-15	5,51E-15	1,77E-17	6,57E-16	1,63E-15	2,75E-17
Am241	1,16E-14	1,09E-12	1,73E-12	2,39E-11	2,23E-11	5,54E-14	3,99E-12	1,03E-11	2,01E-13
Cm244	1,76E-21	1,23E-15	1,96E-15	2,72E-14	2,54E-14	6,29E-17	4,67E-15	1,22E-14	2,46E-16

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Na-22	7,38E-09	4,56E-09	7,24E-09	1,01E-07	9,51E-08	1,03E-10	1,27E-09	3,75E-09	4,88E-11
S-35 *	2,34E-15	1,39E-14	2,21E-16	2,88E-13	2,73E-15	7,11E-18	4,40E-16	6,23E-16	2,13E-17
Cl-36 *	8,52E-12	4,83E-12	7,80E-14	7,13E-12	6,99E-13	3,05E-15	6,47E-14	9,00E-14	2,63E-15
K-40	6,29E-10	3,67E-10	5,84E-10	7,99E-09	7,53E-09	7,07E-12	8,47E-11	2,51E-10	3,26E-12
Ca-45	5,62E-28	0,00E+01	0,00E+01	1,03E-20	7,65E-21	7,98E-23	4,18E-21	1,18E-20	1,91E-22
Sc-46	7,28E-09	4,42E-09	7,04E-09	9,84E-08	9,24E-08	9,63E-11	1,16E-09	3,45E-09	4,48E-11
Mn-53	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Co-56	1,40E-08	8,18E-09	1,30E-08	1,77E-07	1,67E-07	1,59E-10	1,92E-09	5,68E-09	7,39E-11
Co-57	4,93E-11	6,23E-11	9,92E-11	1,41E-09	1,32E-09	2,91E-12	6,54E-11	1,83E-10	2,56E-12
Co-58	3,15E-09	1,98E-09	3,15E-09	4,46E-08	4,18E-08	4,76E-11	5,83E-10	1,72E-09	2,24E-11
As-73	4,45E-16	5,68E-13	9,13E-13	1,14E-11	1,08E-11	2,21E-14	1,60E-12	4,29E-12	7,89E-14
Se-75	5,33E-10	4,21E-10	6,70E-10	9,64E-09	8,99E-09	1,49E-11	2,24E-10	6,48E-10	8,65E-12
Se-79 *	2,67E-15	1,72E-14	2,73E-14	3,59E-14	3,39E-13	8,79E-16	5,51E-14	7,79E-14	2,66E-15
Sr-85	1,34E-09	8,97E-10	1,43E-09	2,04E-08	1,91E-08	2,46E-11	3,10E-10	9,15E-10	1,19E-11
Y-91 *	1,27E-10	4,33E-11	6,99E-11	6,40E-10	6,26E-10	2,69E-12	4,20E-11	5,88E-11	1,65E-12
Zr-93 *	1,27E-21	2,61E-16	4,15E-16	5,97E-15	5,51E-15	1,30E-17	1,04E-15	1,51E-15	5,50E-17
Zr-95+	4,82E-09	3,04E-09	4,84E-09	6,85E-08	6,42E-08	7,34E-11	8,98E-10	2,66E-09	3,46E-11
Nb-93m	5,97E-20	1,01E-14	1,49E-14	5,23E-13	4,71E-13	4,66E-16	3,10E-14	8,69E-14	1,56E-15
Mo-93	3,35E-19	5,66E-14	8,34E-14	2,93E-12	2,64E-12	2,61E-15	1,74E-13	4,87E-13	8,74E-15
Tc-97	5,76E-19	9,83E-14	1,47E-13	3,97E-12	3,62E-12	3,25E-15	2,20E-13	6,15E-13	1,11E-14
Tc-97m	4,33E-14	2,16E-13	3,34E-13	6,12E-12	5,67E-12	7,81E-15	3,67E-13	1,01E-12	1,70E-14
Pd-107 *	7,45E-38	3,19E-17	2,53E-18	8,08E-16	3,64E-17	7,57E-20	7,26E-18	1,05E-17	3,83E-19
Cd-109	0,00E+01	6,16E-13	9,59E-13	1,33E-11	1,26E-11	9,67E-15	6,83E-13	1,89E-12	3,52E-14
Sn-113+	5,69E-10	4,00E-10	6,36E-10	9,15E-09	8,54E-09	1,21E-11	1,58E-10	4,63E-10	6,09E-12
Sn-126+	5,74E-09	3,73E-09	5,93E-09	8,43E-08	7,89E-08	9,57E-11	1,20E-09	3,55E-09	4,64E-11
Sb-124	6,78E-09	4,07E-09	6,48E-09	8,95E-08	8,41E-08	8,61E-11	1,05E-09	3,10E-09	4,03E-11
Te-123m	9,80E-11	9,74E-11	1,55E-10	2,22E-09	2,07E-09	4,23E-12	7,50E-11	2,14E-10	2,92E-12
Te-127m+ *	1,54E-11	3,05E-13	4,93E-13	5,17E-13	4,99E-12	1,92E-14	6,85E-13	9,73E-13	3,27E-14
I-125	8,08E-17	3,10E-12	4,98E-12	5,01E-11	4,85E-11	4,91E-14	3,60E-12	9,91E-12	1,88E-13
I-129	4,73E-17	1,89E-12	3,07E-12	2,95E-11	2,86E-11	3,47E-14	2,57E-12	7,07E-12	1,35E-13
Cs-135 *	1,54E-14	4,58E-14	7,30E-15	8,97E-13	8,52E-14	2,39E-16	1,26E-14	1,77E-14	5,87E-16
Ce-139	1,07E-10	1,03E-10	1,64E-10	2,34E-09	2,19E-09	4,39E-12	7,68E-11	2,20E-10	3,02E-12
Ce-144+	1,27E-10	7,94E-11	1,26E-10	1,73E-09	1,63E-09	1,80E-12	2,59E-11	7,53E-11	1,01E-12
Sm-147	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Eu-155	6,55E-12	1,62E-11	2,59E-11	3,59E-10	3,35E-10	7,62E-13	2,75E-11	7,46E-11	1,14E-12
Gd-153	8,90E-12	2,37E-11	3,79E-11	5,08E-10	4,76E-10	1,05E-12	4,01E-11	1,09E-10	1,74E-12
Tb-160	3,64E-09	2,24E-09	3,56E-09	4,98E-08	4,68E-08	5,04E-11	6,22E-10	1,84E-09	2,40E-11
Tm-170 *	1,65E-11	7,81E-12	6,33E-12	1,12E-10	5,50E-11	2,61E-13	5,48E-12	7,63E-12	2,25E-13
Tm-171	1,02E-15	7,49E-14	1,20E-13	1,53E-12	1,44E-12	2,99E-15	2,07E-13	5,53E-13	9,96E-15
Ta-182	4,51E-09	2,72E-09	4,33E-09	6,01E-08	5,65E-08	5,76E-11	7,23E-10	2,13E-09	2,80E-11

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W-181	1,96E-13	4,83E-12	7,75E-12	1,00E-10	9,44E-11	2,00E-13	1,33E-11	3,54E-11	6,28E-13
W-185 *	6,12E-13	5,72E-13	9,18E-14	9,29E-12	9,02E-13	3,35E-15	1,04E-13	1,44E-13	4,39E-15
Os-185	2,02E-09	1,30E-09	2,06E-09	2,93E-08	2,74E-08	3,25E-11	4,15E-10	1,22E-09	1,61E-11
Ir-192	1,76E-09	1,24E-09	1,97E-09	2,82E-08	2,64E-08	3,72E-11	4,89E-10	1,44E-09	1,88E-11
Tl-204 *	7,46E-12	3,98E-12	6,43E-13	5,75E-11	5,68E-12	2,60E-14	5,67E-13	7,90E-13	2,32E-14
Pb-210+ *	3,17E-11	3,03E-13	4,91E-14	4,57E-13	4,47E-13	2,00E-15	5,16E-14	7,28E-14	2,31E-15
Bi-207	5,01E-09	3,10E-09	4,94E-09	6,92E-08	6,49E-08	7,10E-11	8,88E-10	2,62E-09	3,43E-11
Po-210	2,82E-14	1,77E-14	2,81E-14	3,97E-13	3,72E-13	4,17E-16	5,09E-15	1,51E-14	1,96E-16
Ra-226+	6,15E-09	3,71E-09	5,91E-09	8,15E-08	7,67E-08	7,97E-11	9,83E-10	2,91E-09	3,79E-11
Ra-228+	3,10E-09	1,91E-09	3,04E-09	4,26E-08	4,00E-08	4,33E-11	5,34E-10	1,58E-09	2,06E-11
Ac-227+	6,45E-10	4,77E-10	7,58E-10	1,09E-08	1,02E-08	1,53E-11	2,26E-10	6,55E-10	8,80E-12
Th-228+	5,63E-09	3,28E-09	5,22E-09	7,02E-08	6,63E-08	6,35E-11	7,94E-10	2,34E-09	3,06E-11
Th-229+	5,75E-10	4,04E-10	6,43E-10	9,11E-09	8,52E-09	1,17E-11	1,80E-10	5,18E-10	7,04E-12
Th-230	9,75E-14	1,30E-13	2,08E-13	2,94E-12	2,74E-12	5,81E-15	1,82E-13	4,96E-13	7,74E-15
Th-232	2,08E-14	4,06E-14	6,47E-14	9,13E-13	8,50E-13	2,02E-15	7,67E-14	2,09E-13	3,38E-15
Pa-231	4,65E-11	3,54E-11	5,64E-11	8,10E-10	7,56E-10	1,19E-12	1,72E-11	5,00E-11	6,69E-13
U-232	5,84E-14	7,77E-14	1,24E-13	1,81E-12	1,68E-12	3,77E-15	1,11E-13	3,08E-13	4,79E-15
U-233	6,09E-14	9,20E-14	1,46E-13	2,10E-12	1,96E-12	4,53E-15	1,17E-13	3,26E-13	4,66E-15
U-236	7,71E-16	1,25E-14	2,00E-14	3,27E-13	2,99E-13	7,94E-16	4,59E-14	1,24E-13	2,07E-15
Pu-236	1,02E-16	6,97E-15	1,10E-14	2,75E-13	2,44E-13	6,24E-16	3,81E-14	1,05E-13	1,80E-15
Pu-242	9,53E-18	3,09E-15	4,83E-15	1,54E-13	1,35E-13	3,56E-16	2,17E-14	6,02E-14	1,04E-15
Pu-244+	1,01E-09	6,40E-10	1,02E-09	1,44E-08	1,35E-08	1,58E-11	1,96E-10	5,78E-10	7,54E-12
Am-242m+ *	1,35E-11	1,15E-13	1,84E-13	2,33E-12	2,21E-12	6,20E-15	2,17E-13	3,04E-13	9,58E-15
Am-243+	1,53E-10	1,43E-10	2,28E-10	3,26E-09	3,05E-09	5,51E-12	1,15E-10	3,24E-10	4,61E-12
Cm-242	2,76E-17	3,86E-15	5,85E-15	2,56E-13	2,24E-13	4,56E-16	2,80E-14	7,80E-14	1,35E-15
Cm-243	1,21E-10	1,05E-10	1,67E-10	2,40E-09	2,24E-09	3,97E-12	6,97E-11	1,99E-10	2,72E-12
Cm-245	2,42E-11	3,22E-11	5,12E-11	7,29E-10	6,81E-10	1,49E-12	3,65E-11	1,01E-10	1,44E-12
Cm-246	8,59E-19	2,05E-15	3,04E-15	1,80E-13	1,56E-13	3,09E-16	1,89E-14	5,31E-14	9,23E-16
Cm-247+	7,01E-10	4,95E-10	7,86E-10	1,13E-08	1,06E-08	1,50E-11	2,02E-10	5,91E-10	7,81E-12
Cm-248	5,07E-18	2,29E-15	3,46E-15	1,58E-13	1,38E-13	2,79E-16	1,73E-14	4,81E-14	8,35E-16
Bk-249 *	2,65E-16	3,16E-15	5,01E-15	6,85E-14	6,44E-14	1,59E-16	1,10E-14	1,58E-14	5,57E-16
Cf-248	3,01E-19	2,18E-15	3,14E-15	2,04E-13	1,78E-13	2,71E-16	1,70E-14	4,78E-14	8,38E-16
Cf-249	6,82E-10	4,84E-10	7,69E-10	1,11E-08	1,03E-08	1,49E-11	1,96E-10	5,76E-10	7,56E-12
Cf-250	7,43E-16	6,46E-15	9,95E-15	2,98E-13	2,66E-13	4,77E-16	2,67E-14	7,36E-14	1,24E-15
Cf-251	7,70E-11	7,65E-11	1,22E-10	1,74E-09	1,63E-09	3,20E-12	6,24E-11	1,76E-10	2,44E-12
Cf-252	1,85E-16	4,41E-15	6,71E-15	2,41E-13	2,14E-13	3,65E-16	2,22E-14	6,12E-14	1,05E-15
Cf-254	9,77E-22	2,07E-18	3,37E-18	3,72E-17	3,55E-17	6,27E-20	4,72E-18	1,29E-17	2,45E-19
Es-254	2,16E-12	1,89E-12	3,00E-12	4,50E-11	4,19E-11	7,08E-14	1,56E-12	4,38E-12	6,60E-14

* Bremsstrahlung included for all scenarios for these nuclides

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TABLE 3.2.4: GAMMA AND BETA DOSE FACTORS FOR ALUMINIUM SCENARIOS

NUCLIDE	OCCUPATIONAL (ALUMINIUM)								PUBLIC (ALUMINIUM)	
	Scrap transport (3.1.1)	Scrap heap (3.2.1)	Manufacture of ingots (3.3.3)	Slag treatment (3.4.3)	Concrete (3.8.2)	Office furniture (3.9.1.a)	Fishing boat (3.9.1.b)	Large object (3.9.1.c)	Radiator (3.9.2.b)	Car engine (3.9.2.c)
	$DF_{ST}+Brem_{ST}$	$DF_{SC}+Brem_{SC}$	$DF_{I}+Brem_{I}$	$DF_{SL}+Brem_{SL}$	$DF_{CS}+Brem_{CS}$	$DF_{FU}+Brem_{FU}$	$DF_{FB}+Brem_{FB}$	$DF_{LAO}+Brem_{LAO}$	$DF_{RAL}+Brem_{RAL}$	$DF_{CE}+Brem_{CE}$
	(Sv h^{-1} per Bq cm^{-3})								(Sv h^{-1} per Bq cm^{-3})	
H3	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
C14	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Mn54	9,68E-09	6,37E-09	1,01E-08	7,95E-08	2,53E-08	5,31E-10	8,45E-10	5,02E-10	1,28E-10	1,69E-09
Fe55	0,00E+01	1,11E-14	1,76E-14	1,38E-13	7,30E-14	1,10E-14	3,06E-14	4,18E-14	2,73E-15	4,21E-15
Co60	3,16E-08	1,99E-08	3,17E-08	2,49E-07	7,32E-08	1,50E-09	2,39E-09	1,42E-09	3,61E-10	4,91E-09
Ni59	0,00E+01	1,53E-14	2,43E-14	1,91E-13	9,63E-14	1,53E-14	4,24E-14	5,79E-14	3,79E-15	5,84E-15
Ni63	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Zn65	7,14E-09	4,57E-09	7,25E-09	5,69E-08	1,72E-08	3,56E-10	5,66E-10	3,36E-10	8,55E-11	1,51E-09
Sr90+ *	4,71E-10	5,86E-11	9,63E-11	6,90E-10	3,95E-10	5,75E-11	9,16E-11	5,47E-11	1,38E-11	3,09E-11
Nb94	1,80E-08	1,19E-08	1,90E-08	1,49E-07	4,79E-08	1,01E-09	1,60E-09	9,51E-10	2,42E-10	3,19E-09
Tc99 *	7,21E-13	5,17E-13	8,46E-13	6,06E-12	3,34E-12	5,08E-13	8,77E-13	5,78E-13	1,23E-13	2,58E-13
Ru106+ *	3,30E-09	1,60E-09	2,56E-09	2,00E-08	7,04E-09	2,54E-10	4,03E-10	2,39E-10	6,10E-11	4,77E-10
Ag108m+	1,72E-08	1,18E-08	1,88E-08	1,47E-07	4,97E-08	1,07E-09	1,70E-09	1,01E-09	2,58E-10	3,30E-09
Ag110m+	3,21E-08	2,10E-08	3,34E-08	2,62E-07	8,23E-08	1,72E-09	2,73E-09	1,62E-09	4,14E-10	5,49E-09
Sb125+	3,21E-09	2,17E-09	3,51E-09	2,49E-08	2,01E-09	2,93E-10	4,78E-10	2,94E-10	7,06E-11	1,56E-10
Cs134	1,73E-08	1,17E-08	1,85E-08	1,45E-07	4,76E-08	1,01E-09	1,60E-09	9,48E-10	2,42E-10	3,17E-09
Cs137+	6,16E-09	4,18E-09	6,64E-09	5,21E-08	1,73E-08	3,68E-10	5,85E-10	3,47E-10	8,85E-11	1,15E-09
Pm147 *	1,20E-13	1,71E-13	2,79E-13	2,00E-12	1,08E-12	1,69E-13	3,06E-13	2,14E-13	4,09E-14	8,64E-14
Sm151	9,35E-52	8,95E-16	1,42E-15	1,11E-14	5,04E-15	8,89E-16	2,44E-15	2,84E-15	2,21E-16	3,40E-16
Eu152	1,29E-08	8,50E-09	1,35E-08	1,06E-07	3,29E-08	7,08E-10	1,13E-09	6,72E-10	1,70E-10	2,20E-09
Eu154 *	1,42E-08	9,32E-09	1,48E-08	1,16E-07	3,58E-08	7,63E-10	1,21E-09	7,20E-10	1,83E-10	2,39E-09
U234	2,51E-14	8,00E-14	5,17E-13	9,33E-13	5,28E-13	7,85E-14	1,27E-13	7,53E-14	1,89E-14	4,10E-14
U235+	8,05E-10	8,31E-10	1,32E-09	1,04E-08	4,02E-09	1,07E-10	1,67E-10	9,76E-11	2,58E-11	2,64E-10
U238+ *	4,48E-10	1,22E-10	1,99E-10	1,43E-09	3,84E-10	5,58E-11	8,87E-11	5,27E-11	1,34E-11	3,00E-11
Np237+	1,78E-10	1,52E-10	2,50E-10	1,79E-09	1,03E-09	1,49E-10	2,34E-10	1,38E-10	3,57E-11	8,08E-11
Pu238	2,32E-15	4,52E-14	1,15E-13	5,50E-13	2,66E-13	4,48E-14	1,08E-13	1,16E-13	1,10E-14	1,88E-14
Pu239+	3,06E-14	4,65E-14	7,58E-14	5,54E-13	2,99E-13	4,58E-14	8,65E-14	7,06E-14	1,11E-14	2,27E-14
Pu240	2,56E-15	7,63E-14	7,39E-14	5,58E-13	2,73E-13	4,56E-14	1,08E-13	1,13E-13	1,12E-14	1,93E-14
Pu241+	5,82E-16	1,07E-15	1,76E-15	1,26E-14	7,23E-15	1,05E-15	1,63E-15	9,58E-16	2,51E-16	5,71E-16
Am241	1,73E-13	1,58E-11	2,59E-11	1,83E-10	1,02E-10	1,55E-11	2,57E-11	1,55E-11	3,75E-12	7,90E-12
Cm244	4,57E-20	4,03E-14	6,43E-14	4,95E-13	2,30E-13	4,00E-14	1,04E-13	1,14E-13	9,91E-15	1,58E-14
Na-22	2,57E-08	1,68E-08	2,69E-08	2,13E-07	6,64E-08	1,38E-09	2,19E-09	1,29E-09	3,32E-10	4,43E-09

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S-35 *	2,10E-14	8,12E-14	1,32E-14	9,50E-13	4,85E-13	7,96E-15	1,53E-14	1,14E-14	1,94E-15	3,76E-15
Cl-36 *	2,16E-11	5,64E-12	9,20E-13	6,71E-11	3,41E-11	4,57E-13	7,41E-13	4,52E-13	1,10E-13	2,68E-13
K-40	2,02E-09	1,25E-09	2,00E-09	1,56E-08	4,45E-09	9,08E-11	1,45E-10	8,57E-11	2,18E-11	3,00E-10
Ca-45	7,42E-27	4,79E-20	9,91E-20	1,00E-18	3,34E-19	2,91E-20	8,18E-20	1,08E-19	7,19E-21	1,49E-20
Sc-46	2,43E-08	1,56E-08	2,50E-08	1,97E-07	6,03E-08	1,26E-09	1,99E-09	1,18E-09	3,01E-10	4,04E-09
Mn-53	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Co-56	4,50E-08	2,80E-08	4,46E-08	3,48E-07	9,92E-08	2,06E-09	3,28E-09	1,94E-09	4,94E-10	6,70E-09
Co-57	4,00E-10	5,34E-10	8,59E-10	6,94E-09	2,70E-09	7,93E-11	1,23E-10	7,07E-11	1,90E-11	1,79E-10
Co-58	1,13E-08	7,51E-09	1,20E-08	9,57E-08	3,06E-08	6,37E-10	1,01E-09	5,92E-10	1,53E-10	2,04E-09
As-73	1,86E-14	1,40E-11	2,26E-11	1,83E-10	7,21E-11	4,36E-12	6,87E-12	4,00E-12	1,05E-12	5,02E-12
Se-75	2,59E-09	2,19E-09	3,53E-09	2,84E-08	1,05E-08	2,59E-10	4,02E-10	2,33E-10	6,20E-11	6,94E-10
Se-79 *	2,50E-14	1,01E-13	1,64E-14	1,19E-12	6,09E-13	9,98E-15	1,90E-14	1,41E-14	2,43E-15	4,72E-15
Sr-85	5,32E-09	3,71E-09	5,97E-09	4,78E-08	1,62E-08	3,45E-10	5,43E-10	3,19E-10	8,28E-11	1,07E-09
Y-91 *	2,11E-10	5,29E-11	8,53E-11	6,43E-10	2,59E-10	2,52E-11	4,03E-11	2,41E-11	6,07E-12	1,96E-11
Zr-93 *	2,14E-20	3,17E-15	5,04E-15	3,87E-14	1,64E-14	3,16E-15	7,93E-15	8,35E-15	7,86E-16	1,25E-15
Zr-95+	1,75E-08	1,16E-08	1,86E-08	1,48E-07	4,74E-08	9,82E-10	1,55E-09	9,12E-10	2,35E-10	3,15E-09
Nb-93m	7,88E-19	3,62E-13	6,17E-13	5,59E-12	2,03E-12	3,27E-13	9,06E-13	1,04E-12	8,10E-14	1,32E-13
Mo-93	4,42E-18	2,03E-12	3,46E-12	3,13E-11	1,14E-11	1,83E-12	5,08E-12	5,84E-12	4,54E-13	7,39E-13
Tc-97	7,60E-18	2,60E-12	4,38E-12	3,88E-11	1,43E-11	2,38E-12	6,55E-12	7,13E-12	5,91E-13	9,53E-13
Tc-97m	5,20E-13	3,68E-12	6,09E-12	5,19E-11	1,97E-11	2,49E-12	6,54E-12	6,59E-12	6,16E-13	1,32E-12
Pd-107 *	1,20E-36	2,65E-16	4,22E-16	6,89E-16	1,80E-16	2,76E-16	7,59E-16	1,03E-15	6,85E-17	1,05E-16
Cd-109	0,00E+01	8,06E-12	1,34E-11	1,13E-10	4,35E-11	7,84E-12	2,03E-11	1,73E-11	1,95E-12	2,98E-12
Sn-113+	2,39E-09	1,76E-09	2,84E-09	2,28E-08	8,05E-09	1,92E-10	3,15E-10	1,91E-10	4,62E-11	5,32E-10
Sn-126+	2,17E-08	1,49E-08	2,39E-08	1,91E-07	6,29E-08	1,34E-09	2,12E-09	1,24E-09	3,22E-10	4,18E-09
Sb-124	2,28E-08	1,46E-08	2,33E-08	1,83E-07	5,48E-08	1,13E-09	1,80E-09	1,06E-09	2,72E-10	3,68E-09
Te-123m	6,35E-10	6,59E-10	1,06E-09	8,57E-09	3,28E-09	9,89E-11	1,60E-10	9,45E-11	2,38E-11	2,18E-10
Te-127m+ *	4,44E-11	4,18E-12	6,67E-13	5,09E-11	2,31E-11	3,91E-13	9,23E-13	8,04E-13	9,65E-14	1,65E-13
I-125	1,07E-15	4,39E-11	7,16E-11	5,89E-10	2,28E-10	3,57E-11	7,38E-11	5,01E-11	8,75E-12	1,63E-11
I-129	6,25E-16	3,11E-11	5,06E-11	4,14E-10	1,60E-10	2,20E-11	4,10E-11	2,55E-11	5,36E-12	1,15E-11
Cs-135 *	1,09E-13	1,87E-13	3,05E-15	2,20E-12	1,15E-12	1,84E-15	3,34E-15	2,36E-15	4,46E-16	8,99E-16
Ce-139	6,65E-10	6,89E-10	1,11E-09	8,96E-09	3,43E-09	1,10E-10	1,74E-10	1,00E-10	2,64E-11	2,28E-10
Ce-144+	4,46E-10	3,21E-10	5,12E-10	4,03E-09	1,26E-09	3,17E-11	5,03E-11	2,93E-11	7,62E-12	8,48E-11
Sm-147	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01	0,00E+01
Eu-155	7,62E-11	2,16E-10	3,48E-10	2,81E-09	1,11E-09	4,36E-11	6,81E-11	3,89E-11	1,05E-11	7,47E-11
Gd-153	1,01E-10	3,38E-10	5,46E-10	4,42E-09	1,74E-09	8,99E-11	1,43E-10	8,18E-11	2,16E-11	1,19E-10
Tb-160	1,24E-08	8,13E-09	1,30E-08	1,03E-07	3,20E-08	6,84E-10	1,08E-09	6,38E-10	1,64E-10	2,14E-09
Tm-170 *	5,15E-12	1,01E-11	8,29E-12	1,18E-10	6,53E-11	4,94E-12	7,98E-12	4,78E-12	1,19E-12	2,62E-12
Tm-171	2,16E-14	1,75E-12	2,82E-12	2,28E-11	9,00E-12	5,14E-13	8,02E-13	4,54E-13	1,23E-13	6,27E-13
Ta-182	1,48E-08	9,69E-09	1,55E-08	1,22E-07	3,70E-08	7,99E-10	1,27E-09	7,47E-10	1,92E-10	2,48E-09
W-181	2,40E-12	1,08E-10	1,75E-10	1,41E-09	5,59E-10	2,94E-11	4,56E-11	2,58E-11	7,05E-12	3,87E-11

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W-185 *	2,29E-12	1,13E-12	1,84E-13	1,34E-11	6,94E-12	9,68E-14	1,63E-13	1,03E-13	2,34E-14	5,42E-14
Os-185	7,48E-09	5,17E-09	8,30E-09	6,62E-08	2,17E-08	4,71E-10	7,42E-10	4,35E-10	1,13E-10	1,44E-09
Ir-192	7,40E-09	5,45E-09	8,76E-09	7,03E-08	2,47E-08	5,53E-10	8,63E-10	5,02E-10	1,33E-10	1,63E-09
Tl-204 *	1,74E-11	6,55E-12	1,06E-11	7,89E-12	3,89E-12	4,54E-12	7,30E-12	4,43E-12	1,09E-12	2,96E-12
Pb-210+ *	5,70E-11	2,26E-12	3,59E-13	2,80E-11	8,91E-12	1,44E-13	2,63E-13	1,82E-13	3,50E-14	6,84E-14
Bi-207	1,73E-08	1,15E-08	1,84E-08	1,46E-07	4,58E-08	9,77E-10	1,54E-09	9,09E-10	2,34E-10	3,06E-09
Po-210	1,00E-13	6,62E-14	1,06E-13	8,44E-13	2,67E-13	5,54E-15	8,77E-15	5,16E-15	1,33E-15	1,78E-14
Ra-226+	2,07E-08	1,34E-08	2,14E-08	1,68E-07	5,08E-08	1,07E-09	1,70E-09	1,00E-09	2,57E-10	3,41E-09
Ra-228+	1,07E-08	6,99E-09	1,12E-08	8,85E-08	2,76E-08	5,82E-10	9,22E-10	5,44E-10	1,40E-10	1,84E-09
Ac-227+	2,84E-09	2,33E-09	3,75E-09	3,01E-08	1,09E-08	2,66E-10	4,15E-10	2,41E-10	6,38E-11	7,19E-10
Th-228+	1,82E-08	1,15E-08	1,82E-08	1,41E-07	4,01E-08	8,64E-10	1,37E-09	8,11E-10	2,07E-10	2,72E-09
Th-229+	2,35E-09	1,93E-09	3,09E-09	2,48E-08	8,64E-09	2,21E-10	3,47E-10	2,03E-10	5,30E-11	5,74E-10
Th-230	6,34E-13	1,50E-12	2,47E-12	2,04E-11	7,83E-12	3,28E-13	5,88E-13	4,69E-13	7,92E-14	5,11E-13
Th-232	1,77E-13	6,53E-13	1,10E-12	9,34E-12	3,55E-12	1,83E-13	3,63E-13	3,40E-13	4,44E-14	2,24E-13
Pa-231	2,14E-10	1,76E-10	2,83E-10	2,28E-09	8,36E-10	2,22E-11	3,64E-11	2,25E-11	5,34E-12	5,51E-11
U-232	4,24E-13	9,75E-13	1,64E-12	1,40E-11	5,26E-12	2,76E-13	5,79E-13	5,83E-13	6,70E-14	3,30E-13
U-233	5,74E-13	9,49E-13	1,55E-12	1,28E-11	4,94E-12	1,77E-13	3,23E-13	2,67E-13	4,27E-14	3,20E-13
U-236	1,53E-14	3,97E-13	7,00E-13	6,28E-12	2,29E-12	1,56E-13	3,67E-13	4,19E-13	3,82E-14	1,36E-13
Pu-236	2,30E-15	3,69E-13	6,70E-13	6,28E-12	2,21E-12	2,00E-13	5,16E-13	6,33E-13	4,92E-14	1,26E-13
Pu-242	2,72E-16	2,22E-13	4,10E-13	3,92E-12	1,36E-12	1,32E-13	3,49E-13	4,37E-13	3,26E-14	7,55E-14
Pu-244+	3,68E-09	2,48E-09	3,98E-09	3,17E-08	1,02E-08	2,17E-10	3,43E-10	2,04E-10	5,20E-11	6,81E-10
Am-242m+ *	5,07E-11	1,66E-12	1,33E-12	1,99E-11	4,04E-12	3,34E-13	7,42E-13	7,66E-13	8,16E-14	1,48E-13
Am-243+	8,33E-10	1,01E-09	1,63E-09	1,31E-08	5,00E-09	1,49E-10	2,33E-10	1,37E-10	3,58E-11	3,32E-10
Cm-242	6,56E-16	2,91E-13	5,28E-13	5,04E-12	1,75E-12	1,96E-13	5,31E-13	6,69E-13	4,84E-14	1,01E-13
Cm-243	6,40E-10	6,36E-10	1,02E-09	8,26E-09	3,12E-09	8,38E-11	1,31E-10	7,74E-11	2,01E-11	2,06E-10
Cm-245	1,98E-10	2,94E-10	4,73E-10	3,83E-09	1,49E-09	4,59E-11	7,21E-11	4,33E-11	1,10E-11	9,90E-11
Cm-246	1,27E-17	2,10E-13	3,85E-13	3,72E-12	1,28E-12	1,54E-13	4,20E-13	5,31E-13	3,81E-14	7,26E-14
Cm-247+	2,95E-09	2,22E-09	3,58E-09	2,87E-08	1,02E-08	2,31E-10	3,61E-10	2,10E-10	5,53E-11	6,72E-10
Cm-248	1,48E-16	1,82E-13	3,30E-13	3,15E-12	1,09E-12	1,24E-13	3,35E-13	4,22E-13	3,05E-14	6,29E-14
Bk-249 *	2,33E-15	2,70E-14	2,18E-14	3,20E-13	1,56E-13	1,31E-14	2,72E-14	2,23E-14	3,22E-15	5,93E-15
Cf-248	4,19E-18	1,91E-13	3,42E-13	3,27E-12	1,14E-12	1,54E-13	4,25E-13	5,33E-13	3,81E-14	6,76E-14
Cf-249	2,91E-09	2,16E-09	3,47E-09	2,79E-08	9,90E-09	2,22E-10	3,48E-10	2,03E-10	5,33E-11	6,54E-10
Cf-250	1,26E-14	2,59E-13	4,51E-13	4,14E-12	1,48E-12	1,62E-13	4,35E-13	5,35E-13	4,01E-14	9,10E-14
Cf-251	4,79E-10	5,38E-10	8,67E-10	7,00E-09	2,68E-09	7,59E-11	1,19E-10	7,05E-11	1,82E-11	1,78E-10
Cf-252	3,68E-15	2,22E-13	3,89E-13	3,60E-12	1,28E-12	1,49E-13	4,02E-13	4,97E-13	3,68E-14	7,82E-14
Cf-254	1,36E-20	4,88E-17	7,89E-17	6,40E-16	2,50E-16	2,15E-17	3,49E-17	2,00E-17	5,19E-18	1,78E-17
Es-254	1,05E-11	1,47E-11	2,41E-11	2,01E-10	7,47E-11	3,97E-12	8,65E-12	8,76E-12	9,68E-13	4,90E-12

* Bremsstrahlung included for all scenarios for these nuclides

Table 3.3 Committed effective doses for unit intake by ingestion and inhalation

Table 3.3 lists the dose coefficients for unit intake by ingestion and inhalation of various radionuclides. These values are taken from the Basic Safety Standards[5]. Values are given for members of the public (adults, 10 year old children and infants of one year) and workers (adults). The choice of dose coefficient is given in the Appendices A and B. The maximum value for each nuclide and age group was extracted from ref. 5, Table (A) and (B) for members of the public and Table (C) for workers.

Below is listed a brief summary of all parameters used in the table.

Parameter	Description
Nuclide	The radionuclide the other parameters are associated to. If denoted by a ”+” the nuclide is assumed to be in secular equilibrium with its short lived daughter(s), eg. ”Sr90+” is ^{90}Sr in equilibrium with ^{90}Y.
DF_{ING}	Dose coefficient for public or workers for ingestion (Sv Bq^{-1}).
DF_{INH}	Dose coefficient for public or workers for inhalation (Sv Bq^{-1}).

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TABLE 3.3: DOSE COEFFICIENTS FOR INGESTION AND INHALATION

NUCLIDE	PUBLIC - Ingestion			PUBLIC - Inhalation			WORKER - Ingestion	WORKER - Inhalation
	DF_{ing} adult	DF_{ing} child - 10y (Sv/Bq)	DF_{ing} baby - 1y	DF_{inh} adult	DF_{inh} child - 10y (Sv/Bq)	DF_{inh} baby - 1y	DF_{ing} adult (Sv/Bq)	DF_{inh} adult (Sv/Bq)
H3	1,80E-11	2,30E-11	4,80E-11	2,60E-10	3,80E-10	1,00E-09	1,80E-11	1,80E-11
C14	5,80E-10	8,00E-10	1,60E-09	5,80E-09	7,40E-09	1,70E-08	5,80E-10	5,80E-10
Mn54	7,10E-10	1,30E-09	3,10E-09	1,50E-09	2,40E-09	6,20E-09	7,10E-10	1,20E-09
Fe55	3,30E-10	1,10E-09	2,40E-09	7,70E-10	1,40E-09	3,20E-09	3,30E-10	9,20E-10
Co60	3,40E-09	1,10E-08	2,70E-08	3,10E-08	4,00E-08	8,60E-08	3,40E-09	1,70E-08
Ni59	6,30E-11	1,10E-10	3,40E-10	4,40E-10	5,90E-10	1,50E-09	6,30E-11	2,20E-10
Ni63	1,50E-10	2,80E-10	8,40E-10	1,30E-09	1,70E-09	4,30E-09	1,50E-10	5,20E-10
Zn65	3,90E-09	6,40E-09	1,60E-08	2,20E-09	3,80E-09	1,00E-08	3,90E-09	2,80E-09
Sr90+	3,07E-08	6,59E-08	9,30E-08	1,62E-07	1,83E-07	4,09E-07	3,07E-08	7,87E-08
Nb94	1,70E-09	3,40E-09	9,70E-09	4,90E-08	5,80E-08	1,20E-07	1,70E-09	2,50E-08
Tc99	6,40E-10	1,30E-09	4,80E-09	1,30E-08	1,70E-08	3,70E-08	7,80E-10	3,20E-09
Ru106+	7,00E-09	1,50E-08	4,90E-08	6,60E-08	9,10E-08	2,30E-07	7,00E-09	3,50E-08
Ag108m+	2,30E-09	4,30E-09	1,10E-08	3,70E-08	4,40E-08	8,70E-08	2,30E-09	1,90E-08
Ag110m+	2,80E-09	5,20E-09	1,40E-08	1,20E-08	1,80E-08	4,10E-08	2,80E-09	7,30E-09
Sb125+	1,30E-09	2,53E-09	7,54E-09	1,30E-08	1,73E-08	4,10E-08	1,30E-09	3,96E-09
Cs134	1,90E-08	1,40E-08	1,60E-08	2,00E-08	2,80E-08	6,30E-08	1,90E-08	9,60E-09
Cs137+	1,30E-08	1,00E-08	1,20E-08	3,90E-08	4,80E-08	1,00E-07	1,30E-08	6,70E-09
Pm147	2,60E-10	5,70E-10	1,90E-09	5,00E-09	7,00E-09	1,80E-08	2,60E-10	3,50E-09
Sm151	9,80E-11	2,00E-10	6,40E-10	4,00E-09	4,50E-09	1,00E-08	9,80E-11	2,60E-09
Eu152	1,40E-09	2,60E-09	7,40E-09	4,20E-08	4,90E-08	1,00E-07	1,40E-09	2,70E-08
Eu154	2,00E-09	4,10E-09	1,20E-08	5,30E-08	6,50E-08	1,50E-07	2,00E-09	3,50E-08
U234	4,90E-08	7,40E-08	1,30E-07	9,40E-06	1,20E-05	2,90E-05	4,90E-08	6,80E-06
U235+	4,73E-08	7,17E-08	1,33E-07	8,50E-06	1,10E-05	2,60E-05	4,63E-08	6,10E-06
U238+	4,89E-08	7,64E-08	1,48E-07	8,01E-06	1,00E-05	2,50E-05	4,79E-08	5,71E-06
Np237+	1,11E-07	1,12E-07	2,16E-07	5,00E-05	5,00E-05	9,30E-05	1,11E-07	1,50E-05
Pu238	2,30E-07	2,40E-07	4,00E-07	1,10E-04	1,10E-04	1,90E-04	2,30E-07	3,00E-05
Pu239	2,50E-07	2,70E-07	4,20E-07	1,20E-04	1,20E-04	2,00E-04	2,50E-07	3,20E-05
Pu240	2,50E-07	2,70E-07	4,20E-07	1,20E-04	1,20E-04	2,00E-04	2,50E-07	3,20E-05
Pu241	4,80E-09	5,10E-09	5,70E-09	2,30E-06	2,40E-06	2,90E-06	4,70E-09	5,80E-07
Am241	2,00E-07	2,20E-07	3,70E-07	9,60E-05	1,00E-04	1,80E-04	2,00E-07	2,70E-05
Cm244	1,20E-07	1,40E-07	2,90E-07	5,70E-05	6,10E-05	1,30E-04	1,20E-07	1,70E-05

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Na-22	3,20E-09	5,50E-09	1,50E-08	1,30E-09	2,40E-09	7,30E-09	3,20E-09	2,00E-09
S-35	7,70E-10	1,60E-09	5,40E-09	1,90E-09	2,60E-09	6,00E-09	7,70E-10	1,10E-09
Cl-36	9,30E-10	1,90E-09	6,30E-09	7,30E-09	1,00E-08	2,60E-08	9,30E-10	5,10E-09
K-40	6,20E-09	1,30E-08	4,20E-08	2,10E-09	4,50E-09	1,70E-08	6,20E-09	3,00E-09
Ca-45	7,10E-10	1,80E-09	4,90E-09	3,70E-09	5,10E-09	1,20E-08	7,60E-10	2,30E-09
Sc-46	1,50E-09	2,90E-09	7,90E-09	6,80E-09	9,80E-09	2,30E-08	1,50E-09	4,80E-09
Mn-53	3,00E-11	6,50E-11	2,20E-10	5,40E-11	1,00E-10	3,40E-10	3,00E-11	3,60E-11
Co-56	2,50E-09	5,80E-09	1,50E-08	6,70E-09	1,00E-08	2,50E-08	2,50E-09	4,90E-09
Co-57	2,10E-10	5,80E-10	1,60E-09	1,00E-09	1,50E-09	3,70E-09	2,10E-10	6,00E-10
Co-58	7,40E-10	1,70E-09	4,40E-09	2,10E-09	3,10E-09	7,50E-09	7,40E-10	1,70E-09
As-73	2,60E-10	5,60E-10	1,90E-09	1,00E-09	1,50E-09	4,00E-09	2,60E-10	6,50E-10
Se-75	2,60E-09	6,00E-09	1,30E-08	1,30E-09	2,50E-09	6,00E-09	2,60E-09	1,70E-09
Se-79	2,90E-09	1,40E-08	2,80E-08	6,80E-09	8,70E-09	2,00E-08	2,90E-09	3,10E-09
Sr-85	5,60E-10	1,50E-09	3,10E-09	8,10E-10	1,30E-09	3,70E-09	5,60E-10	5,60E-10
Y-91	2,40E-09	5,20E-09	1,80E-08	8,90E-09	1,30E-08	3,40E-08	2,40E-09	6,10E-09
Zr-93	1,10E-09	5,80E-10	7,60E-10	2,50E-08	9,70E-09	6,40E-09	2,80E-10	2,90E-08
Zr-95+	1,53E-09	3,00E-09	8,81E-09	7,69E-09	1,08E-08	2,49E-08	1,46E-09	5,50E-09
Nb-93m	1,20E-10	2,70E-10	9,10E-10	1,80E-09	2,50E-09	6,50E-09	1,20E-10	8,60E-10
Mo-93	3,10E-09	4,00E-09	6,90E-09	2,30E-09	2,80E-09	5,80E-09	2,60E-09	1,40E-09
Tc-97	6,80E-11	1,40E-10	4,90E-10	1,80E-09	2,20E-09	4,80E-09	8,30E-11	1,60E-10
Tc-97m	5,50E-10	1,10E-09	4,10E-09	4,10E-09	5,70E-09	1,30E-08	6,60E-10	2,70E-09
Pd-107	3,70E-11	8,10E-11	2,80E-10	5,90E-10	7,80E-10	2,00E-09	3,70E-11	2,90E-10
Cd-109	2,00E-09	3,50E-09	9,50E-09	8,10E-09	1,40E-08	3,70E-08	2,00E-09	9,60E-09
Sn-113+	7,58E-10	1,66E-09	5,18E-09	2,72E-09	4,04E-09	1,01E-08	7,58E-10	1,93E-09
Sn-126+	5,07E-09	1,06E-08	3,22E-08	2,85E-08	4,17E-08	1,02E-07	5,07E-09	1,85E-08
Sb-124	2,50E-09	5,20E-09	1,60E-08	8,60E-09	1,30E-08	3,10E-08	2,50E-09	4,70E-09
Te-123m	1,40E-09	2,80E-09	8,80E-09	5,10E-09	7,10E-09	1,60E-08	1,40E-09	3,40E-09
Te-127m+	2,47E-09	5,55E-09	1,92E-08	9,94E-09	1,43E-08	3,38E-08	2,47E-09	6,38E-09
I-125	1,50E-08	3,10E-08	5,70E-08	5,10E-09	1,10E-08	2,30E-08	1,50E-08	7,30E-09
I-129	1,10E-07	1,90E-07	2,20E-07	3,60E-08	6,70E-08	8,60E-08	1,10E-07	5,10E-08
Cs-135	2,00E-09	1,70E-09	2,30E-09	8,60E-09	1,10E-08	2,40E-08	2,00E-09	9,90E-10
Ce-139	2,60E-10	5,40E-10	1,60E-09	1,90E-09	2,80E-09	8,50E-09	2,60E-10	1,40E-09
Ce-144+	5,25E-09	1,11E-08	3,93E-08	5,30E-08	7,80E-08	2,70E-07	5,25E-09	2,90E-08
Sm-147	4,90E-08	6,40E-08	1,40E-07	9,60E-06	1,10E-05	2,30E-05	4,90E-08	6,10E-06
Eu-155	3,20E-10	6,80E-10	2,20E-09	6,90E-09	9,20E-09	2,30E-08	3,20E-10	4,70E-09
Gd-153	2,70E-10	5,80E-10	1,80E-09	2,10E-09	3,90E-09	1,20E-08	2,70E-10	2,50E-09
Tb-160	1,60E-09	3,30E-09	1,00E-08	7,00E-09	1,00E-08	2,50E-08	1,60E-09	5,40E-09
Tm-170	1,30E-09	2,90E-09	9,80E-09	7,00E-09	1,10E-08	2,80E-08	1,30E-09	5,20E-09
Tm-171	1,10E-10	2,30E-10	7,80E-10	1,40E-09	2,00E-09	5,70E-09	1,10E-10	9,10E-10

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Ta-182	1,50E-09	3,10E-09	9,40E-09	1,00E-08	1,50E-08	3,40E-08	1,50E-09	7,40E-09
W-181	7,60E-11	1,60E-10	4,70E-10	2,70E-11	5,70E-11	1,90E-10	7,60E-11	4,30E-11
W-185	4,40E-10	9,70E-10	3,30E-09	1,20E-10	2,70E-10	1,00E-09	4,40E-10	2,20E-10
Os-185	5,10E-10	9,80E-10	2,60E-09	1,60E-09	2,40E-09	5,80E-09	5,10E-10	1,40E-09
Ir-192	1,40E-09	2,80E-09	8,70E-09	6,60E-09	9,50E-09	2,20E-08	1,40E-09	4,90E-09
Tl-204	1,20E-09	2,50E-09	8,50E-09	3,90E-10	8,80E-10	3,30E-09	1,30E-09	6,20E-10
Pb-210+	6,91E-07	1,90E-06	3,61E-06	5,69E-06	7,33E-06	1,83E-05	6,81E-07	1,16E-06
Bi-207	1,30E-09	2,50E-09	7,10E-09	5,60E-09	8,20E-09	2,00E-08	1,30E-09	3,20E-09
Po-210	1,20E-06	2,60E-06	8,80E-06	4,30E-06	5,90E-06	1,40E-05	2,40E-07	2,20E-06
Ra-226+	2,80E-07	8,01E-07	9,62E-07	9,53E-06	1,20E-05	2,91E-05	2,80E-07	2,23E-06
Ra-228+	6,90E-07	3,90E-06	5,70E-06	1,60E-05	2,01E-05	4,82E-05	6,70E-07	1,73E-06
Ac-227+	1,21E-06	1,97E-06	4,26E-06	5,68E-04	7,45E-04	1,65E-03	1,21E-06	6,43E-04
Th-228+	1,43E-07	4,31E-07	1,09E-06	4,36E-05	5,97E-05	1,60E-04	1,41E-07	3,45E-05
Th-229+	6,13E-07	1,17E-06	2,38E-06	2,56E-04	3,11E-04	5,55E-04	5,99E-07	8,03E-05
Th-230	2,10E-07	2,40E-07	4,10E-07	1,00E-04	1,10E-04	2,00E-04	2,10E-07	2,80E-05
Th-232	2,30E-07	2,90E-07	4,50E-07	1,10E-04	1,30E-04	2,20E-04	2,20E-07	2,90E-05
Pa-231	7,10E-07	9,20E-07	1,30E-06	1,40E-04	1,50E-04	2,30E-04	7,10E-07	8,90E-05
U-232	3,30E-07	5,70E-07	8,20E-07	3,70E-05	4,30E-05	9,70E-05	3,30E-07	2,60E-05
U-233	5,10E-08	7,80E-08	1,40E-07	9,60E-06	1,20E-05	3,00E-05	5,00E-08	6,90E-06
U-236	4,70E-08	7,00E-08	1,30E-07	8,70E-06	1,10E-05	2,70E-05	4,60E-08	6,30E-06
Pu-236	8,70E-08	1,00E-07	2,20E-07	4,00E-05	4,40E-05	9,50E-05	8,60E-08	1,30E-05
Pu-242	2,40E-07	2,60E-07	4,00E-07	1,10E-04	1,20E-04	1,90E-04	2,40E-07	3,10E-05
Pu-244+	2,41E-07	2,62E-07	4,18E-07	1,10E-04	1,20E-04	1,90E-04	2,41E-07	3,00E-05
Am-242m+	1,90E-07	2,01E-07	3,02E-07	9,20E-05	9,40E-05	1,50E-04	1,90E-07	2,40E-05
Am-243+	2,01E-07	2,22E-07	3,76E-07	9,60E-05	1,00E-04	1,70E-04	2,01E-07	2,70E-05
Cm-242	1,20E-08	2,40E-08	7,60E-08	5,90E-06	8,20E-06	2,10E-05	1,20E-08	3,70E-06
Cm-243	1,50E-07	1,60E-07	3,30E-07	6,90E-05	7,30E-05	1,50E-04	1,50E-07	2,00E-05
Cm-245	2,10E-07	2,30E-07	3,70E-07	9,90E-05	1,00E-04	1,80E-04	2,10E-07	2,70E-05
Cm-246	2,10E-07	2,20E-07	3,70E-07	9,80E-05	1,00E-04	1,80E-04	2,10E-07	2,70E-05
Cm-247+	1,90E-07	2,10E-07	3,51E-07	9,00E-05	9,40E-05	1,60E-04	1,90E-07	2,50E-05
Cm-248	7,70E-07	8,40E-07	1,40E-06	3,60E-04	3,70E-04	6,50E-04	7,70E-07	9,50E-05
Bk-249	9,70E-10	1,40E-09	2,90E-09	1,60E-07	1,80E-07	3,30E-07	9,70E-10	1,00E-07
Cf-248	2,80E-08	6,00E-08	1,60E-07	8,80E-06	1,40E-05	3,20E-05	2,80E-08	6,10E-06
Cf-249	3,50E-07	4,70E-07	8,70E-07	7,00E-05	8,00E-05	1,50E-04	3,50E-07	4,50E-05
Cf-250	1,60E-07	2,30E-07	5,50E-07	3,40E-05	4,20E-05	9,80E-05	1,60E-07	2,20E-05
Cf-251	3,60E-07	4,70E-07	8,80E-07	7,10E-05	8,10E-05	1,50E-04	3,60E-07	4,60E-05
Cf-252	9,00E-08	1,90E-07	5,10E-07	2,00E-05	3,20E-05	8,70E-05	9,00E-08	1,30E-05
Cf-254	4,00E-07	8,40E-07	2,60E-06	4,10E-05	7,00E-05	1,90E-04	4,00E-07	2,20E-05
Es-254	2,80E-08	6,00E-08	1,60E-07	8,60E-06	1,30E-05	3,10E-05	2,80E-08	6,00E-06

Table 3.4 Root concentration factors and animal transfer factors

The green vegetable root concentration factor (GVCF) and root vegetable concentration factor (RVCF) represent the accumulation of various radionuclides in two types of plants, via root uptake from the soil. This can then be used to calculate the ingested activities of each radionuclide and hence produce the doses from ingestion of contaminated foodstuffs. Similarly the animal transfer rate (F_T) is used to calculate the activity of radionuclides, from ingestion of copper in pig feed, transferred to an animal (in this case a pig) which is subsequently consumed by an adult human.

The data apply to all relevant scenarios and types of VLLW. The table gives values for all relevant radionuclides. Below is a description of the headings and parameters used

Parameter	Description
Nuclide	The radionuclide the other parameters are associated to. If denoted by a ”+” the nuclide is assumed to be in secular equilibrium with its short lived daughter(s), eg. ”Sr90+” is ^{90}Sr in equilibrium with ^{90}Y.
F_T	The animal transfer rate, in Bq kg^{-1} per Bq d^{-1}. This is a measure of how quickly different radionuclides are taken up by an animal. In this case a pig is used.
GVCF	The root concentration factor for green vegetables, via root uptake.
RVCF	The root concentration factor for root vegetables, via root uptake.

Appendix D

TABLE 3.4: ROOT CONCENTRATION FACTORS AND ANIMAL TRANSFER RATES

NUCLIDE	Green vegetable root concentration factor GVCF	Root vegetable root concentration factor RVCF	Animal transfer rate F_T Bq kg^{-1} per Bq d^{-1}
H3	5,00E-00	5,00E-00	1,00E-00
C14	2,00E-00	1,00E-00	1,00E-00
Mn54	1,00E-01	1,00E-01	3,60E-03
Fe55	2,00E-04	3,00E-04	2,60E-02
Co60	1,00E-02	1,00E-02	1,70E-01
Ni59	1,00E-02	1,00E-02	3,00E-03
Ni63	1,00E-02	1,00E-02	3,00E-03
Zn65	1,00E-00	5,00E-01	1,50E-01
Sr90+	3,00E-01	1,00E-01	3,90E-02
Nb94	1,00E-02	1,00E-02	1,00E-02
Tc99	5,00E-00	5,00E-00	1,00E-00
Ru106+	1,00E-02	1,00E-02	1,00E-02
Ag108m+	2,00E-01	2,00E-01	5,50E-03
Ag110m+	2,00E-01	2,00E-01	5,50E-03
Sb125+	1,00E-02	1,00E-02	1,00E-02
Cs134	7,00E-03	5,00E-03	2,50E-01
Cs137+	7,00E-03	5,00E-03	2,50E-01
Pm147	3,00E-03	3,00E-03	1,00E-00
Sm151	2,00E-03	2,00E-03	1,00E-00
Eu152	3,00E-03	3,00E-03	1,00E-02
Eu154	3,00E-03	3,00E-03	1,00E-02
U234	1,00E-03	1,00E-03	4,00E-02
U235+	1,00E-03	1,00E-03	4,00E-02
U238+	1,00E-03	1,00E-03	4,00E-02
Np237+	2,00E-03	1,00E-03	5,00E-03
Pu238	1,00E-05	5,00E-05	1,00E-04
Pu239	1,00E-05	5,00E-05	1,00E-04
Pu240	1,00E-05	5,00E-05	1,00E-04
Pu241	1,00E-05	5,00E-05	1,00E-04
Am241	5,00E-05	8,00E-05	2,00E-04
Cm244	5,00E-05	3,00E-05	1,00E-02
Na-22	4,00E-01	4,00E-01	8,00E-02
S-35	6,00E-01	6,00E-01	1,00E-01
Cl-36	5,00E-00	5,00E-00	8,00E-02
K-40	1,00E-00	1,00E-00	2,00E-02
Ca-45	6,00E-02	6,00E-02	1,00E-03
Sc-46	2,00E-01	2,00E-01	2,00E-02
Mn-53	1,00E-01	1,00E-01	3,60E-03
Co-56	1,00E-02	1,00E-02	1,70E-01
Co-57	1,00E-02	1,00E-02	1,70E-01
Co-58	1,00E-02	1,00E-02	1,70E-01
As-73	2,00E-03	2,00E-03	2,00E-03
Se-75	1,00E-00	1,00E-00	2,00E-02
Se-79	1,00E-00	1,00E-00	2,00E-02
Sr-85	3,00E-01	1,00E-01	3,90E-02
Y-91	1,00E-02	1,00E-02	1,00E-03
Zr-93	1,00E-04	1,00E-04	2,00E-02
Zr-95+	1,00E-04	1,00E-04	2,00E-02
Nb-93m	1,00E-02	1,00E-02	1,00E-02
Mo-93	1,00E-01	1,00E-02	7,00E-03
Tc-97	5,00E-00	5,00E-00	1,00E-00
Tc-97m	5,00E-00	5,00E-00	1,00E-00

TABLE 3.4 (cont.)			
Pd-107	2,00E-02	2,00E-02	4,00E-03
Cd-109	4,00E-01	4,00E-01	4,00E-04
Sn-113+	1,00E-01	6,00E-02	8,00E-02
Sn-126+	1,00E-01	6,00E-02	8,00E-02
Sb-124	1,00E-02	1,00E-02	1,00E-02
Te-123m	3,00E-03	4,00E-04	8,00E-02
Te-127m+	3,00E-03	4,00E-04	8,00E-02
I-125	2,00E-02	2,00E-02	1,00E-02
I-129	2,00E-02	2,00E-02	1,00E-02
Cs-135	7,00E-03	5,00E-03	2,50E-01
Ce-139	1,00E-03	1,00E-03	2,00E-03
Ce-144+	1,00E-03	1,00E-03	2,00E-03
Sm-147	2,00E-03	2,00E-03	1,00E-00
Eu-155	3,00E-03	3,00E-03	5,00E-03
Gd-153	3,00E-03	3,00E-03	4,00E-03
Tb-160	3,00E-03	3,00E-03	5,00E-03
Tm-170	3,00E-03	3,00E-03	5,00E-03
Tm-171	3,00E-03	3,00E-03	5,00E-03
Ta-182	7,00E-03	7,00E-03	5,00E-01
W-181	2,00E-02	2,00E-02	4,00E-02
W-185	2,00E-02	2,00E-02	4,00E-02
Os-185	5,00E-02	5,00E-02	4,00E-01
Ir-192	2,00E-02	2,00E-02	2,00E-03
Tl-204	3,00E-01	3,00E-01	4,00E-02
Pb-210+	1,00E-02	1,00E-02	4,00E-04
Bi-207	2,00E-01	2,00E-01	2,00E-02
Po-210	2,00E-04	2,00E-04	5,00E-03
Ra-226+	1,00E-02	1,00E-02	9,00E-04
Ra-228+	1,00E-02	1,00E-02	9,00E-04
Ac-227+	1,00E-03	1,00E-03	6,00E-02
Th-228+	5,00E-04	5,00E-04	2,00E-04
Th-229+	5,00E-04	5,00E-04	2,00E-04
Th-230	5,00E-04	5,00E-04	2,00E-04
Th-232	5,00E-04	5,00E-04	2,00E-04
Pa-231	4,00E-02	4,00E-02	5,00E-03
U-232	1,00E-03	1,00E-03	4,00E-02
U-233	1,00E-03	1,00E-03	4,00E-02
U-236	1,00E-03	1,00E-03	4,00E-02
Pu-236	1,00E-05	5,00E-05	1,00E-04
Pu-242	1,00E-05	5,00E-05	1,00E-04
Pu-244+	1,00E-05	5,00E-05	1,00E-04
Am-242m+	5,00E-05	8,00E-05	2,00E-04
Am-243+	5,00E-05	8,00E-05	2,00E-04
Cm-242	5,00E-05	3,00E-05	1,00E-02
Cm-243	5,00E-05	3,00E-05	1,00E-02
Cm-245	5,00E-05	3,00E-05	1,00E-02
Cm-246	5,00E-05	3,00E-05	1,00E-02
Cm-247+	5,00E-05	3,00E-05	1,00E-02
Cm-248	5,00E-05	3,00E-05	1,00E-02
Bk-249	3,00E-03	3,00E-03	2,00E-04
Cf-248	3,00E-03	3,00E-03	2,00E-04
Cf-249	3,00E-03	3,00E-03	2,00E-04
Cf-250	3,00E-03	3,00E-03	2,00E-04
Cf-251	3,00E-03	3,00E-03	2,00E-04
Cf-252	3,00E-03	3,00E-03	2,00E-04
Cf-254	3,00E-03	3,00E-03	2,00E-04
Es-254	3,00E-03	3,00E-03	2,00E-04