INTRODUCTION OF THE DERIVED LIMITS FOR RADIOACTIVE CONTAMINATION ON SURFACE BASED ON THE ICRP PUBLICATION 61.

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Abstract.

By analyzing the publications of National Radiological Protection Board-NRPB-DL1(1), NRBP-DL2(2) and NRPB-DL2 Supplement(3) that determined the derived limits for surface contamination, based on publications ICRP 26(4) and 30(5), we had determined the new limits based on publications ICRP 60(6) and 61(7) using the same factors found in the publications mentioned above.

1. Introduction.

We had determined the new limits based on publications ICRP 60 and 61 using the same factors found in the publications mentioned above. For this we make a summary of the models and equations adopted in the publications of National Radiological Protection Board-NRPB-DL1, NRBP-DL2 and NRPB-DL2 Supplement and of the modifications that we had to introduce to adjust to the LIAs' values presented in the publication ICRP 61.

2. The Model of Derived Limits for External Irradiation of Hand in Active Areas is:

$$DL=\frac{0,25}{D_1}$$

Where:

DL = derived limit ($Bq.cm^{-2}$)

0,25 is the results of the following considerations:

The skin in active areas, it is assumed that the skin is in continuos contact with the contaminated surfaces during working hours;

The dose equivalent limit for skin recommended by ICRP is 0,5 Sv in a year based on the prevention of non-stochastic effects; For workers exposed for 2000 hours each year.

D_1 = average of the equivalent dose rates per units surface activity at tissue depths of 50 and 100 mm ($mSvh^{-1}$ Bq^{-1} cm^2) (4)

As there was not modified in the ICRP 60 the limit value for hand, the equation still keeps valid, and also the table based on it.

3. The Model of Derived Limits for Inhalation of Ressuspended Activity in Active Areas is:

$$DL = \frac{DAC \cdot 10^{-6}}{RF \cdot 10^{-2}}$$

Where:

DAC= derived air concentration for workers (Bq m^{-3})
RF = ressuspension factor (4)
10^{-6} is a conversion factor of DAC given from m^3 to cm^3
10^{-2} is a conversion factor of RF given from m^{-1} to cm^{-1}.

On this equation there is only one variable that changed, the DAC, which assumes values according to ALI's inhalation values from ICRP 61 publication.

4. The Model of Derived Limits for External Irradiation of Hand in the Case of Body Surface Contamination is:

$$DL = \frac{0,057}{D_1}$$

Where:

DL = derived limit (Bq cm^{-2})

0,057 is the results of the following considerations:

The model used for contamination on the skin assumes very cautiously that the contamination does persist throughout the year;

Since the recommended dose equivalent limit for skin is 0,5 Sv in a year;

The average level of skin contamination should not give a dose equivalent rate to the basal layer of the epidermis exceeding 57 mSv h^{-1};

The DL is then the surface activity that would deliver this dose equivalent rate to the basal layer.

D_1 = average of the equivalent dose rates per units surface activity at tissue depths of 50 and 100 mm (mSv h^{-1} Bq^{-1} cm^2) (4)

As there was not modified in the ICRP 60 the limit value for hand, the equation still keeps valid, and also the table based on it.

5. The Model of Derived Limits for Ingestion of Material on the Skin in the Surfaces of the Body is:

$$DL = \frac{ALI}{5 \cdot 50 \cdot 10}$$

Where:

ALI= annual limit of intake via ingestion for workers (Bq).
5 = working days in a week.
50 = weeks in a year.

Contamination on the skin may be transferred to the mouth and swallowed.

It is appropriately cautions to assume that a person ingest all activity from 10 cm^2 of contaminates skin each working day.

The DL is then activity on 10 cm^2 of skin, which if ingested each working day, would give an intake corresponding to the ALI for radionuclide of interest.

On this equation there is only one variable that changed, the ALI, which assumes values according to ALI's ingestion values from ICRP 61 publication.

We also did the analysis of the radionuclides that had shown variation in their old standard classification reaching other bands.

6. RESULTS

Table 1- Isotopes Classification

Isotopo	Classe	Isotopo	Classe	Isotopo	Classe	Isotopo	Classe	Isotopo	Classe
3 H	VI	64 Cu	IV	111 In	IV	226 Ra	II	238 U	I
14 C	IV	65 Zn	V	123 I	IV	227 Ac	I	239 Pu	I
22 Na	IV	67 Cu	IV	125 I	V	227 Th	II	240 Pu	I
33 P	IV	67 Ga	IV	129 Cs	V	228 Th	I	241 Am	I
35 S	IV	68 Ge	IV	131 Cs	VI	228 Ra	III	241 Pu	III
43 K	IV	68 Ga	IV	147 Sm	III	230 Th	I	242 Pu	I
45 Ca	IV	75 Se	V	147 Pm	IV	231 Pa	I	244 Cm	I
51 Cr	VI	77 Br	V	169 Yb	IV	232 U	I	113m In	IV
52 Fe	III	81 Rb	IV	197 Hg	V	232 Th	I	87m Sr	V
54 Mn	V	85 Sr	V	204 Tl	IV	233 U	I	99m Tc	IV
55 Fe	VI	87 Y	IV	210 Pb	II	234 U	I	DEPL U	II
56 Co	IV	90 Sr	III	210 Po	II	235 U	II	ENR U	II
57 Co	V	90 Y	IV	210 Bi	IV	236 U	II	NAT Th	II
58 Co	IV	99 Mo	IV	223 Ra	II	237 Np	I	NAT U	II
63 Ni	VI	109 Cd	IV	224 Ra	III	238 Pu	I		

Table 2 - Initial Classification of DLs for Active Area Surfaces and Skin

	I	II	III	IV	V	VI
Active Area	0.1	1	10	100	1 000	10 000
Skin	10	10	10	10	100	1 000

7. References

1. Harrison, N.T.; Bryant, P.M.; Clarke, R.H.; Morley, F.M. National Radiological Protection Board, NRPB-DL1, The estimation of derived limits. 1979

2. Wrixon, A.D,; Linsley, G.S.; Binns, K.C.; White, D.F.; National Radiological Protection Board, NRBP-DL2, Derived limits for surface contamination. 1979

3. Wrixon, A.D.; Linsley, G.S.; National Radiological Protection Board, NRBP-DL2 Supplement, Derived limits for surface contamination. 1982

4. ICRP Publication 26. Recommendation of the International Commission on Radiological Protection. 1977

5. ICRP Publication 30. Limits of intakes of radionuclides by workers. 1979

6. ICRP Publication 60. Recommendations of the International Commission on Radiological Protection. 1990

7. ICRP Publication 61. Annual limits on intake of radionuclides by workers based on the 1990 recommendations. 1991

Table 3 - DLs for active area surface contamination

ISOTOPE	Exposure pathway			
	external irradiation of skin		Inhalation	
	D1 ($mSv.h^{-1}.Bq^{-1}.cm^2$)	DL ($Bq.cm^{-2}$)	DAC ($Bq.m^{-3}$)	DL ($Bq.cm^{-2}$)
3H			4.00E+05	8.00E+05
14C	3.00E-04	8.00E+02	2.00E+04	3.00E+04
22Na	2.00E-03	1.00E+02	4.00E+03	8.00E+03
33P	8.00E-04	3.00E+02	1.00E+04	2.00E+04
35S	3.00E-04	8.00E+02	1.00E+04	2.00E+04
43K	2.00E-03	1.00E+02	4.00E+04	8.00E+04
45Ca	8.00E-04	3.00E+02	4.00E+03	8.00E+03
51Cr	1.00E-05	2.00E+04	8.00E+04	2.00E+05
54Mn	6.00E-05	4.00E+03	4.00E+03	8.00E+03
52Fe	4.00E-03	6.00E+01	2.00E+04	3.00E+04
55Fe	1.00E-05	2.00E+04	1.00E+04	2.00E+04
56Co	6.00E-04	4.00E+02	8.00E+02	2.00E+03
57Co	9.00E-05	3.00E+03	3.00E+03	6.00E+03
58Co	4.00E-04	6.00E+02	3.00E+03	6.00E+03
63Ni	5.00E-08	5.00E+06	8.00E+03	2.00E+04
64Cu	1.00E-03	2.00E+02	1.00E+05	2.00E+05
67Cu	2.00E-03	1.00E+02	2.00E+04	4.00E+04
65Zn	9.00E-05	3.00E+03	2.00E+03	3.00E+03
67Ga	3.00E-04	9.00E+02	4.00E+04	8.00E+04
68Ga	2.00E-03	1.00E+02	2.00E+05	4.00E+05
68Ge	2.00E-03	1.00E+02	4.00E+02	8.00E+02
75Se	1.00E-04	2.00E+03	4.00E+03	8.00E+03
77Br	9.00E-05	3.00E+03	1.00E+05	2.00E+05
81Rb	2.00E-03	2.00E+02	2.00E+05	4.00E+05
85Sr	6.00E-05	4.00E+03	4.00E+03	8.00E+03
87mSr	4.00E-05	6.00E+03	8.00E+05	2.00E+06
90Sr	2.00E-03	1.00E+02	2.00E+01	5.00E+01
87Y	5.00E-04	5.00E+02	2.00E+04	3.00E+04
90Y	2.00E-03	1.00E+02	3.00E+03	6.00E+03
99Mo	2.00E-03	1.00E+02	8.00E+03	2.00E+04
99mTc	3.00E-04	1.00E+03	8.00E+05	2.00E+06
109Cd	1.00E-05	2.00E+04	4.00E+02	8.00E+02
111In	4.00E-04	6.00E+02	4.00E+04	7.00E+04
113mIn	9.00E-04	3.00E+02	8.00E+05	2.00E+06
123I	4.00E-04	7.00E+02	8.00E+04	2.00E+05
125I	2.00E-05	1.00E+04	8.00E+02	2.00E+03
129Cs	9.00E-05	3.00E+03	2.00E+05	4.00E+05
131Cs	1.00E-05	2.00E+04	2.00E+05	4.00E+05
147Pm	7.00E-04	3.00E+02	8.00E+02	2.00E+03
147Sm			8.00E-01	2.00E+01
169Yb	2.00E-03	1.00E+02	4.00E+03	7.00E+03
197Hg	2.00E-04	2.00E+03	2.00E+04	5.00E+04
204Tl	2.00E-03	1.00E+02	2.00E+04	3.00E+04
210Pb	4.00E-04	7.00E+02	4.00E+00	8.00E+00
210Bi	2.00E-03	1.00E+02	2.00E+02	3.00E+02
210Po			4.00E+00	8.00E+00
223Ra			4.00E+00	8.00E+00
224Ra			8.00E+00	2.00E+01
226Ra			4.00E+00	7.00E+00
228Ra			8.00E+00	2.00E+01
227Ac			8.00E-03	2.00E-02
227Th			2.00E+00	4.00E+00
228Th			8.00E-02	2.00E-01
230Th			2.00E-01	3.00E-01
232Th			4.00E-02	7.00E-01
NATTh				
231Pa			4.00E-02	8.00E-02
232U			4.00E-02	8.00E-02
233U			2.00E-01	4.00E-01
234U			2.00E-01	5.00E-01
235U			2.00E-01	5.00E+00
236U			2.00E-01	5.00E+00
238U			2.00E-01	5.00E-01
DEPLU				
NATU				
ENRU				
237Np			1.00E-01	2.00E-01
238Pu			1.00E-01	2.00E-01
239Pu			1.00E-01	2.00E-01
240Pu			1.00E-01	2.00E-01
241Pu			8.00E+00	2.00E+01
242Pu			1.00E-01	2.00E-01
241Am			1.00E-01	2.00E-01
244Cm			2.00E-01	4.00E-01

D_1 = average of the equivalent dose rates per units surface activity at tissue depths of 50 and 100 mm ($mSv.h^{-1}.Bq^{-1}.cm^2$)(4)

DAC = derived air concentration for 40h working week ($Bq.m^{-3}$)

Table 4 - DLs for skin contamination

ISOTOPE	Exposure pathway			
	external irradiation of skin		Ingestion	
	D1	DL	ALI	DL
	mSv.h^{-1}.Bq^{-1}.cm^{2}	Bq.cm^{-2}	Bq	Bq.cm^{-2}
3H			1.00E+09	4.00E+05
14C	3.00E-04	2.00E+02	4.00E+07	2.00E+04
22Na	2.00E-03	3.00E+01	7.00E+06	3.00E+03
33P	8.00E-04	7.00E+01	8.00E+07	3.00E+04
35S	3.00E-04	2.00E+02	7.00E+07	3.00E+04
43K	2.00E-03	3.00E+01	9.00E+07	4.00E+04
45Ca	8.00E-04	7.00E+01	2.00E+07	8.00E+03
51Cr	1.00E-05	4.00E+03	4.00E+08	2.00E+05
54Mn	6.00E-05	1.00E+03	3.00E+07	1.00E+04
52Fe	4.00E-03	1.00E+01	1.00E+07	4.00E+03
55Fe	1.00E-05	4.00E+03	1.00E+08	4.00E+04
56Co	6.00E-04	9.00E+01	6.00E+06	2.00E+03
57Co	9.00E-05	7.00E+02	6.00E+07	2.00E+04
58Co	4.00E-04	1.00E+02	2.00E+07	8.00E+03
63Ni	5.00E-08	1.00E+06	1.00E+08	4.00E+04
64Cu	1.00E-03	5.00E+01	2.00E+08	8.00E+04
67Cu	2.00E-03	3.00E+01	5.00E+07	2.00E+04
65Zn	9.00E-05	7.00E+02	5.00E+06	2.00E+03
67Ga	3.00E-04	2.00E+02	8.00E+07	3.00E+04
68Ga	2.00E-03	3.00E+01	2.00E+08	8.00E+04
68Ge	2.00E-03	3.00E+01	7.00E+07	3.00E+04
75Se	1.00E-04	5.00E+02	9.00E+06	4.00E+03
77Br	9.00E-05	7.00E+02	2.00E+08	8.00E+04
81Rb	2.00E-03	4.00E+01	4.00E+08	2.00E+05
85Sr	6.00E-05	9.00E+02	4.00E+07	2.00E+04
87mSr	4.00E-04	1.00E+02	7.00E+08	3.00E+05
90Sr	2.00E-03	3.00E+01	6.00E+05	2.00E+02
87Y	5.00E-04	1.00E+02	3.00E+07	1.00E+04
90Y	2.00E-03	3.00E+01	5.00E+06	2.00E+03
99Mo	2.00E-03	3.00E+01	1.00E+07	4.00E+03
99mTc	3.00E-04	2.00E+02	1.00E+09	4.00E+05
109Cd	1.00E-05	6.00E+03	9.00E+06	4.00E+03
111In	4.00E-04	1.00E+02	5.00E+07	2.00E+04
113mIn	9.00E-04	6.00E+01	9.00E+08	4.00E+05
123I	4.00E-04	2.00E+02	9.00E+07	4.00E+04
125I	2.00E-05	3.00E+03	1.00E+06	4.00E+02
129Cs	9.00E-05	6.00E+02	3.00E+08	1.00E+05

D_1 = average of the equivalent dose rates per units surface activity at tissue depths of 50 and 100 mm (mSv.h^{-1}.Bq^{-1}.cm^{2})(4)

ISOTOPE	Exposure pathway			
	external irradiation of skin		Ingestion	
	D1	DL	ALI	DL
	mSv.h^{-1}.Bq^{-1}.cm^{2}	Bq.cm^{-2}	Bq	Bq.cm^{-2}
131Cs	1.00E-05	5.00E+03	3.00E+08	1.00E+05
147Pm	7.00E-04	8.00E+01	5.00E+07	2.00E+04
147Sm			6.00E+05	2.00E+02
169Yb	2.00E-03	3.00E+01	2.00E+07	8.00E+03
197Hg	2.00E-04	4.00E+02	3.00E+07	1.00E+04
204Tl	2.00E-03	3.00E+01	3.00E+07	1.00E+04
210Pb	4.00E-04	2.00E+02	2.00E+04	8.00E+00
210Bi	2.00E-03	3.00E+01	1.00E+07	4.00E+03
210Po			9.00E+04	4.00E+01
223Ra			2.00E+05	8.00E+01
224Ra			3.00E+05	1.00E+02
226Ra			9.00E+04	4.00E+01
228Ra			7.00E+04	3.00E+01
227Ac			9.00E+03	4.00E+00
227Th			2.00E+06	8.00E+02
228Th			3.00E+05	1.00E+02
230Th			3.00E+05	1.00E+02
232Th			5.00E+04	2.00E+01
NATTh				
231Pa			1.00E+04	4.00E+00
232U			2.00E+05	8.00E+01
233U			7.00E+05	3.00E+02
234U			7.00E+05	3.00E+02
235U			7.00E+05	3.00E+02
236U			7.00E+05	3.00E+02
238U			8.00E+05	3.00E+02
DEPLU				
NATU				
ENRU				
237Np			3.00E+04	1.00E+01
238Pu			4.00E+04	2.00E+01
239Pu			4.00E+04	2.00E+01
240Pu			4.00E+04	2.00E+01
241Pu			2.00E+06	8.00E+02
242Pu			4.00E+04	2.00E+01
241Am			3.00E+04	1.00E+01
244Cm			6.00E+04	2.00E+01

ALI = annual limit of intake via ingestion for workers (Bq).

Table 5 - Radionuclides by Class for Active Areas

I	0.1
ISOT	Bq.cm^{-2}
241 Am	4.8E-1
244 Cm	7.2E-1
237 Np	2.4E-1
238 Pu	2.4E-1
239 Pu	4.0E-1
240 Pu	4.0E-1
242 Pu	4.8E-1
228 Th	1.6E-1
230 Th	2.4E-1
232 Th	2.4E-1
233 U	2.4E-1
234 U	2.4E-1
238 U	3.2E-1
227 Ac	1.6E-2
231 Pa	8.0E-2
232 U	8.0E-2

II	1
ISOT	Bq.cm^{-2}
210 Pb	4.0E+0
210 Po	4.8E+0
223 Ra	4.8E+0
226 Ra	4.8E+0
227 Th	4.8E+0
NAT Th	2.2E+0
235 U	4.8E+0
236 U	7.2E+0
DEPL U	8.0E+0
ENR U	8.0E+0
NAT U	8.0E+0

III	10
ISOT	Bq.cm^{-2}
52 Fe	1.6E+1
90 Sr	1.6E+1
147 Sm	1.6E+1
224 Ra	1.6E+1
228 Ra	4.8E+1
241 Pu	6.1E+1

IV	100
ISOT	Bq.cm^{-2}
210 Bi	1.2E+2
14 C	8.4E+2
45 Ca	3.0E+2
109 Cd	8.0E+2
56 Co	4.0E+2
58 Co	6.5E+2
64 Cu	2.3E+2
67 Cu	1.1E+2
67 Ga	9.3E+2
68 Ga	1.4E+2
68 Ge	1.1E+2
123 I	6.8E+2
111 In	5.8E+2
113m In	2.7E+2
43 K	1.2E+2
99 Mo	1.5E+2
22 Na	1.3E+2
33 P	3.0E+2
147 Pm	3.3E+2
81 Rb	1.6E+2
35 S	7.9E+2
99m Tc	9.5E+2
204 Tl	1.3E+2
87 Y	4.8E+2
90 Y	1.4E+2
169 Yb	1.1E+2

V	1 000
ISOT	Bq.cm^{-2}
Br	1.6E+3
57 Co	1.6E+3
129 Cs	2.0E+3
197 Hg	2.8E+3
125 I	2.8E+3
54 Mn	2.9E+3
75 Se	2.9E+3
85 Sr	3.9E+3
87m Sr	4.3E+3
65 Zn	5.9E+3

VI	10 000
ISOT	Bq.cm^{-2}
77 Cr	1.9E+4
131 Cs	2.1E+4
55 Fe	2.0E+4
3 H	8.0E+5
63 Ni	1.6E+4

Table 6 - Radionuclides by Class for Skin

I	10
ISOT	Bq.cm-2
241 Am	2.8E+2
244 Cm	2.0E+1
237 Np	1.6E+1
238 Pu	1.2E+1
239 Pu	2.8E+2
240 Pu	2.4E+1
242 Pu	3.2E+2
228 Th	1.2E+2
230 Th	1.2E+1
232 Th	1.6E+1
233 U	1.6E+1
234 U	1.6E+1
238 U	1.2E+2
227 Ac	3.6E+0
231 Pa	4.0E+0
232 U	8.0E+1

II	10
ISOT	Bq.cm-2
210 Pb	8.0E+2
210 Po	2.8E+2
223 Ra	2.8E+2
226 Ra	2.8E+2
227 Th	2.8E+2
NAT Th	1.2E+2
235 U	2.8E+2
236 U	3.6E+1
DEPL U	8.0E+0
ENR U	3.6E+1
NAT U	8.0E+1

III	10
ISOT	Bq.cm-2
52 Fe	2.4E+2
90 Sr	1.2E+2
147 Sm	2.8E+1
224 Ra	8.0E+2
228 Ra	3.2E+1
241 Pu	1.4E+1

IV	10
ISOT	Bq.cm-2
210 Bi	2.8E+1
14 C	2.0E+2
45 Ca	6.8E+1
109 Cd	3.6E+3
56 Co	9.0E+1
58 Co	1.5E+2
64 Cu	5.3E+1
67 Cu	2.6E+1
67 Ga	2.1E+2
68 Ga	3.2E+1
68 Ge	2.5E+1
123 I	1.5E+2
111 In	1.3E+2
113m In	6.0E+1
43 K	2.6E+1
99 Mo	3.4E+1
22 Na	2.9E+1
33 P	6.9E+1
147 Pm	7.6E+1
81 Rb	3.6E+1
35 S	1.8E+2
99m Tc	2.2E+2
204 Tl	2.9E+1
87 Y	1.1E+2
90 Y	3.2E+1
169 Yb	2.5E+1

V	100
ISOT	Bq.cm-2
77 Br	3.6E+2
57 Co	4.0E+2
129 Cs	4.6E+2
197 Hg	6.7E+2
125 I	6.4E+2
54 Mn	6.6E+2
75 Se	6.7E+2
85 Sr	8.9E+2
87m Sr	9.8E+2
65 Zn	1.4E+2

VI	1 000
ISOT	Bq.cm-2
51 Cr	4.2E+3
131 Cs	4.8E+3
55 Fe	4.5E+3
3 H	4.0E+5
63 Ni	4.0E+4