DERIVED LIMITS FOR APPLICATION TO THE CONTROL OF ROUTINE RELEASES

Stephanie M Haywood, Jane R Simmonds and Gordon S Linsley
National Radiological Protection Board, Chilton, Didcot, Oxon, UK

INTRODUCTION

The National Radiological Protection Board has undertaken a programme of work in which derived quantities for use in the control of routine discharges of radioactivity to the environment have been calculated for a range of commonly occurring radionuclides. The quantities, which are intended for general application within the UK, are referred to as Generalised Derived Limits (GDLs) and are convenient reference levels against which the results of environmental monitoring can be compared and atmospheric discharges assessed. Compliance with Derived Limits should ensure that the appropriate dose equivalent limits are not exceeded. Due to their general nature, GDLs are intended for application only when the environmental contamination or discharge to atmosphere is less than a small fraction, say 5%, of the GDL; above this level a more realistic site specific assessment may be necessary to take account of possible variations or uncertainties in parameter values and to identify more accurately the location and habits of the critical group.

GDLs may be calculated for any environmental materials liable to be subject to routine sampling, such as water, soil, grass, sediments and various foodstuffs derived from the terrestrial and aquatic environments, and they may also be specified for discharge to atmosphere. In this paper a selection of GDLs is presented for several commonly occurring nuclides, namely ^{90}Sr, ^{137}Cs, ^{131}I, ^{239}Pu and ^{241}Am. A full range of GDLs have been reported elsewhere for these and other nuclides of strontium, caesium, iodine, plutonium, americium and curium(1) and the calculation of GDLs for nuclides of other elements will be undertaken in the future.

PRINCIPLES FOR THE CALCULATION OF DERIVED LIMITS

To ensure virtual certainty of compliance with the dose equivalent limits for members of the public, assumptions of a deliberately pessimistic nature are incorporated in the GDL calculations. For example, the exposures considered are those of a hypothetical population group, the critical group, whose members are subject to above average exposures by virtue of their location, age or habits, such as elevated consumption rates. The intake rates used in GDL calculations represent higher than average consumption rates but not extreme values which would be applicable only to a few individuals in the population. They thus provide an appropriately conservative basis for the estimation of GDLs in foodstuffs.

For a particular radionuclide, GDLs are determined by considering the concentration in environmental materials which lead to the critical group receiving the annual dose equivalent limit for members of the public (either 5 mSv effective dose equivalent or 50 mSv to a single organ or tissue if this is the more restrictive). When the exposure route is by ingestion or inhalation of activity, annual limits of intake (ALIs) for members of the public are used in GDL calculations. ALIs are related to the annual dose equivalent limits by means of defined metabolic and dosimetric models for man. ALIs may be determined by either stochastic or non-stochastic effects; the more restrictive gives the ALI which is used in GDL calculations. The principles and method of calculation of ALIs are those given in ICRP Publication 30(2). For adult members of the public, the ALI's are taken to be one tenth of those given for workers in ICRP 30, except in certain cases where it is considered that, for the form of elements likely to be found in the environment, alternative metabolic parameter values are more appropriate[3]. For children, ALIs are evaluated using a model which predicts the variation of dose per unit intake with age[3]. In addition an extended integration time following intake, up to a mean lifetime of 70 years is used. The values of the ALIs used in GDL calculations for adults and children for the nuclides considered are given in Reference 1.

GDL calculations are performed for three age groups - adults, children aged 10 years and infants - taking into account the variation with age of the ALI and dietary and other habits. The most restrictive value of those obtained for the three age groups is taken as the GDL.

GENERALISED DERIVED LIMITS IN ENVIRONMENTAL MATERIALS

The GDL in an environmental material m, for a particular pathway p is given for activity taken into the body by

$$GDL_{m,p} = \frac{A}{I_m} \quad (\mathrm{Bq\ kg^{-1}\ or\ Bq\ l^{-1}}) \qquad \text{........ (1)}$$

where A is the appropriate ALI ($\mathrm{Bq\ y^{-1}}$)
and I_m is the annual intake of material, m ($\mathrm{kg\ y^{-1}}$ or $\mathrm{l\ y^{-1}}$).

When the exposure route is external irradiation the GDL is given by

$$GDL_{m,p} = \frac{H_L}{H_m^E} \quad (\mathrm{Bq\ kg^{-1}}) \qquad \text{........ (2)}$$

where H_L is the annual dose equivalent limit ($\mathrm{Sv\ y^{-1}}$)
and H_m^E is the annual dose equivalent from external exposure from unit concentration of the nuclide in material m ($\mathrm{Sv\ y^{-1}}$ per $\mathrm{Bq\ kg^{-1}}$)

For each environmental material the GDL_m is then calculated by summing the contributions from all significant pathways of exposure, p, as follows

$$\frac{1}{GDL_m} = \sum_p \frac{1}{GDL_{m,p}} \qquad \text{........ (3)}$$

For example, to calculate a GDL for activity in soil account must be taken of all relevant pathways to man which may include inhalation of activity resuspended from the ground, external irradiation from the ground, and the ingestion of contaminated crops grown in the soil and of products from grazing animals.

GENERALISED DERIVED LIMITS FOR DISCHARGE TO ATMOSPHERE

The discharge of radionuclides to atmosphere may lead to members of the public being exposed by a number of pathways, including

external exposure from the cloud
internal exposure from inhalation of the cloud
external exposure from deposited activity
internal exposure from inhalation of activity resuspended from the ground

and internal exposure from ingestion of contaminated foodstuffs.

The GDL for the discharge of a radionuclide to the atmosphere, GDL_A, is given by

$$GDL_A = \frac{H_L}{H^E} + \frac{H_L}{H^I} \quad (Bq\ y^{-1}) \qquad \text{........ (4)}$$

where H_L is the annual dose equivalent limit ($Sv\ y^{-1}$)

H^E is the annual dose equivalent from external radiation at the appropriate distance from the discharge point per unit annual discharge of a nuclide ($Sv\ y^{-1}$ per $Bq\ y^{-1}$)

and H^I is the time integrated dose equivalent due to the annual intake of a nuclide by inhalation and ingestion at the appropriate distance from the discharge point per unit annual discharge ($Sv\ y^{-1}$ per $Bq\ y^{-1}$)

For the purpose of calculating GDL_A, reference values are used for the parameters which influence dispersion in, and deposition from the atmosphere(4). The critical group is assumed to be located at a distance of 100 m from the point of discharge but to derive its food uniformly from within 1 km of the discharge point. The average concentration in food is approximated by taking the concentration in food at a distance of 500 m from the discharge point. The GDLs for discharge are evaluated assuming that the discharge continues for a period of 50 years, to allow build up of activity to occur in soils and other environmental materials.

When the discharge is greater than about 5% of the GDL, a more realistic site specific estimate of the derived limit for discharge to atmosphere may be warranted, taking into account the conditions of the release and the location and habits of the exposed population. A procedure for this is described in Reference 5.

RESULTS OF GENERALISED DERIVED LIMIT CALCULATIONS

A selection of GDLs for five commonly occurring nuclides are given in Table 1. It can be seen from Table 1 that for these nuclides the critical age group is usually infants or adults. The adult age category is, with the exception of the GDL for milk, the most restrictive age group throughout for ^{239}Pu and ^{241}Am, whereas for ^{90}Sr, ^{137}Cs and ^{131}I the most restrictive age group is infants. The relative significance of the pathways which contribute to the GDL for stack discharge depends upon the nuclide. For ^{239}Pu and ^{241}Am the most important route of exposure during conditions of continuous discharge to atmosphere is inhalation in the initial cloud, while for ^{90}Sr and ^{131}I the major contributor is the dose from the consumption of contaminated food, mostly milk and milk products. For ^{137}Cs, the doses from the consumption of foodstuffs and external irradiation from deposited activity are of equal importance.

A full range of GDLs for these and other nuclides are reported in Reference 1, including GDLs in aquatic materials such as water (fresh water, sea water and drinking water) and marine foodstuffs.

REFERENCES

1. Generalised derived limits for radioisotopes of plutonium (NRPB-DL5), americium and curium (NRPB-DL6), caesium (NRPB-DL7), strontium (NRPB-DL8) and iodine (NRPB-DL9). Chilton, NRPB-DL series, 1982-1983 (London, HMSO).

2. ICRP, Limits for intake of radionuclides by workers. Oxford, Pergamon Press, ICRP Publication 30, Part 1. Ann. ICRP, 2, 3/4 (1979), Part 2, Ann. ICRP, 4, 3/4 (1980), Part 3, Ann. ICRP 6, 2/3 (1981).

3. NRPB, Metabolic and dosimetric models for application to members of the public. Chilton, NRPB-GS3 (to be published).

4. Harrison, N T and Simmonds, J R, Dosimetric quantities and basic data for the evaluation of generalised derived limits. Chilton, NRPB-DL3 (1980) (London, HMSO).

5. Hallam, J, Harrison, N T and Jones, J A, A procedure for estimating site specific derived limits for the discharge of radioactive material to the atmosphere. Chilton, NRPB-DL4 (1983) (London, HMSO).

TABLE 1

GENERALISED DERIVED LIMITS

GDL	Unit	Nuclide				
		^{90}Sr	^{137}Cs	^{131}I	^{239}Pu	^{241}Am
Milk[a]	Bq l^{-1}	2 10^{2}*	3 10^{2}*	5 10^{1}*	1‡	8 10^{-1}‡
Beef and veal[a]	Bq kg^{-1}	2 10^{3}	5 10^{3}**	1 10^{3}**	8 10^{1}	8 10^{1}
Green vegetables[a]	Bq kg^{-1}	1 10^{3}*	2 10^{3}*	5 10^{2}*	6 10^{1}	6 10^{1}
Grain products[a]	Bq kg^{-1}	8 10^{2}*	1 10^{3}*	3 10^{2}*	4 10^{1}	4 10^{1}
Well-mixed soil[b]	Bq kg^{-1}	2 10^{3}*	3 10^{3}*	- [c]	3 10^{3}	3 10^{3}
Surface contamination[d]						
1) soil	Bq m^{-2}	-	-	-	2 10^{3}	2 10^{3}
2) urban	Bq m^{-2}	-	-	-	5 10^{1}	5 10^{1}
Discharge to[e] atmosphere	Bq y^{-1}	2 10^{12}*	1 10^{12}*	3 10^{11}*	1 10^{10}[f]	1 10^{10}

Notes:
a All food products as fresh weight.
b Soil evenly contaminated down to 30 cm, no deposition.
c The half-life of ^{131}I is too short for this GDL to be significant.
d These GDLs are only relevant for those nuclides for which inhalation related pathways are important. They are calculated for surface deposits in the absence of continuous deposition and are based on the resuspension pathway only.
e Using reference discharge parameters - see text.
f This value may be relaxed by a factor of three if the plutonium is discharged as PuO_2.

The critical group is adults except where indicated by
- * for infants aged 1 year
- ** for children aged 10 years
- ‡ for infants drinking milk in the first year of life (average age 6 months). See Reference 1 (NRPB-DL5).