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Derivation of Reference Values for Schedule 1 of the REPPIR-2019 Regulations

Specified quantities of inventory holdings for more than 700 radionuclides

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Derivation of Reference Values for Schedule 1 of the REPPIR-2019 Regulations

Specified quantities of inventory holdings for more than 700 radionuclides

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Abstract

This report summarises the methodology for derivation of reference values for Schedule 1 of the REPPIR-2019 regulations. The report also discusses aspects of the underlying assumptions, including the dose criteria applied, specifies default parameters for the calculations, and presents the values themselves, for over 700 radionuclides.

The methodology is commensurate with scientific evidence and international good practice, bearing in mind that simplicity and minimal non-default data inputs should be the aim for the majority of users. The methodology only includes releases to atmosphere and duty holders are required to undertake site-specific calculations for other feasible release pathways if these apply.

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Report version 1.0

Contents

1 Introduction

Calculations were undertaken and issued by the National Radiological Protection Board (Carey et al, 2001) to derive the reference values in Schedule 2 of the REPPIR-2001 regulations (HSE, 2002). The reference values are in the form of specified quantities of inventory holdings for more than 700 radionuclides, derived by modelling the consequences of pessimistic release and occupancy scenarios involving the accidental release of radioactive substances from premises. Compliance with these values represents a simple means of determining the applicability of REPPIR regulations. Where the quantity of any radionuclide on the premises exceeds the specified quantity in Becquerels or, if there is more than one radionuclide on the premises, if the sum of the quantity ratios is greater than one, REPPIR regulations apply to those premises.

Public Health England, the successor body to NRPB, was asked by Department for Business, Energy and Industrial Strategy (BEIS) to review the Schedule 2 assessment methodology and, once approved, to recalculate the values. The new values are issued in Schedule 1 of REPPIR-2019. In this report, 'Schedule 2' refers to the reference values associated with REPPIR-2001 and 'Schedule 1' refers to the reference values associated with REPPIR-2019.

This report summarises the revised methodology, and discusses aspects of the underlying assumptions, including the dose criteria applied. The aim of the methodology is to define a process for the calculation of the baseline values, and to specify default parameters for these calculations. The methodology is commensurate with scientific evidence and international good practice, bearing in mind that simplicity and minimal non-default data inputs should be the aim for most users. The methodology only includes releases to atmosphere and duty holders are required to undertake site-specific calculations for other feasible release pathways if these apply.

Based on the methodology described here, Schedule 1 values for REPPIR-2019 have been calculated and are presented in Appendix A. These values have been compared against the Schedule 2 values of REPPIR-2001, discussed in Appendix B.

2 Content

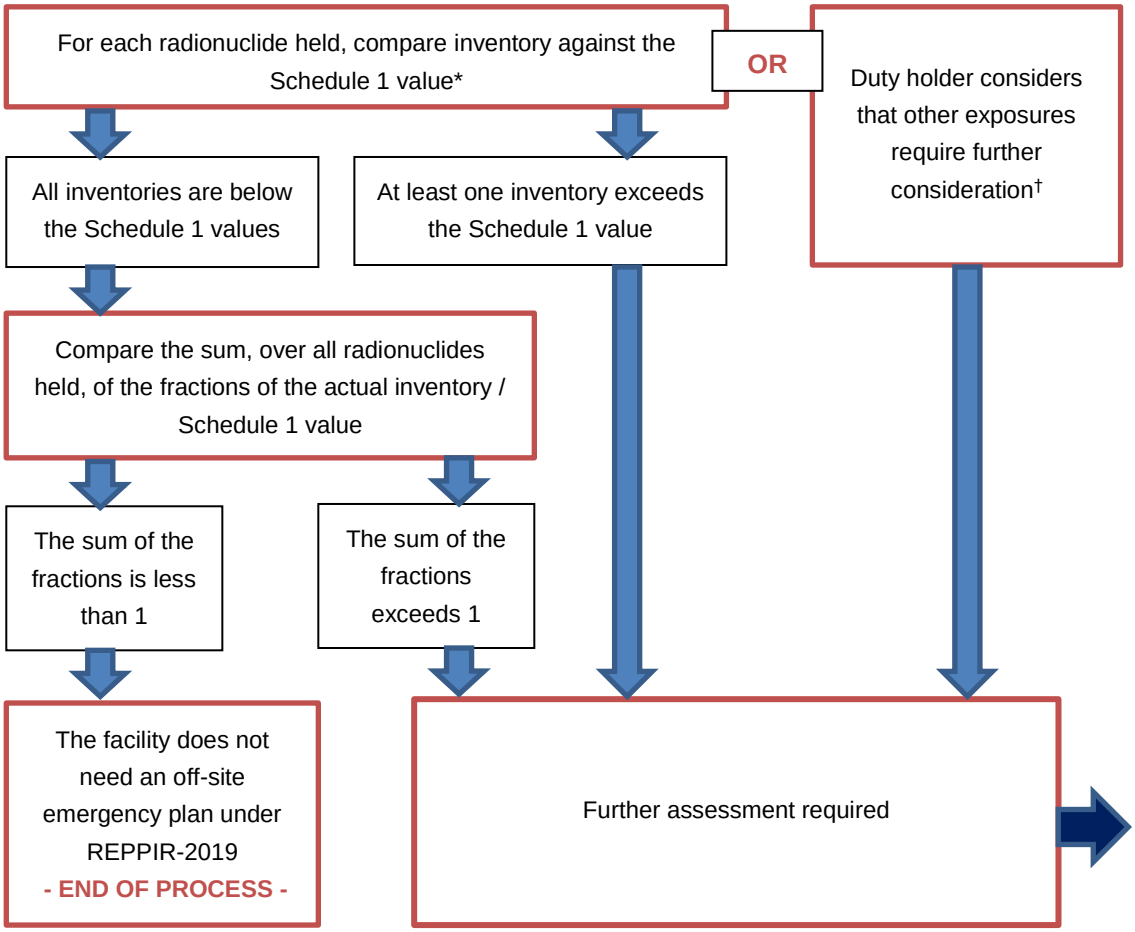
Department for Business Energy and Industrial Strategy (BEIS), with Health and Safety Executive (HSE), Ministry of Defence (MOD) and Office for Nuclear Regulation (ONR), have agreed that the 5 mSv effective dose threshold for offsite emergency planning in the UK is no longer appropriate, and that there will be no use of a trigger dose in REPPIR-2019, but that there will instead be an approach based on prioritising preparedness activities around those sites with the greatest hazard. For all sites, there will be a graded and proportionate approach to planning. The flowchart for the process is shown in Figure 1, to clarify where Schedule 1 sits within the REPPIR-2019 process.

The requirement of Schedule 1 values is to consider emergencies resulting in members of the public off-site receiving exposure to ionising radiation in excess of agreed dose criteria. The dose criteria have been specified by BEIS for use in this methodology and are discussed in the section below. The need for a screening value which can determine those duty holders

who do not need to progress to a more detailed assessment should be proportionate in nature; consequently, the methodology described here for calculating the Schedule 1 values is intentionally a conservative one.

The methodology for Schedule 1 values applies to a generic location and site. It includes all appropriate exposure pathways but for releases to atmosphere only. Other release scenarios (such as release to a water body) are not included here due to the site-specific nature of subsequent exposures. Where the possibility of additional exposure pathways exists, a site-specific assessment should be undertaken. This is discussed further below.

Figure 1 The Schedule 1 flow chart



Footnotes:

* The Schedule 1 value for each radionuclide is the most limiting of the values calculated for 3 age groups, and for the following dose criteria:

1 mSv in 1 year effective dose
25 mSv in 1 year thyroid dose (but see discussion in Section 4)
50 mSv in 1 year dose to skin

Additionally, for a subset of radionuclides, for the inhalation and ingestion pathways, the 3-month-old breast-fed infant, and doses to the foetus are also considered.

† Duty holders are required to consider a range of possible exposure routes for their site which are not included in the Schedule 1 calculations and which will therefore require additional analysis and assessment (see Section 5). These may include, for example, the potential for releases to water bodies or sewerage systems, criticality, direct shine, and circumstances in which the lens of eye may be specifically irradiated.

3 Dose criteria used to derive the Schedule 1 values

In the context of Schedule 1 values, there is a reduction from the previous effective dose basis of 5 mSv in the first year, as used in Schedule 2 of REPPIR-2001, to 1 mSv in the first year. The dose criteria have been agreed with BEIS for use in this methodology and are shown in Table 1 together with the values used previously.

Table 1 Dose criteria (mSv in first year) to derive Schedule 1 values for members of the public

	Effective	Thyroid	Skin	Lens of eye
Schedule 1 - REPPIR-2019	1	25	50	*
Schedule 2 - REPPIR-2001	5	†	50	15

Notes:

* Lens of the eye is not included in the default Schedule 1 calculations. If the exposure pathway is deemed plausible by the duty holder a site-specific calculation must be performed. If this is undertaken, the relevant dose limit would remain 15 mSv in the first year, as in the 2001 Regulations.

† Thyroid doses were not included in the 2001 Schedule 2 calculations.

This methodology introduces a thyroid dose criterion. The administration of stable iodine has the potential to reduce doses to the thyroid from radioactive iodine, and hence consideration of the need for stable iodine planning should be considered through estimation of the dose to the thyroid from isotopes of iodine. The use of stable iodine will only avert dose from radionuclides of iodine and not from other radionuclides, hence the thyroid criterion relates only to radioisotopes of iodine and not to other radionuclides which may also deliver a dose to the thyroid. Also, the thyroid dose criterion relates only to exposure via inhalation, as stable iodine is not administered to avert doses from ingestion.

The selection of the dose criterion of 25 mSv for the thyroid approximates to the same level of risk (considering risk from cancer incidence which includes both fatal and non-fatal cancers, and other detriments including a weighting for ‘quality of life detriment’) as the effective dose criterion of 1 mSv, based on the ICRP Publication 103 (ICRP, 2007) tissue weighting factor for the thyroid of 0.04. It is important to note that because the thyroid criterion relates to the same level of risk as the criterion for effective dose, it is never limiting for Schedule 1 calculations, in part because the calculations relating to the 1 mSv effective criterion include consideration of ingestion pathways, whereas the calculations relating to the thyroid dose criterion consider only the inhalation pathway, and also because doses to organs other than the thyroid contribute to effective dose. It is, however, retained as a separate criterion for consistency with potential applicability in a later or additional site-specific risk assessment (if this is required).

PHE and its predecessor bodies have specified Emergency Reference Levels (ERLs) of averted dose for use in the planning of emergency protective actions: in particular, evacuation, sheltering and stable iodine prophylaxis. It is the dose averted or avoided by these protective actions that determines their benefit. The aim of ERLs is the reduction of early exposures so that the benefits and drawbacks of each protective action are separately balanced. ERLs relate to the dose averted in the first few days by a specific protective action from the short-term exposure pathways only. ERLs are not intended to be limits on dose or indicators of

doses which may be 'safely' received by an individual, but indicate the range of levels of dose (expected to be averted by the protective action) within which the greatest overall benefit of taking that protective action would be maximised, taking into account the potential for harm and disruption which arises from it.

The use of the base-line criterion of 1 mSv effective dose over the first year can be considered in terms of the dose contour it relates to in comparison with the lower ERL for sheltering, and also the lower ERLs for evacuation and stable iodine. The lower ERL for sheltering is 3 mSv averted dose, so for a comparison in terms of total dose from the inhalation pathway, the lower ERL approximates to 5 to 7.5 mSv total dose, over a few days. In general, considering a range of releases (from very large through to smaller), the base-line criterion of 1 mSv effective dose over the first year is more conservative in terms of the extent of a dose contour from a generic release location, for a range of weather conditions, than the lower ERLs for sheltering, evacuation and stable iodine. This is mostly because the 1 mSv criterion considers doses over the whole of the first year. The same is not observed for a dose criterion of 5 to 7.5 mSv effective dose over the first year, which although generally conservative may in some circumstances permit a possibility of a contour not extending far enough to encompass all locations where urgent protective actions may be needed.

Similarly, the base-line criterion of 1 mSv total effective dose over the first year can be considered in terms of how it relates to possible values for the Reference Level (ICRP, 2007) of 20 mSv and 100 mSv effective residual dose in the first year (including doses received in the emergency phase). Reference Levels are aimed at achieving optimised planning and response over all exposure pathways and protective actions, encouraging 'holistic' planning for all phases of the emergency, not just the urgent phase. Considering the same range of releases, as above, the dose contours related to these values of Reference Level would extend less far from a release location than the contour related to the base-line criterion of 1 mSv.

In summary, broad calculations indicate that the use of a criterion of 1 mSv effective dose over the first year is likely to result in contours which encompass those resulting from the lower ERLs and will also encompass contours relating to the national Reference Level if set at 100 mSv effective dose in the first year.

4 A conservative approach

Although the values estimated in the previous methodology (Schedule 2, REPPIR-2001) were described as being '*derived by modelling the consequences of a worst-case release and occupancy accident scenario involving the release of radioactive substances from a premises*' (Carey et al, 2001) it can be considered that there was some inconsistency in the degree of pessimism applied in different aspects. For example, very pessimistic assumptions were made for the amount of food consumed, the percentage of this that is assumed to be locally obtained, and the distance of green vegetable and milk production to the release point. Conversely, relatively pessimistic weather conditions prevailing at the time of the release were not considered; for example, the influence of rain was not included in the calculations.

In the revised methodology, a more uniform and conservative but not extremely pessimistic approach has been taken, corresponding approximately to the 95th percentile of the likelihood

distribution in the values relating to the relevant dose criterion. Taken collectively the resulting values are appropriate for application as conservative screening quantities.

5 General assumptions

The methodology uses assessment tools that are well established but includes some new approaches in the context of these calculations, in particular, regarding weather conditions. The data and approaches recommended in the methodology are summarised in this section, including those for meteorological data, atmospheric dispersion, food chain modelling, the modelling appropriate for other exposure pathways (external dose, inhalation) and individual location and habits. In particular, key assumptions regarding the source of food are discussed.

The key features of the methodology are:

- the revised Schedule 1 values are based on integrating the exposure for a period of 1 year from the time of release (the committed dose)
- the accrued dose is the sum of the annual (first year) direct external radiation dose and the committed dose from intakes over the first year (ingestion of contaminated food, and inhalation)
- a release fraction of 1 is assumed (i.e. that all the material in the inventory is released)
- it is assumed that the release is of a representative duration of 30 minutes and occurs at ground level. A short duration release will give rise to higher concentrations and depositions at the maximum point than a release which is more prolonged and which may experience changes in weather
- the values presented are the most restrictive of the values for each radionuclide for the 3 age groups considered (1-year-old infant, 10-year-old child, 20-year-old adult). Additionally, for a subset of radionuclides, for the inhalation and ingestion pathways, the 3-month-old breast-fed infant, and doses to the foetus were also considered
- the assumed weather conditions relate to the 95th percentile of distributions of air concentration and deposition observed for UK sites
- the wind is assumed to blow in the direction of the exposed individual (i.e. the individual is assumed to be at the point of maximum air concentration or deposition – depending on pathway – at the specified distance from the discharge point)
- it is assumed that the exposed individual spends a significant proportion of their year located at a distance of 100 m downwind of the discharge point, and it is cautiously assumed that individuals will be outside during the entire passage of the plume
- it is further assumed that the individual obtains 100% of their green vegetables and milk from a location 1 km from the discharge point, at the point of maximum deposition at this distance
- for food consumption, only intakes from milk and green vegetables are considered in the methodology. This selection is based on: (a) these 2 foodstuffs are most likely to contribute dose in the short term as a result of releases in an emergency; (b) only a limited number of foodstuffs are likely to be obtainable from a very close-in distance to the discharge point (1 km); and (c) the selection of 2 foodstuffs used in the past to calculate ingestion doses (Smith et al, 2004) – the ‘Top Two’ approach – from agricultural production close to the site of release

The methodology for Schedule 1 applies to a generic location and site. It includes all appropriate exposure pathways for atmospheric releases only and is, as described above, conservative. The previous methodology included calculational methods for releases to river and into sewers, but the Schedule 2 values in REPPIR-2001 did not actually include the effect of these scenarios (only including releases to atmosphere). Scenarios other than releases to atmosphere are not included in the revised methodology. Modelling assumptions and parameters for releases to water bodies and sewers (for example, water abstraction for public drinking water very close to the release point, and the use of water for irrigation of foodstuffs) would vary very significantly from one location to another. Such assumptions applied generically could result in severe limitations on inventories in circumstances where such releases cannot arise. For this reason, duty holders are required to consider the feasibility of pathways other than a release to atmosphere for their site, and to undertake site-specific calculations should these circumstances be credible. Duty holders are also required to consider other aspects of exposure which may additionally arise at their site and undertake site-specific calculations for these circumstances if required.

5.1 Protective actions

Protective actions during the year following the release are disregarded, i.e. there is assumed to be no sheltering, evacuation or stable iodine protective actions. In addition, no food restrictions are assumed, even if the levels corresponding to the dose criteria exceed the European Union maximum permitted levels of radionuclides in marketed foods currently applicable to the UK. This is to ensure that the potential need for food restrictions should be planned for, if necessary, through the application of the Schedule 1 values. There is also the possibility that a person may be consuming non-marketed food from their garden, farm or allotment; dealing with this situation could also be required in the emergency plan.

5.2 Location and habits

Regarding location assumptions, the person receiving exposure is assumed to be 100 m downwind from the release point for all of their initial exposures (while the plume is present). No protection factors are assumed for these exposures i.e. the person is assumed to be outdoors during this early exposure. For the remainder of the first year the person is assumed to be at this location 70% of the time, within a solidly-built building, and for 30% of the first year they are assumed to be at a different location (one where they receive no dose, such as commuting to work, time in employment or attendance at school). As above, all of the doses are assumed to be uninfluenced by urgent protective actions (i.e. sheltering or evacuation or stable iodine).

5.3 Meteorology and dispersion modelling

A significant change from the Schedule 2 REPPIR-2001 methodology is in the treatment of weather and associated dispersion modelling. The earlier methodology considered only releases occurring in Pasquill Stability Category D, which typically occurs in the UK around 65% of the time (Clarke, 1979). In addition, only dry conditions were considered. The effect of

considering rain during the release varies with exposure pathway and radionuclide. In general, pathways which primarily depend upon concentrations in air may exhibit lower doses in wet conditions than in dry, because of the influence of rain in lowering the concentrations in air due to enhanced deposition. Pathways which depend primarily upon deposition on the ground will exhibit higher doses due to the increased ground deposition occurring during rain.

There is uncertainty inherent in the choice of dispersion model, which may lead to uncertainty in predictions greater than those associated with the parameters and assumptions used in other parts of the methodology. Previous Schedule 2 REPPIR-2001 calculations were based on the NRPB-R91 model (Clarke, 1979). In NRPB-W54, a short duration release methodology (Smith et al, 2004), it was estimated that doses predicted by the NRPB-R91 model were greater by up to a factor of about 5 at close-in distances compared to the ADMS model (CERC, 2002). Similarly, in Bedwell et al (2011) a factor of 3 was identified between NRPB-R91 and the NAME model for Pasquill stability category D conditions, at distances of the order of a few kilometres, with larger factors identified for less frequent weather conditions.

For continuous discharges, it can be assumed that releases will occur in the full range of meteorological conditions experienced at a particular site. However, for a very short release over 30 minutes, as considered here, the meteorological conditions experienced by the dispersing plume will be limited and are likely to result in predicted air concentrations and depositions significantly different from those expected as a result of average meteorological conditions. It is important that the meteorological conditions are represented in a way appropriate to a conservative estimate of dose.

Consequently, this methodology applies a probabilistic approach to meteorology and dispersion rather than a single atmospheric stability category. The Met Office's NAME model (Jones et al, 2007) together with PHE's probabilistic accident consequence tool (Charnock et al, 2013) PACE, have been used to analyse historical UK meteorological data to determine time integrated air concentrations and deposition concentrations per unit release for use in this methodology. The values selected correspond to the 95th percentile of weather conditions. Table 2 shows the activity concentrations in air and on the ground applied in this methodology, based on this analysis.

As described above, the deposited activity concentrations per unit release correspond to the 95th percentile of weather conditions. Precipitation was observed in all scenarios considered in the derivation of these concentrations, thus the deposition is dominated by wet rather than dry deposition processes. Wet deposition was modelled using the Met Office's NAME model. NAME applies a scavenging coefficient approach (Webster and Thomson, 2014), which is considered to be a function of precipitation rate, type of precipitation (rain and snow), and deposition process (rainout and washout); however, the model currently assumes no dependency on radionuclide or on physical or chemical form. Other than for iodine isotopes, data describing the wet deposition of chemical forms of radionuclides is very sparse and is insufficient to justify the use of multiple scavenging coefficients. For iodine, on the basis of the methods detailed in ADMLC (2001) and the precipitation rates corresponding to the 95th percentile of weather conditions, assuming 1 µm particles in the modelling of wet deposition is always at least as cautious as considering the 2 primary chemical forms of iodine (elemental iodine vapour and methyl iodide). For elemental iodine, the assumption of 1 µm particulate may be less conservative than for other radionuclides; however, this is smaller in comparison to the conservatism elsewhere in the overall methodology. For these reasons and for simplicity, a single scavenging coefficient applicable to 1 µm particles has been assumed for

all radionuclides. Exceptions to this approach are for noble gases, which are assumed not to be deposited, and for tritium and for carbon isotopes, which are particularly mobile in the environment, and for which an alternative to the scavenging coefficient method for determining deposition is employed.

Table 2 Time integrated activity concentration in air and deposited activity concentration used to derive Schedule 1 values for members of the public

	100 m from release location*	1000 m from release location*
Time integrated activity concentration in air (Bq s m^{-3} per Bq release)	1.1 10^{-4}	1.2 10^{-5} †
Deposited activity concentration (Bq m^{-2} per Bq release)	1.4 10^{-7}	3.0 10^{-8}

Notes:

* The value shown for each distance from the release location represents the maximum activity concentration in air or on the ground at that distance, based on historical weather data analysed for a selection of UK locations.

† Activity concentration in air at 1000 m from the release location, required for ingestion dose estimates for ^{11}C, ^{14}C and ^{35}S in gaseous or vapour forms (only).

5.4 Radionuclides

The radionuclides for which Schedule 1 values have been calculated are:

- for the purposes of continuity with the previous REPPIR legislation, all the radionuclides that appeared in Schedule 2 REPPIR-2001 are included
- for consistency with other legislation, all the radionuclides that appear in the Ionising Radiations Regulations 2017 are included
- the International Commission on Radiological Protection (ICRP) provides public inhalation and ingestion dose coefficients in its Publication 119 (ICRP, 2012). All the radionuclides in this publication are included

Since the publication of REPPIR 2001, ICRP has renamed some radionuclides in order to better identify ground and excited states. In ICRP Publication 119, Table 2.3 shows those radionuclides that have been renamed. The radionuclides included in this report follow this naming convention. For example:

- in REPPIR 2001, ^{89}Nb appeared as both a short-lived and long-lived form, with half-lives of 66 minutes and 122 minutes, respectively. ICRP has renamed these radionuclides, so that the short-lived form is now ^{89m}Nb, and the long-lived form is now ^{89}Nb
- radionuclides which exist in a metastable state are given an “m” suffix e.g. ^{89m}Nb. Where a radionuclide has 2 metastable states, the one with the higher energy is identified with an “n” suffix, and the one with the lower energy is identified with an “m” suffix, e.g. ^{190n}Ir and ^{190m}Ir
- new data has been used to identify the ground and excited state of radionuclides. In the case of ^{102}Rh, what was previously ^{102}Rh is now ^{102m}Rh, and what was ^{102m}Rh is now ^{102}Rh

As potential users of Schedule 1 values may be unfamiliar with this renaming convention, and to avoid doubt, all the radionuclides are listed below along with their half-life (taken from ICRP Publication 107 (ICRP, 2008)), thus definitively identifying each radionuclide.

When a radionuclide travels through the environment and interacts with a person's body, the dose imparted will depend on the radionuclide physical and chemical form. For example, isotopes of carbon (^{11}C, ^{14}C) may appear in particulate form, or as carbon dioxide, carbon monoxide, methane gas, or as carbon vapour. After inhaling particulates, radionuclides may be absorbed by the lung at different rates: fast, medium, slow. ICRP provides dose coefficients for radionuclides in their various forms. Schedule 1 values are calculated for all forms where possible and practical.

The limited availability of data has, in some cases, restricted the range of Schedule 1 values as a function of chemical form, for single radionuclides. For example, inhalation and ingestion dose coefficients have not been identified for organically bound tritium in gaseous or vapour form and therefore such a form has not been included. For some radionuclides, such as ^{35}S, the limited availability of data has resulted in a discord for different chemical forms and different exposure pathways. For example, for gaseous forms of ^{35}S, data availability restricts consideration of sulphur dioxide and carbon disulphide to the inhalation exposure pathway only, and consideration of hydrogen sulphide and carbonyl sulphide to the ingestion exposure pathway only. Due to a lack of information describing how these chemical forms behave in the environment, and more specifically a lack of information describing the transformation between different chemical forms in the environment, no summation of contributions for chemically consistent forms over the range of exposure pathways could be performed. Therefore, in such cases, a conservative approach was applied, whereby the chemical form resulting in the most conservative contribution to dose for each exposure pathway was identified and the respective doses summed (even though this may not reflect the chemical processes which occur in the environment). Thus, for each radionuclide, the most restrictive value is presented, but following the convention in REPPIR 2001, values for other forms are sometimes given.

5.5 Radioactive decay

Once radionuclides are released, they will continue to decay according to their radioactive half-lives (ICRP Publication 107), but any progeny radionuclides that are formed following radioactive decay of parent radionuclides in the air or on the ground are not taken into account. So, for example, progeny are not taken into account in the external dose models for exposure to the plume, or from exposure to radioactive material deposited on the skin or on the ground. In particular, short-lived progeny, which may be present in the release and perhaps in equilibrium with their parent (e.g. ^{137m}Ba from ^{137}Cs), are not taken into account. However, once inhaled or ingested, progeny radionuclides that are formed within the body are taken into account via the various dose coefficients (ICRP Publication 119). Similarly, any progeny radionuclides that are formed within foods before they are consumed are taken into account in the food chain model (see below), although the extent of this differs for some radionuclides due to the underlying modelling.

5.6 Food

To predict the consequences of the deposition of radioactive material onto land, food chain model results are required. The food chain model results used in this methodology are time integrated activity concentrations in food per unit deposit. The time integrated concentrations estimated by the food chain model are then combined with habit data and ingestion dose coefficients to calculate doses from ingestion of terrestrial foods. The calculation of doses from the ingestion of foods then requires 3 further assumptions: ingestion rates, local production rates, and agricultural practices.

The individual ingestion rates of green vegetables and cow's milk are taken from Smith and Jones (2003), and are summarised in Table 3. The intake rates are representative of people who consume at the 95th percentile rate of intake (rather than the previously used 97.5th percentile) of the individual annual ingestion rates for green vegetables and milk. Smith and Jones (2003) concluded that it is very unlikely that individuals will consume more than 2 foods at enhanced rates, and furthermore only a small area will be available for production of food at the point of maximum deposition at 1 km from the discharge. Hence, in this methodology only ingestion from green vegetables and cow's milk are considered.

Table 3 Ingestion rates based on national food surveys used in methodology *

Food	Ingestion rates †		
	Adult	Child	Infant
Green vegetables (kg y^{-1})	35	15	9.5
Milk (litres y^{-1})	210	220	290

Notes

* Smith and Jones (2003)

† These ingestion rates may be modified by the fraction of food that is locally produced. The fraction used in the methodology is 100 percent

The PHE model FARMLAND (Brown and Simmonds, 1995) is used to estimate the transfer into foodstuffs over a year from the time of deposition, with conservative assumptions regarding time of harvest and the amount of food assumed to be obtained locally. There is assumed to be no loss of activity due to food preparation and cooking (so, for example, a cabbage is assumed to be eaten with all its outside leaves and without either washing or cooking). FARMLAND predicts the activity (Bq y kg^{-1} per Bq m^{-2} deposited) integrated over the first 365 days after the release for all radionuclides considered (for green vegetable and milk). Pessimistic estimates of Bq y kg^{-1} per Bq m^{-2} values for green vegetables and milk were estimated for the radionuclides not considered in FARMLAND, except:

- time integrated activity concentrations of tritium (^{3}H) in food per unit deposit have been taken from the model TRIF (Higgins et al, 1996), conservatively assuming no atmospheric losses of tritium (i.e. no disparity as a function of weather or distance downwind) and a single conservative value as a function of the chemical and physical form

- an approach detailed in Smith et al (1998) has been used to calculate radioactivity concentrations of ^{11}C and ^{14}C in green vegetables, scaling by the ratio of green vegetable versus milk specific activity (as detailed in Smith and Simmonds (2009)) to calculate radioactivity concentrations of ^{11}C and ^{14}C in milk (assuming equilibrium in the activity between the 2 foodstuffs). This approach applies to isotopes of carbon in gaseous and vapour form only
- Smith et al (2004) consider an approach for estimating the uptake of gaseous forms (specifically $CO^{35}S$ and $H_2{}^{35}S$) of ^{35}S via plant leaves using the SGAS model. This approach is applied in this methodology to estimate the time integrated activity concentrations in food per unit time integrated activity concentration in air

It should be noted that the use of the FARMLAND model replaces the approach applied in the previous methodology for green vegetables, where sophisticated foodchain modelling was not applied. The simple approach adopted previously was based on the percentage of deposit intercepted by crops. In the previous methodology, FARMLAND was applied in the estimation of activity concentrations in milk, but only for a limited number of radionuclides.

It is necessary to consider the percentage of each foodstuff that is assumed to be locally produced. It is assumed here that only the foods which are of local origin will contain radionuclides resulting from the release (in this context, 'local' means produced at a single point centred at 1 km of the discharge point, at the point of maximum deposition at this distance). Clearly, there is a limit to how much food can be produced at one location and in reality, the foods consumed by the great majority of individuals will come from a much wider area. There is also the question of the size of the area required to produce the food. In the case of green vegetables, the area required to sustain a small number of individuals for a short period may be quite small, but for milk the area will be larger. The assumption in the previous methodology that an area of approximately 1 km^2 is needed to produce enough food to support a few individuals, with a distance of 0.5 km being used if the food production area lies immediately adjacent to the point of discharge, does not take into account the minimum distance of agricultural production from the point of the release, which is likely to be at least a hundred metres. This methodology adopts a less extreme but still very conservative approach to the issue of locally sourced food. It is assumed that the exposed individual obtains all of their milk and green vegetables for the year from a location centred on 1 km downwind of the discharge point. The methodology implicitly assumes that green vegetables are in harvest throughout the year, and that the release occurs during the summer months when cows are outdoors grazing pasture, which is clearly an additional cautious assumption.

Other foods in the diet are assumed to be uncontaminated. It is very unlikely that individuals will source all their grain, beef and sheep meat from the close-in distance considered (1 km); inclusion of these would make the ingestion dose estimates extremely unrealistic. In particular, there is no evidence to indicate that grain in the UK is grown, milled and consumed on a very local scale. As there has been an increase in recent years in the non-commercial keeping of hens for egg production, the possible effect of egg-producing hens being located at 1 km from the release point, obtaining a significant portion of their diet from grass at that point, and then supplying an individual with eggs throughout the year at a high rate of consumption, has been investigated. This was found to not significantly alter the Schedule 1 values, for any of the radionuclides examined (data on the transfer from a hen's diet to eggs is only available for a limited number of radionuclides), and this pathway has therefore not been considered further.

Ingestion dose coefficients account for the contribution to ingestion dose made by progeny following the intake of the parent radionuclide. The growth of progeny in foods prior to ingestion is only included in FARMLAND if the dose from the subsequent ingestion of the progeny is a significant fraction of the dose from the parent. It is considered only necessary to include 2 progeny. These are ^{125m}Te (from ^{125}Sb) which contributes significantly to the committed effective dose over both the short and longer term, and ^{241}Am (from ^{241}Pu) which makes a significant contribution over the longer term only.

5.7 Inhalation and external exposure pathways

Non-food exposure routes are external exposure (to the plume or deposited material), and inhalation of the plume.

For both these pathways it is assumed that the exposed individual is located at a distance of 100 m downwind from the release location. The assumption in the methodology is that the release occurs at ground level with no associated energy. Under these circumstances, it is conservative to assume that the individual is located at 100m. For elevated release points, the peak concentration in air would be further downwind, but that does not apply to the conditions considered here. Location and habit related assumptions are described below.

The dose from inhalation of the plume is calculated using time integrated activity concentrations in air, habit data and inhalation dose coefficients. Inhalation rates are summarised in Table 4.

External exposure to the plume only occurs during the passage of the plume but external exposure to material deposited on the ground occurs after the plume has passed and may well persist throughout the first year of exposure for long-lived radionuclides. The external exposure from a unit deposit of radioactive material will vary with time due to migration through the soil and radioactive decay. Dose rate per unit deposit values were derived from Veinot et al (2017). Dose rate coefficients account for the contributions from gamma rays, annihilation quanta and hard X-rays, assuming a source plane at depth 0.3 cm and accounting for the presence of vegetation, surface irregularities, and particle movement due to weathering. Beta doses to skin, and estimation of the bremsstrahlung dose were also considered. Values of dose rate per unit activity concentration in air were derived from Bellamy et al (2017). Contributions from gamma rays (photons), beta electrons, discrete electrons (internal conversion and auger electrons) and bremsstrahlung were all estimated and summed.

Skin areas were assumed to be those areas of the head plus the areas of the hands that are usually exposed to ultra-violet radiation (UVR) from the Sun, and were based on values presented in ICRP Publication 89 (ICRP, 2002) and EPA (EPA, 1997). ICRP Publication 89 considers skin thickness as a function of age and skin region. Conservative (i.e. thinner) skin thicknesses more akin to the face than the palms of the hands and fingers were considered and derived. On the basis of such skin thicknesses, skin equivalent dose rates to the basal layer of the skin epidermis for beta irradiation from Cross et al (1992) and Kocher and Eckerman (1987) were assumed for adults, and infants and children, respectively. It was also assumed that material deposits on the skin at the same rate as to the ground and resides on the skin for a period of 12 hours before being washed off.

There is a significant difference between the skin areas considered in this methodology and those assumed previously. The previous methodology considered the exposure of skin relative to the total (whole body) skin area and did not differentiate between UVR and non-UVR exposed skin. This methodology considers the exposure of skin relative to the total UVR exposed skin area, and therefore does differentiate between UVR and non-UVR exposed skin. This is considered appropriate because the considered areas of exposed skin are predominantly UVR exposed skin areas. This difference is compounded by the previous methodology assuming only a very small skin area is exposed (approximating to the area of the face). In the new methodology, the area of contaminated skin approximates to the area of the whole head plus the area of the hands.

5.8 Other exposure routes

The calculations included in the Schedule 1 methodology are explicitly linked to releases to atmosphere. Other exposure routes have not been included in the revised methodology, as discussed above, although there was a dose assessment methodology included for several other exposure routes in NRPB-M1311 (Carey et al, 2001). For example, Table 3 of NRPB-M1311 (Carey et al, 2001) indicates that the most restrictive exposure pathway and release scenario for isotopes of cobalt is the external exposure from conditioned soil from the sewage treatment works to members of the public, if such an exposure pathway is plausible, and similarly the most restrictive exposure pathway and release scenario for ^{192}Ir is the external exposure to a sewage treatment worker from the sewage tank. However, in the transposition of the NRPB-M1311 values into Schedule 2 of REPPIR 2001 only the results of the atmospheric assessments were included and the results for river exposures, sewer worker and public sewerage doses were not taken into account in the Schedule 2 values.

Duty holders should consider the possibility of other exposure routes than atmospheric releases, for example via releases to rivers or sewers. This may require consideration of potential occupational exposure of (for example) sewerage workers. Also, pathways not included explicitly in these calculations should be taken into account if the possibility of them exists, for example exposure of the lens of the eye, exposure by direct shine or criticality. This includes consideration of the full impact of radionuclide progeny where this may be of significance in site-specific circumstances (as discussed above, progeny are considered in parts of the calculations and in the estimation of Schedule 1 values, but not all elements of the calculation fully consider all progeny and in specific circumstances this may influence the dose received).

If required, an assessment of potential exposure of members of the public from a release to sewers should consider inadvertent ingestion of conditioned soil, inhalation of resuspended conditioned soil, external irradiation from conditioned soil and ingestion of animal products from sewage sludge applied to farmland. An assessment of potential dose to sewage workers should consider the inadvertent ingestion of sewage sludge, inhalation of resuspended sludge and external irradiation above the sewage tanks.

6 Summary table of assumptions

Table 4 shows a summary of the assumptions in this methodology, together with differences between this methodology and the Schedule 2 REPPIR-2001 methodology.

Table 4 Tabulated summary of the Schedule 1 REPPIR-2019 assessment methodology and comparison with Schedule 2 REPPIR-2001 method and values

	Calculation of Schedule 2 values for REPPIR-2001	Calculation of Schedule 1 values for REPPIR-2019
Dose criteria (mSv y^{-1})		
Effective dose threshold (mSv y^{-1})	5	1
Thyroid dose threshold (mSv y^{-1})	none	25
Skin dose threshold (mSv y^{-1})	50	50
Lens of the eye dose threshold (mSv y^{-1})	15 (but not reported as limiting in the Schedule 2 values)	Calculations no longer in the default Schedule 1 values
Locations		
Location of the individual	100 m throughout plume passage, and 100 m for 10% of the first year thereafter	100 m throughout plume passage, and 100 m for 70% of the first year thereafter
Location of food production	500 m	1 km
Atmospheric Dispersion Model (ADM) Approach		
	Gaussian, NRPB-R91: Pasquill stability category D without rain	Probabilistic analysis of historical UK meteorological data using NAME and PACE, to estimate 95th percentile concentrations
Habit Data		
Inhalation rate	Infant: 6.0 x 10^{-5} m^3 s^{-1} Child: 1.8 x 10^{-4} m^3 s^{-1} Adult: 2.3 x 10^{-4} m^3 s^{-1} (Robinson, 1996)	Infant: 8.6 x 10^{-5} m^3 s^{-1} Child: 2.4 x 10^{-4} m^3 s^{-1} Adult: 3.0 x 10^{-4} m^3 s^{-1} Breast-fed infant: 5.3 x 10^{-5} m^3 s^{-1} (ICRP, 1994)
Occupancy (% of time spent at location)	10% occupancy assumed for groundshine calculation 100% occupancy assumed for all other exposure pathways	70% occupancy assumed for groundshine calculation 100% occupancy assumed for all other exposure pathways
Location/shielding factors (protection offered at the location)	None	No protection assumed during plume passage For the remainder of the 1st year, 0.1 assumed for groundshine calculation while at 100 m; corresponding to residence in a solidly built building No protection assumed for all other pathways for the remainder of the 1st year while at 100 m
Area of contaminated skin	Adult face: 100 cm^2 Child face: 53 cm^2 Infant face: 22 cm^2 (ICRP, 1975)	Adult: 2325 cm^2 Child: 1811 cm^2 Infant: 1106 cm^2 (ICRP, 2002) and (EPA, 1997)
Total (UVR-exposed) skin area	Total skin area: Adult: 1.8 x 10^4 cm^2 Child: 9.6 x 10^3 cm^2 Infant: 3.9 x 10^3 cm^2	Total UVR-exposed skin area: Adult: 3000 cm^2 Child: 2100 cm^2 Infant: 1100 cm^2

	Calculation of Schedule 2 values for REPPIR-2001	Calculation of Schedule 1 values for REPPIR-2019
	(ICRP, 1975)	(ICRP, 2002)
Interception factor and subsequent weathering of activity on green vegetables	0.016 (Brown and Simmonds, 1995)	Included via the FARMLAND model (Brown and Simmonds, 1995)
Fraction of activity remaining on and in food following preparation	Assume there are no preparation losses	Included via the FARMLAND model (Brown and Simmonds, 1995)
Ingestion rate	Green veg: - Adult: 80 kg y^{-1} - Child: 35 kg y^{-1} - Infant: 15 kg y^{-1} Milk: - Adult: 240 L y^{-1} - Child: 240 L y^{-1} - Infant: 320 L y^{-1} Byrom et al (1995) – 97.5th percentile ingestion rate	Green veg: - Adult: 35 kg y^{-1} - Child: 15 kg y^{-1} - Infant: 9.5 kg y^{-1} Milk: - Adult: 210 L y^{-1} - Child: 220 L y^{-1} - Infant: 290 L y^{-1} Smith and Jones (2003)– 95th percentile ingestion rate
Dose Calculations		
Inhalation & ingestion dose coefficients	ICRP (1996) (for members of the public)	ICRP (2012) for effective dose coefficients, ICRP (1996) for thyroid dose coefficients, ICRP (2001) for dose coefficients to the foetus and ICRP (2004) for dose coefficients to the breast fed infant (all for members of the public)
Lung absorption types	F, M & S	F, M & S
External from cloud dose coefficients	Average beta and gamma energies per disintegration, and dose per activity concentrations per energy (Harvey et al, 1993) – however this reference, references NRPB/CEA (1979) as the source of the dose (rate) per activity concentrations per energy	Adult, 10 year old child and 1 year old infant effective dose rate per unit activity concentration in air values derived from (Bellamy et al, 2017)
External from ground dose coefficients	Effective dose rate 1 m above an infinite plane for beta and gamma radiation. From: (Kocher, 1983) and Federal Guidance Report 12 (Eckerman and Ryman, 1993)	Adult, 10 year old child and 1 year old infant effective dose rate per unit deposit values derived from (Veinot et al, 2017)
Skin dose coefficients	Gamma and beta dose rate for skin (Harvey et al, 1993) – however this references Chaptinel et al (1988) and Kocher and Eckerman (1987) as the source of the dose rates per unit deposit for gamma irradiation and beta irradiation, respectively	Skin equivalent dose rates for beta irradiation only. Cross et al (1992) is the primary reference for adult coefficients; Kocher and Eckerman (1987) is the primary reference for 10 year old child and 1 year old infant coefficients)
Organ/tissues	Effective and skin	Effective, skin & thyroid
Age groups	1 year old, 10 year old and adult only	Primarily adult, 10 year old child and 1 year old infant, but also foetus and breast fed infant for a subset of radionuclides
Dose integration period	Inhalation & external from cloud: 30 minutes External from ground and ingestion: 1 year Skin: 12 hours	Inhalation & external from cloud: 30 minutes External from ground & ingestion: 1 year Skin: 12 hours
Dose description	Committed dose (assumed to age 70) and equivalent dose to skin	Committed effective dose to age 70 years and committed equivalent dose to age 70 years

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Appendix A Schedule 1 REPPIR-2019 values

Notes

Radionuclide: named according to the ICRP publication 107 naming convention. In particular, “m” and “n” suffixes are used to identify radionuclides with multiple metastable states. If a radionuclide has changed its name since REPPIR 2001, its previous name is additionally given.

Half life: from ICRP publication 107 - given to definitively identify each radionuclide. Mixed units are used: (y)ears, (d)ays, (h)ours, (m)inutes, (s)econds.

Form: where ICRP provides a dose coefficient for a radionuclide in a particular chemical form, an activity (Bq) for that chemical form has been additionally listed.

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Actinium						
Ac-224	2.78 h		2×10^{11}	2×10^{11}		⇔ Same
Ac-225	10.0 d		3×10^{09}	3×10^{09}		⇔ Same
Ac-226	29.37 h		2×10^{10}	2×10^{10}		⇔ Same
Ac-227	21.772 y		5×10^{07}	4×10^{07}		⇧ 1
Ac-228	6.15 h		7×10^{11}	5×10^{11}		⇧ 1
Aluminium						
Al-26	7.17×10^{5} y		6×10^{11}	7×10^{10}		⇧ 9
Americium						
Am-237	73.0 m		2×10^{14}	4×10^{12}		⇧ 50
Am-238	98 m		9×10^{13}	6×10^{12}		⇧ 15
Am-239	11.9 h		3×10^{13}	2×10^{12}		⇧ 15
Am-240	50.8 h		1×10^{13}	4×10^{12}		⇧ 3
Am-241	432.2 y		3×10^{08}	3×10^{08}		⇔ Same
Am-242	16.02 h		1×10^{12}	1×10^{12}		⇔ Same
Am-242m	141 y		3×10^{08}	3×10^{08}		⇔ Same
Am-243	7.37×10^{3} y		3×10^{08}	3×10^{08}		⇔ Same
Am-244	10.1 h		7×10^{12}	2×10^{12}		⇧ 4
Am-244m	26 m		2×10^{14}	2×10^{14}		⇔ Same
Am-245	2.05 h		1×10^{14}	2×10^{12}		⇧ 50
Am-246	39 m		9×10^{13}	1×10^{12}		⇧ 90
Am-246m	25.0 m		1×10^{14}	2×10^{12}		⇧ 50
Antimony						
Sb-115	32.1 m		2×10^{14}	2×10^{12}		⇧ 100
Sb-116	15.8 m		9×10^{13}	2×10^{12}		⇧ 45
Sb-116m	60.3 m		4×10^{13}	2×10^{12}		⇧ 20
Sb-117	2.80 h		3×10^{14}	1×10^{13}		⇧ 30

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Sb-118m	5.00 h		3×10^{13}	7×10^{12}		⇧ 4
Sb-119	38.19 h		1×10^{14}	1×10^{13}		⇧ 10
Sb-120	15.89 m		3×10^{14}	2×10^{12}	Sb-120s	⇧ 150
Sb-120m	5.76 d		7×10^{12}	3×10^{12}	Sb-120l	⇧ 2
Sb-122	2.7238 d		5×10^{12}	2×10^{12}		⇧ 3
Sb-124	60.20 d		2×10^{12}	4×10^{11}		⇧ 5
Sb-124n	20.2 m		1×10^{15}	4×10^{12}	Sb-124ml	⇧ 250
Sb-125	2.75856 y		2×10^{12}	4×10^{11}		⇧ 5
Sb-126	12.35 d		3×10^{12}	1×10^{12}		⇧ 3
Sb-126m	19.15 m		1×10^{14}	2×10^{12}		⇧ 50
Sb-127	3.85 d		4×10^{12}	2×10^{12}		⇧ 2
Sb-128	9.01 h		1×10^{13}	2×10^{12}	Sb-128l	⇧ 5
Sb-128m	10.4 m		1×10^{14}	1×10^{12}	Sb-128s	⇧ 100
Sb-129	4.40 h		2×10^{13}	2×10^{12}		⇧ 10
Sb-130	39.5 m		4×10^{13}	1×10^{12}		⇧ 40
Sb-131	23.03 m		5×10^{13}	2×10^{12}		⇧ 25
Argon						
Ar-37	35.04 d		2×10^{20}	4×10^{17}		⇧ 500
Ar-39	269 y		4×10^{16}	2×10^{16}		⇧ 2
Ar-41	109.61 m		7×10^{13}	4×10^{13}		⇧ 2
Arsenic						
As-69	15.23 m		1×10^{14}	7×10^{11}		⇧ 143
As-70	52.6 m		3×10^{13}	1×10^{12}		⇧ 30
As-71	65.28 h		2×10^{13}	3×10^{12}		⇧ 7
As-72	26.0 h		5×10^{12}	9×10^{11}		⇧ 6
As-73	80.30 d		2×10^{13}	8×10^{12}		⇧ 3
As-74	17.77 d		5×10^{12}	2×10^{12}		⇧ 3
As-76	1.0778 d		5×10^{12}	9×10^{11}		⇧ 6
As-77	38.83 h		2×10^{13}	2×10^{12}		⇧ 10
As-78	90.7 m		3×10^{13}	7×10^{11}		⇧ 43
Astatine						
At-207	1.80 h		1×10^{13}	4×10^{12}		⇧ 3
At-211	7.214 h		2×10^{11}	2×10^{11}		⇔ Same
Barium						
Ba-126	100 m		3×10^{13}	2×10^{13}		⇧ 2
Ba-128	2.43 d		4×10^{12}	1×10^{13}		⇩ 3

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Ba-131	11.50 d		1×10^{13}	6×10^{12}		⇧ 2
Ba-131m	14.6 m		1×10^{15}	3×10^{12}		⇧ 333
Ba-133	10.52 y		2×10^{12}	4×10^{11}		⇧ 5
Ba-133m	38.9 h		1×10^{13}	2×10^{12}		⇧ 5
Ba-135m	28.7 h		2×10^{13}	2×10^{12}		⇧ 10
Ba-139	83.06 m		7×10^{13}	1×10^{12}		⇧ 70
Ba-140	12.752 d		3×10^{12}	2×10^{12}		⇧ 2
Ba-141	18.27 m		1×10^{14}	1×10^{12}		⇧ 100
Ba-142	10.6 m		2×10^{14}	2×10^{12}		⇧ 100
Berkelium						
Bk-245	4.94 d		9×10^{12}	3×10^{12}		⇧ 3
Bk-246	1.80 d		2×10^{13}	6×10^{12}		⇧ 3
Bk-247	1.38×10^{3} y		4×10^{08}	3×10^{08}		⇧ 1
Bk-249	330 d		2×10^{11}	2×10^{11}		⇔ Same
Bk-250	3.212 h		2×10^{13}	2×10^{12}		⇧ 10
Beryllium						
Be-7	53.22 d		2×10^{14}	2×10^{13}		⇧ 10
Be-10	1.51×10^{6} y		8×10^{11}	6×10^{11}		⇧ 1
Bismuth						
Bi-200	36.4 m		6×10^{13}	2×10^{12}		⇧ 30
Bi-201	108 m		4×10^{13}	2×10^{12}		⇧ 20
Bi-202	1.72 h		4×10^{13}	3×10^{12}		⇧ 13
Bi-203	11.76 h		2×10^{13}	4×10^{12}		⇧ 5
Bi-205	15.31 d		8×10^{12}	2×10^{12}		⇧ 4
Bi-206	6.243 d		4×10^{12}	2×10^{12}		⇧ 2
Bi-207	32.9 y		2×10^{12}	1×10^{11}		⇧ 20
Bi-210	5.013 d		3×10^{11}	2×10^{11}		⇧ 2
Bi-210m	3.04×10^{6} y		8×10^{09}	6×10^{09}		⇧ 1
Bi-212	60.55 m		1×10^{12}	7×10^{11}		⇧ 1
Bi-213	45.59 m		1×10^{12}	7×10^{11}		⇧ 1
Bi-214	19.9 m		3×10^{12}	1×10^{12}		⇧ 3
Bromine						
Br-74	25.4 m		3×10^{13}	8×10^{11}		⇧ 38
Br-74m	46 m		3×10^{13}	6×10^{11}		⇧ 50
Br-75	96.7 m		6×10^{13}	2×10^{12}		⇧ 30

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Br-76	16.2 h		1×10^{13}	1×10^{12}		⇧ 10
Br-77	57.036 h		8×10^{13}	4×10^{13}		⇧ 2
Br-80	17.68 m		3×10^{14}	1×10^{12}		⇧ 300
Br-80m	4.4205 h		7×10^{13}	5×10^{12}		⇧ 14
Br-82	35.30 h		1×10^{13}	3×10^{12}		⇧ 3
Br-83	2.40 h		1×10^{14}	2×10^{12}		⇧ 50
Br-84	31.80 m		6×10^{13}	7×10^{11}		⇧ 86
Cadmium						
Cd-104	57.7 m		2×10^{14}	1×10^{13}		⇧ 20
Cd-107	6.50 h		1×10^{14}	4×10^{12}		⇧ 25
Cd-109	461.4 d		2×10^{12}	2×10^{12}		⇔ Same
Cd-113	7.7×10^{15} y		2×10^{11}	2×10^{11}		⇔ Same
Cd-113m	14.1 y		2×10^{11}	1×10^{11}		⇧ 2
Cd-115	53.46 h		6×10^{12}	2×10^{12}		⇧ 3
Cd-115m	44.6 d		2×10^{12}	2×10^{12}		⇔ Same
Cd-117	2.49 h		3×10^{13}	2×10^{12}		⇧ 15
Cd-117m	3.36 h		2×10^{13}	2×10^{12}		⇧ 10
Caesium						
Cs-125	45 m		1×10^{14}	2×10^{12}		⇧ 50
Cs-127	6.25 h		2×10^{14}	1×10^{13}		⇧ 20
Cs-129	32.06 h		1×10^{14}	2×10^{13}		⇧ 5
Cs-130	29.21 m		2×10^{14}	2×10^{12}		⇧ 100
Cs-131	9.689 d		2×10^{14}	6×10^{13}		⇧ 3
Cs-132	6.479 d		2×10^{13}	9×10^{12}		⇧ 2
Cs-134	2.0648 y		4×10^{11}	7×10^{10}		⇧ 6
Cs-134m	2.903 h		2×10^{14}	4×10^{12}		⇧ 50
Cs-135	2.3×10^{6} y		3×10^{12}	9×10^{11}		⇧ 3
Cs-135m	53 m		1×10^{14}	8×10^{12}		⇧ 13
Cs-136	13.16 d		5×10^{12}	8×10^{11}		⇧ 6
Cs-137	30.1671 y		4×10^{11}	1×10^{11}		⇧ 4
Cs-138	33.41 m		5×10^{13}	8×10^{11}		⇧ 63
Calcium						
Ca-41	1.02×10^{5} y		6×10^{13}	3×10^{13}		⇧ 2
Ca-45	162.67 d		2×10^{12}	3×10^{12}		⇩ 2
Ca-47	4.536 d		2×10^{12}	2×10^{12}		⇔ Same

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Californium						
Cf-244	19.4 m		3×10^{12}	2×10^{12}		⇧ 2
Cf-246	35.7 h		6×10^{10}	5×10^{10}		⇧ 1
Cf-248	334 d		3×10^{09}	2×10^{09}		⇧ 2
Cf-249	351 y		4×10^{08}	3×10^{08}		⇧ 1
Cf-250	13.08 y		9×10^{08}	7×10^{08}		⇧ 1
Cf-251	900 y		4×10^{08}	3×10^{08}		⇧ 1
Cf-252	2.645 y		1×10^{09}	1×10^{09}		⇔ Same
Cf-253	17.81 d		2×10^{10}	2×10^{10}		⇔ Same
Cf-254	60.5 d		5×10^{08}	4×10^{08}		⇧ 1
Carbon						
C-11	20.39 m		2×10^{14}	2×10^{12}		⇧ 100
		carbon dioxide	2×10^{14}	1×10^{14}		⇧ 2
		carbon monoxide	3×10^{14}	1×10^{14}		⇧ 3
		methane	3×10^{14}			New
		vapour	2×10^{14}	1×10^{14}		⇧ 2
C-14	5.70×10^{3} y		5×10^{12}	3×10^{12}		⇧ 2
		carbon dioxide	3×10^{12}	3×10^{15}		⇩ 1000
		carbon monoxide	3×10^{12}	1×10^{16}		⇩ 3333
		methane	3×10^{12}			New
		vapour	3×10^{12}	4×10^{13}		⇩ 13
Cerium						
Ce-134	3.16 d		3×10^{12}	1×10^{13}		⇩ 3
Ce-135	17.7 h		1×10^{13}	2×10^{12}		⇧ 5
Ce-137	9.0 h		3×10^{14}	2×10^{13}		⇧ 15
Ce-137m	34.4 h		1×10^{13}	2×10^{12}		⇧ 5
Ce-139	137.641 d		9×10^{12}	2×10^{12}		⇧ 5
Ce-141	32.508 d		5×10^{12}	2×10^{12}		⇧ 3
Ce-143	33.039 h		7×10^{12}	2×10^{12}		⇧ 4
Ce-144	284.91 d		4×10^{11}	3×10^{11}		⇧ 1
Chlorine						
Cl-36	3.01×10^{5} y		3×10^{12}	2×10^{12}		⇧ 2
Cl-38	37.24 m		5×10^{13}	6×10^{11}		⇧ 83
Cl-39	55.6 m		6×10^{13}	1×10^{12}		⇧ 60

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Chromium						
Cr-48	21.56 h		4×10^{13}	4×10^{13}	⇔	Same
Cr-49	42.3 m		9×10^{13}	2×10^{12}	⇧	45
Cr-51	27.7025 d		2×10^{14}	3×10^{13}	⇧	7
Cobalt						
Co-55	17.53 h		9×10^{12}	2×10^{12}	⇧	5
Co-56	77.23 d		1×10^{12}	2×10^{11}	⇧	5
Co-57	271.74 d		1×10^{13}	1×10^{12}	⇧	10
Co-58	70.86 d		5×10^{12}	6×10^{11}	⇧	8
Co-58m	9.04 h		4×10^{14}	2×10^{13}	⇧	20
Co-60	5.2713 y		6×10^{11}	6×10^{10}	⇧	10
Co-60m	10.467 m		5×10^{15}	7×10^{12}	⇧	714
Co-61	1.650 h		1×10^{14}	2×10^{12}	⇧	50
Co-62m	13.91 m		7×10^{13}	9×10^{11}	⇧	78
Copper						
Cu-60	23.7 m		4×10^{13}	1×10^{12}	⇧	40
Cu-61	3.333 h		5×10^{13}	2×10^{12}	⇧	25
Cu-64	12.700 h		6×10^{13}	4×10^{12}	⇧	15
Cu-67	61.83 h		2×10^{13}	3×10^{12}	⇧	7
Curium						
Cm-238	2.4 h		6×10^{12}	5×10^{12}	⇧	1
Cm-240	27 d		8×10^{09}	7×10^{09}	⇧	1
Cm-241	32.8 d		7×10^{11}	5×10^{11}	⇧	1
Cm-242	162.8 d		5×10^{09}	4×10^{09}	⇧	1
Cm-243	29.1 y		4×10^{08}	4×10^{08}	⇔	Same
Cm-244	18.10 y		5×10^{08}	4×10^{08}	⇧	1
Cm-245	8.5×10^{3} y		3×10^{08}	2×10^{08}	⇧	2
Cm-246	4.76×10^{3} y		3×10^{08}	2×10^{08}	⇧	2
Cm-247	1.56×10^{7} y		3×10^{08}	3×10^{08}	⇔	Same
Cm-248	3.48×10^{5} y		8×10^{07}	7×10^{07}	⇧	1
Cm-249	64.15 m		2×10^{14}	2×10^{12}	⇧	100
Cm-250	8300 y		1×10^{07}	1×10^{07}	⇔	Same
Dysprosium						
Dy-155	9.9 h		6×10^{13}	1×10^{13}	⇧	6
Dy-157	8.14 h		1×10^{14}	1×10^{14}	⇔	Same

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Dy-159	144.4 d		4×10^{13}	8×10^{12}		⇧ 5
Dy-165	2.334 h		7×10^{13}	2×10^{12}		⇧ 35
Dy-166	81.6 h		5×10^{12}	3×10^{12}		⇧ 2
Einsteinium						
Es-250m	2.22 h		4×10^{13}	1×10^{13}	Es-250	⇧ 4
Es-251	33 h		1×10^{13}	6×10^{12}		⇧ 2
Es-253	20.47 d		1×10^{10}	8×10^{09}		⇧ 1
Es-254	275.7 d		3×10^{09}	2×10^{09}		⇧ 2
Es-254m	39.3 h		6×10^{10}	5×10^{10}		⇧ 1
Erbium						
Er-161	3.21 h		7×10^{13}	6×10^{12}		⇧ 12
Er-165	10.36 h		5×10^{14}	2×10^{14}		⇧ 3
Er-169	9.40 d		1×10^{13}	3×10^{12}		⇧ 3
Er-171	7.516 h		2×10^{13}	2×10^{12}		⇧ 10
Er-172	49.3 h		8×10^{12}	3×10^{12}		⇧ 3
Europium						
Eu-145	5.93 d		1×10^{13}	4×10^{12}		⇧ 3
Eu-146	4.61 d		7×10^{12}	3×10^{12}		⇧ 2
Eu-147	24.1 d		1×10^{13}	4×10^{12}		⇧ 3
Eu-148	54.5 d		3×10^{12}	4×10^{11}		⇧ 8
Eu-149	93.1 d		4×10^{13}	8×10^{12}		⇧ 5
Eu-150	36.9 y		5×10^{11}	1×10^{11}	Eu-150l	⇧ 5
Eu-150m	12.8 h		2×10^{13}	2×10^{12}	Eu-150s	⇧ 10
Eu-152	13.537 y		6×10^{11}	1×10^{11}		⇧ 6
Eu-152m	9.3116 h		2×10^{13}	2×10^{12}		⇧ 10
Eu-154	8.593 y		5×10^{11}	1×10^{11}		⇧ 5
Eu-155	4.7611 y		4×10^{12}	2×10^{12}		⇧ 2
Eu-156	15.19 d		3×10^{12}	2×10^{12}		⇧ 2
Eu-157	15.18 h		1×10^{13}	2×10^{12}		⇧ 5
Eu-158	45.9 m		6×10^{13}	1×10^{12}		⇧ 60
Fermium						
Fm-252	25.39 h		9×10^{10}	7×10^{10}		⇧ 1
Fm-253	3.00 d		7×10^{10}	6×10^{10}		⇧ 1
Fm-254	3.240 h		4×10^{11}	3×10^{11}		⇧ 1
Fm-255	20.07 h		1×10^{11}	9×10^{10}		⇧ 1
Fm-257	100.5 d		3×10^{09}	3×10^{09}		⇔ Same

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Fluorine						
F-18	109.77 m		8×10^{13}	2×10^{12}		⇧ 40
Francium						
Fr-222	14.2 m		3×10^{12}	1×10^{12}		⇧ 3
Fr-223	22.00 m		4×10^{12}	2×10^{12}		⇧ 2
Gadolinium						
Gd-145	23.0 m		7×10^{13}	2×10^{12}		⇧ 35
Gd-146	48.27 d		3×10^{12}	2×10^{12}		⇧ 2
Gd-147	38.1 h		1×10^{13}	5×10^{12}		⇧ 2
Gd-148	74.6 y		1×10^{09}	9×10^{08}		⇧ 1
Gd-149	9.28 d		1×10^{13}	6×10^{12}		⇧ 2
Gd-151	124 d		1×10^{13}	5×10^{12}		⇧ 2
Gd-152	1.08×10^{14} y		2×10^{09}	1×10^{09}		⇧ 2
Gd-153	240.4 d		7×10^{12}	2×10^{12}		⇧ 4
Gd-159	18.479 h		2×10^{13}	2×10^{12}		⇧ 10
Gallium						
Ga-65	15.2 m		1×10^{14}	1×10^{12}		⇧ 100
Ga-66	9.49 h		7×10^{12}	9×10^{11}		⇧ 8
Ga-67	3.2612 d		4×10^{13}	5×10^{12}		⇧ 8
Ga-68	67.71 m		6×10^{13}	2×10^{12}		⇧ 30
Ga-70	21.14 m		3×10^{14}	1×10^{12}		⇧ 300
Ga-72	14.10 h		8×10^{12}	2×10^{12}		⇧ 4
Ga-73	4.86 h		3×10^{13}	2×10^{12}		⇧ 15
Germanium						
Ge-66	2.26 h		7×10^{13}	3×10^{12}		⇧ 23
Ge-67	18.9 m		9×10^{13}	7×10^{11}		⇧ 129
Ge-68	270.95 d		2×10^{12}	1×10^{12}		⇧ 2
Ge-69	39.05 h		3×10^{13}	2×10^{12}		⇧ 15
Ge-71	11.43 d		6×10^{14}	7×10^{14}		⇩ 1
Ge-75	82.78 m		2×10^{14}	2×10^{12}		⇧ 100
Ge-77	11.30 h		2×10^{13}	1×10^{12}		⇧ 20
Ge-78	88 m		7×10^{13}	2×10^{12}		⇧ 35
Gold						
Au-193	17.65 h		6×10^{13}	7×10^{12}		⇧ 9
Au-194	38.02 h		2×10^{13}	1×10^{13}		⇧ 2

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Au-195	186.098 d		1×10^{13}	3×10^{12}		⇧ 3
Au-198	2.69517 d		7×10^{12}	2×10^{12}		⇧ 4
Au-198m	2.27 d		6×10^{12}	2×10^{12}		⇧ 3
Au-199	3.139 d		2×10^{13}	3×10^{12}		⇧ 7
Au-200	48.4 m		1×10^{14}	1×10^{12}		⇧ 100
Au-200m	18.7 h		8×10^{12}	2×10^{12}		⇧ 4
Au-201	26 m		3×10^{14}	2×10^{12}		⇧ 150
Hafnium						
Hf-170	16.01 h		2×10^{13}	4×10^{12}		⇧ 5
Hf-172	1.87 y		7×10^{11}	5×10^{11}		⇧ 1
Hf-173	23.6 h		4×10^{13}	6×10^{12}		⇧ 7
Hf-175	70 d		1×10^{13}	2×10^{12}		⇧ 5
Hf-177m	51.4 m		5×10^{13}	2×10^{12}		⇧ 25
Hf-178m	31 y		1×10^{11}	4×10^{10}		⇧ 3
Hf-179m	25.05 d		4×10^{12}	2×10^{12}		⇧ 2
Hf-180m	5.5 h		4×10^{13}	2×10^{12}		⇧ 20
Hf-181	42.39 d		4×10^{12}	1×10^{12}		⇧ 4
Hf-182	9×10^{6} y		1×10^{11}	7×10^{10}		⇧ 1
Hf-182m	61.5 m		1×10^{14}	2×10^{12}		⇧ 50
Hf-183	1.067 h		8×10^{13}	2×10^{12}		⇧ 40
Hf-184	4.12 h		2×10^{13}	2×10^{12}		⇧ 10
Holmium						
Ho-155	48 m		1×10^{14}	2×10^{12}		⇧ 50
Ho-157	12.6 m		4×10^{14}	4×10^{12}		⇧ 100
Ho-159	33.05 m		4×10^{14}	6×10^{12}		⇧ 67
Ho-161	2.48 h		6×10^{14}	1×10^{13}		⇧ 60
Ho-162	15.0 m		1×10^{15}	5×10^{12}		⇧ 200
Ho-162m	67.0 m		2×10^{14}	4×10^{12}		⇧ 50
Ho-164	29 m		7×10^{14}	2×10^{12}		⇧ 350
Ho-164m	38.0 m		5×10^{14}	4×10^{12}		⇧ 125
Ho-166	26.80 h		6×10^{12}	1×10^{12}		⇧ 6
Ho-166m	1.20×10^{3} y		2×10^{11}	8×10^{10}		⇧ 3
Ho-167	3.1 h		7×10^{13}	2×10^{12}		⇧ 35
Hydrogen						
H-3	12.32 y		1×10^{14}	7×10^{13}		⇧ 1

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)		Factor by which value has increased or decreased (rounded to nearest whole number)
		organically bound tritium	3×10^{14}	1×10^{14}		⇧	3
		elemental gas	7×10^{14}	1×10^{18}		⇩	1429
		tritiated methane	2×10^{15}	1×10^{17}		⇩	50
		tritiated water vapour	7×10^{14}	1×10^{15}		⇩	1
Indium							
In-109	4.2 h		9×10^{13}	7×10^{12}		⇧	13
In-110	4.9 h		3×10^{13}	2×10^{13}	In-110l	⇧	2
In-110m	69.1 m		5×10^{13}	1×10^{12}	In-110s	⇧	50
In-111	2.8047 d		3×10^{13}	9×10^{12}		⇧	3
In-112	14.97 m		5×10^{14}	2×10^{12}		⇧	250
In-113m	1.6579 h		2×10^{14}	5×10^{12}		⇧	40
In-114	71.9 s		4×10^{15}	1×10^{12}		⇧	4000
In-114m	49.51 d		9×10^{11}	9×10^{11}		⇔	Same
In-115	4.41×10^{14} y		7×10^{10}	6×10^{10}		⇧	1
In-115m	4.486 h		8×10^{13}	3×10^{12}		⇧	27
In-116m	54.41 m		5×10^{13}	2×10^{12}		⇧	25
In-117	43.2 m		1×10^{14}	2×10^{12}		⇧	50
In-117m	116.2 m		7×10^{13}	2×10^{12}		⇧	35
In-119m	18.0 m		2×10^{14}	9×10^{11}		⇧	222
Iodine							
I-120	81.6 m		2×10^{13}	6×10^{11}		⇧	33
		methyl iodide	2×10^{13}	2×10^{13}		⇔	Same
		elemental	1×10^{13}	2×10^{13}		⇩	2
I-120m	53 m		2×10^{13}	7×10^{11}		⇧	29
		methyl iodide	2×10^{13}	2×10^{13}		⇔	Same
		elemental	2×10^{13}	2×10^{13}		⇔	Same
I-121	2.12 h		9×10^{13}	4×10^{12}		⇧	23
		methyl iodide	9×10^{13}	1×10^{14}		⇩	1
		elemental	8×10^{13}	1×10^{14}		⇩	1
I-123	13.27 h		3×10^{13}	9×10^{12}		⇧	3
		methyl iodide	3×10^{13}	6×10^{13}		⇩	2
		elemental	3×10^{13}	5×10^{13}		⇩	2
I-124	4.1760 d		6×10^{11}	2×10^{12}		⇩	3
		methyl iodide	5×10^{11}	1×10^{12}		⇩	2

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
		elemental	4×10^{11}	9×10^{11}	⇩	2
I-125	59.400 d		1×10^{12}	1×10^{11}	⇧	10
		methyl iodide	1×10^{12}	1×10^{12}	⇔	Same
		elemental	8×10^{11}	1×10^{12}	⇩	1
I-126	12.93 d		3×10^{11}	8×10^{11}	⇩	3
		methyl iodide	3×10^{11}	6×10^{11}	⇩	2
		elemental	2×10^{11}	5×10^{11}	⇩	3
I-128	24.99 m		2×10^{14}	1×10^{12}	⇧	200
		methyl iodide	2×10^{14}	5×10^{14}	⇩	3
		elemental	2×10^{14}	2×10^{14}	⇔	Same
I-129	1.57×10^{7} y		2×10^{11}	1×10^{10}	⇧	20
		methyl iodide	2×10^{11}	2×10^{11}	⇔	Same
		elemental	1×10^{11}	2×10^{11}	⇩	2
I-130	12.36 h		3×10^{12}	3×10^{12}	⇔	Same
		methyl iodide	3×10^{12}	6×10^{12}	⇩	2
		elemental	3×10^{12}	5×10^{12}	⇩	2
I-131	8.02070 d		3×10^{11}	9×10^{10}	⇧	3
		methyl iodide	2×10^{11}	7×10^{11}	⇩	4
		elemental	2×10^{11}	6×10^{11}	⇩	3
I-132	2.295 h		4×10^{13}	2×10^{12}	⇧	20
		methyl iodide	3×10^{13}	3×10^{13}	⇔	Same
		elemental	3×10^{13}	2×10^{13}	⇧	2
I-132m	1.387 h		3×10^{13}	2×10^{12}	⇧	15
		methyl iodide	3×10^{13}	5×10^{13}	⇩	2
		elemental	2×10^{13}	4×10^{13}	⇩	2
I-133	20.8 h		4×10^{12}	2×10^{12}	⇧	2
		methyl iodide	3×10^{12}	3×10^{12}	⇔	Same
		elemental	2×10^{12}	2×10^{12}	⇔	Same
I-134	52.5 m		4×10^{13}	2×10^{12}	⇧	20
		methyl iodide	4×10^{13}	4×10^{13}	⇔	Same
		elemental	4×10^{13}	3×10^{13}	⇧	1
I-135	6.57 h		2×10^{13}	2×10^{12}	⇧	10
		methyl iodide	1×10^{13}	1×10^{13}	⇔	Same
		elemental	1×10^{13}	9×10^{12}	⇧	1
Iridium						
Ir-182	15 m		1×10^{14}	1×10^{12}	⇧	100

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Ir-184	3.09 h		3×10^{13}	2×10^{12}		⇧ 15
Ir-185	14.4 h		3×10^{13}	3×10^{12}		⇧ 10
Ir-186	16.64 h		2×10^{13}	3×10^{12}	Ir-186l	⇧ 7
Ir-186m	1.92 h		7×10^{13}	2×10^{12}	Ir-186s	⇧ 35
Ir-187	10.5 h		6×10^{13}	6×10^{12}		⇧ 10
Ir-188	41.5 h		1×10^{13}	5×10^{12}		⇧ 2
Ir-189	13.2 d		2×10^{13}	9×10^{12}		⇧ 2
Ir-190	11.78 d		5×10^{12}	2×10^{12}		⇧ 3
Ir-190m	1.120 h		1×10^{15}	1×10^{13}	Ir-190ms	⇧ 100
Ir-190n	3.087 h		8×10^{13}	3×10^{12}	Ir-190ml	⇧ 27
Ir-192	73.827 d		3×10^{12}	6×10^{11}		⇧ 5
Ir-192n	241 y		8×10^{11}	4×10^{11}	Ir-192m	⇧ 2
Ir-193m	10.53 d		2×10^{13}	4×10^{12}		⇧ 5
Ir-194	19.28 h		6×10^{12}	1×10^{12}		⇧ 6
Ir-194m	171 d		1×10^{12}	1×10^{11}		⇧ 10
Ir-195	2.5 h		7×10^{13}	2×10^{12}		⇧ 35
Ir-195m	3.8 h		3×10^{13}	2×10^{12}		⇧ 15
Iron						
Fe-52	8.275 h		7×10^{12}	2×10^{12}		⇧ 4
Fe-55	2.737 y		2×10^{13}	8×10^{12}		⇧ 3
Fe-59	44.495 d		3×10^{12}	8×10^{11}		⇧ 4
Fe-60	1.5×10^{6} y		8×10^{10}	4×10^{10}		⇧ 2
Krypton						
Kr-74	11.50 m		2×10^{14}	5×10^{13}		⇧ 4
Kr-76	14.8 h		2×10^{14}	1×10^{14}		⇧ 2
Kr-77	74.4 m		1×10^{14}	6×10^{13}		⇧ 2
Kr-79	35.04 h		4×10^{14}	2×10^{14}		⇧ 2
Kr-81	2.29×10^{5} y		3×10^{16}	7×10^{15}		⇧ 4
Kr-81m	13.10 s		7×10^{16}	5×10^{14}		⇧ 140
Kr-83m	1.83 h		3×10^{18}	3×10^{16}		⇧ 100
Kr-85	10.756 y		2×10^{16}	1×10^{16}		⇧ 2
Kr-85m	4.480 h		6×10^{14}	4×10^{14}		⇧ 2
Kr-87	76.3 m		1×10^{14}	7×10^{13}		⇧ 1
Kr-88	2.84 h		5×10^{13}	3×10^{13}		⇧ 2
Lanthanum						
La-131	59 m		1×10^{14}	2×10^{12}		⇧ 50

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
La-132	4.8 h		2×10^{13}	2×10^{12}		⇧ 10
La-135	19.5 h		3×10^{14}	2×10^{14}		⇧ 2
La-137	6.0×10^{4} y		3×10^{12}	2×10^{12}		⇧ 2
La-138	1.02×10^{11} y		2×10^{11}	2×10^{11}		⇔ Same
La-140	1.6781 d		1×10^{13}	2×10^{12}		⇧ 5
La-141	3.92 h		2×10^{13}	1×10^{12}		⇧ 20
La-142	91.1 m		3×10^{13}	1×10^{12}		⇧ 30
La-143	14.2 m		2×10^{14}	7×10^{11}		⇧ 286
Lead						
Pb-195m	15 m		1×10^{14}	2×10^{12}		⇧ 50
Pb-198	2.4 h		8×10^{13}	4×10^{12}		⇧ 20
Pb-199	90 m		9×10^{13}	6×10^{12}		⇧ 15
Pb-200	21.5 h		2×10^{13}	3×10^{12}		⇧ 7
Pb-201	9.33 h		5×10^{13}	8×10^{12}		⇧ 6
Pb-202	5.25×10^{4} y		2×10^{12}	6×10^{11}		⇧ 3
Pb-202m	3.53 h		4×10^{13}	4×10^{12}		⇧ 10
Pb-203	51.873 h		3×10^{13}	9×10^{12}		⇧ 3
Pb-205	1.53×10^{7} y		3×10^{13}	1×10^{13}		⇧ 3
Pb-209	3.253 h		1×10^{14}	2×10^{12}		⇧ 50
Pb-210	22.20 y		5×10^{09}	3×10^{09}		⇧ 2
Pb-211	36.1 m		2×10^{12}	2×10^{12}		⇔ Same
Pb-212	10.64 h		1×10^{11}	1×10^{11}		⇔ Same
Pb-214	26.8 m		3×10^{12}	1×10^{12}		⇧ 3
Lutetium						
Lu-169	34.06 h		2×10^{13}	6×10^{12}		⇧ 3
Lu-170	2.012 d		9×10^{12}	3×10^{12}		⇧ 3
Lu-171	8.24 d		1×10^{13}	4×10^{12}		⇧ 3
Lu-172	6.70 d		6×10^{12}	3×10^{12}		⇧ 2
Lu-173	1.37 y		7×10^{12}	2×10^{12}		⇧ 4
Lu-174	3.31 y		5×10^{12}	1×10^{12}		⇧ 5
Lu-174m	142 d		5×10^{12}	3×10^{12}		⇧ 2
Lu-176	3.85×10^{10} y		4×10^{11}	3×10^{11}		⇧ 1
Lu-176m	3.635 h		5×10^{13}	2×10^{12}		⇧ 25
Lu-177	6.647 d		1×10^{13}	3×10^{12}		⇧ 3
Lu-177m	160.4 d		1×10^{12}	3×10^{11}		⇧ 3

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Lu-178	28.4 m		2×10^{14}	1×10^{12}		⇧ 200
Lu-178m	23.1 m		1×10^{14}	1×10^{12}		⇧ 100
Lu-179	4.59 h		4×10^{13}	2×10^{12}		⇧ 20
Magnesium						
Mg-28	20.915 h		4×10^{12}	5×10^{12}		⇩ 1
Manganese						
Mn-51	46.2 m		7×10^{13}	1×10^{12}		⇧ 70
Mn-52	5.591 d		5×10^{12}	2×10^{12}		⇧ 3
Mn-52m	21.1 m		6×10^{13}	8×10^{11}		⇧ 75
Mn-53	3.7×10^{6} y		2×10^{14}	1×10^{14}		⇧ 2
Mn-54	312.12 d		4×10^{12}	3×10^{11}		⇧ 13
Mn-56	2.5789 h		3×10^{13}	1×10^{12}		⇧ 30
Mendelevium						
Md-257	5.2 h		1×10^{12}	9×10^{11}		⇧ 1
Md-258	55 d		4×10^{09}	4×10^{09}		⇔ Same
Mercury						
Hg-193	3.80 h	inorganic	6×10^{13}	3×10^{12}		⇧ 20
		organic	8×10^{13}	3×10^{12}		⇧ 27
		vapour	2×10^{13}	2×10^{13}		⇔ Same
Hg-193m	11.8 h	inorganic	2×10^{13}	2×10^{12}		⇧ 10
		organic	3×10^{13}	2×10^{12}		⇧ 15
		vapour	7×10^{12}	6×10^{12}		⇧ 1
Hg-194	440 y	inorganic	2×10^{12}	1×10^{12}		⇧ 2
		organic	9×10^{11}	3×10^{11}		⇧ 3
		vapour	7×10^{11}	6×10^{11}		⇧ 1
Hg-195	10.53 h	inorganic	8×10^{13}	5×10^{12}		⇧ 16
		organic	1×10^{14}	5×10^{12}		⇧ 20
		vapour	2×10^{13}	1×10^{13}		⇧ 2
Hg-195m	41.6 h	inorganic	1×10^{13}	3×10^{12}		⇧ 3
		organic	2×10^{13}	3×10^{12}		⇧ 7
		vapour	3×10^{12}	3×10^{12}		⇔ Same
Hg-197	64.94 h	inorganic	3×10^{13}	7×10^{12}		⇧ 4
		organic	5×10^{13}	7×10^{12}		⇧ 7
		vapour	6×10^{12}	5×10^{12}		⇧ 1
Hg-197m	23.8 h	inorganic	1×10^{13}	2×10^{12}		⇧ 5

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
		organic	2×10^{13}	2×10^{12}		⇧ 10
		vapour	4×10^{12}	5×10^{12}		⇩ 1
Hg-199m	42.66 m	inorganic	2×10^{14}	2×10^{12}		⇧ 100
		organic	2×10^{14}	2×10^{12}		⇧ 100
		vapour	1×10^{14}	1×10^{14}		⇔ Same
Hg-203	46.612 d	inorganic	8×10^{12}	3×10^{12}		⇧ 3
		organic	8×10^{12}	3×10^{12}		⇧ 3
		vapour	3×10^{12}	3×10^{12}		⇔ Same
Molybdenum						
Mo-90	5.56 h		2×10^{13}	2×10^{12}		⇧ 10
Mo-93	4.0×10^{3} y		6×10^{12}	2×10^{12}		⇧ 3
Mo-93m	6.85 h		3×10^{13}	4×10^{12}		⇧ 8
Mo-99	65.94 h		1×10^{13}	2×10^{12}		⇧ 5
Mo-101	14.61 m		1×10^{14}	2×10^{12}		⇧ 50
Neodymium						
Nd-136	50.65 m		9×10^{13}	4×10^{12}		⇧ 23
Nd-138	5.04 h		1×10^{13}	5×10^{13}		⇩ 5
Nd-139	29.7 m		2×10^{14}	2×10^{12}		⇧ 100
Nd-139m	5.50 h		3×10^{13}	3×10^{12}		⇧ 10
Nd-141	2.49 h		8×10^{14}	2×10^{13}		⇧ 40
Nd-147	10.98 d		6×10^{12}	2×10^{12}		⇧ 3
Nd-149	1.728 h		6×10^{13}	2×10^{12}		⇧ 30
Nd-151	12.44 m		2×10^{14}	1×10^{12}		⇧ 200
Neon						
Ne-19	17.22 s		1×10^{16}	6×10^{13}		⇧ 167
Neptunium						
Np-232	14.7 m		2×10^{14}	3×10^{12}		⇧ 67
Np-233	36.2 m		2×10^{15}	2×10^{14}		⇧ 10
Np-234	4.4 d		1×10^{13}	5×10^{12}		⇧ 2
Np-235	396.1 d		3×10^{13}	2×10^{13}		⇧ 2
Np-236	1.54×10^{5} y		4×10^{09}	3×10^{09}	Np-236l	⇧ 1
Np-236m	22.5 h		3×10^{12}	3×10^{12}	Np-236s	⇔ Same
Np-237	2.144×10^{6} y		6×10^{08}	5×10^{08}		⇧ 1
Np-238	2.117 d		6×10^{12}	2×10^{12}		⇧ 3
Np-239	2.3565 d		9×10^{12}	1×10^{12}		⇧ 9

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Np-240	61.9 m		6×10^{13}	7×10^{11}		⇧ 86
Nickel						
Ni-56	6.075 d		9×10^{12}	4×10^{12}		⇧ 2
		nickel carbonyl	9×10^{12}	1×10^{13}		⇩ 1
Ni-57	35.60 h		1×10^{13}	2×10^{12}		⇧ 5
		nickel carbonyl	1×10^{13}	2×10^{13}		⇩ 2
Ni-59	1.01×10^{5} y		6×10^{13}	4×10^{13}		⇧ 2
		nickel carbonyl	3×10^{13}	2×10^{13}		⇧ 2
Ni-63	100.1 y		2×10^{13}	1×10^{13}		⇧ 2
		nickel carbonyl	1×10^{13}	1×10^{13}		⇔ Same
Ni-65	2.51719 h		4×10^{13}	1×10^{12}		⇧ 40
		nickel carbonyl	3×10^{13}	4×10^{13}		⇩ 1
Ni-66	54.6 h		3×10^{12}	5×10^{12}		⇩ 2
		nickel carbonyl	3×10^{12}	1×10^{13}		⇩ 3
Nitrogen						
N-13	9.965 m	gas	4×10^{14}	6×10^{13}		⇧ 7
Niobium						
Nb-88	14.5 m		5×10^{13}	7×10^{11}		⇧ 71
Nb-89	2.03 h		2×10^{13}	1×10^{12}	Nb-89l	⇧ 20
Nb-89m	66 m		5×10^{13}	8×10^{11}	Nb-89s	⇧ 63
Nb-90	14.60 h		7×10^{12}	2×10^{12}		⇧ 4
Nb-93m	16.13 y		1×10^{13}	1×10^{13}		⇔ Same
Nb-94	2.03×10^{4} y		5×10^{11}	1×10^{11}		⇧ 5
Nb-95	34.991 d		9×10^{12}	2×10^{12}		⇧ 5
Nb-95m	3.61 d		1×10^{13}	2×10^{12}		⇧ 5
Nb-96	23.35 h		8×10^{12}	2×10^{12}		⇧ 4
Nb-97	72.1 m		9×10^{13}	2×10^{12}		⇧ 45
Nb-98m	51.3 m		4×10^{13}	1×10^{12}	Nb-98	⇧ 40
Osmium						
Os-180	21.5 m		5×10^{14}	1×10^{13}		⇧ 50
Os-181	105 m		6×10^{13}	3×10^{12}		⇧ 20
Os-182	22.10 h		2×10^{13}	6×10^{12}		⇧ 3
Os-185	93.6 d		7×10^{12}	7×10^{11}		⇧ 10

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Os-189m	5.8 h		4×10^{14}	1×10^{13}		⇧ 40
Os-191	15.4 d		9×10^{12}	4×10^{12}		⇧ 2
Os-191m	13.10 h		7×10^{13}	7×10^{12}		⇧ 10
Os-193	30.11 h		1×10^{13}	2×10^{12}		⇧ 5
Os-194	6.0 y		3×10^{11}	2×10^{11}		⇧ 2
Oxygen						
O-15	122.24 s	gas	2×10^{15}			New
Palladium						
Pd-100	3.63 d		1×10^{13}	7×10^{12}		⇧ 1
Pd-101	8.47 h		8×10^{13}	8×10^{12}		⇧ 10
Pd-103	16.991 d		3×10^{13}	4×10^{13}		⇩ 1
Pd-107	6.5×10^{6} y		5×10^{13}	3×10^{13}		⇧ 2
Pd-109	13.7012 h		1×10^{13}	2×10^{12}		⇧ 5
Phosphorus						
P-32	14.263 d		7×10^{11}	1×10^{11}		⇧ 7
P-33	25.34 d		4×10^{12}	3×10^{12}		⇧ 1
Platinum						
Pt-186	2.08 h		8×10^{13}	9×10^{13}		⇩ 1
Pt-188	10.2 d		1×10^{13}	6×10^{12}		⇧ 2
Pt-189	10.87 h		7×10^{13}	6×10^{12}		⇧ 12
Pt-191	2.802 d		3×10^{13}	7×10^{12}		⇧ 4
Pt-193	50 y		2×10^{14}	1×10^{14}		⇧ 2
Pt-193m	4.33 d		2×10^{13}	3×10^{12}		⇧ 7
Pt-195m	4.02 d		1×10^{13}	3×10^{12}		⇧ 3
Pt-197	19.8915 h		2×10^{13}	2×10^{12}		⇧ 10
Pt-197m	95.41 m		1×10^{14}	2×10^{12}		⇧ 50
Pt-199	30.80 m		2×10^{14}	2×10^{12}		⇧ 100
Pt-200	12.5 h		8×10^{12}	2×10^{12}		⇧ 4
Plutonium						
Pu-234	8.8 h		1×10^{12}	1×10^{12}		⇔ Same
Pu-235	25.3 m		2×10^{15}	2×10^{13}		⇧ 100
Pu-236	2.858 y		8×10^{08}	6×10^{08}		⇧ 1
Pu-237	45.2 d		4×10^{13}	1×10^{13}		⇧ 4
Pu-238	87.7 y		3×10^{08}	2×10^{08}		⇧ 2
Pu-239	2.411×10^{4} y		3×10^{08}	2×10^{08}		⇧ 2

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Pu-240	6564 y		3×10^{08}	2×10^{08}		⇧ 2
Pu-241	14.35 y		1×10^{10}	1×10^{10}		⇔ Same
Pu-242	3.75×10^{5} y		3×10^{08}	2×10^{08}		⇧ 2
Pu-243	4.956 h		8×10^{13}	2×10^{12}		⇧ 40
Pu-244	8.00×10^{7} y		3×10^{08}	2×10^{08}		⇧ 2
Pu-245	10.5 h		1×10^{13}	2×10^{12}		⇧ 5
Pu-246	10.84 d		2×10^{12}	2×10^{12}		⇔ Same
Polonium						
Po-203	36.7 m		8×10^{13}	3×10^{12}		⇧ 27
Po-205	1.66 h		7×10^{13}	7×10^{12}		⇧ 10
Po-206	8.8 d		1×10^{11}	1×10^{11}		⇔ Same
Po-207	5.80 h		5×10^{13}	8×10^{12}		⇧ 6
Po-208	2.898 y		3×10^{09}	2×10^{09}		⇧ 2
Po-209	102 y		2×10^{09}	2×10^{09}		⇔ Same
Po-210	138.376 d		4×10^{09}	4×10^{09}		⇔ Same
Potassium						
K-40	1.251×10^{9} y		1×10^{12}	2×10^{12}		⇩ 2
K-42	12.360 h		2×10^{13}	7×10^{11}		⇧ 29
K-43	22.3 h		3×10^{13}	2×10^{12}		⇧ 15
K-44	22.13 m		5×10^{13}	6×10^{11}		⇧ 83
K-45	17.3 m		8×10^{13}	9×10^{11}		⇧ 89
Praseodymium						
Pr-136	13.1 m		1×10^{14}	1×10^{12}		⇧ 100
Pr-137	1.28 h		1×10^{14}	2×10^{12}		⇧ 50
Pr-138m	2.12 h		4×10^{13}	2×10^{12}		⇧ 20
Pr-139	4.41 h		2×10^{14}	7×10^{12}		⇧ 29
Pr-142	19.12 h		6×10^{12}	1×10^{12}		⇧ 6
Pr-142m	14.6 m		6×10^{14}	2×10^{15}		⇩ 3
Pr-143	13.57 d		5×10^{12}	2×10^{12}		⇧ 3
Pr-144	17.28 m		2×10^{14}	2×10^{12}		⇧ 100
Pr-145	5.984 h		2×10^{13}	1×10^{12}		⇧ 20
Pr-147	13.4 m		2×10^{14}	1×10^{12}		⇧ 200
Promethium						
Pm-141	20.90 m		2×10^{14}	1×10^{12}		⇧ 200
Pm-143	265 d		9×10^{12}	9×10^{11}		⇧ 10

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Pm-144	363 d		2×10^{12}	2×10^{11}		⇧ 10
Pm-145	17.7 y		8×10^{12}	3×10^{12}		⇧ 3
Pm-146	5.53 y		1×10^{12}	2×10^{11}		⇧ 5
Pm-147	2.6234 y		5×10^{12}	4×10^{12}		⇧ 1
Pm-148	5.368 d		3×10^{12}	1×10^{12}		⇧ 3
Pm-148m	41.29 d		2×10^{12}	5×10^{11}		⇧ 4
Pm-149	53.08 h		8×10^{12}	2×10^{12}		⇧ 4
Pm-150	2.68 h		3×10^{13}	1×10^{12}		⇧ 30
Pm-151	28.40 h		1×10^{13}	2×10^{12}		⇧ 5
Protactinium						
Pa-227	38.3 m		4×10^{11}	3×10^{11}		⇧ 1
Pa-228	22 h		4×10^{11}	3×10^{11}		⇧ 1
Pa-230	17.4 d		4×10^{10}	3×10^{10}		⇧ 1
Pa-231	3.276×10^{4} y		2×10^{08}	2×10^{08}		⇔ Same
Pa-232	1.31 d		3×10^{12}	2×10^{12}		⇧ 2
Pa-233	26.967 d		5×10^{12}	2×10^{12}		⇧ 3
Pa-234	6.70 h		1×10^{13}	5×10^{11}		⇧ 20
Radium						
Ra-223	11.43 d		3×10^{09}	3×10^{09}		⇔ Same
Ra-224	3.66 d		8×10^{09}	7×10^{09}		⇧ 1
Ra-225	14.9 d		4×10^{09}	3×10^{09}		⇧ 1
Ra-226	1600 y		3×10^{09}	2×10^{09}		⇧ 2
Ra-227	42.2 m		6×10^{13}	2×10^{12}		⇧ 30
Ra-228	5.75 y		2×10^{09}	1×10^{09}		⇧ 2
Rhenium						
Re-177	14.0 m		5×10^{14}	2×10^{12}		⇧ 250
Re-178	13.2 m		1×10^{14}	2×10^{12}		⇧ 50
Re-181	19.9 h		2×10^{13}	3×10^{12}		⇧ 7
Re-182	64.0 h		5×10^{12}	2×10^{12}	Re-182l	⇧ 3
Re-182m	12.7 h		3×10^{13}	4×10^{12}	Re-182s	⇧ 8
Re-184	38.0 d		6×10^{12}	1×10^{12}		⇧ 6
Re-184m	169 d		3×10^{12}	7×10^{11}		⇧ 4
Re-186	3.7183 d		5×10^{12}	2×10^{12}		⇧ 3
Re-186m	2.00×10^{5} y		2×10^{12}	1×10^{12}		⇧ 2
Re-187	4.12×10^{10} y		1×10^{15}	5×10^{14}		⇧ 2

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Re-188	17.0040 h		6×10^{12}	1×10^{12}		⇧ 6
Re-188m	18.59 m		3×10^{14}	3×10^{12}		⇧ 100
Re-189	24.3 h		1×10^{13}	2×10^{12}		⇧ 5
Rhodium						
Rh-99	16.1 d		1×10^{13}	4×10^{12}		⇧ 3
Rh-99m	4.7 h		9×10^{13}	9×10^{12}		⇧ 10
Rh-100	20.8 h		1×10^{13}	4×10^{12}		⇧ 3
Rh-101	3.3 y		4×10^{12}	7×10^{11}		⇧ 6
Rh-101m	4.34 d		4×10^{13}	2×10^{13}		⇧ 2
Rh-102	207 d		2×10^{12}	6×10^{11}	Rh-102m	⇧ 3
Rh-102m	3.742 y		9×10^{11}	1×10^{11}	Rh-102	⇧ 9
Rh-103m	56.114 m		2×10^{15}	3×10^{15}		⇩ 2
Rh-105	35.36 h		2×10^{13}	2×10^{12}		⇧ 10
Rh-106m	131 m		3×10^{13}	2×10^{12}		⇧ 15
Rh-107	21.7 m		3×10^{14}	2×10^{12}		⇧ 150
Rubidium						
Rb-79	22.9 m		9×10^{13}	1×10^{12}		⇧ 90
Rb-81	4.576 h		9×10^{13}	2×10^{12}		⇧ 45
Rb-81m	30.5 m		8×10^{14}	4×10^{12}		⇧ 200
Rb-82m	6.472 h		3×10^{13}	3×10^{12}		⇧ 10
Rb-83	86.2 d		6×10^{12}	1×10^{12}		⇧ 6
Rb-84	32.77 d		4×10^{12}	1×10^{12}		⇧ 4
Rb-86	18.642 d		3×10^{12}	2×10^{11}		⇧ 15
Rb-87	4.923×10^{10} y		6×10^{12}	4×10^{12}		⇧ 2
Rb-88	17.78 m		9×10^{13}	5×10^{11}		⇧ 180
Rb-89	15.15 m		8×10^{13}	9×10^{11}		⇧ 89
Ruthenium						
Ru-94	51.8 m		9×10^{13}	1×10^{14}		⇩ 1
		ruthenium tetroxide	8×10^{13}	1×10^{14}		⇩ 1
Ru-97	2.9 d		6×10^{13}	3×10^{13}		⇧ 2
		ruthenium tetroxide	6×10^{13}	1×10^{14}		⇩ 2
Ru-103	39.26 d		7×10^{12}	2×10^{12}		⇧ 4
		ruthenium tetroxide	1×10^{13}	1×10^{13}		⇔ Same
Ru-105	4.44 h		3×10^{13}	2×10^{12}		⇧ 15

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
		ruthenium tetroxide	3×10^{13}	6×10^{13}		⇩ 2
Ru-106	373.59 d		4×10^{11}	3×10^{11}		⇧ 1
		ruthenium tetroxide	8×10^{11}	8×10^{11}		⇔ Same
Samarium						
Sm-141	10.2 m		1×10^{14}	1×10^{12}		⇧ 100
Sm-141m	22.6 m		7×10^{13}	2×10^{12}		⇧ 35
Sm-142	72.49 m		5×10^{13}	9×10^{12}		⇧ 6
Sm-145	340 d		1×10^{13}	3×10^{12}		⇧ 3
Sm-146	1.03×10^{8} y		3×10^{09}	2×10^{09}		⇧ 2
Sm-147	1.060×10^{11} y		3×10^{09}	3×10^{09}		⇔ Same
Sm-151	90 y		7×10^{12}	6×10^{12}		⇧ 1
Sm-153	46.50 h		1×10^{13}	2×10^{12}		⇧ 5
Sm-155	22.3 m		3×10^{14}	2×10^{12}		⇧ 150
Sm-156	9.4 h		3×10^{13}	2×10^{12}		⇧ 15
Scandium						
Sc-43	3.891 h		4×10^{13}	2×10^{12}		⇧ 20
Sc-44	3.97 h		2×10^{13}	2×10^{12}		⇧ 10
Sc-44m	58.61 h		4×10^{12}	9×10^{12}		⇩ 2
Sc-46	83.79 d		2×10^{12}	3×10^{11}		⇧ 7
Sc-47	3.3492 d		1×10^{13}	3×10^{12}		⇧ 3
Sc-48	43.67 h		5×10^{12}	2×10^{12}		⇧ 3
Sc-49	57.2 m		1×10^{14}	1×10^{12}		⇧ 100
Selenium						
Se-70	41.1 m		6×10^{13}	2×10^{12}		⇧ 30
Se-73	7.15 h		3×10^{13}	2×10^{12}		⇧ 15
Se-73m	39.8 m		2×10^{14}	2×10^{12}		⇧ 100
Se-75	119.779 d		4×10^{12}	2×10^{11}		⇧ 20
Se-79	2.95×10^{5} y		2×10^{12}	5×10^{10}		⇧ 40
Se-81	18.45 m		3×10^{14}	2×10^{12}		⇧ 150
Se-81m	57.28 m		1×10^{14}	4×10^{12}		⇧ 25
Se-83	22.3 m		6×10^{13}	2×10^{12}		⇧ 30
Silicon						
Si-31	157.3 m		6×10^{13}	2×10^{12}		⇧ 30
Si-32	132 y		3×10^{11}	2×10^{11}		⇧ 2

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Silver						
Ag-102	12.9 m		7×10^{13}	1×10^{12}	⇧	70
Ag-103	65.7 m		1×10^{14}	2×10^{12}	⇧	50
Ag-104	69.2 m		5×10^{13}	3×10^{12}	⇧	17
Ag-104m	33.5 m		7×10^{13}	2×10^{12}	⇧	35
Ag-105	41.29 d		1×10^{13}	2×10^{12}	⇧	5
Ag-106	23.96 m		2×10^{14}	2×10^{12}	⇧	100
Ag-106m	8.28 d		6×10^{12}	2×10^{12}	⇧	3
Ag-108m	418 y		6×10^{11}	1×10^{11}	⇧	6
Ag-110m	249.76 d		1×10^{12}	3×10^{10}	⇧	33
Ag-111	7.45 d		6×10^{12}	2×10^{12}	⇧	3
Ag-112	3.130 h		2×10^{13}	7×10^{11}	⇧	29
Ag-115	20.0 m		1×10^{14}	9×10^{11}	⇧	111
Sodium						
Na-22	2.6019 y		1×10^{12}	1×10^{11}	⇧	10
Na-24	14.9590 h		1×10^{13}	2×10^{12}	⇧	5
Strontium						
Sr-80	106.3 m		3×10^{13}	1×10^{14}	⇩	3
Sr-81	22.3 m		8×10^{13}	9×10^{11}	⇧	89
Sr-82	25.36 d		1×10^{12}	2×10^{12}	⇩	2
Sr-83	32.41 h		2×10^{13}	3×10^{12}	⇧	7
Sr-85	64.84 d		1×10^{13}	1×10^{12}	⇧	10
Sr-85m	67.63 m		6×10^{14}	3×10^{13}	⇧	20
Sr-87m	2.815 h		2×10^{14}	7×10^{12}	⇧	29
Sr-89	50.53 d		2×10^{12}	1×10^{12}	⇧	2
Sr-90	28.79 y		2×10^{11}	8×10^{10}	⇧	3
Sr-91	9.63 h		1×10^{13}	2×10^{12}	⇧	5
Sr-92	2.66 h		2×10^{13}	2×10^{12}	⇧	10
Sulphur						
S-35	87.51 d	inorganic	1×10^{13}	1×10^{12}	⇧	10
		organic	1×10^{13}	2×10^{11}	⇧	50
		gas / vapour	1×10^{11}			New
Tantalum						
Ta-172	36.8 m		7×10^{13}	2×10^{12}	⇧	35
Ta-173	3.14 h		4×10^{13}	2×10^{12}	⇧	20

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Ta-174	1.14 h		8×10^{13}	2×10^{12}		⇧ 40
Ta-175	10.5 h		4×10^{13}	2×10^{12}		⇧ 20
Ta-176	8.09 h		2×10^{13}	3×10^{12}		⇧ 7
Ta-177	56.56 h		7×10^{13}	1×10^{13}		⇧ 7
Ta-178m	2.36 h		7×10^{13}	3×10^{12}	Ta-178l	⇧ 23
Ta-179	1.82 y		3×10^{13}	6×10^{12}		⇧ 5
Ta-180	8.152 h		1×10^{14}	6×10^{12}	Ta-180m	⇧ 17
Ta-182	114.43 d		2×10^{12}	3×10^{11}		⇧ 7
Ta-182m	15.84 m		4×10^{14}	2×10^{12}		⇧ 200
Ta-183	5.1 d		5×10^{12}	2×10^{12}		⇧ 3
Ta-184	8.7 h		1×10^{13}	2×10^{12}		⇧ 5
Ta-185	49.4 m		1×10^{14}	1×10^{12}		⇧ 100
Ta-186	10.5 m		1×10^{14}	9×10^{11}		⇧ 111
Technetium						
Tc-93	2.75 h		7×10^{13}	5×10^{13}		⇧ 1
Tc-93m	43.5 m		1×10^{14}	4×10^{12}		⇧ 25
Tc-94	293 m		3×10^{13}	6×10^{12}		⇧ 5
Tc-94m	52.0 m		5×10^{13}	1×10^{12}		⇧ 50
Tc-95	20.0 h		4×10^{13}	4×10^{13}		⇔ Same
Tc-95m	61 d		8×10^{12}	1×10^{12}		⇧ 8
Tc-96	4.28 d		8×10^{12}	4×10^{12}		⇧ 2
Tc-96m	51.5 m		7×10^{14}	2×10^{13}		⇧ 35
Tc-97	2.6×10^{6} y		2×10^{13}	9×10^{12}		⇧ 2
Tc-97m	90.1 d		6×10^{12}	5×10^{12}		⇧ 1
Tc-98	4.2×10^{6} y		5×10^{11}	1×10^{11}		⇧ 5
Tc-99	2.111×10^{5} y		2×10^{12}	5×10^{10}		⇧ 40
Tc-99m	6.015 h		3×10^{14}	1×10^{13}		⇧ 30
Tc-101	14.2 m		3×10^{14}	2×10^{12}		⇧ 150
Tc-104	18.3 m		6×10^{13}	6×10^{11}		⇧ 100
Tellurium						
Te-116	2.49 h		5×10^{13}	6×10^{12}		⇧ 8
		vapour	6×10^{13}	2×10^{14}		⇩ 3
Te-121	19.16 d		2×10^{13}	4×10^{12}		⇧ 5
		vapour	2×10^{13}	3×10^{13}		⇩ 2
Te-121m	154 d		3×10^{12}	1×10^{12}		⇧ 3
		vapour	2×10^{12}	3×10^{12}		⇩ 2

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Te-123	6.00 x 10^{14} y		4 x 10^{12}	6 x 10^{12}		⇩ 2
		vapour	2 x 10^{12}	2 x 10^{12}		⇔ Same
Te-123m	119.25 d		4 x 10^{12}	2 x 10^{12}		⇧ 2
		vapour	3 x 10^{12}	5 x 10^{12}		⇩ 2
Te-125m	57.40 d		5 x 10^{12}	2 x 10^{12}		⇧ 3
		vapour	6 x 10^{12}	8 x 10^{12}		⇩ 1
Te-127	9.35 h		4 x 10^{13}	2 x 10^{12}		⇧ 20
		vapour	5 x 10^{13}	2 x 10^{14}		⇩ 4
Te-127m	109 d		2 x 10^{12}	1 x 10^{12}		⇧ 2
		vapour	2 x 10^{12}	2 x 10^{12}		⇔ Same
Te-129	69.6 m		1 x 10^{14}	2 x 10^{12}		⇧ 50
		vapour	1 x 10^{14}	4 x 10^{14}		⇩ 4
Te-129m	33.6 d		2 x 10^{12}	1 x 10^{12}		⇧ 2
		vapour	2 x 10^{12}	3 x 10^{12}		⇩ 2
Te-131	25.0 m		9 x 10^{13}	1 x 10^{12}		⇧ 90
		vapour	8 x 10^{13}	1 x 10^{14}		⇩ 1
Te-131m	30 h		4 x 10^{12}	2 x 10^{12}		⇧ 2
		vapour	3 x 10^{12}	5 x 10^{12}		⇩ 2
Te-132	3.204 d		4 x 10^{12}	3 x 10^{12}		⇧ 1
		vapour	2 x 10^{12}	2 x 10^{12}		⇔ Same
Te-133	12.5 m		8 x 10^{13}	1 x 10^{12}		⇧ 80
		vapour	8 x 10^{13}	7 x 10^{13}		⇧ 1
Te-133m	55.4 m		2 x 10^{13}	1 x 10^{12}		⇧ 20
		vapour	2 x 10^{13}	2 x 10^{13}		⇔ Same
Te-134	41.8 m		6 x 10^{13}	3 x 10^{12}		⇧ 20
		vapour	6 x 10^{13}	7 x 10^{13}		⇩ 1
Terbium						
Tb-147	1.64 h		3 x 10^{13}	2 x 10^{12}		⇧ 15
Tb-149	4.118 h		5 x 10^{12}	2 x 10^{12}		⇧ 3
Tb-150	3.48 h		2 x 10^{13}	2 x 10^{12}		⇧ 10
Tb-151	17.609 h		2 x 10^{13}	4 x 10^{12}		⇧ 5
Tb-153	2.34 d		1 x 10^{13}	7 x 10^{12}		⇧ 1
Tb-154	21.5 h		1 x 10^{13}	4 x 10^{12}		⇧ 3
Tb-155	5.32 d		4 x 10^{13}	1 x 10^{13}		⇧ 4
Tb-156	5.35 d		7 x 10^{12}	3 x 10^{12}		⇧ 2
Tb-156m	24.4 h		5 x 10^{13}	1 x 10^{13}	Tb-156ml	⇧ 5

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Tb-156n	5.3 h		9×10^{13}	4×10^{12}	Tb-156ms	⇧ 23
Tb-157	71 y		2×10^{13}	1×10^{13}		⇧ 2
Tb-158	180 y		6×10^{11}	2×10^{11}		⇧ 3
Tb-160	72.3 d		2×10^{12}	5×10^{11}		⇧ 4
Tb-161	6.906 d		9×10^{12}	2×10^{12}		⇧ 5
Thallium						
Tl-194	33.0 m		2×10^{14}	1×10^{13}		⇧ 20
Tl-194m	32.8 m		7×10^{13}	2×10^{12}		⇧ 35
Tl-195	1.16 h		1×10^{14}	4×10^{12}		⇧ 25
Tl-197	2.84 h		2×10^{14}	5×10^{12}		⇧ 40
Tl-198	5.3 h		5×10^{13}	7×10^{12}		⇧ 7
Tl-198m	1.87 h		7×10^{13}	2×10^{12}		⇧ 35
Tl-199	7.42 h		2×10^{14}	6×10^{12}		⇧ 33
Tl-200	26.1 h		3×10^{13}	1×10^{13}		⇧ 3
Tl-201	72.912 h		9×10^{13}	7×10^{12}		⇧ 13
Tl-202	12.23 d		2×10^{13}	7×10^{12}		⇧ 3
Tl-204	3.78 y		6×10^{12}	2×10^{12}		⇧ 3
Thorium						
Th-226	30.57 m		6×10^{11}	4×10^{11}		⇧ 2
Th-227	18.68 d		3×10^{09}	2×10^{09}		⇧ 2
Th-228	1.9116 y		7×10^{08}	6×10^{08}		⇧ 1
Th-229	7.34×10^{3} y		1×10^{08}	1×10^{08}		⇔ Same
Th-230	7.538×10^{4} y		3×10^{08}	2×10^{08}		⇧ 2
Th-231	25.52 h		2×10^{13}	2×10^{12}		⇧ 10
Th-232	1.405×10^{10} y		3×10^{08}	2×10^{08}		⇧ 2
Th-234	24.10 d		2×10^{12}	3×10^{12}		⇩ 2
Thulium						
Tm-162	21.70 m		9×10^{13}	2×10^{12}		⇧ 45
Tm-166	7.70 h		2×10^{13}	3×10^{12}		⇧ 7
Tm-167	9.25 d		1×10^{13}	4×10^{12}		⇧ 3
Tm-170	128.6 d		2×10^{12}	2×10^{12}		⇔ Same
Tm-171	1.92 y		2×10^{13}	1×10^{13}		⇧ 2
Tm-172	63.6 h		5×10^{12}	2×10^{12}		⇧ 3
Tm-173	8.24 h		3×10^{13}	2×10^{12}		⇧ 15
Tm-175	15.2 m		2×10^{14}	2×10^{12}		⇧ 100

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Tin						
Sn-110	4.11 h		3×10^{13}	6×10^{13}	⇩	2
Sn-111	35.3 m		2×10^{14}	2×10^{12}	⇧	100
Sn-113	115.09 d		6×10^{12}	5×10^{12}	⇧	1
Sn-117m	13.76 d		7×10^{12}	3×10^{12}	⇧	2
Sn-119m	293.1 d		9×10^{12}	5×10^{12}	⇧	2
Sn-121	27.03 h		3×10^{13}	3×10^{12}	⇧	10
Sn-121m	43.9 y		5×10^{12}	4×10^{12}	⇧	1
Sn-123	129.2 d		2×10^{12}	2×10^{12}	⇔	Same
Sn-123m	40.06 m		2×10^{14}	2×10^{12}	⇧	100
Sn-125	9.64 d		2×10^{12}	1×10^{12}	⇧	2
Sn-126	2.30×10^{5} y		8×10^{11}	5×10^{11}	⇧	2
Sn-127	2.10 h		3×10^{13}	2×10^{12}	⇧	15
Sn-128	59.07 m		5×10^{13}	2×10^{12}	⇧	25
Titanium						
Ti-44	60.0 y		2×10^{11}	2×10^{11}	⇔	Same
Ti-45	184.8 m		4×10^{13}	2×10^{12}	⇧	20
Tungsten						
W-176	2.3 h		1×10^{14}	5×10^{12}	⇧	20
W-177	132 m		9×10^{13}	3×10^{12}	⇧	30
W-178	21.6 d		5×10^{13}	6×10^{13}	⇩	1
W-179	37.05 m		2×10^{15}	1×10^{13}	⇧	200
W-181	121.2 d		9×10^{13}	1×10^{13}	⇧	9
W-185	75.1 d		2×10^{13}	4×10^{12}	⇧	5
W-187	23.72 h		1×10^{13}	2×10^{12}	⇧	5
W-188	69.78 d		4×10^{12}	3×10^{12}	⇧	1
Uranium						
U-230	20.8 d		2×10^{09}	2×10^{09}	⇔	Same
U-231	4.2 d		2×10^{13}	7×10^{12}	⇧	3
U-232	68.9 y		8×10^{08}	6×10^{08}	⇧	1
U-233	1.592×10^{5} y		3×10^{09}	3×10^{09}	⇔	Same
U-234	2.455×10^{5} y		3×10^{09}	3×10^{09}	⇔	Same
U-235	7.04×10^{8} y		3×10^{09}	3×10^{09}	⇔	Same
U-236	2.342×10^{7} y		3×10^{09}	3×10^{09}	⇔	Same
U-237	6.75 d		8×10^{12}	2×10^{12}	⇧	4

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
U-238	4.468 x 10^{9} y		4 x 10^{09}	3 x 10^{09}		⇧ 1
U-239	23.45 m		3 x 10^{14}	2 x 10^{12}		⇧ 150
U-240	14.1 h		8 x 10^{12}	2 x 10^{12}		⇧ 4
Vanadium						
V-47	32.6 m		9 x 10^{13}	1 x 10^{12}		⇧ 90
V-48	15.9735 d		3 x 10^{12}	1 x 10^{12}		⇧ 3
V-49	330 d		3 x 10^{14}	2 x 10^{14}		⇧ 2
Xenon						
Xe-120	40 m		3 x 10^{14}	1 x 10^{14}		⇧ 3
Xe-121	40.1 m		7 x 10^{13}	3 x 10^{13}		⇧ 2
Xe-122	20.1 h		2 x 10^{15}	1 x 10^{15}		⇧ 2
Xe-123	2.08 h		2 x 10^{14}	9 x 10^{13}		⇧ 2
Xe-125	16.9 h		4 x 10^{14}	2 x 10^{14}		⇧ 2
Xe-127	36.4 d		4 x 10^{14}	2 x 10^{14}		⇧ 2
Xe-129m	8.88 d		4 x 10^{15}	2 x 10^{15}		⇧ 2
Xe-131m	11.84 d		1 x 10^{16}	4 x 10^{15}		⇧ 3
Xe-133	5.243 d		3 x 10^{15}	1 x 10^{15}		⇧ 3
Xe-133m	2.19 d		3 x 10^{15}	2 x 10^{15}		⇧ 2
Xe-135	9.14 h		4 x 10^{14}	2 x 10^{14}		⇧ 2
Xe-135m	15.29 m		4 x 10^{14}	1 x 10^{14}		⇧ 4
Xe-138	14.08 m		1 x 10^{14}	5 x 10^{13}		⇧ 2
Ytterbium						
Yb-162	18.87 m		3 x 10^{14}	1 x 10^{13}		⇧ 30
Yb-166	56.7 h		1 x 10^{13}	8 x 10^{12}		⇧ 1
Yb-167	17.5 m		6 x 10^{14}	4 x 10^{12}		⇧ 150
Yb-169	32.026 d		6 x 10^{12}	3 x 10^{12}		⇧ 2
Yb-175	4.185 d		2 x 10^{13}	4 x 10^{12}		⇧ 5
Yb-177	1.911 h		8 x 10^{13}	2 x 10^{12}		⇧ 40
Yb-178	74 m		7 x 10^{13}	2 x 10^{12}		⇧ 35
Yttrium						
Y-86	14.74 h		9 x 10^{12}	2 x 10^{12}		⇧ 5
Y-86m	48 m		2 x 10^{14}	1 x 10^{13}		⇧ 20
Y-87	79.8 h		2 x 10^{13}	2 x 10^{13}		⇔ Same
Y-88	106.65 d		2 x 10^{12}	2 x 10^{11}		⇧ 10
Y-90	64.10 h		3 x 10^{12}	2 x 10^{12}		⇧ 2

Radionuclide	Half-life	Form	Revised value (Bq)	REPPIR 2001 value (Bq)	REPPIR2001 radionuclide name (if different)	Factor by which value has increased or decreased (rounded to nearest whole number)
Y-90m	3.19 h		4×10^{13}	7×10^{12}	⇧	6
Y-91	58.51 d		2×10^{12}	2×10^{12}	⇔	Same
Y-91m	49.71 m		3×10^{14}	2×10^{13}	⇧	15
Y-92	3.54 h		2×10^{13}	6×10^{11}	⇧	33
Y-93	10.18 h		7×10^{12}	8×10^{11}	⇧	9
Y-94	18.7 m		9×10^{13}	6×10^{11}	⇧	150
Y-95	10.3 m		1×10^{14}	6×10^{11}	⇧	167
Zinc						
Zn-62	9.186 h		9×10^{12}	1×10^{13}	⇩	1
Zn-63	38.47 m		7×10^{13}	1×10^{12}	⇧	70
Zn-65	244.06 d		3×10^{12}	5×10^{10}	⇧	60
Zn-69	56.4 m		2×10^{14}	2×10^{12}	⇧	100
Zn-69m	13.76 h		2×10^{13}	2×10^{13}	⇔	Same
Zn-71m	3.96 h		3×10^{13}	2×10^{12}	⇧	15
Zn-72	46.5 h		6×10^{12}	3×10^{12}	⇧	2
Zirconium						
Zr-86	16.5 h		1×10^{13}	2×10^{13}	⇩	2
Zr-88	83.4 d		6×10^{12}	1×10^{12}	⇧	6
Zr-89	78.41 h		1×10^{13}	4×10^{12}	⇧	3
Zr-93	1.53×10^{6} y		1×10^{12}	8×10^{11}	⇧	1
Zr-95	64.032 d		3×10^{12}	8×10^{11}	⇧	4
Zr-97	16.744 h		4×10^{12}	2×10^{12}	⇧	2

Appendix B Comparison of Schedule 1 REPPIR-2019 values with Schedule 2 REPPIR-2001 values

B1 Summary of changes

Using the revised methodology, 862 Schedule 1 REPPIR-2019 values have been calculated for 771 radionuclides. Some radionuclides have several chemical forms, each of which has a separate Schedule 1 value. In Schedule 2 REPPIR-2001, there were 863 values for 761 radionuclides.

In Schedule 2 REPPIR-2001, the maximum value was 1 x 10^{18} Bq (for tritium, ^{3}H) – elemental gas), and the minimum value was 1 x 10^{7} Bq for ^{250}Cm. The maximum revised value is 2 x 10^{20} Bq (for ^{37}Ar), and the minimum value remains 1 x 10^{7} Bq (for ^{250}Cm). In order to gain a better understanding of the spread of the results, the cumulative number of values in each power-of-ten band are detailed below.

Value (Bq)	Number of values	
	Schedule 2 REPPIR-2001	Schedule 1 REPPIR-2019
< 10^{7}	0	0
10^{7} – 10^{8}	3	3
10^{8} – 10^{9}	27	26
10^{9} – 10^{10}	30	30
10^{10} – 10^{11}	24	11
10^{11} – 10^{12}	120	61
10^{12} – 10^{13}	502	207
10^{13} – 10^{14}	101	351
10^{14} – 10^{15}	39	148
10^{15} – 10^{16}	10	17
10^{16} – 10^{17}	4	6
10^{17} – 10^{18}	2	0
10^{18} – 10^{19}	1	1
10^{19} – 10^{20}	0	0
10^{20} – 10^{21}	0	1
> 10^{21}	0	0
Total	863	862

Since the publication of REPPIR-2001, ICRP has changed the name of 28 radionuclides, and has removed tantalum-180m (^{180m}Ta). In REPPIR-2001, values were provided for ^{180}Ta and ^{180m}Ta. ICRP has changed the name of ^{180}Ta to ^{180m}Ta, and ^{180m}Ta to ^{180}Ta. Also, ICRP describes (what is now) ^{180m}Ta as “observationally stable”, and therefore provides no dose coefficients for it. Hence, there is now a Schedule 1 value provided for ^{180}Ta (previously called ^{180m}Ta), but not for ^{180m}Ta (previously called ^{180}Ta).

Compared with Schedule 2 REPPIR-2001, Schedule 1 REPPIR-2019 now has:

- 3 entirely new values added: for ^{11}C (methane form), ^{14}C (methane form), and ^{15}O
- a single value for organically bound tritium (^{3}H, OBT), instead of separate values for OBT and OBT gas/vapour
- no specific value for tritiated water; instead, a generic tritium (^{3}H) value is provided
- a single value for ^{35}S gas/vapour; instead of separate values for the vapour form of ^{35}S, carbon disulphide vapour, and sulphur dioxide gas

Where direct comparisons can be made between the Schedule 2 REPPIR-2001 values and the newly calculated Schedule 1 values (taking into account ICRP name changes), 74 values have not changed, 67 have decreased, and 717 have increased.

For every value, it is the effective dose criterion that determines the new Schedule 1 value. This criterion was 5 mSv in the first year for REPPIR-2001, and is now 1 mSv in the first year. Consequently, all other things being equal, one might expect all values to have decreased, less activity being required to be released to reach 1 mSv than 5 mSv. However, not all things are equal as a new dose calculation methodology has also been implemented. This new methodology is more realistic (i.e. less highly conservative), and so in the majority of cases, the new methodology leads to decrease the effective dose resulting from each becquerel released, and therefore more activity can be released before the dose criterion is exceeded (even though the dose criterion is lower), i.e. the majority of Schedule 1 values have increased.

B2 A minority of values have decreased

Of the 67 values that have decreased, the majority are for radionuclides in gas/vapour forms for which a greater range of dose pathways have now been included in the calculation methodology. Of those values that have decreased, only 5 values have decreased by more than a factor of 10, as follows:

Radionuclide (form)	Schedule 2 REPPIR-2001 (Bq)	Schedule 1 REPPIR-2019 (Bq)
C-14 (carbon dioxide)	3×10^{15}	3×10^{12}
C-14 (carbon monoxide)	1×10^{16}	3×10^{12}
C-14 (vapour)	4×10^{13}	3×10^{12}
H-3 (elemental gas)	1×10^{18}	7×10^{14}
H-3 (tritiated methane)	1×10^{17}	2×10^{15}

All these tabulated radionuclide forms are gases/vapours, for which only the inhalation dose and external dose from the cloud pathways were included in the Schedule 2 REPPIR-2001 calculation. Under the new methodology, additional pathways have been included, most notably the ingestion of milk by infants, which dominates the total effective dose for all of these radionuclides, except for ^{3}H (elemental gas). The total effective dose from ^{3}H (elemental gas) is dominated by the dose received by the fetus following inhalation of material by its mother; this is another pathway not included in the Schedule 2 REPPIR-2001 methodology. Hence for these radionuclides, more dose (from more pathways) results for each becquerel released,

and hence less activity can be released before the dose criterion is exceeded, and therefore the Schedule 1 values have decreased.

B3 The majority of values have increased

A total of 717 values have increased. These are:

- 399 values have increased by less than a factor of 10
- 246 values have increased by a factor of 10 or more, but less than a factor of 100
- 71 values have increased by a factor of 100 or more, but less than a factor of 1000
- 1 value (for ^{114}In), has increased by a factor of more than 1000

As an illustration, the values for the following radionuclides have increased by more than a factor of 300.

Radionuclide	Schedule 2 REPPIR-2001 (Bq)	Schedule 1 REPPIR-2019 (Bq)
In-114	1×10^{12}	4×10^{15}
Co-60m	7×10^{12}	5×10^{15}
Ar-37	4×10^{17}	2×10^{20}
Ho-164	2×10^{12}	7×10^{14}
Ba-131m	3×10^{12}	1×10^{15}
Br-80	1×10^{12}	3×10^{14}
Ga-70	1×10^{12}	3×10^{14}

As mentioned above, in the majority of cases, the new methodology works to decrease the effective dose resulting from each becquerel released, and therefore more activity can be released before the dose criterion is exceeded, i.e. the majority of Schedule 1 values have increased. The following features of the methodology are examples of why less dose results from the Schedule 1 REPPIR-2019 methodology than the one for Schedule 2 REPPIR-2001.

- Under the new methodology, the **calculation of equivalent dose to skin** is more accurate and less highly conservative than before. For example, although the period of skin exposure is the same (12 hours), the decay of activity on skin has been added to the new methodology. Therefore, particularly for radionuclides with a very short half-life, less equivalent dose to skin will result. For example, in the case of ^{114}In, which has a half-life of just 71.9 seconds, 12 hours of decay introduces a dose reduction factor of 0.0024. This difference has a significant effect, as in REPPIR-2001 it was the large equivalent dose to skin compared with the respective criterion that determined the Schedule 2 value for many radionuclides. For Schedule 1 REPPIR-2019, the equivalent dose to skin never exceeds the respective criterion; all Schedule 1 values are determined by the effective dose criterion. To return to the example of ^{114}In, it is now the effective dose from ingestion of green vegetables that dominates, rather than the dose to skin. For all radionuclides listed in the table above, which show the largest increase in value, it is the difference in the dose to skin methodology that accounts for the increase.
- Also, under the new methodology, the calculation of effective ingestion dose from the **consumption of milk** is less highly conservative than before. Several factors are important here:

- In the previous methodology, dose from ingestion of milk was only calculated for about 60 radionuclides, with the emphasis placed on those thought to be important for milk consumption. Under the new Schedule 1 REPPIR-2019 methodology, milk concentration factors have been applied for nearly all radionuclides based on new improved food chain modelling capability. For some radionuclides, lower milk concentration factors than those used previously are now appropriate. For example, for ^{79}Se there is a factor of 40 difference between the new concentration factor and the previous one, which acts to reduce the dose from this pathway under the new methodology. However, for the majority of radionuclides, an increased dose from this pathway results under the new methodology, due to the dose from milk ingestion having not previously been calculated at all for these radionuclides.
- Under the previous methodology, it was assumed that foodstuffs were located at 500m from the release point (for both milk and green vegetables). Under the new methodology, foodstuffs are assumed to be located at 1 km from the release. Activity concentration on the ground, which is the basis for all ingestion dose calculations, decreases with distance from the release point for the release modelled in this scenario. The change in the location of foodstuffs means that the activity concentrations on the ground are less under the new methodology than the old one, and this will act to reduce the ingestion doses. The activity concentration on the ground at 500 m used for Schedule 2 REPPIR-2001 was 5×10^{-7} Bq m^{-2} per Bq released, compared with the activity concentration on the ground at 1 km used for Schedule 1 REPPIR-2019 of 3×10^{-8} Bq m^{-2} per Bq released.
- Under the new methodology, consumption rates are based on the 95th percentile rate, rather than the 97th percentile rate. For example, under the new methodology, infants consume 290 litres of milk per year, but under the previous methodology they consume 320 litres per year. This acts to decrease the ingestion dose calculated under the new methodology.

- Updated **dispersion** modelling (NRPB-R91 in Schedule 2 REPPIR 2001 is replaced by the use of NAME in Schedule 1 REPPIR-2019) leads to a reduction in the time integrated activity concentration in the air and on the ground. As these values are the foundations for the calculation of dose from the various pathways, the lower values in the new methodology result in lower doses.

Time integrated activity concentration in air and deposited activity concentration at 100m from release location

	Schedule 2 REPPIR-2001*	Schedule 1 REPPIR-2019†
Time integrated activity concentration in air (Bq s m^{-3} per Bq release)	9.0 10^{-4}	1.1 10^{-4}
Deposited activity concentration (Bq m^{-2} per Bq release)	9.0 10^{-6}	1.4 10^{-7}

Notes:

* From Gaussian, NRPB-R91 model.

† From probabilistic analysis of historical UK meteorological data using NAME and PACE to estimate 95th percentile concentrations.

The differences in skin dose, ingestion of milk, and dispersion factors described above are the key factors which result in the majority of Schedule 1 REPPIR-2019 values being larger and hence less restrictive than those in Schedule 2 REPPIR-2001. All differences in the methodologies combine to affect the magnitude of the differences seen. In the majority of cases, the decrease in the effective dose criterion, which should act to decrease the values, is outweighed by the effect of the new methodology, which acts to decrease the majority of doses, and therefore increase the Schedule 1 REPPIR-2019 values.

To illustrate the combination of factors, take the case of ^{75}Se. The new Schedule 1 REPPIR-2019 value is 4 x 10^{12} Bq. The previous Schedule 2 REPPIR-2001 value was 2 x 10^{11} Bq. The new value is 20 times greater than the previous one. The factors which contribute to this difference are:

- the activity concentrations in milk (per unit deposit) are greater in Schedule 2 by a factor of ~20
- the activity concentration on the ground is greater in Schedule 2 by a factor of ~16
- these 2 factors result in the effective dose from milk being greater in Schedule 2 by a factor of ~320
- in Schedule 2, the ingestion of milk is the only significant pathway for ^{75}Se
- however, in Schedule 1, the following exposure pathways all make significant contributions to the total effective dose: ingestion of contaminated green vegetables, external exposure from the plume, and inhalation of the plume
- the total effective dose in Schedule 2 (mainly from ingestion of milk), is ~85 times greater than the total effective dose in Schedule 1 (from all pathways)
- taking into account the change in effective dose criteria (5 mSv in Schedule 2, and 1 mSv in Schedule 1), the ^{75}Se value in Schedule 1 is 20 times that in Schedule 2