IAEA TRANSSC Technical Expert Group on Radiation Protection

Working group on $A_1/A_2$

# UPDATE OF THE Q SYSTEM TO DERIVE THE $A_1/A_2$ BASIC VALUES OF THE IAEA TRANSPORT REGULATIONS NO. SSR-6

## Report of the WG $A_1/A_2$ for the 2021-2023 SSR-6 review and revision cycles

Version 1.0

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# 1. INTRODUCTION

The $A_1$ and $A_2$ values tabulated in the IAEA transport regulations SSR-6 [1] have been determined to limit the contents of packages so that "*the radiological consequences […] are deemed to be acceptable, within the principles of radiological protection, following failure of the package after an accident*" (para. 402.1 in SSG-26 [2]) where the package has lost its safety and radiation protection functions. These values were derived from the "Q system" (where "Q" stands for "Quantity") radiological model, based on 5 different exposure scenarios and described in the advisory material SSG-26, using reference doses of 50 mSv (effective dose), 500 mSv (equivalent dose to the skin) and 150 mSv (equivalent dose to the lens of the eye). It is considered that exposures below these limits would not lead to significant health detriment, either deterministic or stochastic in the event of an accident [60].

$A_1$ and $A_2$ values are also often used to express the package standard performances required in the different transport conditions defined in SSR-6, as they represent equivalent radiological consequences for whatever radionuclide is involved.

The current Q system is the successor of the radiotoxicity classification system used in the 1961 [4], 1964 [5] and 1967 [6] editions of the Regulations, and the "$A_1/A_2$ system" derived in the 1973 edition [7]. The Q system was first introduced in the 1985 edition [9], using a similar yet more comprehensive method, taking into account the latest changes in ICRP recommendations (ICRP 26) at that time to improve the "$A_1/A_2$ system". The $A_1$ and $A_2$ values were then updated with the 1996 edition of the Regulations [11] to use the then new ICRP 60 recommendations [25] and the latest data from ICRP at that time. Since then, they have remained unchanged in the subsequent editions of the regulations.

However, the ICRP has published updated and more complete data that supersede the previous data sets. New means of calculation are also available. Furthermore, there was a need in some countries to have $A_1/A_2$ values for additional radionuclides. Unfortunately, simple calculations of additional $A_1/A_2$ values or recalculation of existing values only using Appendix I of SSG-26 [2] led to inconsistencies, and the unavailability of required information to do this task or to interpret the basic radionuclide values provided in the transport regulations were identified by several organizations. Some of the determined problems in the current Q system are listed below:

- Q and A values are calculated using outdated input data,
- inhalation dose coefficients are partly not consistent with the dose coefficients of ICRP 68,
- some of the dose coefficients listed in SSG-26, seem to be "calculated backwards" from Q values listed in SSG-26, therefore some values (especially for small coefficients) cannot be reproduced,
- Q values are limited to 1 000 TBq without justification or documentation,
- determination of "unlimited" values for LSA material is not thoroughly documented,
- treatment of progenies is not always consistent and differs between the Q value pathways,
- some assertion (low ingestion dose, low impact of multiple pathway principle, arbitrary derivation of $Q_A = Q_F = 10^4 Q_C$ for alpha emitters etc.) are not properly justified,
- approximations are done in the physics for energy deposition.

In response to these problems, members of TRANSSC asked for an international meeting since several institutions were discussing the Q system. The first meeting held in September 2013 gathered participants from the following institutions: Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), Institut de Radioprotection et de Sûreté Nucléaire (IRSN), Japan Nuclear Energy Safety Organisation (JNES, now Nuclear Regulation Authority, NRA), Public Health England (PHE, now UK Health Security Agency, UKHSA) and World Nuclear Transport Institute (WNTI). However, as no complete proposal was available, the TRANSSC concluded at its November 2013 meeting (TRANSSC 27) that no change to SSR-6 Safety Standard could be provided. It was, however, identified that further meetings were needed to exchange views and conclusions about possible improved methods and associated results. Afterwards, the participants agreed that the current Q system should be reviewed, and the International

Working Group on Review of $A_1$ and $A_2$ Values (WG $A_1/A_2$) for the IAEA Transport Regulations was founded. The Japanese National Maritime Transport Institute (NMRI) and Mitsubish Heavy Industries - Nuclear Systems and Solution Engineering Co., Ltd (MHI NS ENG) joined the group in 2016. The European Organization for Nuclear Research (CERN) joined in 2018. WG $A_1/A_2$ is now associated to the TRANSSC Technical Expert Group on Radiation Protection (TTEG-RP).

The scope of the WG was then defined as follows:

- reviewing the method and data used to determine the Q values,
- discussing impact of changes in A values on a scientific basis,
- discussing further improvements of the current Q system,
- providing and recording details on the new methods and results.

The WG especially focused on developing a calculation method that is standardized, in agreement with the physics and applicable to all radionuclides. More details about the progress made by the WG throughout the years are provided in publications [43], [48], [51] and [57], and in the presentations ref. [70] to [84] made to the TRANSSC.

The present report is an update of the interim report v1.0 issued by the WG before TRANSSC 45 [85]. It contains additional information related to the basis of the Q system, some use of the method in the IAEA regulations, the treatment of tritium and krypton 85, the consequence of the 10-day rule on some radionuclides, the analysis of the changes in the method, and clarifies some paragraphs, especially those related to (α,nγ) reactions, intake of particles, contamination with alpha particles, submersion dose coefficients, the 10-day rule concept, the unlimited values and the validation process; it also now includes links to references, the proposed revision of Table I.1, I.2 and II.2 of SSG-26, Table 3 of SSR-6, Table 2 / footnotes a and b of SSR-6 and a paragraph dedicated to the recommendations of the WG to the TRANSSC.

# 2. REVIEW OF THE Q SYSTEM

## 2.1. Principles

Previous recommendations and available data (ICRP 32 [20], ICRP 38 [22], ICRP 51 [23], ICRP 60 [25], and ICRP 68 [26]) have been updated (ICRP 103 [29], ICRP 107 [30], ICRP 116 [32] and ICRP 130 [35][36][37][38][39]). These updates now include new kinds of data such as additional nuclear data (spectra for beta and neutron emitters, delayed beta / prompt and delayed gammas / neutrons, etc.), new or updated fluence-to-dose coefficients (skin dose coefficients in the event of contamination for all the radiation available in ICRP publication 107, effective dose coefficients for beta and for neutrons, etc.), updated and new intake coefficients. Most coefficients are based on an updated computational phantom representing the reference adult male and female (ICRP publications 110 [31] and 145 [41]) and are tabulated for different radiation fields. The higher incidence of eye cataracts than previously expected was also considered (ICRP publication 118 [33]).

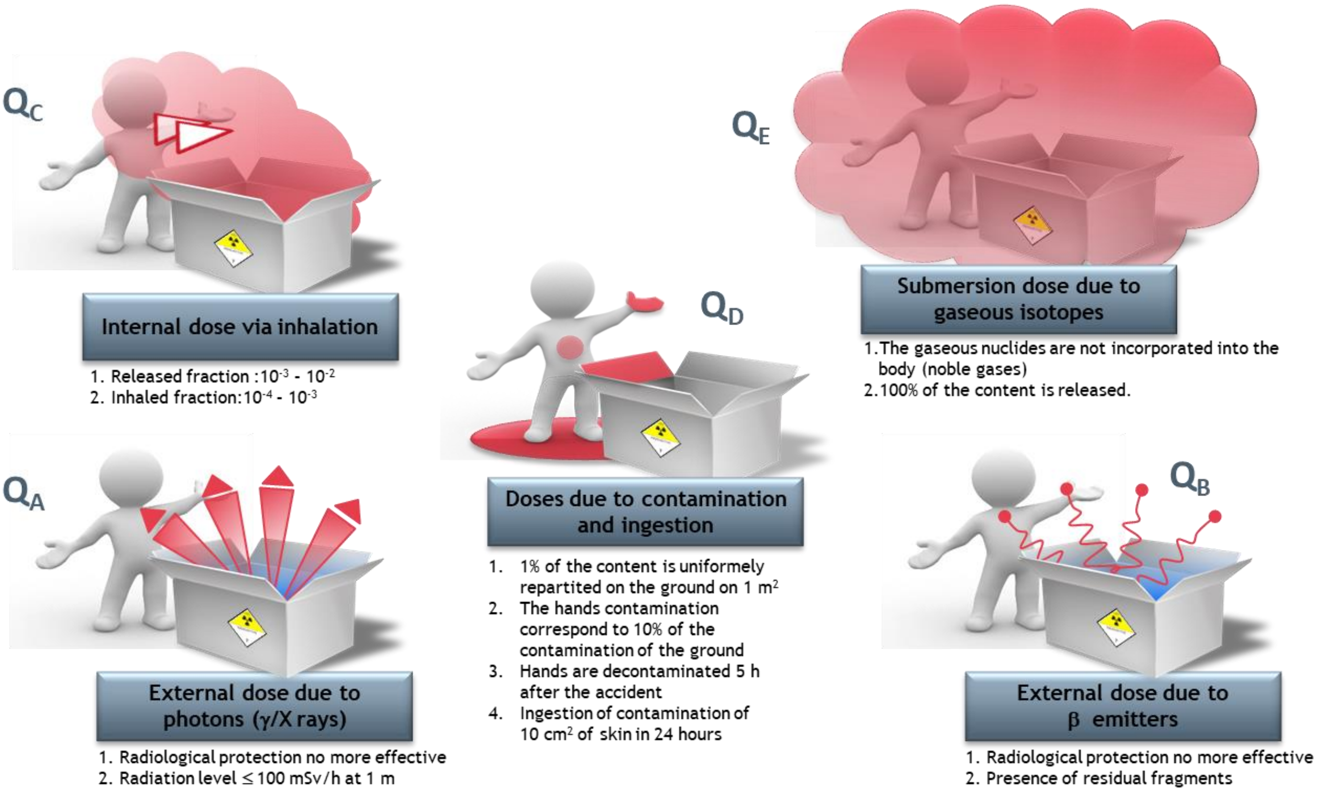
The updated ICRP data can be used within the current Q system with similar analytical calculation methods. However, the current dose calculation model is not adapted to process these new data in entirety. Some of the new data correspond to radiations, the dose contributions of which were previously not explicitly considered in the Q system, and for which new calculation methods are necessary. For that purpose, the WG agreed to use a new calculation approach based on Monte Carlo (MC) methods (probabilistic approach to describe as precisely as possible the transport of radiation) considering all particles (photons, electrons, neutrons, alphas, protons) and their interactions with matter as well as secondary particles resulting from different interactions (e. g. Bremsstrahlung, (n,p) reactions, etc.). Different Monte-Carlo codes (MCNP, FLUKA, GEANT4, PHITS) and cross section databases (ENDF, JEFF, etc.) were used by the working group. The choice of this computational method and the different software used allow for reliable calculations for the proposed revision of the "Q system" and should make it stable for the future.

For this review, the general principle of the Q system has been kept in its current form as much as possible, as the WG agreed that it represents a reasonable accident scenario in which a Type A package is damaged because of a severe transport accident and all of its contents is released leading to the exposure of a person standing for 30 min at a distance of 1 m from the package or in a confined area of 300 $m^3$ volume. In the current Q system, five different exposure pathways (cf. Figure 1) resulting in a dose to this person are considered; for each exposure pathway the activity limit in the package is calculated in such a way that, in case of such an accident, the dose taken by anyone in the vicinity of the damaged package would be limited by the worst of the following criteria:

- an effective dose of 50 mSv (the worker dose limit at the time the original Q system was devised), or
- an equivalent dose to the skin of 500 mSv, or
- an equivalent dose to the eye of 150 mSv, though this criterion was eventually not considered.

These activities are called the Q values. The 5 Q values are:

- $Q_A$ the activity that would give rise to an effective dose of 50 mSv from external gamma radiation.
- $Q_B$ the activity that would give rise to an equivalent dose to the skin of 500 mSv from external beta radiation.
- $Q_C$ the activity that would give rise to a committed effective dose of 50 mSv from inhalation.
- $Q_D$ the activity that would give rise to an equivalent dose to the skin of 500 mSv from skin contamination or a committed effective dose 50 mSv through subsequent ingestion.
- $Q_E$ the activity of a noble gas that would give rise to an external effective dose by submersion of 50 mSv, or an equivalent dose to the skin of 500 mSv, whichever is the most restrictive. $Q_E$ is listed instead of $Q_D$ for noble gases.



1. Released fraction : $10^{-3}$ - $10^{-2}$
2. Inhaled fraction: $10^{-4}$ - $10^{-3}$

1. The gaseous nuclides are not incorporated into the body (noble gases)
2. 100% of the content is released.

1. 1% of the content is uniformely repartited on the ground on 1 $m^2$
2. The hands contamination correspond to 10% of the contamination of the ground
3. Hands are decontaminated 5 h after the accident
4. Ingestion of contamination of 10 $cm^2$ of skin in 24 hours

1. Radiological protection no more effective
2. Radiation level ≤ 100 mSv/h at 1 m

1. Radiological protection no more effective
2. Presence of residual fragments

***Figure 1. Exposure scenarios considered in the Q system***

$A_1$ is the lowest of $Q_A$ and $Q_B$ and is thus used to characterize undispersible radioactive material such as “special form radioactive material” defined in the regulations, as only external radiations are considered. $A_2$ is the lowest of all the Q values. In the original $A_1/A_2$ System [4], to protect against any possible effects of bremsstrahlung radiation, an upper cut-off limit of 1 000 Ci was applied to the $A_1$ and $A_2$ values. That cut-off was kept in the 1985 edition [9]. When the Q system was revised in the 1990s [12], this upper limit was retained at 40 TBq, although it was recognized that it was an arbitrary value. The Q values have an upper arbitrary limit of 1 000 TBq although no reference to this limit could be found in any documentation. Considering the principle of limitation, the WG also decided to keep those cut-off limits.

The Q values are rounded to two significant figures and the A values to one significant figure. The WG kept that concept, but the A values are rounded according to the raw Q values, not the rounded ones. Whether A values were derived from the raw or rounded Q values is not explained in the current Q system.

It is important to emphasize that que Q system addressed both workers and members of the public, as a transport accident may occur anywhere. Indeed, the IAEA Regulations are meant to protect the population, not only the workers (103.2 of SSG-26 [2]). In 1973 and 1987, the foreword of Safety Series No. 37 [15][16] conveys the same message. The 1987 edition of Safety Series No. 7 [13], which introduces the first version of the Q System, aligns with this perspective, noting that the accident scenario implies "*persons in the vicinity of a Type A package involved in a severe transport accident*". Workers are never specifically mentioned. While the dose criteria originate from the workers practice (annual effective/equivalent dose limit, quarterly intake limit/half of the maximum permissible annual intakes for workers [15]), translated into a criteria for a "one-off" exposure as a reasonable approach, they were later proved to be reasonable, even penalizing, to address accident reference levels in several ICRP publications; for the record, the original Q System mentions that: "*For Safety Series No. 6, this approach* [radiation workers annual dose limit] *was considered to be acceptable on a once in a lifetime basis for members of the public inadvertently exposed near the scene of a severe accident involving a Type A package*" [13].

## 2.2. Use of the Q system in the regulations

$A_1$ and $A_2$ values, defined in para. 201 and listed in Table 2 of SSR-6 [1], are used to characterize:

- LSA-II and LSA-III specific activity limits ($10^{-4}$ $A_2$/g for solids and gases, $10^{-5}$ $A_2$/g for liquids and $2.10^{-3}$ $A_2$/g for compact solids – para. 409 and I.62),
- Content activity limits for type A packages (1 $A_1$ or 1 $A_2$ – para. 429),
- Content activity limits for excepted packages (items, packages) depending on their chemical forms (para. 422 and Table 4),
- Content activity limit for the transport of radioactive content by air (3000 $A_1$ / $10^5$ $A_2$, 3 000 $A_2$ – para. 410 and 433),
- In modal regulations, the security activity threshold, above which the radioactive content is considered "high consequence radioactive material" per single package, implying a transport security plan (3 000 $A_2$ – e.g. para. 1.4.3.1.3 of the UN Model Regulations),
- Content activity limits of LSA and SCO in a conveyance (10 or 100 $A_2$ – para. 522 and Table 6),
- Criteria for release rate of radioactive content in NCT and ACT for type B and type C packages ($10^{-6}$ $A_2$/h and 1 $A_2$/week – para. 659 and 671),
- Values for unidentified radionuclides, or those not listed in Table 2 (para. 402 and Table 3),
- Other criteria (LSA-I material, transport documents, notification to authorities, test for low dispersible radioactive material, dynamic crush test, enhanced immersion test, approval of shipments – respectively para. 409, 546, 558, 605, 659, 660/730, 825).

Since the Q system was developed for solids/aerosols and noble gases, special considerations were introduced in the SSR-6:

- Type A packages designed to transport liquid or gaseous radioactive contents (except noble gases and tritium gas) shall survive the 9-m free drop test and the enhanced penetration test (para. 650 and 651),

- Water containing tritium can be considered as LSA-II if the tritium activity concentration is less than 0,8 TBq/L (para. 409),
- The specific activity limit for LSA-III material is higher than the limit defined in the Q system because of the “compactness” of the content (para. 409 and 409.6),
- The specific activity limit for liquid LSA-II material is lower to consider a possible activity increase during transport (para. 409 and 409.7),
- Tritium gas transported in excepted packages has specific activity limits (para. 422 and 422.5),
- Content activity limits for SCO and LSA depends on whether they are combustible (para. 410 and 522),
- Special activity limit for $^{85}$Kr of 10 $A_2$ for type B and C packages (para. 659 and 671).

The scope of the WG did not originally include the review of the SSR-6 and SSG-26 paragraphs that make use of the results and the method developed in the Q system. However, this report will address some of those aspects when they are relevant.

# 3. EVALUATION OF $Q_A$ AND $Q_B$

## 3.1. Derivation of the current Q system

For the $Q_A$ and $Q_B$ exposure scenarios, a person is considered to be standing 1 m away from the package and is exposed for 30 minutes; the package has been damaged by the accident and no longer provides shielding or containment.

The $Q_A$ value is the activity of a given radionuclide in the material contained in a Type A package damaged in such an accident that leads to an effective dose of 50 mSv from external exposure to gamma and X-rays. The $Q_A$ value is obtained using the equation:

$$Q_A = \frac{DL_{eff}}{\dot{e}_{pt} \cdot t}$$

where $DL_{eff}$ is the dose criterion for effective dose (50 mSv), $\dot{e}_{pt}$ is the effective dose rate from a point source from gamma or X-rays at 1 m (Sv $Bq^{-1}$ $h^{-1}$) per unit activity and *t* is the exposure time (0.5 h). Current values of the effective dose rate $\dot{e}_{pt}$ at 1 m were derived as a proportion of the whole-body dose calculated using the linear attenuation formula.

Alpha and neutron emitters are not considered in this evaluation and are treated in the current Q system through special considerations.

For alpha emitters, it is not in general appropriate to calculate $Q_A$ and $Q_B$ values for special form material, because of their relatively weak gamma and beta emissions. The former $A_1/A_2$ System introduced an arbitrary $A_1$ value of $10^3$ $A_3$ (ancestor of $Q_C$) for alpha emitters. In recognition of the good record in the transport of special form radioactive material and the reduction in many $Q_C$ values for alpha emitters by a factor of up to 10 after the update of the $A_1/A_2$ System to the Q system in 1985, a tenfold increase in the arbitrary factor of $10^3$ above was used. The Q system now specifies an additional value for alpha emitters, called $Q_F$, which was then arbitrarily set at $10^4$ $Q_C$ and is listed instead of $Q_A$. It is unclear whether this figure was also destined to account for (α,nγ) reactions.

In the few cases of spontaneous fission neutron emitting radionuclides ($^{252}$Cf, $^{254}$Cf and $^{248}$Cm) the $Q_A$ value takes account of the contribution of neutron irradiation to the dose. The $Q_A$ value for $^{252}$Cf was evaluated using the dose rate per unit activity taken from ICRP Publication 74, and the values for the other two radionuclides were based on the $^{252}$Cf dose rate per unit activity allowing for their respective neutron emission rates relative to $^{252}$Cf. With these special cases, it is unclear whether neutrons from spontaneous fissions and (α,n) reactions were considered.

The $Q_B$ value is the activity of a given radionuclide in a source contained in a Type A package damaged in an accident that leads to an equivalent dose to the skin of 500 mSv or to the eye lens of 150 mSv, from external exposure to beta particles. The exposure scenario for $Q_B$ considers that, after the accident, the source provides some residual shielding and that the person exposed is standing at 1 m from the source for 30 minutes. The SSG-26 states that the dose to the skin is always limiting for maximum beta energies and that specific consideration of dose to the lens of the eye is then unnecessary. Thus the $Q_B$ scenario only considers the equivalent dose to the skin.

The $Q_B$ value is obtained using the equation:

$$Q_B = \frac{DL_{skin}}{\dot{e}_\beta \cdot t}$$

where $DL_{skin}$ is the dose criterion for dose to the skin (500 mSv), $\dot{e}_\beta$ is the equivalent dose rate to the skin from a point source from beta particles at 1 m (Sv $Bq^{-1}$ $h^{-1}$) per unit activity and t is the exposure time (0.5 h). Current values of the effective dose rate $\dot{e}_\beta$ is calculated using a deterministic formula based on a shielding factor for the maximum energy of the beta spectrum assuming a thickness of the residual shielding and the dose rate in water evaluated by Cross et al. [63] considering the Continuous Slowing Down Approximation (CSDA).

The consideration for a residual shielding comes from the 150 mg·$cm^{-2}$ absorber introduced in the calculations of the current $Q_B$ values. It is stated as an arbitrary figure originally chosen to simulate either residual shielding between the radioactive source and the bystander (due to package debris or because of the capsule containing the source), or auto-shielding of the source itself. This value is not properly documented in SSG-26 and was mentioned as a simple derivation of an assumption made in the 1973 edition of the IAEA Regulations . Indeed, a thickness of 0.2 mm of steel was considered as a reasonable assumption for $^{90}$Sr, then was used to derive the $Q_B$ values of all other radionuclides [15]. This 0.2 mm of steel later became this “shielding factor” of 150 mg·$cm^{-2}$. This residual shielding leads to reduce the dose due to beta emission as compared with a non-shielded pure beta source, e.g. by a factor of 3 for energies greater than 2 MeV; the $A_1/A_2$ system then the Q system tabulated reducing factors as a function of the maximal beta energy in order to evaluate $Q_B$. However, since such shielding would also give rise to bremsstrahlung (secondary photon emissions), and that the evaluation of the dose thus induced could not be evaluated, both the $A_1/A_2$ system and the Q system limited the $A_1$ values to a maximum of 1 000 Ci then 40 TBq.

For both $Q_A$ and $Q_B$, the radioactive material is treated as a point source, values of photon energies and yields were provided by ICRP publication 38, and the dose conversion factors from exposure free-in-air to effective dose were obtained from data tabulated in ICRP publication 51 for an isotropic radiation geometry. No single method for the interpolation of the data is provided in relevant documents and this operation may differ and lead to different results when calculating $Q_A$ and $Q_B$ values.

## 3.2. Update proposed by the WG

At the beginning of the revision work, it was decided to directly calculate the $Q_A$ and $Q_B$ values using MC-simulation tools, with focus on a short list of about 20 radionuclides of importance, considering the main types of radiation emitted; the dose coefficients were directly encoded in the input files. However, because of the issue related to the choice of the field geometry at that time and the benefits of being able to compare different calculation tools, it was decided to evaluate surface fluence through a detector located at 1 m from the point source, then to process the results using the fluence-to-dose coefficients agreed upon (antero-posterior AP, rotational ROT or fully isotropic ISO field). The fluence at the detector depends on the physical processes and interaction cross-sections of the particles on their way to the detector used in the corresponding code. Therefore the code output was well-suited for validation procedures. Some of the early work performed by members of the WG is described in [44], [45], [46] and [47]. A general overview about the new method agreed by the WG is presented in [50].

For photons, electrons and positrons, fluences were calculated for monoenergetic energies from 1 keV to 12 MeV at least equivalent to what is used in the ICRP publication 116; in fact, fluences are evaluated in bins, which does not entirely comply with the ICRP 116 dose coefficient listed in Tables A.1, A.3 and A.4 of annex A, and Table G1 of Annex G, since they are defined for incident mono-energetic particles; those dose coefficients were then log-log interpolated on the calculated fluence mesh: hence the energies considered in the construction of the fluence bins contain the energies defined in ICRP publication 116 (e.g. some calculations considered 10 000 bins between 1 keV and 10 MeV, each one having a width of 1 keV). For neutrons, the individual energy bins of the source were derived from the spectra used in ICRP publication 107, and fluences are evaluated the same way as aforementioned using Table A.5.

This new method makes it possible, the evaluation of any radionuclide as long as their spectra is known, and to manage with less effort the evolution of the values when new standards on spectra will be published, instead of recalculating the values for each radionuclide. Eventually, this method can be seen as a standardization since it can be applied to all the radionuclides referenced in the literature: it is then theoretically possible to evaluate dose rates, hence $Q_A$ and $Q_B$ values, e.g. for all ENDF/B-VIII radionuclides (more than 1 700).

The WG also decided that the principle of using only one type of radiation to determine either the effective dose or an equivalent dose, not allowing for all kinds of particles, should be revised since ICRP recommendations now provide coefficients for most of the incident radiations of interest, and new calculation techniques (large scale MC methods) are now available that allow precise evaluation of the associated total exposure of individuals. For example, effective dose coefficients now exist for beta, neutron and gamma emissions meaning that the $Q_A$ value for $^{137}$Cs can now take into account the effective dose due to both its gamma and beta emissions. More details about that aspect are provided in [49].

The geometric model for the MC calculations is as follows (cf. Figure 2): a sphere of 1 m radius with a point source at the centre of the sphere is surrounded by a residual shielding made of 0.5 mm of stainless steel with a density of 7.8 g.cm$^{-3}$; the inner part of the 1-m radius sphere is made of air. The fluence is recorded at the surface of the 1-m sphere. Considering that backscattering was taken into account when deriving the ICRP 116 dose coefficients, it was decided that the surface of the 1-m-radius sphere would be the boundaries of the calculation universe.

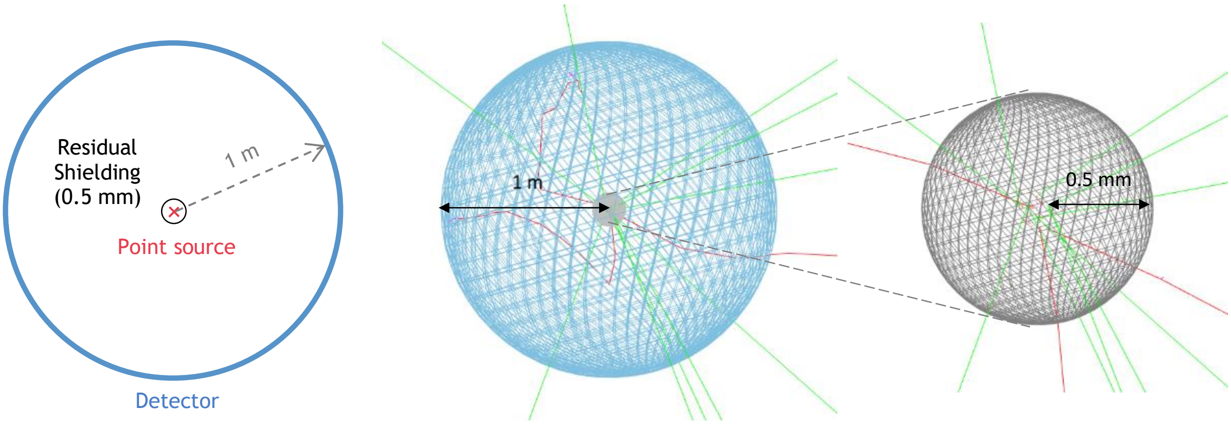


***Figure 2. MC model considered to derive $Q_A$ and $Q_B$***

A residual shielding of 0.2 mm of steel was originally considered in deriving the $Q_B$ values (which correspond to a mass thickness of 150 mg.cm$^{-2}$, called "shielding factor" in the Q system). However, after further investigations on actual sources, it was found that, with the exception of $^{90}$Sr, no other special form radioactive source would be shielded by such a thin layer of stainless steel, the minimum thickness used being between 0.4 and 0.6 mm for sources such as $^{192}$Ir where the minimum thickness is sought to reach maximum efficiency for gammagraphy. Besides, the 0.2 mm thickness is only used for the beta window protector, which represents only one face of the encapsulated source, the rest of the capsule being more than 1 mm in thickness. In the end, the WG decided to use a reasonable thickness of 0.5 mm for both $Q_A$ and $Q_B$. This thickness was also considered in the former $A_1/A_2$ System to evaluate the $A_1$ values of primary X-ray emitters [15]. Details about the use of the shielding factor can be found in [52].

Regarding the irradiation geometry, ICRP publication 116 (and the former publication 51) provides dose coefficients for different exposures to a parallel beam of ionizing radiations, as shown in Figure 3: AP (antero-posterior, for a person facing a source), ROT (rotational, for a person standing up walking around a contaminated field or a source), PA (postero-anterior, for an exposure from the back), RLAT & LLAT (for a lateral exposure from the right or left side) and ISO (isotropic, exposure in a large homogenous cloud of radioactive gas or in a highly scattered radiation field).

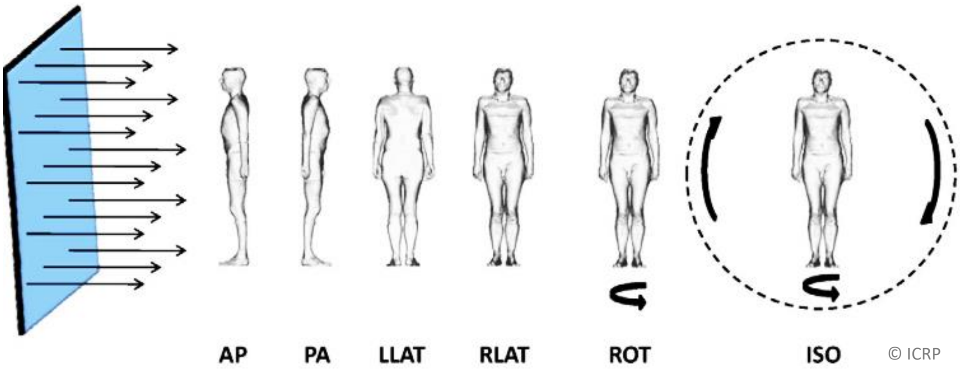


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***Figure 3. ICRP 116 exposure geometries***

The WG agreed that the irradiation field should average the exposure from a severe transport accident (where a type A package would lose its contents) and that the parallel beam of ionizing radiation used to define the dose coefficients listed in ICRP publication 116 is unrealistic for a point source only 1 m away from a person, as shown in Figure 4. It was decided to keep the ISO field of irradiation (though ROT would also be a reasonable candidate as the dose rates would increase by less than 30% compared to the ISO field, as presented in Figure 5). Besides it was considered unlikely that someone will remain static for more than 30 minutes (except if he lays unconscious next to the source). Eventually, ICRP publication 116 does not provide dose coefficients for all particles for the ROT, RLAT, LLAT and PA geometries. Since the Q system scenarios were not meant to be accurate as it had to represent a global severe accident situation, and that the benefit of calculating new dose coefficients would not be very significant, the WG decided  to use the dose coefficients provided in ICRP 116 for the ISO geometry and not to calculate new dose coefficients.

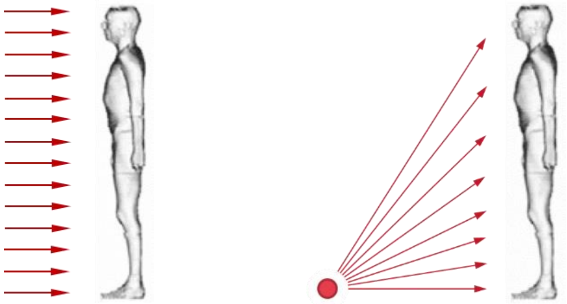

***Figure 4. ICRP 116 AP exposure geometry vs. realistic AP exposure geometry for the $Q_A$ and $Q_B$ scenarios***

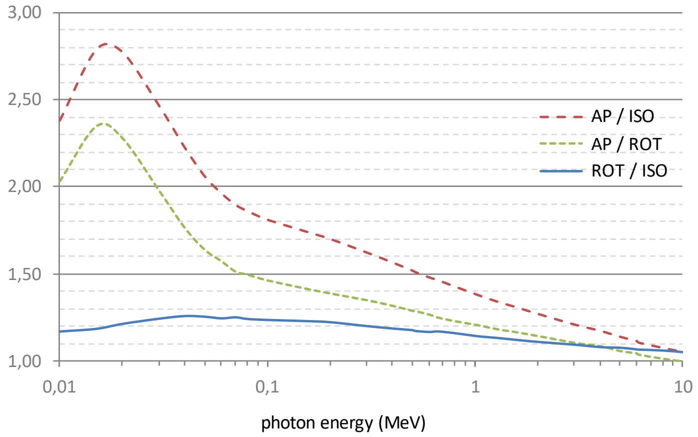

***Figure 5. Comparison of photon dose coefficients between AP, ISO and ROT geometries***

The new $Q_A$ and $Q_B$ respectively represent the total effective dose and total equivalent dose to the skin for all kinds of primary and secondary particles (photons, electrons, positrons, neutrons) that can contribute to the dose; they are no longer limited to the effects of photons or electrons. Since the statement of SSG-26 regarding the non-significance of the equivalent dose to the eye lens compared to that of the skin is not documented or justified, the WG also evaluated the total equivalent dose to the eye lens for all particles: a $Q_{B,eye}$ value was derived using the same equation as $Q_{B,skin}$. $Q_B$ would then be the minimum between $Q_{B,eye}$ and $Q_{B,skin}$.

An important question was raised during the review of $Q_B$. When using the coefficients from ICRP publication 116, the $Q_{B,skin}$ values incorporate dose coefficients from various radiation types (photons, neutrons, electrons, and positrons); however, these coefficients are calculated differently. The average skin dose for photons and neutrons is determined across the entire skin organ, based on the anthropomorphic phantom from ICRP publication 110 with a 2 mm thickness, while, in contrast, the dose coefficients for electrons and positrons target the most exposed $cm^2$ of the basal layer of the skin, which lies at a depth between 50 and 100 µm. The local skin dose is then evaluated at a local position through the skin in the body, and not averaged over the full skin. This concept is presented in Figure 6. The WG then decided to homogenize the calculation method by deriving local skin-equivalent dose coefficients for photons and neutrons. This meant creating new dose coefficient databases using the same method presented in the ICRP publication 116. The issue is important as it also concerns the $Q_D$ calculations. For the special case of positrons, the WG used the coefficients derived by Bourgois et al. [62] since the same method was applied. Local skin dose coefficients are slightly more conservative than mean skin dose coefficients. The evaluation of the local skin dose coefficient databases is described in [54] and [55].

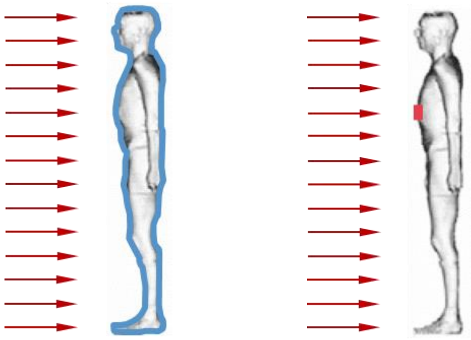

***Figure 6. Mean skin dose vs. local skin dose geometries***

The method to derive $Q_A$ and $Q_B$ can then be summarized as follows:

- MC calculations, for each individual energy bin, of fluences using a point source with residual shielding and a 1-m-radius sphere detector;
- evaluation of $\dot{e}_{eff}$, $\dot{e}_{eq,skin}$ and $\dot{e}_{eq,eye}$ (replacing $\dot{e}_{pt}$ and $\dot{e}_{\beta}$) for each radionuclide using the fluences previously calculated weighted by their energy spectra, and the dose conversion coefficients as follows:
  - decay data for photon, neutron, electron and positron energies and their respective yields are provided by ICRP publication 107; other sources were used when spectra from ICRP publication 107 [30] were considered incomplete (e. g. treatment of dual β+/β- emitters[1] for which the JEFF3.3 [68] or ENDF/B-VIII.0 [67] libraries was used to differentiate the spectra, or treatment of (α, nγ) reactions for which the TENDL library [66] was used);;
  - fluence-to-dose conversion coefficients were obtained from data tabulated in ICRP publication 116 [32] for an isotropic irradiation geometry; when data were not available, the WG evaluated and published their own dose conversion factors using the same method as ICRP to derive those quantities (e. g. conversion factors for the equivalent dose to the most exposed surface of the skin[2]).
- evaluation of $Q_A$ and $Q_B$ using the current Q system formula described above; in this framework, following information and recommendations stated ICRP publications 103[3] [29] and 118 [33], it was decided to keep the dose criteria of 50 mSv (effective) and 500 mSv (equivalent, skin) as being reasonable. For the lens of the eye, the WG decided to use a criterion of 250 mSv corresponding to half of the one-off dose for which ICRP publication 118 indicate that a deterministic risk of cataract exists.

As for neutrons, spontaneous fission spectra are derived from the ICRP publication 107 while (α,nγ) spectra are treated through the SOURCES4C [64] and TALYS codes [65]. As a matter of fact, ICRP publications do not provide any data related to (α,nγ) reactions, as they depend on the interactions of the α particles (following the α-decay) with the source medium, and the mass ratio between the radioactive compound and the stable element target. For that specific case, the WG performed parametric and sensitivity analyses including all possible alpha-emitting radionuclides. Two commonly used targets were considered: beryllium (mass ratio of 5) because this is the most penalizing, and oxygen (molar ratio of 5) because this is the most common (oxide forms). After preliminary calculations for both targets and some common actinides ($^{241}$Am, $^{239}$Pu and $^{244}$Cm), it was decided that, for the sake of safety, only the beryllium target would be considered in the complete analysis – but the method described hereafter could be reproduced for oxygen or any other target.

Based on SOURCES4C [64], the neutron dose as a function of the alpha mean energies has been determined (cf. Figure 7), while the photon contribution has been calculated with the TALYS code [65] as a function of monoenergetic alpha energies. From these calculations, a database was derived allowing for the calculations of neutron and gamma emission rate and dose contributions for all alpha emitters. In the end, the arbitrary $Q_F$ value is discarded.

Further details on the method to derive the (α,nγ) dose coefficients are provided in [58].

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[1] Namely $^{106}$Ag, $^{108}$Ag, $^{74}$As, $^{78}$Br, $^{80}$Br, $^{36}$Cl, $^{130}$Cs, $^{132}$Cs, $^{64}$Cu, $^{150m}$Eu, $^{152}$Eu, $^{152m}$Eu, $^{126}$I, $^{128}$I, $^{112}$In, $^{114}$In, $^{40}$K, $^{54}$Mn, $^{84}$Rb, $^{102}$Rh, $^{122}$Sb and $^{168}$Tm.

[2] Average over any 1 cm$^2$ area of exposed skin, regardless of the area exposed, at a nominal depth of 70 µm

[3] Table 5 and Table 8 of ICRP 103 [29] state that a reference level of 100 mSv, set for the highest planned residual dose from a radiological emergency, may be used, especially for “other rescue operations” (different from the saving ones). Para. 241 explains that a reference “one-off” exposure of 50 mSv could be used, and that dose rising towards 100 mSv would always require protective actions. Para 278 explicitly addresses emergency situations with mentioning the planned residual doses in the range of 20 to 100 mSv. Therefore, the 50 mSv criterion was kept by the WG. The 100 mSv reference level was also introduced in the 2013-59/EURATOM directive in Europe.

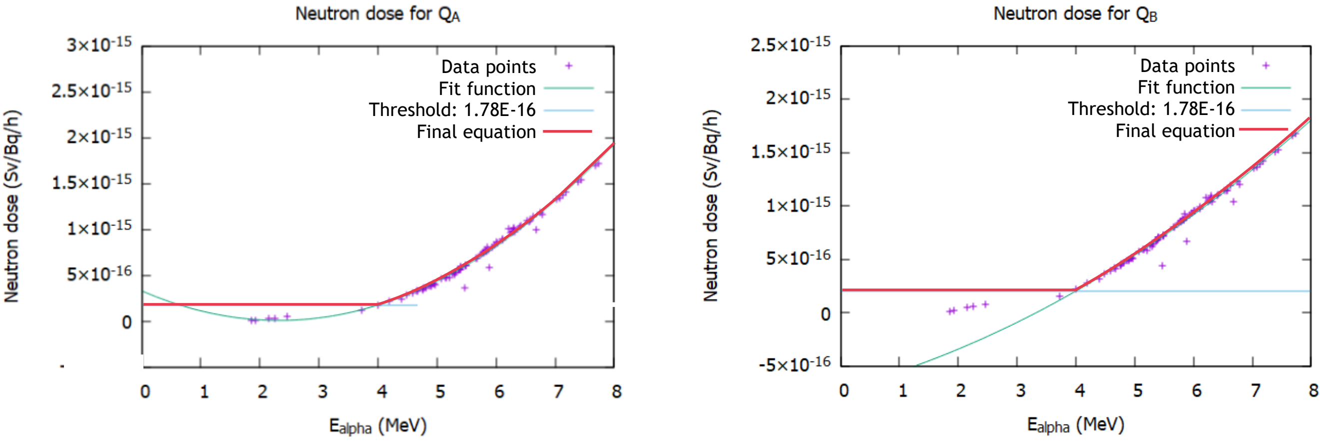

***Figure 7. (α,nγ) effective dose for $Q_A$ and $Q_B$ per primary α particle***

# 4. EVALUATION OF $Q_C$

## 4.1. Derivation of the current Q system

The $Q_C$ value for a radionuclide transported in a non-special form is determined by the inhalation effective dose to a reference person exposed to the radioactive material released from a damaged Type A package following an indoor or outdoor accident. Indoor scenarios consider a storeroom or a cargo handling bay with a volume of 300 $m^3$ and four room air changes per hour; outdoor scenarios consider the effect of the wind 10 to 100 m away from the package. It is considered that a fraction of $10^{-2}$ to $10^{-3}$ of the activity will be instantly resuspended in the air and that, considering a time exposure of 30 min, a person in the vicinity of the package would inhale of $10^{-3}$ to $10^{-4}$ of the resuspended fraction. Therefore, a total fraction of $10^{-6}$ of the activity released by the package contributes to a committed effective dose due to inhalation.

The $Q_C$ value is then obtained using the equation:

$$Q_C = \frac{DL_{inh}}{10^{-6} \cdot e_{inh}}$$

where $DL_{inh}$ is the dose criterion for the internal effective dose due to inhalation (50 mSv) and $e_{inh}$ is the inhalation dose coefficient in Sv/Bq. Current values of the dose coefficients are documented to be from ICRP publication 68 [26] for a particle size (Activity Median Aerodynamic Diameter, AMAD) of 1 µm and the most restrictive chemical form (generally type S – slow rate absorption), though investigations made by the WG showed that some dose coefficients could be different from the ICRP publication.

## 4.2. Update proposed by the WG

The WG $A_1/A_2$ did not question the scenario of exposure, the parameters of which are well documented.

$e_{inh}$ were updated according to ICRP publications 130 [35], 134 [36], 137 [37], 141 [38] and 151 [39], between 2015 and 2022. New worker inhalation dose coefficients for aerosols of particle size from 0.001 µm to 20 µm were calculated and new chemical forms were introduced by ICRP; the highest dose coefficients are often those for nanoparticles. During the review of the Q system, it was unclear whether the particle size of the materials normally transported is comparable to that of nanoparticles, and whether dose coefficients for nanoparticles should therefore be used instead of those for an AMAD of 1 µm as in the current Q system.

ICRP publications 72 [27] and 119 [34] state the current AMAD of 1 µm should correspond to the exposure of the public, while current values were derived for workers – in fact, the "workers" dose coefficient is similar to the "adult" dose coefficients; ICRP publications 119 [34] and 130 [35] also state that, for occupational exposure, the default value generally recommended for the AMAD is 5 µm and that, when the size distribution of the radioactive aerosol is not known, the default AMAD value of 5 µm should also be used. ICRP publications suggest that those two diameters are characteristic of aerosols produced by dispersion mechanisms, except for daughter radionuclides of gases (namely radon) for which nanoparticles are created as a result of radioactive decay. It was also noted that significant amounts of nanoparticles are unlikely to be produced in an accident ($10^6$ particles of 10 nm are necessary to have the same mass as a 1 µm particle, which seems far above the likely distribution of particles of that size in powders usually transported). Consequently, the proposed revised Q system uses the highest inhalation dose coefficient for the AMAD values of 1 µm and 5 µm.

The adult intake dose coefficients were taken into account, as in the current Q system. The WG considered that it would be overly conservative to consider age-dependent dose coefficients such as those currently derived in the ICRP publication 72 (also included in ICRP publication 119)[4].

# 5. EVALUATION OF $Q_D$

## 5.1. Derivation of the current Q system

The $Q_D$ value is determined from the dose to the skin of a person contaminated with non-special form radioactive material as a consequence of handling a damaged Type A package. The contamination can then be ingested, resulting in an intake dose. In this scenario, it is considered that 1% of the package content is spread uniformly over an area of 1 $m^2$ and that handling of the debris could result in contamination of the hands to 10% of this level; the exposed person does not wear gloves but washes their hands within a period of 5 h. Therefore, it is considered that a fraction per unit area of $10^{-3}$ $m^{-2}$ of the total package activity is spread on the hands when estimating the dose to the skin.

The $Q_{D,skin}$ value is then obtained using the equation:

$$Q_{D,skin} = \frac{DL_{skin}}{10^{-3} \cdot \dot{h}_{skin} \cdot t}$$

where $DL_{skin}$ is the dose criterion for equivalent skin dose (500 mSv), $\dot{h}_{skin}$ is the equivalent skin dose rate per unit activity per unit area from a surface source spread on the skin ($Sv.s^{-1}.Bq^{-1}.m^2$) and t is the exposure time (5 h or $1.8 \times 10^4$ s).

ICRP has not published skin dose coefficients due to contamination $\dot{h}_{skin}$ (ICRP publications 59 [25] and 118 [33] detail the deterministic effects involving irradiation of the skin; ICRP publication 118 also addresses the eye lens). The current Q system evaluates the skin contamination $Q_D$ values with the dose coefficients taken from Cross et al. [63] which uses Monte Carlo calculations for an air/water interface, for a source of 100 $cm^2$ (or 1 $cm^2$), the dose being calculated by integration at depths in water between 60 and 80 µm through a surface of 1 $cm^2$.

The possible uptake of radioactive material via ingestion was considered, assuming that a person may ingest all the contamination from $10^{-3}$ $m^2$ (10 $cm^2$) of skin over a period of 24 h, resulting in an intake fraction of the total radioactive content of $10^{-6}$.

The $Q_{D,ing}$ value is then obtained using the equation:

$$Q_{D,ing} = \frac{DL_{ing}}{10^{-6} \cdot e_{ing}}$$

where $DL_{ing}$ is the dose criterion for the internal effective dose due to ingestion (50 mSv) and $e_{ing}$ is the ingestion dose coefficient in Sv/Bq. Current values of the dose coefficients can be found in the ICRP publication 68. However, the current Q system considers that the inhalation dose, using the same $10^{-6}$ fraction, will always be more restrictive than the ingestion dose according to data found in ICRP publication 68. Therefore $Q_{D,ing}$ is not evaluated.

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[4] As of time of writing, the age- and sex-dependent intake coefficients from ICRP 72 have not yet been updated.

## 5.2. Update proposed by the WG

While the Cross et al. method [63], based on MC calculations, is similar to the one used for the current review of the Q system, the WG agreed to consider an air/skin cube model detailed in ICRP Publication 116 for more accuracy and standardization with the other Q values (which is also consistent with the way $Q_B$ coefficients were evaluated). As shown in Figure 8, the model includes a surface source (instead of the parallel beam considered in ICRP publication 116) of 38.5 cm$^2$ representing a hand palm. The dose is then integrated at depths between 50 and 100 µm on the most exposed 1 cm$^2$ surface.

Contrary to the fluence method used to derive $Q_A$ and $Q_B$ the MC models simulate energy dependent dose coefficients, based on the energy deposition method, in case of $Q_{D,skin}$ for all types of primary particles, for each mono-energetic particle (from 1 keV to 12 MeV for positron, photon, electron, from 4.14 10$^{-7}$ MeV to 15 MeV – ICRP 107 binning – for neutrons, and from 4 to 20 MeV for alpha). The coefficients are then convolved with the decay emission spectra database (ICRP 107) to produce the dose coefficients for each radionuclide.

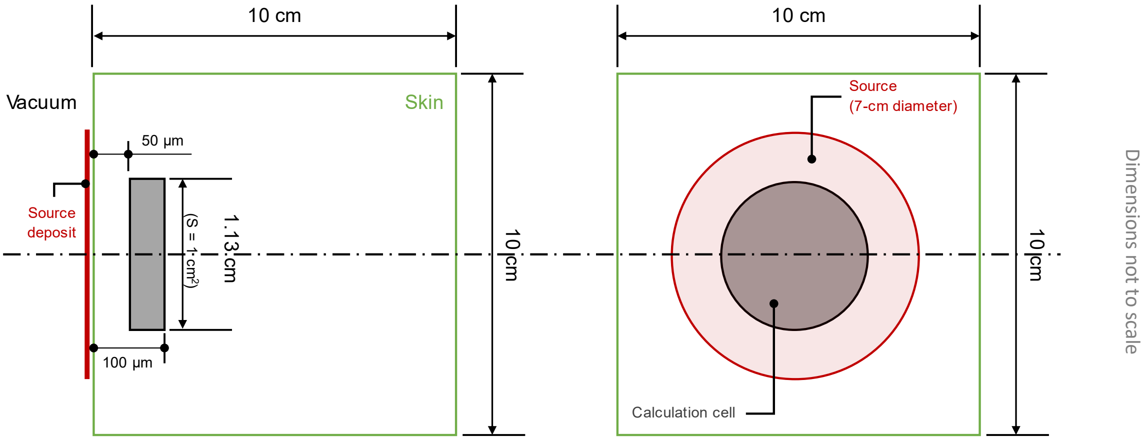

*Figure 8. MC model considered to derive $Q_{D,skin}$*

The WG also evaluated the skin dose due to contamination by alpha emitters. New local skin dose coefficients for all particles were evaluated and published by the WG. When alpha particles are emitted toward the skin slab with an incident energy in the [5-6.5] MeV range, considerable discrepancies in deposited energy between the different particle transport codes used were found. The WG noticed that, at those energies, when alpha particles barely reach the scoring volume, secondary particles, especially protons, are mostly responsible for the dose. Alpha particles with energy exceeding 7 MeV are the main contributors to the dose as they penetrate deeper in the skin, to the scoring volume (cf. Figure 9). Due to differences in the stopping power corrections of the MC codes, the energy range between 5 and 6.5 MeV provides strong relative variations of the dose to the skin among the codes. Those discrepancies were explained by the corrections implemented in the Bethe theory for low energy alpha that differ among the codes. The WG then agreed to consider the maximal dose coefficients among the three different evaluations (using an average would, at most, divide the dose coefficients by a factor of 3 for an energy of 5 MeV and would not significantly change anything above 7 MeV). Details about alpha contamination and the comparison of the dose evaluation between the codes are provided in [56].

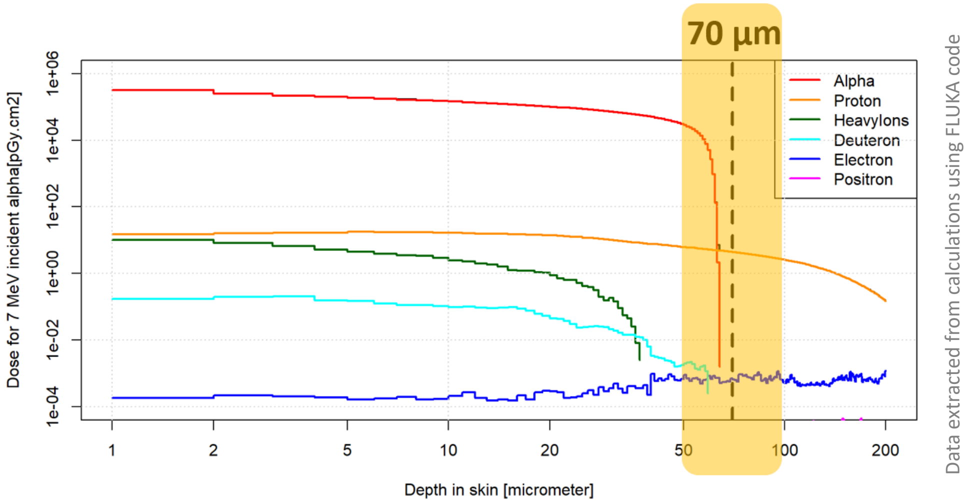

***Figure 9. Penetration depth in skin of primary & secondary particles (7-MeV α)***

As for $Q_{D,ing}$, the parameters of the scenario were not modified. Since ingestion dose coefficients were updated in ICRP publications 130, 134, 137, 141, 151 , the WG decided to evaluate $Q_{D,ing}$ for all radionuclides available in ICRP publication 107. It was found that the assumption made by the Q system, that ingestion dose is always lower than the inhalation dose, was wrong: in the update of the Q system, for 70 isotopes, $Q_{D,ing}$ is less than $Q_C$. However, the statement could be seen as correct in the derivation of the $A_2$ values because, in the end, only two iodine isotopes have an $A_2$ value driven by $Q_{D,ing}$: $^{125}$I and $^{129}$I.

# 6. EVALUATION OF $Q_E$

## 6.1. Derivation of the current Q system

The $Q_E$ value for gaseous isotopes which do not become incorporated into the body is determined by consideration of the submersion dose following their release in an accident when transported as non-special form radioactive material in either a compressed or an uncompressed state. The scenario and assumptions are identical as those used to derive $Q_C$, except that, in the case of $Q_E$ a release fraction of 1 is assumed. Both effective dose and equivalent skin dose are calculated.

The $Q_E$ value is then obtained using the equation:

$$Q_E = \frac{DL_{sub} \cdot V_{eq}}{\dot{h}_{sub} \cdot t}$$

where $DL_{sub}$ is the dose criterion for either external effective dose due to inhalation (50 mSv) or equivalent skin dose (500 mSv), $\dot{h}_{sub}$ is the effective or skin dose coefficient in Sv.s$^{-1}$.Bq$^{-1}$.m$^3$, $V_{eq}$ is the average equivalent volume in which the gas is released considering a ventilation of 4 h$^{-1}$ (i.e. 694 m$^3$) over the time of exposure t (0.5 h). Current values of the dose coefficients $\dot{h}_{sub}$ are found in the U.S. Federal Guidance Report No. 12.

The $Q_E$ scenario addresses only noble gases for which at least one isotope with a significant half-life exists, namely Ne, Ar, Kr, Xe and Rn. Radon is indeed a noble gas but it only exists as a radioactive material and the decay products of the isotopes of interest, $^{222}$Rn and $^{220}$Rn (because they belong to the natural uranium and thorium decay chains), are solid radioisotopes that can be deposited in the lung, thus delivering an inhalation dose, which does not correspond to the definition of gases that should be considered in the $Q_E$ scenario.

ICRP publication 32 [20] was used to address the $^{222}$Rn case. $^{220}$Rn, which has the same issue, is not considered in the current Q system. Then the $Q_C$ equation was used, considering a 100% release fraction, but the activity was considered as a $Q_E$ value.

## 6.2. Update proposed by the WG

In the proposed revised Q system, the parameters for calculating $Q_E$ remain unchanged. Only the dose coefficients are updated by using new publications: ICRP publication 144 [40] for effective and skin equivalent dose coefficients and ICRP publication 137 [37] for $^{220}$Rn and $^{222}$Rn. Though the U.S. Federal Guidance Report No. 12 was updated in Report No. 15, the ICRP publications were retained for standardization. However, for consistency purposes, the semi-infinite cloud model used in the Guidance was also considered to choose the dose coefficients from ICRP publication 144.

ICRP publication 151 [39] proposes coefficients for different room sizes, that would be closer to the original intent of considering a limited room volume (300 m$^3$); however, those coefficients only exist for effective dose, not equivalent dose to the skin. In the end, the WG decided to consider the semi-infinite cloud model as in the current Q system, justifying the use of the dose coefficients from ICRP publication 144. It is important to underline that those coefficients are calculated with polygon mesh skin models of the adult phantoms (male and female) from ICRP Publication 145 [41], which significantly refines the phantoms used in ICRP Publication 110 [31] used to derive ICRP publication 151 effective dose coefficients. The equivalent skin dose is now estimated at depth between 50 µm and 100 µm, no longer on the entire “skin organ” as it used to be, and is thus consistent with the new approach.

As for radon isotopes, while the current Q system considered it is a $Q_E$ value because the release of radon, considered as a noble gas, corresponds to the $Q_E$ scenario, the calculation method used was that of $Q_C$ since inhalation pathway actually corresponds to that scenario. Therefore the associated formula presented in § 4.1 was used assuming a 100% release fraction. In those radon special cases, the inhalation pathway delivers much higher doses than the external exposure pathway considered in $Q_E$.

# 7. TREATMENT OF PROGENIES

## 7.1. Basis of the current Q system

The Q system introduced a rule to account for the progenies in the evaluation of the $A_1$ and $A_2$ values. This rule, often referred to as the “10-day rule”, states that:

- if the half-life of daughter radionuclides is less than 10 days and lower than that of the parent radionuclide, then the mixture is considered in equilibrium,
- in all other cases, the radionuclides should be considered in a mixture law by the consignor / designer.

This concept was introduced in the 1973 regulations [7] as follows: if the daughter radionuclide is assumed to come into equilibrium with the parent, for a transport duration of up to 50 days, $A_1$ is calculated for both the parent and the daughter, and the most limiting of the two values is assigned to the parent nuclide. The same rule applied for parent radionuclides having short-lived daughter of a half-life not greater than 10 days. The concept was a refinement of the previous rules considered in the edition of the regulations prior to 1973: for example, in the 1964 and 1967 editions, mixtures consisting of a single radioactive decay chain where the radionuclides are in the naturally occurring proportions[5] had to be considered as consisting of a single radionuclide. At that time, the radiotoxicity classification system was only based on the exposure due to intake of radioactive material, as recommended by ICRP publication 1 [20] for accident situations [12].

## 7.2. Issues and update proposed by the WG

While the principles seem simple, the WG noted that, for many radionuclides considered in “transient” equilibrium, the application of the rule is not clearly explained in SSG-26, and hypotheses had to be considered by members of the WG to derive the current values. For example, with the $^{47}$Ca / $^{47}$Sc couple mentioned in Appendix I of SSG-26, the half-lives of which are respectively 4.54 days and 3.35 days, it appears that the current

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[5] This referred to natural equilibrium, not naturally occurring radioactive material (namely $^{238}$U, $^{235}$U and $^{232}$Th chain) as the term could suggest.

value was calculated after 10 days of in-growth, using a mixture rule with the total activity of the chain, instead of assuming equilibrium with the reference to the activity of the parent radionuclide only. However, this observation does not apply to other radionuclides considered in equilibrium in Table 2 of SSR-6: in some cases, different hypotheses had to be made to recalculate the current values, in other cases, it was simply impossible to find the same values.

The 10-day rule should allow only the activity of the parent radionuclide to be taken into account (by the designer, consignor, etc.), meaning that this “super parent” (for example referred to as “$^{47}$Ca+”[6]) will virtually contain the radiation emissions of all its daughter radionuclides (i.e. $^{47}$Ca+ emits radiations from both $^{47}$Ca and $^{47}$Sc), as exemplified in Figure 10. Therefore, the A value of a mixture should always be lower than that of the parent alone, i.e. more restrictive (using the same activity of the parent). This was not the case for the $^{47}$Ca / $^{47}$Sc decay chain in the current Q system because the A values of the mixture was greater than that of $^{47}$Ca alone.

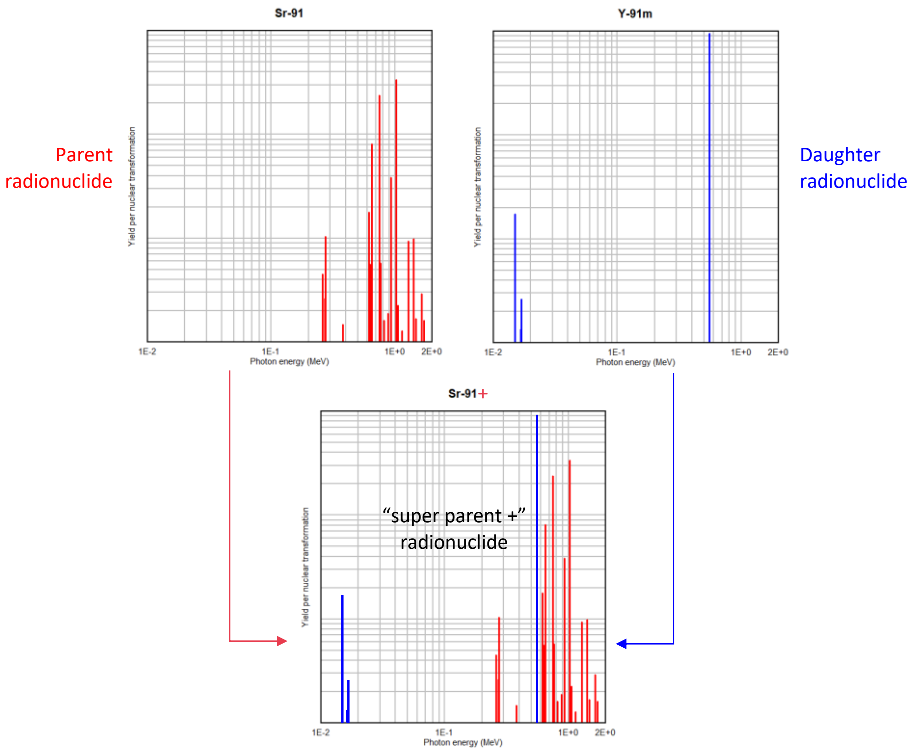

***Figure 10. 10-day rule concept: example with the $^{91}$Sr / $^{91m}$Y decay chain***

In fact, the derivation of the Q values consists in applying the mixture rule defined in para. 405 of SSR-6 on each single Q value of the pure parent and daughter radionuclides (X(i) in para. 405), considering the activity of the parent only. It means that the fraction f(i) referred to in para. 405 is equal to the equilibrium ratio only and does not depend on the time variation of activity ratios:

$$\text{From para. 405: } Q = \left[\sum_i \frac{f_i}{Q_i}\right]^{-1} \text{ with } f_i = \frac{A_i}{\sum_i A_i}$$

$$\text{with reference to the activity of the parent only: } \sum_i A(i) \text{ is replaced by } A_{parent}$$

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[6] Notation used in e.g. RP 65 [69] to underline that the parent radionuclide is considered together with its daughters.

$$\text{thus, at equilibrium: } f(i) = \frac{A_i(t \to \infty)}{A_{parent}(t \to \infty)} = \left( \prod_{j=2}^{i} BR_{j-1,j} \right) \times \frac{T_{parent}^{i-1}}{\prod_{k=2}^{i} T_{parent} - T_k}$$

Where :

- $A_i$ is the activity of the nuclide at generation i in the decay chain ($A_1$ is noted as $A_{parent}$),
- $T_i$ is the half-life of the nuclide at generation i in the decay chain ($T_1$ is noted as $T_{parent}$),
- $BR_{i-1,i}$ is the branching ratio between nuclide at generation i and its direct parent at generation i-1.

A simple example to explain this issue is $^{137}$Cs / $^{137m}$Ba decay chain, the half-lives of which are respectively 30.2 years and 2.55 min. Let us consider a mixture consisting of 5 TBq of $^{137}$Cs and 4.7 TBq of $^{137m}$Ba. Since, the 10-day rule allows the consignor to consider only the activity of the parent radionuclide, only 5 TBq of $^{137}$Cs is taken into account: in that case, $^{137}$Cs inherently contains the energy emissions of $^{137m}$Ba (i.e. the 662 keV gamma emission), therefore the $Q_A$ value of $^{137}$Cs in equilibrium with $^{137m}$Ba (noted "$^{137}$Cs+") is 1.9 TBq. Using the mixture rule on those two pure radionuclides (with $Q_A$ of 1620 TBq and 1.8 TBq respectively), with a total activity of 9.7 TBq, will give the same "quantity of $Q_A$" (i.e. hazard level), equal to 2.7, as 5 TBq of $^{137}$Cs+. In that case, the equivalent $Q_A$ value of the mixture will be equal to 3.7 TBq. This illustrates that the method provided by the 10-day rule, where only the activity of the parent is considered, and the method using the mixture rule, where the activities of all radionuclides are considered, are equivalent.

Considering Q values at equilibrium is convenient for most cases, since the users do not have to apply complex mixture rules, sometimes having to consider the possible increase in hazard level because of the build-up of the daughter during the time of transport. Besides, mixtures can be transported a significant time after their production (e.g. wastes), meaning they may reach an equilibrium even before they are transported. In the end, considering equilibrium maximizes the hazard level of the transport, which is a safe approach.

However, equilibrium may, in reality, not be reached before the arrival at the consignee; therefore, some Q values may be seen as overly conservative. Participants of the WG noted the example of irradiated targets for medical isotopes extraction that may be transported only hours after their irradiation (mainly due to the limited half-life of the radionuclides). Besides, mixtures may not be in equilibrium when loaded in a package.

Another question was raised regarding the way the rule is built: how to deal with complex chains with several branches, some of them having half-lives higher than that of parent? The simple and practical answer would be to consider the full chain in equilibrium (though this could be conservative in many cases). The issue was especially clear for $^{230}$Pa where only an insignificant part of the decay chain was considered, as shown in Figure 11. However, to keep the practice that has been used for decades, and since the table 2 in SSR-6 details the progenies considered in the decay chain to avoid any confusion, the WG decided to keep the current algorithm.

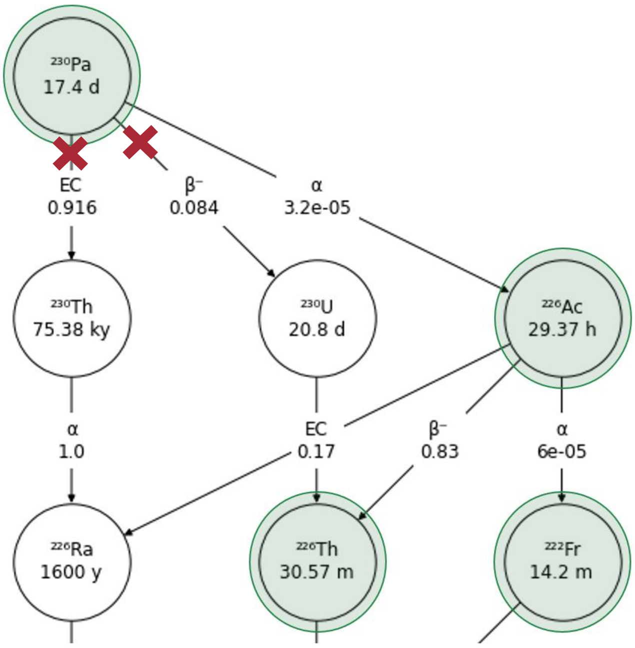

***Figure 11. 10-day rule applied to $^{230}$Pa (extract of the first decay levels)***

Overall, in practice, the WG recognized that a risk of error may appear in the calculation of the quantity of $A_1$ or $A_2$ to be put in a package when dealing with radionuclides that can be produced outside of a decay chain or with different parents: in the simple case of a mixture of $^{90}$Sr and $^{90}$Y, for which the half-lives are respectively 28,8 years and 2.67 days, $^{90}$Y may have been produced by another process (irradiation) than the decay of $^{90}$Sr, but would be discarded from the evaluation of the quantity of $A_2$ of the content because it would be assumed in equilibrium with its parent $^{90}$Sr. This would also lead to the same issue with a mixture containing $^{47}$Ca and $^{47}$Sc, especially since their half-lives are close.

The WG then suggested that the Q and A values could be given without progeny and that the consignor should work out the value for mixture transported. The currently proposed update of table 2 still uses the 10-day rule but the WG can easily provide individual values without such rule, for single radionuclides (e. g. values for $^{137}$Cs and values for $^{137m}$Ba).While this possibility would clarify the use of SSR-6 Table 2, be more accurate for the user, and remove the risk of error when dealing with radionuclides coming from different chains, this would also transfer the burden to evaluate the A value to the consignor, who would have to determine the transport time at which this value is the lowest, which is a different method from what has been applied for more than 50 years.

In the end, for all radionuclides in which the 10-day rule applies, the WG evaluated the Q and A values at equilibrium. Since the secular equilibrium is a mathematical boundary condition of the equations for transient equilibrium, secular equilibrium is reached automatically when relevant. While the distinction seems meaningless since both equilibria are calculated at an infinite time by definition, the WG had to define a time at which a transient equilibrium occurs to facilitate the calculation process: 1,000 times the half-life of the mother radionuclide was chosen. The calculated values are in adequation with the ones that would be calculated using the formula mentioned above.

## 7.3. Special considerations

Expanding the principle of the 10-day rule to the physical production of daughters, the WG realized that some noble gases may produce solid particles (radon isotopes being the best example), while solid radionuclides may produce gases (e.g. radium and iodine). Theoretically, those isotopes may respectively have $Q_C/Q_D$ values and $Q_E$ values because they will release solid particles and noble gases during an accident.

The WG then decided to evaluate the theoretical $Q_C$ and $Q_D$ values for noble gases, the daughters[7] of which are solids, and the theoretical $Q_E$ values for solid isotopes, the daughters[7] of which are noble gases.

# 8. UNLIMITED VALUES

## 8.1. Basis of the current Q system

The current Q system considers an upper cut-off of the mass of radionuclides that can be absorbed (inhalation or ingestion) or which should be easily identified in case of skin contamination.

Currently, the mass limit for inhalation corresponds to 10 mg and is used to define the “unlimited value” in both deriving the $Q_C$ and A values. Therefore, considering that, by definition, inhaling $10^{-6}$ $Q_C$ leads to an effective dose of 50 mSv, an activity is considered unlimited if its corresponding specific activity is lower than $10^{-4}$ $Q_C$/g. The mass of 10 mg is not currently documented in the Q system. However, in the 1961 edition of the Safety Series No. 7 [12], the hypothesis of an “extremely dusty atmosphere” of 10 mg/m$^3$ following an accident was assumed; it’s likely that the limit of 10 mg was a figure derived from that dust concentration and a range of breathing rate comprised between 1.2 m$^3$/h (normal) and 2.4 m$^3$/h (effort, representative of the state of commotion in an emergency situation), giving a range of intake comprised between 6 and 12 mg. The WG assumed that hypothesis has been kept throughout the revisions of the radionuclide basic values until the last update of the Q system, and sees it as still valid today.

Those considerations are used to define low specific activity (LSA) material criterion: unlimited $A_2$ for LSA-I material, $10^{-4}$ $A_2$/g for solid and gaseous LSA-II, $10^{-5}$ $A_2$/g for liquid LSA-II considering a concentration building factor of 10 and 2 $10^{-3}$ $A_2$/g for LSA-III material considering its compact nature.

As for skin contamination, it was considered that typically 1–10 mg/cm$^2$ of dirt present on the hands would be readily discernible and would be removed promptly by wiping or washing, irrespective of the possible activity. Considering that, by definition, being contaminated by $10^{-3}$ $Q_D$/m$^2$ lead to an equivalent skin dose of 500 mSv, $Q_D$ is considered unlimited if its corresponding specific activity is lower than $10^{-5}$ $Q_D$/g. Considering the model used in the updated Q system, this would represent 385 mg of contamination and 100 mg of ingested material.

These rules do not explain the given “unlimited” $A_1$ values in SSR-6. Therefore, there seems to be another rule which is not documented.

## 8.2. Update proposed by the WG

### 8.2.1. Criteria

The WG decided to continue following the same rules.

Currently there is no mass limit defined for $A_1$ values though “unlimited” values are defined in the current SSG-26 and SSR-6. The WG then decided to use a mass criterion of 1 metric ton (1 000 kg), i.e. corresponding to specific activity criteria of $10^{-6}$ $Q_A$/g and $10^{-6}$ $Q_B$/g. While this value sounds arbitrary, it corresponds to the mass limit used to define “bulk quantities” of radioactive material when dealing with exemption values (cf. IAEA GSR Part 3). The objective is that the point source assumption can no longer be used because such mass would strongly decrease

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[7] In equilibrium according to the 10-day rule, at the time of the accident.

the exposure, so that it is never possible to reach an effective dose of 50 mSv or an equivalent skin dose of 500 mSv in 30 minutes at 1 m, whatever the mass of material involved.

The WG noted that, in the current Q system, there was no situation for which an $A_1$ value would be unlimited with a limited $A_2$. Considering that, during a severe accident, some material could escape from the special form radioactive material because, theoretically, the fire test for such sources does not last as long as the fire test for approved packages, the WG decided to keep the same tacit rule that can be formulated as follows: if $Q_A$ and $Q_B$ are unlimited, but $Q_C$, $Q_D$ or $Q_E$ is limited, then $A_1$ is derived according to the usual procedure without any regard for the mass criterion.

This concerns 21 radionuclides, for which $Q_A$ and $Q_B$ are all higher than 50 TBq (sometimes "unlimited", such as for $^3H$ or $^{37}Ar$, as no dose could be evaluated at 1 m from the source). Applying this rule leads to define an $A_1$ value of 40 TBq for all of them.

### 8.2.2. LSA material

Since the creation of the concept of LSA in 1961, its definition was based on an inhalation limit during an accident (criteria were 0,1 µCi/g and 1 µCi/g depending on the classification group, based on an intake of 1 mg). The $A_1/A_2$ system then introduced the intake limit of 10 mg to derive the LSA criterion of $10^{-4}$ $A_2$/g that is also used to define "unlimited" $A_2$ values; it is important to underline that the $A_1/A_2$ system was considering scenarios with external exposure (now $Q_A$ and $Q_B$) to derive $A_1$, and internal exposure due to inhalation only to derive $A_3$ (now $Q_C$). This criterion has been used ever since, especially to define LSA-II[8] material, which is based on the $Q_C$ scenario since the first edition of the Q system in 1985. The dose rate criterion of 10 mSv/h at 3 m for LSA and SCO materials, stated in para 517, is to cover the $Q_A$ and $Q_B$ scenarios, i.e. exposure from external radiations, because it roughly corresponds to the "100 mSv/h at 1 m" criterion used in the Q system for a point source, which should be conservative because of the expected actual size of LSA and SCO materials.

The WG noted that there could be a theoretical radiation protection issue in case of an accident, as defined in the Q system:

- The first issue lies in the application of the scenario to vapors and gases; the concept of "dust concentration" on which is based the LSA criterion does not exist for those forms. The specific case of noble gases is treated differently in the $Q_E$ scenario with a 100% release fraction, but there is no criterion to define LSA-II gases either.
- Besides, the Q system now defines another LSA / "unlimited Q" criterion based on the $Q_D$ scenario: $10^{-5}$ $Q_D$/g. Thus, if $A_2$ is based on the $Q_D$ value (or if $Q_D$ is lower than 10 x $Q_C$), there is a risk that the LSA-II criterion is underestimated because, in that case, the limit should be $10^{-5}$ $A_2$/g for solids (i.e. $10^{-6}$ $A_2$/g for liquid LSA-II and $2.10^{-4}$ $A_2$/g for LSA-III).

Therefore, since it was not within the scope of their work, the WG recommends reviewing the adequacy of the LSA criterion of $10^{-4}$ $A_2$/g with regards to a possible radiation protection issue in case of an accident as defined by the Q system.

## 8.3. Special case of enriched uranium

The WG found difficulties in evaluating the Q values of enriched unirradiated uranium (the irradiated case being not considered – the mixture rule is to be used), especially $Q_C$. Currently, it is considered that unirradiated U enriched to less than 20% has unlimited Q values. SSG-26 explains that the definition of ASTM C996-90 was used to evaluate the Q values. This standard defined "commercial" unirradiated uranium as natural uranium can be contaminated with $^{232}U$, $^{236}U$ and fission products ($^{99}Tc$) to certain limits depending on the enrichment level of $^{235}U$. $^{234}U$ present in natural uranium (because it belongs to the $^{238}U$ chain) also increases through the enrichment process. It is also underlined that the SSR-6 definition of "unirradiated uranium" does not completely match the C996-90 definition as it includes traces of plutonium and does not consider the presence of $^{232}U$.

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[8] The former LSA-III material used to be called "Low Level Solid" in 1973 and had the same criterion of $2.10^{-3}$ $A_2$/g.

Considering all those isotopes, including plutonium, in a mixture ended in significantly lowering the enrichment limit, down to 11%, for which the $Q_C$ of the enriched uranium can be considered “unlimited”.

To derive the updated value, the WG applied the same method as in the current Q system by considering the most severe chemical form mentioned in the ICRP publication 68, the “S” (slow lung absorption) form. However, the ICRP publication 137 update now introduces a new S chemical form, the former S one likely becoming the new “M/S” (medium/slow lung absorption) form, because it also applies to uranium dioxide and other common chemical forms of uranium as in the former S form mentioned in ICRP publication 68. Considering this M/S form would lead to keep “unlimited” $A_1$ and $A_2$ values for “U(enriched to less than 20%)”.

Introducing different chemical forms for U(enriched) would be both consistent with the fact that only uranium isotopes have different values according to their chemical form, and inconsistent with the method used in the Q system for mixtures, especially for the material made of uranium such as U(depleted) or U(natural).

The WG therefore proposes to create 2 new entries in table 2 with associated footnotes (that should refer to all the actual chemical compounds mentioned in ICRP 137), which have “unlimited” $A_1$ and $A_2$ values: “U(enriched to less than 20%, all chemical forms except S)” and “U(enriched to less than 10%)”. “U(enriched to less than 20%)” then has limited values.

# 9. OTHER SPECIAL CASES

Two radionuclides are specifically addressed as exceptions in the Q system as they use different scenarios: $^{85}$Kr and $^{3}$H (tritium, also noted T).

## 9.1. Krypton 85

The actual value of $^{85}$Kr to be used in the safety demonstrations related to the release of radioactive material in normal and accident conditions of transport is 10 $A_2$. That multiplication factor was first introduced in the 1973 edition of the regulations [7] to define an activity release limit for type B(M) packages in accident conditions of transport only. It was not documented in either the regulations [7] or the advisory material [15]. As a reminder, $A_3$ activity limits for noble gases were derived by Fairbairn et al. in 1966 [61], based on the recommendations of ICRP Publication 1 [20]. That model considered the exposure of a person in a van of 50 m$^3$ with 4 air changes per hour, for 8 hours; external exposure resulting from either submersion or irradiation at 3 m from a point source were considered. At that time, there was a distinction between compressed gas (100 % release) and uncompressed gas ($10^{-3}$ release), and the dose criteria were 3 rem (30 mSv) for the whole body and 8 rem (80 mSv) for the skin.

That factor was later kept in the 1985 edition of the regulations for both normal and accident conditions of transport for all type B packages, i.e. B(U) and B(M). The 1987 edition of Safety Series No. 7 [13], in which the Q system is described, explains that the 10-time factor can be justified in recognition of the fact that the type B limit appeared unduly restrictive in comparison with safety standards commonly applied at power reactor sites, especially for severe accident conditions which are expected to occur only very infrequently. In fact, one of the first derivations of the Q values in 1981 (on which the criticism is based), $A_2$ (then named “$Q_2$”) was less restrictive than $A_1$ (“$Q_1$”): during an accident with release of gases, the point source hypothesis is no longer relevant. In the end, the final $Q_E$ value was 7 times the original $Q_B$ value on which the former $Q_2$ was based.

The 10-time factor was also aimed to be justified by comparing the doses resulting, on the one hand from intake of solid particles, on the other hand from external exposure from a noble gas (cf. para AII.2 of [13]): the ratio between those two quantities was about 15 in 1987. However, the parameters used and their units – especially the dilution factors that were considered at the same level – are not detailed. The results presented are confusing since, in the Q system, activities are derived from the same dose limits and that $Q_C$ and $Q_E$ uses the same scenario parameters.

That comparison between doses was kept in the 2002 edition of the TS-G-1.1 with no further justification (cf. para. I.78 [18]); the ratio was 680 (change in the method to evaluate $Q_E$). The calculation seems to demonstrate that there is a difference in the release fraction considered (100 % vs. $10^{-3}$) between the two scenarios. Besides, the effective dose coefficient was considered (for comparison purposes, since $Q_C$ is only evaluated through a committed effective dose), though the $A_2$ value of $^{85}$Kr is driven by the skin dose (with a ratio of 5.5), and the $Q_E$ actual activities (to reach the dose criteria) are respectively 79 TBq and 14 TBq. A value of 100 TBq (i.e. 10 $A_2$) is therefore less than 10 $Q_E$ because of the rounding method.

An additional justification was introduced in the 2012 edition of SSG-26 [19] for the specific release of $^{85}$Kr from a type B package in normal and accident conditions of transport. In normal conditions, an exposure of 200 h in a 300 $m^3$ warehouse (which is equivalent to the original parameters considered to derive the $10^{-6}$ $A_2$/h criterion), leads to a maximal release rate of 6.4 $10^{-4}$ $A_2$/h for an annual skin dose limit for the public of 50 mSv. The result would be about the same considering an annual effective dose limit for the public of 1 mSv. In accident conditions, two scenarios are studied: a person exposed at 100 m of the accident, and another exposed at 15 m. The calculated skin doses are 11 and 180 mSv, which is below the 500 mSv criterion. Getting closer to the package would result in higher doses, which would lead to exceeding the criterion.

In fact, $^{85}$Kr is recognized as the only gaseous radionuclide of practical importance because it is one of the major radioactive gases (with tritium) found in spent fuel, which usually require large heavy type B packages used outdoors or in large warehouses. Thus that additional justification makes sense.

In conclusion, it seems that the use of a 10-time factor on $A_2$ for the transport of $^{85}$Kr in a type B or a type C package is safe. It was not within the scope of the WG to re-evaluate that factor since the latest update was made in 2009 and that this was originally outside the scope of the Q system (rather within the scope of the other uses of the $A_1$ and $A_2$ values in the SSR-6). Therefore, considering the uncertainties in the justification of the 10-time factor mentioned above, and the fact that the latest evaluation considers an activity limit of 100 TBq, the WG recommends mentioning that activity instead of the current "10 $A_2$" in para. 656 and 671 of the SSR-6 [1].

## 9.2. Tritium

Tritium has always been treated separately owing to its special biological behavior, as a gas or in compounds and molecules (because it is an isotope of hydrogen that can then replace it, thus leading to multiple biological situations). Thus additional concentration limits were seen as necessary for this radionuclide. A range of possible accident scenarios involving the release of tritiated water with consequent wetting of the skin of the hands and inhalation of saturated vapor in a confined space or outdoor were developed.

In the 1990 edition of the Safety Series No. 7, those scenarios were removed as it was considered that, for the purpose of determining the $A_1$ and $A_2$ values, the specific activity of such compounds, especially tritiated water, was no longer required in the Q system method. However, those specific scenarios are still in use to determine the LSA-II criterion of 0.8 TBq/L for "water with tritium" in the SSR-6.

The WG updated the $A_1$ and $A_2$ values according to the Q scenarios. The review of the scenarios used to derive the LSA-II criteria was not originally within the scope of the WG. However, here is a summary of those considerations regarding tritium.

Though the scenarios are different, the criterion of 0,8 TBq/L is consistent with the $10^{-5}$ $A_2$/g criterion for liquid LSA-II if "tritiated water" is considered using the proper ICRP dose coefficient of $2.10^{-11}$ Sv/Bq. When deriving the Q system in 1981, a limit of 0.25 TBq/L with a $Q_C$ value of 500 TBq (considering the general performance of a type A package designed to transport liquids and gases) were mentioned [60], which is more restrictive. However, considering that the Q values for all forms of tritium are quite high, and that different exposure scenarios lead to limits comprised between 0,14 and 2 TBq/L, it was considered reasonable to define an upper limit of 1 TBq/L (now 0.8 TBq/L), under which the risk to get an effective dose of 50 mSv or a skin dose of 500 mSv during an accident as defined in the Q system is seen as very low.

The main issue was the use of the term "water with a tritium concentration of" because all the scenarios considered "tritiated water" (i.e. in the form of HTO or $T_2O$). In the case of unknown forms of tritium inside water (such as contaminated water), the maximal dose coefficient from ICRP should be used ($5,2.10^{-10}$ Sv/Bq for carbon tritide, AMAD 1 µm), which is 26 times higher than the current dose coefficient, thus leading to a theoretical concentration limit of about 0,04 TBq/L for LSA-II material. In fact, this limit should be higher since, in that case, the absorption of tritium through the skin via tritiated water will not be considered. As a matter of fact, the scenarios such as “organic tritium mixed with liquid” and “particles containing tritium mixed with liquids” were not envisaged, since the intake dose limit was 1 ALI = $3.10^9$ Bq (1 ALI leads to an effective dose of 50 mSv – it gives an effective dose coefficient of $1{,}7.10^{-11}$ Sv/Bq) for vapors of tritiated water, and that it was recommended at that time that, for organic forms of tritium, to consider a decrease factor of 50.

Therefore, the WG recommends to clearly mention “tritiated water” when defining the LSA-II specific criterion of 0.8 TBq/L for tritium.

Tritium is also mentioned in the regulations through the term “tritium gas”:

- in para. 651 of SSR-6 as an exception (with noble gases) to the additional enhanced mechanical tests that type A packages transporting gases should survive.
- in Table 4 of SSR-6 as a special case for the definition of activity limits of excepted package.

The intake dose coefficient of the gaseous form of tritium is about $10^4$ times that of the vapor form. Even if tritiated water vapor were to be formed during the storage of tritium (hypothesis made in 1985), the resulting fraction of tritiated water within the content should be low. Eventually, the WG noticed that ICRP dose coefficients should also cover gaseous organic tritium (e.g. methane such as $CH_3T$). Thus, there should not be any discrepancy in making an exception for gaseous tritium in para. 651.

As for table 4, an increase factor of 20 was used to define the excepted quantities of tritium because the actual Q values for tritium gas are much higher than the current threshold of 40 TBq.

However, ICRP also introduced a dose coefficient for “unspecified gaseous form”, which is the same as the one for tritiated water. Using this coefficient with a 100% release fraction leads to an effective dose much higher than 500 mSv. The WG noted that there could be a possible interpretation of “tritium gas”, especially in the foreign translations: while “tritium gas” seems to clearly relate to HT and $T_2$ gaseous forms, the French translation simply refers to “package containing tritium” (i.e. “packaged designed to transport gases […] containing tritium” of para. 651) could be interpreted as all gases containing tritium).

Therefore, the WG recommends that the term “tritium gas” be clearly defined in the SSG-26 and adequately translated in other languages, to reflect the fact that it is in either the HT or $T_2$ gaseous forms.

# 10. MULTI-PATH CUMULATIVE DOSE

With the new method presented above, $Q_A$ and $Q_B$ are now described as total effective dose and total skin equivalent dose, respectively, due to all radiations. As such, they inherently cumulate the effects of all radiations; $A_1$ can then be clearly considered as the most restrictive value of $Q_A$ and $Q_B$ since they are different kind of doses that cannot add up.

As for $A_2$ values, considering the release of a certain quantity of radioactive material, it seems reasonable to assume that, if a fraction of the package activity contributes to the dose of a scenario, another fraction may contribute to the dose of another scenario. Theoretically, during an accident, an individual may be exposed to more than one exposure pathway. Thus, to evaluate the total dose received by such an individual, it may be possible to cumulate the effects of different scenarios considering either the effective dose or the skin equivalent dose, as follows:

- effective dose:
  - an average respirable aerosol fraction of 0,1 % of the content is involved in the evaluation of $Q_C$, while a dispersion of 1 % of the contents is assumed when evaluating $Q_D$,ing; then the rest (98,9 % which is close to 100 %) remains available to contribute to external irradiation dose leading to $Q_A$. Thus $A_{2,eff}$ can be calculated with these three contributions considering the effective dose with the aforementioned fractions; or
  - the total radioactive content released (fraction of 100 %) will contribute to calculate the submersion effective dose leading to $Q_E$, which does not change the current method;
- skin equivalent dose:
  - a release fraction of 1 % is at the origin of the contamination taken into account in the evaluation of $Q_{D,skin}$, the rest (99 %) remains available to contribute to the skin equivalent dose taken into account when evaluating $Q_B$. Thus $A_{2,skin}$ can be calculated with these two contributions considering the skin equivalent dose with the aforementioned fractions.
  - the total radioactive content released (fraction of 100 %) will contribute to calculate the submersion equivalent dose to the skin to $Q_E$, which does not change the current method.

The $A_{2,cumul}$ value would then be the minimum of ($A_{2,eff}$; $A_{2,skin}$; $Q_E$).

Current SSG-26 explains in para. I.79 that multiple exposure pathways were not retained because the "*examination of table I.2 shows that this consideration applies only to a relatively small number of radionuclides*". No further element was presented to support this assertion. Besides, in this justification, a comparison between $Q_A$ and $Q_B$ was mentioned though they do not represent the same kind of dose. The influence of those considerations was evaluated by the WG (cf. Figure 18. Changes in $A_2$ values between the current Q system and the proposed update if multiple pathway exposure is considered). Contrary to what was stated in SSG-26, the consequences on the $A_2$ values are significant. . The current updated table 2 does not consider the multiple pathway hypothesis.

# 11. VALIDATION PROCESS

The new calculation method developed from 2016 is only based on the use of several databases either produced from the WG or from other sources, such as ICRP publications:

- decay emission spectra (all Q values),
- source-energy-to-fluence coefficients, for each unit energy and each particle ($Q_A$, $Q_B$),
- energy-dependent fluence-to-dose conversion coefficients for each particle and each kind of dose of interest ($Q_A$, $Q_B$),
- mean-energy-to-dose coefficients for alpha emitters based on (α,nγ) reactions ($Q_A$, $Q_B$),
- energy-dependent dose coefficients ($Q_{D,skin}$),
- intake dose coefficient for each radionuclide ($Q_C$, $Q_{D,ing}$), with special considerations for $^{220}$Rn and $^{222}$Rn,
- external dose coefficient for noble gases ($Q_E$).

Compared to the method of the current Q system, it is no longer necessary to evaluate the Q values with direct calculations for each single radionuclide (from the spectrum to the Q value). In this regard, it is possible to develop tools dealing with those databases, the concept of which is presented in Figure 12. As such, they can easily be updated with future databases.

CERN, GRS, IRSN and MHI NS ENG developed such interfaces; these tools mainly served the purpose of comparing the results derived from different sets of code/library. The WG then developed a single reference tool called CORAL [53], that aims at gathering and comparing the different databases created by the WG, and evaluating the Q and A values using any kind of hypothesis and database. The previous early interfaces developed by the members of the WG were used to validate the processing method of the databases by CORAL. The WG proposed

TRANSSC Member States and the IAEA to release a custom version of CORAL to facilitate the evaluation of any Q and $A_1/A_2$ values among transport stakeholders.

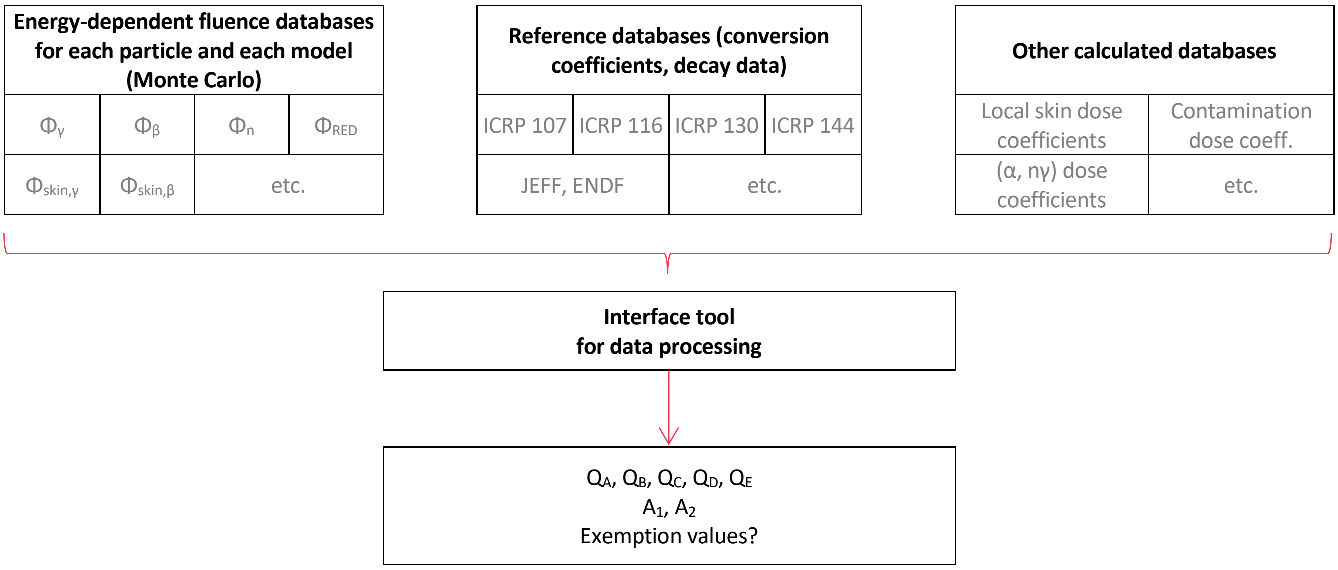

***Figure 12. Overview of the tool principles to evaluate the radionuclide basic values.***

Regarding the validation process of the results of the MC calculations, the transfer functions[9] were all compared within the WG. The slight discrepancies observed among the codes are due to differences in nuclear data and the physics models (Kerma approximation, multi-group processing, stopping power, etc.); in most cases, the differences were less than 10% (cf. Figure 13). Therefore, the averages of the transfer functions were used to evaluate the Q values.

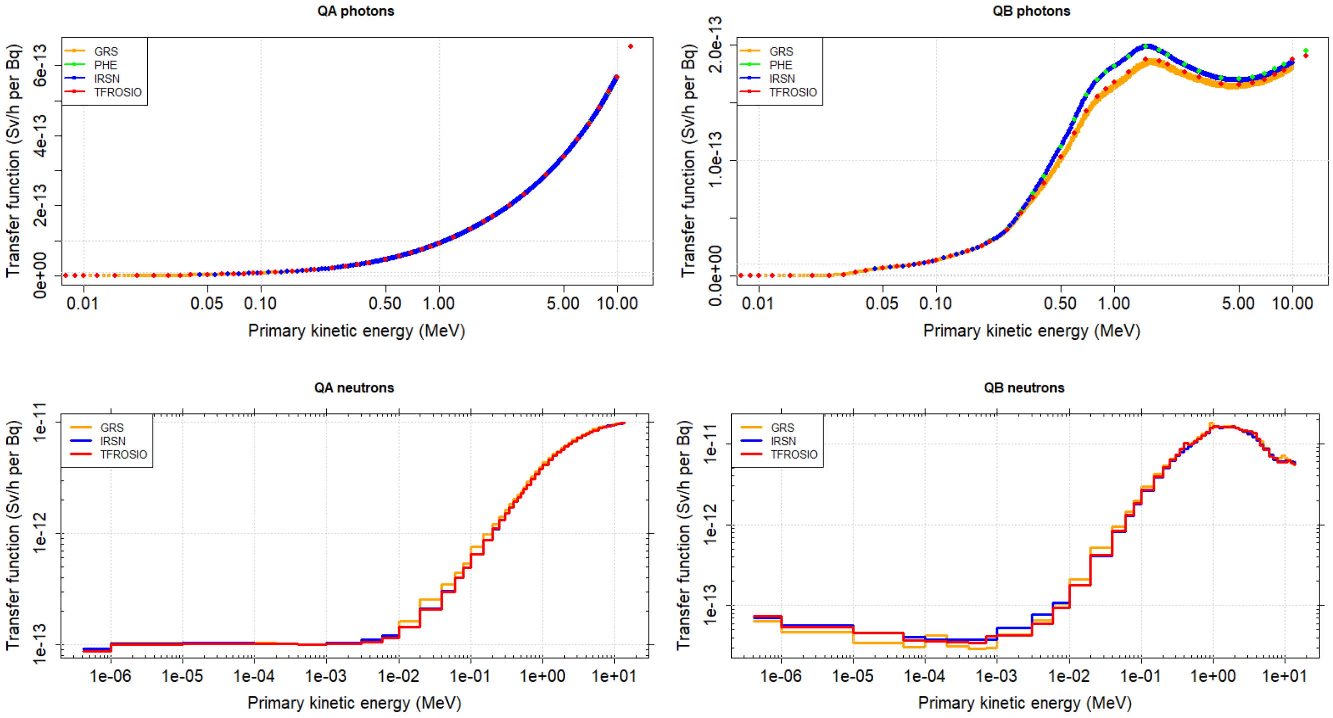

***Figure 13. Example of code comparison using CORAL: $Q_A$ & $Q_B$ transfer functions for photons and neutrons***

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[9] Quantity expressed as a function the primary particle type and energy that expresses the dose in one scenario of the Q system. It can either be the result from convolving fluence-to-dose conversion coefficients with fluences calculated with MC simulations as in the method used to evaluate $Q_A$ and $Q_B$ or energy-dependent dose coefficients as produced for $Q_{D,skin}$.

The largest discrepancies were observed in the treatment of alpha contamination to evaluate $Q_{D,skin}$ for the [5-6.5] MeV range due to the different physics used by the MC codes (cf. para. 5.2 above). As a consequence, the most conservative values were retained.

Finally, the databases produced by the WG as well as the CORAL code have provided quantitative and qualitative agreement within the WG, which complete the validation phase.

# 12. RESULTS

## 12.1. Summary of changes

The following section summarizes the differences between the current Q system and the update proposed by the WG. The list of $A_1$ and $A_2$ values derived by the WG using the method described throughout this report is given in Table 5.

***Table 1. History of the radionuclide classification methods used in the transport regulations***

| Chronology | ICRP Recom. | IAEA | | | Classification Method |
|---|---|---|---|---|---|
| | | Transport regulations | Method description | BSS | |
| 1959 | **ICRP 1** | | | | - |
| 1961 | | **SS6** | **SS7** | | Radiotoxicity 3 groups |
| 1962 | | | | **SS9** | |
| 1964 | ICRP 6 | **SS6** | | | Radiotoxicity 8 groups |
| 1966 | **ICRP 9** | | | | |
| 1967 | | **SS6** | | **SS9** | Radiotoxicity 7 groups |
| 1969 | ICRP 15 | | | | |
| 1973 | | **SS6** | **SS37** | | $A_1/A_2$ System |
| 1977 | **ICRP 26** | | | | |
| 1982 | | | | **SS9** | |
| 1985 | | **SS6** | | | Q System |
| 1987 | | | **SS7** | | |
| 1991 | **ICRP 60** | | | | |
| 1996 | | **ST-1** | | **SS115** | Q System (revised) |
| 2002 | | | **TS-G-1.1** | | |
| 2007 | **ICRP 103** | | | | |
| 2012 | | **SSR-6** | **SSG-26** | | |
| 2014 | | | | **GSR Part 3** | |
| 2018 | | **SSR-6** | | | |
| 2022 | | | **SSG-26** | | |

*Table 2. Changes in the calculations method between the current Q system and the proposed update*

| | Current Q system | Update of the Q system |
|---|---|---|
| **Recommendations** | ICRP 60 | ICRP 103 |
| **Spectra** | ICRP 38 | ICRP 107 |
| | No data | SOURCES4C and TALYS for (α,nγ) spectra |
| | | JEFF3.3 & ENDF/B-VIII databases for dual $\beta^+/\beta^-$ emitters |
| **External dose coefficients** | ICRP 51 ($Q_A$) | ICRP 116 ($Q_A$, $Q_B$, $Q_{D,skin}$) |
| | Cross et al. ($Q_B$, $Q_{D,skin}$) | |
| | Federal Guidance Report 12 ($Q_E$) | ICRP 144 ($Q_E$) |
| **Intake dose coefficients** | ICRP 68 ($Q_C$, $Q_{D,ing}$)<br>ICRP 32 ($Q_C$ / $Q_E$ for Rn) | ICRP 130, 134, 137, 141, 151 ($Q_C$, $Q_{D,ing}$) |
| **Progenies** | 10-day rule | 10-day rule, or no consideration of progenies (mixture rule to be considered by the users) |
| **Calculations** | Deterministic & Probabilistic | Probabilistic (Monte-Carlo) |
| | 1 radionuclide → 1 value: necessity to perform lengthy calculations in case of updates of the spectra and dose coefficients | 1 energy → 1 energy-dependent fluence or dose → 1 point of the transfer function → 1 value by convolution with the transfer function; quick updates with any spectra and dose coefficients |
| | Several sources, documentation missing | Unified method + detailed report |

*Table 3. Radiations considered in each Q value between the current Q system and the proposed update*

| | Current Q system | Update of the Q system |
|---|---|---|
| **$Q_A$** | Effective dose (photons) | Effective dose (all radiations) |
| **$Q_B$** | Equivalent dose to the skin (beta radiations)<br>Equivalent dose to the eye lens (beta radiations) mentioned but not evaluated | Equivalent dose to the skin (all radiations)<br>Equivalent dose to the eye (all radiations) |
| **$Q_C$** | Effective dose due to inhalation (all radiations) | Effective dose due to inhalation (all radiations) |
| **$Q_D$** | Effective dose due to ingestion (all radiations) mentioned but not evaluated. | Effective dose due to ingestion (all radiations) |
| | Equivalent dose to the skin due to contamination (beta radiations) | Equivalent dose to the skin due to contamination (all radiations) |
| **$Q_E$** | Effective dose due to external exposure via submersion in noble gases (photons) | Effective dose due to external exposure via submersion in noble gases (all radiations) |
| | Equivalent dose to the skin due to external exposure via submersion in noble gases (beta radiations) | Equivalent dose to the skin due to external exposure via submersion in noble gases (all radiations) |
| **$Q_F$** | External effective dose due to alpha particles (= $10^4$ $Q_C$) | Discarded: now included in $Q_A$ and $Q_B$ (effective and skin equivalent doses) |

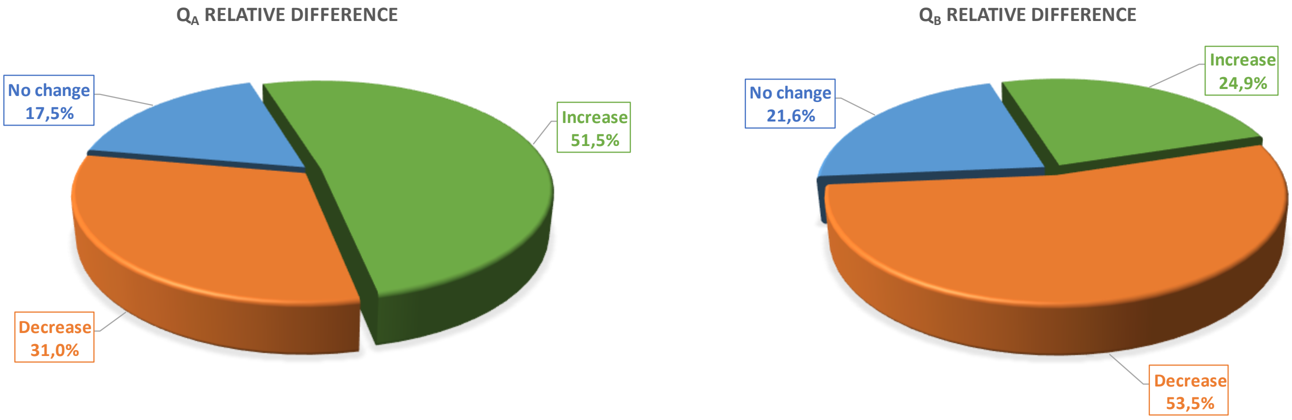


*Figure 14. Changes in $Q_A$ and $Q_B$ values between the current Q system and the proposed update*

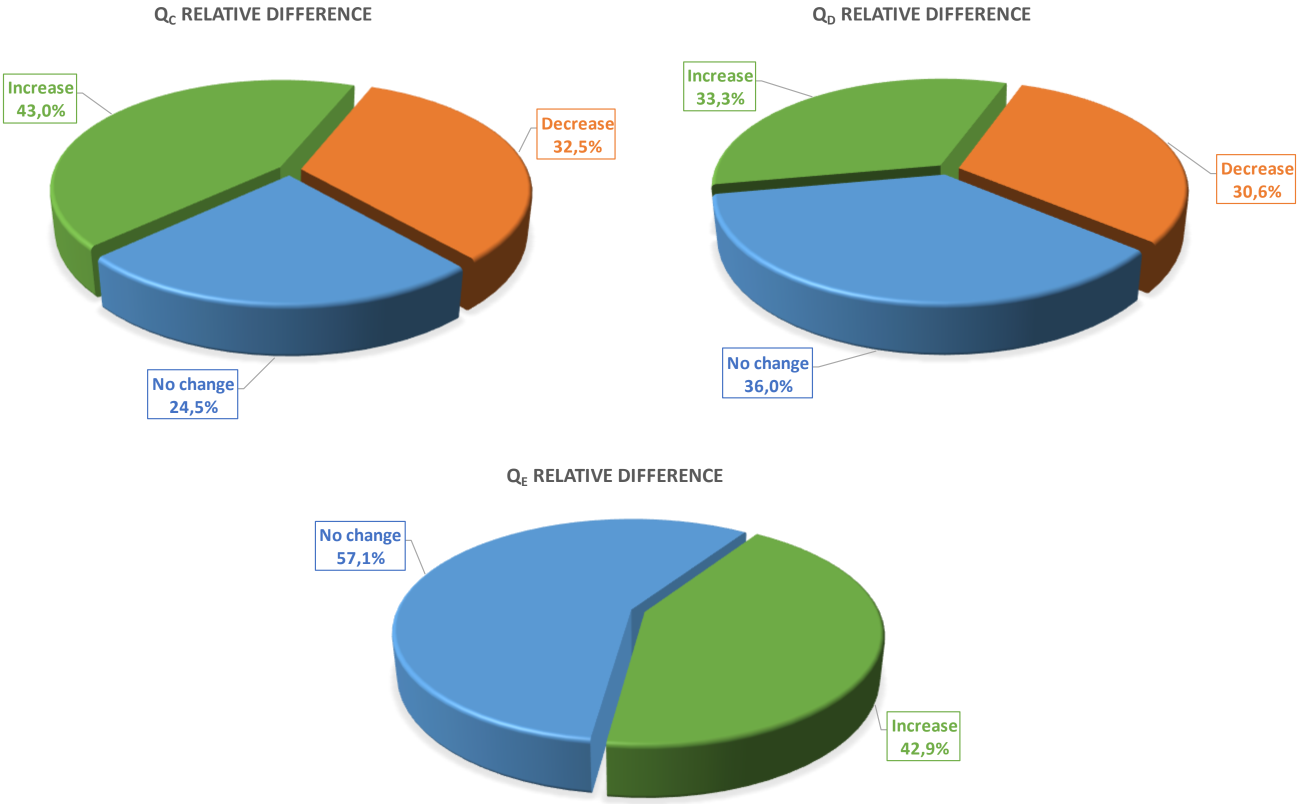
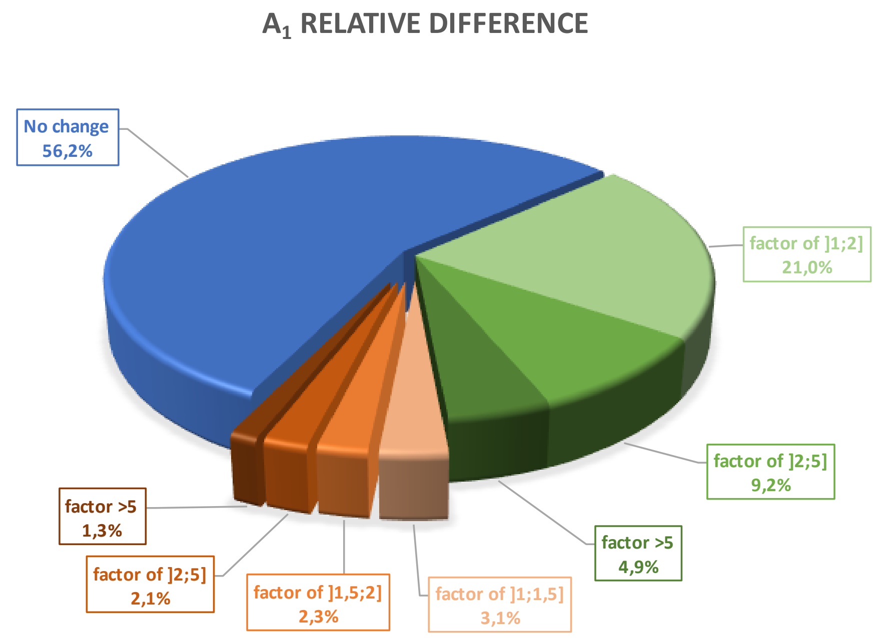


*Figure 15. Changes in $Q_C$, $Q_D$ and $Q_E$ values between the current Q system and the proposed update*



***Blue**: no change in A values* ***Orange gradient**: decrease of A values* ***Green gradient**: increase of A values*

***Figure 16. Changes in $A_1$ values between the current Q system and the proposed update***

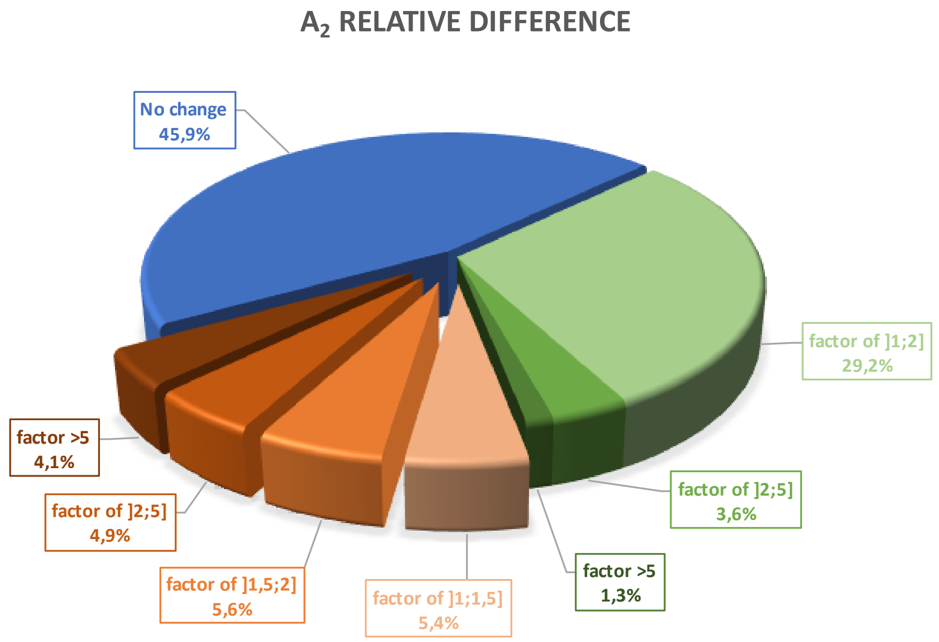


***Figure 17. Changes in $A_2$ values between the current Q system and the proposed update***

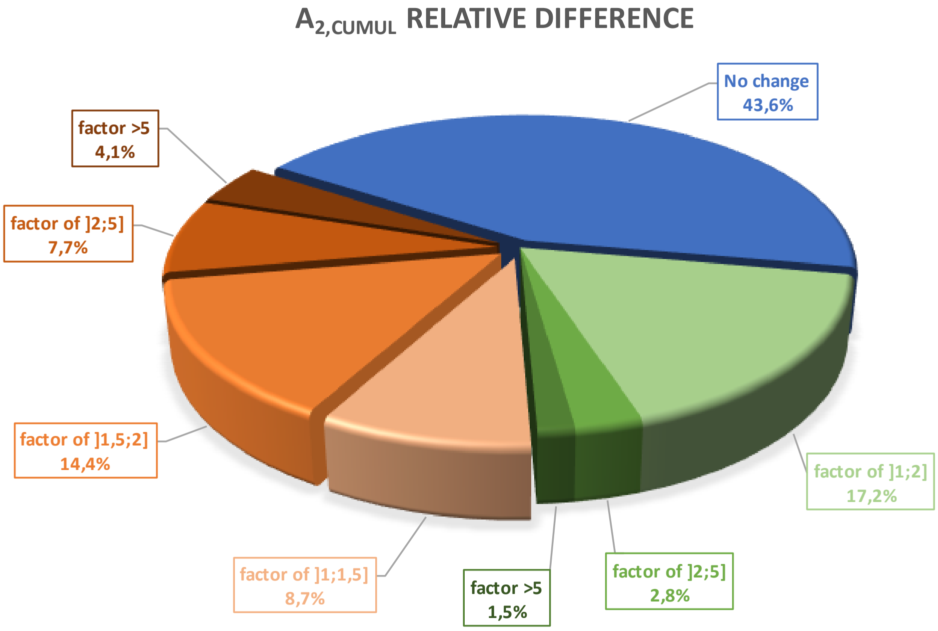


*Figure 18. Changes in $A_2$ values between the current Q system and the proposed update if multiple pathway exposure is considered*

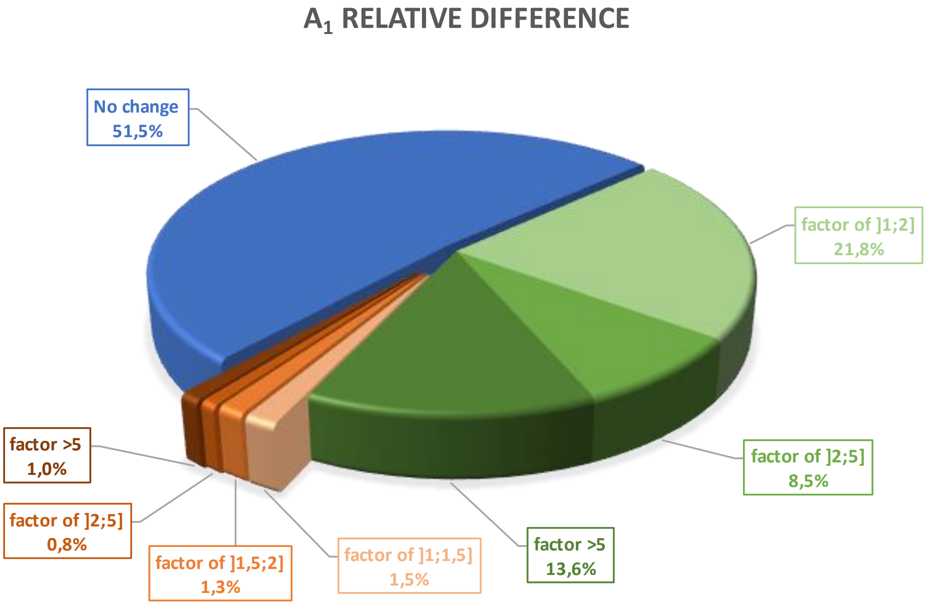


*Figure 19. Changes in $A_1$ values between the current Q system and the proposed update if the 10-day rule is not considered*

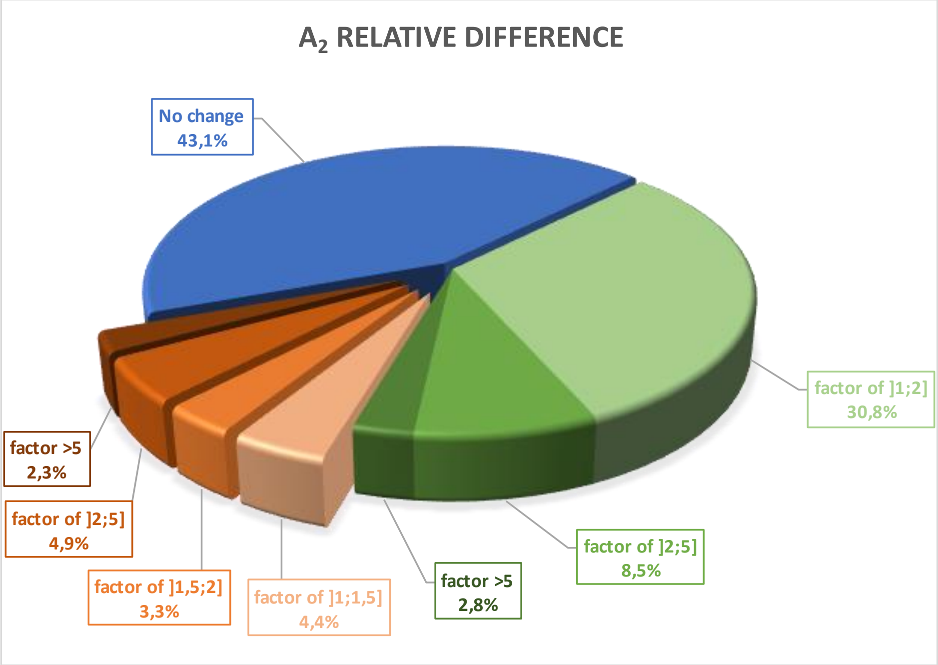


***Figure 20. Changes in $A_2$ values between the current Q system and the proposed update if the 10-day rule is not considered***

## 12.2. Analysis of changes

The following paragraphs will mainly focus on the radionuclides, the $A_1$ and $A_2$ values of which decreased as a consequence of the update of the Q system. Therefore $Q_E$ is not addressed.

More details are provided in [59].

### 12.2.1. $Q_A$ and $Q_B$

$Q_A$ and $Q_B$ are respectively the significant scenarios for 286 and 62 $A_1$ values of the current radionuclides mentioned in table 2 of SSR-6 (the others are considered above the $A_1$ threshold). They also determine 127 $A_2$ values. With the new approach, 6 $Q_A$ values and 10 $Q_B$ (i.e. 16 $A_1$ values) lead to a decrease in $A_2$ values. $Q_{B,eye}$ values never lead $A_1$ or $A_2$ values.

Generally, many of the significant decreases of $Q_A$ and $Q_B$ are due to the consideration of all particles in the evaluation of the dose.

It is also important to note that the increase in $Q_A$ values are mostly due to the consideration of a residual shielding, especially for weak gamma emitters, which is not the case in the current Q system where shielding is only considered for the $Q_B$ scenario. To a lesser extent, the increase of $Q_B$ values is due to the larger thickness of the updated residual shielding (0.5 mm vs. 0.2 mm).

However, even if decreases in $Q_A$ and $Q_B$ values represent 31.0 % and 53.5 % of the current list of radionuclides, only 8.3% of the $A_1$ values decrease (i.e. for 32 radionuclides) because, in most cases, the consideration of new particles in a scenario was not sufficient to decrease the value to the same level as in the other scenario (e.g. gamma radiations in $Q_B$ are already considered in $Q_A$).

The $A_1$ values of 15 radionuclides ($^{212}$Bi, $^{47}$Ca, $^{250}$Cf, $^{166}$Dy, $^{182}$Hf, $^{114m}$In, $^{212}$Pb, $^{148m}$Pm, $^{188}$Pt, $^{102m}$Rh, $^{92}$Sr, $^{230}$U (fast lung absorption), $^{230}$U (medium lung absorption), $^{230}$U (slow lung absorption), $^{122}$Xe) are significantly[10] lower if the new approach is applied. The WG recalculated the A values of those 15 radionuclides using the formalism of the current Q system. As shown in Table 4, for seven of them, the WG failed to reproduce the current values, essentially because the calculation procedure and documentation of the current Q system is partly not consistent (as mentioned in the introduction).

***Table 4. Comparison of $A_1$ values (SSR-6, recalculated, new approach)***

| Radionuclide | $A_1$ (SSR-6) (TBq) | $A_1$ (recalculated) (TBq) | $A_1$ (new approach) (TBq) |
|---|---|---|---|
| **Bi-212** | 7E-01 | 5E-01 | 5E-01 |
| **Ca-47** | 3E+00 | 7E-01 | 8E-01 |
| **Dy-166** | 9E-01 | 4E-01 | 4E-01 |
| **Pb-212** | 7E-01 | 5E-01 | 4E-01 |
| **Pm-148m** | 8E-01 | 5E-01 | 5E-01 |
| **Pt-188** | 1E+00 | 6E-01 | 4E-01 |
| **Sr-92** | 1E+00 | 8E-01 | 8E-01 |

The reason for the changes of the $A_1$ values of $^{114m}$In and $^{102m}$Rh is the use of new nuclear decay data from in ICRP publication 107. The change for $^{122}$Xe is due to the explicit consideration of positrons in the Monte Carlo calculations for $Q_B$ in the new approach. The $A_1$ value for $^{182}$Hf is no longer "unlimited" in the new approach due to, on the one hand the new defined mass criterion, on the other hand its now limited $A_2$ value. The changes in $A_1$ values of $^{250}$Cf and $^{230}$U originate from the consideration of neutrons and (α,nγ) reactions.

### 12.2.2. $Q_C$

$Q_C$ determines 108 $A_2$ values of the current radionuclides list in table 2 of SSR-6. 40 updated values led to a decrease in $A_2$ values. The main changes originate from the update of the dose coefficients according to ICRP publications 130, 134, 137, 141 and 151 (instead of ICRP publication 68 in the current Q system).

For the now limited value of U(enriched to less than 20%), the WG applied the same method as the current Q system by considering the most severe chemical form mentioned in the ICRP publications 130 to 151, i.e. the "S" (slow lung absorption) form. However, the ICRP publication 137 introduced a new S chemical form, the former S one likely becoming the new "M/S" (medium/slow) form, because it also applies to uranium dioxide and other common chemical forms of uranium. Considering this M/S form would lead to keep unlimited $A_1$ and $A_2$ values for U(enriched to less than 20%).

Introducing different chemical forms for U(enriched) would be at the same time consistent with the fact that only uranium isotopes have different values according to their chemical form, and inconsistent with the method used in the Q system, especially for the material made of uranium such as U(depleted) or U(natural). This distinction would also lead to likely create three new entries in table 2 with associated footnotes (that should refer to all the actual chemical compounds mentioned in ICRP 137), such as: U (enriched to less than 20%, slow lung absorption), U(enriched to less than 20%, all lung types absorption except slow), U(enriched to less than 10%, all lung types absorption). The second and third entries would lead to unlimited $A_1$ and $A_2$ values; the first one would lead to $A_1 = 5 \times 10^{-1}$ TBq and $A_2 = 2 \times 10^{-3}$ TBq.

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[10] The criterion to define a "significant" change is as follows: the current and updated mantissa of the $A_1$ values are separated by at leas one integer. For example, a decrease from $3.10^{-1}$ to $2.10^{-1}$ TBq is not considered "significant' (it can be due to the rounding method applied to derive the A values), while a decrease from $7.10^{0}$ to $5.10^{0}$ TBq is.

### 12.2.3. $Q_D$

$Q_D$ determines 161 $A_2$ values of the current radionuclides mentioned in table 2 of SSR-6 (159 for $Q_{D,skin}$). 23 updated values led to a decrease in $A_2$ values.

Those of $^{129}$I and $^{59}$Ni are no longer “unlimited” in the new approach. For $^{129}$I, the reason for this change is that $Q_{D,ing}$ is now calculated (using the former ingestion dose coefficient from ICRP publication 68 would have also lead to a limited $A_2$ value). For $^{59}$Ni, the photon contribution to $Q_{D,skin}$ is dominant (while only electrons contribution are considered in the current Q system).

For $^{191m}$Os, the current $Q_{D,skin}$ value is not reproduceable. Recalculation of the value using the current formalism results in $Q_{D,skin} = 1.6 \times 10^1$ TBq instead of $2.7 \times 10^1$ TBq. The new approach leads to $Q_{D,skin} = 1.4 \times 10^1$ TBq.

Changes in $A_2$ for the other radionuclides led by $Q_{D,skin}$ are mainly due to the fact that contributions of all particles are considered in the new approach. Particularly for $^{225}$Ac, $^{211}$At, $^{212}$Bi, $^{212}$Pb, $^{223}$Ra, $^{224}$Ra, $^{225}$Ra, $^{226}$Ra, $^{222}$Rn, and $^{230}$U, α particles from their daughters significantly contribute to the skin dose, especially polonium isotopes. The main α-energies of these nuclides are 7.45 MeV ($^{211}$Po), 8.79 MeV ($^{212}$Po), 8.38 MeV ($^{213}$Po), 7.69 MeV ($^{214}$Po) and 7.39 MeV ($^{215}$Po), which are in an energy range where the results of the different simulations of the WG are consistent. None of the radionuclides emitting α particles below 6.5 MeV, where the evaluations of the dose lead to significantly different results, lead the $A_2$ value. For those, $Q_C$ values are generally lower.

$^{222}$Rn is a special case of the 10-day rule explained in para. 7.3. Using the latest external and internal dose coefficients (from ICRP publication 144 and 137 respectively) would increase the $Q_E$ value from $4.2 \times 10^{-3}$ TBq to $1.1 \times 10^{-1}$ TBq. However, the daughters of $^{222}$Rn are the same as those of $^{226}$Ra, the $Q_{D,skin}$ value of which is driven by the dose due to the α particles of $^{214}$Po. Thus, their $A_2$ values are the same.

# 13. CONCLUSION

The WG $A_1/A_2$ could produce new values and clarify the Q system through a rigorous scientific approach and validation process (data, calculations and software). In this regard, several calculation codes and processing tools could be compared, and the method is documented, leading to the reproducibility of the calculations. The updated method, implemented in the CORAL software developed by the WG, allows for a quick update of the values, as long as the exposure scenarios do not change, and for producing Q and A values for all 1252 radionuclides of the ICRP publications – with or without their progenies.

The consideration of the latest ICRP data and recommendations, in addition to the new calculation approach by Monte Carlo method, leads to decrease 8,7 % of $A_1$ values and 20,0 % of $A_2$ values.

The WG will produce a fully documented report including all data to be used in other situations related to radiation protection. The decision to update the $A_1$ and $A_2$ values will be taken by the TRANSSC during the revision cycle, considering different aspects (practices, financial consequences, use of new radionuclides – especially medical isotopes, industrial aspects, etc.).

**In this perspective, the WG recommends:**

- **using the new $A_1$ and $A_2$ values as they comply with the latest ICRP recommendations, and were derived from a standardized, documented procedure;**
- **not selecting part of the new values (e.g. those increasing), should they be not retained by the TRANSSC in the future update;**
- **clarifying the term “water containing tritium” as “tritiated water” in SSR-6, and the term “tritium gas” as $T_2$ or HT forms in SSG-26, paying particular attention to its translation in other languages;**
- **using a specified value of 100 TBq for $^{85}$Kr instead of 10 $A_2$ in para. 659 and 671 of SSR-6;**
- **reviewing the basis of the definition of LSA-II material, considering pathways involving radioactive gas and contamination, not only inhalation of solid particles.**

Considering the stability of the current values that have been in use for almost 30 years (previously 4, 2, 6, 12 and 11 years in the former systems), the WG would understand that the users may need some time to adapt to the new values. This could be done through multilateral approval (similarly to what is required in para. 403 for radionuclides not listed in Table 2) or transitional arrangements, which would be a first in the history of the transport regulations for the radionuclide basic values. **The WG then suggests limiting the transitional period to 5 years, starting from the publication of the SSR-6 (rev. 2), during which the current $A_1$ and $A_2$ values could be used.** This timeframe is based on the expected period, on the one hand to develop small type B packages for medical purpose and to let health establishments to adapt to the use of generally bigger and more complex type B packages, on the other hand to develop solutions for particular situations involving LSA material or excepted packages (especially those transporting liquids and gases). However, the WG is not aware of the diversity of such situations and **recommends that Member States and Industrial observers of the TRANSSC start reviewing the consequences of the use of the new values, as soon as possible.**

Regarding the consideration of progenies through the 10-day rule, the WG realized that such a simple rule could have complex consequences and would sometimes be overly conservative for special use involving no storage and quick transport. **The WG suggests broadening the scope of the regulations by allowing the 10 day-rule not to be used (the $A_1$ and $A_2$ values would then be tabulated without their daughters in another table).** However, that possibility would lead to define additional safety requirements so that the overall level of safety in transport is at least equivalent to that which would be provided if the 10-day rule was used (daughter build-up, unexpected transport events, other uncertainties in the definition of the content, use of multilateral approval, etc.). In this regard, the proposal by the WG to issue a custom version of CORAL for the users, could facilitate that process.

The proposed values should remain stable for a fairly reasonable period of time. As ICRP updates data and recommendations on a regular basis (e. g. new phantom recently published), those new values will likely be challenged in the future. More precise models could also be tested. However, now that the method is fully documented, the change in $A_1$ and $A_2$ values should be easier to assess before taking the decision to update them, considering the philosophy of the Q system.

On a side note, considering the security aspects, the classification threshold of “high consequence radioactive material” will also change since modal regulations use a value of 3 000 $A_2$. The WG also underlines that the current system defining the D values use similar scenarios as in the Q system (but the dose objectives are different): there could be changes in the D values if the same approach as the one developed in this report was applied.

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[82] B. Louis: *IAEA / TRANSSC 43 / TTEG RP - WG $A_1/A_2$ – Status of work*, Agenda Item 3.4.1, presentation, TRANSSC 43, 1-4 November 2021.

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# APPENDICES

# List of current and new $A_1$/$A_2$ values

***Table 5. Changes in $A_1$ and $A_2$ values (SSR-6 Table 2) between the current Q system and the proposed update***

| Radionuclide | $A_1$ | | $A_2$ | | NEW / CURRENT | |
|---|---|---|---|---|---|---|
| | IAEA SSR-6 | WG $A_1$/$A_2$ | IAEA SSR-6 | WG $A_1$/$A_2$ | | |
| | TBq | TBq | TBq | TBq | $A_1$ | $A_2$ |
| **Ac-225** | 8E-1 | 4E+0 | 6E-3 | 7E-4 | 5,00 | 0,12 |
| **Ac-226** | x | 6E+0 | x | 2E-3 | x | x |
| **Ac-227** | 9E-1 | 4E+1 | 9E-5 | 5E-4 | 44,44 | 5,56 |
| **Ac-228** | 6E-1 | 1E+0 | 5E-1 | 6E-1 | 1,67 | 1,20 |
| **Ag-105** | 2E+0 | 2E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Ag-108m** | 7E-1 | 7E-1 | 7E-1 | 3E-1 | 1,00 | 0,43 |
| **Ag-110m** | 4E-1 | 4E-1 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **Ag-111** | 2E+0 | 4E+1 | 6E-1 | 7E-1 | 20,00 | 1,17 |
| **Al-26** | 1E-1 | 4E-1 | 1E-1 | 1E-1 | 4,00 | 1,00 |
| **Am-241** | 1E+1 | 4E+1 | 1E-3 | 2E-3 | 4,00 | 2,00 |
| **Am-242m** | 1E+1 | 4E+1 | 1E-3 | 2E-3 | 4,00 | 2,00 |
| **Am-243** | 5E+0 | 5E+0 | 1E-3 | 2E-3 | 1,00 | 2,00 |
| **Ar-37** | 4E+1 | Unlimited | 4E+1 | Unlimited | - | - |
| **Ar-39** | 4E+1 | 4E+1 | 2E+1 | 2E+1 | 1,00 | 1,00 |
| **Ar-41** | 3E-1 | 9E-1 | 3E-1 | 3E-1 | 3,00 | 1,00 |
| **As-72** | 3E-1 | 2E-1 | 3E-1 | 2E-1 | 0,67 | 0,67 |
| **As-73** | 4E+1 | 4E+1 | 4E+1 | 3E+1 | 1,00 | 0,75 |
| **As-74** | 1E+0 | 1E+0 | 9E-1 | 1E+0 | 1,00 | 1,11 |
| **As-76** | 3E-1 | 2E-1 | 3E-1 | 2E-1 | 0,67 | 0,67 |
| **As-77** | 2E+1 | 4E+1 | 7E-1 | 7E-1 | 2,00 | 1,00 |
| **At-211** | 2E+1 | 2E+1 | 5E-1 | 4E-3 | 1,00 | 0,01 |
| **Au-193** | 7E+0 | 8E+0 | 2E+0 | 3E+0 | 1,14 | 1,50 |
| **Au-194** | 1E+0 | 1E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Au-195** | 1E+1 | 2E+1 | 6E+0 | 6E+0 | 2,00 | 1,00 |
| **Au-198** | 1E+0 | 3E+0 | 6E-1 | 7E-1 | 3,00 | 1,17 |
| **Au-199** | 1E+1 | 1E+1 | 6E-1 | 7E-1 | 1,00 | 1,17 |
| **Ba-131** | 2E+0 | 2E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Ba-133** | 3E+0 | 3E+0 | 3E+0 | 2E+0 | 1,00 | 0,67 |
| **Ba-133m** | 2E+1 | 2E+1 | 6E-1 | 7E-1 | 1,00 | 1,17 |
| **Ba-135m** | 2E+1 | 3E+1 | 6E-1 | 6E-1 | 1,50 | 1,00 |
| **Ba-140** | 5E-1 | 4E-1 | 3E-1 | 3E-1 | 0,80 | 1,00 |
| **Be-10** | 4E+1 | 4E+1 | 6E-1 | 6E-1 | - | 1,00 |
| **Be-7** | 2E+1 | 2E+1 | 2E+1 | 2E+1 | 1,00 | 1,00 |

| Radionuclide | $A_1$ | | $A_2$ | | NEW / CURRENT | |
|---|---|---|---|---|---|---|
| | IAEA SSR-6 | WG $A_1$/$A_2$ | IAEA SSR-6 | WG $A_1$/$A_2$ | $A_1$ | $A_2$ |
| | TBq | TBq | TBq | TBq | | |
| **Bi-205** | 7E-1 | 7E-1 | 7E-1 | 7E-1 | 1,00 | 1,00 |
| **Bi-206** | 3E-1 | 3E-1 | 3E-1 | 3E-1 | 1,00 | 1,00 |
| **Bi-207** | 7E-1 | 7E-1 | 7E-1 | 4E-1 | 1,00 | 0,57 |
| **Bi-210** | 1E+0 | 4E+1 | 6E-1 | 6E-1 | 40,00 | 1,00 |
| **Bi-210m** | 6E-1 | 2E+0 | 2E-2 | 2E-3 | 3,33 | 0,10 |
| **Bi-212** | 7E-1 | 5E-1 | 6E-1 | 1E-3 | 0,71 | 0,002 |
| **Bk-247** | 8E+0 | 8E+0 | 8E-4 | 2E-3 | 1,00 | 2,50 |
| **Bk-249** | 4E+1 | 4E+1 | 3E-1 | 7E-1 | 1,00 | 2,33 |
| **Br-76** | 4E-1 | 3E-1 | 4E-1 | 3E-1 | 0,75 | 0,75 |
| **Br-77** | 3E+0 | 4E+0 | 3E+0 | 4E+0 | 1,33 | 1,33 |
| **Br-82** | 4E-1 | 4E-1 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **C-11** | 1E+0 | 1E+0 | 6E-1 | 6E-1 | 1,00 | 1,00 |
| **C-14** | 4E+1 | 4E+1 | 3E+0 | 4E+0 | 1,00 | 1,33 |
| **Ca-41** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Ca-45** | 4E+1 | 4E+1 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Ca-47** | 3E+0 | 8E-1 | 3E-1 | 2E-1 | 0,27 | 0,67 |
| **Cd-109** | 3E+1 | 4E+1 | 2E+0 | 3E+0 | 1,33 | 1,50 |
| **Cd-113m** | 4E+1 | 4E+1 | 5E-1 | 8E-1 | 1,00 | 1,60 |
| **Cd-115** | 3E+0 | 3E+0 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **Cd-115m** | 5E-1 | 1E+0 | 5E-1 | 6E-1 | 2,00 | 1,20 |
| **Ce-132** | x | 5E+0 | x | 5E+0 | x | x |
| **Ce-133m** | x | 5E-1 | x | 5E-1 | x | x |
| **Ce-134** | x | 3E-1 | x | 3E-1 | x | x |
| **Ce-135** | x | 1E+0 | x | 1E+0 | x | x |
| **Ce-137** | x | 4E+1 | x | 4E+1 | x | x |
| **Ce-137m** | x | 2E+1 | x | 6E-1 | x | x |
| **Ce-139** | 7E+0 | 9E+0 | 2E+0 | 2E+0 | 1,29 | 1,00 |
| **Ce-141** | 2E+1 | 2E+1 | 6E-1 | 7E-1 | 1,00 | 1,17 |
| **Ce-143** | 9E-1 | 4E+0 | 6E-1 | 6E-1 | 4,44 | 1,00 |
| **Ce-144** | 2E-1 | 2E-1 | 2E-1 | 2E-1 | 1,00 | 1,00 |
| **Cf-248** | 4E+1 | 4E+1 | 6E-3 | 8E-3 | 1,00 | 1,33 |
| **Cf-249** | 3E+0 | 3E+0 | 8E-4 | 2E-3 | 1,00 | 2,50 |
| **Cf-250** | 2E+1 | 6E+0 | 2E-3 | 3E-3 | 0,30 | 1,50 |
| **Cf-251** | 7E+0 | 1E+1 | 7E-4 | 2E-3 | 1,43 | 2,86 |
| **Cf-252** | 1E-1 | 1E-1 | 3E-3 | 4E-3 | 1,00 | 1,33 |
| **Cf-253** | 4E+1 | 4E+1 | 4E-2 | 1E-1 | 1,00 | 2,50 |
| **Cf-254** | 1E-3 | 4E-3 | 1E-3 | 2E-3 | 4,00 | 2,00 |

| Radionuclide | $A_1$ | | $A_2$ | | NEW / CURRENT | |
|---|---|---|---|---|---|---|
| | IAEA SSR-6 | WG $A_1$/$A_2$ | IAEA SSR-6 | WG $A_1$/$A_2$ | | |
| | TBq | TBq | TBq | TBq | $A_1$ | $A_2$ |
| **Cl-36** | 1E+1 | 4E+1 | 6E-1 | 5E-1 | 4,00 | 0,83 |
| **Cl-38** | 2E-1 | 2E-1 | 2E-1 | 2E-1 | 1,00 | 1,00 |
| **Cm-240** | 4E+1 | 4E+1 | 2E-2 | 3E-2 | 1,00 | 1,50 |
| **Cm-241** | 2E+0 | 2E+0 | 1E+0 | 2E+0 | 1,00 | 2,00 |
| **Cm-242** | 4E+1 | 4E+1 | 1E-2 | 1E-2 | 1,00 | 1,00 |
| **Cm-243** | 9E+0 | 9E+0 | 1E-3 | 2E-3 | 1,00 | 2,00 |
| **Cm-244** | 2E+1 | 4E+1 | 2E-3 | 3E-3 | 2,00 | 1,50 |
| **Cm-245** | 9E+0 | 1E+1 | 9E-4 | 2E-3 | 1,11 | 2,22 |
| **Cm-246** | 9E+0 | 2E+1 | 9E-4 | 2E-3 | 2,22 | 2,22 |
| **Cm-247** | 3E+0 | 3E+0 | 1E-3 | 2E-3 | 1,00 | 2,00 |
| **Cm-248** | 2E-2 | 7E-2 | 3E-4 | 5E-4 | 3,50 | 1,67 |
| **Co-55** | 5E-1 | 5E-1 | 5E-1 | 5E-1 | 1,00 | 1,00 |
| **Co-56** | 3E-1 | 3E-1 | 3E-1 | 3E-1 | 1,00 | 1,00 |
| **Co-57** | 1E+1 | 1E+1 | 1E+1 | 1E+1 | 1,00 | 1,00 |
| **Co-58** | 1E+0 | 1E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Co-58m** | 4E+1 | 4E+1 | 4E+1 | 4E+1 | 1,00 | 1,00 |
| **Co-60** | 4E-1 | 4E-1 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **Cr-51** | 3E+1 | 4E+1 | 3E+1 | 4E+1 | 1,33 | 1,33 |
| **Cs-129** | 4E+0 | 4E+0 | 4E+0 | 4E+0 | 1,00 | 1,00 |
| **Cs-131** | 3E+1 | 4E+1 | 3E+1 | 4E+1 | 1,33 | 1,33 |
| **Cs-132** | 1E+0 | 2E+0 | 1E+0 | 2E+0 | 2,00 | 2,00 |
| **Cs-134** | 7E-1 | 7E-1 | 7E-1 | 7E-1 | 1,00 | 1,00 |
| **Cs-134m** | 4E+1 | 4E+1 | 6E-1 | 8E-1 | 1,00 | 1,33 |
| **Cs-135** | 4E+1 | 4E+1 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Cs-136** | 5E-1 | 5E-1 | 5E-1 | 5E-1 | 1,00 | 1,00 |
| **Cs-137** | 2E+0 | 2E+0 | 6E-1 | 5E-1 | 1,00 | 0,83 |
| **Cu-64** | 6E+0 | 6E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Cu-67** | 1E+1 | 1E+1 | 7E-1 | 8E-1 | 1,00 | 1,14 |
| **Dy-159** | 2E+1 | 4E+1 | 2E+1 | 4E+1 | 2,00 | 2,00 |
| **Dy-165** | 9E-1 | 1E+1 | 6E-1 | 7E-1 | 11,11 | 1,17 |
| **Dy-166** | 9E-1 | 4E-1 | 3E-1 | 3E-1 | 0,44 | 1,00 |
| **Er-169** | 4E+1 | 4E+1 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Er-171** | 8E-1 | 3E+0 | 5E-1 | 6E-1 | 3,75 | 1,20 |
| **Eu-147** | 2E+0 | 3E+0 | 2E+0 | 3E+0 | 1,50 | 1,50 |
| **Eu-148** | 5E-1 | 5E-1 | 5E-1 | 5E-1 | 1,00 | 1,00 |
| **Eu-149** | 2E+1 | 3E+1 | 2E+1 | 3E+1 | 1,50 | 1,50 |
| **Eu-150** | 7E-1 | 7E-1 | 7E-1 | 5E-1 | 1,00 | 0,71 |

| Radionuclide | $A_1$ | | $A_2$ | | NEW / CURRENT | |
|---|---|---|---|---|---|---|
| | IAEA SSR-6 | WG $A_1$/$A_2$ | IAEA SSR-6 | WG $A_1$/$A_2$ | | |
| | TBq | TBq | TBq | TBq | $A_1$ | $A_2$ |
| **Eu-150m** | 2E+0 | 2E+1 | 7E-1 | 8E-1 | 10,00 | 1,14 |
| **Eu-152** | 1E+0 | 1E+0 | 1E+0 | 7E-1 | 1,00 | 0,70 |
| **Eu-152m** | 8E-1 | 8E-1 | 8E-1 | 8E-1 | 1,00 | 1,00 |
| **Eu-154** | 9E-1 | 9E-1 | 6E-1 | 6E-1 | 1,00 | 1,00 |
| **Eu-155** | 2E+1 | 2E+1 | 3E+0 | 4E+0 | 1,00 | 1,33 |
| **Eu-156** | 7E-1 | 7E-1 | 7E-1 | 7E-1 | 1,00 | 1,00 |
| **F-18** | 1E+0 | 1E+0 | 6E-1 | 7E-1 | 1,00 | 1,17 |
| **Fe-52** | 3E-1 | 2E-1 | 3E-1 | 2E-1 | 0,67 | 0,67 |
| **Fe-53** | x | 2E-1 | x | 2E-1 | x | x |
| **Fe-55** | 4E+1 | 4E+1 | 4E+1 | 4E+1 | 1,00 | 1,00 |
| **Fe-59** | 9E-1 | 9E-1 | 9E-1 | 9E-1 | 1,00 | 1,00 |
| **Fe-60** | 4E+1 | 4E+1 | 2E-1 | 3E-1 | 1,00 | 1,50 |
| **Ga-67** | 7E+0 | 8E+0 | 3E+0 | 4E+0 | 1,14 | 1,33 |
| **Ga-68** | 5E-1 | 4E-1 | 5E-1 | 4E-1 | 0,80 | 0,80 |
| **Ga-72** | 4E-1 | 4E-1 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **Gd-146** | 5E-1 | 4E-1 | 5E-1 | 4E-1 | 0,80 | 0,80 |
| **Gd-148** | 2E+1 | 4E+1 | 2E-3 | 4E-3 | 2,00 | 2,00 |
| **Gd-153** | 1E+1 | 2E+1 | 9E+0 | 1E+1 | 2,00 | 1,11 |
| **Gd-159** | 3E+0 | 2E+1 | 6E-1 | 7E-1 | 6,67 | 1,17 |
| **Ge-68** | 5E-1 | 4E-1 | 5E-1 | 4E-1 | 0,80 | 0,80 |
| **Ge-69** | 1E+0 | 1E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Ge-71** | 4E+1 | 4E+1 | 4E+1 | 4E+1 | 1,00 | 1,00 |
| **Ge-77** | 3E-1 | 6E-1 | 3E-1 | 6E-1 | 2,00 | 2,00 |
| **H-3** | 4E+1 | 4E+1 | 4E+1 | 4E+1 | 1,00 | 1,00 |
| **Hf-172** | 6E-1 | 5E-1 | 6E-1 | 5E-1 | 0,83 | 0,83 |
| **Hf-175** | 3E+0 | 3E+0 | 3E+0 | 3E+0 | 1,00 | 1,00 |
| **Hf-181** | 2E+0 | 2E+0 | 5E-1 | 6E-1 | 1,00 | 1,20 |
| **Hf-182** | Unlimited | 5E+0 | Unlimited | 5E+0 | - | - |
| **Hg-194** | 1E+0 | 1E+0 | 1E+0 | 5E-1 | 1,00 | 0,50 |
| **Hg-195m** | 3E+0 | 3E+0 | 7E-1 | 8E-1 | 1,00 | 1,14 |
| **Hg-197** | 2E+1 | 2E+1 | 1E+1 | 1E+1 | 1,00 | 1,00 |
| **Hg-197m** | 1E+1 | 1E+1 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **Hg-203** | 5E+0 | 5E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Ho-166** | 4E-1 | 6E-1 | 4E-1 | 6E-1 | 1,50 | 1,50 |
| **Ho-166m** | 6E-1 | 7E-1 | 5E-1 | 3E-1 | 1,17 | 0,60 |
| **I-123** | 6E+0 | 8E+0 | 3E+0 | 3E+0 | 1,33 | 1,00 |
| **I-124** | 1E+0 | 1E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |

| Radionuclide | $A_1$ | | $A_2$ | | NEW / CURRENT | |
|---|---|---|---|---|---|---|
| | IAEA SSR-6 | WG $A_1$/$A_2$ | IAEA SSR-6 | WG $A_1$/$A_2$ | | |
| | TBq | TBq | TBq | TBq | $A_1$ | $A_2$ |
| **I-125** | 2E+1 | 4E+1 | 3E+0 | 4E+0 | 2,00 | 1,33 |
| **I-126** | 2E+0 | 3E+0 | 1E+0 | 1E+0 | 1,50 | 1,00 |
| **I-129** | Unlimited | 4E+1 | Unlimited | 5E-1 | - | - |
| **I-131** | 3E+0 | 3E+0 | 7E-1 | 8E-1 | 1,00 | 1,14 |
| **I-132** | 4E-1 | 5E-1 | 4E-1 | 5E-1 | 1,25 | 1,25 |
| **I-133** | 7E-1 | 2E+0 | 6E-1 | 7E-1 | 2,86 | 1,17 |
| **I-134** | 3E-1 | 4E-1 | 3E-1 | 4E-1 | 1,33 | 1,33 |
| **I-135** | 6E-1 | 7E-1 | 6E-1 | 7E-1 | 1,17 | 1,17 |
| **In-111** | 3E+0 | 3E+0 | 3E+0 | 3E+0 | 1,00 | 1,00 |
| **In-113m** | 4E+0 | 4E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **In-114m** | 1E+1 | 5E-1 | 5E-1 | 3E-1 | 0,05 | 0,60 |
| **In-115m** | 7E+0 | 7E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Ir-189** | 1E+1 | 2E+1 | 1E+1 | 1E+1 | 2,00 | 1,00 |
| **Ir-190** | 7E-1 | 8E-1 | 7E-1 | 8E-1 | 1,14 | 1,14 |
| **Ir-192** | 1E+0 | 1E+0 | 6E-1 | 7E-1 | 1,00 | 1,17 |
| **Ir-193m** | 4E+1 | 4E+1 | 4E+0 | 5E+0 | 1,00 | 1,25 |
| **Ir-194** | 3E-1 | 4E-1 | 3E-1 | 4E-1 | 1,33 | 1,33 |
| **K-40** | 9E-1 | Unlimited | 9E-1 | Unlimited | - | - |
| **K-42** | 2E-1 | 2E-1 | 2E-1 | 2E-1 | 1,00 | 1,00 |
| **K-43** | 7E-1 | 1E+0 | 6E-1 | 7E-1 | 1,43 | 1,17 |
| **Kr-79** | 4E+0 | 4E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Kr-81** | 4E+1 | 4E+1 | 4E+1 | 4E+1 | 1,00 | 1,00 |
| **Kr-85** | 1E+1 | 4E+1 | 1E+1 | 2E+1 | 4,00 | 2,00 |
| **Kr-85m** | 8E+0 | 8E+0 | 3E+0 | 3E+0 | 1,00 | 1,00 |
| **Kr-87** | 2E-1 | 2E-1 | 2E-1 | 2E-1 | 1,00 | 1,00 |
| **La-132** | x | 4E-1 | x | 4E-1 | x | x |
| **La-133** | x | 8E+0 | x | 7E+0 | x | x |
| **La-134** | x | 3E-1 | x | 3E-1 | x | x |
| **La-135** | x | 4E+1 | x | 4E+1 | x | x |
| **La-137** | 3E+1 | 4E+1 | 6E+0 | 6E+0 | 1,33 | 1,00 |
| **La-140** | 4E-1 | 5E-1 | 4E-1 | 5E-1 | 1,25 | 1,25 |
| **Lu-172** | 6E-1 | 6E-1 | 6E-1 | 6E-1 | 1,00 | 1,00 |
| **Lu-173** | 8E+0 | 8E+0 | 8E+0 | 8E+0 | 1,00 | 1,00 |
| **Lu-174** | 9E+0 | 1E+1 | 9E+0 | 9E+0 | 1,11 | 1,00 |
| **Lu-174m** | 2E+1 | 3E+1 | 1E+1 | 9E+0 | 1,50 | 0,90 |
| **Lu-177** | 3E+1 | 4E+1 | 7E-1 | 8E-1 | 1,33 | 1,14 |
| **Mg-28** | 3E-1 | 2E-1 | 3E-1 | 2E-1 | 0,67 | 0,67 |

| Radionuclide | $A_1$ | | $A_2$ | | NEW / CURRENT | |
|---|---|---|---|---|---|---|
| | IAEA SSR-6 | WG $A_1$/$A_2$ | IAEA SSR-6 | WG $A_1$/$A_2$ | | |
| | TBq | TBq | TBq | TBq | $A_1$ | $A_2$ |
| **Mn-51** | x | 3E-1 | x | 3E-1 | x | x |
| **Mn-52** | 3E-1 | 3E-1 | 3E-1 | 3E-1 | 1,00 | 1,00 |
| **Mn-53** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Mn-54** | 1E+0 | 1E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Mn-56** | 3E-1 | 3E-1 | 3E-1 | 3E-1 | 1,00 | 1,00 |
| **Mo-93** | 4E+1 | 4E+1 | 2E+1 | 6E+0 | 1,00 | 0,30 |
| **Mo-99** | 1E+0 | 4E+0 | 6E-1 | 6E-1 | 4,00 | 1,00 |
| **N-13** | 9E-1 | 1E+0 | 6E-1 | 6E-1 | 1,11 | 1,00 |
| **Na-22** | 5E-1 | 5E-1 | 5E-1 | 5E-1 | 1,00 | 1,00 |
| **Na-24** | 2E-1 | 3E-1 | 2E-1 | 3E-1 | 1,50 | 1,50 |
| **Nb-90** | x | 3E-1 | x | 3E-1 | x | x |
| **Nb-92m** | x | 1E+0 | x | 1E+0 | x | x |
| **Nb-93m** | 4E+1 | 4E+1 | 3E+1 | 1E+1 | 1,00 | 0,33 |
| **Nb-94** | 7E-1 | 7E-1 | 7E-1 | 3E-1 | 1,00 | 0,43 |
| **Nb-95** | 1E+0 | 1E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Nb-97** | 9E-1 | 2E+0 | 6E-1 | 6E-1 | 2,22 | 1,00 |
| **Nd-147** | 6E+0 | 9E+0 | 6E-1 | 7E-1 | 1,50 | 1,17 |
| **Nd-149** | 6E-1 | 3E+0 | 5E-1 | 5E-1 | 5,00 | 1,00 |
| **Ni-56** | x | 6E-1 | x | 6E-1 | x | x |
| **Ni-57** | 6E-1 | 6E-1 | 6E-1 | 6E-1 | 1,00 | 1,00 |
| **Ni-59** | Unlimited | 4E+1 | Unlimited | 4E+1 | - | - |
| **Ni-63** | 4E+1 | 4E+1 | 3E+1 | 2E+1 | 1,00 | 0,67 |
| **Ni-65** | 4E-1 | 5E-1 | 4E-1 | 5E-1 | 1,25 | 1,25 |
| **Np-235** | 4E+1 | 4E+1 | 4E+1 | 4E+1 | 1,00 | 1,00 |
| **Np-236** | 9E+0 | 9E+0 | 2E-2 | 1E-2 | 1,00 | 0,50 |
| **Np-236m** | 2E+1 | 3E+1 | 2E+0 | 2E+0 | 1,50 | 1,00 |
| **Np-237** | 2E+1 | 4E+1 | 2E-3 | 2E-3 | 2,00 | 1,00 |
| **Np-239** | 7E+0 | 7E+0 | 4E-1 | 5E-1 | 1,00 | 1,25 |
| **Os-185** | 1E+0 | 2E+0 | 1E+0 | 2E+0 | 2,00 | 2,00 |
| **Os-191** | 1E+1 | 2E+1 | 2E+0 | 2E+0 | 2,00 | 1,00 |
| **Os-191m** | 4E+1 | 4E+1 | 3E+1 | 1E+1 | 1,00 | 0,33 |
| **Os-193** | 2E+0 | 2E+1 | 6E-1 | 6E-1 | 10,00 | 1,00 |
| **Os-194** | 3E-1 | 4E-1 | 3E-1 | 4E-1 | 1,33 | 1,33 |
| **P-32** | 5E-1 | 7E-1 | 5E-1 | 6E-1 | 1,40 | 1,20 |
| **P-33** | 4E+1 | 4E+1 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Pa-230** | 2E+0 | 2E+0 | 7E-2 | 2E-1 | 1,00 | 2,86 |
| **Pa-231** | 4E+0 | 3E+1 | 4E-4 | 5E-4 | 7,50 | 1,25 |

| Radionuclide | $A_1$ | | $A_2$ | | NEW / CURRENT | |
|---|---|---|---|---|---|---|
| | IAEA SSR-6 | WG $A_1/A_2$ | IAEA SSR-6 | WG $A_1/A_2$ | | |
| | TBq | TBq | TBq | TBq | $A_1$ | $A_2$ |
| **Pa-233** | 5E+0 | 5E+0 | 7E-1 | 7E-1 | 1,00 | 1,00 |
| **Pb-201** | 1E+0 | 1E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Pb-202** | 4E+1 | 4E+1 | 2E+1 | 3E-1 | 1,00 | 0,02 |
| **Pb-203** | 4E+0 | 4E+0 | 3E+0 | 3E+0 | 1,00 | 1,00 |
| **Pb-205** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Pb-210** | 1E+0 | 4E+1 | 5E-2 | 3E-3 | 40,00 | 0,06 |
| **Pb-212** | 7E-1 | 4E-1 | 2E-1 | 9E-4 | 0,57 | 0,005 |
| **Pd-103** | 4E+1 | 4E+1 | 4E+1 | 4E+1 | 1,00 | 1,00 |
| **Pd-107** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Pd-109** | 2E+0 | 4E+1 | 5E-1 | 5E-1 | 20,00 | 1,00 |
| **Pm-143** | 3E+0 | 4E+0 | 3E+0 | 4E+0 | 1,33 | 1,33 |
| **Pm-144** | 7E-1 | 7E-1 | 7E-1 | 7E-1 | 1,00 | 1,00 |
| **Pm-145** | 3E+1 | 4E+1 | 1E+1 | 9E+0 | 1,33 | 0,90 |
| **Pm-147** | 4E+1 | 4E+1 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Pm-148m** | 8E-1 | 5E-1 | 7E-1 | 5E-1 | 0,63 | 0,71 |
| **Pm-149** | 2E+0 | 4E+1 | 6E-1 | 7E-1 | 20,00 | 1,17 |
| **Pm-151** | 2E+0 | 4E+0 | 6E-1 | 7E-1 | 2,00 | 1,17 |
| **Po-210** | 4E+1 | 4E+1 | 2E-2 | 2E-2 | 1,00 | 1,00 |
| **Pr-142** | 4E-1 | 4E-1 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **Pr-143** | 3E+0 | 4E+1 | 6E-1 | 7E-1 | 13,33 | 1,17 |
| **Pt-188** | 1E+0 | 4E-1 | 8E-1 | 4E-1 | 0,40 | 0,50 |
| **Pt-191** | 4E+0 | 4E+0 | 3E+0 | 3E+0 | 1,00 | 1,00 |
| **Pt-193** | 4E+1 | 4E+1 | 4E+1 | 3E+1 | 1,00 | 0,75 |
| **Pt-193m** | 4E+1 | 4E+1 | 5E-1 | 7E-1 | 1,00 | 1,40 |
| **Pt-195m** | 1E+1 | 2E+1 | 5E-1 | 6E-1 | 2,00 | 1,20 |
| **Pt-197** | 2E+1 | 4E+1 | 6E-1 | 7E-1 | 2,00 | 1,17 |
| **Pt-197m** | 1E+1 | 2E+1 | 6E-1 | 6E-1 | 2,00 | 1,00 |
| **Pu-236** | 3E+1 | 4E+1 | 3E-3 | 3E-3 | 1,33 | 1,00 |
| **Pu-237** | 2E+1 | 3E+1 | 2E+1 | 3E+1 | 1,50 | 1,50 |
| **Pu-238** | 1E+1 | 4E+1 | 1E-3 | 1E-3 | 4,00 | 1,00 |
| **Pu-239** | 1E+1 | 4E+1 | 1E-3 | 1E-3 | 4,00 | 1,00 |
| **Pu-240** | 1E+1 | 4E+1 | 1E-3 | 1E-3 | 4,00 | 1,00 |
| **Pu-241** | 4E+1 | 4E+1 | 6E-2 | 6E-2 | 1,00 | 1,00 |
| **Pu-242** | 1E+1 | 4E+1 | 1E-3 | 1E-3 | 4,00 | 1,00 |
| **Pu-244** | 4E-1 | 6E-1 | 1E-3 | 1E-3 | 1,50 | 1,00 |
| **Ra-223** | 4E-1 | 2E+0 | 7E-3 | 2E-3 | 5,00 | 0,29 |
| **Ra-224** | 4E-1 | 4E-1 | 2E-2 | 8E-4 | 1,00 | 0,04 |

| Radionuclide | $A_1$ | | $A_2$ | | NEW / CURRENT | |
|---|---|---|---|---|---|---|
| | IAEA SSR-6 | WG $A_1$/$A_2$ | IAEA SSR-6 | WG $A_1$/$A_2$ | $A_1$ | $A_2$ |
| | TBq | TBq | TBq | TBq | | |
| **Ra-225** | 2E-1 | 1E+0 | 4E-3 | 2E-4 | 5,00 | 0,05 |
| **Ra-226** | 2E-1 | 6E-1 | 3E-3 | 2E-3 | 3,00 | 0,67 |
| **Ra-228** | 6E-1 | 1E+0 | 2E-2 | 1E-3 | 1,67 | 0,05 |
| **Rb (natural)** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Rb-81** | 2E+0 | 2E+0 | 8E-1 | 2E+0 | 1,00 | 2,50 |
| **Rb-83** | 2E+0 | 2E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Rb-84** | 1E+0 | 1E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Rb-86** | 5E-1 | 6E-1 | 5E-1 | 6E-1 | 1,20 | 1,20 |
| **Rb-87** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Re (natural)** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Re-184** | 1E+0 | 1E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Re-184m** | 3E+0 | 3E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Re-186** | 2E+0 | 4E+1 | 6E-1 | 7E-1 | 20,00 | 1,17 |
| **Re-187** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Re-188** | 4E-1 | 4E-1 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **Re-189** | 3E+0 | 2E+1 | 6E-1 | 6E-1 | 6,67 | 1,00 |
| **Rh-101** | 4E+0 | 4E+0 | 3E+0 | 4E+0 | 1,00 | 1,33 |
| **Rh-102** | 5E-1 | 2E+0 | 5E-1 | 2E+0 | 4,00 | 4,00 |
| **Rh-102m** | 2E+0 | 5E-1 | 2E+0 | 5E-1 | 0,25 | 0,25 |
| **Rh-103m** | 4E+1 | 4E+1 | 4E+1 | 4E+1 | 1,00 | 1,00 |
| **Rh-105** | 1E+1 | 1E+1 | 8E-1 | 9E-1 | 1,00 | 1,13 |
| **Rh-99** | 2E+0 | 2E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Rn-222** | 3E-1 | 6E-1 | 4E-3 | 2E-3 | 2,00 | 0,50 |
| **Ru-103** | 2E+0 | 2E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Ru-105** | 1E+0 | 1E+0 | 6E-1 | 5E-1 | 1,00 | 0,83 |
| **Ru-106** | 2E-1 | 2E-1 | 2E-1 | 2E-1 | 1,00 | 1,00 |
| **Ru-97** | 5E+0 | 5E+0 | 5E+0 | 5E+0 | 1,00 | 1,00 |
| **S-35** | 4E+1 | 4E+1 | 3E+0 | 4E+0 | 1,00 | 1,33 |
| **Sb-119** | x | 4E+1 | x | 4E+1 | x | x |
| **Sb-120m** | x | 5E-1 | x | 5E-1 | x | x |
| **Sb-122** | 4E-1 | 1E+0 | 4E-1 | 6E-1 | 2,50 | 1,50 |
| **Sb-124** | 6E-1 | 6E-1 | 6E-1 | 6E-1 | 1,00 | 1,00 |
| **Sb-125** | 2E+0 | 3E+0 | 1E+0 | 2E+0 | 1,50 | 2,00 |
| **Sb-126** | 4E-1 | 4E-1 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **Sc-44** | 5E-1 | 5E-1 | 5E-1 | 5E-1 | 1,00 | 1,00 |
| **Sc-46** | 5E-1 | 5E-1 | 5E-1 | 5E-1 | 1,00 | 1,00 |
| **Sc-47** | 1E+1 | 1E+1 | 7E-1 | 8E-1 | 1,00 | 1,14 |

| Radionuclide | $A_1$ |  | $A_2$ |  | NEW / CURRENT |  |
|---|---|---|---|---|---|---|
|  | IAEA SSR-6 | WG $A_1$/$A_2$ | IAEA SSR-6 | WG $A_1$/$A_2$ |  |  |
|  | TBq | TBq | TBq | TBq | $A_1$ | $A_2$ |
| **Sc-48** | 3E-1 | 3E-1 | 3E-1 | 3E-1 | 1,00 | 1,00 |
| **Se-75** | 3E+0 | 3E+0 | 3E+0 | 3E+0 | 1,00 | 1,00 |
| **Se-79** | 4E+1 | 4E+1 | 2E+0 | 3E+0 | 1,00 | 1,50 |
| **Si-31** | 6E-1 | 2E+0 | 6E-1 | 6E-1 | 3,33 | 1,00 |
| **Si-32** | 4E+1 | 4E+1 | 5E-1 | 2E-1 | 1,00 | 0,40 |
| **Sm-145** | 1E+1 | 4E+1 | 1E+1 | 3E+1 | 4,00 | 3,00 |
| **Sm-147** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Sm-151** | 4E+1 | 4E+1 | 1E+1 | 1E+1 | 1,00 | 1,00 |
| **Sm-153** | 9E+0 | 3E+1 | 6E-1 | 7E-1 | 3,33 | 1,17 |
| **Sn-113** | 4E+0 | 4E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Sn-117m** | 7E+0 | 9E+0 | 4E-1 | 5E-1 | 1,29 | 1,25 |
| **Sn-119m** | 4E+1 | 4E+1 | 3E+1 | 2E+1 | 1,00 | 0,67 |
| **Sn-121m** | 4E+1 | 4E+1 | 9E-1 | 1E+0 | 1,00 | 1,11 |
| **Sn-123** | 8E-1 | 2E+0 | 6E-1 | 7E-1 | 2,50 | 1,17 |
| **Sn-125** | 4E-1 | 3E-1 | 4E-1 | 3E-1 | 0,75 | 0,75 |
| **Sn-126** | 6E-1 | 5E-1 | 4E-1 | 9E-2 | 0,83 | 0,23 |
| **Sr-82** | 2E-1 | 2E-1 | 2E-1 | 2E-1 | 1,00 | 1,00 |
| **Sr-83** | 1E+0 | 1E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Sr-85** | 2E+0 | 2E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Sr-85m** | 5E+0 | 5E+0 | 2E+0 | 5E+0 | 1,00 | 2,50 |
| **Sr-87m** | 3E+0 | 3E+0 | 3E+0 | 3E+0 | 1,00 | 1,00 |
| **Sr-89** | 6E-1 | 1E+0 | 6E-1 | 6E-1 | 1,67 | 1,00 |
| **Sr-90** | 3E-1 | 3E-1 | 3E-1 | 1E-1 | 1,00 | 0,33 |
| **Sr-91** | 3E-1 | 6E-1 | 3E-1 | 6E-1 | 2,00 | 2,00 |
| **Sr-92** | 1E+0 | 8E-1 | 3E-1 | 8E-1 | 0,80 | 2,67 |
| **Ta-178m** | 1E+0 | 1E+0 | 8E-1 | 9E-1 | 1,00 | 1,13 |
| **Ta-179** | 3E+1 | 4E+1 | 3E+1 | 4E+1 | 1,33 | 1,33 |
| **Ta-182** | 9E-1 | 9E-1 | 5E-1 | 6E-1 | 1,00 | 1,20 |
| **Tb-149** | 8E-1 | 8E-1 | 8E-1 | 8E-1 | 1,00 | 1,00 |
| **Tb-157** | 4E+1 | 4E+1 | 4E+1 | 3E+1 | 1,00 | 0,75 |
| **Tb-158** | 1E+0 | 1E+0 | 1E+0 | 5E-1 | 1,00 | 0,50 |
| **Tb-160** | 1E+0 | 1E+0 | 6E-1 | 6E-1 | 1,00 | 1,00 |
| **Tb-161** | 3E+1 | 4E+1 | 7E-1 | 8E-1 | 1,33 | 1,14 |
| **Tc-95** | x | 1E+0 | x | 1E+0 | x | x |
| **Tc-95m** | 2E+0 | 2E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Tc-96** | 4E-1 | 4E-1 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **Tc-96m** | 4E-1 | 3E+1 | 4E-1 | 3E+1 | 75,00 | 75,00 |

| Radionuclide | $A_1$ | | $A_2$ | | NEW / CURRENT | |
|---|---|---|---|---|---|---|
| | IAEA SSR-6 | WG $A_1$/$A_2$ | IAEA SSR-6 | WG $A_1$/$A_2$ | | |
| | TBq | TBq | TBq | TBq | $A_1$ | $A_2$ |
| **Tc-97** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Tc-97m** | 4E+1 | 4E+1 | 1E+0 | 2E+0 | 1,00 | 2,00 |
| **Tc-98** | 8E-1 | 8E-1 | 7E-1 | 3E-1 | 1,00 | 0,43 |
| **Tc-99** | 4E+1 | 4E+1 | 9E-1 | 1E+0 | 1,00 | 1,11 |
| **Tc-99m** | 1E+1 | 1E+1 | 4E+0 | 5E+0 | 1,00 | 1,25 |
| **Te-118** | x | 2E-1 | x | 2E-1 | x | x |
| **Te-119** | x | 1E+0 | x | 1E+0 | x | x |
| **Te-119m** | x | 8E-1 | x | 8E-1 | x | x |
| **Te-121** | 2E+0 | 2E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Te-121m** | 5E+0 | 6E+0 | 3E+0 | 3E+0 | 1,20 | 1,00 |
| **Te-123m** | 8E+0 | 9E+0 | 1E+0 | 1E+0 | 1,13 | 1,00 |
| **Te-125m** | 2E+1 | 4E+1 | 9E-1 | 1E+0 | 2,00 | 1,11 |
| **Te-127** | 2E+1 | 4E+1 | 7E-1 | 7E-1 | 2,00 | 1,00 |
| **Te-127m** | 2E+1 | 4E+1 | 5E-1 | 6E-1 | 2,00 | 1,20 |
| **Te-129** | 7E-1 | 2E+0 | 6E-1 | 6E-1 | 2,86 | 1,00 |
| **Te-129m** | 8E-1 | 2E+0 | 4E-1 | 5E-1 | 2,50 | 1,25 |
| **Te-131m** | 7E-1 | 7E-1 | 5E-1 | 5E-1 | 1,00 | 1,00 |
| **Te-132** | 5E-1 | 4E-1 | 4E-1 | 4E-1 | 0,80 | 1,00 |
| **Th (natural)** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Th-227** | 1E+1 | 9E+0 | 5E-3 | 2E-2 | 0,90 | 4,00 |
| **Th-228** | 5E-1 | 5E-1 | 1E-3 | 9E-4 | 1,00 | 0,90 |
| **Th-229** | 5E+0 | 1E+1 | 5E-4 | 3E-4 | 2,00 | 0,60 |
| **Th-230** | 1E+1 | 4E+1 | 1E-3 | 1E-3 | 4,00 | 1,00 |
| **Th-231** | 4E+1 | 4E+1 | 2E-2 | 1E+0 | 1,00 | 50,00 |
| **Th-232** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Th-234** | 3E-1 | 4E-1 | 3E-1 | 4E-1 | 1,33 | 1,33 |
| **Ti-44** | 5E-1 | 5E-1 | 4E-1 | 1E-1 | 1,00 | 0,25 |
| **Tl-200** | 9E-1 | 9E-1 | 9E-1 | 9E-1 | 1,00 | 1,00 |
| **Tl-201** | 1E+1 | 2E+1 | 4E+0 | 5E+0 | 2,00 | 1,25 |
| **Tl-202** | 2E+0 | 2E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Tl-204** | 1E+1 | 4E+1 | 7E-1 | 8E-1 | 4,00 | 1,14 |
| **Tm-167** | 7E+0 | 9E+0 | 8E-1 | 9E-1 | 1,29 | 1,13 |
| **Tm-170** | 3E+0 | 4E+1 | 6E-1 | 7E-1 | 13,33 | 1,17 |
| **Tm-171** | 4E+1 | 4E+1 | 4E+1 | 4E+1 | 1,00 | 1,00 |
| **U (depleted)** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **U (natural)** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **U (enriched to less than 20%, except slow lung absorption)** | x | Unlimited | x | Unlimited | x | x |

| Radionuclide | $A_1$ | | $A_2$ | | NEW / CURRENT | |
|---|---|---|---|---|---|---|
| | IAEA SSR-6 | WG $A_1/A_2$ | IAEA SSR-6 | WG $A_1/A_2$ | $A_1$ | $A_2$ |
| | TBq | TBq | TBq | TBq | | |
| **U (enriched to less than 20%)** | Unlimited | 5E-1 | Unlimited | 2E-3 | - | - |
| **U (enriched to less than 10%)** | x | Unlimited | x | Unlimited | x | x |
| **U (purified)** | x | Unlimited | x | Unlimited | x | x |
| **U-230 (fast lung absorption)** | 4E+1 | 1E+1 | 1E-1 | 2E-3 | 0,25 | 0,02 |
| **U-230 (medium lung absorption)** | 4E+1 | 1E+1 | 4E-3 | 2E-3 | 0,25 | 0,50 |
| **U-230 (slow lung absorption)** | 3E+1 | 1E+1 | 3E-3 | 2E-3 | 0,33 | 0,67 |
| **U-232 (fast lung absorption)** | 4E+1 | 4E+1 | 1E-2 | 3E-2 | 1,00 | 3,00 |
| **U-232 (medium lung absorption)** | 4E+1 | 4E+1 | 7E-3 | 1E-3 | 1,00 | 0,14 |
| **U-232 (slow lung absorption)** | 1E+1 | 4E+1 | 1E-3 | 4E-4 | 4,00 | 0,40 |
| **U-233 (fast lung absorption)** | 4E+1 | 4E+1 | 9E-2 | 8E-2 | 1,00 | 0,89 |
| **U-233 (medium lung absorption)** | 4E+1 | 4E+1 | 2E-2 | 6E-3 | 1,00 | 0,30 |
| **U-233 (slow lung absorption)** | 4E+1 | 4E+1 | 6E-3 | 2E-3 | 1,00 | 0,33 |
| **U-234 (fast lung absorption)** | 4E+1 | 4E+1 | 9E-2 | 8E-2 | 1,00 | 0,89 |
| **U-234 (medium lung absorption)** | 4E+1 | 4E+1 | 2E-2 | 6E-3 | 1,00 | 0,30 |
| **U-234 (slow lung absorption)** | 4E+1 | 4E+1 | 6E-3 | 2E-3 | 1,00 | 0,33 |
| **U-235 (all lung types absorption)** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **U-236 (fast lung absorption)** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **U-236 (medium lung absorption)** | 4E+1 | 4E+1 | 2E-2 | 6E-3 | 1,00 | 0,30 |
| **U-236 (slow lung absorption)** | 4E+1 | 4E+1 | 6E-3 | 2E-3 | 1,00 | 0,33 |
| **U-238 (all lung types absorption)** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **V-48** | 4E-1 | 4E-1 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **V-49** | 4E+1 | 4E+1 | 4E+1 | 4E+1 | 1,00 | 1,00 |
| **W-178** | 9E+0 | 1E+1 | 5E+0 | 5E+0 | 1,11 | 1,00 |
| **W-181** | 3E+1 | 4E+1 | 3E+1 | 4E+1 | 1,33 | 1,33 |
| **W-185** | 4E+1 | 4E+1 | 8E-1 | 9E-1 | 1,00 | 1,13 |
| **W-187** | 2E+0 | 2E+0 | 6E-1 | 7E-1 | 1,00 | 1,17 |
| **W-188** | 4E-1 | 4E-1 | 3E-1 | 4E-1 | 1,00 | 1,33 |
| **Xe-122** | 4E-1 | 2E-1 | 4E-1 | 2E-1 | 0,50 | 0,50 |
| **Xe-123** | 2E+0 | 2E+0 | 7E-1 | 7E-1 | 1,00 | 1,00 |
| **Xe-127** | 4E+0 | 5E+0 | 2E+0 | 2E+0 | 1,25 | 1,00 |
| **Xe-131m** | 4E+1 | 4E+1 | 4E+1 | 4E+1 | 1,00 | 1,00 |
| **Xe-133** | 2E+1 | 4E+1 | 1E+1 | 2E+1 | 2,00 | 2,00 |
| **Xe-135** | 3E+0 | 5E+0 | 2E+0 | 2E+0 | 1,67 | 1,00 |
| **Y-87** | 1E+0 | 1E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Y-88** | 4E-1 | 4E-1 | 4E-1 | 4E-1 | 1,00 | 1,00 |
| **Y-89m** | x | 1E+0 | x | 1E+0 | x | x |
| **Y-90** | 3E-1 | 3E-1 | 3E-1 | 3E-1 | 1,00 | 1,00 |

| Radionuclide | $A_1$ | | $A_2$ | | NEW / CURRENT | |
|---|---|---|---|---|---|---|
| | IAEA SSR-6 | WG $A_1$/$A_2$ | IAEA SSR-6 | WG $A_1$/$A_2$ | | |
| | TBq | TBq | TBq | TBq | $A_1$ | $A_2$ |
| **Y-91** | 6E-1 | 1E+0 | 6E-1 | 6E-1 | 1,67 | 1,00 |
| **Y-91m** | 2E+0 | 2E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Y-92** | 2E-1 | 2E-1 | 2E-1 | 2E-1 | 1,00 | 1,00 |
| **Y-93** | 3E-1 | 2E-1 | 3E-1 | 2E-1 | 0,67 | 0,67 |
| **Yb-169** | 4E+0 | 4E+0 | 1E+0 | 1E+0 | 1,00 | 1,00 |
| **Yb-175** | 2E+0 | 3E+1 | 2E+0 | 1E+0 | 15,00 | 0,50 |
| **Zn-65** | 2E+0 | 2E+0 | 2E+0 | 2E+0 | 1,00 | 1,00 |
| **Zn-69** | 3E+0 | 4E+1 | 6E-1 | 7E-1 | 13,33 | 1,17 |
| **Zn-69m** | 3E+0 | 3E+0 | 6E-1 | 6E-1 | 1,00 | 1,00 |
| **Zr-88** | 3E+0 | 3E+0 | 3E+0 | 3E+0 | 1,00 | 1,00 |
| **Zr-89** | x | 9E-1 | x | 9E-1 | x | x |
| **Zr-93** | Unlimited | Unlimited | Unlimited | Unlimited | 1,00 | 1,00 |
| **Zr-95** | 2E+0 | 1E+0 | 8E-1 | 1E+0 | 0,50 | 1,25 |
| **Zr-97** | 4E-1 | 4E-1 | 4E-1 | 3E-1 | 1,00 | 0,75 |

***Table 6. Changes in $A_1$ and $A_2$ values (SSR-6 Table 3) between the current Q system and the proposed update***

| Radioactive content | $A_1$ IAEA SSR-6 TBq | $A_1$ WG $A_1/A_2$ TBq | $A_2$ IAEA SSR-6 TBq | $A_2$ WG $A_1/A_2$ TBq | NEW / CURRENT $A_1$ | NEW / CURRENT $A_2$ |
|---|---|---|---|---|---|---|
| Only beta or gamma emitting nuclides are known to be present | 1E-01 | 1E-01 | 2E-02 | 2E-02 | 1.00 | 1.00 |
| Alpha emitting nuclides, but no neutron emitters are known to be present | 2E-01 | 2E-01 | 9E-05 | 3E-04 | 1.00 | 3.33 |
| Neutron emitting nuclides are known to be present or no relevant data are available | 1E-03 | 4E-03 | 9E-05 | 8E-05 | 4.00 | 0.89 |

*The table was established from the $A_1$ and $A_2$ values calculated for all the radionuclides listed in the ICRP publication 107.*

# List of updated Q values

*Table 7. Q values of radionuclides (SSG-26 Table I.2) in the proposed update of the Q system*

| *Radionuclide* | $Q_A$ TBq | $Q_{B,skin}$ TBq | $Q_{B,eye}$ TBq | $Q_C$ TBq | $Q_{D,ing}$ TBq | $Q_{D,skin}$ TBq | $Q_{E,eff}$ TBq | $Q_{E,skin}$ TBq |
|---|---|---|---|---|---|---|---|---|
| Ac-225 | 4,0E+00 | 3,8E+00 | 1,6E+01 | 1,7E-02 | 2,3E+00 | 7,4E-04 | Unlimited | Unlimited |
| Ac-226 | 6,0E+00 | 3,4E+01 | 2,5E+01 | 6,4E-02 | 2,2E+02 | 1,9E-03 | 7,1E+02 | 5,6E+03 |
| Ac-227 | 1,5E+03 | 4,8E+03 | 6,1E+03 | 4,6E-04 | 2,9E-01 | 4,1E+01 | Unlimited | Unlimited |
| Ac-228 | 1,3E+00 | 2,0E+00 | 5,2E+00 | 3,9E+00 | 3,1E+02 | 5,9E-01 | Unlimited | Unlimited |
| Ag-105 | 2,3E+00 | 1,1E+01 | 9,2E+00 | 5,4E+01 | 1,4E+02 | 1,5E+01 | Unlimited | Unlimited |
| Ag-108m | 6,7E-01 | 2,4E+00 | 2,7E+00 | 3,1E-01 | 3,1E+01 | 4,6E+00 | Unlimited | Unlimited |
| Ag-110m | 3,9E-01 | 1,7E+00 | 1,6E+00 | 2,9E+00 | 2,2E+01 | 2,0E+00 | Unlimited | Unlimited |
| Ag-111 | 3,9E+01 | 1,5E+02 | 1,6E+02 | 6,8E+01 | 2,4E+02 | 6,7E-01 | Unlimited | Unlimited |
| Al-26 | 4,2E-01 | 2,1E+00 | 1,8E+00 | 1,3E-01 | 3,9E+01 | 7,5E-01 | Unlimited | Unlimited |
| Am-241 | 5,1E+01 | 2,9E+02 | 2,0E+02 | 1,7E-03 | 8,5E-01 | 3,5E+01 | Unlimited | Unlimited |
| Am-242m | 7,8E+01 | 4,1E+02 | 3,5E+02 | 1,9E-03 | 8,3E-01 | 9,3E-01 | Unlimited | Unlimited |
| Am-243 | 5,5E+00 | 2,9E+01 | 2,4E+01 | 1,7E-03 | 8,6E-01 | 4,7E-01 | Unlimited | Unlimited |
| Ar-37 | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited |
| Ar-39 | 1,5E+03 | 7,3E+03 | 6,1E+03 | Unlimited | Unlimited | Unlimited | 1,9E+02 | 2,2E+01 |
| Ar-41 | 8,6E-01 | 3,7E+00 | 3,7E+00 | Unlimited | Unlimited | Unlimited | 3,2E-01 | 2,0E+00 |
| As-72 | 5,6E-01 | 2,1E-01 | 1,2E+00 | 6,8E+01 | 6,1E+01 | 6,6E-01 | Unlimited | Unlimited |
| As-73 | 3,3E+02 | 1,4E+03 | 1,2E+03 | 5,5E+01 | 4,6E+02 | 2,7E+01 | Unlimited | Unlimited |
| As-74 | 1,4E+00 | 3,9E+00 | 5,7E+00 | 3,1E+01 | 7,6E+01 | 9,9E-01 | Unlimited | Unlimited |
| As-76 | 1,5E+00 | 2,3E-01 | 2,1E+00 | 8,9E+01 | 8,8E+01 | 6,1E-01 | Unlimited | Unlimited |
| As-77 | 1,3E+02 | 6,2E+02 | 5,2E+02 | 2,6E+02 | 5,2E+02 | 7,2E-01 | Unlimited | Unlimited |
| At-211 | 2,4E+01 | 1,5E+02 | 1,0E+02 | 6,2E-01 | 4,2E-01 | 4,2E-03 | Unlimited | Unlimited |
| Au-193 | 7,9E+00 | 4,0E+01 | 3,3E+01 | 9,6E+02 | 1,3E+03 | 2,5E+00 | Unlimited | Unlimited |
| Au-194 | 1,1E+00 | 5,7E+00 | 4,7E+00 | 2,5E+02 | 1,9E+02 | 5,4E+00 | Unlimited | Unlimited |
| Au-195 | 1,9E+01 | 1,0E+02 | 8,1E+01 | 3,6E+01 | 5,0E+02 | 6,4E+00 | Unlimited | Unlimited |
| Au-198 | 2,7E+00 | 1,2E+01 | 1,1E+01 | 1,2E+02 | 1,9E+02 | 6,5E-01 | Unlimited | Unlimited |
| Au-199 | 1,3E+01 | 7,4E+01 | 5,8E+01 | 1,7E+02 | 9,3E+02 | 7,3E-01 | Unlimited | Unlimited |
| Ba-131 | 2,5E+00 | 1,1E+01 | 9,7E+00 | 7,0E+01 | 9,1E+01 | 2,3E+00 | Unlimited | Unlimited |
| Ba-133 | 3,1E+00 | 1,4E+01 | 1,3E+01 | 2,1E+00 | 5,0E+01 | 8,4E+00 | Unlimited | Unlimited |
| Ba-133m | 2,2E+01 | 1,0E+02 | 8,9E+01 | 2,6E+02 | 7,3E+02 | 6,5E-01 | Unlimited | Unlimited |
| Ba-135m | 2,6E+01 | 1,2E+02 | 1,0E+02 | 3,6E+02 | 8,5E+02 | 6,5E-01 | Unlimited | Unlimited |
| Ba-140 | 4,0E-01 | 1,0E+00 | 1,7E+00 | 1,2E+01 | 3,1E+01 | 3,0E-01 | Unlimited | Unlimited |
| Be-10 | 1,2E+03 | 5,9E+03 | 5,0E+03 | 5,6E-01 | 1,1E+02 | 6,4E-01 | Unlimited | Unlimited |
| Be-7 | 2,2E+01 | 9,6E+01 | 8,8E+01 | 5,8E+02 | 2,4E+03 | 5,4E+02 | Unlimited | Unlimited |
| Bi-205 | 6,7E-01 | 3,8E+00 | 2,9E+00 | 4,6E+01 | 8,2E+01 | 7,8E+00 | Unlimited | Unlimited |
| Bi-206 | 3,4E-01 | 1,8E+00 | 1,4E+00 | 3,9E+01 | 4,2E+01 | 1,2E+00 | Unlimited | Unlimited |

| ***Radionuclide*** | $Q_A$ TBq | $Q_{B,skin}$ TBq | $Q_{B,eye}$ TBq | $Q_C$ TBq | $Q_{D,ing}$ TBq | $Q_{D,skin}$ TBq | $Q_{E,eff}$ TBq | $Q_{E,skin}$ TBq |
|---|---|---|---|---|---|---|---|---|
| Bi-207 | 7,2E-01 | 2,8E+00 | 3,0E+00 | 3,9E-01 | 6,0E+01 | 4,1E+00 | Unlimited | Unlimited |
| Bi-210 | 3,9E+02 | 4,8E+01 | 1,7E+03 | 5,8E-01 | 4,6E+01 | 6,7E-01 | Unlimited | Unlimited |
| Bi-210m | 4,1E+00 | 1,7E+00 | 1,8E+01 | 2,1E-03 | 2,0E+00 | 5,2E-01 | Unlimited | Unlimited |
| Bi-212 | 8,1E-01 | 4,9E-01 | 3,1E+00 | 1,7E+00 | 4,6E+02 | 1,1E-03 | Unlimited | Unlimited |
| Bk-247 | 8,2E+00 | 4,4E+01 | 3,5E+01 | 1,7E-03 | 9,3E-01 | 1,4E+00 | Unlimited | Unlimited |
| Bk-249 | 1,9E+05 | 6,9E+05 | 6,6E+05 | 7,5E-01 | 4,2E+02 | 1,7E+01 | Unlimited | Unlimited |
| Br-76 | 3,9E-01 | 3,4E-01 | 1,0E+00 | 1,0E+02 | 1,1E+02 | 1,0E+00 | Unlimited | Unlimited |
| Br-77 | 3,5E+00 | 1,6E+01 | 1,4E+01 | 6,2E+02 | 5,8E+02 | 1,5E+01 | Unlimited | Unlimited |
| Br-82 | 4,1E-01 | 2,0E+00 | 1,7E+00 | 8,8E+01 | 1,0E+02 | 8,3E-01 | Unlimited | Unlimited |
| C-11 | 1,1E+00 | 4,6E+00 | 4,2E+00 | 2,8E+03 | 1,9E+03 | 6,3E-01 | Unlimited | Unlimited |
| C-14 | 6,9E+04 | 2,6E+05 | 2,4E+05 | 4,2E+00 | 3,1E+02 | 4,0E+00 | Unlimited | Unlimited |
| Ca-41 | Unlimited | Unlimited | Unlimited | 8,3E+01 | 8,8E+03 | 3,4E+02 | Unlimited | Unlimited |
| Ca-45 | 1,6E+04 | 7,0E+04 | 6,2E+04 | 2,8E+01 | 1,9E+02 | 1,5E+00 | Unlimited | Unlimited |
| Ca-47 | 7,7E-01 | 1,5E+00 | 3,3E+00 | 2,5E+01 | 5,3E+01 | 1,6E-01 | Unlimited | Unlimited |
| Cd-109 | 4,2E+02 | 2,2E+03 | 1,9E+03 | 1,1E+01 | 5,0E+01 | 2,6E+00 | Unlimited | Unlimited |
| Cd-113m | 1,8E+03 | 8,8E+03 | 7,4E+03 | 9,4E-01 | 4,6E+00 | 7,8E-01 | Unlimited | Unlimited |
| Cd-115 | 3,1E+00 | 1,3E+01 | 1,2E+01 | 9,5E+01 | 1,6E+02 | 4,0E-01 | Unlimited | Unlimited |
| Cd-115m | 2,0E+01 | 1,1E+00 | 9,9E+01 | 9,3E+00 | 5,1E+01 | 6,4E-01 | Unlimited | Unlimited |
| Ce-132 | 4,8E+00 | 2,5E+01 | 2,0E+01 | 5,0E+02 | 3,6E+02 | 7,7E+00 | Unlimited | Unlimited |
| Ce-133m | 4,6E-01 | 2,0E+00 | 1,9E+00 | 3,4E+02 | 2,2E+02 | 1,0E+00 | Unlimited | Unlimited |
| Ce-134 | 1,3E+00 | 2,8E-01 | 2,2E+00 | 5,2E+01 | 6,9E+01 | 9,3E-01 | Unlimited | Unlimited |
| Ce-135 | 1,4E+00 | 6,4E+00 | 5,6E+00 | 4,2E+02 | 2,9E+02 | 5,9E+00 | Unlimited | Unlimited |
| Ce-137 | 7,5E+01 | 2,5E+02 | 2,5E+02 | 8,8E+03 | 5,3E+03 | 6,6E+01 | Unlimited | Unlimited |
| Ce-137m | 1,9E+01 | 7,8E+01 | 7,1E+01 | 2,7E+02 | 6,1E+02 | 6,0E-01 | Unlimited | Unlimited |
| Ce-139 | 9,2E+00 | 4,9E+01 | 3,9E+01 | 3,6E+01 | 5,7E+02 | 2,5E+00 | Unlimited | Unlimited |
| Ce-141 | 1,8E+01 | 9,5E+01 | 7,6E+01 | 3,9E+01 | 8,1E+02 | 6,8E-01 | Unlimited | Unlimited |
| Ce-143 | 4,3E+00 | 6,2E+00 | 1,7E+01 | 1,3E+02 | 2,1E+02 | 6,4E-01 | Unlimited | Unlimited |
| Ce-144 | 2,5E+00 | 1,9E-01 | 2,0E+00 | 9,8E-01 | 4,8E+01 | 4,1E-01 | Unlimited | Unlimited |
| Cf-248 | 6,6E+01 | 3,7E+02 | 2,3E+02 | 8,3E-03 | 8,1E+00 | 9,8E-01 | Unlimited | Unlimited |
| Cf-249 | 3,4E+00 | 1,5E+01 | 1,4E+01 | 1,7E-03 | 9,6E-01 | 4,4E+00 | Unlimited | Unlimited |
| Cf-250 | 6,0E+00 | 1,9E+01 | 1,9E+01 | 2,8E-03 | 1,7E+00 | 1,7E+01 | Unlimited | Unlimited |
| Cf-251 | 1,0E+01 | 5,8E+01 | 4,4E+01 | 1,6E-03 | 9,4E-01 | 6,0E-01 | Unlimited | Unlimited |
| Cf-252 | 1,5E-01 | 4,0E-01 | 4,4E-01 | 3,9E-03 | 2,0E+00 | 9,9E-01 | Unlimited | Unlimited |
| Cf-253 | 4,1E+03 | 1,6E+04 | 1,5E+04 | 9,6E-02 | 1,6E+02 | 1,6E+00 | Unlimited | Unlimited |
| Cf-254 | 4,3E-03 | 1,1E-02 | 1,3E-02 | 2,1E-03 | 2,8E-01 | 3,3E-02 | Unlimited | Unlimited |
| Cl-36 | 8,9E+02 | 4,4E+03 | 3,7E+03 | 5,0E-01 | 5,1E+01 | 6,9E-01 | Unlimited | Unlimited |
| Cl-38 | 4,7E-01 | 1,9E-01 | 5,7E-01 | 8,6E+02 | 3,3E+02 | 5,8E-01 | Unlimited | Unlimited |
| Cm-240 | 1,0E+02 | 9,5E+02 | 3,8E+02 | 3,3E-02 | 4,6E+01 | 6,5E-01 | Unlimited | Unlimited |
| Cm-241 | 2,3E+00 | 1,1E+01 | 9,5E+00 | 2,5E+00 | 1,9E+02 | 1,6E+00 | Unlimited | Unlimited |

| ***Radionuclide*** | $Q_A$ TBq | $Q_{B,skin}$ TBq | $Q_{B,eye}$ TBq | $Q_C$ TBq | $Q_{D,ing}$ TBq | $Q_{D,skin}$ TBq | $Q_{E,eff}$ TBq | $Q_{E,skin}$ TBq |
|---|---|---|---|---|---|---|---|---|
| Cm-242 | 1,1E+02 | 1,0E+03 | 4,1E+02 | 1,4E-02 | 1,4E+01 | 8,4E+00 | Unlimited | Unlimited |
| Cm-243 | 9,1E+00 | 5,0E+01 | 3,9E+01 | 2,2E-03 | 1,1E+00 | 9,5E-01 | Unlimited | Unlimited |
| Cm-244 | 1,3E+02 | 1,1E+03 | 4,7E+02 | 2,5E-03 | 1,3E+00 | 4,4E+01 | Unlimited | Unlimited |
| Cm-245 | 1,2E+01 | 7,1E+01 | 5,5E+01 | 1,7E-03 | 8,3E-01 | 2,5E+00 | Unlimited | Unlimited |
| Cm-246 | 1,9E+01 | 5,3E+01 | 5,7E+01 | 1,7E-03 | 8,3E-01 | 4,5E+01 | Unlimited | Unlimited |
| Cm-247 | 3,3E+00 | 1,5E+01 | 1,3E+01 | 1,9E-03 | 9,1E-01 | 7,6E-01 | Unlimited | Unlimited |
| Cm-248 | 6,8E-02 | 1,5E-01 | 2,0E-01 | 5,2E-04 | 2,2E-01 | 4,6E-01 | Unlimited | Unlimited |
| Co-55 | 5,4E-01 | 1,3E+00 | 2,2E+00 | 1,3E+02 | 1,0E+02 | 7,9E-01 | Unlimited | Unlimited |
| Co-56 | 3,2E-01 | 1,7E+00 | 1,4E+00 | 5,8E+00 | 2,6E+01 | 2,7E+00 | Unlimited | Unlimited |
| Co-57 | 1,1E+01 | 6,0E+01 | 4,8E+01 | 4,2E+01 | 4,2E+02 | 1,0E+01 | Unlimited | Unlimited |
| Co-58 | 1,1E+00 | 5,2E+00 | 4,5E+00 | 2,1E+01 | 9,3E+01 | 3,7E+00 | Unlimited | Unlimited |
| Co-58m | 2,2E+07 | 1,9E+07 | 3,1E+07 | 3,6E+03 | 1,9E+04 | 7,5E+01 | Unlimited | Unlimited |
| Co-60 | 4,4E-01 | 2,7E+00 | 1,9E+00 | 8,5E-01 | 1,6E+01 | 1,1E+00 | Unlimited | Unlimited |
| Cr-51 | 3,6E+01 | 1,7E+02 | 1,5E+02 | 1,1E+03 | 3,9E+03 | 8,1E+01 | Unlimited | Unlimited |
| Cs-129 | 4,5E+00 | 2,0E+01 | 1,8E+01 | 7,7E+02 | 5,8E+02 | 2,1E+01 | Unlimited | Unlimited |
| Cs-131 | 7,9E+02 | 1,2E+03 | 1,5E+03 | 1,4E+03 | 9,6E+02 | 1,1E+02 | Unlimited | Unlimited |
| Cs-132 | 1,6E+00 | 6,9E+00 | 6,3E+00 | 1,5E+02 | 9,8E+01 | 1,5E+01 | Unlimited | Unlimited |
| Cs-134 | 6,9E-01 | 3,2E+00 | 2,8E+00 | 1,8E+00 | 3,6E+00 | 9,7E-01 | Unlimited | Unlimited |
| Cs-134m | 7,5E+01 | 3,7E+02 | 3,1E+02 | 1,4E+03 | 3,3E+03 | 7,8E-01 | Unlimited | Unlimited |
| Cs-135 | 1,2E+04 | 5,1E+04 | 4,5E+04 | 2,0E+00 | 3,9E+01 | 1,2E+00 | Unlimited | Unlimited |
| Cs-136 | 5,1E-01 | 2,6E+00 | 2,1E+00 | 2,6E+01 | 1,9E+01 | 8,0E-01 | Unlimited | Unlimited |
| Cs-137 | 1,9E+00 | 8,3E+00 | 7,7E+00 | 5,2E-01 | 3,6E+00 | 6,9E-01 | Unlimited | Unlimited |
| Cu-64 | 5,8E+00 | 2,5E+01 | 2,3E+01 | 7,3E+02 | 9,3E+02 | 1,2E+00 | Unlimited | Unlimited |
| Cu-67 | 1,1E+01 | 6,0E+01 | 4,7E+01 | 2,1E+02 | 4,2E+02 | 8,2E-01 | Unlimited | Unlimited |
| Dy-159 | 5,6E+01 | 1,9E+02 | 1,8E+02 | 1,0E+02 | 1,4E+03 | 7,5E+01 | Unlimited | Unlimited |
| Dy-165 | 3,9E+01 | 9,7E+00 | 1,6E+02 | 8,6E+02 | 7,7E+02 | 6,5E-01 | Unlimited | Unlimited |
| Dy-166 | 8,5E+00 | 4,3E-01 | 3,0E+01 | 3,2E+01 | 8,0E+01 | 2,8E-01 | Unlimited | Unlimited |
| Er-169 | 7,9E+03 | 3,6E+04 | 3,1E+04 | 1,4E+02 | 6,0E+03 | 1,1E+00 | Unlimited | Unlimited |
| Er-171 | 3,2E+00 | 1,2E+01 | 1,3E+01 | 3,6E+02 | 4,2E+02 | 5,5E-01 | Unlimited | Unlimited |
| Eu-147 | 2,5E+00 | 1,2E+01 | 1,0E+01 | 6,9E+01 | 2,5E+02 | 3,8E+00 | Unlimited | Unlimited |
| Eu-148 | 4,9E-01 | 2,3E+00 | 2,0E+00 | 1,3E+01 | 5,8E+01 | 8,1E+00 | Unlimited | Unlimited |
| Eu-149 | 2,6E+01 | 1,1E+02 | 9,7E+01 | 1,1E+02 | 1,2E+03 | 3,4E+01 | Unlimited | Unlimited |
| Eu-150 | 7,2E-01 | 3,3E+00 | 2,9E+00 | 4,6E-01 | 5,4E+01 | 6,1E+00 | Unlimited | Unlimited |
| Eu-150m | 2,3E+01 | 8,7E+01 | 9,3E+01 | 4,2E+02 | 5,8E+02 | 7,6E-01 | Unlimited | Unlimited |
| Eu-152 | 9,6E-01 | 4,4E+00 | 4,0E+00 | 6,7E-01 | 7,7E+01 | 1,4E+00 | Unlimited | Unlimited |
| Eu-152m | 3,4E+00 | 8,5E-01 | 1,3E+01 | 3,3E+02 | 2,9E+02 | 8,3E-01 | Unlimited | Unlimited |
| Eu-154 | 8,8E-01 | 2,7E+00 | 3,7E+00 | 6,2E-01 | 6,9E+01 | 6,3E-01 | Unlimited | Unlimited |
| Eu-155 | 2,4E+01 | 1,3E+02 | 1,1E+02 | 7,0E+00 | 1,1E+03 | 3,6E+00 | Unlimited | Unlimited |
| Eu-156 | 8,8E-01 | 7,2E-01 | 3,2E+00 | 2,1E+01 | 7,5E+01 | 7,3E-01 | Unlimited | Unlimited |

| ***Radionuclide*** | $Q_A$ TBq | $Q_{B,skin}$ TBq | $Q_{B,eye}$ TBq | $Q_C$ TBq | $Q_{D,ing}$ TBq | $Q_{D,skin}$ TBq | $Q_{E,eff}$ TBq | $Q_{E,skin}$ TBq |
|---|---|---|---|---|---|---|---|---|
| F-18 | 1,1E+00 | 4,7E+00 | 4,4E+00 | 9,8E+02 | 1,0E+03 | 6,6E-01 | Unlimited | Unlimited |
| Fe-52 | 3,2E-01 | 1,7E-01 | 8,7E-01 | 9,9E+01 | 7,0E+01 | 3,8E-01 | Unlimited | Unlimited |
| Fe-53 | 8,1E-01 | 2,0E-01 | 1,5E+00 | Unlimited | Unlimited | 6,2E-01 | Unlimited | Unlimited |
| Fe-55 | 8,0E+09 | 4,5E+10 | 3,6E+10 | 4,2E+01 | 1,7E+02 | 7,4E+01 | Unlimited | Unlimited |
| Fe-59 | 9,3E-01 | 5,5E+00 | 3,9E+00 | 8,9E+00 | 2,9E+01 | 1,0E+00 | Unlimited | Unlimited |
| Fe-60 | 2,7E+02 | 4,3E+02 | 1,1E+03 | 2,6E-01 | 1,9E+00 | 1,9E+00 | Unlimited | Unlimited |
| Ga-67 | 7,8E+00 | 4,0E+01 | 3,3E+01 | 4,2E+02 | 9,3E+02 | 3,9E+00 | Unlimited | Unlimited |
| Ga-68 | 1,1E+00 | 4,0E-01 | 3,4E+00 | 9,1E+02 | 4,6E+02 | 6,9E-01 | Unlimited | Unlimited |
| Ga-72 | 4,1E-01 | 6,7E-01 | 1,5E+00 | 1,2E+02 | 9,4E+01 | 6,5E-01 | Unlimited | Unlimited |
| Gd-146 | 3,9E-01 | 1,8E+00 | 1,6E+00 | 7,8E+00 | 4,3E+01 | 1,1E+00 | Unlimited | Unlimited |
| Gd-148 | 5,5E+02 | 4,8E+03 | 2,4E+03 | 3,9E-03 | 2,5E+00 | Unlimited | Unlimited | Unlimited |
| Gd-153 | 1,8E+01 | 7,9E+01 | 7,0E+01 | 2,4E+01 | 7,1E+02 | 9,9E+00 | Unlimited | Unlimited |
| Gd-159 | 2,2E+01 | 9,8E+01 | 8,9E+01 | 3,3E+02 | 5,3E+02 | 6,9E-01 | Unlimited | Unlimited |
| Ge-68 | 1,1E+00 | 4,0E-01 | 3,4E+00 | 1,5E+00 | 1,3E+02 | 6,8E-01 | Unlimited | Unlimited |
| Ge-69 | 1,2E+00 | 5,3E+00 | 4,8E+00 | 2,1E+02 | 5,1E+02 | 2,4E+00 | Unlimited | Unlimited |
| Ge-71 | Unlimited | Unlimited | Unlimited | 3,6E+03 | 3,3E+04 | 5,9E+01 | Unlimited | Unlimited |
| Ge-77 | 9,8E-01 | 5,5E-01 | 3,6E+00 | 1,6E+02 | 2,3E+02 | 6,1E-01 | Unlimited | Unlimited |
| H-3 | Unlimited | Unlimited | Unlimited | 9,6E+01 | 9,8E+02 | 5,6E+05 | Unlimited | Unlimited |
| Hf-172 | 5,5E-01 | 2,9E+00 | 2,3E+00 | 1,4E+00 | 4,4E+01 | 1,5E+00 | Unlimited | Unlimited |
| Hf-175 | 3,4E+00 | 1,6E+01 | 1,4E+01 | 3,9E+01 | 2,9E+02 | 4,6E+00 | Unlimited | Unlimited |
| Hf-181 | 2,1E+00 | 9,6E+00 | 8,6E+00 | 1,9E+01 | 2,0E+02 | 5,6E-01 | Unlimited | Unlimited |
| Hf-182 | 4,9E+00 | 2,5E+01 | 2,1E+01 | 1,6E-01 | 1,7E+01 | 3,3E+00 | Unlimited | Unlimited |
| Hg-194 | 1,1E+00 | 5,7E+00 | 4,7E+00 | 5,4E-01 | 5,2E+01 | 5,2E+00 | Unlimited | Unlimited |
| Hg-195m | 3,5E+00 | 1,7E+01 | 1,5E+01 | 1,5E+02 | 4,1E+02 | 8,5E-01 | Unlimited | Unlimited |
| Hg-197 | 2,1E+01 | 1,1E+02 | 9,2E+01 | 2,8E+02 | 1,3E+03 | 9,8E+00 | Unlimited | Unlimited |
| Hg-197m | 1,4E+01 | 7,6E+01 | 6,1E+01 | 1,9E+02 | 1,0E+03 | 4,1E-01 | Unlimited | Unlimited |
| Hg-203 | 4,9E+00 | 2,5E+01 | 2,0E+01 | 3,9E+01 | 2,2E+02 | 1,3E+00 | Unlimited | Unlimited |
| Ho-166 | 1,6E+01 | 6,5E-01 | 5,6E+01 | 1,4E+02 | 1,7E+02 | 6,1E-01 | Unlimited | Unlimited |
| Ho-166m | 6,8E-01 | 3,2E+00 | 2,8E+00 | 2,5E-01 | 4,2E+01 | 1,2E+00 | Unlimited | Unlimited |
| I-123 | 8,3E+00 | 4,4E+01 | 3,6E+01 | 4,6E+02 | 2,8E+02 | 3,3E+00 | Unlimited | Unlimited |
| I-124 | 1,0E+00 | 1,4E+00 | 3,8E+00 | 8,8E+00 | 5,8E+00 | 2,5E+00 | Unlimited | Unlimited |
| I-125 | 7,4E+02 | 1,1E+03 | 1,4E+03 | 5,8E+00 | 3,9E+00 | 5,8E+01 | Unlimited | Unlimited |
| I-126 | 2,6E+00 | 1,0E+01 | 1,0E+01 | 3,6E+00 | 2,4E+00 | 1,5E+00 | Unlimited | Unlimited |
| I-129 | 4,9E+02 | 9,1E+02 | 1,1E+03 | 7,8E-01 | 5,3E-01 | 3,5E+00 | Unlimited | Unlimited |
| I-131 | 2,9E+00 | 1,3E+01 | 1,2E+01 | 4,6E+00 | 3,1E+00 | 7,6E-01 | Unlimited | Unlimited |
| I-132 | 4,8E-01 | 8,8E-01 | 1,9E+00 | 4,2E+02 | 1,8E+02 | 6,3E-01 | Unlimited | Unlimited |
| I-133 | 1,8E+00 | 5,1E+00 | 7,1E+00 | 2,6E+01 | 1,6E+01 | 6,6E-01 | Unlimited | Unlimited |
| I-134 | 4,2E-01 | 7,4E-01 | 1,7E+00 | 9,6E+02 | 4,2E+02 | 6,0E-01 | Unlimited | Unlimited |
| I-135 | 6,7E-01 | 2,7E+00 | 2,9E+00 | 1,3E+02 | 6,6E+01 | 7,0E-01 | 6,4E+00 | 4,1E+01 |

| *Radionuclide* | $Q_A$ TBq | $Q_{B,skin}$ TBq | $Q_{B,eye}$ TBq | $Q_C$ TBq | $Q_{D,ing}$ TBq | $Q_{D,skin}$ TBq | $Q_{E,eff}$ TBq | $Q_{E,skin}$ TBq |
|---|---|---|---|---|---|---|---|---|
| In-111 | 3,1E+00 | 1,7E+01 | 1,3E+01 | 3,3E+02 | 3,3E+02 | 3,0E+00 | Unlimited | Unlimited |
| In-113m | 4,4E+00 | 1,9E+01 | 1,8E+01 | 2,5E+03 | 2,2E+03 | 1,6E+00 | Unlimited | Unlimited |
| In-114m | 7,8E+00 | 4,7E-01 | 2,1E+01 | 5,6E+00 | 7,6E+01 | 3,2E-01 | Unlimited | Unlimited |
| In-115m | 7,3E+00 | 3,4E+01 | 3,0E+01 | 1,1E+03 | 1,4E+03 | 1,1E+00 | Unlimited | Unlimited |
| Ir-189 | 1,9E+01 | 9,8E+01 | 7,9E+01 | 1,9E+02 | 1,2E+03 | 1,5E+01 | Unlimited | Unlimited |
| Ir-190 | 7,5E-01 | 3,4E+00 | 3,1E+00 | 5,0E+01 | 8,5E+01 | 1,6E+00 | Unlimited | Unlimited |
| Ir-192 | 1,4E+00 | 6,3E+00 | 5,6E+00 | 1,1E+01 | 1,1E+02 | 6,7E-01 | Unlimited | Unlimited |
| Ir-193m | 4,6E+03 | 2,3E+04 | 1,9E+04 | 1,2E+02 | 1,4E+04 | 5,2E+00 | Unlimited | Unlimited |
| Ir-194 | 5,6E+00 | 3,8E-01 | 1,1E+01 | 1,5E+02 | 1,5E+02 | 6,2E-01 | Unlimited | Unlimited |
| K-40 | 6,9E+00 | 2,8E+00 | 3,0E+01 | 1,9E-01 | 1,6E+01 | 7,1E-01 | Unlimited | Unlimited |
| K-42 | 1,2E+00 | 1,7E-01 | 9,8E-01 | 1,2E+02 | 1,2E+02 | 5,9E-01 | Unlimited | Unlimited |
| K-43 | 1,1E+00 | 4,2E+00 | 4,6E+00 | 1,7E+02 | 2,4E+02 | 6,6E-01 | Unlimited | Unlimited |
| Kr-79 | 4,4E+00 | 2,0E+01 | 1,8E+01 | Unlimited | Unlimited | Unlimited | 1,9E+00 | 1,4E+01 |
| Kr-81 | 1,4E+03 | 7,1E+03 | 5,9E+03 | Unlimited | Unlimited | Unlimited | 5,2E+02 | 7,3E+02 |
| Kr-85 | 3,3E+02 | 1,5E+03 | 1,4E+03 | Unlimited | Unlimited | Unlimited | 8,9E+01 | 1,8E+01 |
| Kr-85m | 7,8E+00 | 4,1E+01 | 3,4E+01 | Unlimited | Unlimited | Unlimited | 3,3E+00 | 1,0E+01 |
| Kr-87 | 8,2E-01 | 1,9E-01 | 9,6E-01 | Unlimited | Unlimited | Unlimited | 4,9E-01 | 1,8E+00 |
| La-132 | 5,3E-01 | 3,7E-01 | 1,4E+00 | 3,3E+02 | 2,0E+02 | 1,3E+00 | Unlimited | Unlimited |
| La-133 | 7,9E+00 | 3,5E+01 | 3,1E+01 | 4,2E+03 | 2,9E+03 | 7,3E+00 | Unlimited | Unlimited |
| La-134 | 1,3E+00 | 2,8E-01 | 2,2E+00 | Unlimited | Unlimited | 9,5E-01 | Unlimited | Unlimited |
| La-135 | 8,4E+01 | 2,9E+02 | 2,9E+02 | 5,0E+03 | 3,1E+03 | 9,9E+01 | Unlimited | Unlimited |
| La-137 | 4,1E+02 | 7,5E+02 | 8,9E+02 | 6,2E+00 | 9,8E+02 | 1,1E+02 | Unlimited | Unlimited |
| La-140 | 4,9E-01 | 1,2E+00 | 2,1E+00 | 6,9E+01 | 6,3E+01 | 6,2E-01 | Unlimited | Unlimited |
| Lu-172 | 5,7E-01 | 3,0E+00 | 2,4E+00 | 5,0E+01 | 7,5E+01 | 2,0E+00 | Unlimited | Unlimited |
| Lu-173 | 7,8E+00 | 3,7E+01 | 3,2E+01 | 1,2E+01 | 5,0E+02 | 9,0E+00 | Unlimited | Unlimited |
| Lu-174 | 1,2E+01 | 6,2E+01 | 4,8E+01 | 9,1E+00 | 7,7E+02 | 1,4E+01 | Unlimited | Unlimited |
| Lu-174m | 2,8E+01 | 1,3E+02 | 1,1E+02 | 1,5E+01 | 1,3E+03 | 9,3E+00 | Unlimited | Unlimited |
| Lu-177 | 3,6E+01 | 1,9E+02 | 1,5E+02 | 1,3E+02 | 1,4E+03 | 8,4E-01 | Unlimited | Unlimited |
| Mg-28 | 3,2E-01 | 1,7E-01 | 8,9E-01 | 5,2E+01 | 4,6E+01 | 3,4E-01 | Unlimited | Unlimited |
| Mn-51 | 1,0E+00 | 2,6E-01 | 2,5E+00 | 1,0E+03 | 4,6E+02 | 6,3E-01 | Unlimited | Unlimited |
| Mn-52 | 3,2E-01 | 1,7E+00 | 1,3E+00 | 4,2E+01 | 4,2E+01 | 1,8E+00 | Unlimited | Unlimited |
| Mn-53 | Unlimited | Unlimited | Unlimited | 5,0E+01 | 1,6E+04 | 8,3E+01 | Unlimited | Unlimited |
| Mn-54 | 1,3E+00 | 6,2E+00 | 5,3E+00 | 9,6E+00 | 1,0E+02 | 3,1E+01 | Unlimited | Unlimited |
| Mn-56 | 5,9E-01 | 3,1E-01 | 1,6E+00 | 4,2E+02 | 2,5E+02 | 6,2E-01 | Unlimited | Unlimited |
| Mo-93 | Unlimited | 6,1E+07 | Unlimited | 6,0E+00 | 2,5E+02 | 8,6E+01 | Unlimited | Unlimited |
| Mo-99 | 4,3E+00 | 1,1E+01 | 1,8E+01 | 1,0E+02 | 1,1E+02 | 5,9E-01 | Unlimited | Unlimited |
| N-13 | 1,1E+00 | 3,4E+00 | 4,2E+00 | Unlimited | Unlimited | 6,2E-01 | Unlimited | Unlimited |
| Na-22 | 5,0E-01 | 2,6E+00 | 2,1E+00 | 1,2E+00 | 1,4E+01 | 7,1E-01 | Unlimited | Unlimited |
| Na-24 | 2,9E-01 | 1,4E+00 | 1,3E+00 | 9,6E+01 | 1,0E+02 | 6,1E-01 | Unlimited | Unlimited |

| *Radionuclide* | $Q_A$ TBq | $Q_{B,skin}$ TBq | $Q_{B,eye}$ TBq | $Q_C$ TBq | $Q_{D,ing}$ TBq | $Q_{D,skin}$ TBq | $Q_{E,eff}$ TBq | $Q_{E,skin}$ TBq |
|---|---|---|---|---|---|---|---|---|
| Nb-90 | 2,8E-01 | 1,0E+00 | 1,2E+00 | 9,8E+01 | 7,1E+01 | 6,5E-01 | Unlimited | Unlimited |
| Nb-92m | 1,1E+00 | 5,9E+00 | 4,7E+00 | 1,1E+02 | 1,4E+02 | 2,8E+01 | Unlimited | Unlimited |
| Nb-93m | 5,6E+07 | 5,8E+07 | 9,6E+07 | 1,4E+01 | 1,9E+03 | 4,7E+02 | Unlimited | Unlimited |
| Nb-94 | 6,9E-01 | 3,3E+00 | 2,8E+00 | 2,8E-01 | 2,2E+01 | 7,6E-01 | Unlimited | Unlimited |
| Nb-95 | 1,4E+00 | 6,5E+00 | 5,7E+00 | 3,9E+01 | 1,7E+02 | 4,5E+00 | Unlimited | Unlimited |
| Nb-97 | 1,6E+00 | 4,0E+00 | 6,5E+00 | 1,1E+03 | 7,7E+02 | 6,4E-01 | Unlimited | Unlimited |
| Nd-147 | 8,8E+00 | 4,0E+01 | 3,6E+01 | 5,0E+01 | 3,3E+02 | 7,2E-01 | Unlimited | Unlimited |
| Nd-149 | 3,1E+00 | 3,3E+00 | 1,3E+01 | 7,3E+02 | 6,7E+02 | 5,5E-01 | Unlimited | Unlimited |
| Ni-56 | 6,4E-01 | 3,2E+00 | 2,7E+00 | 4,2E+01 | 8,3E+01 | 1,1E+01 | Unlimited | Unlimited |
| Ni-57 | 5,8E-01 | 3,5E+00 | 2,5E+00 | 1,2E+02 | 1,0E+02 | 1,3E+00 | Unlimited | Unlimited |
| Ni-59 | 7,0E+04 | 3,0E+05 | 2,8E+05 | 3,3E+01 | 4,6E+03 | 6,4E+01 | Unlimited | Unlimited |
| Ni-63 | 6,1E+06 | 1,3E+07 | 1,5E+07 | 1,6E+01 | 1,7E+03 | 2,2E+04 | Unlimited | Unlimited |
| Ni-65 | 1,8E+00 | 5,3E-01 | 6,3E+00 | 6,1E+02 | 4,2E+02 | 6,5E-01 | Unlimited | Unlimited |
| Np-235 | 2,5E+03 | 1,4E+04 | 1,2E+04 | 9,1E+01 | 5,9E+03 | 1,1E+02 | Unlimited | Unlimited |
| Np-236 | 9,5E+00 | 5,3E+01 | 4,2E+01 | 1,0E-02 | 9,1E+00 | 5,2E-01 | Unlimited | Unlimited |
| Np-236m | 2,8E+01 | 1,5E+02 | 1,2E+02 | 9,3E+00 | 1,5E+03 | 1,7E+00 | Unlimited | Unlimited |
| Np-237 | 5,2E+01 | 3,0E+02 | 2,2E+02 | 2,1E-03 | 1,7E+00 | 1,1E+01 | Unlimited | Unlimited |
| Np-239 | 7,1E+00 | 3,8E+01 | 3,1E+01 | 1,2E+02 | 5,9E+02 | 4,8E-01 | Unlimited | Unlimited |
| Os-185 | 1,6E+00 | 7,2E+00 | 6,5E+00 | 2,4E+01 | 1,7E+02 | 1,6E+01 | Unlimited | Unlimited |
| Os-191 | 1,8E+01 | 9,4E+01 | 7,6E+01 | 6,3E+01 | 1,1E+03 | 2,2E+00 | Unlimited | Unlimited |
| Os-191m | 2,7E+02 | 1,4E+03 | 1,1E+03 | 6,3E+02 | 1,8E+04 | 1,4E+01 | Unlimited | Unlimited |
| Os-193 | 1,7E+01 | 4,7E+01 | 7,0E+01 | 2,0E+02 | 3,6E+02 | 6,4E-01 | Unlimited | Unlimited |
| Os-194 | 5,6E+00 | 3,8E-01 | 1,1E+01 | 3,8E-01 | 6,3E+01 | 6,1E-01 | Unlimited | Unlimited |
| P-32 | 3,2E+01 | 7,3E-01 | 1,5E+02 | 2,1E+01 | 2,9E+01 | 6,2E-01 | Unlimited | Unlimited |
| P-33 | 1,7E+04 | 7,3E+04 | 6,5E+04 | 9,3E+01 | 1,9E+02 | 1,5E+00 | Unlimited | Unlimited |
| Pa-230 | 1,7E+00 | 8,4E+00 | 6,9E+00 | 2,3E-01 | 1,6E+02 | 4,3E+00 | 2,1E+07 | 1,7E+08 |
| Pa-231 | 3,1E+01 | 1,6E+02 | 1,2E+02 | 5,0E-04 | 2,8E-01 | 1,0E+01 | Unlimited | Unlimited |
| Pa-233 | 5,5E+00 | 2,6E+01 | 2,3E+01 | 3,1E+01 | 4,2E+02 | 7,0E-01 | Unlimited | Unlimited |
| Pb-201 | 1,5E+00 | 7,2E+00 | 6,2E+00 | 3,9E+02 | 5,0E+02 | 3,1E+00 | Unlimited | Unlimited |
| Pb-202 | 5,6E+02 | 4,9E+03 | 2,4E+03 | 3,1E-01 | 4,2E+00 | 1,4E+02 | Unlimited | Unlimited |
| Pb-203 | 3,9E+00 | 1,9E+01 | 1,6E+01 | 2,2E+02 | 4,2E+02 | 2,6E+00 | Unlimited | Unlimited |
| Pb-205 | Unlimited | 7,6E+13 | Unlimited | 2,3E+01 | 5,5E+02 | 1,4E+02 | Unlimited | Unlimited |
| Pb-210 | 2,9E+02 | 4,7E+01 | 1,2E+03 | 3,3E-03 | 1,6E-01 | 6,7E-01 | Unlimited | Unlimited |
| Pb-212 | 7,0E-01 | 4,4E-01 | 2,7E+00 | 1,5E-01 | 8,7E+00 | 9,5E-04 | Unlimited | Unlimited |
| Pd-103 | 9,4E+03 | 3,5E+04 | 3,5E+04 | 2,2E+02 | 2,0E+03 | 8,7E+01 | Unlimited | Unlimited |
| Pd-107 | 5,1E+09 | 6,0E+09 | 8,5E+09 | 2,8E+01 | 6,8E+04 | 1,8E+05 | Unlimited | Unlimited |
| Pd-109 | 2,0E+02 | 5,2E+02 | 8,6E+02 | 2,6E+02 | 5,0E+02 | 5,3E-01 | Unlimited | Unlimited |
| Pm-143 | 3,7E+00 | 1,6E+01 | 1,5E+01 | 2,3E+01 | 3,3E+02 | 5,0E+01 | Unlimited | Unlimited |
| Pm-144 | 7,0E-01 | 3,1E+00 | 2,8E+00 | 4,2E+00 | 7,4E+01 | 1,2E+01 | Unlimited | Unlimited |

| ***Radionuclide*** | $Q_A$ TBq | $Q_{B,skin}$ TBq | $Q_{B,eye}$ TBq | $Q_C$ TBq | $Q_{D,ing}$ TBq | $Q_{D,skin}$ TBq | $Q_{E,eff}$ TBq | $Q_{E,skin}$ TBq |
|---|---|---|---|---|---|---|---|---|
| Pm-145 | 1,3E+02 | 3,5E+02 | 3,6E+02 | 9,3E+00 | 1,1E+03 | 8,4E+01 | Unlimited | Unlimited |
| Pm-147 | 2,6E+04 | 1,1E+05 | 9,8E+04 | 1,2E+01 | 6,0E+03 | 2,1E+00 | Unlimited | Unlimited |
| Pm-148m | 5,4E-01 | 1,9E+00 | 2,2E+00 | 1,1E+01 | 6,0E+01 | 7,6E-01 | Unlimited | Unlimited |
| Pm-149 | 8,0E+01 | 1,5E+02 | 3,3E+02 | 1,6E+02 | 3,3E+02 | 6,7E-01 | Unlimited | Unlimited |
| Pm-151 | 3,5E+00 | 1,5E+01 | 1,4E+01 | 2,1E+02 | 3,1E+02 | 6,7E-01 | Unlimited | Unlimited |
| Po-210 | 1,8E+02 | 1,5E+03 | 6,5E+02 | 1,8E-02 | 2,8E-01 | 7,8E+01 | Unlimited | Unlimited |
| Pr-142 | 6,3E+00 | 3,5E-01 | 1,0E+01 | 1,5E+02 | 1,5E+02 | 6,3E-01 | Unlimited | Unlimited |
| Pr-143 | 6,4E+02 | 2,9E+03 | 2,7E+03 | 5,0E+01 | 3,6E+02 | 6,8E-01 | Unlimited | Unlimited |
| Pt-188 | 4,3E-01 | 2,8E+00 | 1,9E+00 | 3,0E+01 | 5,6E+01 | 8,3E-01 | Unlimited | Unlimited |
| Pt-191 | 4,2E+00 | 2,0E+01 | 1,7E+01 | 2,6E+02 | 4,6E+02 | 3,2E+00 | Unlimited | Unlimited |
| Pt-193 | Unlimited | Unlimited | Unlimited | 2,6E+01 | 1,4E+04 | 1,3E+02 | Unlimited | Unlimited |
| Pt-193m | 1,4E+02 | 7,6E+02 | 6,2E+02 | 1,6E+02 | 4,6E+03 | 6,5E-01 | Unlimited | Unlimited |
| Pt-195m | 2,1E+01 | 1,1E+02 | 9,1E+01 | 1,3E+02 | 1,3E+03 | 5,8E-01 | Unlimited | Unlimited |
| Pt-197 | 5,6E+01 | 3,1E+02 | 2,4E+02 | 2,8E+02 | 1,1E+03 | 7,0E-01 | Unlimited | Unlimited |
| Pt-197m | 1,6E+01 | 7,6E+01 | 6,6E+01 | 9,4E+02 | 1,6E+03 | 6,1E-01 | Unlimited | Unlimited |
| Pu-236 | 1,4E+02 | 1,2E+03 | 4,9E+02 | 2,9E-03 | 2,2E+00 | 4,2E+01 | Unlimited | Unlimited |
| Pu-237 | 3,0E+01 | 1,7E+02 | 1,4E+02 | 1,8E+02 | 1,7E+03 | 4,4E+01 | Unlimited | Unlimited |
| Pu-238 | 1,6E+02 | 1,4E+03 | 5,8E+02 | 1,2E-03 | 4,6E-01 | 5,2E+01 | Unlimited | Unlimited |
| Pu-239 | 2,0E+02 | 1,6E+03 | 7,2E+02 | 1,1E-03 | 4,2E-01 | 8,2E+01 | Unlimited | Unlimited |
| Pu-240 | 2,0E+02 | 1,6E+03 | 7,2E+02 | 1,1E-03 | 4,2E-01 | 7,2E+01 | Unlimited | Unlimited |
| Pu-241 | 2,7E+05 | 1,5E+06 | 1,2E+06 | 6,0E-02 | 4,6E+01 | 2,2E+04 | Unlimited | Unlimited |
| Pu-242 | 2,1E+02 | 1,2E+03 | 7,2E+02 | 1,2E-03 | 4,2E-01 | 4,0E+02 | Unlimited | Unlimited |
| Pu-244 | 2,0E+00 | 6,0E-01 | 6,2E+00 | 1,2E-03 | 4,5E-01 | 4,0E-01 | Unlimited | Unlimited |
| Ra-223 | 3,1E+00 | 1,8E+00 | 1,3E+01 | 1,6E-02 | 1,2E+00 | 2,3E-03 | 8,2E+00 | 6,1E+01 |
| Ra-224 | 6,5E-01 | 4,3E-01 | 2,5E+00 | 2,3E-02 | 1,4E+00 | 8,3E-04 | 7,4E+02 | 5,7E+03 |
| Ra-225 | 1,3E+00 | 1,2E+00 | 5,3E+00 | 4,4E-03 | 4,5E-01 | 2,4E-04 | Unlimited | Unlimited |
| Ra-226 | 6,0E-01 | 5,7E-01 | 2,0E+00 | 2,1E-03 | 3,8E-01 | 1,7E-03 | 1,2E+03 | 9,3E+03 |
| Ra-228 | 1,3E+00 | 2,0E+00 | 5,2E+00 | 1,4E-03 | 1,5E-01 | 5,9E-01 | Unlimited | Unlimited |
| Rb (natural) | 6,9E+03 | 3,1E+04 | 2,7E+04 | 1,5E+00 | 5,8E+01 | 8,8E-01 | Unlimited | Unlimited |
| Rb-81 | 1,8E+00 | 8,1E+00 | 7,2E+00 | 7,8E+02 | 9,6E+02 | 2,1E+00 | 4,1E+00 | 2,6E+01 |
| Rb-83 | 2,2E+00 | 9,8E+00 | 9,0E+00 | 3,6E+01 | 3,1E+01 | 2,8E+01 | 1,4E+04 | 3,7E+03 |
| Rb-84 | 1,2E+00 | 2,9E+00 | 5,0E+00 | 2,4E+01 | 2,1E+01 | 2,1E+00 | Unlimited | Unlimited |
| Rb-86 | 7,9E+00 | 6,0E-01 | 3,1E+01 | 1,7E+01 | 2,9E+01 | 6,4E-01 | Unlimited | Unlimited |
| Rb-87 | 6,9E+03 | 3,1E+04 | 2,7E+04 | 1,5E+00 | 5,8E+01 | 8,8E-01 | Unlimited | Unlimited |
| Re (natural) | Unlimited | Unlimited | Unlimited | 4,2E+02 | 3,6E+04 | Unlimited | Unlimited | Unlimited |
| Re-184 | 1,3E+00 | 6,1E+00 | 5,1E+00 | 3,1E+01 | 8,3E+01 | 2,0E+00 | Unlimited | Unlimited |
| Re-184m | 3,1E+00 | 1,5E+01 | 1,3E+01 | 6,1E+00 | 7,9E+01 | 1,5E+00 | Unlimited | Unlimited |
| Re-186 | 5,9E+01 | 1,8E+02 | 2,6E+02 | 1,1E+02 | 9,1E+01 | 6,6E-01 | Unlimited | Unlimited |
| Re-187 | Unlimited | Unlimited | Unlimited | 4,2E+02 | 3,6E+04 | Unlimited | Unlimited | Unlimited |

| ***Radionuclide*** | $Q_A$ TBq | $Q_{B,skin}$ TBq | $Q_{B,eye}$ TBq | $Q_C$ TBq | $Q_{D,ing}$ TBq | $Q_{D,skin}$ TBq | $Q_{E,eff}$ TBq | $Q_{E,skin}$ TBq |
|---|---|---|---|---|---|---|---|---|
| Re-188 | 8,0E+00 | 4,4E-01 | 1,8E+01 | 1,4E+02 | 8,1E+01 | 5,7E-01 | Unlimited | Unlimited |
| Re-189 | 2,1E+01 | 1,1E+02 | 8,8E+01 | 2,2E+02 | 1,5E+02 | 6,4E-01 | Unlimited | Unlimited |
| Rh-101 | 4,5E+00 | 2,4E+01 | 1,9E+01 | 6,7E+00 | 1,3E+02 | 3,7E+00 | Unlimited | Unlimited |
| Rh-102 | 2,2E+00 | 7,5E+00 | 8,8E+00 | 6,9E+00 | 9,3E+01 | 1,7E+00 | Unlimited | Unlimited |
| Rh-102m | 5,1E-01 | 2,4E+00 | 2,1E+00 | 1,3E+00 | 2,2E+01 | 1,1E+01 | Unlimited | Unlimited |
| Rh-103m | 1,3E+05 | 3,0E+05 | 3,3E+05 | 3,1E+04 | 5,4E+05 | 6,8E+02 | Unlimited | Unlimited |
| Rh-105 | 1,5E+01 | 6,9E+01 | 6,0E+01 | 3,3E+02 | 1,0E+03 | 9,0E-01 | Unlimited | Unlimited |
| Rh-99 | 2,0E+00 | 9,5E+00 | 8,3E+00 | 6,8E+01 | 1,9E+02 | 4,3E+00 | Unlimited | Unlimited |
| Rn-222 | 6,0E-01 | 5,6E-01 | 2,0E+00 | 1,1E-01 | 4,0E+02 | 1,7E-03 | 1,2E+03 | 9,3E+03 |
| Ru-103 | 2,2E+00 | 9,6E+00 | 8,8E+00 | 3,1E+01 | 1,9E+02 | 2,0E+00 | Unlimited | Unlimited |
| Ru-105 | 1,5E+00 | 4,3E+00 | 5,9E+00 | 3,9E+02 | 3,9E+02 | 5,2E-01 | Unlimited | Unlimited |
| Ru-106 | 1,3E+00 | 1,7E-01 | 1,1E+00 | 7,3E-01 | 1,9E+01 | 5,9E-01 | Unlimited | Unlimited |
| Ru-97 | 5,2E+00 | 2,7E+01 | 2,2E+01 | 6,1E+02 | 5,6E+02 | 1,1E+01 | Unlimited | Unlimited |
| S-35 | 6,3E+04 | 2,4E+05 | 2,2E+05 | 6,4E+01 | 1,9E+03 | 3,8E+00 | Unlimited | Unlimited |
| Sb-119 | 5,4E+03 | 5,5E+03 | 8,4E+03 | 2,9E+03 | 2,3E+03 | 8,2E+01 | Unlimited | Unlimited |
| Sb-120m | 4,5E-01 | 2,6E+00 | 1,9E+00 | 5,9E+01 | 6,0E+01 | 3,0E+00 | Unlimited | Unlimited |
| Sb-122 | 2,3E+00 | 1,0E+00 | 8,7E+00 | 8,1E+01 | 1,1E+02 | 6,5E-01 | Unlimited | Unlimited |
| Sb-124 | 5,9E-01 | 9,0E-01 | 2,4E+00 | 6,8E+00 | 4,6E+01 | 7,3E-01 | Unlimited | Unlimited |
| Sb-125 | 2,6E+00 | 1,1E+01 | 1,0E+01 | 3,3E+00 | 1,4E+02 | 1,5E+00 | Unlimited | Unlimited |
| Sb-126 | 3,9E-01 | 1,0E+00 | 1,6E+00 | 1,9E+01 | 3,9E+01 | 6,7E-01 | Unlimited | Unlimited |
| Sc-44 | 5,1E-01 | 9,4E-01 | 2,1E+00 | 3,3E+02 | 2,2E+02 | 6,4E-01 | Unlimited | Unlimited |
| Sc-46 | 5,4E-01 | 2,9E+00 | 2,3E+00 | 8,2E+00 | 6,6E+01 | 9,5E-01 | Unlimited | Unlimited |
| Sc-47 | 1,1E+01 | 6,4E+01 | 5,0E+01 | 1,9E+02 | 7,6E+02 | 8,0E-01 | Unlimited | Unlimited |
| Sc-48 | 3,3E-01 | 1,9E+00 | 1,4E+00 | 6,4E+01 | 5,6E+01 | 6,8E-01 | Unlimited | Unlimited |
| Se-75 | 3,1E+00 | 1,6E+01 | 1,3E+01 | 2,8E+01 | 2,0E+01 | 8,8E+00 | Unlimited | Unlimited |
| Se-79 | 6,0E+04 | 2,2E+05 | 2,1E+05 | 3,9E+00 | 2,6E+01 | 3,4E+00 | Unlimited | Unlimited |
| Si-31 | 7,6E+01 | 1,7E+00 | 5,9E+02 | 6,9E+02 | 5,1E+02 | 6,3E-01 | Unlimited | Unlimited |
| Si-32 | 2,3E+04 | 9,6E+04 | 8,7E+04 | 1,5E-01 | 4,6E+02 | 1,8E+00 | Unlimited | Unlimited |
| Sm-145 | 5,2E+01 | 1,6E+02 | 1,6E+02 | 2,6E+01 | 8,3E+02 | 5,3E+01 | Unlimited | Unlimited |
| Sm-147 | 5,5E+02 | 4,8E+03 | 2,4E+03 | 4,6E-03 | 1,7E+00 | Unlimited | Unlimited | Unlimited |
| Sm-151 | 2,7E+06 | 6,4E+06 | 6,9E+06 | 1,2E+01 | 4,2E+03 | 1,6E+03 | Unlimited | Unlimited |
| Sm-153 | 2,7E+01 | 1,2E+02 | 1,1E+02 | 1,7E+02 | 5,8E+02 | 6,8E-01 | Unlimited | Unlimited |
| Sn-113 | 4,3E+00 | 1,9E+01 | 1,7E+01 | 1,5E+01 | 1,9E+02 | 1,6E+00 | Unlimited | Unlimited |
| Sn-117m | 8,9E+00 | 5,0E+01 | 3,9E+01 | 6,1E+01 | 5,4E+02 | 4,7E-01 | Unlimited | Unlimited |
| Sn-119m | 9,3E+03 | 9,9E+03 | 1,5E+04 | 1,9E+01 | 9,4E+02 | 4,5E+01 | Unlimited | Unlimited |
| Sn-121m | 2,6E+03 | 6,4E+03 | 7,2E+03 | 1,7E+00 | 3,9E+02 | 9,7E-01 | Unlimited | Unlimited |
| Sn-123 | 6,6E+01 | 2,4E+00 | 3,8E+02 | 4,6E+00 | 1,1E+02 | 6,5E-01 | Unlimited | Unlimited |
| Sn-125 | 2,3E+00 | 3,3E-01 | 4,6E+00 | 2,2E+01 | 7,3E+01 | 6,5E-01 | Unlimited | Unlimited |
| Sn-126 | 6,6E-01 | 5,2E-01 | 2,6E+00 | 9,3E-02 | 1,9E+01 | 4,4E-01 | Unlimited | Unlimited |

| ***Radionuclide*** | $Q_A$ TBq | $Q_{B,skin}$ TBq | $Q_{B,eye}$ TBq | $Q_C$ TBq | $Q_{D,ing}$ TBq | $Q_{D,skin}$ TBq | $Q_{E,eff}$ TBq | $Q_{E,skin}$ TBq |
|---|---|---|---|---|---|---|---|---|
| Sr-82 | 7,2E-01 | 1,5E-01 | 8,4E-01 | 5,4E+00 | 2,1E+01 | 6,1E-01 | Unlimited | Unlimited |
| Sr-83 | 1,3E+00 | 5,4E+00 | 5,5E+00 | 2,1E+02 | 1,9E+02 | 2,1E+00 | Unlimited | Unlimited |
| Sr-85 | 2,2E+00 | 9,7E+00 | 8,8E+00 | 4,6E+01 | 1,3E+02 | 2,3E+01 | Unlimited | Unlimited |
| Sr-85m | 5,5E+00 | 3,0E+01 | 2,3E+01 | 1,5E+04 | 1,0E+04 | 1,4E+01 | Unlimited | Unlimited |
| Sr-87m | 3,5E+00 | 1,6E+01 | 1,4E+01 | 2,8E+03 | 2,2E+03 | 3,2E+00 | Unlimited | Unlimited |
| Sr-89 | 6,8E+01 | 1,4E+00 | 6,0E+02 | 8,8E+00 | 5,6E+01 | 6,4E-01 | Unlimited | Unlimited |
| Sr-90 | 6,4E+00 | 2,8E-01 | 6,8E+00 | 1,3E-01 | 2,0E+00 | 3,4E-01 | Unlimited | Unlimited |
| Sr-91 | 9,5E-01 | 5,6E-01 | 2,8E+00 | 1,8E+02 | 1,6E+02 | 6,1E-01 | Unlimited | Unlimited |
| Sr-92 | 8,3E-01 | 3,6E+00 | 3,6E+00 | 3,1E+02 | 2,8E+02 | 7,6E-01 | Unlimited | Unlimited |
| Ta-178m | 1,0E+00 | 4,8E+00 | 4,2E+00 | 9,3E+02 | 9,6E+02 | 9,0E-01 | Unlimited | Unlimited |
| Ta-179 | 7,2E+01 | 3,3E+02 | 2,8E+02 | 7,1E+01 | 3,1E+03 | 1,0E+02 | Unlimited | Unlimited |
| Ta-182 | 8,7E-01 | 4,8E+00 | 3,7E+00 | 6,7E+00 | 1,0E+02 | 6,4E-01 | Unlimited | Unlimited |
| Tb-149 | 8,4E-01 | 3,1E+00 | 3,5E+00 | 1,2E+01 | 5,4E+02 | 2,3E+00 | Unlimited | Unlimited |
| Tb-157 | 5,9E+02 | 1,9E+03 | 1,9E+03 | 2,6E+01 | 6,9E+03 | 1,5E+02 | Unlimited | Unlimited |
| Tb-158 | 1,4E+00 | 7,2E+00 | 5,7E+00 | 5,0E-01 | 8,3E+01 | 2,0E+00 | Unlimited | Unlimited |
| Tb-160 | 9,8E-01 | 5,0E+00 | 4,1E+00 | 8,9E+00 | 1,0E+02 | 6,4E-01 | Unlimited | Unlimited |
| Tb-161 | 6,3E+01 | 2,7E+02 | 2,4E+02 | 9,4E+01 | 9,3E+02 | 8,3E-01 | Unlimited | Unlimited |
| Tc-95 | 1,4E+00 | 6,4E+00 | 5,6E+00 | 5,0E+02 | 3,6E+02 | 2,9E+01 | Unlimited | Unlimited |
| Tc-95m | 1,6E+00 | 7,4E+00 | 6,4E+00 | 3,3E+01 | 1,1E+02 | 9,3E+00 | Unlimited | Unlimited |
| Tc-96 | 4,3E-01 | 2,1E+00 | 1,8E+00 | 7,0E+01 | 5,6E+01 | 1,3E+01 | Unlimited | Unlimited |
| Tc-96m | 2,6E+01 | 1,4E+02 | 1,1E+02 | 7,8E+03 | 5,9E+03 | 1,5E+02 | Unlimited | Unlimited |
| Tc-97 | Unlimited | 9,8E+06 | Unlimited | 8,5E+00 | 1,1E+03 | 9,1E+01 | Unlimited | Unlimited |
| Tc-97m | 3,9E+03 | 2,1E+04 | 1,7E+04 | 3,1E+01 | 2,3E+02 | 1,8E+00 | Unlimited | Unlimited |
| Tc-98 | 7,6E-01 | 3,4E+00 | 3,1E+00 | 3,1E-01 | 2,9E+01 | 8,2E-01 | Unlimited | Unlimited |
| Tc-99 | 8,5E+03 | 3,8E+04 | 3,4E+04 | 1,7E+00 | 1,9E+02 | 1,1E+00 | Unlimited | Unlimited |
| Tc-99m | 1,0E+01 | 5,7E+01 | 4,5E+01 | 3,9E+03 | 3,6E+03 | 5,0E+00 | Unlimited | Unlimited |
| Te-118 | 1,2E+00 | 2,4E-01 | 2,0E+00 | 2,8E+01 | 4,2E+01 | 8,1E-01 | Unlimited | Unlimited |
| Te-119 | 1,5E+00 | 6,7E+00 | 5,9E+00 | 5,3E+02 | 3,9E+02 | 1,4E+01 | Unlimited | Unlimited |
| Te-119m | 7,5E-01 | 4,4E+00 | 3,2E+00 | 1,0E+02 | 8,9E+01 | 6,2E+00 | Unlimited | Unlimited |
| Te-121 | 1,9E+00 | 8,5E+00 | 7,8E+00 | 1,0E+02 | 1,6E+02 | 2,7E+01 | Unlimited | Unlimited |
| Te-121m | 5,8E+00 | 3,2E+01 | 2,5E+01 | 1,0E+01 | 1,2E+02 | 2,7E+00 | Unlimited | Unlimited |
| Te-123m | 9,3E+00 | 5,2E+01 | 4,1E+01 | 1,9E+01 | 1,9E+02 | 1,5E+00 | Unlimited | Unlimited |
| Te-125m | 6,9E+02 | 1,2E+03 | 1,5E+03 | 3,3E+01 | 2,6E+02 | 1,1E+00 | Unlimited | Unlimited |
| Te-127 | 1,9E+02 | 8,8E+02 | 7,9E+02 | 6,3E+02 | 1,1E+03 | 7,3E-01 | Unlimited | Unlimited |
| Te-127m | 1,8E+02 | 7,2E+02 | 6,7E+02 | 9,3E+00 | 1,0E+02 | 5,8E-01 | Unlimited | Unlimited |
| Te-129 | 1,6E+01 | 2,4E+00 | 7,1E+01 | 1,2E+03 | 8,2E+02 | 6,4E-01 | Unlimited | Unlimited |
| Te-129m | 1,4E+01 | 1,7E+00 | 5,9E+01 | 1,1E+01 | 5,4E+01 | 4,9E-01 | Unlimited | Unlimited |
| Te-131m | 7,1E-01 | 1,3E+00 | 2,9E+00 | 4,5E+01 | 4,5E+01 | 5,5E-01 | Unlimited | Unlimited |
| Te-132 | 4,3E-01 | 8,3E-01 | 1,7E+00 | 2,6E+01 | 2,3E+01 | 4,2E-01 | Unlimited | Unlimited |

| ***Radionuclide*** | $Q_A$ TBq | $Q_{B,skin}$ TBq | $Q_{B,eye}$ TBq | $Q_C$ TBq | $Q_{D,ing}$ TBq | $Q_{D,skin}$ TBq | $Q_{E,eff}$ TBq | $Q_{E,skin}$ TBq |
|---|---|---|---|---|---|---|---|---|
| Th (natural) | 4,7E-01 | 3,9E-01 | 1,8E+00 | 2,9E-04 | 9,5E-04 | 1,1E-01 | 5,7E+03 | 7,3E+02 |
| Th-227 | 9,1E+00 | 4,8E+01 | 3,8E+01 | 1,5E-02 | 3,9E+01 | 3,4E+00 | Unlimited | Unlimited |
| Th-228 | 7,4E-01 | 4,9E-01 | 2,8E+00 | 1,4E-03 | 7,6E-01 | 9,4E-04 | 7,3E+02 | 5,7E+03 |
| Th-229 | 1,5E+01 | 8,4E+01 | 6,5E+01 | 2,9E-04 | 2,4E-01 | 2,1E+00 | Unlimited | Unlimited |
| Th-230 | 2,6E+02 | 2,1E+03 | 9,9E+02 | 1,5E-03 | 8,3E-01 | 1,6E+02 | Unlimited | Unlimited |
| Th-231 | 1,3E+02 | 6,8E+02 | 5,6E+02 | 2,9E+02 | 2,9E+03 | 1,4E+00 | Unlimited | Unlimited |
| Th-232 | 5,1E+02 | 4,3E+03 | 2,2E+03 | 5,0E-04 | 7,1E-01 | 2,9E+02 | Unlimited | Unlimited |
| Th-234 | 8,0E+00 | 3,7E-01 | 1,2E+01 | 1,0E+01 | 8,5E+01 | 5,2E-01 | Unlimited | Unlimited |
| Ti-44 | 4,8E-01 | 9,2E-01 | 2,0E+00 | 1,2E-01 | 2,1E+01 | 6,3E-01 | Unlimited | Unlimited |
| Tl-200 | 8,6E-01 | 4,1E+00 | 3,6E+00 | 2,4E+02 | 2,4E+02 | 5,6E+00 | Unlimited | Unlimited |
| Tl-201 | 1,6E+01 | 8,6E+01 | 6,9E+01 | 5,0E+02 | 6,9E+02 | 4,7E+00 | Unlimited | Unlimited |
| Tl-202 | 2,4E+00 | 1,1E+01 | 9,9E+00 | 1,5E+02 | 1,1E+02 | 1,1E+01 | Unlimited | Unlimited |
| Tl-204 | 5,7E+02 | 2,9E+03 | 2,4E+03 | 2,3E+00 | 6,2E+01 | 7,7E-01 | Unlimited | Unlimited |
| Tm-167 | 9,5E+00 | 4,7E+01 | 3,9E+01 | 1,0E+02 | 6,1E+02 | 8,8E-01 | Unlimited | Unlimited |
| Tm-170 | 2,4E+02 | 1,1E+03 | 1,0E+03 | 7,9E+00 | 3,3E+02 | 6,7E-01 | Unlimited | Unlimited |
| Tm-171 | 2,9E+03 | 1,3E+04 | 1,1E+04 | 4,2E+01 | 2,5E+04 | 9,9E+01 | Unlimited | Unlimited |
| U (depleted) | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited |
| U (natural) | 5,5E-01 | 2,2E-01 | 1,7E+00 | 4,2E-04 | 1,7E-03 | 6,6E-02 | 9,2E+03 | 1,2E+03 |
| U (enriched to less than 20%, except slow lung absorption) | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited |
| U (enriched to less than 20%) | 4,8E-01 |  |  | 2,5E-03 | Unlimited |  | Unlimited | Unlimited |
| U (enriched to less than 10%) | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited |
| U (natural, purified) | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited | Unlimited |
| U-230 (fast lung absorption) | 1,3E+01 | 1,1E+02 | 5,0E+01 | 3,1E-02 | 3,9E+00 | 1,6E-03 | 6,0E+02 | 4,7E+03 |
| U-230 (medium lung absorption) | 1,3E+01 | 1,1E+02 | 5,0E+01 | 9,4E-03 | 3,9E+00 | 1,6E-03 | 6,0E+02 | 4,7E+03 |
| U-230 (slow lung absorption) | 1,3E+01 | 1,1E+02 | 5,0E+01 | 9,1E-03 | 3,9E+00 | 1,6E-03 | 6,0E+02 | 4,7E+03 |
| U-232 (fast lung absorption) | 1,7E+02 | 1,4E+03 | 6,4E+02 | 2,8E-02 | 2,8E-01 | 5,1E+01 | Unlimited | Unlimited |
| U-232 (medium lung absorption) | 1,7E+02 | 1,4E+03 | 6,4E+02 | 1,5E-03 | 2,8E-01 | 5,1E+01 | Unlimited | Unlimited |
| U-232 (slow lung absorption) | 1,7E+02 | 1,4E+03 | 6,4E+02 | 4,2E-04 | 2,8E-01 | 5,1E+01 | Unlimited | Unlimited |
| U-233 (fast lung absorption) | 2,4E+02 | 1,9E+03 | 9,0E+02 | 7,7E-02 | 1,4E+00 | 2,4E+02 | Unlimited | Unlimited |
| U-233 (medium lung absorption) | 2,4E+02 | 1,9E+03 | 9,0E+02 | 5,8E-03 | 1,4E+00 | 2,4E+02 | Unlimited | Unlimited |
| U-233 (slow lung absorption) | 2,4E+02 | 1,9E+03 | 9,0E+02 | 2,2E-03 | 1,4E+00 | 2,4E+02 | Unlimited | Unlimited |
| U-234 (fast lung absorption) | 2,6E+02 | 2,1E+03 | 9,6E+02 | 7,8E-02 | 1,4E+00 | 1,9E+02 | Unlimited | Unlimited |
| U-234 (medium lung absorption) | 2,6E+02 | 2,1E+03 | 9,6E+02 | 5,9E-03 | 1,4E+00 | 1,9E+02 | Unlimited | Unlimited |
| U-234 (slow lung absorption) | 2,6E+02 | 2,1E+03 | 9,6E+02 | 2,2E-03 | 1,4E+00 | 1,9E+02 | Unlimited | Unlimited |
| U-235 (all lung types absorption) | 7,1E+00 | 4,0E+01 | 3,1E+01 | 2,4E-03 | 1,6E+00 | 1,2E+00 | Unlimited | Unlimited |
| U-236 (fast lung absorption) | 3,3E+02 | 2,7E+03 | 1,3E+03 | 8,3E-02 | 1,6E+00 | 2,6E+02 | Unlimited | Unlimited |
| U-236 (medium lung absorption) | 3,3E+02 | 2,7E+03 | 1,3E+03 | 6,3E-03 | 1,6E+00 | 2,6E+02 | Unlimited | Unlimited |
| U-236 (slow lung absorption) | 3,3E+02 | 2,7E+03 | 1,3E+03 | 2,4E-03 | 1,6E+00 | 2,6E+02 | Unlimited | Unlimited |

| ***Radionuclide*** | $Q_A$ TBq | $Q_{B,skin}$ TBq | $Q_{B,eye}$ TBq | $Q_C$ TBq | $Q_{D,ing}$ TBq | $Q_{D,skin}$ TBq | $Q_{E,eff}$ TBq | $Q_{E,skin}$ TBq |
|---|---|---|---|---|---|---|---|---|
| U-238 (all lung types absorption) | 4,3E+02 | 3,2E+03 | 1,7E+03 | 2,5E-03 | 1,6E+00 | 3,7E+02 | Unlimited | Unlimited |
| V-48 | 3,8E-01 | 2,0E+00 | 1,6E+00 | 2,2E+01 | 3,6E+01 | 1,2E+00 | Unlimited | Unlimited |
| V-49 | Unlimited | Unlimited | Unlimited | 6,9E+02 | 8,8E+03 | 1,2E+02 | Unlimited | Unlimited |
| W-178 | 1,0E+01 | 4,3E+01 | 4,1E+01 | 1,3E+02 | 7,6E+02 | 4,9E+00 | Unlimited | Unlimited |
| W-181 | 4,3E+01 | 2,0E+02 | 1,7E+02 | 1,5E+02 | 1,6E+03 | 8,3E+01 | Unlimited | Unlimited |
| W-185 | 3,9E+03 | 1,9E+04 | 1,6E+04 | 2,9E+01 | 8,2E+02 | 9,4E-01 | Unlimited | Unlimited |
| W-187 | 2,5E+00 | 7,6E+00 | 9,9E+00 | 2,2E+02 | 2,8E+02 | 6,8E-01 | Unlimited | Unlimited |
| W-188 | 7,8E+00 | 4,4E-01 | 1,7E+01 | 4,4E+00 | 4,0E+01 | 3,8E-01 | Unlimited | Unlimited |
| Xe-122 | 8,5E-01 | 1,9E-01 | 1,1E+00 | Unlimited | Unlimited | 7,5E-01 | 9,8E+00 | 6,3E+01 |
| Xe-123 | 1,8E+00 | 3,4E+00 | 7,4E+00 | Unlimited | Unlimited | Unlimited | 7,2E-01 | 4,7E+00 |
| Xe-127 | 4,7E+00 | 2,4E+01 | 2,0E+01 | Unlimited | Unlimited | Unlimited | 1,9E+00 | 1,4E+01 |
| Xe-131m | 2,7E+02 | 9,0E+02 | 9,0E+02 | Unlimited | Unlimited | Unlimited | 6,5E+01 | 5,9E+01 |
| Xe-133 | 4,2E+01 | 2,1E+02 | 1,8E+02 | Unlimited | Unlimited | Unlimited | 1,7E+01 | 4,9E+01 |
| Xe-135 | 4,7E+00 | 2,4E+01 | 2,0E+01 | Unlimited | Unlimited | Unlimited | 1,9E+00 | 7,3E+00 |
| Y-87 | 1,4E+00 | 6,3E+00 | 5,7E+00 | 1,8E+02 | 1,8E+02 | 2,8E+00 | Unlimited | Unlimited |
| Y-88 | 4,3E-01 | 2,9E+00 | 1,8E+00 | 7,4E+00 | 5,5E+01 | 1,7E+01 | Unlimited | Unlimited |
| Y-89m | 1,2E+00 | 6,1E+00 | 4,9E+00 | Unlimited | Unlimited | 3,0E+01 | Unlimited | Unlimited |
| Y-90 | 6,4E+00 | 2,8E-01 | 6,8E+00 | 5,9E+01 | 8,9E+01 | 6,2E-01 | Unlimited | Unlimited |
| Y-91 | 4,8E+01 | 1,1E+00 | 3,6E+02 | 7,5E+00 | 1,3E+02 | 6,4E-01 | Unlimited | Unlimited |
| Y-91m | 2,1E+00 | 9,0E+00 | 8,2E+00 | 6,9E+03 | 4,6E+03 | 9,9E+00 | Unlimited | Unlimited |
| Y-92 | 1,1E+00 | 1,7E-01 | 9,0E-01 | 2,8E+02 | 1,7E+02 | 5,9E-01 | Unlimited | Unlimited |
| Y-93 | 2,3E+00 | 2,0E-01 | 1,9E+00 | 1,7E+02 | 1,3E+02 | 6,0E-01 | Unlimited | Unlimited |
| Yb-169 | 4,3E+00 | 2,2E+01 | 1,8E+01 | 3,1E+01 | 2,9E+02 | 1,2E+00 | Unlimited | Unlimited |
| Yb-175 | 2,9E+01 | 1,4E+02 | 1,2E+02 | 1,9E+02 | 1,5E+03 | 9,7E-01 | Unlimited | Unlimited |
| Zn-65 | 1,9E+00 | 1,1E+01 | 8,0E+00 | 1,3E+01 | 1,2E+01 | 2,1E+01 | Unlimited | Unlimited |
| Zn-69 | 6,3E+02 | 3,1E+03 | 2,6E+03 | 1,8E+03 | 1,7E+03 | 6,7E-01 | Unlimited | Unlimited |
| Zn-69m | 2,6E+00 | 1,2E+01 | 1,1E+01 | 2,8E+02 | 2,9E+02 | 5,9E-01 | Unlimited | Unlimited |
| Zr-88 | 2,9E+00 | 1,3E+01 | 1,2E+01 | 9,1E+00 | 2,3E+02 | 1,3E+01 | Unlimited | Unlimited |
| Zr-89 | 9,4E-01 | 4,6E+00 | 3,9E+00 | 1,3E+02 | 1,3E+02 | 2,4E+00 | Unlimited | Unlimited |
| Zr-93 | 5,3E+06 | 1,2E+07 | 1,3E+07 | 6,9E+00 | 1,0E+03 | 3,1E+03 | Unlimited | Unlimited |
| Zr-95 | 1,5E+00 | 6,7E+00 | 6,0E+00 | 1,1E+01 | 1,6E+02 | 9,5E-01 | Unlimited | Unlimited |
| Zr-97 | 6,5E-01 | 4,4E-01 | 2,6E+00 | 7,8E+01 | 7,1E+01 | 3,0E-01 | Unlimited | Unlimited |

*N.B.: the criteria defining "unlimited values" (masses of 1 t for $Q_A$ and $Q_B$, 10 mg for $Q_C$ and 10 mg/cm$^2$ for $Q_D$) and the upper threshold of 1 000 TBq are not applied here – but criteria and threshold were considered in Table 5 to derive $A_1$ and $A_2$ values. Therefore, the Q values listed in Table 7 are raw. When "Unlimited" is mentioned:*

- *for $Q_A$, $Q_B$ and $Q_{D,skin}$: the radiations were too weak to reach the scoring element, resulting in a zero dose;*
- *for $Q_C$ and $Q_{D,ing}$: ICRP provides no data (because the dose coefficients would be non-significant, especially for radionuclides with short half-lives), and radioactive noble gases have no solid daughter;*
- *for $Q_E$: same as above and there are no radioactive noble gas in the decay chain (parents and daughters).*

# List of updated dose coefficients

***Table 8. Dose coefficients of radionuclides (SSG-26 Table I.1 and II.2) in the proposed update of the Q system***

| ***Radionuclide*** | $\dot{e}_{eff}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,skin}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,eye}$ Sv.h$^{-1}$.Bq$^{-1}$ | $e_{inh}$ Sv.Bq$^{-1}$ | $e_{ing}$ Sv.Bq$^{-1}$ | $\dot{h}_{skin}$ Sv.h$^{-1}$/(Bq.m$^{-2}$) | $\dot{h}_{sub,eff}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) | $\dot{h}_{sub,eq}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| Ac-225 | 2,5E-14 | 2,6E-13 | 3,1E-14 | 3,0E-06 | 2,2E-08 | 1,4E-07 | - | - |
| Ac-226 | 1,7E-14 | 2,9E-14 | 2,0E-14 | 7,8E-07 | 2,3E-10 | 5,3E-08 | 9,6E-14 | 1,2E-13 |
| Ac-227 | 6,6E-17 | 2,1E-16 | 8,2E-17 | 1,1E-04 | 1,7E-07 | 2,4E-12 | - | - |
| Ac-228 | 7,9E-14 | 5,0E-13 | 9,6E-14 | 1,3E-08 | 1,6E-10 | 1,7E-10 | - | - |
| Ag-105 | 4,4E-14 | 9,5E-14 | 5,4E-14 | 9,3E-10 | 3,5E-10 | 6,9E-12 | - | - |
| Ag-108m | 1,5E-13 | 4,1E-13 | 1,8E-13 | 1,6E-07 | 1,6E-09 | 2,2E-11 | - | - |
| Ag-110m | 2,5E-13 | 5,8E-13 | 3,1E-13 | 1,7E-08 | 2,3E-09 | 5,1E-11 | - | - |
| Ag-111 | 2,5E-15 | 6,7E-15 | 3,1E-15 | 7,4E-10 | 2,1E-10 | 1,5E-10 | - | - |
| Al-26 | 2,4E-13 | 4,7E-13 | 2,8E-13 | 3,9E-07 | 1,3E-09 | 1,4E-10 | - | - |
| Am-241 | 2,0E-15 | 3,5E-15 | 2,5E-15 | 2,9E-05 | 5,9E-08 | 2,9E-12 | - | - |
| Am-242m | 1,3E-15 | 2,4E-15 | 1,4E-15 | 2,6E-05 | 6,0E-08 | 1,1E-10 | - | - |
| Am-243 | 1,8E-14 | 3,4E-14 | 2,1E-14 | 2,9E-05 | 5,8E-08 | 2,1E-10 | - | - |
| Ar-37 | - | - | - | - | - | - | - | - |
| Ar-39 | 6,7E-17 | 1,4E-16 | 8,1E-17 | - | - | - | 3,5E-13 | 3,1E-11 |
| Ar-41 | 1,2E-13 | 2,7E-13 | 1,4E-13 | - | - | - | 2,2E-10 | 3,4E-10 |
| As-72 | 1,8E-13 | 4,8E-12 | 4,1E-13 | 7,4E-10 | 8,2E-10 | 1,5E-10 | - | - |
| As-73 | 3,1E-16 | 7,2E-16 | 4,1E-16 | 9,1E-10 | 1,1E-10 | 3,7E-12 | - | - |
| As-74 | 7,1E-14 | 2,6E-13 | 8,8E-14 | 1,6E-09 | 6,6E-10 | 1,0E-10 | - | - |
| As-76 | 6,6E-14 | 4,4E-12 | 2,3E-13 | 5,6E-10 | 5,7E-10 | 1,7E-10 | - | - |
| As-77 | 8,0E-16 | 1,6E-15 | 9,7E-16 | 1,9E-10 | 9,7E-11 | 1,4E-10 | - | - |
| At-211 | 4,2E-15 | 6,8E-15 | 5,0E-15 | 8,1E-08 | 1,2E-07 | 2,4E-08 | - | - |
| Au-193 | 1,3E-14 | 2,5E-14 | 1,5E-14 | 5,2E-11 | 3,9E-11 | 4,0E-11 | - | - |
| Au-194 | 9,0E-14 | 1,8E-13 | 1,1E-13 | 2,0E-10 | 2,6E-10 | 1,9E-11 | - | - |
| Au-195 | 5,3E-15 | 1,0E-14 | 6,2E-15 | 1,4E-09 | 1,0E-10 | 1,6E-11 | - | - |
| Au-198 | 3,7E-14 | 8,3E-14 | 4,5E-14 | 4,2E-10 | 2,7E-10 | 1,5E-10 | - | - |
| Au-199 | 7,5E-15 | 1,3E-14 | 8,6E-15 | 3,0E-10 | 5,4E-11 | 1,4E-10 | - | - |
| Ba-131 | 4,1E-14 | 9,3E-14 | 5,1E-14 | 7,2E-10 | 5,5E-10 | 4,4E-11 | - | - |
| Ba-133 | 3,2E-14 | 7,0E-14 | 3,9E-14 | 2,4E-08 | 1,0E-09 | 1,2E-11 | - | - |
| Ba-133m | 4,5E-15 | 9,6E-15 | 5,6E-15 | 1,9E-10 | 6,9E-11 | 1,6E-10 | - | - |
| Ba-135m | 3,8E-15 | 8,1E-15 | 4,8E-15 | 1,4E-10 | 5,9E-11 | 1,6E-10 | - | - |
| Ba-140 | 2,5E-13 | 9,7E-13 | 3,0E-13 | 4,3E-09 | 1,6E-09 | 3,3E-10 | - | - |
| Be-10 | 8,3E-17 | 1,7E-16 | 1,0E-16 | 8,9E-08 | 4,4E-10 | 1,6E-10 | - | - |
| Be-7 | 4,6E-15 | 1,0E-14 | 5,7E-15 | 8,7E-11 | 2,1E-11 | 1,9E-13 | - | - |
| Bi-205 | 1,5E-13 | 2,6E-13 | 1,7E-13 | 1,1E-09 | 6,1E-10 | 1,3E-11 | - | - |
| Bi-206 | 3,0E-13 | 5,7E-13 | 3,6E-13 | 1,3E-09 | 1,2E-09 | 8,5E-11 | - | - |

| ***Radionuclide*** | $\dot{e}_{eff}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,skin}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,eye}$ Sv.h$^{-1}$.Bq$^{-1}$ | $e_{inh}$ Sv.Bq$^{-1}$ | $e_{ing}$ Sv.Bq$^{-1}$ | $\dot{h}_{skin}$ Sv.h$^{-1}$/(Bq.m$^{-2}$) | $\dot{h}_{sub,eff}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) | $\dot{h}_{sub,eq}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| Bi-207 | 1,4E-13 | 3,6E-13 | 1,7E-13 | 1,3E-07 | 8,3E-10 | 2,5E-11 | - | - |
| Bi-210 | 2,6E-16 | 2,1E-14 | 3,0E-16 | 8,7E-08 | 1,1E-09 | 1,5E-10 | - | - |
| Bi-210m | 2,4E-14 | 5,8E-13 | 2,9E-14 | 2,4E-05 | 2,5E-08 | 1,9E-10 | - | - |
| Bi-212 | 1,2E-13 | 2,0E-12 | 1,6E-13 | 2,9E-08 | 1,1E-10 | 9,6E-08 | - | - |
| Bk-247 | 1,2E-14 | 2,3E-14 | 1,4E-14 | 3,0E-05 | 5,4E-08 | 7,3E-11 | - | - |
| Bk-249 | 5,2E-19 | 1,5E-18 | 7,6E-19 | 6,7E-08 | 1,2E-10 | 6,1E-12 | - | - |
| Br-76 | 2,6E-13 | 3,0E-12 | 4,9E-13 | 4,9E-10 | 4,5E-10 | 9,9E-11 | - | - |
| Br-77 | 2,8E-14 | 6,1E-14 | 3,5E-14 | 8,1E-11 | 8,6E-11 | 6,8E-12 | - | - |
| Br-82 | 2,4E-13 | 5,1E-13 | 2,9E-13 | 5,7E-10 | 4,9E-10 | 1,2E-10 | - | - |
| C-11 | 9,4E-14 | 2,2E-13 | 1,2E-13 | 1,8E-11 | 2,7E-11 | 1,6E-10 | - | - |
| C-14 | 1,4E-18 | 3,9E-18 | 2,1E-18 | 1,2E-08 | 1,6E-10 | 2,5E-11 | - | - |
| Ca-41 | - | - | - | 6,0E-10 | 5,7E-12 | 3,0E-13 | - | - |
| Ca-45 | 6,2E-18 | 1,4E-17 | 8,0E-18 | 1,8E-09 | 2,7E-10 | 6,9E-11 | - | - |
| Ca-47 | 1,3E-13 | 6,9E-13 | 1,5E-13 | 2,0E-09 | 9,4E-10 | 6,3E-10 | - | - |
| Cd-109 | 2,4E-16 | 4,6E-16 | 2,7E-16 | 4,7E-09 | 1,0E-09 | 3,9E-11 | - | - |
| Cd-113m | 5,6E-17 | 1,1E-16 | 6,8E-17 | 5,3E-08 | 1,1E-08 | 1,3E-10 | - | - |
| Cd-115 | 3,3E-14 | 7,9E-14 | 4,1E-14 | 5,3E-10 | 3,1E-10 | 2,5E-10 | - | - |
| Cd-115m | 5,0E-15 | 8,9E-13 | 5,1E-15 | 5,4E-09 | 9,9E-10 | 1,6E-10 | - | - |
| Ce-132 | 2,1E-14 | 4,0E-14 | 2,5E-14 | 1,0E-10 | 1,4E-10 | 1,3E-11 | - | - |
| Ce-133m | 2,2E-13 | 5,1E-13 | 2,6E-13 | 1,5E-10 | 2,2E-10 | 9,8E-11 | - | - |
| Ce-134 | 7,8E-14 | 3,6E-12 | 2,3E-13 | 9,6E-10 | 7,3E-10 | 1,1E-10 | - | - |
| Ce-135 | 7,2E-14 | 1,6E-13 | 8,9E-14 | 1,2E-10 | 1,7E-10 | 1,7E-11 | - | - |
| Ce-137 | 1,3E-15 | 4,0E-15 | 2,0E-15 | 5,7E-12 | 9,4E-12 | 1,5E-12 | - | - |
| Ce-137m | 5,2E-15 | 1,3E-14 | 7,1E-15 | 1,9E-10 | 8,2E-11 | 1,7E-10 | - | - |
| Ce-139 | 1,1E-14 | 2,1E-14 | 1,3E-14 | 1,4E-09 | 8,8E-11 | 4,0E-11 | - | - |
| Ce-141 | 5,7E-15 | 1,1E-14 | 6,5E-15 | 1,3E-09 | 6,2E-11 | 1,5E-10 | - | - |
| Ce-143 | 2,4E-14 | 1,6E-13 | 2,9E-14 | 4,0E-10 | 2,4E-10 | 1,6E-10 | - | - |
| Ce-144 | 4,0E-14 | 5,2E-12 | 2,6E-13 | 5,1E-08 | 1,0E-09 | 2,5E-10 | - | - |
| Cf-248 | 1,5E-15 | 2,7E-15 | 2,2E-15 | 6,0E-06 | 6,2E-09 | 1,0E-10 | - | - |
| Cf-249 | 3,0E-14 | 6,5E-14 | 3,7E-14 | 3,0E-05 | 5,2E-08 | 2,3E-11 | - | - |
| Cf-250 | 1,7E-14 | 5,3E-14 | 2,7E-14 | 1,8E-05 | 2,9E-08 | 6,0E-12 | - | - |
| Cf-251 | 9,8E-15 | 1,7E-14 | 1,1E-14 | 3,1E-05 | 5,3E-08 | 1,7E-10 | - | - |
| Cf-252 | 6,8E-13 | 2,5E-12 | 1,1E-12 | 1,3E-05 | 2,5E-08 | 1,0E-10 | - | - |
| Cf-253 | 2,4E-17 | 6,2E-17 | 3,4E-17 | 5,2E-07 | 3,2E-10 | 6,2E-11 | - | - |
| Cf-254 | 2,3E-11 | 9,2E-11 | 3,9E-11 | 2,4E-05 | 1,8E-07 | 3,1E-09 | - | - |
| Cl-36 | 1,1E-16 | 2,3E-16 | 1,4E-16 | 1,0E-07 | 9,9E-10 | 1,5E-10 | - | - |
| Cl-38 | 2,1E-13 | 5,2E-12 | 8,8E-13 | 5,8E-11 | 1,5E-10 | 1,7E-10 | - | - |
| Cm-240 | 9,8E-16 | 1,1E-15 | 1,3E-15 | 1,5E-06 | 1,1E-09 | 1,6E-10 | - | - |
| Cm-241 | 4,3E-14 | 9,3E-14 | 5,2E-14 | 2,0E-08 | 2,6E-10 | 6,5E-11 | - | - |

| ***Radionuclide*** | $\dot{e}_{eff}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,skin}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,eye}$ Sv.h$^{-1}$.Bq$^{-1}$ | $e_{inh}$ Sv.Bq$^{-1}$ | $e_{ing}$ Sv.Bq$^{-1}$ | $\dot{h}_{skin}$ Sv.h$^{-1}$/(Bq.m$^{-2}$) | $\dot{h}_{sub,eff}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) | $\dot{h}_{sub,eq}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| Cm-242 | 8,9E-16 | 9,8E-16 | 1,2E-15 | 3,6E-06 | 3,5E-09 | 1,2E-11 | - | - |
| Cm-243 | 1,1E-14 | 2,0E-14 | 1,3E-14 | 2,3E-05 | 4,6E-08 | 1,1E-10 | - | - |
| Cm-244 | 7,8E-16 | 9,3E-16 | 1,1E-15 | 2,0E-05 | 3,9E-08 | 2,3E-12 | - | - |
| Cm-245 | 8,1E-15 | 1,4E-14 | 9,1E-15 | 2,9E-05 | 6,0E-08 | 4,1E-11 | - | - |
| Cm-246 | 5,3E-15 | 1,9E-14 | 8,7E-15 | 2,9E-05 | 6,0E-08 | 2,2E-12 | - | - |
| Cm-247 | 3,0E-14 | 6,7E-14 | 3,8E-14 | 2,7E-05 | 5,5E-08 | 1,3E-10 | - | - |
| Cm-248 | 1,5E-12 | 6,5E-12 | 2,5E-12 | 9,6E-05 | 2,3E-07 | 2,2E-10 | - | - |
| Co-55 | 1,8E-13 | 7,5E-13 | 2,3E-13 | 3,9E-10 | 4,9E-10 | 1,3E-10 | - | - |
| Co-56 | 3,2E-13 | 6,0E-13 | 3,7E-13 | 8,6E-09 | 1,9E-09 | 3,8E-11 | - | - |
| Co-57 | 9,3E-15 | 1,7E-14 | 1,0E-14 | 1,2E-09 | 1,2E-10 | 9,8E-12 | - | - |
| Co-58 | 9,0E-14 | 1,9E-13 | 1,1E-13 | 2,4E-09 | 5,4E-10 | 2,7E-11 | - | - |
| Co-58m | 4,5E-21 | 5,4E-20 | 1,6E-20 | 1,4E-11 | 2,6E-12 | 1,3E-12 | - | - |
| Co-60 | 2,3E-13 | 3,7E-13 | 2,6E-13 | 5,9E-08 | 3,2E-09 | 9,2E-11 | - | - |
| Cr-51 | 2,8E-15 | 6,0E-15 | 3,4E-15 | 4,4E-11 | 1,3E-11 | 1,2E-12 | - | - |
| Cs-129 | 2,2E-14 | 5,1E-14 | 2,8E-14 | 6,5E-11 | 8,7E-11 | 4,8E-12 | - | - |
| Cs-131 | 1,3E-16 | 8,3E-16 | 3,3E-16 | 3,7E-11 | 5,2E-11 | 9,0E-13 | - | - |
| Cs-132 | 6,4E-14 | 1,5E-13 | 8,0E-14 | 3,4E-10 | 5,1E-10 | 6,5E-12 | - | - |
| Cs-134 | 1,4E-13 | 3,2E-13 | 1,8E-13 | 2,8E-08 | 1,4E-08 | 1,0E-10 | - | - |
| Cs-134m | 1,3E-15 | 2,7E-15 | 1,6E-15 | 3,7E-11 | 1,5E-11 | 1,3E-10 | - | - |
| Cs-135 | 8,7E-18 | 2,0E-17 | 1,1E-17 | 2,5E-08 | 1,3E-09 | 8,4E-11 | - | - |
| Cs-136 | 1,9E-13 | 3,8E-13 | 2,3E-13 | 1,9E-09 | 2,7E-09 | 1,3E-10 | - | - |
| Cs-137 | 5,2E-14 | 1,2E-13 | 6,5E-14 | 9,7E-08 | 1,4E-08 | 1,5E-10 | - | - |
| Cu-64 | 1,7E-14 | 3,9E-14 | 2,1E-14 | 6,9E-11 | 5,4E-11 | 8,1E-11 | - | - |
| Cu-67 | 9,3E-15 | 1,7E-14 | 1,1E-14 | 2,4E-10 | 1,2E-10 | 1,2E-10 | - | - |
| Dy-159 | 1,8E-15 | 5,2E-15 | 2,7E-15 | 5,0E-10 | 3,5E-11 | 1,3E-12 | - | - |
| Dy-165 | 2,6E-15 | 1,0E-13 | 3,1E-15 | 5,8E-11 | 6,5E-11 | 1,5E-10 | - | - |
| Dy-166 | 1,2E-14 | 2,3E-12 | 1,7E-14 | 1,5E-09 | 6,3E-10 | 3,5E-10 | - | - |
| Er-169 | 1,3E-17 | 2,8E-17 | 1,6E-17 | 3,5E-10 | 8,4E-12 | 8,9E-11 | - | - |
| Er-171 | 3,2E-14 | 8,3E-14 | 3,8E-14 | 1,4E-10 | 1,2E-10 | 1,8E-10 | - | - |
| Eu-147 | 4,0E-14 | 8,1E-14 | 4,9E-14 | 7,3E-10 | 2,0E-10 | 2,7E-11 | - | - |
| Eu-148 | 2,0E-13 | 4,3E-13 | 2,5E-13 | 4,0E-09 | 8,7E-10 | 1,2E-11 | - | - |
| Eu-149 | 3,8E-15 | 9,4E-15 | 5,2E-15 | 4,6E-10 | 4,3E-11 | 3,0E-12 | - | - |
| Eu-150 | 1,4E-13 | 3,0E-13 | 1,7E-13 | 1,1E-07 | 9,2E-10 | 1,7E-11 | - | - |
| Eu-150m | 4,4E-15 | 1,2E-14 | 5,4E-15 | 1,2E-10 | 8,6E-11 | 1,3E-10 | - | - |
| Eu-152 | 1,0E-13 | 2,3E-13 | 1,2E-13 | 7,5E-08 | 6,5E-10 | 7,3E-11 | - | - |
| Eu-152m | 2,9E-14 | 1,2E-12 | 3,8E-14 | 1,5E-10 | 1,7E-10 | 1,2E-10 | - | - |
| Eu-154 | 1,1E-13 | 3,7E-13 | 1,4E-13 | 8,1E-08 | 7,2E-10 | 1,6E-10 | - | - |
| Eu-155 | 4,1E-15 | 7,8E-15 | 4,7E-15 | 7,1E-09 | 4,4E-11 | 2,8E-11 | - | - |
| Eu-156 | 1,1E-13 | 1,4E-12 | 1,5E-13 | 2,4E-09 | 6,7E-10 | 1,4E-10 | - | - |

| ***Radionuclide*** | $\dot{e}_{eff}$ $Sv.h^{-1}.Bq^{-1}$ | $\dot{e}_{eq,skin}$ $Sv.h^{-1}.Bq^{-1}$ | $\dot{e}_{eq,eye}$ $Sv.h^{-1}.Bq^{-1}$ | $e_{inh}$ $Sv.Bq^{-1}$ | $e_{ing}$ $Sv.Bq^{-1}$ | $\dot{h}_{skin}$ $Sv.h^{-1}/(Bq.m^{-2})$ | $\dot{h}_{sub,eff}$ $Sv.h^{-1}/(Bq.m^{-3})$ | $\dot{h}_{sub,eq}$ $Sv.h^{-1}/(Bq.m^{-3})$ |
|---|---|---|---|---|---|---|---|---|
| F-18 | 9,2E-14 | 2,1E-13 | 1,1E-13 | 5,1E-11 | 4,8E-11 | 1,5E-10 | - | - |
| Fe-52 | 3,1E-13 | 5,9E-12 | 5,7E-13 | 5,0E-10 | 7,2E-10 | 2,7E-10 | - | - |
| Fe-53 | 1,2E-13 | 5,1E-12 | 3,3E-13 | - | - | 1,6E-10 | - | - |
| Fe-55 | 1,3E-23 | 2,2E-23 | 1,4E-23 | 1,2E-09 | 2,9E-10 | 1,4E-12 | - | - |
| Fe-59 | 1,1E-13 | 1,8E-13 | 1,3E-13 | 5,6E-09 | 1,7E-09 | 1,0E-10 | - | - |
| Fe-60 | 3,7E-16 | 2,3E-15 | 4,4E-16 | 1,9E-07 | 2,6E-08 | 5,3E-11 | - | - |
| Ga-67 | 1,3E-14 | 2,5E-14 | 1,5E-14 | 1,2E-10 | 5,4E-11 | 2,6E-11 | - | - |
| Ga-68 | 9,2E-14 | 2,5E-12 | 1,5E-13 | 5,5E-11 | 1,1E-10 | 1,5E-10 | - | - |
| Ga-72 | 2,4E-13 | 1,5E-12 | 3,2E-13 | 4,1E-10 | 5,3E-10 | 1,6E-10 | - | - |
| Gd-146 | 2,6E-13 | 5,4E-13 | 3,1E-13 | 6,4E-09 | 1,2E-09 | 9,1E-11 | - | - |
| Gd-148 | 1,8E-16 | 2,1E-16 | 2,1E-16 | 1,3E-05 | 2,0E-08 | - | - | - |
| Gd-153 | 5,6E-15 | 1,3E-14 | 7,2E-15 | 2,1E-09 | 7,0E-11 | 1,0E-11 | - | - |
| Gd-159 | 4,5E-15 | 1,0E-14 | 5,6E-15 | 1,5E-10 | 9,4E-11 | 1,5E-10 | - | - |
| Ge-68 | 9,2E-14 | 2,5E-12 | 1,5E-13 | 3,3E-08 | 4,0E-10 | 1,5E-10 | - | - |
| Ge-69 | 8,7E-14 | 1,9E-13 | 1,1E-13 | 2,4E-10 | 9,8E-11 | 4,2E-11 | - | - |
| Ge-71 | - | - | - | 1,4E-11 | 1,5E-12 | 1,7E-12 | - | - |
| Ge-77 | 1,0E-13 | 1,8E-12 | 1,4E-13 | 3,1E-10 | 2,2E-10 | 1,7E-10 | - | - |
| H-3 | - | - | - | 5,2E-10 | 5,1E-11 | 1,8E-16 | - | - |
| Hf-172 | 1,8E-13 | 3,5E-13 | 2,2E-13 | 3,5E-08 | 1,1E-09 | 6,6E-11 | - | - |
| Hf-175 | 3,0E-14 | 6,5E-14 | 3,6E-14 | 1,3E-09 | 1,7E-10 | 2,2E-11 | - | - |
| Hf-181 | 4,7E-14 | 1,0E-13 | 5,8E-14 | 2,7E-09 | 2,5E-10 | 1,8E-10 | - | - |
| Hf-182 | 2,0E-14 | 4,0E-14 | 2,4E-14 | 3,2E-07 | 3,0E-09 | 3,0E-11 | - | - |
| Hg-194 | 9,0E-14 | 1,8E-13 | 1,1E-13 | 9,3E-08 | 9,7E-10 | 1,9E-11 | - | - |
| Hg-195m | 2,9E-14 | 5,8E-14 | 3,4E-14 | 3,3E-10 | 1,2E-10 | 1,2E-10 | - | - |
| Hg-197 | 4,7E-15 | 8,8E-15 | 5,5E-15 | 1,8E-10 | 3,8E-11 | 1,0E-11 | - | - |
| Hg-197m | 7,1E-15 | 1,3E-14 | 8,2E-15 | 2,6E-10 | 4,9E-11 | 2,5E-10 | - | - |
| Hg-203 | 2,0E-14 | 4,1E-14 | 2,5E-14 | 1,3E-09 | 2,3E-10 | 7,9E-11 | - | - |
| Ho-166 | 6,3E-15 | 1,5E-12 | 9,0E-15 | 3,7E-10 | 3,0E-10 | 1,7E-10 | - | - |
| Ho-166m | 1,5E-13 | 3,2E-13 | 1,8E-13 | 2,0E-07 | 1,2E-09 | 8,5E-11 | - | - |
| I-123 | 1,2E-14 | 2,3E-14 | 1,4E-14 | 1,1E-10 | 1,8E-10 | 3,1E-11 | - | - |
| I-124 | 1,0E-13 | 7,4E-13 | 1,3E-13 | 5,7E-09 | 8,6E-09 | 4,1E-11 | - | - |
| I-125 | 1,4E-16 | 9,5E-16 | 3,6E-16 | 8,6E-09 | 1,3E-08 | 1,8E-12 | - | - |
| I-126 | 3,9E-14 | 9,7E-14 | 4,9E-14 | 1,4E-08 | 2,1E-08 | 6,8E-11 | - | - |
| I-129 | 2,0E-16 | 1,1E-15 | 4,6E-16 | 6,4E-08 | 9,4E-08 | 2,8E-11 | - | - |
| I-131 | 3,4E-14 | 7,6E-14 | 4,2E-14 | 1,1E-08 | 1,6E-08 | 1,3E-10 | - | - |
| I-132 | 2,1E-13 | 1,1E-12 | 2,6E-13 | 1,2E-10 | 2,8E-10 | 1,6E-10 | - | - |
| I-133 | 5,7E-14 | 1,9E-13 | 7,0E-14 | 1,9E-09 | 3,1E-09 | 1,5E-10 | - | - |
| I-134 | 2,4E-13 | 1,4E-12 | 3,0E-13 | 5,2E-11 | 1,2E-10 | 1,7E-10 | - | - |
| I-135 | 1,5E-13 | 3,8E-13 | 1,7E-13 | 4,0E-10 | 7,6E-10 | 1,5E-10 | 1,1E-11 | 1,7E-11 |

| ***Radionuclide*** | $\dot{e}_{eff}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,skin}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,eye}$ Sv.h$^{-1}$.Bq$^{-1}$ | $e_{inh}$ Sv.Bq$^{-1}$ | $e_{ing}$ Sv.Bq$^{-1}$ | $\dot{h}_{skin}$ Sv.h$^{-1}$/(Bq.m$^{-2}$) | $\dot{h}_{sub,eff}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) | $\dot{h}_{sub,eq}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| In-111 | 3,2E-14 | 5,9E-14 | 3,8E-14 | 1,5E-10 | 1,5E-10 | 3,3E-11 | - | - |
| In-113m | 2,3E-14 | 5,2E-14 | 2,8E-14 | 2,0E-11 | 2,3E-11 | 6,2E-11 | - | - |
| In-114m | 1,3E-14 | 2,1E-12 | 2,4E-14 | 8,9E-09 | 6,6E-10 | 3,1E-10 | - | - |
| In-115m | 1,4E-14 | 3,0E-14 | 1,7E-14 | 4,5E-11 | 3,7E-11 | 9,5E-11 | - | - |
| Ir-189 | 5,3E-15 | 1,0E-14 | 6,3E-15 | 2,7E-10 | 4,2E-11 | 6,9E-12 | - | - |
| Ir-190 | 1,3E-13 | 2,9E-13 | 1,6E-13 | 1,0E-09 | 5,9E-10 | 6,4E-11 | - | - |
| Ir-192 | 7,3E-14 | 1,6E-13 | 9,0E-14 | 4,5E-09 | 4,5E-10 | 1,5E-10 | - | - |
| Ir-193m | 2,2E-17 | 4,3E-17 | 2,6E-17 | 4,2E-10 | 3,5E-12 | 1,9E-11 | - | - |
| Ir-194 | 1,8E-14 | 2,7E-12 | 4,8E-14 | 3,3E-10 | 3,4E-10 | 1,6E-10 | - | - |
| K-40 | 1,5E-14 | 3,6E-13 | 1,6E-14 | 2,6E-07 | 3,2E-09 | 1,4E-10 | - | - |
| K-42 | 8,5E-14 | 5,9E-12 | 5,1E-13 | 4,3E-10 | 4,2E-10 | 1,7E-10 | - | - |
| K-43 | 8,8E-14 | 2,4E-13 | 1,1E-13 | 2,9E-10 | 2,1E-10 | 1,5E-10 | - | - |
| Kr-79 | 2,3E-14 | 4,9E-14 | 2,8E-14 | - | - | - | 3,7E-11 | 5,0E-11 |
| Kr-81 | 7,1E-17 | 1,4E-16 | 8,5E-17 | - | - | - | 1,3E-13 | 9,4E-13 |
| Kr-85 | 3,0E-16 | 6,6E-16 | 3,7E-16 | - | - | - | 7,7E-13 | 3,8E-11 |
| Kr-85m | 1,3E-14 | 2,4E-14 | 1,5E-14 | - | - | - | 2,1E-11 | 6,6E-11 |
| Kr-87 | 1,2E-13 | 5,4E-12 | 5,2E-13 | - | - | - | 1,4E-10 | 3,9E-10 |
| La-132 | 1,9E-13 | 2,7E-12 | 3,7E-13 | 1,5E-10 | 2,5E-10 | 7,9E-11 | - | - |
| La-133 | 1,3E-14 | 2,9E-14 | 1,6E-14 | 1,2E-11 | 1,7E-11 | 1,4E-11 | - | - |
| La-134 | 7,7E-14 | 3,6E-12 | 2,3E-13 | - | - | 1,1E-10 | - | - |
| La-135 | 1,2E-15 | 3,5E-15 | 1,7E-15 | 1,0E-11 | 1,6E-11 | 1,0E-12 | - | - |
| La-137 | 2,4E-16 | 1,3E-15 | 5,6E-16 | 8,1E-09 | 5,1E-11 | 9,2E-13 | - | - |
| La-140 | 2,1E-13 | 8,1E-13 | 2,4E-13 | 7,3E-10 | 7,9E-10 | 1,6E-10 | - | - |
| Lu-172 | 1,8E-13 | 3,3E-13 | 2,1E-13 | 1,0E-09 | 6,7E-10 | 5,0E-11 | - | - |
| Lu-173 | 1,3E-14 | 2,7E-14 | 1,6E-14 | 4,1E-09 | 1,0E-10 | 1,1E-11 | - | - |
| Lu-174 | 8,6E-15 | 1,6E-14 | 1,0E-14 | 5,5E-09 | 6,5E-11 | 7,1E-12 | - | - |
| Lu-174m | 3,5E-15 | 7,7E-15 | 4,5E-15 | 3,4E-09 | 4,0E-11 | 1,1E-11 | - | - |
| Lu-177 | 2,8E-15 | 5,2E-15 | 3,3E-15 | 3,9E-10 | 3,5E-11 | 1,2E-10 | - | - |
| Mg-28 | 3,1E-13 | 5,9E-12 | 5,6E-13 | 9,6E-10 | 1,1E-09 | 3,0E-10 | - | - |
| Mn-51 | 1,0E-13 | 3,9E-12 | 2,0E-13 | 4,9E-11 | 1,1E-10 | 1,6E-10 | - | - |
| Mn-52 | 3,1E-13 | 5,7E-13 | 3,8E-13 | 1,2E-09 | 1,2E-09 | 5,6E-11 | - | - |
| Mn-53 | - | - | - | 1,0E-09 | 3,1E-12 | 1,2E-12 | - | - |
| Mn-54 | 7,8E-14 | 1,6E-13 | 9,5E-14 | 5,2E-09 | 5,0E-10 | 3,3E-12 | - | - |
| Mn-56 | 1,7E-13 | 3,2E-12 | 3,0E-13 | 1,2E-10 | 2,0E-10 | 1,6E-10 | - | - |
| Mo-93 | - | 1,6E-20 | - | 8,3E-09 | 2,0E-10 | 1,2E-12 | - | - |
| Mo-99 | 2,3E-14 | 9,3E-14 | 2,7E-14 | 4,8E-10 | 4,5E-10 | 1,7E-10 | - | - |
| N-13 | 9,5E-14 | 3,0E-13 | 1,2E-13 | - | - | 1,6E-10 | - | - |
| Na-22 | 2,0E-13 | 3,8E-13 | 2,4E-13 | 4,1E-08 | 3,5E-09 | 1,4E-10 | - | - |
| Na-24 | 3,4E-13 | 7,0E-13 | 3,8E-13 | 5,2E-10 | 4,8E-10 | 1,6E-10 | - | - |

| *Radionuclide* | $\dot{e}_{eff}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,skin}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,eye}$ Sv.h$^{-1}$.Bq$^{-1}$ | $e_{inh}$ Sv.Bq$^{-1}$ | $e_{ing}$ Sv.Bq$^{-1}$ | $\dot{h}_{skin}$ Sv.h$^{-1}$/(Bq.m$^{-2}$) | $\dot{h}_{sub,eff}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) | $\dot{h}_{sub,eq}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| Nb-90 | 3,6E-13 | 9,7E-13 | 4,2E-13 | 5,1E-10 | 7,0E-10 | 1,5E-10 | - | - |
| Nb-92m | 8,8E-14 | 1,7E-13 | 1,1E-13 | 4,5E-10 | 3,5E-10 | 3,5E-12 | - | - |
| Nb-93m | 1,8E-21 | 1,7E-20 | 5,2E-21 | 3,7E-09 | 2,7E-11 | 2,2E-13 | - | - |
| Nb-94 | 1,4E-13 | 3,1E-13 | 1,8E-13 | 1,8E-07 | 2,3E-09 | 1,3E-10 | - | - |
| Nb-95 | 7,1E-14 | 1,5E-13 | 8,7E-14 | 1,3E-09 | 3,0E-10 | 2,2E-11 | - | - |
| Nb-97 | 6,2E-14 | 2,5E-13 | 7,7E-14 | 4,5E-11 | 6,5E-11 | 1,6E-10 | - | - |
| Nd-147 | 1,1E-14 | 2,5E-14 | 1,4E-14 | 1,0E-09 | 1,5E-10 | 1,4E-10 | - | - |
| Nd-149 | 3,2E-14 | 3,0E-13 | 3,9E-14 | 6,9E-11 | 7,5E-11 | 1,8E-10 | - | - |
| Ni-56 | 1,6E-13 | 3,2E-13 | 1,9E-13 | 1,2E-09 | 6,0E-10 | 9,2E-12 | - | - |
| Ni-57 | 1,7E-13 | 2,9E-13 | 2,0E-13 | 4,1E-10 | 5,0E-10 | 7,6E-11 | - | - |
| Ni-59 | 1,4E-18 | 3,3E-18 | 1,8E-18 | 1,5E-09 | 1,1E-11 | 1,6E-12 | - | - |
| Ni-63 | 1,6E-20 | 7,6E-20 | 3,4E-20 | 3,1E-09 | 3,0E-11 | 4,5E-15 | - | - |
| Ni-65 | 5,6E-14 | 1,9E-12 | 8,0E-14 | 8,2E-11 | 1,2E-10 | 1,6E-10 | - | - |
| Np-235 | 3,9E-17 | 7,1E-17 | 4,3E-17 | 5,5E-10 | 8,5E-12 | 9,3E-13 | - | - |
| Np-236 | 1,1E-14 | 1,9E-14 | 1,2E-14 | 5,0E-06 | 5,5E-09 | 2,0E-10 | - | - |
| Np-236m | 3,6E-15 | 6,8E-15 | 4,1E-15 | 5,4E-09 | 3,3E-11 | 5,9E-11 | - | - |
| Np-237 | 1,9E-15 | 3,4E-15 | 2,3E-15 | 2,4E-05 | 3,0E-08 | 9,3E-12 | - | - |
| Np-239 | 1,4E-14 | 2,6E-14 | 1,6E-14 | 4,2E-10 | 8,5E-11 | 2,1E-10 | - | - |
| Os-185 | 6,3E-14 | 1,4E-13 | 7,7E-14 | 2,1E-09 | 2,9E-10 | 6,5E-12 | - | - |
| Os-191 | 5,7E-15 | 1,1E-14 | 6,6E-15 | 7,9E-10 | 4,4E-11 | 4,6E-11 | - | - |
| Os-191m | 3,7E-16 | 7,2E-16 | 4,4E-16 | 8,0E-11 | 2,8E-12 | 7,0E-12 | - | - |
| Os-193 | 5,9E-15 | 2,1E-14 | 7,1E-15 | 2,5E-10 | 1,4E-10 | 1,6E-10 | - | - |
| Os-194 | 1,8E-14 | 2,7E-12 | 4,8E-14 | 1,3E-07 | 8,0E-10 | 1,6E-10 | - | - |
| P-32 | 3,1E-15 | 1,4E-12 | 3,3E-15 | 2,4E-09 | 1,7E-09 | 1,6E-10 | - | - |
| P-33 | 5,8E-18 | 1,4E-17 | 7,6E-18 | 5,4E-10 | 2,7E-10 | 6,8E-11 | - | - |
| Pa-230 | 6,0E-14 | 1,2E-13 | 7,2E-14 | 2,2E-07 | 3,2E-10 | 2,3E-11 | 3,3E-18 | 4,1E-18 |
| Pa-231 | 3,3E-15 | 6,5E-15 | 4,0E-15 | 1,0E-04 | 1,8E-07 | 1,0E-11 | - | - |
| Pa-233 | 1,8E-14 | 3,8E-14 | 2,2E-14 | 1,6E-09 | 1,2E-10 | 1,5E-10 | - | - |
| Pb-201 | 6,7E-14 | 1,4E-13 | 8,1E-14 | 1,3E-10 | 1,0E-10 | 3,3E-11 | - | - |
| Pb-202 | 1,8E-16 | 2,0E-16 | 2,0E-16 | 1,6E-07 | 1,2E-08 | 7,3E-13 | - | - |
| Pb-203 | 2,6E-14 | 5,2E-14 | 3,1E-14 | 2,3E-10 | 1,2E-10 | 3,9E-11 | - | - |
| Pb-205 | - | 1,3E-26 | - | 2,2E-09 | 9,1E-11 | 7,3E-13 | - | - |
| Pb-210 | 5,2E-16 | 2,2E-14 | 6,3E-16 | 1,5E-05 | 3,2E-07 | 1,5E-10 | - | - |
| Pb-212 | 1,4E-13 | 2,3E-12 | 1,9E-13 | 3,3E-07 | 5,7E-09 | 1,1E-07 | - | - |
| Pd-103 | 1,1E-17 | 2,8E-17 | 1,4E-17 | 2,3E-10 | 2,5E-11 | 1,2E-12 | - | - |
| Pd-107 | 2,0E-23 | 1,7E-22 | 5,9E-23 | 1,8E-09 | 7,4E-13 | 5,5E-16 | - | - |
| Pd-109 | 5,0E-16 | 1,9E-15 | 5,8E-16 | 1,9E-10 | 1,0E-10 | 1,9E-10 | - | - |
| Pm-143 | 2,7E-14 | 6,1E-14 | 3,4E-14 | 2,2E-09 | 1,5E-10 | 2,0E-12 | - | - |
| Pm-144 | 1,4E-13 | 3,2E-13 | 1,8E-13 | 1,2E-08 | 6,8E-10 | 8,5E-12 | - | - |

| ***Radionuclide*** | $\dot{e}_{eff}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,skin}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,eye}$ Sv.h$^{-1}$.Bq$^{-1}$ | $e_{inh}$ Sv.Bq$^{-1}$ | $e_{ing}$ Sv.Bq$^{-1}$ | $\dot{h}_{skin}$ Sv.h$^{-1}$/(Bq.m$^{-2}$) | $\dot{h}_{sub,eff}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) | $\dot{h}_{sub,eq}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| Pm-145 | 9,5E-16 | 3,1E-15 | 1,6E-15 | 5,4E-09 | 4,6E-11 | 1,2E-12 | - | - |
| Pm-147 | 3,9E-18 | 9,3E-18 | 5,1E-18 | 4,1E-09 | 8,4E-12 | 4,8E-11 | - | - |
| Pm-148m | 1,9E-13 | 5,2E-13 | 2,3E-13 | 4,5E-09 | 8,4E-10 | 1,3E-10 | - | - |
| Pm-149 | 1,3E-15 | 6,5E-15 | 1,5E-15 | 3,2E-10 | 1,5E-10 | 1,5E-10 | - | - |
| Pm-151 | 2,8E-14 | 6,5E-14 | 3,5E-14 | 2,4E-10 | 1,6E-10 | 1,5E-10 | - | - |
| Po-210 | 5,6E-16 | 6,6E-16 | 7,7E-16 | 2,8E-06 | 1,8E-07 | 1,3E-12 | - | - |
| Pr-142 | 1,6E-14 | 2,8E-12 | 4,8E-14 | 3,3E-10 | 3,4E-10 | 1,6E-10 | - | - |
| Pr-143 | 1,6E-16 | 3,5E-16 | 1,9E-16 | 1,0E-09 | 1,4E-10 | 1,5E-10 | - | - |
| Pt-188 | 2,3E-13 | 3,5E-13 | 2,7E-13 | 1,7E-09 | 9,0E-10 | 1,2E-10 | - | - |
| Pt-191 | 2,4E-14 | 5,1E-14 | 2,9E-14 | 1,9E-10 | 1,1E-10 | 3,2E-11 | - | - |
| Pt-193 | - | - | - | 1,9E-09 | 3,5E-12 | 7,6E-13 | - | - |
| Pt-193m | 6,9E-16 | 1,3E-15 | 8,1E-16 | 3,1E-10 | 1,1E-11 | 1,5E-10 | - | - |
| Pt-195m | 4,8E-15 | 9,0E-15 | 5,5E-15 | 3,9E-10 | 4,0E-11 | 1,7E-10 | - | - |
| Pt-197 | 1,8E-15 | 3,3E-15 | 2,0E-15 | 1,8E-10 | 4,4E-11 | 1,4E-10 | - | - |
| Pt-197m | 6,3E-15 | 1,3E-14 | 7,6E-15 | 5,3E-11 | 3,2E-11 | 1,6E-10 | - | - |
| Pu-236 | 7,4E-16 | 8,4E-16 | 1,0E-15 | 1,7E-05 | 2,3E-08 | 2,4E-12 | - | - |
| Pu-237 | 3,4E-15 | 6,0E-15 | 3,7E-15 | 2,8E-10 | 3,0E-11 | 2,3E-12 | - | - |
| Pu-238 | 6,3E-16 | 7,4E-16 | 8,6E-16 | 4,1E-05 | 1,1E-07 | 1,9E-12 | - | - |
| Pu-239 | 5,1E-16 | 6,1E-16 | 7,0E-16 | 4,5E-05 | 1,2E-07 | 1,2E-12 | - | - |
| Pu-240 | 5,1E-16 | 6,1E-16 | 7,0E-16 | 4,5E-05 | 1,2E-07 | 1,4E-12 | - | - |
| Pu-241 | 3,7E-19 | 6,8E-19 | 4,3E-19 | 8,4E-07 | 1,1E-09 | 4,6E-15 | - | - |
| Pu-242 | 4,9E-16 | 8,5E-16 | 6,9E-16 | 4,3E-05 | 1,2E-07 | 2,6E-13 | - | - |
| Pu-244 | 5,1E-14 | 1,7E-12 | 8,1E-14 | 4,2E-05 | 1,1E-07 | 2,5E-10 | - | - |
| Ra-223 | 3,3E-14 | 5,6E-13 | 3,9E-14 | 3,2E-06 | 4,1E-08 | 4,3E-08 | 8,3E-12 | 1,1E-11 |
| Ra-224 | 1,5E-13 | 2,3E-12 | 2,0E-13 | 2,2E-06 | 3,5E-08 | 1,2E-07 | 9,3E-14 | 1,2E-13 |
| Ra-225 | 7,7E-14 | 8,1E-13 | 9,4E-14 | 1,1E-05 | 1,1E-07 | 4,1E-07 | - | - |
| Ra-226 | 1,7E-13 | 1,8E-12 | 2,5E-13 | 2,3E-05 | 1,3E-07 | 5,8E-08 | 5,7E-14 | 7,4E-14 |
| Ra-228 | 7,9E-14 | 5,0E-13 | 9,6E-14 | 3,7E-05 | 3,4E-07 | 1,7E-10 | - | - |
| Rb (natural) | 1,4E-17 | 3,2E-17 | 1,8E-17 | 3,4E-08 | 8,7E-10 | 1,1E-10 | - | - |
| Rb-81 | 5,6E-14 | 1,2E-13 | 6,9E-14 | 6,4E-11 | 5,2E-11 | 4,7E-11 | 1,7E-11 | 2,6E-11 |
| Rb-83 | 4,5E-14 | 1,0E-13 | 5,6E-14 | 1,4E-09 | 1,6E-09 | 3,6E-12 | 4,9E-15 | 1,8E-13 |
| Rb-84 | 8,1E-14 | 3,4E-13 | 1,0E-13 | 2,1E-09 | 2,4E-09 | 4,7E-11 | - | - |
| Rb-86 | 1,3E-14 | 1,7E-12 | 1,6E-14 | 2,9E-09 | 1,7E-09 | 1,6E-10 | - | - |
| Rb-87 | 1,4E-17 | 3,2E-17 | 1,8E-17 | 3,4E-08 | 8,7E-10 | 1,1E-10 | - | - |
| Re (natural) | - | - | - | 1,2E-10 | 1,4E-12 | - | - | - |
| Re-184 | 8,0E-14 | 1,6E-13 | 9,8E-14 | 1,6E-09 | 6,0E-10 | 4,9E-11 | - | - |
| Re-184m | 3,2E-14 | 6,5E-14 | 3,9E-14 | 8,2E-09 | 6,3E-10 | 7,0E-11 | - | - |
| Re-186 | 1,7E-15 | 5,7E-15 | 1,9E-15 | 4,5E-10 | 5,5E-10 | 1,5E-10 | - | - |
| Re-187 | - | - | - | 1,2E-10 | 1,4E-12 | - | - | - |

| *Radionuclide* | $\dot{e}_{eff}$ $Sv.h^{-1}.Bq^{-1}$ | $\dot{e}_{eq,skin}$ $Sv.h^{-1}.Bq^{-1}$ | $\dot{e}_{eq,eye}$ $Sv.h^{-1}.Bq^{-1}$ | $e_{inh}$ $Sv.Bq^{-1}$ | $e_{ing}$ $Sv.Bq^{-1}$ | $\dot{h}_{skin}$ $Sv.h^{-1}/(Bq.m^{-2})$ | $\dot{h}_{sub,eff}$ $Sv.h^{-1}/(Bq.m^{-3})$ | $\dot{h}_{sub,eq}$ $Sv.h^{-1}/(Bq.m^{-3})$ |
|---|---|---|---|---|---|---|---|---|
| Re-188 | 1,3E-14 | 2,3E-12 | 2,8E-14 | 3,7E-10 | 6,2E-10 | 1,8E-10 | - | - |
| Re-189 | 4,8E-15 | 9,4E-15 | 5,7E-15 | 2,3E-10 | 3,3E-10 | 1,6E-10 | - | - |
| Rh-101 | 2,2E-14 | 4,1E-14 | 2,6E-14 | 7,5E-09 | 3,8E-10 | 2,7E-11 | - | - |
| Rh-102 | 4,5E-14 | 1,3E-13 | 5,7E-14 | 7,3E-09 | 5,4E-10 | 6,0E-11 | - | - |
| Rh-102m | 2,0E-13 | 4,2E-13 | 2,4E-13 | 3,9E-08 | 2,3E-09 | 9,1E-12 | - | - |
| Rh-103m | 7,9E-19 | 3,3E-18 | 1,5E-18 | 1,6E-12 | 9,2E-14 | 1,5E-13 | - | - |
| Rh-105 | 6,8E-15 | 1,5E-14 | 8,3E-15 | 1,5E-10 | 4,9E-11 | 1,1E-10 | - | - |
| Rh-99 | 4,9E-14 | 1,1E-13 | 6,0E-14 | 7,4E-10 | 2,7E-10 | 2,3E-11 | - | - |
| Rn-222 | 1,7E-13 | 1,8E-12 | 2,5E-13 | 4,7E-07 | 1,2E-10 | 5,9E-08 | 5,7E-14 | 7,4E-14 |
| Ru-103 | 4,6E-14 | 1,0E-13 | 5,7E-14 | 1,6E-09 | 2,6E-10 | 5,1E-11 | - | - |
| Ru-105 | 6,9E-14 | 2,3E-13 | 8,5E-14 | 1,3E-10 | 1,3E-10 | 1,9E-10 | - | - |
| Ru-106 | 7,5E-14 | 6,1E-12 | 4,6E-13 | 6,9E-08 | 2,6E-09 | 1,7E-10 | - | - |
| Ru-97 | 1,9E-14 | 3,6E-14 | 2,3E-14 | 8,2E-11 | 9,0E-11 | 9,0E-12 | - | - |
| S-35 | 1,6E-18 | 4,2E-18 | 2,2E-18 | 7,8E-10 | 2,7E-11 | 2,7E-11 | - | - |
| Sb-119 | 1,9E-17 | 1,8E-16 | 6,0E-17 | 1,7E-11 | 2,2E-11 | 1,2E-12 | - | - |
| Sb-120m | 2,2E-13 | 3,9E-13 | 2,6E-13 | 8,5E-10 | 8,4E-10 | 3,4E-11 | - | - |
| Sb-122 | 4,4E-14 | 9,6E-13 | 5,7E-14 | 6,2E-10 | 4,5E-10 | 1,6E-10 | - | - |
| Sb-124 | 1,7E-13 | 1,1E-12 | 2,1E-13 | 7,4E-09 | 1,1E-09 | 1,4E-10 | - | - |
| Sb-125 | 3,9E-14 | 8,8E-14 | 4,8E-14 | 1,5E-08 | 3,7E-10 | 6,7E-11 | - | - |
| Sb-126 | 2,6E-13 | 1,0E-12 | 3,2E-13 | 2,6E-09 | 1,3E-09 | 1,5E-10 | - | - |
| Sc-44 | 2,0E-13 | 1,1E-12 | 2,4E-13 | 1,5E-10 | 2,3E-10 | 1,6E-10 | - | - |
| Sc-46 | 1,8E-13 | 3,4E-13 | 2,2E-13 | 6,1E-09 | 7,6E-10 | 1,1E-10 | - | - |
| Sc-47 | 8,8E-15 | 1,6E-14 | 9,9E-15 | 2,7E-10 | 6,6E-11 | 1,3E-10 | - | - |
| Sc-48 | 3,1E-13 | 5,3E-13 | 3,6E-13 | 7,8E-10 | 8,9E-10 | 1,5E-10 | - | - |
| Se-75 | 3,2E-14 | 6,3E-14 | 3,8E-14 | 1,8E-09 | 2,5E-09 | 1,2E-11 | - | - |
| Se-79 | 1,7E-18 | 4,5E-18 | 2,4E-18 | 1,3E-08 | 1,9E-09 | 3,0E-11 | - | - |
| Si-31 | 1,3E-15 | 5,9E-13 | 8,5E-16 | 7,3E-11 | 9,8E-11 | 1,6E-10 | - | - |
| Si-32 | 4,3E-18 | 1,0E-17 | 5,8E-18 | 3,3E-07 | 1,1E-10 | 5,8E-11 | - | - |
| Sm-145 | 1,9E-15 | 6,5E-15 | 3,2E-15 | 1,9E-09 | 6,0E-11 | 1,9E-12 | - | - |
| Sm-147 | 1,8E-16 | 2,1E-16 | 2,1E-16 | 1,1E-05 | 2,9E-08 | - | - | - |
| Sm-151 | 3,8E-20 | 1,6E-19 | 7,2E-20 | 4,2E-09 | 1,2E-11 | 6,2E-14 | - | - |
| Sm-153 | 3,8E-15 | 8,1E-15 | 4,7E-15 | 3,0E-10 | 8,7E-11 | 1,5E-10 | - | - |
| Sn-113 | 2,3E-14 | 5,3E-14 | 2,9E-14 | 3,4E-09 | 2,6E-10 | 6,3E-11 | - | - |
| Sn-117m | 1,1E-14 | 2,0E-14 | 1,3E-14 | 8,2E-10 | 9,3E-11 | 2,1E-10 | - | - |
| Sn-119m | 1,1E-17 | 1,0E-16 | 3,3E-17 | 2,7E-09 | 5,3E-11 | 2,2E-12 | - | - |
| Sn-121m | 3,8E-17 | 1,6E-16 | 7,0E-17 | 3,0E-08 | 1,3E-10 | 1,0E-10 | - | - |
| Sn-123 | 1,5E-15 | 4,2E-13 | 1,3E-15 | 1,1E-08 | 4,6E-10 | 1,5E-10 | - | - |
| Sn-125 | 4,4E-14 | 3,0E-12 | 1,1E-13 | 2,3E-09 | 6,9E-10 | 1,5E-10 | - | - |
| Sn-126 | 1,5E-13 | 1,9E-12 | 1,9E-13 | 5,4E-07 | 2,6E-09 | 2,3E-10 | - | - |

| ***Radionuclide*** | $\dot{e}_{eff}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,skin}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,eye}$ Sv.h$^{-1}$.Bq$^{-1}$ | $e_{inh}$ Sv.Bq$^{-1}$ | $e_{ing}$ Sv.Bq$^{-1}$ | $\dot{h}_{skin}$ Sv.h$^{-1}$/(Bq.m$^{-2}$) | $\dot{h}_{sub,eff}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) | $\dot{h}_{sub,eq}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| Sr-82 | 1,4E-13 | 6,5E-12 | 5,9E-13 | 9,2E-09 | 2,4E-09 | 1,6E-10 | - | - |
| Sr-83 | 7,5E-14 | 1,9E-13 | 9,1E-14 | 2,4E-10 | 2,6E-10 | 4,8E-11 | - | - |
| Sr-85 | 4,5E-14 | 1,0E-13 | 5,7E-14 | 1,1E-09 | 3,8E-10 | 4,3E-12 | - | - |
| Sr-85m | 1,8E-14 | 3,4E-14 | 2,1E-14 | 3,3E-12 | 5,0E-12 | 7,1E-12 | - | - |
| Sr-87m | 2,9E-14 | 6,5E-14 | 3,5E-14 | 1,8E-11 | 2,3E-11 | 3,1E-11 | - | - |
| Sr-89 | 1,5E-15 | 7,3E-13 | 8,4E-16 | 5,7E-09 | 8,9E-10 | 1,6E-10 | - | - |
| Sr-90 | 1,6E-14 | 3,6E-12 | 7,3E-14 | 3,8E-07 | 2,5E-08 | 3,0E-10 | - | - |
| Sr-91 | 1,1E-13 | 1,8E-12 | 1,8E-13 | 2,7E-10 | 3,2E-10 | 1,7E-10 | - | - |
| Sr-92 | 1,2E-13 | 2,8E-13 | 1,4E-13 | 1,6E-10 | 1,8E-10 | 1,3E-10 | - | - |
| Ta-178m | 9,9E-14 | 2,1E-13 | 1,2E-13 | 5,4E-11 | 5,2E-11 | 1,1E-10 | - | - |
| Ta-179 | 1,4E-15 | 3,0E-15 | 1,8E-15 | 7,0E-10 | 1,6E-11 | 1,0E-12 | - | - |
| Ta-182 | 1,2E-13 | 2,1E-13 | 1,4E-13 | 7,5E-09 | 5,0E-10 | 1,6E-10 | - | - |
| Tb-149 | 1,2E-13 | 3,2E-13 | 1,4E-13 | 4,1E-09 | 9,3E-11 | 4,4E-11 | - | - |
| Tb-157 | 1,7E-16 | 5,2E-16 | 2,7E-16 | 1,9E-09 | 7,3E-12 | 6,9E-13 | - | - |
| Tb-158 | 7,1E-14 | 1,4E-13 | 8,7E-14 | 1,0E-07 | 6,0E-10 | 5,1E-11 | - | - |
| Tb-160 | 1,0E-13 | 2,0E-13 | 1,2E-13 | 5,6E-09 | 4,9E-10 | 1,6E-10 | - | - |
| Tb-161 | 1,6E-15 | 3,7E-15 | 2,1E-15 | 5,3E-10 | 5,4E-11 | 1,2E-10 | - | - |
| Tc-95 | 7,2E-14 | 1,6E-13 | 8,9E-14 | 1,0E-10 | 1,4E-10 | 3,4E-12 | - | - |
| Tc-95m | 6,4E-14 | 1,3E-13 | 7,8E-14 | 1,5E-09 | 4,5E-10 | 1,1E-11 | - | - |
| Tc-96 | 2,3E-13 | 4,8E-13 | 2,8E-13 | 7,1E-10 | 8,9E-10 | 7,9E-12 | - | - |
| Tc-96m | 3,8E-15 | 7,4E-15 | 4,6E-15 | 6,4E-12 | 8,5E-12 | 6,7E-13 | - | - |
| Tc-97 | - | 1,0E-19 | - | 5,9E-09 | 4,4E-11 | 1,1E-12 | - | - |
| Tc-97m | 2,6E-17 | 4,9E-17 | 2,9E-17 | 1,6E-09 | 2,2E-10 | 5,7E-11 | - | - |
| Tc-98 | 1,3E-13 | 2,9E-13 | 1,6E-13 | 1,6E-07 | 1,7E-09 | 1,2E-10 | - | - |
| Tc-99 | 1,2E-17 | 2,6E-17 | 1,5E-17 | 2,9E-08 | 2,7E-10 | 9,6E-11 | - | - |
| Tc-99m | 9,9E-15 | 1,8E-14 | 1,1E-14 | 1,3E-11 | 1,4E-11 | 2,0E-11 | - | - |
| Te-118 | 8,6E-14 | 4,1E-12 | 2,6E-13 | 1,8E-09 | 1,2E-09 | 1,2E-10 | - | - |
| Te-119 | 6,9E-14 | 1,5E-13 | 8,5E-14 | 9,5E-11 | 1,3E-10 | 7,0E-12 | - | - |
| Te-119m | 1,3E-13 | 2,3E-13 | 1,6E-13 | 5,0E-10 | 5,6E-10 | 1,6E-11 | - | - |
| Te-121 | 5,2E-14 | 1,2E-13 | 6,4E-14 | 5,0E-10 | 3,2E-10 | 3,7E-12 | - | - |
| Te-121m | 1,7E-14 | 3,1E-14 | 2,0E-14 | 5,0E-09 | 4,3E-10 | 3,7E-11 | - | - |
| Te-123m | 1,1E-14 | 1,9E-14 | 1,2E-14 | 2,6E-09 | 2,6E-10 | 6,8E-11 | - | - |
| Te-125m | 1,4E-16 | 8,6E-16 | 3,4E-16 | 1,5E-09 | 1,9E-10 | 8,9E-11 | - | - |
| Te-127 | 5,2E-16 | 1,1E-15 | 6,4E-16 | 8,0E-11 | 4,6E-11 | 1,4E-10 | - | - |
| Te-127m | 5,6E-16 | 1,4E-15 | 7,4E-16 | 5,4E-09 | 5,0E-10 | 1,7E-10 | - | - |
| Te-129 | 6,1E-15 | 4,1E-13 | 7,1E-15 | 4,1E-11 | 6,1E-11 | 1,6E-10 | - | - |
| Te-129m | 7,4E-15 | 6,0E-13 | 8,4E-15 | 4,4E-09 | 9,3E-10 | 2,1E-10 | - | - |
| Te-131m | 1,4E-13 | 7,8E-13 | 1,8E-13 | 1,1E-09 | 1,1E-09 | 1,8E-10 | - | - |
| Te-132 | 2,3E-13 | 1,2E-12 | 2,9E-13 | 1,9E-09 | 2,2E-09 | 2,4E-10 | - | - |

| ***Radionuclide*** | $\dot{e}_{eff}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,skin}$ Sv.h$^{-1}$.Bq$^{-1}$ | $\dot{e}_{eq,eye}$ Sv.h$^{-1}$.Bq$^{-1}$ | $e_{inh}$ Sv.Bq$^{-1}$ | $e_{ing}$ Sv.Bq$^{-1}$ | $\dot{h}_{skin}$ Sv.h$^{-1}$/(Bq.m$^{-2}$) | $\dot{h}_{sub,eff}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) | $\dot{h}_{sub,eq}$ Sv.h$^{-1}$/(Bq.m$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| Th (natural) | 2,1E-13 | 2,5E-12 | 2,7E-13 | 1,7E-04 | 5,3E-05 | 9,6E-10 | 1,2E-14 | 9,3E-13 |
| Th-227 | 1,1E-14 | 2,1E-14 | 1,3E-14 | 3,3E-06 | 1,3E-09 | 3,0E-11 | - | - |
| Th-228 | 1,4E-13 | 2,1E-12 | 1,8E-13 | 3,7E-05 | 6,6E-08 | 1,1E-07 | 9,4E-14 | 1,2E-13 |
| Th-229 | 6,7E-15 | 1,2E-14 | 7,7E-15 | 1,7E-04 | 2,1E-07 | 4,8E-11 | - | - |
| Th-230 | 3,8E-16 | 4,8E-16 | 5,0E-16 | 3,4E-05 | 6,0E-08 | 6,4E-13 | - | - |
| Th-231 | 8,0E-16 | 1,5E-15 | 9,0E-16 | 1,7E-10 | 1,7E-11 | 7,3E-11 | - | - |
| Th-232 | 2,0E-16 | 2,3E-16 | 2,3E-16 | 1,0E-04 | 7,0E-08 | 3,5E-13 | - | - |
| Th-234 | 1,2E-14 | 2,7E-12 | 4,3E-14 | 4,9E-09 | 5,9E-10 | 1,9E-10 | - | - |
| Ti-44 | 2,1E-13 | 1,1E-12 | 2,6E-13 | 4,1E-07 | 2,4E-09 | 1,6E-10 | - | - |
| Tl-200 | 1,2E-13 | 2,4E-13 | 1,4E-13 | 2,1E-10 | 2,1E-10 | 1,8E-11 | - | - |
| Tl-201 | 6,4E-15 | 1,2E-14 | 7,3E-15 | 1,0E-10 | 7,2E-11 | 2,2E-11 | - | - |
| Tl-202 | 4,1E-14 | 9,1E-14 | 5,1E-14 | 3,3E-10 | 4,5E-10 | 8,8E-12 | - | - |
| Tl-204 | 1,8E-16 | 3,4E-16 | 2,1E-16 | 2,2E-08 | 8,1E-10 | 1,3E-10 | - | - |
| Tm-167 | 1,1E-14 | 2,1E-14 | 1,3E-14 | 4,8E-10 | 8,2E-11 | 1,1E-10 | - | - |
| Tm-170 | 4,1E-16 | 9,3E-16 | 5,0E-16 | 6,3E-09 | 1,5E-10 | 1,5E-10 | - | - |
| Tm-171 | 3,4E-17 | 7,7E-17 | 4,4E-17 | 1,2E-09 | 2,0E-12 | 1,0E-12 | - | - |
| U (depleted) | - | - | - | - | - | - | - | - |
| U (natural) | 1,8E-13 | 4,5E-12 | 2,9E-13 | 1,2E-04 | 2,9E-05 | 1,5E-09 | 7,4E-15 | 5,7E-13 |
| U (enriched to less than 20%, except slow lung absorption) | - | - | - | - | - | - | - | - |
| U (enriched to less than 20%) | 2,1E-13 | - | - | 2,0E-05 | - | - | - | - |
| U (enriched to less than 10%) | - | - | - | - | - | - | - | - |
| U (purified) | - | - | - | - | - | - | - | - |
| U-230 (fast lung absorption) | 7,8E-15 | 9,3E-15 | 1,0E-14 | 1,6E-06 | 1,3E-08 | 6,2E-08 | 1,1E-13 | 1,4E-13 |
| U-230 (medium lung absorption) | 7,8E-15 | 9,3E-15 | 1,0E-14 | 5,3E-06 | 1,3E-08 | 6,2E-08 | 1,1E-13 | 1,4E-13 |
| U-230 (slow lung absorption) | 7,8E-15 | 9,3E-15 | 1,0E-14 | 5,5E-06 | 1,3E-08 | 6,2E-08 | 1,1E-13 | 1,4E-13 |
| U-232 (fast lung absorption) | 5,7E-16 | 6,9E-16 | 7,8E-16 | 1,8E-06 | 1,8E-07 | 2,0E-12 | - | - |
| U-232 (medium lung absorption) | 5,7E-16 | 6,9E-16 | 7,8E-16 | 3,4E-05 | 1,8E-07 | 2,0E-12 | - | - |
| U-232 (slow lung absorption) | 5,7E-16 | 6,9E-16 | 7,8E-16 | 1,2E-04 | 1,8E-07 | 2,0E-12 | - | - |
| U-233 (fast lung absorption) | 4,1E-16 | 5,2E-16 | 5,6E-16 | 6,5E-07 | 3,5E-08 | 4,2E-13 | - | - |
| U-233 (medium lung absorption) | 4,1E-16 | 5,2E-16 | 5,6E-16 | 8,6E-06 | 3,5E-08 | 4,2E-13 | - | - |
| U-233 (slow lung absorption) | 4,1E-16 | 5,2E-16 | 5,6E-16 | 2,3E-05 | 3,5E-08 | 4,2E-13 | - | - |
| U-234 (fast lung absorption) | 3,8E-16 | 4,8E-16 | 5,2E-16 | 6,4E-07 | 3,5E-08 | 5,4E-13 | - | - |
| U-234 (medium lung absorption) | 3,8E-16 | 4,8E-16 | 5,2E-16 | 8,5E-06 | 3,5E-08 | 5,4E-13 | - | - |
| U-234 (slow lung absorption) | 3,8E-16 | 4,8E-16 | 5,2E-16 | 2,3E-05 | 3,5E-08 | 5,4E-13 | - | - |
| U-235 (all lung types absorption) | 1,4E-14 | 2,5E-14 | 1,6E-14 | 2,1E-05 | 3,2E-08 | 8,8E-11 | - | - |
| U-236 (fast lung absorption) | 3,0E-16 | 3,7E-16 | 4,0E-16 | 6,0E-07 | 3,2E-08 | 3,9E-13 | - | - |
| U-236 (medium lung absorption) | 3,0E-16 | 3,7E-16 | 4,0E-16 | 7,9E-06 | 3,2E-08 | 3,9E-13 | - | - |
| U-236 (slow lung absorption) | 3,0E-16 | 3,7E-16 | 4,0E-16 | 2,1E-05 | 3,2E-08 | 3,9E-13 | - | - |

| **Radionuclide** | $\dot{e}_{eff}$ $Sv.h^{-1}.Bq^{-1}$ | $\dot{e}_{eq,skin}$ $Sv.h^{-1}.Bq^{-1}$ | $\dot{e}_{eq,eye}$ $Sv.h^{-1}.Bq^{-1}$ | $e_{inh}$ $Sv.Bq^{-1}$ | $e_{ing}$ $Sv.Bq^{-1}$ | $\dot{h}_{skin}$ $Sv.h^{-1}/(Bq.m^{-2})$ | $\dot{h}_{sub,eff}$ $Sv.h^{-1}/(Bq.m^{-3})$ | $\dot{h}_{sub,eq}$ $Sv.h^{-1}/(Bq.m^{-3})$ |
|---|---|---|---|---|---|---|---|---|
| U-238 (all lung types absorption) | 2,3E-16 | 3,1E-16 | 2,9E-16 | 2,0E-05 | 3,1E-08 | 2,8E-13 | - | - |
| V-48 | 2,7E-13 | 5,1E-13 | 3,2E-13 | 2,3E-09 | 1,4E-09 | 8,8E-11 | - | - |
| V-49 | - | - | - | 7,3E-11 | 5,7E-12 | 8,6E-13 | - | - |
| W-178 | 1,0E-14 | 2,3E-14 | 1,2E-14 | 3,8E-10 | 6,6E-11 | 2,1E-11 | - | - |
| W-181 | 2,3E-15 | 4,9E-15 | 2,9E-15 | 3,3E-10 | 3,2E-11 | 1,2E-12 | - | - |
| W-185 | 2,6E-17 | 5,4E-17 | 3,2E-17 | 1,7E-09 | 6,1E-11 | 1,1E-10 | - | - |
| W-187 | 4,1E-14 | 1,3E-13 | 5,0E-14 | 2,3E-10 | 1,8E-10 | 1,5E-10 | - | - |
| W-188 | 1,3E-14 | 2,3E-12 | 2,9E-14 | 1,1E-08 | 1,3E-09 | 2,7E-10 | - | - |
| Xe-122 | 1,2E-13 | 5,2E-12 | 4,5E-13 | - | - | 1,3E-10 | 7,0E-12 | 1,1E-11 |
| Xe-123 | 5,6E-14 | 3,0E-13 | 6,8E-14 | - | - | - | 9,6E-11 | 1,5E-10 |
| Xe-127 | 2,2E-14 | 4,2E-14 | 2,6E-14 | - | - | - | 3,6E-11 | 4,9E-11 |
| Xe-131m | 3,7E-16 | 1,1E-15 | 5,6E-16 | - | - | - | 1,1E-12 | 1,2E-11 |
| Xe-133 | 2,4E-15 | 4,8E-15 | 2,8E-15 | - | - | - | 4,0E-12 | 1,4E-11 |
| Xe-135 | 2,1E-14 | 4,1E-14 | 2,6E-14 | - | - | - | 3,5E-11 | 9,4E-11 |
| Y-87 | 7,0E-14 | 1,6E-13 | 8,7E-14 | 2,8E-10 | 2,8E-10 | 3,6E-11 | - | - |
| Y-88 | 2,4E-13 | 3,4E-13 | 2,7E-13 | 6,8E-09 | 9,1E-10 | 5,9E-12 | - | - |
| Y-89m | 8,3E-14 | 1,7E-13 | 1,0E-13 | - | - | 3,4E-12 | - | - |
| Y-90 | 1,6E-14 | 3,6E-12 | 7,3E-14 | 8,5E-10 | 5,6E-10 | 1,6E-10 | - | - |
| Y-91 | 2,1E-15 | 8,9E-13 | 1,4E-15 | 6,7E-09 | 4,0E-10 | 1,6E-10 | - | - |
| Y-91m | 4,9E-14 | 1,1E-13 | 6,1E-14 | 7,3E-12 | 1,1E-11 | 1,0E-11 | - | - |
| Y-92 | 8,8E-14 | 5,9E-12 | 5,5E-13 | 1,8E-10 | 3,0E-10 | 1,7E-10 | - | - |
| Y-93 | 4,4E-14 | 5,0E-12 | 2,6E-13 | 3,0E-10 | 3,9E-10 | 1,7E-10 | - | - |
| Yb-169 | 2,3E-14 | 4,6E-14 | 2,8E-14 | 1,6E-09 | 1,7E-10 | 8,7E-11 | - | - |
| Yb-175 | 3,4E-15 | 7,4E-15 | 4,2E-15 | 2,6E-10 | 3,3E-11 | 1,0E-10 | - | - |
| Zn-65 | 5,3E-14 | 9,3E-14 | 6,3E-14 | 3,8E-09 | 4,3E-09 | 4,7E-12 | - | - |
| Zn-69 | 1,6E-16 | 3,3E-16 | 1,9E-16 | 2,8E-11 | 2,9E-11 | 1,5E-10 | - | - |
| Zn-69m | 3,8E-14 | 8,6E-14 | 4,7E-14 | 1,8E-10 | 1,7E-10 | 1,7E-10 | - | - |
| Zr-88 | 3,4E-14 | 7,8E-14 | 4,3E-14 | 5,5E-09 | 2,2E-10 | 7,6E-12 | - | - |
| Zr-89 | 1,1E-13 | 2,2E-13 | 1,3E-13 | 3,8E-10 | 4,0E-10 | 4,3E-11 | - | - |
| Zr-93 | 1,9E-20 | 8,5E-20 | 3,8E-20 | 7,3E-09 | 5,0E-11 | 9,1E-06 | - | - |
| Zr-95 | 6,8E-14 | 1,5E-13 | 8,4E-14 | 4,5E-09 | 3,2E-10 | 2,9E-02 | - | - |
| Zr-97 | 1,5E-13 | 2,3E-12 | 1,9E-13 | 6,4E-10 | 7,0E-10 | 9,3E-02 | - | - |

*N.B.: for the radionuclides complying with the 10-day rule, as listed in Table 9, the dose coefficients take into account the contribution of progenies at the time of the accident (e.g. the $^{47}$Ca dose coefficient includes that of $^{47}$Sc in equilibrium according to the 10-day rule – in the case of $e_{inh}$, it is then different from the dose coefficient of $^{47}$Ca alone found in ICRP publications).*

# List of radionuclides in equilibrium

***Table 9. Radionuclides complying with the 10-day rule (SSR-6 Table 2 / footnote a) in the proposed update of the Q system***

| *Radionuclide* | Progenies considered in the "10-day rule" equilibrium |
|---|---|
| Ac-225 | At-217 \| Bi-213 \| Fr-221 \| Pb-209 \| Po-213 \| Tl-209 |
| Ac-226 | Fr-222 \| Po-214 \| Ra-222 \| Rn-218 \| Th-226 |
| Ac-227 | At-219 \| Bi-211 \| Bi-215 \| Fr-223 \| Pb-211 \| Po-211 \| Po-215 \| Tl-207 |
| Ag-108m | Ag-108 |
| Ag-110m | Ag-110 |
| Am-242m | Am-242 \| Np-238 |
| Am-243 | Np-239 |
| At-211 | Po-211 |
| Ba-131 | Cs-131 |
| Ba-140 | La-140 |
| Bi-210 | Tl-206 |
| Bi-210m | Tl-206 |
| Bi-212 | Po-212 \| Tl-208 |
| Bk-249 | Am-245 |
| Ca-47 | Sc-47 |
| Cd-115 | In-115m |
| Cd-115m | In-115m |
| Ce-133m | La-133 |
| Ce-134 | La-134 |
| Ce-137m | Ce-137 |
| Ce-144 | Pr-144 \| Pr-144m |
| Cf-253 | Cm-249 |
| Cm-247 | Pu-243 |
| Cs-137 | Ba-137m |
| Dy-166 | Ho-166 |
| Fe-52 | Mn-52m |
| Fe-60 | Co-60m |
| Gd-146 | Eu-146 |
| Ge-68 | Ga-68 |
| Hf-172 | Lu-172 \| Lu-172m |
| Hg-194 | Au-194 |
| Hg-195m | Hg-195 |
| I-135 | Xe-135m |
| In-111 | Cd-111m |

| *Radionuclide* | Progenies considered in the "10-day rule" equilibrium |
|---|---|
| In-114m | In-114 |
| Ir-189 | Os-189m |
| Mg-28 | Al-28 |
| Mo-99 | Tc-99m |
| Np-235 | U-235m |
| Np-236 | Pa-232 |
| Os-194 | Ir-194 |
| Pa-230 | Ac-226 \| Fr-222 \| Po-214 \| Ra-222 \| Rn-218 \| Th-226 |
| Pb-210 | Bi-210 \| Hg-206 \| Tl-206 |
| Pb-212 | Bi-212 \| Po-212 \| Tl-208 |
| Pd-103 | Rh-103m |
| Pm-148m | Pm-148 |
| Pt-188 | Ir-188 |
| Pu-239 | U-235m |
| Pu-241 | U-237 |
| Pu-244 | Np-240 \| Np-240m \| U-240 |
| Ra-223 | Bi-211 \| Pb-211 \| Po-211 \| Po-215 \| Rn-219 \| Tl-207 |
| Ra-224 | Bi-212 \| Pb-212 \| Po-212 \| Po-216 \| Rn-220 \| Tl-208 |
| Ra-225 | Ac-225 \| At-217 \| Bi-213 \| Fr-221 \| Pb-209 \| Po-213 \| Tl-209 |
| Ra-226 | At-218 \| Bi-214 \| Pb-214 \| Po-214 \| Po-218 \| Rn-218 \| Rn-222 \| Tl-210 |
| Ra-228 | Ac-228 |
| Rb-81 | Kr-81m |
| Rb-83 | Kr-83m |
| Re-189 | Os-189m |
| Rn-222 | At-218 \| Bi-214 \| Pb-214 \| Po-214 \| Po-218 \| Rn-218 \| Tl-210 |
| Ru-103 | Rh-103m |
| Ru-106 | Rh-106 |
| Sn-113 | In-113m |
| Sn-121m | Sn-121 |
| Sn-126 | Sb-126m |
| Sr-82 | Rb-82 |
| Sr-90 | Y-90 |
| Sr-91 | Y-91m |
| Tc-95m | Tc-95 |
| Te-118 | Sb-118 |
| Te-119m | Sb-119 |
| Te-127m | Te-127 |
| Te-129m | Te-129 |
| Te-131m | Te-131 |

| *Radionuclide* | Progenies considered in the "10-day rule" equilibrium |
|---|---|
| Te-132 | I-132 |
| Th-228 | Bi-212 \| Pb-212 \| Po-212 \| Po-216 \| Ra-224 \| Rn-220 \| Tl-208 |
| Th-234 | Pa-234 \| Pa-234m |
| Ti-44 | Sc-44 |
| U-230 | Po-214 \| Ra-222 \| Rn-218 \| Th-226 |
| U-235 | Th-231 |
| W-178 | Ta-178 |
| W-188 | Re-188 |
| Xe-122 | I-122 |
| Y-87 | Sr-87m |
| Zn-69m | Zn-69 |
| Zr-95 | Nb-95m |
| Zr-97 | Nb-97 |

*The activity to be taken into account is that of the parent nuclide only.*

### *Table 10. Mixtures in secular equilibrium (SSR-6 Table 2 / footnote b) in the proposed update of the Q system*

| *Radionuclide* | Progenies considered in the SSR-6 Table 2 mixtures |
|---|---|
| Rb (natural) | **Rb-87** |
| Re (natural) | **Re-187** |
| Th (natural) | Ac-228 \| Bi-212 \| Pb-208 \| Pb-212 \| Po-212 \| Po-216 \| Ra-224 \| Ra-228 \| Rn-220 \| Th-228 \| **Th-232** \| Tl-208 |
| U (depleted) | Pa-234 \| Pa-234m \| Th-231 \| Th-234 \| **U-234** \| **U-235** \| **U-238** |
| U (natural) | Ac-227 \| At-218 \| Bi-210 \| Bi-214 \| Bi-211 \| Fr-223 \| Hg-206 \| Pa-231 \| Pa-234 \| Pa-234m \| Pb-206 \| Pb-210 \| Pb-211 \| Pb-214 \| Po-210 \| Po-211 \| Po-214 \| Po-215 \| Po-218 \| Ra-223 \| Ra-226 \| Rn-218 \| Rn-219 \| Rn-222 \| Th-227 \| Th-230 \| Th-231 \| Th-234 \| Tl-206 \| Tl-207 \| Tl-210 \| U-234 \| U-235 \| **U-238** |
| U (enriched to less than 20%, except slow lung absorption) | Pa-234 \| Pa-234m \| Th-231 \| Th-234 \| **U-234** \| **U-235** \| **U-238** |
| U (enriched to less than 20%) | Pa-234 \| Pa-234m \| Th-231 \| Th-234 \| **U-234** \| **U-235** \| **U-238** |
| U (enriched to less than 10%) | Pa-234 \| Pa-234m \| Th-231 \| Th-234 \| **U-234** \| **U-235** \| **U-238** |
| U (purified) | Pa-234 \| Pa-234m \| Th-231 \| Th-234 \| **U-234** \| **U-235** \| **U-238** |

*The activity to be taken into account is that of the nuclides in **bold red**.*

IAEA TRANSSC Technical Expert Group on Radiation Protection

Working group on $A_1/A_2$

**Update of the Q system to derive the $A_1/A_2$ basic values of the IAEA transport regulations No. SSR-6**

Version 1.0
October 2023

Report of the WG $A_1/A_2$ for the 2021-2023 SSR-6 review and revision cycles