

IRSN

INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

Review of A_1 and A_2 values: Overview of the new calculation method

PATRAM

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Summary

- Reminder on A_1/A_2 and its current limits
- Presentation of the new proposed method
 - MC calculations
 - By fluences
- Quick talk on Q_A
- Focus on Q_B and its new DCF
- Focus on Q_D and its new DCF
- Conclusion

Reminder on A_1/A_2

➤ Definition of A_1 and A_2

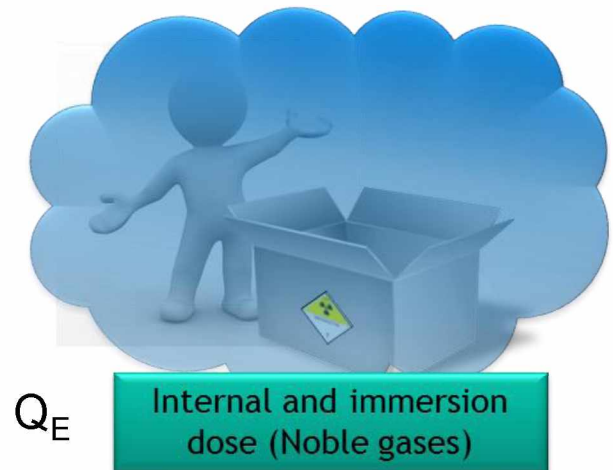
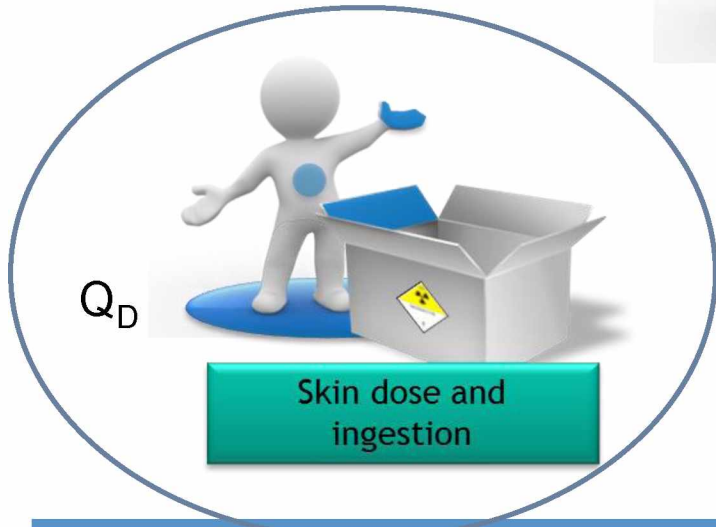
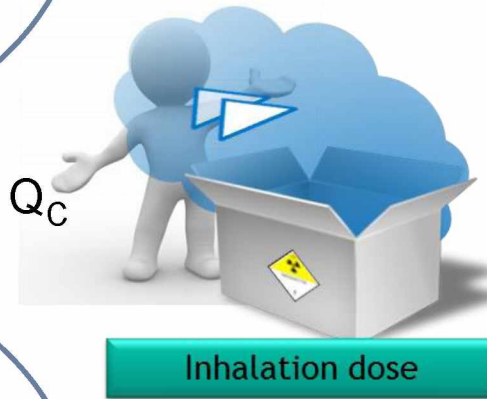
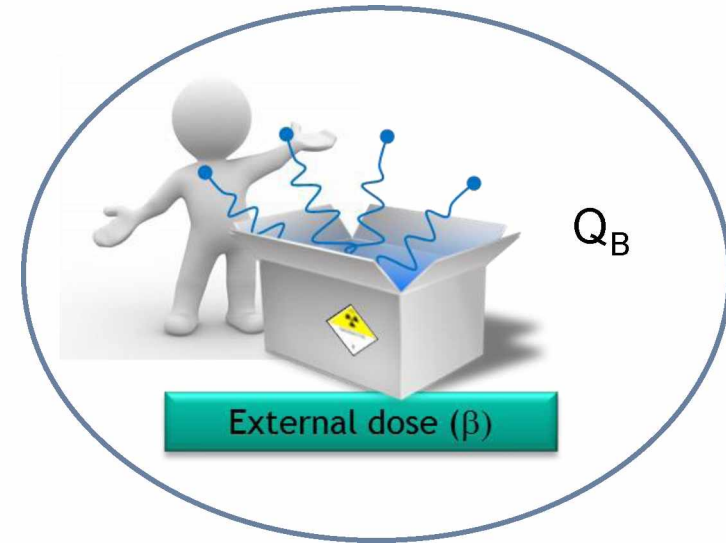
■ IAEA transport regulations SSR-6 :

- For each radionuclide: two values: A_1 and A_2
- Limits the contents of packages so that «*radiological consequences ... are acceptable* »
- Derived from Q-system

■ Q-system

- Comes from SSG-26
- Based on 5 different exposure scenarios

Reminder on A_1/A_2



Current method

➤ How?

■ Using:

- Empirical and/or analytical formula
- Outdated scientific paper or ICRP publications for some data
- Lack of traceability of some coefficients

New method being proposed

➤ Why?

- Several evolutions from the last Q system on:
 - Nuclear data (emissions): ICRP 107
 - Dose coefficients: ICRP 74 & 116
 - ...
- Need of Q values for new radionuclides
- ➔ Decision of the WG to (re-)create Q values for all radionuclides, by taking into account the latest data

New method being proposed for Q_A Q_B

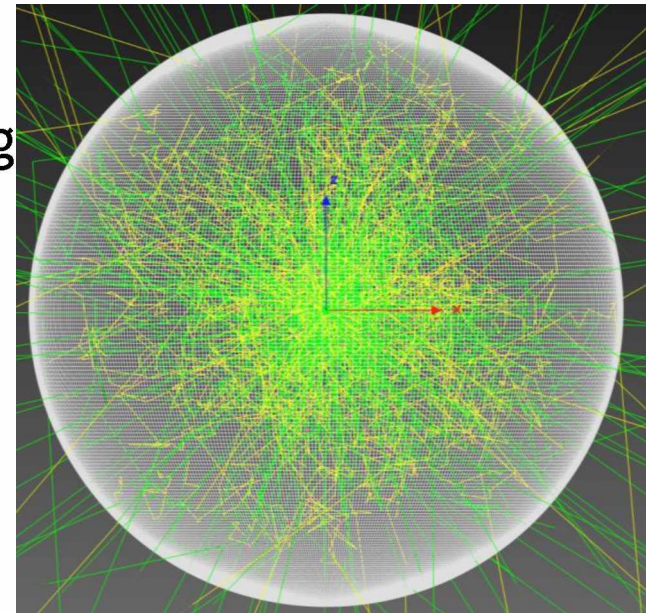
➤ How?

■ Use of Monte-Carlo codes to record @ 1m, **fluences** of all particles

- Primary particles (from the source: γ , β , neutron...)
- Secondary particles (due to ray-matter interactions)
- Tertiary particles
- ...

■ Use of the latest data by post-processing

- Nuclear data: ICRP107
- **Dose Coefficient Factors (DCF):**
 - ICRP116
 - Our own DCF



New method being proposed for Q_A Q_B

↗ Q_A

- Dealing with exposure to whole body
- What if we consider every radiation ?
- Please see poster #1402 (Review of the A_1 and A_2 values: impact of all radiations on Q_A and Q_B) to see influence (or not) of every radiation

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Review of the A_1 and A_2 values: impact of all radiations on Q_A and Q_B

Introduction

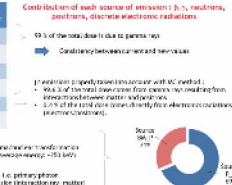
The A_1 and A_2 values of the Q System, described in the advisory material (SSG 26), have been developed to provide maximum allowed contents by weight not designed to mitigate accidents. Current values were determined by ICRP according to specific scenarios for the exposure pathway. From 2011, the IRSN has published new radiological data. In September 2019, an international group was created to discuss the improvement of calculation methods associated to the Q system. After this framework, it has been decided to change the current A_1 and A_2 values and to be invited to a more accurate new, based on Monte Carlo calculation. This document shows the methodology to be used to determine the new values and to compare new results for the currently published values.

Q_A

| Method | Current approach | New approach |
|--------------------------|----------------------------|--|
| Radionuclides | gamma | All radionuclides (alpha, beta, gamma, x-rays, discrete electronic radiations) |
| Type of source | Point source | Area source |
| Distribution (thickness) | 1 micron | 1 micron |
| Shielding | None | Forward shielding (0.5 cm of stainless steel (SS)) |
| Target | Whole body | Whole body |
| Calculation method | AR interaction | AR and AR+beta interaction |
| Dose coefficient | ICRP 51 effective dose [1] | ICRP 119 effective dose [2] |

Results for some radionuclides

| Radionuclide | Q_A (ICRP 51) | Q_A (ICRP 119) | Ratio |
|--------------|-----------------|------------------|-------|
| Co-60 | 0.44 | 0.05 | 0.11 |
| Cs-134 | 0.81 | 0.06 | 0.07 |
| Eu-154 | 0.85 | 0.00 | 0.00 |
| Ir-192 | 1.27 | 1.00 | 0.78 |
| P-32 | 1.04 | 1.00 | 0.96 |
| Y-90 | 2.03 | 4.00 | 1.97 |

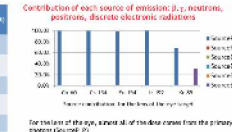


Q_B

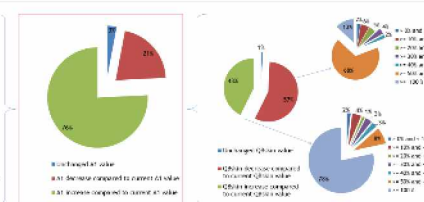
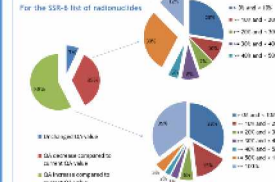
| Method | Current approach | New approach |
|--------------------------|-----------------------------------|--|
| Radionuclides | gamma | All radionuclides (alpha, beta, gamma, x-rays, discrete electronic radiations) |
| Type of source | Point source | Area source |
| Distribution (thickness) | 1 micron | 1 micron |
| Shielding | None | Forward shielding (0.5 cm of stainless steel (SS)) |
| Target | Skin | Layer of skin |
| Calculation method | Monte Carlo (Fig. 1 below) | AR and AR+beta interaction (Monte Carlo simulation (Fig. 2)) |
| Dose coefficient | ICRP 51 skin dose coefficient [3] | ICRP 119 skin dose coefficient for photon and electron [4] |

Results for some radionuclides

| Radionuclide | Q_B (ICRP 51) | Q_B (ICRP 119) | Ratio |
|--------------|-----------------|------------------|-------|
| Co-60 | 2.8 | 1.1 | 0.39 |
| Cs-134 | 3 | 1.2 | 0.4 |
| Ir-192 | 2.4 | 2.2 | 0.9 |
| P-32 | 4.5 | 3.5 | 0.78 |
| Y-90 | 5 | 3.4 | 0.68 |



Conclusions & outlooks



New method being proposed for Q_A Q_B

↗ Q_B

- Q_A deals with whole body exposure
- Q_B initially designed for the skin exposure
- Proposal: consider **every radiation, in the same way as for Q_A**
- Due to the recent decrease of dose limitation: lens of the eye is no more negligible compared to extremities
 - EURATOM statement (from ICRP recommendation): lowering eye dose limit (*i.e.* 20 mSv instead of 150 mSv for planned exposure)
- → $Q_{B,skin}$ and $Q_{B,eye}$

Focus on Q_B

↗ $Q_{B,skin}$

- Represents exposure to the skin
- More precisely: to the most exposed square centimeter
- Existence of Dose Conversion Factors (DCF) ?
- Yes and no !
- DCF for the whole skin organ tissue for gamma and neutron
 - Anthropomorphic voxelized phantom with 2mm skin thickness
 - Not realist
- Development of our own DCF

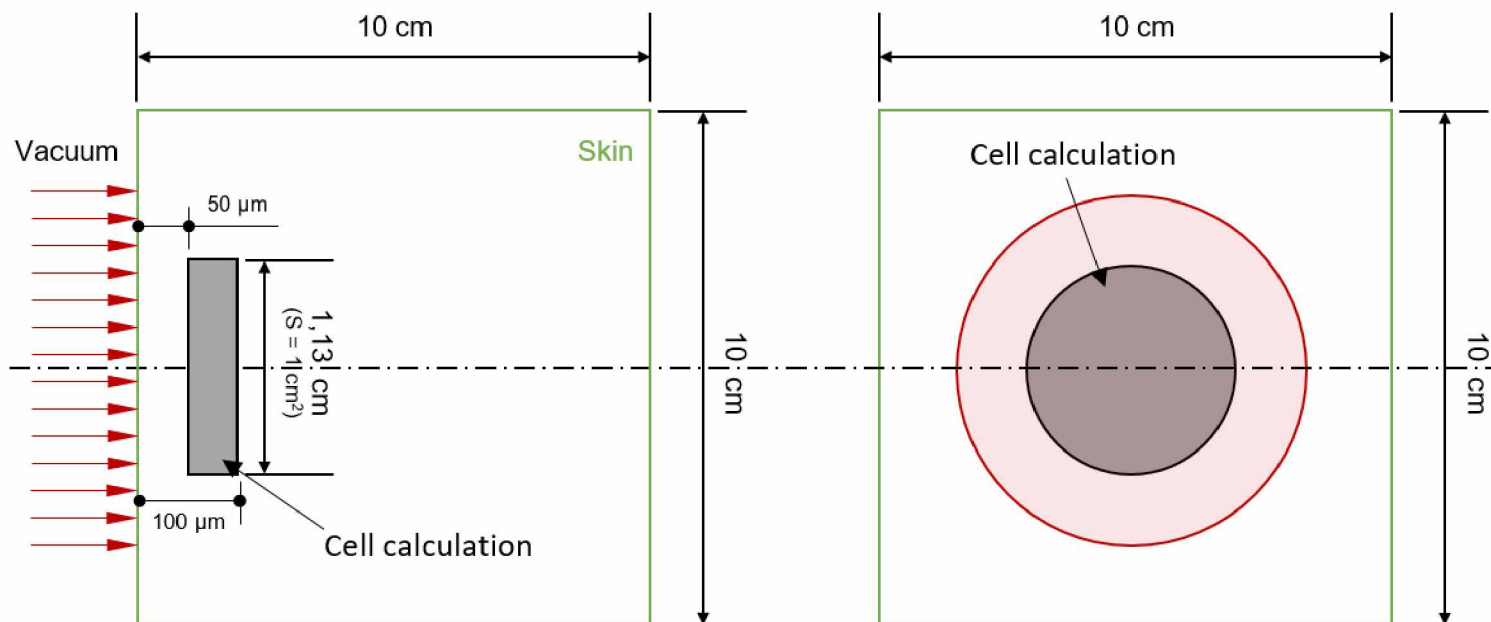


Focus on Q_B

↗ $Q_{B,skin}$

Development of *local skin dose* DCF for gamma and neutron by IRSN

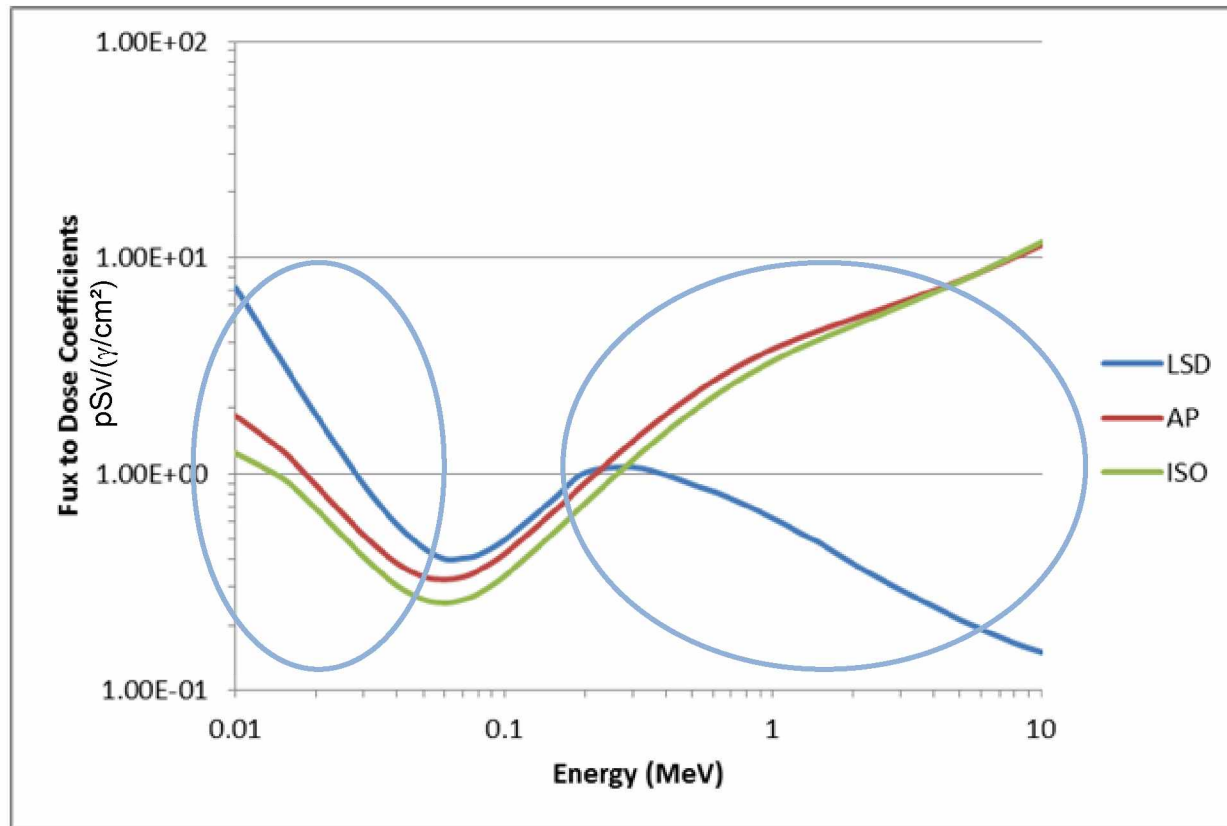
- Based on ICRP116



Focus on Q_B

↗ $Q_{B,skin}$

■ Real impact ? Let's see for γ



Focus on Q_B

↗ $Q_{B,skin}$

■ Final impact

| Nuclide | $Q_{B,skin}$ (use of “whole skin organ”) | $Q_{B,skin}$ (use of “local skin dose”) |
|---------|--|---|
| | (TBq) | (TBq) |
| Co-60 | 1.8 | 2.6 |
| Cs-134 | 2.24 | 2.98 |
| Eu-154 | 2.11 | 2.56 |
| F-18 | 3.57 | 4.50 |
| Ir-192 | 5.25 | 6.03 |

■ Same order of magnitude

Focus on Q_B

↗ $Q_{B,eye}$

- Due to the recent decrease of dose limitation: lens of the eye is no more negligible compared to extremities
- Use of fluences/primary particles, previously created and recorded
 - No additional MC calculation
- Postprocessed with DCF issued from ICRP 116
 - For photons, neutrons & electrons
 - IRSN proposed to assess DCF for positrons

Focus on Q_B

➔ Overall comparison of some values

| Nuclide | $Q_{B,skin}$ | $Q_{B,eye}$ (dose limit of 150 mSv) | Current Q_B |
|---------|--------------|-------------------------------------|---------------|
| | (TBq) | | |
| Co-60 | 1.8 | 1.1 | 730 |
| Cs-134 | 2.2 | 1.7 | 3.6 |
| Eu-154 | 2.1 | 2.2 | 1.6 |
| F-18 | 3.6 | 2.6 | 28 |
| Ir-192 | 5.3 | 3.4 | 46 |

- Same order of magnitude

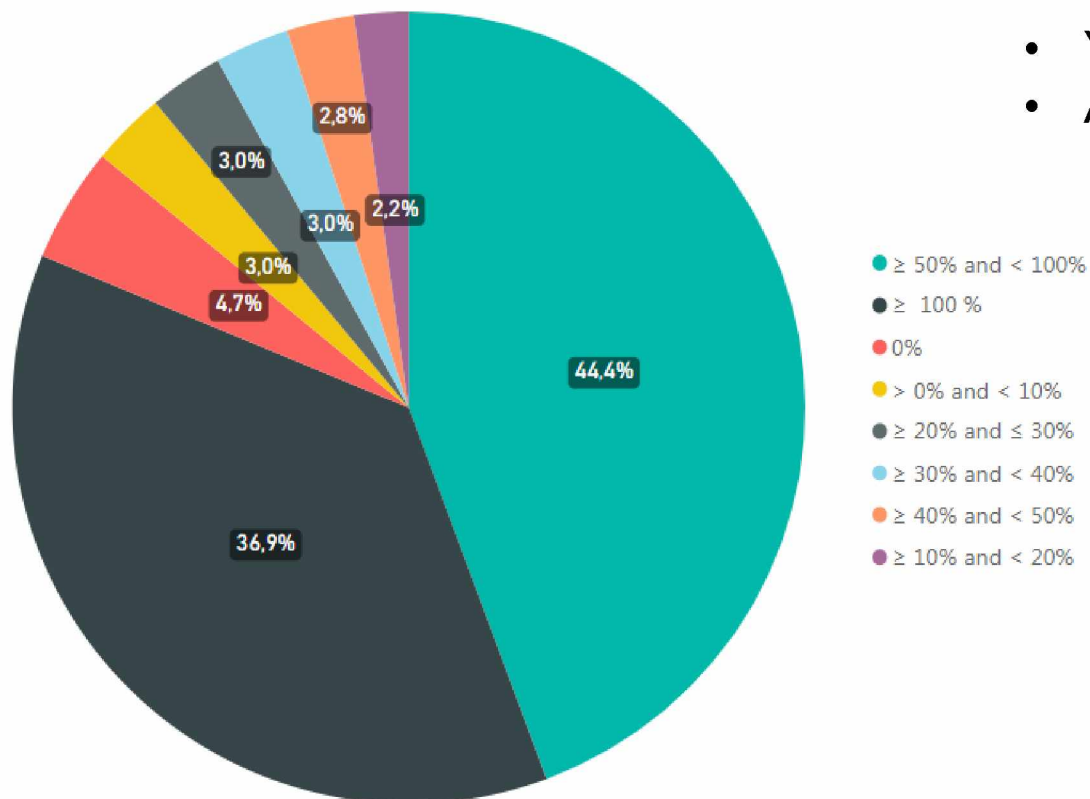
- except for high-energy gamma emitters

- Please see poster #1402 (Review of the A_1 and A_2 values: impact of all radiations on Q_A and Q_B) for further explanations

Focus on Q_B

➔ Overall impact

▮ Absolute impact of the new method for SSR-6's 275 radionuclides

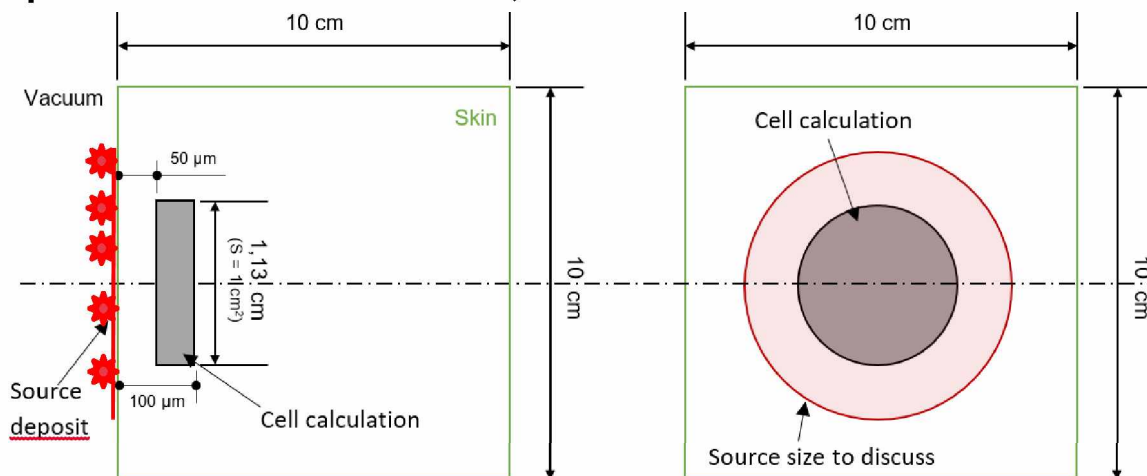


- Yes, but only for Q_B
- A_1 is mainly (87%) led by Q_A

Focus on Q_D

➔ Ingestion and skin contamination

- Ingestion: use of coefficients from future ICRP publications
- Skin contamination: ???
- By consistency : every radiation is considered
- IRSN proposed a new model, based on ICRP 116



Focus on Q_D

➔ Impact of the new method

| Nuclide | Q_D (IRSN's proposal) | Q_D (Current) | Relative deviation |
|---------|-------------------------|-----------------|--------------------|
| | (TBq) | | |
| Co-60 | 1.12 | 0.97 | + 15% |
| Cs-134 | 1.00 | 0.92 | + 9% |
| Eu-154 | 0.64 | 0.55 | + 16% |
| F-18 | 0.67 | 0.58 | + 16% |
| Ir-192 | 0.68 | 0.61 | + 11% |

■ Impact of the new method, **not so important.**

Conclusion

- New method, generally, more accurate than before
- Generally, minor change in numerical values for Q_D
- When major change for Q_B , not necessarily reflected on A_1
- Keep in mind: still some discussion about the choice of the model (source size, medium composition...)
- → Change of numerical values still to be validated/accepted by TRANSCC
- → Implementation of all these values in an user-friendly software

Thank you for your attention

Questions ?