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PANDUAN TEKNIKAL

ASSESSMENT AND LICENSING OF CONSUMER PRODUCT CONTAINING RADIOACTIVE MATERIAL

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1. PURPOSE

This guideline applies for an assessment and licensing of consumer products that contains the amount of radioactive materials exceeding the activity concentration as specified in the Appendix 1.

2. SCOPE

This guidelines is applicable for assessment and licensing on the manufacturing, selling, transporting, storage, import and export, and disposal of all consumer products containing radioactive material with the activity or activity concentration higher than the limits as specified in this guidelines. It does not include building materials, ceramic tiles, spa waters, minerals and foodstuff and it excluded products and appliances installed in public places (e.g exit signs).

3. DEFINITION

"**Consumer product**" means a device, an article or a thing such as a smoke detector, luminous dial or ion generating tube that contains the amount of radioactive materials as determined by the appropriate authority.

"**Safety assessment**" means a review of the aspects of design and operation of a the radiation source, including the analysis of the provisions for safety and protection established in the design and operation of the radiation source and the analysis of risks associated with normal exposure and accidental exposure.

4. RADIATION PROTECTION SYSTEM

4.1 Based on Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010, no person shall carry out any practices unless the practice is justified to produce sufficient benefits to the exposed individuals or to society to offset the radiation harm that it might, taking into account the social, economic and other relevant factors.

4.2 Radiation protection and safety shall be optimized so that magnitude of the dose to individual, number of people exposed and probability to be exposed are always as low as reasonable achievable, taking into account an economic and social factors.

5. ASSESSMENT AND LICENSING CRITERIA FOR CONSUMER PRODUCT CONTAINING RADIOACTIVE MATERIAL

5.1 The licensing process should initially consider justification process where benefits must exceed the detriment for the use of the consumer products.

5.2 The practices are deemed to be unjustified whenever the result in an increase, by deliberate addition of radioactive material or by activation in the activity of the associated products:

a) Practices involving food, beverages, cosmetics or any other commodity or product intended for ingestion, inhallation or percutaneous intake by, or an application to, a human being, except for justified practices involving medical exposure; and

b) Practices involving the frivolous use of a radiation or radioactive material, nuclear material or prescribed substance in commodities or products such as toys and personal jewellery or a decorative items.

5.3 For the product deem to be justified, the Board sets basic criteria to be considered for an exemption to the control of consumer product containing radioactive material if, under reasonably acceptable in all normal conditions :-

a) the effective dose to be incurred by any individual member of the public from the practice or source within practices are less than 10 microsievert per year. The General Safety Requirements Part 3 (GSR-Part 3) developed by International Atomic Energy Agency (IAEA) in taking into account the low probability scenario states that any criteria may be specified by the regulatory body where the effective dose committed during one year is not more than 1 mSv and it will not cause radiological risk to the user and the member of the public for internal or external exposure or both; or

b) based on the criteria given in Appendix 1; ***Table I-1****: Levels For Exemption Of Moderate Amounts Of Material Without Further Consideration: Exempt Activity Concentrations And Exempt Activities of Radionuclides* (*GSR Part 3)* and ***Table I-3****: Levels For Clearance of Material: Activity Concentrations of Radionuclides of Natural Origin* the licensing controls are applicable for consumer product that containing activity or activity concentration exceeds value in Appendix 1.

5.4 As for reference, Checklist for Assessment and Licensing of Consumer Product Containing Radioactive Material is shown in Appendix 2 meanwhile Flow Chart on Procedure for Assessment and Licensing of Consumer Product Containing Radioactive Material is shown in Appendix 3.

6. RADIATION SAFETY ASSESSMENT

6.1 Radiation Safety Assessment is important in determining the optimization of the protection. It includes an assessment of the dose that may be received during normal used, reasonably foreseeable accidents and disposal. Assessed dose is compared with prescribed dose limit.

6.2. There are several consumer products that may be in single used or in small quantity and are also similar products are fixed at the work place or in the public areas in big quantity. For example, the ionization chamber smoke detector, “EXIT” or “KELUAR” signage that contained tritium element. A separate safety assessment should also be conducted for the consumer product that handled in bulk such as during storage and transportation.

6.3 An example of the structure for Radiation Safety Assessment Reports is shown in Appendix 4. In this guidance, a few example on calculation of radiation doses from ionization chamber smoke detectors during normal and abnormal circumtances (storage, during fire etc) are shown in Appendix 5. In addition to that, Appendix 6 demonstrate the radiation dose calculation from "pendant".

7. IMPLEMENTATION

This guidance document will be effectively applicable on the date of issued. If any further questions regarding this guidelines, please contact the Atomic Energy Licensing Board as address below.

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8. REFERENCES

i. Akta Perlesenan Tenaga Atom 1984 (Akta 304)

ii. Peraturan-Peraturan Pelesenan Tenaga Atom (Perlindungan Sinaran Keselamatan Asas) 2010 [P.U (A) 46]

iii. KOD/EMT/125: Keperluan Melesenkan Pengedar Utama Pendant Yang Mengandungi Bahan Radioaktif Semula jadi di Bawah Akta 304

iv. INTERNATIONAL ATOMIC ENERGY AGENCY, Exemption from Regulatory Control of Manufactured Items Containing Small Amounts of Radioactive Substances ,TECDOC 1679, IAEA, Vienna (2012)

v. INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, General Safety Requirements Part 3, No. GSR Part 3, IAEA, Vienna (2014)

vi. Commission of the European Communities, Radiation Protection 65, Principles and Methods for Establishing Concentrations and Quantities (Exemption values) Below which Reporting is not Required in the European Directive.

Appendix 1

EXEMPTION LIMITS IN ASSESSMENT AND LICENSING OF CONSUMER PRODUCT

Table I-1:

Levels For Exemption Of Moderate Amounts Of Material Without Further Consideration: Exempt Activity Concentrations And Exempt Activities of Radionuclides

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
H-3	1 E+06	1 E +09
Be-7	1 E+03	1 E +07
Be-10	1 E+04	1 E +06
C-11	1 E+01	1 E +06
C-14	1 E+04	1 E +07
N-13	1 E+02	1 E +09
Ne-19	1 E+02	1 E +09
O-15	1 E+02	1 E +09
F-18	1 E+01	1 E +06
Na-22	1 E+01	1 E +06
Na-24	1 E+01	1 E +05
Mg-28	1 E+01	1 E +05
Al-26	1 E+01	1 E +05
Si-31	1 E+03	1 E +06
Si-32	1 E+03	1 E +06
P-32	1 E+03	1 E +05
P-33	1 E+05	1 E +08
S-35	1 E+05	1 E +08
Cl-36	1 E+04	1 E +06
Cl-38	1 E+01	1 E +05
Cl-39	1 E+01	1 E +05
Ar-37	1 E+06	1 E +08
Ar-39	1 E+07	1 E +04
Ar-41	1 E+02	1 E +09
K-40	1 E+02	1 E +06
K-42	1 E+02	1 E +06
K-43	1 E+01	1 E +06
K-44	1 E+01	1 E +05
K-45	1 E+01	1 E +05
Ca-41	1 E+05	1 E +07

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Ca-45	1 E+04	1 E +07
Ca-47	1 E+01	1 E +06
Sc-43	1 E+01	1 E +06
Sc-44	1 E+01	1 E +05
Sc-45	1 E+02	1 E +07
Sc-46	1 E+01	1 E +06
Sc-47	1 E+02	1 E +06
Sc-48	1 E+01	1 E +05
Sc-49	1 E+03	1 E +05
Ti-44	1 E+01	1 E +05
Ti-45	1 E+01	1 E +06
V-47	1 E+01	1 E +05
V-48	1 E+01	1 E +05
V-49	1 E+04	1 E +07
Cr-48	1 E+02	1 E +06
Cr-49	1 E+01	1 E +06
Cr-51	1 E+03	1 E +07
Mn-51	1 E+01	1 E +05
Mn-52	1 E+01	1 E +05
Mn-52m	1 E+01	1 E +05
Mn-53	1 E+04	1 E +09
Mn-54	1 E+01	1 E +06
Mn-56	1 E+01	1 E +05
Fe-52	1 E+01	1 E +06
Fe-55	1 E+04	1 E +06
Fe-59	1 E+01	1 E +06
Fe-60	1 E+02	1 E +05
Co-55	1 E+01	1 E +06
Co-56	1 E+01	1 E +05
Co-57	1 E+02	1 E +06
Co-58	1 E+01	1 E +06
Co-58m	1 E+04	1 E +07
Co-60	1 E+01	1 E +05
Co-60m	1 E+03	1 E +06
Co-61	1 E+02	1 E +06
Co-62m	1 E+01	1 E +05
Ni-56	1 E+01	1 E +06
Ni-57	1 E+01	1 E +06
Ni-59	1 E+04	1 E +08
Ni-63	1 E+05	1 E +08
Ni-65	1 E+01	1 E +06

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Ni-66	1 E+04	1 E +07
Cu-60	1 E+01	1 E +05
Cu-61	1 E+01	1 E +06
Cu-64	1 E+02	1 E +06
Cu-67	1 E+02	1 E +06
Zn-62	1 E+02	1 E +06
Zn-63	1 E+01	1 E +05
Zn-65	1 E+01	1 E +06
Zn-69	1 E+04	1 E +06
Zn-69m	1 E+02	1 E +06
Zn-71m	1 E+01	1 E +06
Zn-72	1 E+02	1 E +06
Ga-65	1 E+01	1 E +05
Ga-66	1 E+01	1 E +05
Ga-67	1 E+02	1 E +06
Ga-68	1 E+01	1 E +05
Ga-70	1 E+02	1 E +06
Ga-72	1 E+01	1 E +05
Ga-73	1 E+02	1 E +06
Ge-66	1 E+01	1 E +06
Ge-67	1 E+01	1 E +05
Ge-68[a]	1 E+01	1 E +05
Ge-69	1 E+01	1 E +06
Ge-71	1 E+04	1 E +08
Ge-75	1 E+03	1 E +06
Ge-77	1 E+01	1 E +05
Ge-78	1 E+02	1 E +06
As-69	1 E+01	1 E +05
As-70	1 E+01	1 E +05
As-71	1 E+01	1 E +06
As-72	1 E+01	1 E +05
As-73	1 E+03	1 E +07
As-74	1 E+01	1 E +06
As-76	1 E+02	1 E +05
As-77	1 E+03	1 E +06
As-78	1 E+01	1 E +05
Se-70	1 E+01	1 E +06
Se-73	1 E+01	1 E +06
Se-73m	1 E+02	1 E +06
Se-75	1 E+02	1 E +06
Se-79	1 E+04	1 E +07

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Se-81	1 E+03	1 E +06
Se-81m	1 E+03	1 E +07
Se-83	1 E+01	1 E +05
Br-74	1 E+01	1 E +05
Br-74m	1 E+01	1 E +05
Br-75	1 E+01	1 E +06
Br-76	1 E+01	1 E +05
Br-77	1 E+02	1 E +06
Br-80	1 E+02	1 E +05
Br-80m	1 E+03	1 E +07
Br-82	1 E+01	1 E +06
Br-83	1 E+03	1 E +06
Br-84	1 E+01	1 E +05
Kr-74	1 E+02	1 E +09
Kr-76	1 E+02	1 E +09
Kr-77	1 E+02	1 E +09
Kr-79	1 E+03	1 E +05
Kr-81	1 E+04	1 E +07
Kr-81m	1 E+03	1 E +10
Kr-83m	1 E+05	1 E +12
Kr-85	1 E+05	1 E +04
Kr-85m	1 E+03	1 E +10
Kr-87	1 E+02	1 E +09
Kr-88	1 E+02	1 E +09
Rb-79	1 E+01	1 E +05
Rb-81	1 E+01	1 E +06
Rb-81m	1 E+03	1 E +07
Rb-82m	1 E+01	1 E +06
Rb-83[a]	1 E+02	1 E +06
Rb-84	1 E+01	1 E +06
Rb-86	1 E+02	1 E +05
Rb-87	1 E+03	1 E +07
Rb-88	1 E+02	1 E +05
Rb-89	1 E+02	1 E +05
Sr-80	1 E+03	1 E +07
Sr-81	1 E+01	1 E +05
Sr-82[a]	1 E+01	1 E +05
Sr-83	1 E+01	1 E +06
Sr-85	1 E+02	1 E +06
Sr-85m	1 E+02	1 E +07
Sr-87m	1 E+02	1 E +06

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Sr-89	1 E+03	1 E +06
Sr-90[a]	1 E+02	1 E +04
Sr-91	1 E+01	1 E +05
Sr-92	1 E+01	1 E +06
Y-86	1 E+01	1 E +05
Y-86m	1 E+02	1 E +07
Y-87[a]	1 E+01	1 E +06
Y-88	1 E+01	1 E +06
Y-90	1 E+03	1 E +05
Y-90m	1 E+01	1 E +06
Y-91	1 E+03	1 E +06
Y-91m	1 E+02	1 E +06
Y-92	1 E+02	1 E +05
Y-93	1 E+02	1 E +05
Y-94	1 E+01	1 E +05
Y-95	1 E+01	1 E +05
Zr-86	1 E+02	1 E +07
Zr-88	1 E+02	1 E +06
Zr-89	1 E+01	1 E +06
Zr-93[a]	1 E+03	1 E +07
Zr-95	1 E+01	1 E +06
Zr-97[a]	1 E+01	1 E +05
Nb-88	1 E+01	1 E +05
Nb-89 (2.03j)	1 E+01	1 E +05
Nb-89m (1.10j)	1 E+01	1 E +05
Nb-90	1 E+01	1 E +05
Nb-93m	1 E+04	1 E +07
Nb-94	1 E+01	1 E +06
Nb-95	1 E+01	1 E +06
Nb-95m	1 E+02	1 E +07
Nb-96	1 E+01	1 E +05
Nb-97	1 E+01	1 E +06
Nb-98	1 E+01	1 E +05
Mo-90	1 E+01	1 E +06
Mo-93	1 E+03	1 E +08
Mo-93m	1 E+01	1 E +06
Mo-99	1 E+02	1 E +06
Mo-101	1 E+01	1 E +06
Tc-93	1 E+01	1 E +06
Tc-93m	1 E+01	1 E +06

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Tc-94	1 E+01	1 E +06
Tc-94m	1 E+01	1 E +05
Tc-95	1 E+01	1 E +06
Tc-95m	1 E+01	1 E +06
Tc-96	1 E+01	1 E +06
Tc-96m	1 E+03	1 E +07
Tc-97	1 E+03	1 E +08
Tc-97m	1 E+03	1 E +07
Tc-98	1 E+01	1 E +06
Tc-99	1 E+04	1 E +07
Tc-99m	1 E+02	1 E +07
Tc-101	1 E+02	1 E +06
Tc-104	1 E+01	1 E +05
Ru-94	1 E+02	1 E +06
Ru-97	1 E+02	1 E +07
Ru-103	1 E+02	1 E +06
Ru-105	1 E+01	1 E +06
Ru-106[a]	1 E+02	1 E +05
Rh-99	1 E+01	1 E +06
Rh-99m	1 E+01	1 E +06
Rh-100	1 E+01	1 E +06
Rh-101	1 E+02	1 E +07
Rh-101m	1 E+02	1 E +07
Rh-102	1 E+01	1 E +06
Rh-102m	1 E+02	1 E +06
Rh-103m	1 E+04	1 E +08
Rh-105	1 E+02	1 E +07
Rh-106m	1 E+01	1 E +05
Rh-107	1 E+02	1 E +06
Pd-100	1 E+02	1 E +07
Pd-101	1 E+02	1 E +06
Pd-103	1 E+03	1 E +08
Pd-107	1 E+05	1 E +08
Pd-109	1 E+03	1 E +06
Ag-102	1 E+01	1 E +05
Ag-103	1 E+01	1 E +06
Ag-104	1 E+01	1 E +06
Ag-104m	1 E+01	1 E +06
Ag-105	1 E+02	1 E +06
Ag-106	1 E+01	1 E +06
Ag-106m	1 E+01	1 E +06

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Ag-108m	1 E+01	1 E +06
Ag-110m	1 E+01	1 E +06
Ag-111	1 E+03	1 E +06
Ag-112	1 E+01	1 E +05
Ag-115	1 E+01	1 E +05
Cd-104	1 E+02	1 E +07
Cd-107	1 E+03	1 E +07
Cd-109	1 E+04	1 E +06
Cd-113	1 E+03	1 E +06
Cd-113m	1 E+03	1 E +06
Cd-115	1 E+02	1 E +06
Cd-115m	1 E+03	1 E +06
Cd-117	1 E+01	1 E +06
Cd-117m	1 E+01	1 E +06
In-109	1 E+01	1 E +06
In-110 (4.9j)	1 E+01	1 E +06
In-110 (69.1j)	1 E+01	1 E +05
In-111	1 E+02	1 E +06
In-112	1 E+02	1 E +06
In-113m	1 E+02	1 E +06
In-114	1 E+03	1 E +05
In-114m	1 E+02	1 E +06
In-115	1 E+03	1 E +05
In-115m	1 E+02	1 E +06
In-116m	1 E+01	1 E +05
In-117	1 E+01	1 E +06
In-117m	1 E+02	1 E +06
In-119m	1 E+02	1 E +05
Sn-110	1 E+02	1 E +07
Sn-111	1 E+02	1 E +06
Sn-113	1 E+03	1 E +07
Sn-117m	1 E+02	1 E +06
Sn-119m	1 E+03	1 E +07
Sn-121	1 E+05	1 E +07
Sn-121m[a]	1 E+03	1 E +07
Sn-123	1 E+03	1 E +06
Sn-123m	1 E+02	1 E +06
Sn-125	1 E+02	1 E +05
Sn-126[a]	1 E+01	1 E +05
Sn-127	1 E+01	1 E +06
Sn-128	1 E+01	1 E +06

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Sb-115	1 E+01	1 E +06
Sb-116	1 E+01	1 E +06
Sb-116m	1 E+01	1 E +05
Sb-117	1 E+02	1 E +07
Sb-118m	1 E+01	1 E +06
Sb-119	1 E+03	1 E +07
Sb-120 (5.76h)	1 E+01	1 E +06
Sb-120 (15.89m)	1 E+02	1 E +06
Sb-122	1 E+02	1 E +04
Sb-124	1 E+01	1 E +06
Sb-124m	1 E+02	1 E +06
Sb-125	1 E+02	1 E +06
Sb-126	1 E+01	1 E +05
Sb-126m	1 E+01	1 E +05
Sb-127	1 E+01	1 E +06
Sb-128 (9.01j)	1 E+01	1 E +05
Sb-128 (10.4m)	1 E+01	1 E +05
Sb-129	1 E+01	1 E +06
Sb-130	1 E+01	1 E +05
Sb-131	1 E+01	1 E +06
Te-116	1 E+02	1 E +07
Te-121	1 E+01	1 E +06
Te-121m	1 E+02	1 E +06
Te-123	1 E+03	1 E +06
Te-123m	1 E+02	1 E +07
Te-125m	1 E+03	1 E +07
Te-127	1 E+03	1 E +06
Te-127m	1 E+03	1 E +07
Te-129	1 E+02	1 E +06
Te-129m	1 E+03	1 E +06
Te-131	1 E+02	1 E +05
Te-131m	1 E+01	1 E +06
Te-132	1 E+02	1 E +07
Te-133	1 E+01	1 E +05
Te-133m	1 E+01	1 E +05
Te-134	1 E+01	1 E +06
I-120	1 E+01	1 E +05
I-120m	1 E+01	1 E +05

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
I-121	1 E+02	1 E +06
I-123	1 E+02	1 E +07
I-124	1 E+01	1 E +06
I-125	1 E+03	1 E +06
I-126	1 E+02	1 E +06
I-128	1 E+02	1 E +05
I-129	1 E+02	1 E +05
I-130	1 E+01	1 E +06
I-131	1 E+02	1 E +06
I-132	1 E+01	1 E +05
I-132m	1 E+02	1 E +06
I-133	1 E+01	1 E +06
I-134	1 E+01	1 E +05
I-135	1 E+01	1 E +06
Xe-120	1 E+02	1 E +09
Xe-121	1 E+02	1 E +09
Xe-122[a]	1 E+02	1 E +09
Xe-123	1 E+02	1 E +09
Xe-125	1 E+03	1 E +09
Xe-127	1 E+03	1 E +05
Xe-129m	1 E+03	1 E +04
Xe-131m	1 E+04	1 E +04
Xe-133m	1 E+03	1 E +04
Xe-133	1 E+03	1 E +04
Xe-135	1 E+03	1 E +10
Xe-135m	1 E+02	1 E +09
Xe-138	1 E+02	1 E +09
Cs-125	1 E+01	1 E +04
Cs-127	1 E+02	1 E +05
Cs-129	1 E+02	1 E +05
Cs-130	1 E+02	1 E +06
Cs-131	1 E+03	1 E +06
Cs-132	1 E+01	1 E +05
Cs-134m	1 E+03	1 E +05
Cs-134	1 E+01	1 E +04
Cs-135	1 E+04	1 E +07
Cs-135m	1 E+01	1 E +06
Cs-136	1 E+01	1 E +05
Cs-137[a]	1 E+01	1 E +04
Cs-138	1 E+01	1 E +04
Ba-126	1 E+02	1 E +07

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Ba-128	1 E+02	1 E +07
Ba-131	1 E+02	1 E +06
Ba-131m	1 E+02	1 E +07
Ba-133	1 E+02	1 E +06
Ba-133m	1 E+02	1 E +06
Ba-135m	1 E+02	1 E +06
Ba-137m	1 E+01	1 E +06
Ba-139	1 E+02	1 E +05
Ba-140[a]	1 E+01	1 E +05
Ba-141	1 E+02	1 E +05
Ba-142	1 E+02	1 E +06
La-131	1 E+01	1 E +06
La-132	1 E+01	1 E +06
La-135	1 E+03	1 E +07
La-137	1 E+03	1 E +07
La-138	1 E+01	1 E +06
La-140	1 E+01	1 E +05
La-141	1 E+02	1 E +05
La-142	1 E+01	1 E +05
La-143	1 E+01	1 E +05
Ce-134	1 E+03	1 E +07
Ce-135	1 E +03	1 E +06
Ce-137	1 E +03	1 E +07
Ce-137m	1 E +03	1 E +06
Ce-139	1 E+02	1 E +06
Ce-141	1 E+02	1 E +07
Ce-143	1 E+02	1 E +06
Ce-144[a]	1 E+02	1 E +05
Pr-136	1 E+01	1 E +05
Pr-137	1 E+02	1 E +06
Pr-138m	1 E+01	1 E +06
Pr-139	1 E+02	1 E +07
Pr-142	1 E+02	1 E +05
Pr-142m	1 E +07	1 E +09
Pr-143	1 E+04	1 E +06
Pr-144	1 E+02	1 E +05
Pr-145	1 E+03	1 E +05
Pr-147	1 E+01	1 E +05
Nd-136	1 E+02	1 E +06
Nd-138	1 E+03	1 E +07
Nd-139	1 E+02	1 E +06

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Nd-139m	1 E+01	1 E +06
Nd-141	1 E+02	1 E +07
Nd-147	1 E+02	1 E +06
Nd-149	1 E+02	1 E +06
Nd-151	1 E+01	1 E +05
Pm-144	1 E+01	1 E +06
Pm-145	1 E+03	1 E +07
Pm-146	1 E+01	1 E +06
Pm-147	1 E+04	1 E +07
Pm-148	1 E+01	1 E +05
Pm-148m	1 E+01	1 E +06
Pm-149	1 E+03	1 E +06
Pm-150	1 E+01	1 E +05
Pm-151	1 E+02	1 E +06
Sm-141	1 E+01	1 E +05
Sm-141m	1 E+01	1 E +06
Sm-142	1 E+02	1 E +07
Sm-145	1 E+02	1 E +07
Sm-146	1 E+01	1 E +05
Sm-147	1 E+01	1 E+04
Sm-151	1 E+04	1 E +08
Sm-153	1 E+02	1 E +06
Sm-155	1 E+02	1 E +06
Sm-156	1 E+02	1 E +06
Eu-145	1 E+01	1 E +06
Eu-146	1 E+01	1 E +06
Eu-147	1 E+02	1 E +06
Eu-148	1 E+01	1 E +06
Eu-149	1 E+02	1 E +07
Eu-150 (34.2a)	1 E+01	1 E +06
Eu-150 (12.6h)	1 E+03	1 E +06
Eu-152	1 E+01	1 E +06
Eu-152m	1 E+02	1 E +06
Eu-154	1 E+01	1 E +06
Eu-155	1 E+02	1 E +07
Eu-156	1 E+01	1 E +06
Eu-157	1 E+02	1 E +06
Eu-158	1 E+01	1 E +05
Gd-145	1 E+01	1 E +05

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Gd-146[a]	1 E+01	1 E +06
Gd-147	1 E+01	1 E +06
Gd-148	1 E+01	1 E+04
Gd-149	1 E+02	1 E +06
Gd-151	1 E+02	1 E +07
Gd-152	1 E+02	1 E +07
Gd-153	1 E+02	1 E +07
Gd-159	1 E+03	1 E +06
Tb-147	1 E+01	1 E +06
Tb-149	1 E+01	1 E +06
Tb-150	1 E+01	1 E +06
Tb-151	1 E+01	1 E +06
Tb-153	1 E+02	1 E +07
Tb-154	1 E+01	1 E +06
Tb-155	1 E+02	1 E +07
Tb-156	1 E+01	1 E +06
Tb-156m (24.4h)	1 E+03	1 E +07
Tb-156m (5h)	1 E+04	1 E +07
Tb-157	1 E+04	1 E +07
Tb-158	1 E+01	1 E +06
Tb-160	1 E+01	1 E +06
Tb-161	1 E+03	1 E +06
Dy-155	1 E+01	1 E +06
Dy-157	1 E+02	1 E +06
Dy-159	1 E+03	1 E +07
Dy-165	1 E+03	1 E +06
Dy-166	1 E+03	1 E +06
Ho-155	1 E+02	1 E +06
Ho-157	1 E+02	1 E +06
Ho-159	1 E+02	1 E +06
Ho-161	1 E+02	1 E +07
Ho-162	1 E+02	1 E +07
Ho-162m	1 E+01	1 E +06
Ho-164	1 E+03	1 E +06
Ho-164m	1 E+03	1 E +07
Ho-166	1 E+03	1 E +05
Ho-166m	1 E+01	1 E +06
Ho-167	1 E+02	1 E +06
Er-161	1 E+01	1 E +06
Er-165	1 E+03	1 E +07

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Er-169	1 E+04	1 E +07
Er-171	1 E+02	1 E +06
Er-172	1 E+02	1 E +06
Tm-162	1 E+01	1 E +06
Tm-166	1 E+01	1 E +06
Tm-167	1 E+02	1 E +06
Tm-170	1 E+03	1 E +06
Tm-171	1 E+04	1 E +08
Tm-172	1 E+02	1 E +06
Tm-173	1 E+02	1 E +06
Tm-175	1 E+01	1 E +06
Yb-162	1 E+02	1 E +07
Yb-166	1 E+02	1 E +07
Yb-167	1 E+02	1 E +06
Yb-169	1 E+02	1 E +07
Yb-175	1 E+03	1 E +07
Yb-177	1 E+02	1 E +06
Yb-178	1 E+03	1 E +06
Lu-169	1 E+01	1 E +06
Lu-170	1 E+01	1 E +06
Lu-171	1 E+01	1 E +06
Lu-172	1 E+01	1 E +06
Lu-173	1 E+02	1 E +07
Lu-174	1 E+02	1 E +07
Lu-174m	1 E+02	1 E +07
Lu-176	1 E+02	1 E +06
Lu-176m	1 E+03	1 E +06
Lu-177	1 E+03	1 E +07
Lu-177m	1 E+01	1 E +06
Lu-178	1 E+02	1 E +05
Lu-178m	1 E+01	1 E +05
Lu-179	1 E+03	1 E +06
Hf-170	1 E+02	1 E +06
Hf-172[a]	1 E+01	1 E +06
Hf-173	1 E+02	1 E +06
Hf-175	1 E+02	1 E +06
Hf-177m	1 E+01	1 E +05
Hf-178m	1 E+01	1 E +06
Hf-179m	1 E+01	1 E +06
Hf-180m	1 E+01	1 E +06
Hf-181	1 E+01	1 E +06

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Hf-182	1 E+02	1 E +06
Hf-182m	1 E+01	1 E +06
Hf-183	1 E+01	1 E +06
Hf-184	1 E+02	1 E +06
Ta-172	1 E+01	1 E +06
Ta -173	1 E+01	1 E +06
Ta-174	1 E+01	1 E +06
Ta-175	1 E+01	1 E +06
Ta-176	1 E+01	1 E +06
Ta-177	1 E+02	1 E +07
Ta-178	1 E+01	1 E +06
Ta-179	1 E+03	1 E +07
Ta-180	1 E+01	1 E +06
Ta-180m	1 E+03	1 E +07
Ta-182	1 E+01	1 E +04
Ta-182m	1 E+02	1 E +06
Ta-183	1 E+02	1 E +06
Ta-184	1 E+01	1 E +06
Ta-185	1 E+02	1 E +05
Ta-186	1 E+01	1 E +05
W-176	1 E+02	1 E +06
W-177	1 E+01	1 E +06
W-178a	1 E+01	1 E +06
W-179	1 E+02	1 E +07
W-181	1 E+04-3	1 E +07
W-185	1 E+04	1 E +07
W-187	1 E+02	1 E +06
W-188a	1 E+02	1 E +05
Re-177	1 E+01	1 E +06
Re-178	1 E+01	1 E +06
Re-181	1 E+01	1 E +06
Re-182 (64h)	1 E+01	1 E +06
Re-182 (12.7h)	1 E+01	1 E +06
Re-184	1 E+01	1 E +06
Re-184m	1 E+02	1 E +06
Re-186	1 E+03	1 E +06
Re-186m	1 E+03	1 E +07
Re-187	1 E +06	1 E +09
Re-188	1 E+02	1 E +05
Re-188m	1 E+02	1 E +07

Radionuclide	**Activity Concentration (Bq/g)**	**Activity (Bq)**
Re-189a	1 E+02	1 E +06
Os-180	1 E+02	1 E +07
Os-181	1 E+01	1 E +06
Os-182	1 E+02	1 E +06
Os-185	1 E+01	1 E +06
Os-189m	1 E +04	1 E +07
Os-191	1 E+02	1 E +07
Os-191m	1 E+03	1 E +07
Os-193	1 E+02	1 E +06
Os-194a	1 E+02	1 E +05
Ir-182	1 E+01	1 E +05
Ir-184	1 E+01	1 E +06
Ir-185	1 E+01	1 E +06
Ir-186 (15.8h)	1 E+01	1 E +06
Ir-186 (1.75h)	1 E+01	1 E +06
Ir-187	1 E+02	1 E +06
Ir-188	1 E+01	1 E +06
Ir-189a	1 E+02	1 E +07
Ir-190	1 E+01	1 E +06
Ir-190m (3.1h)	1 E+01	1 E +06
Ir-190m (1.2h)	1 E +04	1 E +07
Ir-192	1 E+01	1 E +04
Ir-192m	1 E+02	1 E +07
Ir-193m	1 E +04	1 E +07
Ir-194	1 E+02	1 E +05
Ir-194m	1 E+01	1 E +06
Ir-195	1 E+02	1 E +06
Ir-195m	1 E+02	1 E +06
Pt-186	1 E+01	1 E +06
Pt-188a	1 E+01	1 E +06
Pt-189	1 E+02	1 E +06
Pt-191	1 E+02	1 E +06
Pt-193m	1 E+03	1 E +07
Pt-195m	1 E+02	1 E +06
Pt-197	1 E+03	1 E +06
Pt-197m	1 E+02	1 E +06
Pt-199	1 E+02	1 E +06
Pt-200	1 E+02	1 E +06
Au-193	1 E+02	1 E +07
Au-194	1 E+01	1 E +06
Au-195	1 E+02	1 E +07

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Au-198	1 E+02	1 E +06
Au-198m	1 E+01	1 E +06
Au-199	1 E+02	1 E +06
Au-200	1 E+02	1 E +05
Au-200m	1 E+01	1 E +06
Au-201	1 E+02	1 E +06
Hg-193	1 E+02	1 E +06
Hg-193m	1 E+01	1 E +06
Hg-194a	1 E+01	1 E +06
Hg-195	1 E+02	1 E +06
Hg-195ma	1 E+02	1 E +06
Hg-197	1 E+02	1 E +07
Hg-197m	1 E+02	1 E +06
Hg-199m	1 E+02	1 E +06
Hg-203	1 E+02	1 E +05
Tl-194	1 E+01	1 E +06
Tl-194m	1 E+01	1 E +06
Tl-195	1 E+01	1 E +06
Tl-197	1 E+02	1 E +06
Tl-198	1 E+01	1 E +06
Tl-198m	1 E+01	1 E +06
Tl-199	1 E+02	1 E +06
T1-200	1 E+01	1 E +06
T1-201	1 E+02	1 E +06
T1-202	1 E+02	1 E +06
T1-204	1 E+04	1 E +04
Pb-195m	1 E+01	1 E +06
Pb-198	1 E+02	1 E +06
Pb-199	1 E+01	1 E +06
Pb-200	1 E+02	1 E +06
Pb-201	1 E+01	1 E +06
Pb-202	1 E+03	1 E +06
Pb-202m	1 E+01	1 E +06
Pb-203	1 E+02	1 E +06
Pb-205	1 E +04	1 E +07
Pb-209	1 E +05	1 E +06
Pb-210*	1 E+01	1 E +04
Pb-211	1 E+02	1 E +06
Pb-212*	1 E+01	1 E +05
Pb-214	1 E+02	1 E +06
Bi-200	1 E+01	1 E +06

Radionuclide	**Activity Concentration (Bq/g)**	**Activity (Bq)**
Bi-201	1 E+01	1 E +06
Bi-202	1 E+01	1 E +06
Bi-203	1 E+01	1 E +06
Bi-205	1 E+01	1 E +06
Bi-206	1 E+01	1 E +05
Bi-207	1 E+01	1 E +04
Bi-210	1 E+03	1 E +06
Bi-210ma	1 E+01	1 E +05
Bi-212*	1 E+01	1 E +05
Bi-213	1 E+02	1 E +06
Bi-214	1 E+01	1 E +05
Po-203	1 E+01	1 E +06
Po-205	1 E+01	1 E +06
Po-207	1 E+01	1 E +06
Po-208	1 E+01	1 E +04
Po-209	1 E+01	1 E +04
Po-210	1 E+01	1 E +04
At-207	1 E+01	1 E +06
At-211	1 E+03	1 E +07
At-212	1 E+03	1 E +07
Fr-222	1 E+03	1 E +05
Rn-220[a]	1 E+04	1 E +07
Rn-222[a]	1 E+01	1 E +08
Ra-223 [a]	1 E+02	1 E +05
Ra-224 [a]	1 E+01	1 E +05
Ra-225	1 E+02	1 E +05
Ra-226 [a]	1 E+01	1 E +04
Ra-227	1 E+02	1 E +06
Ra-228 [a]	1 E+01	1 E +05
Ac-224	1 E+02	1 E +06
Ac-225 [a]	1 E+01	1 E +04
Ac-226	1 E+02	1 E +05
Ac-227 [a]	1 E-01	1 E+03
Ac-228	1 E+01	1 E +06
Th-226 [a]	1 E+03	1 E +07
Th-227	1 E+01	1 E +04
Th-228 [a]	1 E+00	1 E +04
Th-229 [a]	1 E+00	1 E +03
Th-230	1 E+00	1 E +04
Th-231	1 E+03	1 E +07

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Th-232	1 E+01	1 E +04
Th-234 [a]	1 E+03	1 E +05
Pa-227	1 E+01	1 E +06
Pa-228	1 E+01	1 E +06
Pa-230	1 E+01	1 E +06
Pa-231	1 E+00	1 E +03
Pa-232	1 E+01	1 E +06
Pa-233	1 E+02	1 E +07
Pa-234	1 E+01	1 E +06
U-230 [a]	1 E+01	1 E +05
U-231	1E+04	1 E +07
U-231	1 E+02	1 E +07
U-232 [a]	1 E+00	1 E +03
U-233	1 E+01	1 E +04
U-234	1 E+01	1 E +04
U-235 [a]	1 E+01	1 E +04
U-236	1 E+01	1 E +04
U-237	1 E+02	1 E +06
U-238 [a]	1 E+01	1 E +04
U-239	1 E+02	1 E +06
U-240	1 E+03	1 E +07
U-240 [a]	1 E+01	1 E +06
Np-232	1 E+01	1 E +06
Np-233	1 E+02	1 E +07
Np-234	1 E+01	1 E +06
Np-235	1 E+03	1 E +07
Np-236 (1.5×105 a)	1 E+02	1 E +05
Np-236 (22.5 h)	1 E+03	1 E +07
Np-237 [a]	1 E+00	1 E +03
Np-238	1 E+02	1 E +06
Np-239	1 E+02	1 E +07
Np-240	1 E+01	1 E +06
Pu-234	1 E+02	1 E +07
Pu-235	1 E+02	1 E +07
Pu-236	1 E+01	1 E +04
Pu-237	1 E+03	1 E +07
Pu-238	1 E+00	1 E +04
Pu-239	1 E+00	1 E +04

Radionuclide	Activity Concentration (Bq/g)	Activity (Bq)
Pu-240	1 E+00	1 E +03
Pu-241	1 E+02	1 E +05
Pu-242	1 E+00	1 E +04
Pu-243	1 E+03	1 E +07
Pu-244	1 E+00	1 E +04
Pu-245	1 E+02	1 E +06
Pu-246	1 E+02	1 E +06
Am-237	1 E+02	1 E +06
Am-238	1 E+01	1 E +06
Am-239	1 E+02	1 E +06
Am-240	1 E+01	1 E +06
Am-241	1 E+00	1 E +04
Am-242	1 E+03	1 E +06
Am-242 [a]	1 E+00	1 E +04
Am-243 [a]	1 E+00	1 E +03
Am-244	1 E+01	1 E +06
Am-244m	1 E +04	1 E +07
Am-245	1 E+03	1 E +06
Am-246	1 E+01	1 E +05
Am-246m	1 E+01	1 E +06
Cm-238	1 E+02	1 E +07
Cm-240	1 E+02	1 E +05
Cm-241	1 E+02	1 E +06
Cm-242	1 E+02	1 E +05
Cm-243	1 E+00	1 E +04
Cm-244	1 E+01	1 E +04
Cm-245	1 E+00	1 E +03
Cm-246	1 E+00	1 E +03
Cm-247	1 E+00	1 E +04
Cm-248	1 E+00	1 E +03
Cm-249	1 E+03	1 E +06
Cm-250	1 E-01	1 E+03
Bk-245	1 E+02	1 E +06
Bk-246	1 E+01	1 E +06
Bk-247	1 E+00	1 E +04
Bk-249	1 E+03	1 E +06
Bk-250	1 E+01	1 E +06
Cf-244	1 E +04	1 E +07
Cf-246	1 E+03	1 E +06
Cf-248	1 E+01	1 E +04
Cf-249	1 E+00	1 E +03

Radionuclide	**Activity Concentration (Bq/g)**	**Activity (Bq)**
Cf-250	1 E+01	1 E +04
Cf-251	1 E+00	1 E +03
Cf-252	1 E+01	1 E +04
Cf-253	1 E+02	1 E +05
Cf-254	1 E+00	1 E +03
Es-250	1 E+02	1 E +06
Es-251	1 E+02	1 E +07
Es-253	1 E+02	1 E +05
Es-254	1 E+01	1 E +04
Es-254m	1 E+02	1 E +06
Fm-252	1 E+03	1 E +06
Fm-253	1 E+02	1 E +06
Fm-254	1 E+04	1 E +07
Fm-255	1 E+03	1 E +06
Fm-257	1 E+01	1 E +05
Md-257	1 E+02	1 E +07
Md-258	1 E+02	1 E +05

[a] Parent radionuclides, and their progeny whose dose contributions are taken into account in the dose calculations (thus requiring only the exemption level of the parent radionuclide to be considered) , are listed in the following:

Parent radionuclide	Progeny
Ge-68	Ga-68
Rb-83	Kr-83m
Sr-82	Rb-82
Sr-90	Y-90
Y-87	Sr-87m
Zr-93	Nb-93m
Zr-97	Nb-97
Ru-106	Rh-106
Ag-108m	Ag-108
Sn-121m	Sn-121 (0.776)
Sn-126	Sb-126m
Xe-122	I-122
Cs-137	Ba-137m
Ba-140	La-140
Ce-134	La-134
Ce-144	Pr-144
Gd-146	Eu-146
Hf-172	Lu-172
W-178	Ta-178

W-188	Re-188
Re-189	Os-189m (0.241)
Ir-189	Os-189m
Pt-188	Ir-188
Hg-194	Au-194
Hg-195m	Hg-195 (0.542)
Pb-210	Bi-210, Po-210
Pb-212	Bi-212, Tl-208 (0.36), Po-212 (0.64)
Bi-210m	Tl-206
Bi-212	Tl-208 (0.36), Po-212 (0.64)
Rn-220	Po-216
Rn-222	Po-218, Pb-214, Bi-214, Po-214
Ra-223	Rn-219, Po-215, Pb-211, Bi-211, Tl-207
Ra-224	Rn-220, Po-216, Pb-212, Bi-212, T1-208(0.36), Po-212 (0.64)
Ra-226	Rn-222, Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi210 , Po -210
Ra-228	Ac-228
Ac-225	Fr-221, At-217, Bi-213, Po-213 (0.978), Tl-209 (0.0216), Pb-209 (0.978)
Ac-227	Fr-223 (0.0138)
Th-226	Ra-222, Rn-218, Po-214
Th-228	Ra-224, Rn-220, Po-216, Pb-212, Bi-212, T1-208 (0.36), Po-212 (0.64)
Th-229	Ra-225, Ac-225, Fr-221, At-217, Bi-213, Po-213, Pb-209
Th-234	Pa-234m
U-230	Th-226, Ra-222, Rn-218, Po-214
U-232	Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, T1-208 (0.36), Po-212 (0.64)
U-235	Th-231
U-238	Th-234, Pa-234rn
U-240	Np-240m
Np-237	Pa-233
Am-242m	Am-242
Am-243	Np-239

Table I-3:

Levels For Clearance of Material: Activity Concentrations of Radionuclides of Natural Origin

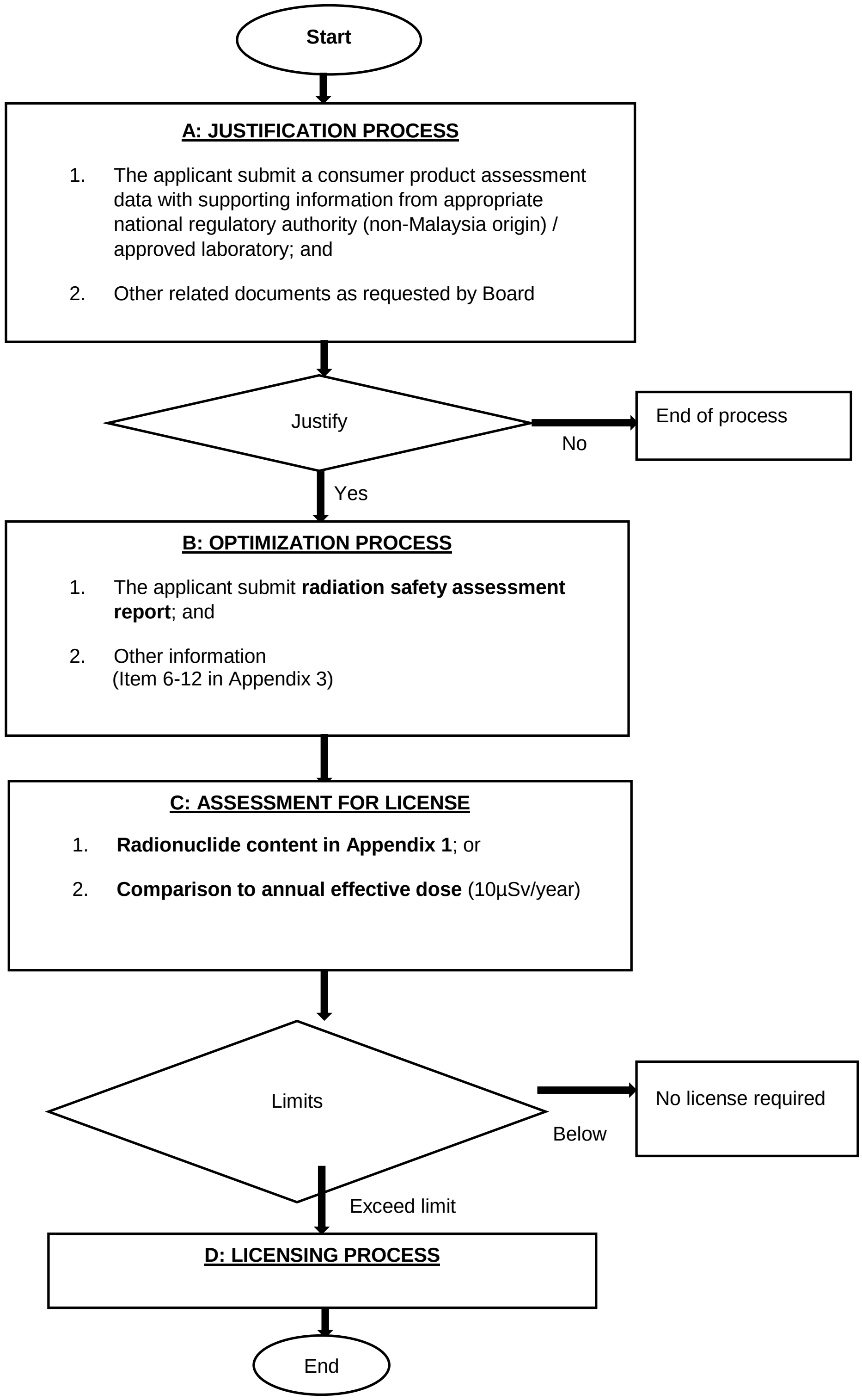
Radionuclide	**Activity concentration (Bq/g)**
K-40	10
Each radionuclide in the uranium and thorium decay chains	1

Reference

INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, General Safety Requirements Part 3, No. GSR Part 3, IAEA, Vienna (2014)

Appendix 2

FLOW CHART ON PROCEDURE FOR ASSESSMENT AND LICENSING OF CONSUMER PRODUCT CONTAINING RADIOACTIVE MATERIAL



Appendix 3

CHECKLIST FOR ASSESSMENT AND LICENSING OF CONSUMER PRODUCT CONTAINING RADIOACTIVE MATERIAL

NO.	ITEMS	YES	NO	REMARKS
PART A (JUSTIFICATION PROCESS)				
1.	Details on the use and benefits, type of radionuclide that contained in the product and the function of radionuclides in consumer product.			
2.	Justification for the choice of radionuclide (especially in terms of related hazards and it half-life compared with other radionuclides).			
3.	Chemical and physical form of radionuclide contained in the products.			
4.	Details on configuration and design of products mainly on containment and shielding for radionuclides during a normal circumstances, abnormal and disposal, as well as the level of accessibility to radioactive material.			
5.	The level of external radiation exposure resulting from the product and the method of measurement.			
PART B (OPTIMIZATION)				
6.	Radiation Safety Assessment Reports from the approved agency			
7.	Quality testing and verification procedures for radionuclides, components and final products to ensure the maximum quantity of radioactive material or a specific maximum radiation level not exceeded and the device is built according to the design specifications.			

CHECKLIST FOR ASSESSMENT AND LICENSING OF CONSUMER PRODUCT CONTAINING RADIOACTIVE MATERIAL

NO.	ITEMS	YES	NO	REMARKS
PART B (OPTIMIZATION)				
8.	Details on prototype testing to show the integrity of the product under normal conditions, the possibility of misuse and damage due to an accident and results of tests carried out.			
9.	The expected life period of the products and the total number of products distributed in a year.			
10.	Information about any advice to be provided regarding the proper use, installation, maintenance, servicing and repair of the products.			i.e: Brochure/ pamphlet
11.	Information on how the product will be labeled.			
12.	Details on disposal route of the products			

- Reference: IAEA TECDOC 1679

Appendix 4

STRUCTURE OF RADIATION SAFETY ASSESSMENT

1. *Introduction*

2. *Objective*

3. *Scope*

4. *Radiation protection requirements, justification and optimization*

5. *Product details*

    5.1 *Use of the product*
    5.2 *Benefits of the use of product and comparison with other alternative product not containing radioactive material*
    5.3 *A potential for non radioactive material in replacing a product containing radioactive material*
    5.4 *Technical design and quality assurance of the product*
    5.5 *Radioactive properties contain in the product*
    5.6 *Life cycle of the product*
        5.6.1 *Transportation*
        5.6.2 *Storage*
        5.6.3 *Installation, production/manufacture, repair and maintainance, replacement and sales*
        5.6.4 *Final usage*
        5.6.5 *Disposal*

6. *Running tests during manufacturing of the product*
    6.1 *Mechanical safety test*
    6.2 *Temperature test*
    6.3 *Packaging test for the transportation*
    6.4 *Additional tests as required by the Board*

7. *Radiological Safety Assessment*
    7.1 *Exposure during normal condition*
    7.2 *Exposure during an accident*
    7.3 *Exposure to the member of the public during disposal*

8. *Labeling and Information*
    8.1 *Product labeling*
    8.2 *Information provided before sale to the user*
    8.3 *Information of the disposal*

9. *Comparison between radiation safety assessment with the licensing criteria*

10. *Summary*

Reference: IAEA TECDOC 1679

Appendix 5

EXAMPLE OF SAFETY ASSESSMENT: RADIATION DOSES FROM IONIZATION CHAMBER SMOKE DETECTORS

INTRODUCTION

1. Ionization chamber smoke detectors are designed to give early warning of fire and are considered consumer products. The estimated doses arising from normal use, incidents, misuse and disposal of ionization chamber smoke detectors are given below. Where internal doses are reported, only the most restrictive of the doses to an adult, a child or an infant is given.

NORMAL USE AND DISPOSAL

2. In normal use of ionization chamber smoke detectors the doses to members of the public are limited to those due to external exposure to radiation. The equivalent dose rate in air, D, at a distance d (m) from the surface of an ionization chamber smoke detector, is given by:

$$D = \frac{t\ x\ A}{d^2}$$

where t the equivalent dose rate given in terms of Sv h^{-1} at 1 m from 1 GBq and A is the activity of the source in GBq [Ref.2]. The value of t for ^{241}Am is 2.4×10^{-6}. Dose coefficients and associated calculations have been updated in line with ICRP Publication 72 *[Ref.3]*.

3. The standard for ionization chamber smoke detectors *[Ref 2]* requires that the activity of the sealed source shall not exceed 40 kBq of ^{241}Am. From the equation it can be concluded that the maximum equivalent dose rate at a distance of 2 m from the source of an ionization chamber smoke detector that satisfies this requirement will be 2.4×10^{-5} µSv h^{-1}.

Calculation:

$D = \frac{t\ x\ A}{d^2}$ (D : equivalent dose rate in air)

d= 2 m (d: distance from source surface)

t = 2.4×10^{-6} Sv h^{-1}

(t: equivalent dose rate, Sv h^{-1} at 1 m from 1 GBq or Gamma ray constant for ^{241}Am)

A = 40 k Bq (convert to GBq)

= $40 \times 10^3 \times 10^{-9}$

= 40×10^{-6}

= 4.0×10^{-5} GBq

$$D = \frac{(2.4 \, x \, 10{-}6) \, (4.0 \, x \, 10 \, {-}5)}{4}$$

D = <u>2.4 x 10^{-5} µSv h^{-1}</u>

(*For this calculation, since the distance from the source is 2m, the type of exposure to human from the source is assumed as homogenous (whole body exposure). Thus effective dose is equal to equivalent dose.*

Normal Use

4. Most ionization chamber smoke detectors will be installed on staircases or in hallways and an individual will spend very little time in these areas. Some, however, may be installed in bedrooms. In estimating the doses, the following assumptions have been made:

(i) The ionization chamber smoke detector is installed in a bedroom. Irradiating the individual for 8 h each day,

(ii) The body to source distance is 2 m.

The maximum effective dose to the individual is therefore 70 nSv each year.

Calculation:

$$D = \frac{t \, x \, A}{d^2} \text{ x exposure duration/day x no. of days/year}$$

= 2.4×10^{-5} µSv $hour^{-1}$ x 8 hours x 365 days

= 0.07 µSv

D = <u>70 n Sv/year</u>

**Assumption the exposure to human is homogenous (whole body exposure)*

Maintenance

5. Ionization chamber smoke detectors installed in homes will be handled during installation, cleaning and battery changes. The maximum equivalent dose rate at the surface of a detector can be calculated to be approximately 1 μSvh^{-1}, assuming that the source is 1 cm below the detector surface, and the maximum equivalent dose rate at 0.5 m from the source can be calculated to be 4×10^{-4} $\mu Sv\ h^{-1}$. In estimating the potential doses the following assumptions have been made:

(i) The ionization chamber smoke detector is handled by the individual for a total of 3 h per year.

(ii) The body to source distance during handling is 0.5 m. The maximum equivalent dose to the hands of an individual is therefore 3 µSv each year and the maximum effective dose to an individual is 0.001 µSv each year.

*** Calculation (1nSv for body, 3 µSv hand (extremities)*

D at distance 0.5 m,

D= $(4 \times 10^{-4}\ \mu Sv\ h^{-1}) \times (3h)$

D= 0.001 µSv

D at distance 1cm (surface), in a year

D=$(1\ \mu Sv\ h^{-1}) \times (3h)$

D= 3 µSv

Disposal

6. Ionization chamber smoke detectors may be disposed of with normal household waste. In practice, this means that some may be sent to a landfill site and some may be incinerated. In estimating the potential effective doses from disposal, the following assumptions have been made:

(i) There are 20 million homes in the United Kingdom;

(ii) Each household in the United Kingdom has one ionization chamber smoke detector;

(iii) Of these ionization chamber smoke detectors, 20% are disposed of each year;

(iv) Of those disposed of each year, 80% are distributed between 500 landfill sites, i.e. a maximum 6400 ionization chamber smoke detectors per site each year;

(v) Of those disposed of each year, 20% are distributed between 200 incinerators, i,e. a maximum of 4000 ionization chamber smoke detectors per incinerator each year.

Disposal to a landfill site

7. The two main pathways for exposure associated with disposal to a landfill site are ingestion of drinking water contaminated with leachate from the site and inhalation of airborne contamination caused by a waste fire. The standard for ionization chamber smoke detectors states that an ionization chamber smoke detector which passes the test for the effects of fire will release no more than 200Bq during a fire. In estimating the doses arising from a waste fire, the following assumptions have been made:

(i) 0f the ionization chamber smoke detectors disposed of at a single landfill site, 1% are involved in waste tires during the year;
(1% from 6400 smoke detectors involved in waste fire: 64 units of smoke detector)

(ii) 200 Bq are released from each ionization chamber smoke detector involved in a fire;

(iii) Each fire is of short duration: this is taken to be 30 min;

(iv) The most exposed individual lives 200 m from the landfill site;

(v) The ground level time integrated concentration for unit release (1 Bq) in normal weather conditions (Pasquill category D) at 200 m from the landfill site is 2.5 x10^{-4} Bq s m^{-3}[Ref.4];

(vi) The breathing rate of an adult is 3.33 x 10^{-4} m^3s^{-1}[Ref.5];

(vii) The committed effective dose per unit intake to an adult via inhalation is 9.6 x 10^{-5} $SvBq^{-1}$ [Ref.5].

The maximum committed effective dose to an adult from one year's intake is therefore 0.1 μSv.

= 1 unit release 200 Bq in fire, for 64 units is shown in below

= 64 units X 200Bq

=<u>12, 800 Bq</u>

Given breathing rate of an adult is $3.33 \times 10^{-4}\ m^3s^{-1}$ and ground level time integrated concentration for unit release (1 Bq) in normal weather conditions (Pasquill category D) at 200 m from the landfill site is 2.5 x 10-4 $Bq.s.m^{-3}$ thus for 12800 Bq

$= (12800\ Bq) \times (3.33 \times 10^{-4}\ m^3s^{-1}) \times (2.5 \times 10^{-4}\ s.m^{-3})$ for unit release of 1 Bq

$= 12800Bq \times 3.33 \times 2.5 \times 10^{-4} \times 10^{-4}$

$= 106560\ Bq \times 10^{-8}$

<u>$= 1.06 \times 10^{-3}$ Bq</u>

Based on 1.06×10^{-3} Bq and committed effective dose per unit intake to an adult via inhalation is 9.6 x 10-5 Sv.Bq-1, thus committed effective dose to an adult from one year's intake is:

$= 1.06 \times 10^{-3}\ Bq \times 9.6 \times 10^{-5}\ Sv.Bq^{-1}$

$= 10.176 \times 10^{-3} \times 10^{-5}\ Sv$

$=1.0176 \times 10^{-7}\ Sv$

$=1.0176 \times 10^{-1}\ \mu Sv$

<u>=0.10 µSv</u>

8. The committed effective dose to an adult drinking contaminated water during one year was estimated in NRPB-R205 as 0.001 µSv from a shallow inland burial of 1 TBq [Ref.6]. If 6,400 detectors of the maximum activity allowed by the standard are disposed of, the total activity disposed of at a single landfill per year would be 260 MBq. This would give a maximum committed effective dose to an adult of 3×10^{-7} µSv from one year's intake.

From reference, 1 TBq is estimated giving the committed effective dose of 0.001 µSv.

260 MBq $= 2.6 \times 10^8$ Bq

= 0.00026 TBq

If 1 TBq = 0.001 µSv; thus committed effective dose for 0.00026 TBq is:

$=0.00026TBq \times 0.001\ \mu Sv \times 1TBq^{-1}$

<u>$= 2.6 \times 10^{-7}$ µSv.</u>

The committed effective dose to an adult is 2.6×10^{-7} µSv.

Disposal via incineration

9. The standard for ionization chamber smoke detectors states that an ionization chamber smoke detector which passes the incineration test will release no more than 1% of its activity during incineration in estimating the doses arising from incineration, the following assumptions have been made:

- (i) Of the radioactive substances in the ionization chamber smoke detectors, 1% is released during incineration;
- (ii) The release is constant throughout the year;
- (iii) The stack height is 50 m;
- (iv) The maximum ground level time integrated concentration for unit release (1 Bq) in normal weather conditions (Pasquill category D) is 3 $x10^{-6}$ $Bqsm^{-3}$ [Ref. 3] ;
- (v) The breathing rate of an adult is 3.33 x 10^{-4} m^3 s^{-1} [Ref.5] ;
- (vi) The committed effective dose per unit intake to an adult via inhalation is 9.6 x 10^{-5} Sv Bq^{-1} [Ref.3]

10. The maximum committed effective dose to an adult from one year release is therefore 0.16 uSv. It can be assumed that the activity remaining in the slag will be disposed of to a landfill, resulting in doses similar to those given above.

Given that activity per 1 unit of smoke detector is 40 kBq, thus if 4000 of smoke detectors is incinerated in a year, total activity is:

4000 unit x 40 kBq = 160,000kBq

During incineration, only 1% of activity will be released, so for 1% is:

$$1\% \text{ of } 160{,}000\text{kBq} = \frac{1}{100} \times 160{,}000\text{kBq}$$

$$= 1600\text{k Bq}$$

According to Pasquill Category D, 1Bq will incur 3 x10^{-6} Bq.s.m^{-3} maximum ground level time integrated concentration for unit release (1 Bq) in normal weather conditions. Thus for 1600kBq:

= 1600 x 10^3 Bq x (3 X10^{-6} s.m^{-3}) for 1 Bq
= 1600 x 3 x 10^3 x 10^{-6} Bq s.m^{-3})
= $\underline{4800 \times 10^{-3} \text{ Bq s.m}^{-3}}$

Given breathing rate of an adult is 3.33 x 10 $^{-4}$ m^3 s $^{-1}$, thus in second adult will inhale:

= 3.33 x 10 $^{-4}$ m^3 s $^{-1}$ x 4800 x 10^{-3} Bq s.m^{-3}
= 3.33 x 4800 x 10 $^{-4}$ x 10^{-3} Bq
= $\underline{15{,}984 \times 10^{-7} \text{ Bq}}$

Since 4000 smoke detectors incinerated in one year, so the committed effective dose to an adult for one year is:

=15,984 x 10^{-7} Bq x 9.6 x 10^{-5} Sv Bq^{-1}
= 153,446.4 x 10^{-12} Sv
= 153,446.4 x 10^{-12} x 10^6 µSv
= 0.15 µSv

INCIDENTS AND MISUSE

11. Potential incidents involving ionization chamber smoke detectors can be categorized as follows:
   (i) fire;
   (ii) misuse and mutilation.

Fire

12. In a survey of known incidents involving smoke detectors in the United Kingdom, fire was found to be the most common occurrence [Ref.7]. The standard for ionization chamber smoke detectors states that an ionization chamber smoke detector which

passes the test for the effects of fire will release no more than 200 Bq during a fire. In estimating the doses during and after a fire the following assumptions have been made:

During fire

- (i) the ionization chamber smoke detector contains 40 kBq ^{241} Am;
- (ii) 200 Bq becomes airborne
- (iii) 10^{-5} of the airborne activity is inhaled by a firefighter;
- (iv) the firefighter attends 20 fires involving ionization chamber smoke detectors each year.

The maximum annual committed effective doses to an adult are therefore 4 µSv during fires.

During fire calculation

During fire, 200Bq of 1 unit smoke detector will become airborne. Out of 200Bq, only 10^{-5} of the airborne activity is inhaled by a firefighter. So, 10^{-5} x 200Bq = 0.002 Bq will be inhaled in 1 fire event

For 20 fire events in a year:
20 x 0.002 Bq = 0.04Bq

The committed effective dose for public (firefighters) for ^{241}Am is 9.6 x10^{-5} Sv.Bq^{-1}. Thus total effective dose to adult during 20 fire events in a year is:
=0.04 Bq x 9.6 x10^{-5} Sv.Bq^{-1}
=0.384 x 10^{-5} Sv
=3.84 µSv

Misuse and mutilation

13. The most significant possible misuse is dismantling of the ionization chamber smoke detector by a member of the public. However, the probability of such an occurrence is small because the ionization chamber must be made tamper proof in order for the ionization chamber smoke detector to comply with the standard. An estimate of the possible dose to an infant who manages to break open the chamber and damage the source has been made using the following assumptions:

(i) Of the source activity, 1% is released owing to damage;

(ii) Of this activity, 10% is transferred to the fingers and ingested;

(iii) The committed effective dose per unit intake to a three month old infant via ingestion is 3.7×10^{-6} Sv Bq^{-1} [Ref.9]

Calculation:

i. = 40 k Bq – activity of the source

= $40 \times 10^{3} \times 0.01$

= 0.4×10^{2} Bq

Therefore 0.4×10^{2} Bq = 40 Bq (released)

Given 3.7×10^{-6} $Sv.Bq^{-1}$ is committed effective dose for infant, thus

= 3.7×10^{-6} $Sv.Bq^{-1}$ x (40 Bq)

= 148×10^{-6} Sv

= 148 µSv

CONCLUSION

14. The possible doses arising from normal use, incidents, misuse and disposal of ionization chamber smoke detectors which comply with the Standard do not exceed the appropriate dose criteria.

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Appendix 6

EXAMPLE OF RADIATION SAFETY ASSESSMENT : RADIATION DOSES FROM "PENDANT"

Effective dose, E is derived as formula in below:

$$E = H_{skin} \times W_{skin} \times \frac{\text{area exposed}}{\text{total area}}$$

where E : effective dose

H : Surface dose rate on pendant

W : Weighting factor organ, in this case for skin

Calculation (1) : Assessment for consumer product considered as point source using direct measurement

Normal use (user) for pendant with r=2cm

$$E = H_{skin} \times W_{skin} \times \frac{\text{area exposed}}{\text{total area}}$$

$$E = (0.227)\,uSv.hr^{-1} \times (0.01) \times \frac{(\pi r^2)}{10^4 cm^2}$$ (where $10^4 cm^2$ is total area for man)

$= \underline{2.85 \times 10^{-6}\ uSvhr^{-1}}$

Assumption people wear a pendant for period of 16hours /day, in one year (365 days)

$= 2.85 \times 10^{-6}\ uSvhr^{-1} \times 16$ hr/day x365 day/year

$= 16644 \times 10^{-6}$ uSv

Thus effective dose, E = **<u>0.0166 uSv/year</u>**

Calculation (2): ***Assessment for consumer product considered as non-homogenous source, using activity concentration of the material***

Normal use (user) for pendant with r=2cm

$$E = H_{skin} \times W_{skin} \times \frac{\text{contact}}{\text{body}}$$

E: Effective dose

H_{skin} : $A_S \times T \times (R_7 + R_{24})$ equivalent dose of skin

$A_S = C \times U$ =activity per unit area

C= Activity concentration of the radiation source (4 Bq/g).

U= Relation mass/surface (g/cm^2)

R_7 = Equivalent dose rate by gamma for skin (Th-232) =1.65 × 10^{-7} (Sv/h)/(Bq/cm²)

R_{24}= Equivalent dose rate by beta radiation (Th-232) = 1.94 × 10^{-6} (Sv/h)/(Bq/cm²)

T= 8 hrs/day (2920 hrs/year)

contact = size of the pendant; πj^2 =3.142 x 9 cm^2 = 28.278 cm^2

area; body = 1E+4 cm² area;

mass of the source = 50 g

density of the source = 5.9 g/cm^3

Thickness of the source = 0.4 cm

W_{Skin} = Tissue weight factor skin = 1E-2;

As = Activity Concentration of the source (C) x Relation of mass to surface area of the source (42.3 g/cm^2) (U)

U = Mass of the source (g) / (ρ. t/2)

Where ρ = density of the source , t/2 = half thickness of the source

ρ = 50 g / 1.18 g.cm^{-2}

= 42.3 g.cm^{-2}

As = 4 Bq/g x 42.3 g.cm^{-2}

= 169.2 Bq.cm^{-2}

So, dose equivalent to skin, H_{skin}

H_{skin} = 169.2 Bq.cm^{-2} x 2920 hr/year x (1.65 × 10^{-7} (Sv/h)/(Bq/cm²) + 1.94 × 10^{-6} (Sv/h)/(Bq/cm²)

= 494,064 Bq.cm^{-2}.hr (1.65 x 10^{-7} + 19.4 x 10^{-7}) Sv/h/Bq/cm^2

= 10,400,047 Bq.cm^{-2}.hr x 10^{-7} Sv.hr^{-1}.Bq^{-1}.cm^2

= 10,400,047 x 10^{-7} x 10^6 uSv

= 104 mSv

E = H_{skin} x W_{skin} x Contact/Body

= 104 mSv x 0.01 x 0.0028

= 0.0029 mSv

= <u>2.9 uSv/year</u>

Calculation (3): during storage (effective dose for workers)

E = CT (GAM R_1 GEOM) + (BETA SHIELD)

Where E = Eff dose ($Sv.y^{-1}$)

C = Activity concentration per unit mass ($Bq.g^{-1}$)

T = Exposure time ($hr.y^{-1}$) ~ 100 hr/year

GAM = Eff DR at 1 m above an infinite thick slab at 1 $Bq.g^{-1}$ Per MeV at gamma energy ($Sv.h^{-1}$) per ($Bq.g^{-1}$ MeV) Based on the Table Rad 65 ~ 1.65×10^{-13} $Sv.hr^{-1}$ per Bq

If 4 Bq/g and 50 g source ~ 200 Bq, So GAM

= 200 Bq x 1.65×10^{-13} $Sv.h^{-}1.Bq^{-1}$

= 330×10^{-13} $Sv.h^{-1}$

R_1 = The average photon energy per disintegration (MeV)

= 2.52 MeV (From Table Rad Prot. 65)

BETA = Eff. DR from beta particles 1 m above a semi infinite slab of 1 $Bq.g^{-1}$ ($Sv.h^{-1}$ per $Bq.g^{-1}$)

1.35×10^{-14} $Sv.hr^{-}1.Bq^{-1}$ (From Table Rad Prot. 65)

If 200 Bq ~ 1.35×10^{-14} $Sv.hr^{-}1.Bq^{-1}$ x 200 Bq

= **~ 270 x 10^{-14} $Sv.h^{-1}$**

SHEILD = 1×10^{-1} ~ 0.1 (Sheilding factor for beta particles)

GEOM = Geometry reduction factor from infinite slab to finite source size (= 2×10^{-2})

E = 4 $Bq.g^{-1}$ x 100 hrs x [(330×10^{-13} $Sv.h^{-1}$ x 2.52 x 2 x 10^{-2}) + 270×10^{-14} $Sv.h^{-1}$ x 1 x 10^{-1})]

= 400 $Bq.g^{-1}$ hrs x [1,663 x 10^{-15} Svh^{-1} + 270 x 10^{-15} Svh^{-1}]

= 400 Bqg^{-1} hrs x 1,933 x 10^{-15} Svh-1 Bq^{-1}.g

= 773,200 x 10^{-15} x 10^{6} µSv/year

= 773,200 x 10^{-9} µSv/year

= **~ 0.7 nSv/year**

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