3. International Radiation Protection Concept for TENORM

3.1 ICRP

3.1.1 Exemption, Exclusion and Occupational Exposure for Natural Radiation

ICRP recommended the system of radiological protection in Publ.60[1]. The system for proposed and continuing practices is based on the general principles which are the justification of a practice, the optimization of protection, and individual dose and risk limits. The types of exposure are occupational exposure, medical exposure and public exposure. The system for intervention is based on the justification and the optimization.

In the Publ.60, ICRP defines that doses incurred in situations where the only available protective action takes the form of intervention are excluded from the scope of the dose limits. Radon in dwellings and in the open air and radioactive materials, natural or artificial, already in the environment, are example of situations that can be influenced only by intervention.

ICRP also describes exclusion and exemption from regulatory control and the basis for them in Publ.60.

In the Publ.75 "General Principle for the Radiation Protection of Workers"[5], ICRP recommends the control of occupational exposure to natural sources such as Radon at work and materials with elevated levels of natural radionuclides. ICRP recommends that the action level for intervention in workplaces should be applied to the effective dose and should be in the range 3-10 mSv in a year. As for materials with elevated levels of natural radionuclides, it is recommended that regulatory agencies choose activity concentrations of parent nuclides within the range 1-10 Bq/g to determine whether the exposures from these materials should be regarded as occupational.

3.1.2 Existing Dose and Intervention Exemption Level

ICRP Publ.82[4] provides guidance on the application of the system of radiological protection to situations of prolonged exposure to ionizing radiation. In this publication, ICRP recommends the application of the system of radiological protection to practices resulting in prolonged exposure and to intervention in prolonged exposure situations, generic reference levels of existing annual dose for intervention, and application of the recommendations to specific prolonged exposure situations.

Generic reference levels for intervention, in terms of existing total annual doses, are given as <100 mSv, above which intervention is almost always justifiable, and <10 mSv, below which intervention is not likely to be justifiable. Intervention exemption levels for commodities, especially building materials, are expressed as an additional annual dose of 1mSv. The dose limit for exposures of the public from practices is expressed as aggregated additional annual doses from all relevant practices of 1 mSv. Dose constraints for sources within practices are expressed as an additional annual dose lower than 1 mSv (e.g. of 0.3 mSv), which could be 0.1 mSv for the prolonged exposure component. An exemption level for practices is expressed as an additional annual dose of 0.01 mSv.

3.2 IAEA

3.2.1 BSS (SS115)

International Basic Safety Standards (BSS) for Protection against Ionizing Radiation and for the Safety of Radiation Sources published in 1996 as Safety Series No 115 of IAEA[3)] has been widely introduced in the radiation protection policy in many countries. The principles of radiation protection in the BSS are generally based on ICRP Publ.60. The principles on regulation of TENORM are also mentioned in the BSS according to the policy of the ICRP recommendation.

The BSS shall apply to practices involving exposure to natural sources specified by the regulatory authority. The natural sources within the scope of the BSS include those related to mines, mills, processing radioactive ores and other source specified by the authority. Exposure to natural sources shall normally be considered as a chronic exposure situation and shall be subjects to the requirements for intervention except some cases of public exposure related to practices and occupational exposure to radon. In the BSS, unmodified concentrations of radionuclides in most raw materials are deemed to be excluded from scope of the standards. This means that every material called as TENORM should be within the scope of the standards, if it can not be exempted. BSS provided criteria for exemption from the requirements of the standards for the regulation as practice. The exemption criteria is selected to be of order of 10μSv/y or less for the effective dose in any member of public and no more than 1 man·Sv of collective effective dose. In the BSS exemption levels for both artificial and natural radionuclides are given which are derived by calculation according to above criteria. The value for natural thorium or uranium is selected to be 1Bq/g and that for ^{40}K is 100 Bq/g. Because these values were derived with calculation in a scenario for a moderate quantity of material, BSS noted that unless the exposure is excluded, exemption for bulk amounts of materials with activity concentrations lower than the exemption levels given in the BSS may require further consideration by the regulatory authority.

3.2.2 RS-G-1.7 (DS161)

In IAEA, coherent system for the concepts of exemption, exclusion and clearance has been discussed for a number of years. After IAEA was requested in the General Conference held in 2000, to discuss the establishment of the level for radioactive concentrations for the smooth international trade of commodities by the some countries which territories were contaminated by the Chernobyl accident, the Radiation Safety Standard Committee (RASSC) and the Waste Safety Standards Committee (WASSC) started to discuss this issue. From the results of discussions over a period of more than 3 years, a document of draft safety guide (draft No. DS161), entitled “Application of the Concepts of Exclusion, Exemption and Clearance” was approved by the Committees in March 2004 and published as Safety Series No. RS-G-1.7[6)] in August 2004. The exclusion levels for radionuclides of natural origin and the exemption levels for radionuclides of artificial origin in bulk amount were provided in the document. As described above the exemption level given in the BSS can be applied only to the exemption of moderate quantities of materials which is considered to be less than 1 ton. Although the levels for artificial radionuclides were derived with calculation based on dose criteria of order 10 μSv/y for normal situation of exposure and 1 mSv/y only for low probability events, those for natural radionuclides were derived using the concept of "exclusion" prescribed in BSS. The values were selected on the basis of consideration of upper end of the worldwide distribution in soil reported in UNSCEAR. The value for ^{40}K was selected to be 10 Bq/g and that for all other nuclides such as ^{238}U and ^{232}Th was 1 Bq/g. In relation to application of the values provided in the document, the values were selected for application to ordinary regulation of radioactive materials, to clearance level and to regulatory control in national and international trade of commodities.

3.3 European Commission : Radiation Protection No. 122 Part II

The European Commission (EC) published the report as Radiation Protection No. 122 Part II entitled "Practical use of the concepts of clearance and exemption (Part II) - Application of the concepts of exemption and clearance to natural radiation sources-"in 2002[7]. The objectives of this report are as follows;

- application of the concepts of exemption and clearance to natural radiation sources, and
- proposal of enveloping scenarios for establishing exemption and clearance values for naturally occurring radionuclides.

The exemption levels in the BSS are not applied to the large volumes of material processed and released by NORM industries, because they are derived only for moderate quantities (a few Mega-gram) of material. In the case of NORM industry, the amounts of material to be considered are in general very large both for exemption and for clearance, contrary to practices for which clearance often relates to much larger volumes than exemption. For exemption and clearance, where appropriate, the same levels should be used for naturally occurring radionuclides.

RP 122 Part II deals with work activities. Work activities where the presence of natural radiation sources leads to a significant increase in the exposure of workers or members of the public and the material is not used because of its radioactive, fissile and fertile properties. Exposures by NORM industry are caused the following activities;

- Product of a process
- Re-use of by–product material
- Disposal of solid waste
- Recycling of scales deposited on steel pipes (oil & gas industry), and
- Atmospheric or liquid discharges.

The derivation of exemption and clearance levels for NORM is carried out through the process shown in Fig. 1.

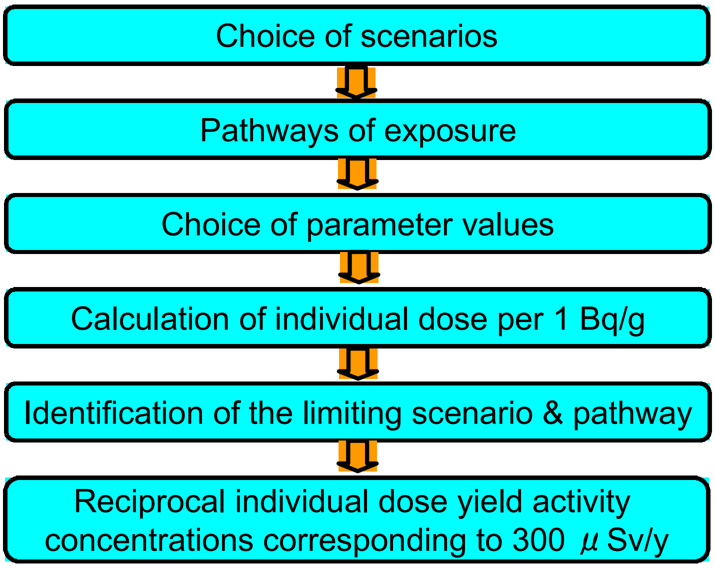

Fig. 1 The Process of the Derivation of Exemption and Clearance Level for NORM

In the derivation of exemption and clearance levels the following enveloping scenarios are considered:

- Transport over long/short distances (workers),
- Disposal on a heap or a landfill (workers),
- Person living in a house near a heap or landfill (members of the general public),
- Transport over long/short distances,
- Storage of moderate quantities, indoors,
- Storage of large quantities, outdoors,
- Road construction with NORM material,
- Building construction with NORM containing building material,
- Building construction using undiluted NORM as unshielded surface cover,
- NORM as surface layer on public places/sports grounds,
- Person living in a house with NORM containing building materials,
- Person living in a house where undiluted NORM as unshielded surface cover is used,
- External exposure to gamma emissions,
- Inhalation of dust containing radioactivity,
- Ingestion of material, and
- Inhalation of ^{222}Rn.

Groundwater pathway is also considered but the results are not reflected to set the levels, because groundwater pathways largely depend on the site conditions. ^{222}Rn concentration in air (Bq/m^3) is calculated and is compared to the level of 200 Bq/m^3 for members of the public and 500 Bq/m^3 for workers, respectively.

In the derivation of level the following materials are considered:

- Waste rock,
- Ash,
- Sand,
- Slag, and
- Sludge from the oil/gas industry.

The EC concluded 300 μSv of annual effective dose increment is appropriate. For natural radiation source (see Fig. 2) because 10 μSv/y would in general not be practicable to implement control scheme and exemption-clearance levels for naturally occurring radionuclides should be set at a higher dose level than for practices. Grounds of dose criterion are as follows:

- Comparable to or smaller than regional variations in total effective dose from natural radiation background (external exposure only),
- Coherent with the exemption level proposed for building materials in EC RP 112, and
- Coherent with dose constraint, e.g. control of effluents.

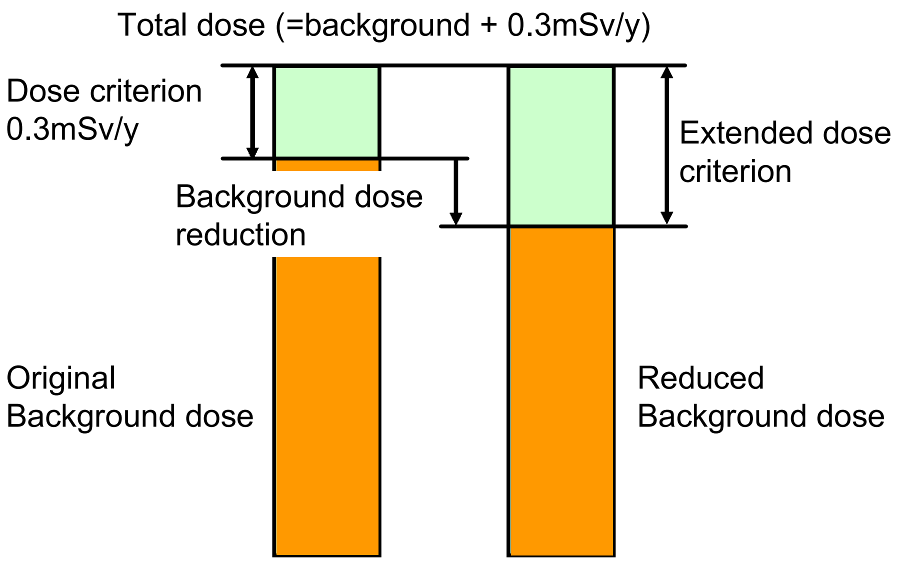

Fig. 2 Scheme for the Application of the Concept of Background Dose Reduction

Table 1 lists the nuclides and decay chains to be considered here. The ^{238}U chain is assumed to be in natural equilibrium with the ^{235}U chain.

Table 1 Summary of Nuclides and Chain Segments that are used in Modeling

Parent	Nuclides considered in secular equilibrium
Uranium decay chains	
^{238}U sec	^{238}U , ^{234}Th , ^{234}Pa m, ^{234}Pa (0.3%), ^{234}U , ^{230}Th , ^{226}Ra , ^{222}Rn , ^{218}Po , ^{214}Pb , ^{214}Bi , ^{214}Po , ^{210}Pb , ^{210}Bi , ^{210}Po
U nat	^{238}U , ^{234}Th , ^{234}Pa m, ^{234}Pa (0.3%), ^{234}U , ^{235}U (4.6%),^{231}Th (4.6%)
^{230}Th	^{230}Th
^{226}Ra +	^{226}Ra , ^{222}Rn , ^{218}Po , ^{214}Pb , ^{214}Bi , ^{214}Po
^{210}Pb +	^{210}Pb , ^{210}Bi
^{210}Po	^{210}Po
Actinium decay chains	
^{235}U sec	^{235}U , ^{231}Th , ^{231}Pa , ^{227}Ac , ^{227}Th (98.6%), ^{223}Fr (1.4%), ^{223}Ra , ^{219}Rn , ^{215}Po , ^{211}Pb , ^{211}Bi , ^{207}Tl , ^{211}Po (0.3%)
^{235}U +	^{235}U , ^{231}Th
^{231}Pa	^{231}Pa
^{227}Ac +	^{227}Ac , ^{227}Th (98.6%), ^{223}Fr (1.4%), ^{223}Ra , ^{219}Rn , ^{215}Po , ^{211}Pb , ^{211}Bi , ^{207}Tl , ^{211}Po (0.3%)
Thorium decay chains	
^{232}Th sec	^{232}Th , ^{228}Ra , ^{228}Ac , ^{228}Th , ^{224}Ra , ^{220}Rn , ^{216}Po , ^{212}Pb , ^{212}Bi , ^{212}Po (64.1%), ^{208}Tl (35.9%)
^{232}Th	^{232}Th
^{228}Ra +	^{228}Ra , ^{228}Ac
^{228}Th +	^{228}Th , ^{224}Ra , ^{220}Rn , ^{216}Po , ^{212}Pb , ^{212}Bi , ^{212}Po (64.1%), ^{208}Tl (35.9%)
^{40}K	
^{40}K	^{40}K

sec: Parent nuclide with their decay products which are in secular equilibrium.
+ : Parent nuclide with their decay products listed in right column which are in equilibrium.
nat: 238U sec and 235Usec in their fixed natural ratio.

In Table 2 the recommended rounded general clearance and exemption levels for all types of material are given. An additional column in Table 2 gives the (considerably higher) values only applicable for wet sludge from the oil and gas industry. The general clearance and exemption values for all materials are very much lower than those for wet sludge from oil and gas industry, essentially because the suspension/inhalation pathway can be ignored.

Table 2 Rounded General Clearance Levels in kBq/kg

Nuclide	All materials	Wet sludges from oil and gas industry
^{238}U sec incl. ^{235}U sec	0.5	5
U nat	5	100
^{230}Th	10	100
^{226}Ra +	0.5	5
^{210}Pb +	5	100
^{210}Po	5	100
^{235}U sec	1	10
^{235}U +	5	50
^{231}Pa	5	50
^{227}Ac +	1	10
^{232}Th sec	0.5	5
^{232}Th	5	100
^{228}Ra +	1	10
^{228}Th +	0.5	5
^{40}K	5	100

[Note] * For radionuclides considered to be in secular equilibrium see Table 1
** ^{238}U sec and ^{235}U sec are in their fixed natural ratio (99.275 and 0.72 % atomic fraction)
*** Separate values for radionuclides of ^{235}U series are given here only for information. For NORM these values are never limiting as ^{238}U and ^{235}U are always in their fixed natural ratio.

As a result of the large volumes of material processed and released by NORM industries, the concept of exemption and clearance are merged in this report and a single set of levels both for exemption and clearance is appropriate. Dose criteria for work activities are 300 μSv/y is appropriate and 0.5 Bq/g for U and Th in secular equilibrium is derived. This level is corresponding to the upper range of concentrations usually found in ores. Therefore, regulatory control for NORM is practicable by using these levels. The ^{222}Rn concentrations were calculated based on the minimum value of all exemption/clearance levels for ^{226}Ra+ for each type of material. The calculation results show the radon concentrations are below 200 Bq/m^3 for members of general public and 500 Bq/m^3 for workers for all exposure scenarios. There is possibility of contamination of groundwater as drinking water; the evaluation of doses is necessary case by case.