# EAN-NORM 2013

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## 1. INTRODUCTION

In 1996, natural radiation sources were already mentioned in standards established by EURATOM as well as those established by the IAEA[12]. Since then, the European Commission has moved ahead publishing, on a regular basis, technical support guidance and recommendations on Natural Occurring Radioactive Material (NORM) issues. In 1997 for instance, recommendations[5] were published to help dealing with "significant increase in exposure due to natural radiations". In 1999 the European Commission published radiological protection principles concerning the natural radioactivity of building materials[6] and reference levels for workplaces processing materials with enhanced levels of naturally occurring radionuclides[9]. Lastly, in 2001 the European Commission published recommendations dealing with exemption and clearance levels for NORM residues[3].

All these recommendations have provided Member States with criteria and a sound technical framework to help establish national regulations for NORM and building materials. Some Member States have already included all or parts of these recommendations in their regulatory framework anticipating the future directive.

Later on, the European Commission decided to harmonize, promote and consolidate these recommendations, introducing them into a new Council directive laying down basic safety standards for the protection against the danger arising from exposure to ionising radiation so called EU-BSS[13].

The latest version of the EU-BSS was approved on 29 May 2013 by the Working Party of the Atomic Question group (WPAQ) under the Art. 31 of the EURATOM Treaty. The final version of this EU-BSS was then submitted to the EU parliament to collect opinions. However, since the directive was written under the EURATOM treaty, there is no obligation to take on board the Parliament's opinions and the European Commission is reluctant to re-open endless discussions with all Member States. In other words, unless rejected by the EU Council, this latest EU-BSS version should be soon final and official.

Parts dealing with NORM and building materials of this directive (EU-BSS) are hereby presented in this paper. They need to be taken into account along with the 2011 EU regulation laying down harmonised conditions for the marketing of construction products[1] so called CPR, containing many relevant articles which complement the aforesaid directive.

From now on, both EU regulatory documents constitute the new basis for building material radiation protection regulation and should be soon followed by more detailed EU standards and guidance.

## 1.1 Standards on dose modelling - Working group CEN-TC351-TG32

The European Commission (EC) has mandated the CEN to establish EU harmonized standards regarding dose assessment and classification of emitted gamma radiation from construction products. These standards should be adopted by all Member States as soon as the EU-BSS will come into force. This document should help complete the EU-BSS and CPR regulatory framework regarding: dose modeling; classification of building materials with CE marking and related technical information about radiation protection. Amongst others, the following decisions were agreed upon by the CEN and the EC for the content of this document:

- The scope will exclude radon and thoron exhalation from building materials because this exhalation is dealt with in a different manner in the EU regulation. Regulatory explanations are given in §3.
- A simple classification (e.g.: A & B) will be established between building materials which may lead to a dose exceeding 1 mSv/year (B) for a member of the public and building materials with no restrictions whatsoever (A).
- Mass per unit area (kg/m²) of the material will be considered in the approach keeping a dose estimate model based on a conservative room model.
- Additional sensitivity analysis regarding the room geometry will be presented to demonstrate that there is no more than 10 % of influence of such geometry upon the determination of doses.

The document will be called: “Construction products: Assessment of release of dangerous substances / TC 351 WI 00351020". The secretariat of the task group in charge of this document is held by NEN (NL).

It is important to underline that the EU regulatory philosophy is to ensure that gamma doses from building materials to a member of the public remain under 1 mSv/year in addition to outdoor external exposure (EU-BSS Art. 75).

A simplified model, so called "index" in the BSS is also proposed as a conservative screening tool ensuring that materials with an index less than 1 do not present any risk to exceed 1mSv/year of indoor gamma radiation to a member of the public, in any type of building construction. This regulatory index being too conservative for thin construction materials or light density products, complementary guidance and calculations are presented in this document to help classify the product.

## 1.2 Standards on activity measurements - Working group CEN-TC351-TG31

In addition to the index calculation and an additional harmonized dose modelling approach to determine the maximum possible dose from any type of building material, the measurement of activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ may also be a concern. The activity concentration determination of these radionuclides may vary a lot from one laboratory to another depending on protocols and methodologies in place so, the European Commission mandated the CEN under the construction product directive[1] so as to help standardize and harmonize activity concentration measurement and test standards.

The three radionuclides chosen to be measured and used in the BSS index calculation were thought to be easy to evaluate for laboratories. However, experience feedback has revealed some technical difficulties. In gamma-spectrometry, the $^{232}$Th gamma emission detection is not so easy to perform out of the noise made by $^{234}$Th (direct progeny of $^{238}$U). So decisions were to be made in the CEN-TG31 group, in charge of the relevant standards, regarding the $^{232}$Th progenies ($^{228}$Ra, $^{228}$Th, $^{228}$Ac, $^{208}$Tl, etc.) to be considered for measurement and about the methodology to be established **to allow proper estimate of the $^{232}$Th activity concentration.**

The hydro-geological history of the earths used to manufacture building materials combined with some industrial processes may lead to a great disequilibrium amongst the whole cascade of $^{232}$Th progenies. Sometimes the $^{228}$Ra is washed out from the material unlike certain progenies and sometimes additional $^{228}$Ra from elsewhere may be naturally added by circulating water in the soil leading to material with different progeny concentrations than expected. Neutron activation techniques, allowing direct measures of $^{232}$Th activity concentrations, were compared to spectrometry techniques with different building materials and showed measurement differences with factors varying from 3 to 10!

Because of the solubility ratio difference between Radium and Thorium, the CEN-TG31 group decided to consider the highest radionuclide activity concentrations amongst the $^{228}$Th and $^{228}$Ra (both $^{232}$Th progenies), the latters are to be determined with their respective progenies ($^{208}$Ta and $^{228}$Ac) for more accuracy. If this approach appeared to be too conservative for a given construction product and there were suspicions of a significant disequilibrium in the cascade of progenies, alternative techniques, such as neutron activation or alpha spectrometry techniques, may be used for direct measurement of $^{232}$Th activity concentration.

The CEN has recently drafted standards about the determination of these three radionuclides' activity concentrations and has just submitted them to a robustness validation process in Poland.

# 2. EUROPEAN REGULATORY APPROACH FOR NORM

## 2.1 NORM industries

The EURATOM Basic Safety Standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation (EU-BSS[13]) has been revised, consolidating 5 existing directives dealing with radiation safety[14]. This huge work, merging several directives and recommendations, should not only help clarify some parts of old directives but also add new requirements dealing with natural radiation sources.

Article 2 of this new EU-BSS states that all practices involving radiation sources are to be regulated including *"human activities which involve the presence of natural radiation sources that lead to a significant increase in the exposure of workers or members of the public, in particular… the processing of materials with naturally-occurring radionuclides..."*

It is also required, according to BSS art. 23, **to identify** *"classes or types of practices involving NORM and leading to exposure of workers or members of the public which cannot be disregarded from a radiation protection point of view..."*.Such an identification process has to take into account the following list extracted from the EU-BSS annex VI:

(1) extraction of rare earths from monazite;
(2) production of thorium compounds and manufacture of thorium-containing products;
(3) processing of niobium/tantalum ore;
(4) oil and gas production;
(5) geothermal energy production;
(6) $TiO_2$ pigment production;
(7) thermal phosphorus production;
(8) zircon and zirconium industry;
(9) production of phosphate fertilisers;
(10) cement production, maintenance of clinker ovens;
(11) coal-fired power plants, maintenance of boilers;
(12) phosphoric acid production;
(13) primary iron production;
(14) tin/lead/copper smelting;
(15) ground water filtration facilities;
(16) mining of ores other than uranium ore.

These identified practices may then be under regulatory control especially regarding discharges to the environment, reuse of NORM residues in building materials and radiation protection of the workers and the public. Regarding discharges to the environment, the EU-BSS has established exemption values as follow:

BSS art. 26c.1 & annex VII - Table A - Part2

| Radionuclides | Activity concentration |
|---|---|
| Natural radionuclides from the $^{238}U$ | 1000 Bq/kg |
| Natural radionuclides from the $^{232}Th$ | 1000 Bq/kg |
| $^{40}K$ | 10 000 Bq/kg |

Unless already exempted by national regulation or regulatory decisions in the light of the values mentioned before, any identified activities **shall be notified** to the regulatory authority (BSS art.25 & 26c.1).

Such a **notification** is followed by a **regulatory control** commensurate with the magnitude and likelihood of exposure especially when the dose liable to be incurred by a member of the public, may exceed 1mSv/year prevailing background natural radiations (BSS 24 & Annex VII).

Even if the identified industry has not planned to discharge NORM residues outside the plant, gamma doses are to be kept under review and, by all means or pathways, shall not be liable to give more than 1 mSv/year to a member of the public (BSS art. 12 & Annex VII). Regarding workplaces, arrangements are to be made to protect workers when doses may exceed 1 mSv/year (BSS art. 35).

According to the annex VII of the BSS, the assessment of doses to members of the public shall take into account not only pathways of exposure through airborne or liquid effluent, but also pathways resulting from the disposal or recycling of solid residues. Nevertheless, Member States may specify dose criteria lower than 1 mSv per year for specific types of practices or specific pathways of exposure. It is also said that, for the purpose of exemption from authorisation, less restrictive dose criteria may be applied. In other words some leeway is given to national regulatory bodies as well as national regulations and ought to be anticipated at national level when transposing the BSS into national regulations.

We should underline that the reference level is 1 mSv/year for "a member of the public" above prevailing background activity for any NORM discharges to the environment. In comparison, the criterion for artificial radionuclides is much more constraining and established at 10 µSv/year (BSS annex VII).

## 2.2 Water quality aspects

Notwithstanding exemption criteria mentioned above and where there is a concern that identified practices may lead to the presence of NORM in water liable to affect the quality of drinking water supplies or affect any other exposure pathways from a radiation protection point of view, the regulatory body may require a notification and regulatory control (BSS art.25.3). Drinking water supply and any other potential contamination pathways need indeed to be kept monitored against contamination and assessed against drinking water standards[8] and national regulations as appropriate.

The water directive[8] requires that the total indicative dose remain under 0.1 mSv/year (such an estimation excludes tritium, potassium-40 as well as radon and its progenies). For tritium itself, it is specifically required not to exceed 100 Bq/l.

## 2.3 Building materials

Building materials are dealt with apart in the BSS directive although 1 mSv/year, for a member of the public remains the maximum reference level to comply with. Most building material requirements laid down in the new EU BSS are not new and come from previous EU principles and recommendations quoted in references [3], [4], [7], [8], [9], [10] and [11]. Such principles and recommendations were reviewed and enhanced by EU Member States to be turned into proper harmonized EU regulations.

Building materials of concern whether from natural origin such as granitoides, porphyries, tuff, pozzolana, lava, alum-shale or from those in which specific residues from identified NORM industries have been incorporated; need to comply with the maximum reference level of 1 mSv/year (compared to outdoor background activity).

The EU RP 112 principles[10] established the first non-prescriptive EU radiation protection framework concerning the natural radioactivity of building materials. This EU RP 112 was based on a publication[15] from the Finnish regulator (STUK) and provides EU Member States with a user friendly screening tool to evaluate building materials' radiation gamma emissions and help check compliance with the maximum reference level mentioned above.

To establish this screening tool, a conservative dose estimate model was first created. This model considered the activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K along with some coefficients derived from Berger's studies. The calculations, which led to the following model, were based on a hypothetical room (similar to a bunker of 4 m x 5 m x 2.8 m) with walls, ceiling and floor of 20 cm thick and made of a material with a fixed density of 2350 kg $m^{-3}$ (similar to concrete). In this model, it is also assumed: an annual exposure time of 7000 hours a year; a dose conversion of 0.7 Sv $Gy^{-1}$ and a fixed background activity of 50 nGy $h^{-1}$.

Considering all these assumptions, the annual dose was then determined by the following simplified formula. Where C is the activity concentration of $^{226}$Ra, $^{232}$Th or $^{40}$K naturally contained in most of building materials:

$$\text{Annual dose or "index"} = C^{226}\text{Ra}/300 + C^{232}\text{Th}/200 + C^{40}\text{K}/3000$$

$C$ in Bq/kg (and the Index is in mSv/year only for the theoretical bunker as described above)

This simplified model was deemed to be sufficiently conservative to be part of the new EU BSS since most dwellings or buildings will not be designed as massive as the bunker described above. An index < 1 with the conditions mentioned above means a dose estimate in compliance with the maximum reference level of 1 mSv/year for a member of the public.

In the new EU-BSS directive, for identified building material, it is required that the activity concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K be determined (BSS art.75 and its annex VII). The index can then be used as a screening tool to allow building material to be placed onto the EU market without any restrictions. Most national regulators and/or building codes will use this Index to release identified building materials without further analysis with respect to radiation protection.

### 2.3.1 Provisions on the marketing of construction products

According to the CPR (articles 4, 11 and 24), before placing construction products onto the market, these products should comply first with some EU harmonized standards and be accompanied by a "**declaration of performance**" which includes health and safety aspects (CPR art. 15 & 16). This declaration of performance and related standards are very important to get the **CE marking**. This marking confirms indeed that the construction product complies with the declared "performance" and the harmonized standards. Finally, it allows free transboundary move in the whole EU.

The manufacturer shall draw up such a declaration of performance with all related documentation and keep distributors informed. This declaration of performance should be accompanied by information on the content of all hazardous substances (art. 25 of CPR and art. 31-33 of EC Regulation n° 1907/2006 of the European Parliament and of the Council of 18/12/2006 – REACH).

The content of the aforesaid declaration of performance (CPR art.6) should also include the construction product uses along with its levels or classes (CPR art. 6.3d and 6.3g).

It should be added that all the supply chain dealing with these construction products is responsible of the risks: manufacturers, importers and distributors. They all need indeed to take into account health and safety of people and the environment (CPR art. 28.2) in adequacy with the declaration of performance.

Moreover, such a responsibility will be monitored by "Market surveillance authorities" (CPR art.56) with technical support as appropriate (CPR art. 29-55).

### 2.3.2 Material density aspects

The material density was a significant issue to be tackled especially for light construction products. Indeed, if we used the original index with lower density products than the concrete ($d < 2350$ kg $m^{-3}$), dose calculations would be overestimated by a factor of 3 or 4. Certain manufacturers would then face big difficulties to comply with the regulation using the BSS index as it is, although real doses would be much less than 1 mSv/year in reality, even in a conservative model room similar to the BSS index bunker.

The German Federal Office for Radiation Protection *(Bundesamt für Strahlenschutz, BfS)*, member of the CEN-TG32 group, decided to establish an improved dose estimate formula taking the material density (ρ) into account and providing a more realistic dose calculation with activity concentrations in Bq/g, a rate conversion factor of 0.7 Sv/Gy, a natural background activity of 50 nGy/h and the same model room dimensions as those used to establish the original BSS index:

$$\text{Dose estimate (mSv/y)} = \left[C^{226}\text{Ra} \cdot (2.6 \ln(\rho) - 13.9) + C^{232}\text{Th} \cdot (3.1 \ln(\rho) - 16.6) + C^{40}\text{K} \cdot (0.2 \ln(\rho) - 1.2)\right] \cdot 7.10^{-4} - 0.245$$

It was decided by the TG-32 working group that the BSS Index will remain a user-friendly screening tool for most of building materials. This means that if the Index < 1 then the dose should be < 1 mSv/y whatever the room design is; for such a reason the material ought to be classified "A".

If the Index exceeded 1 then a more realistic equation as mentioned above would be considered indeed. Then, if the dose estimate is less than 1 mSv/year, the construction product will still be classified "A" if not, it will be classified as a "B"-product.

To be conservative enough and consistent with other CEN Technical Specifications, it was decided that the bunker dimensions to be considered to determine the dose estimate will be a 20 cm-thick bunker of (4 x 3 x 2.5) $m^3$ with no door and no window. In this model, it is still assumed: an annual exposure time of 7000 hours a year to a member of the public placed in the center of the room; a dose conversion of 0.7 Sv $Gy^{-1}$ and a fixed background activity of 50 nGy $h^{-1}$.

### 2.3.3 Material thickness aspects

Beyond density aspects, the thickness of materials could also be a concern when establishing a dose estimate with a 20 cm-thick bunker model as described above.

For thin construction products (thinner than 20cm) such as bricks for instance and with a BSS index exceeding 1, the TG32 group decided to enhance the equation considering the density (ρ) along with the "bunker thickness" (d). In other words, both parameters "ρ" and "d" could be considered in a single equation.

Combining both parameters, the German Bfs ended up with a simpler and enhanced equation:

$$\text{Enhanced dose estimate (mSv/y)} = \left[C^{226}\text{Ra}.[2.81+1.63(\rho d)-0.0161(\rho d)^2] + C^{232}\text{Th}.[(3.19+1.85(\rho d)-0.0178(\rho d)^2] + C^{40}\text{K}.[0.223+0.128(\rho d)-0.00114(\rho d)^2]\right].10^{-4} - 0.245 \text{ mSv/y}$$

All calculations were made with "R²" using the Cubature code[1] (a package for adaptive multidimensional integration over hypercubes.

Finally, for superficial or very thin materials such as tiles with a BSS index exceeding 1, the TG-32 group decided to consider the 20-cm thick bunker as described above, made of an "average" concrete and coated in all directions by the superficial construction product we wish to classify.

If we do not consider any shielding effect of the tiles it would be the same as adding the dose provided by a 20 cm-thick bunker made of concrete with the dose provided by a thin bunker construction made of the tile's material…

[1] C code by Steven G. Johnson, R by Balasubramanian Narasimhan –
See: http://ab-initio.mit.edu/wiki/index.php/Cubature

### 2.3.4 CE marking and classification

Considering the latest equation, if the dose estimate is less than 1 mSv/year either for a coated bunker (superficial materials) or plain bunker made of the same material in all directions (bulk materials), the product will then be classified "A".

If not, the construction product will be classified "B" and its uses will have to be further investigated to help establish instructions in the mandatory "declaration of performance" of the product. Instructions may then be: *"to be used for floors only"* or *"no more than x kg per room"* or, why not: *"not to use for building constructions"* (we may consider establishing a "C-product" category for such products if need be).

Such instructions would depend on additional specific dose calculations where for instance, we replace the concrete walls by "B" bricks, keeping ceiling and floor made of concrete (if dose estimate < 1 mSv/y then instructions could be: *"for walls only"*, if dose estimate > 1 mSv/y, instructions may then be: *"not to use in building constructions"* or restrictions on the material thickness or other appropriate cunning criteria may be established.

### 2.3.5 Radon exhalation & building materials

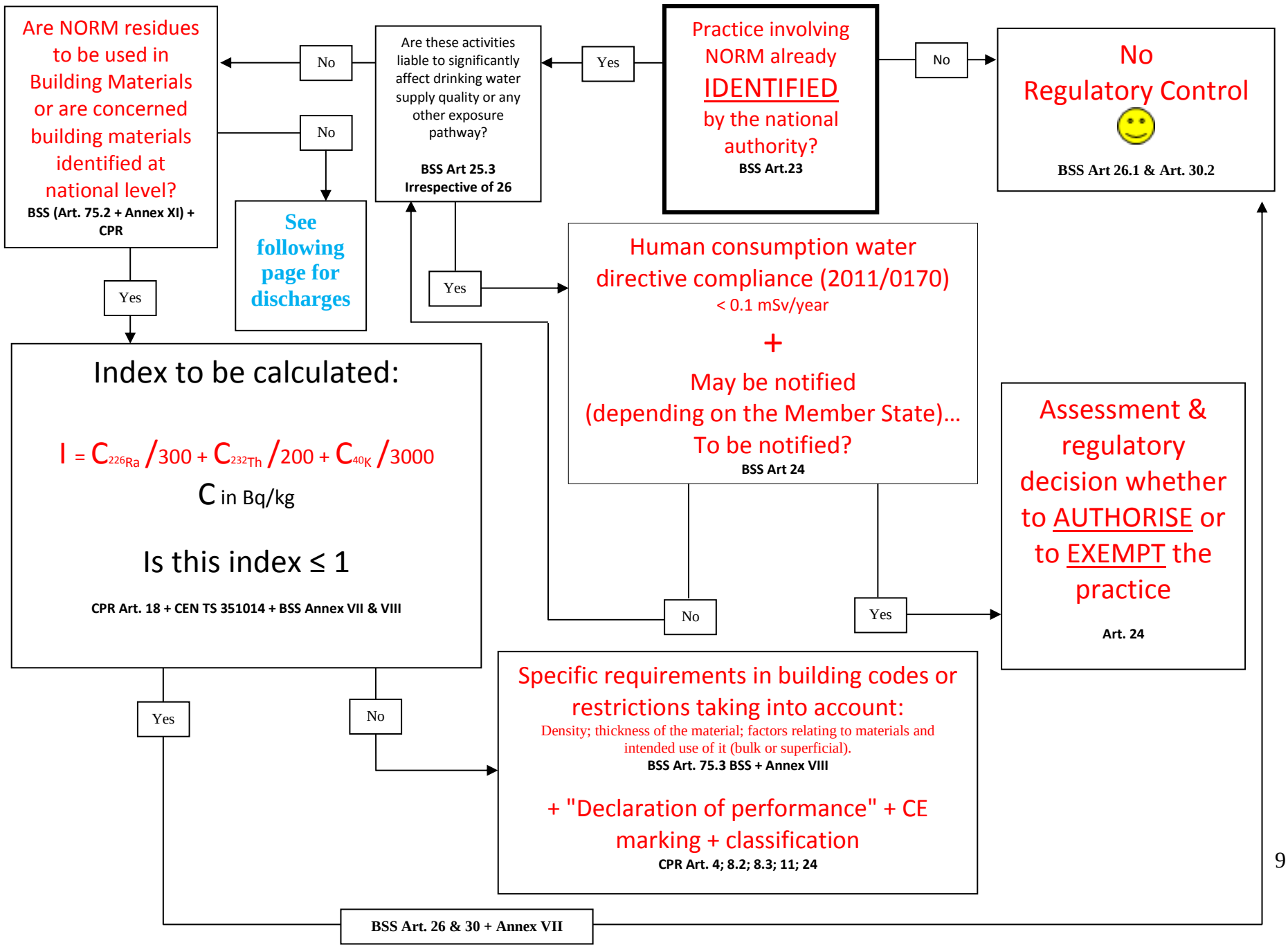
Regarding radon exhalation from building materials, Member States decided not to deal with this issue in the screening process, which should address gamma radiations only. However, radon exhalation might be dealt with apart, including additional requirements, in national action plans.

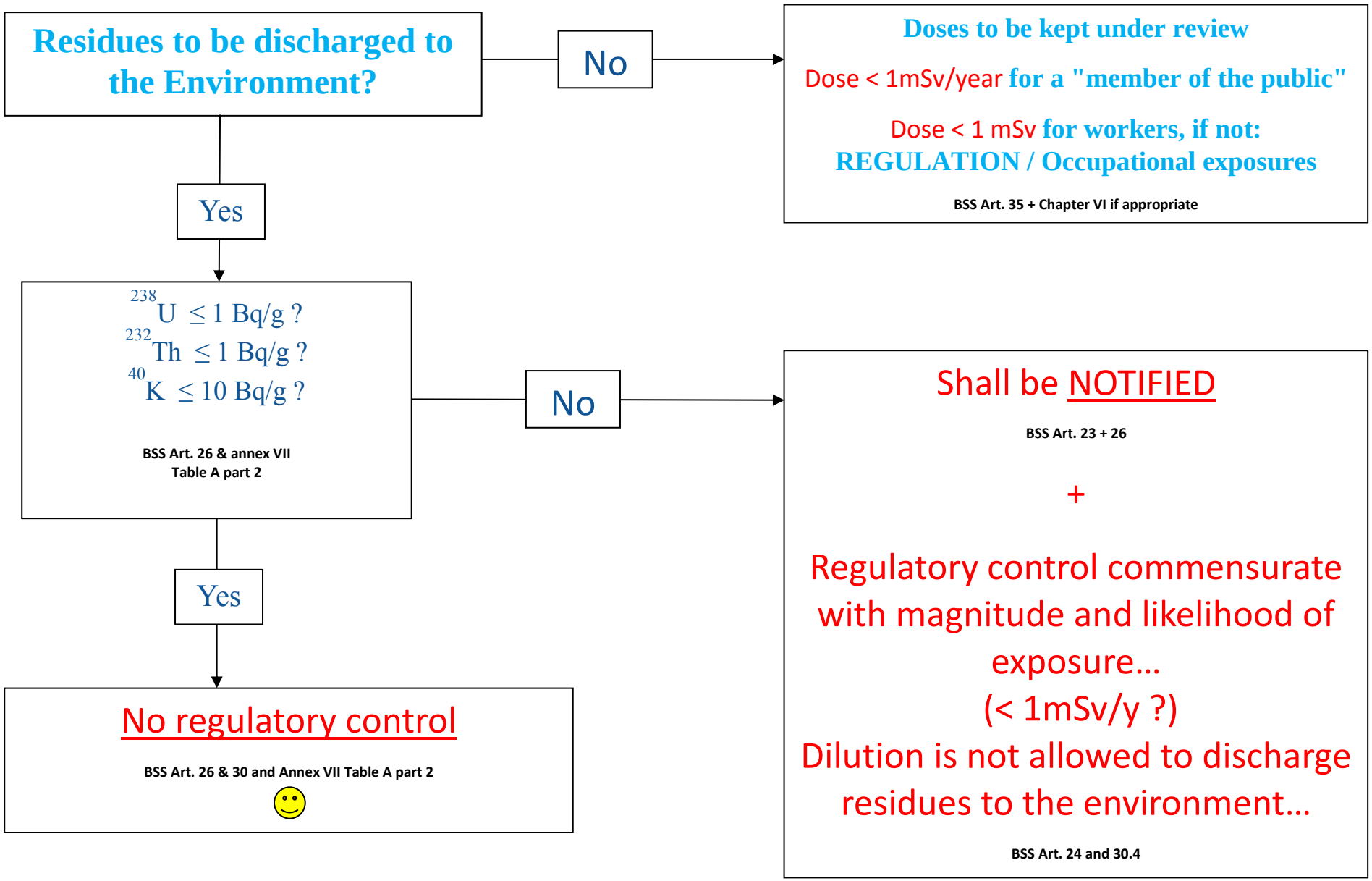
Specific BSS parts are dealing with radon issues, fixing a maximum national reference level for all buildings, at 300 $Bq.m^{-3}$ (BSS art.74.1).

It is important and required for Member States to promote actions to identify dwellings with radon concentration (as an annual average) exceeding the reference level mentioned above and to encourage, where appropriate, by technical or financial means, radon concentration-reducing measures in these dwellings (BSS art. 74.2). Action plans will have to be established by all EU Member States to seriously tackle this national health concern.

## 3. CONCLUSION

The EU has established a clear and harmonized EU framework dealing with NORM and building materials combining the CPR, the BSS and two sets of CEN standards. EU labelling rules, classification and “CE” marking for these building materials will soon be established in a harmonized way within Europe and will allow free and safe transboundary circulation of building materials. Such a framework concerns gamma radiation only; for radon, additional safety features may have to be taken into consideration but "radon protection" will concern buildings rather than construction products, taking into account other radon sources as appropriate.


Practice involving NORM already IDENTIFIED by the national authority?
BSS Art.23
No
No Regulatory Control
BSS Art 26.1 & Art. 30.2
Yes
Are these activities liable to significantly affect drinking water supply quality or any other exposure pathway?
BSS Art 25.3
Irrespective of 26
No
Are NORM residues to be used in Building Materials or are concerned building materials identified at national level?
BSS (Art. 75.2 + Annex XI) + CPR
No
See following page for discharges
Yes
Index to be calculated:
$I = C_{226Ra}/300 + C_{232Th}/200 + C_{40K}/3000$
C in Bq/kg
Is this index ≤ 1
CPR Art. 18 + CEN TS 351014 + BSS Annex VII & VIII
Yes
No
Yes
Human consumption water directive compliance (2011/0170)
< 0.1 mSv/year
+
May be notified (depending on the Member State)…
To be notified?
BSS Art 24
No
Yes
Assessment & regulatory decision whether to AUTHORISE or to EXEMPT the practice
Art. 24
Specific requirements in building codes or restrictions taking into account:
Density; thickness of the material; factors relating to materials and intended use of it (bulk or superficial).
BSS Art. 75.3 BSS + Annex VIII
+ "Declaration of performance" + CE marking + classification
CPR Art. 4; 8.2; 8.3; 11; 24
BSS Art. 26 & 30 + Annex VII


Residues to be discharged to the Environment?
No
Doses to be kept under review
Dose < 1mSv/year for a "member of the public"
Dose < 1 mSv for workers, if not:
REGULATION / Occupational exposures
BSS Art. 35 + Chapter VI if appropriate
Yes
238U ≤ 1 Bq/g ?
232Th ≤ 1 Bq/g ?
40K ≤ 10 Bq/g ?
BSS Art. 26 & annex VII
Table A part 2
No
Shall be NOTIFIED
BSS Art. 23 + 26
+
Regulatory control commensurate with magnitude and likelihood of exposure…
(< 1mSv/y ?)
Dilution is not allowed to discharge residues to the environment…
BSS Art. 24 and 30.4
Yes
No regulatory control
BSS Art. 26 & 30 and Annex VII Table A part 2

## REFERENCES


[1] EU regulation n° 305/2011 laying down harmonised conditions for the marketing of construction products and repealing Council directive 89/106/EEC.

[2] IAEA guide n° RS-G-1.7 (2004) - Application of the concepts of exclusion, exemption and clearance.

[3] **European Commission, Radiation Protection 122** - Practical use of the concepts of clearance and exemption - Part II : Application of the concepts of exemption and clearance to natural radiation sources (2001).

[4] European Commission services considerations with regard to natural radiation sources in BSS directive 16/01/2009.

[5] **European Commission, Radiation Protection 88** - Recommendation for the implementation of title VII of the European BSS concerning significant increase in exposure due to natural radioactive sources 1997 – ISBN 92-827-5336-0

[6] **European Commission, Radiation Protection 112** – Radiological protection principles concerning the natural radioactivity of building materials.

[7] IAEA, Assessing the needs for radiation protection measures in work involving mineral and raw materials, Safety report series n° 49 – 2006.

[8] Proposal for a council directive laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption - 2011/0170 (NLE) - 27/06/11. This proposal has been recently approved by MS and should be published soon.

[9] **European Commission, Radiation Protection 95** – Reference levels for workplaces processing materials with enhanced levels of naturally occurring radionuclides.

[10] **European Commission, Radiation Protection 96** – Enhanced radioactivity of building materials (Dec. 1997).

[11] **European Commission, Radiation Protection 107** - Establishment of reference levels for regulatory control of workplaces where materials are processed which contain enhanced levels of naturally-occurring radionuclides, Luxembourg, 1999 – ISBN 92-828-6655-6.

[12] IAEA Safety Series n°115, International Basic Safety Standards for the protection against Ionizing Radiation and for the Safety of Radiation Sources.

[13] EURATOM BSS or Council directive laying down the basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation. Draft presented under article 31 Euratom Treaty for the Opinion of the European Economic and Social Committee, the Working Party of the Atomic Question group and the EU parliament – Version approved on 29 May 2013.

[14] The new BSS will incorporate in addition to the existing **council 96/29/Euratom** of 13/05/1996 laying down the basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation: the **council directive 97/43/Euratom** of 30/06/1997 on health protection of individuals against the danger of ionising radiation in relation to medical exposure ; the **council directive 2003/122/Euratom** of 22/12/2003 on the control of high-activity sealed radioactive sources and orphan sources ; the **council directive 90/641/Euratom** of 4/12/90 on the operational protection of outside workers exposed to the risk of ionising radiation during their activities in controlled areas ; **council directive 89/618/Euratom** of 27/11/1989 on informing the general public about health protection measures to be applied and steps to be taken in the event of a radiological emergency.

[15] Radiation Dose Assessments for materials with elevated natural radioactivity. STUK-B-STO 32- NOV. 1995 – Mika Markkanen (Finnish Center for Radiation and Nuclear Safety)