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Abstract

Since 1996 the European Commission, along with the IAEA, has drafted several principles, guidance and specific recommendations dealing with naturally occurring radioactive material (NORM). The Commission has recently decided to harmonize, promote and consolidate these principles and recommendations, introducing them into the new EU directive laying down basic safety standards for the protection against the danger arising from exposure to ionising radiation (EU-BSS). This upgraded Council Directive is currently under discussion amongst EU member states, especially for the incorporation of residues from industries processing NORM into building materials. Opinions differ a lot from one country to another and enhanced coordination needs to be established between the new EU-BSS directive project and the EU regulation laying down harmonised conditions for the marketing of construction products (CPD). Nevertheless, trying to keep unified in their diversity, the EU member states agreed on the principle to recycle NORM into building materials when it is justified (considering economical and social aspects) and when exposure to ionising radiation to any member of the public is acceptable from a radiation protection point of view.

A screening tool, providing a maximum gamma dose estimate for a given material, was then established. This screening tool considers the activity concentrations of Radium 226, Thorium 228 and Potassium 40 and specific coefficients derived from a given model 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 with a density similar to concrete's (2350 kg m^{-3}):

$$\text{Index} = C^{226}\text{Ra}/300 + C^{232}\text{Th}/200 + C^{40}\text{K}/3000$$

C in Bq/kg (and the Index in mSv for a theoretical bunker as described above)

These three radionuclides and their progenies are considered to be the most common radioactive elements regarding natural radiation doses to the public in dwellings or buildings. With such an index screening tool, based on such a very conservative model, it is considered that building materials with an index less than 1 can be placed on the EU market without any restriction. However, if the index were to exceed 1, for a given building material, restrictions or specific conditions might be applied depending on the density, thickness and uses of such a material. A national regulatory process and proper EU standards will have to be established to get harmonized technical specifications, coherent restriction policies and common product labelling in Europe prior placing building materials, containing NORM, on the market. The regulatory approach and related EU standards to be drafted should still feed many discussions not only within the competent Working Party of the Atomic Question Group but also within the mandated European Committees (CEN) in charge of the establishment of technical standards.

EU REGULATORY PROGRESS FOR NORM & BUILDING MATERIALS

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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[6] concerning the natural radioactivity of building materials and reference levels[9] for workplaces processing materials with enhanced levels of naturally occurring radionuclides. Lastly, in 2001 the European Commission published recommendations[3] dealing with exemption and clearance levels for NORM residues. All these recommendations have provided member states with criteria and a sound technical framework to help establish national regulations for NORM. Several EU States have already included all or parts of these recommendations in their regulatory framework.

The European Commission decided to harmonize, promote and consolidate these recommendations, introducing them into the new EU-BSS directive. The latest EU regulatory framework regarding NORM and building materials are hereby presented and take into account the technical working group meetings held in Brussels on 23rd October and 26th November 2012. An important work has been performed trying to match the Construction Product Directive[1], the new EU-BSS directive[13], IAEA standards[2],[12] and EU Member States' expectations.

2. EUROPEAN REGULATORY APPROACH FOR NORM

2.1 General approach

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]) is currently being revised and consolidated with 5 existing directives dealing with radiation safety[14]. This huge work, with several directives to be merged, should not only help to clarify some parts of old directives but also to add new requirements dealing with natural radiation sources.

Article 2 of the new EU-BSS states that all practices involving radiation sources are to be regulated including *"planned exposure situations resulting from 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 activities in industries processing materials with naturally occurring radionuclides, or activities related to such processing."*

It is also required, according to article 24, **to identify** *"practices involving NORM and leading to exposure of workers or members of the public..."*.Such an identification process has to take into account the EU-BSS annex V where a coal-fired power plant is registered for instance. The term *"practice"* is defined as *"any activity that involves the operation or introduction of radiation sources or which alters exposure pathways and is managed as a planned exposure situation"*.

The EU-BSS directive[14] requires that a national "positive list" of **identified industries** processing NORM, be established. Industries from this national "positive list" may then be submitted to a national regulatory process depending on the activity concentrations of Uranium 238, Thorium 232, Potassium 40 and all related progenies in the materials used in the industrial process.

An industry processing NORM may have its practice exempted if the NORM used complies with the limits set out in the EU-BSS directive as presented below (annex VI, Table A, Part2 & Art. 25b.1):

Radionuclides	Activity concentration
^{238}U	< 1000 Bq/kg
^{232}Th	< 1000 Bq/kg
^{40}K	< 10 000 Bq/kg

If the "practice" performs by an **identified industry** cannot be exempted then such an industrial process shall be **notified** to the national regulatory authority (art.24 & 25b.1). The latter should then assess the situation and take a **regulatory decision** whether **to exempt or authorise** (art. 25.a & annex VI) the practice with attached conditions as appropriate. Discharges of NORM residues to the environment, such as fly ash for instance, shall naturally comply with the same table.

It should be added that, according to the EU-BSS definitions, an "authorisation" could be a simple "registration" or a "licence", the latter implying a dedicated licensing process described in the EU-BSS directive (art.28).

Regarding drinking water protection, the EU BSS added that if any identified practices are liable to significantly affect drinking water quality or any other exposure pathway, whether below exempted activity concentrations or not, a **notification** may have to be issued to the regulatory authority (25b.4), depending on member states' regulatory framework; if notified, a **regulatory decision** will have to be taken (art.25.a and annex VI). Lastly, if drinking water quality were concerned, the water directive would also bring additional regulatory limits and requirements[8].

Before October 2012, practices liable to lead to an effective dose to *"a member of the public"* exceeding **0.3 mSv/year** impled **an authorisation** but the opinion has evolved lately and most of member states, now, wish to have 1 mSv/year rather than 0.3 mSv/year as a unique maximum reference level for the public and the workers. Member states wished indeed, to keep the EU BSS consistent with IAEA reference levels[2],[12] and building material EU requirements where 1 mSv/year to "a member of the public" is the reference level to comply

with. Moreover, Germany explained that one can comply with exemption levels, mentioned above, and exceeds 0.3 mSv/y for a member of the public in certain scenarios. In addition to this, Member States wished to keep some flexibility whether to authorise or exempt the practice; art.25.a was then softened to give this regulatory decision to the national authority.

2.2 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, whether made from natural stones (alum shale, granite, gneiss, porphyries, syenite, basalt, tuff, pozzolana, lava...) or from materials in which specific residues from identified NORM industries have been incorporated, need to comply with the maximum reference level of 1 mSv/year for "a member of the public" (compared to outdoor background activity).

The EU RP 112 principles[10] which was based on a 1995 publication of Mika Markkanen from the Finnish regulator, provided EU member states with a user friendly screening tool to evaluate building materials' radiation gamma emissions and check compliance with the maximum reference level mentioned above. To establish this screening tool, a conservative dose estimate model was first created. This model considers the activity concentrations of Radium 226, Thorium 228 and Potassium 40 along with some coefficients derived from Berger's studies. The calculations, which led to the model, are 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 a material density similar to concrete (2350 kg m^{-3}). 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 is 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:

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

C in Bq/kg (and the Index in mSv for a 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 the bunker described above.

In the new EU-BSS directive, it is required that the manufacturer introducing NORM residues in building materials, **notify** such a practice if the "index" mentioned above is liable to exceed 1 (art. 25b.3 & art.75) or any other specific value established in national regulation (26/11/12 meeting). It was agreed indeed that the value of the index may exceed 1 without leading to a dose exceeding 1 mSv/year to a member of the public, especially for light density products or thin building materials (such as tiles) where the index becomes much too conservative. It was

also stated that building material uses should also be taken into account in the regulatory framework. Harmonised standards will be established by the CEN in due course in parallel to the EU-BSS directive.

Most experts around the table in Brussels agreed that following this **notification,** the regulatory body will have to perform a review and assessment of the potential effects of the building material on "a member of the public" and take regulatory decision whether to attach requirements and/or restrictions prior placing the product on the EU market (art. 75.4; annex VII and the CPD directive[1]). National generic authorisations for certain "practices" may naturally be established based on CEN standards and national building codes. Discussions held on the 26th of November did not fully conclude on whether a decision is to be taken by a national authority or should be dealt with only by national building codes.

The regulatory review may take into account the real use of the building material, its real thickness and its real density as appropriate. Nevertheless, the regulatory philosophy shall remain to keep doses to members of the public under 1 mSv/year from building materials.

The thickness impact upon the dose estimate model described above is more or less linear; the thinner the model room structures are the lower the dose is:

$$\text{Dose estimate (mSv/year)} = \text{Thickness(cm)}/20\left[C^{226}\text{Ra}/300 + C^{232}\text{Th}/200 + C^{40}\text{K}/3000\right]$$

Thin or "superficial" building materials such as tiles or decoration products may then contain NORMs with higher activity concentrations than usual and still be authorized without any restrictions.

To avoid a complicated formula, the EU-RP112 document considers the original index and the following table:

Uses	**Categories**	
	A ≤ 1mSv	**B>1mSv**
Bulk materials (1)	I≤1 (Type A1)	I>1 (Type B1)
Superficial materials with restricted uses (2)	I≤6 (Type A2)	I>6 (Type B2)

Nevertheless, "bulk" and "superficial" ought to be defined in national building codes if such a table were to be kept in the EU regulatory framework. The logic should be to defined "superficial materials" as thin materials such as tiles with a maximum thickness of 3 cm for instance. However other dose models and calculations showed that the thickness impact on doses is not that significant.

For the time being, it was decided to remove this table from the EU-BSS draft. It is thought indeed that the CEN-TG32 working group will work on this issue and should establish the

right standards taking into consideration the building material thickness amongst other parameters.

Beyond this thickness aspect, the material density is also a significant issue to be tackled. If we used the original index with lower density products than the concrete's ($d<2350$ kg m^{-3}) the dose calculation would be overestimated by a factor of 3 or 4. Certain manufacturers would then face big difficulties to comply with the index although real doses would be much less than 1 mSv/year even with a the conservative model room mentioned before.

The German Federal Office for Radiation Protection *(Bundesamt für Strahlenschutz, BfS)*, member of the CEN-TG32 group, has recently established an improved dose estimate formula taking the material density (d) 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 index:

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

Some more work is still to be performed by the European Commission's Working Party of the Atomic Question Group as well as the CEN-TG32 group to finalize some detailed regulatory aspects but somehow, the EU regulatory framework for building materials regarding NORM is already designed.

In addition to these models and general approach to evaluate a dose estimate through some measurements and calculations, the determination of activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K is also a concern in such an approach. 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 easy to perform due to the noise made by ^{234}Th (direct progeny of ^{238}U). So decisions need 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 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 Radium 228 is washed out from the material unlike certain progenies and sometimes additional Radium 228 from elsewhere can be naturally added by circulating water in the soil leading to material with different progeny concentrations than expected. Neutron activation techniques, directly measuring the activity concentration of Thorium 232, 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). It should be added that ^{228}Th and ^{228}Ra are determined with their respective progenies (^{208}Ta and ^{228}Ac) in the procedure. If there is a suspicion of a significant disequilibrium in the cascade of progenies, alternative techniques, such as neutron activation or alpha spectrometry techniques, may allow better determination or direct measurement of ^{232}Th activity concentration if necessary. 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.

2.3 Other requirements

For occupational practices involving NORM, the EU-BSS directive has established that if effective doses to workers are liable to exceed 6mSv/year, national requirements based on appropriate parts of the Chapter VI of the EU-BSS dealing with the protection of the workers, apprentices and students shall apply. Under 6 mSv per year, the "undertaking or the employer", as appropriate, shall, at least, keep exposures under review (art. 33.2).

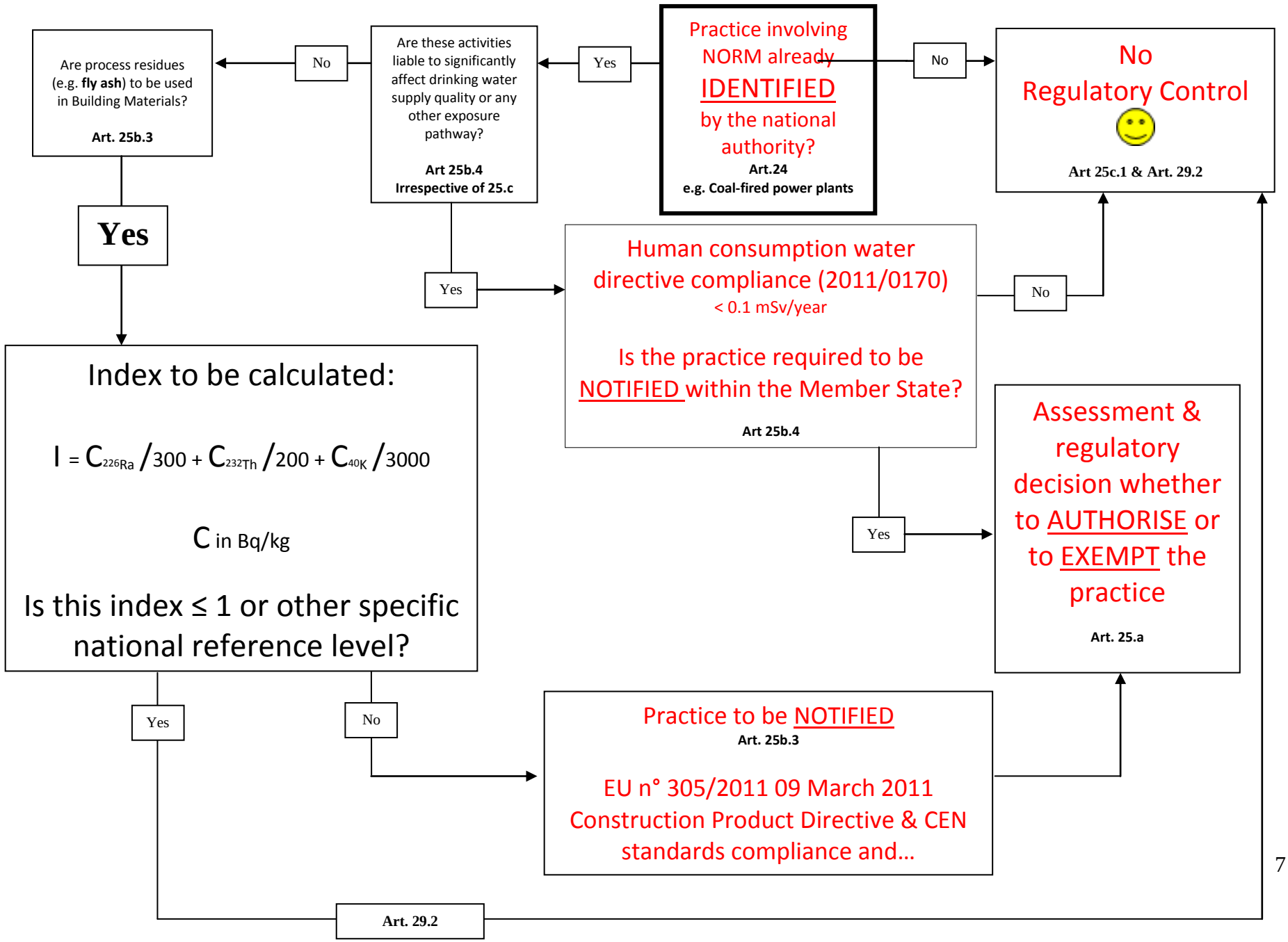
Regarding clearance aspects for NORM, the index calculation for building materials combined with general exemption values for NORM, lead to consider a maximum reference level of 1 mSv/year for "a member of the public" above prevailing background activity for any NORM discharges. In comparison, the criterion for artificial radionuclides is more constraining, with 10 µSv/year as a reference level (annex VI EU-BSS).

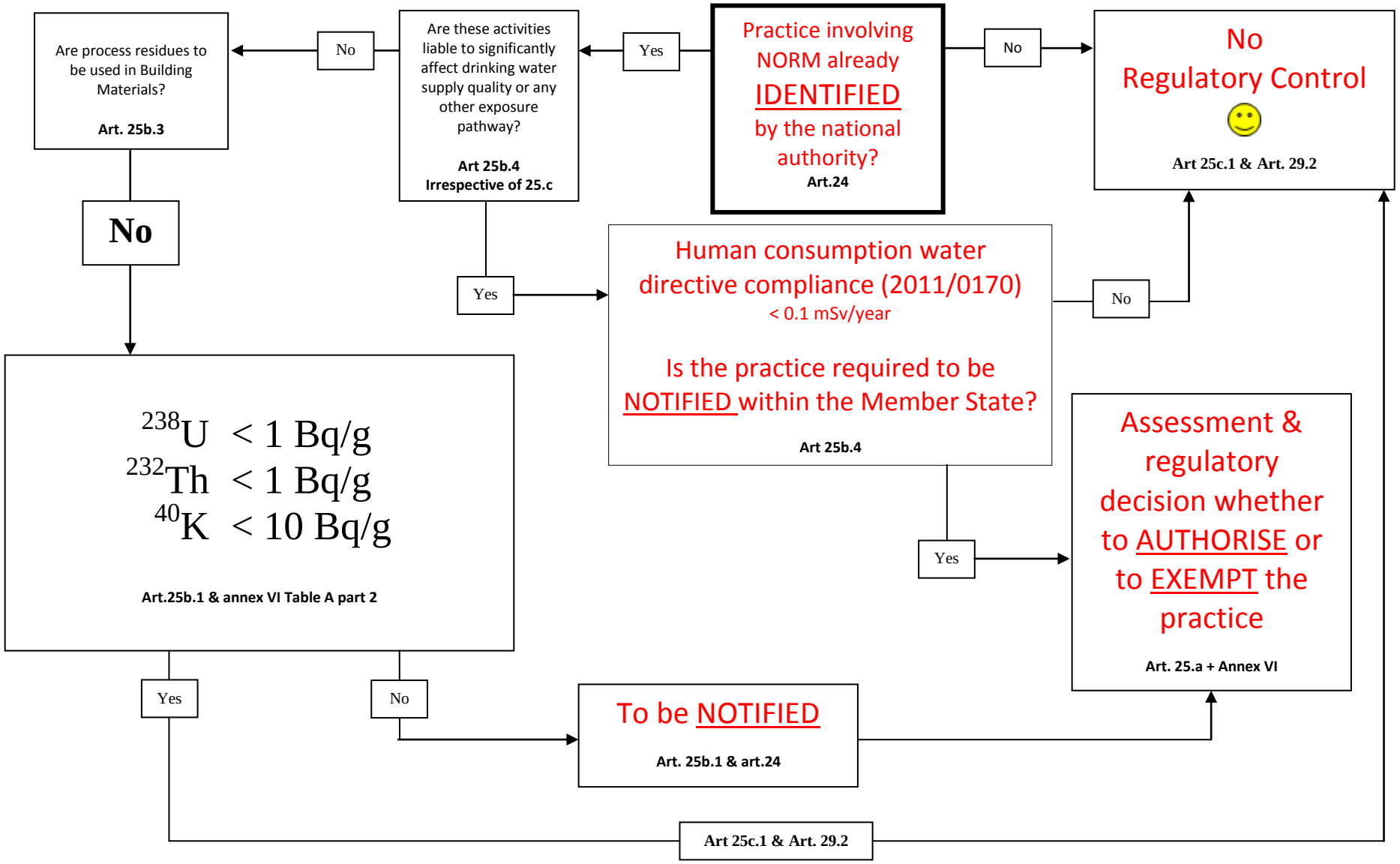
Additionally, drinking water supply and any other potential contamination pathways need to be kept monitored against contamination and assessed against drinking water standards[8] and national regulations as appropriate.

Regarding Radon exhalation from building materials, Member States decided not to deal with this issue in the screening process. Only gamma radiation is to be determined for building materials for marketing purposes. Radon is dealt with apart in national action plans with a focus on dwellings or buildings rather than construction products. Specific BSS parts are dealing with Radon issues, fixing a maximum national reference level for all buildings, at 300 $Bq.m^{-3}$. Such a number is still under discussions especially with northern European countries and should be accompanied by some flexibilities.

3. CONCLUSION

The technical group (WPAQ) dealing with NORM requirements in the EU-BSS directive and the CEN working groups (TG31 and TG32) working on standards and more especially on the determination of activity concentration of Thorium, Radium and Potassium and, on dose modelling for building materials, should establish within a reasonable timescale, a harmonized EU framework dealing with NORM and building materials. EU labelling rules, classification and "CE" marking for these building materials will be established in CEN standards and should allow free and safe transboundary circulation of these materials in the European Union as required by the CPD.


Practice involving NORM already IDENTIFIED by the national authority?
Art.24
e.g. Coal-fired power plants
No
No Regulatory Control
Art 25c.1 & Art. 29.2
Yes
Are these activities liable to significantly affect drinking water supply quality or any other exposure pathway?
Art 25b.4
Irrespective of 25.c
No
Are process residues (e.g. fly ash) to be used in Building Materials?
Art. 25b.3
Yes
Yes
Human consumption water directive compliance (2011/0170)
< 0.1 mSv/year
Is the practice required to be NOTIFIED within the Member State?
Art 25b.4
No
Yes
Assessment & regulatory decision whether to AUTHORISE or to EXEMPT the practice
Art. 25.a
Index to be calculated:
I = C226Ra /300 + C232Th /200 + C40K /3000
C in Bq/kg
Is this index ≤ 1 or other specific national reference level?
Yes
No
Practice to be NOTIFIED
Art. 25b.3
EU n° 305/2011 09 March 2011 Construction Product Directive & CEN standards compliance and…
Art. 29.2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Art 25c.1 & Art. 29.2
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Are these activities liable to significantly affect drinking water supply quality or any other exposure pathway?
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Are process residues to be used in Building Materials?
Art. 25b.3
No
Yes
Human consumption water directive compliance (2011/0170)
< 0.1 mSv/year
Is the practice required to be NOTIFIED within the Member State?
Art 25b.4
No
Yes
Assessment & regulatory decision whether to AUTHORISE or to EXEMPT the practice
Art. 25.a + Annex VI
238U < 1 Bq/g
232Th < 1 Bq/g
40K < 10 Bq/g
Art.25b.1 & annex VI Table A part 2
Yes
No
To be NOTIFIED
Art. 25b.1 & art.24
Art 25c.1 & Art. 29.2

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.

[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 - 29/09/2011.

[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.