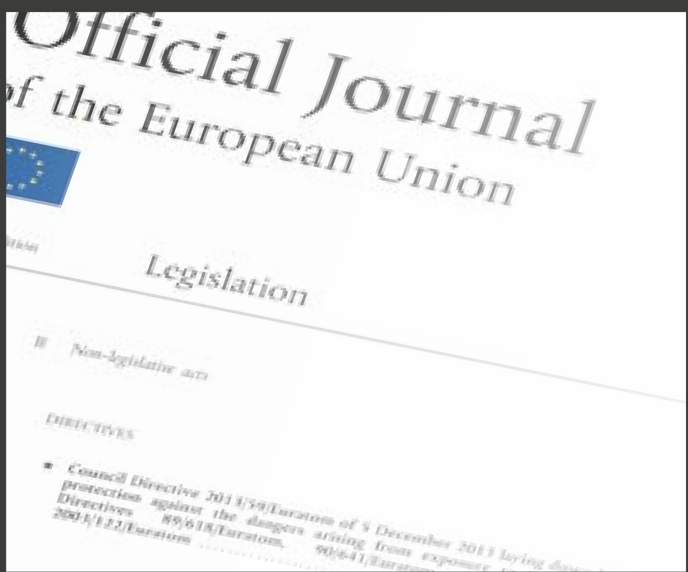


Official Journal
f the European Union
Legislation

Chapter 1
Rationale

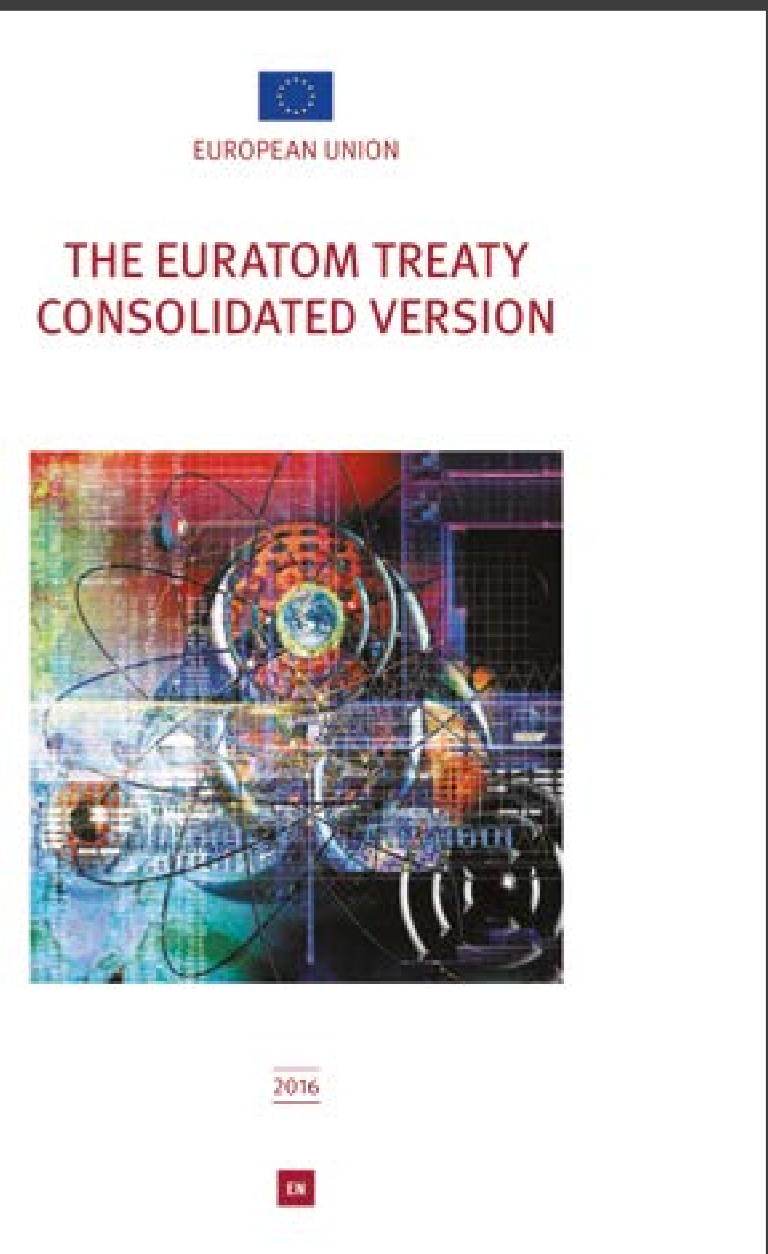
Natural ionising radiation is considered the largest contributor to the collective effective dose received by the world's population. Man is continuously exposed to ionising radiation from several sources that can be grouped into two categories: first, high-energy cosmic rays incident on the Earth's atmosphere and releasing secondary radiation (cosmic contribution); and, second, radioactive nuclides generated when the Earth was formed and still present in its crust (terrestrial contribution). Terrestrial radioactivity is mostly produced by the uranium (U) and thorium (Th) radioactive families together with potassium (^{40}K), a long-lived radioactive isotope of the elemental potassium. In most cases, radon (^{222}Rn), a noble gas produced by radioactive decay of the ^{238}U progeny, is the major contributor to the total dose.

This European Atlas of Natural Radiation has been conceived and developed as a tool for the public to become familiar with natural radioactivity; be informed about the levels of such radioactivity caused by different sources; and have a more balanced view of the annual dose received by the world's population, to which natural radioactivity is the largest contributor. At the same time, it provides reference material and generates harmonised data, both for the scientific community and national competent authorities.

Intended as an encyclopaedia of natural radioactivity, the Atlas describes the different sources of such radioactivity, cosmic and terrestrial, and represents the state-of-the art of this topic. In parallel, it contains a collection of maps of Europe showing the levels of natural sources of radiation.

This work unfolds as a sequence of chapters: the rationale behind; some necessary background information; terrestrial radionuclides; radon; radionuclides in water and river sediments; radionuclides in food; cosmic radiation and cosmogenic radionuclides. The final chapter delivers the overall goal of the Atlas: a population-weighted average of the annual effective dose due to natural sources of radon, estimated for each European country as well as for all of them together, giving, therefore, an overall European estimate.

As a complement, this introductory chapter offers an overview of the legal basis and requirements on protecting the public from exposure to natural radiation sources. In Europe, radiation has a long tradition. Based on the Euratom Treaty, the European Atomic Energy Community early established a set of legislation for protecting the public against dangers arising from artificial ('man-made') ionising radiation, but this scope has since been extended to include natural radiation. Indeed, the recently modernised and consolidated Basic Safety Standards Directive from 2013 contains detailed provisions on the protection from all natural radiation sources, including radon, cosmic rays, natural radionuclides in building material, and naturally occurring radioactive material.



Clockwise from top-left:

A profile of a typical well drained soil under temperate forest and shows evidence of the main soil processes: humus formation, weathering, leaching and clay translocation.
Source: Erika Micheli.

Harvesting the wheat crop, Turkey.
Source: meriç tuna on Unsplash.

Cover of the EURATOM Treaty (consolidated version).
Source: https://www.consilium.europa.eu/en/documents-publications/publications/euratom-treaty/

Starlit sky over Steinernes Meer, Schönau am Königssee, Germany.
Source: Manuel Will on Unsplash.

Cover of Council Directive 2013/59/Euratom (Basic Safety Standards Directive).
Source: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013L0059

Rationale

1.1 Introduction

In order to describe the history and the motivation behind the European Atlas of Natural Radiation (EANR), this section seeks to answer four simple questions:

a. Who has developed the EANR?

b. Why has the EANR been created?

c. What does the EANR contain?

d. How is the EANR structured?

a. Who has developed the EANR?

The European Commission (EC) develops and operates systems for collecting, checking and reporting information about the levels of radioactivity in Europe's environment on a continuous basis for routine and emergency conditions. This endeavour is in line with its mission, based on the Euratom Treaty Articles 35, 36 and 39 (European Union, 2016), which are quoted below:

Art. 35: *Each Member State shall establish the facilities necessary to carry out continuous monitoring of the level of radioactivity in the air, water and soil and to ensure compliance with the basic standards.*

The Commission shall have the right of access to such facilities; it may verify their operation and efficiency.

Art. 36: *The appropriate authorities shall periodically communicate information on the checks referred to in Article 35 to the Commission so that it is kept informed of the level of radioactivity to which the public is exposed.*

Art. 39: *The Commission shall set up within the framework of the Joint Nuclear Research Centre, as soon as the latter has been established, a health and safety documentation and study section.*

In particular, this section shall have the task of collecting the documentation and information referred to in Articles 33, 36 and 37 and of assisting the Commission in carrying out the tasks assigned to it by this Chapter.

In this framework, since 1987, the **Radioactivity Environmental Monitoring (REM) group** of the EC Joint Research Centre (JRC) supports the European Commission in its responsibilities to provide qualified information on the levels of environmental radioactivity, both for routine and emergency situations, through the following activities:

Radioactivity Environmental Monitoring database (REMdb)

The Radioactivity Environmental Monitoring database (REMdb) was created in the aftermath of the Chernobyl accident (1986) by the European Commission (EC) – Directorate-General Joint Research Centre (DG JRC), located in Ispra, Italy. Since then it has been maintained there with the aim to keep a historical record of the Chernobyl accident and to store the radioactivity monitoring data gathered through the national environmental monitoring programmes of the Member States (MSs). By collecting and checking this information in the REMdb, JRC supports the DG for Energy in its responsibilities to return qualified information to the MSs (competent authorities and general public) on the levels of radioactive contamination of the various compartments of the environment (air concentration, surface and drinking water, milk and mixed diet) on the European Union scale. The REMdb has been accepting data on radionuclide concentrations from European Union (EU) MSs in both environmental samples and foodstuffs from 1984 onwards. To date, the total number of data records stored in REMdb exceeds 5 million, in this way providing the scientific community, authorities and the general public with a valuable archive of environmental radioactivity topics in Europe. For further information about the REMdb, see: https://rem.jrc.ec.europa.eu/RemWeb/.

ECURIE and EURDEP

After the Chernobyl accident, and in order to improve the international emergency preparedness and response procedures the European Commission defined and put in place a Decision (Council Decision 87/600/EURATOM) that essentially obliges a country that intends to implement widespread countermeasures for protecting its population to notify the European Commission without delay. The same Council Decision also specifies that radiological monitoring data have to be exchanged and made available. Over the past 25 years, the European Commission has invested in improving the rapid exchange of information and data in the event of a major accident. The resulting mechanisms for the early phase of emergency support are the early notification system ECURIE (European Community Urgent Radiological Information Exchange) and the automatic data exchange platform EURDEP (European Radiological Data Exchange Platform). 39 countries exchange real-time monitoring information collected from more than 5 500 automatic surveillance systems once per hour in a standard data-format through secure ftp and web-services. This large-scale data harmonisation and exchange system for radioactivity measurements is unique in the world. The clear concept behind EURDEP is to better equip the decision makers with notified and continuous information available in the form of real-time monitoring data to define the most appropriate countermeasures. For further information, see the EURDEP website: https://eurdep.jrc.ec.europa.eu.

Nuclear Emergency Preparedness and Response

Over the past years, the REM group has undertaken several research and training activities on Nuclear Emergency Preparedness and Response (NEP&R), based on the use of trajectory models and atmospheric dispersion models (ADMs) as well as procedures to improve harmonisation of the monitoring data. For further information, see: https://rem.jrc.ec.europa.eu/RemWeb/ and https://remon.jrc.ec.europa.eu/.

European Atlas of Natural Radiation

After the European Commission published the 'Atlas of Caesium Deposition on Europe after the Chernobyl Accident' (European Communities, 1998), the REM group of the JRC embarked on a European Atlas of Natural Radiation (EANR) with the support of the relevant national/international organisations and the scientific community (see Preamble).

b. Why has the EANR been created?

Natural radioactivity or ionising radiation is considered to be the largest contributor to the collective effective dose received by the world's population. Man is continuously exposed to ionising radiation from several natural sources that can be classified in two broad categories: high-energy cosmic rays incident on the Earth's atmosphere and releasing secondary radiation (cosmic contribution); and radioactive nuclides generated during the formation of the Earth and still present in the Earth's crust (terrestrial contribution). Terrestrial radioactivity is mostly produced by the uranium (U) and thorium (Th) radioactive families together with potassium (^{40}K), which is a long-lived radioactive isotope of the elemental potassium. In most circumstances, radon (^{222}Rn), a noble gas produced in the radioactive decay of

The Joint Research Centre of the European Commission

The European Union

The European Union (EU) is an economic and political association of European countries with a combined population of over 500 million inhabitants (7.3 % of the world's population) and an economy representing approximately 20 % of global Gross Domestic Product (GDP). The EU has evolved from the original six countries of the European Coal and Steel Community (1951) and the European Economic Community (1958), to 28 Member States. The term 'European Union' was established under the 1993 Maastricht Treaty. The EU is represented at the United Nations, the WTO, the G8 and the G20. The EU operates through a system of supranational independent institutions and intergovernmental negotiated decisions adopted by the Member States. Important EU institutions include the European Commission, the Council of the European Union, the Court of Justice of the European Union, and the European Central Bank. The members of the European Parliament are elected every five years by EU citizens.

The European Commission

The European Commission is the executive body of the EU responsible for proposing legislation, verifying the implementation of the decisions, upholding the Union's treaties and the day-to-day running of the EU. The Commission acts as a cabinet government, with 28 Commission members - one representative per Member State. The Commission is composed of thirty-four Directorates-General.

The Joint Research Centre (JRC) is the European Commission's science and knowledge service which employs scientists to carry out research in order to provide independent scientific advice and support to EU policy. As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle. Its work has a direct impact on the lives of citizens by contributing with its research outcomes to a healthy and safe environment, secure energy supplies, sustainable mobility and consumer health and safety. The JRC draws on over 50 years of scientific work experience and continually builds its expertise based on its scientific Directorates, which host specialist laboratories and unique research facilities. They are located in Belgium (Brussels and Geel), Germany, Italy, the Netherlands and Spain. While most of the scientific work serves the policy Directorates-General of the European Commission, the JRC addresses key societal challenges while stimulating innovation and developing new methods, tools and standards. The JRC shares know-how with the Member States, the scientific community and international partners. The JRC collaborates with over a thousand organisations worldwide whose scientists have access to many JRC facilities through various collaboration agreements.

https://ec.europa.eu/jrc/en/about

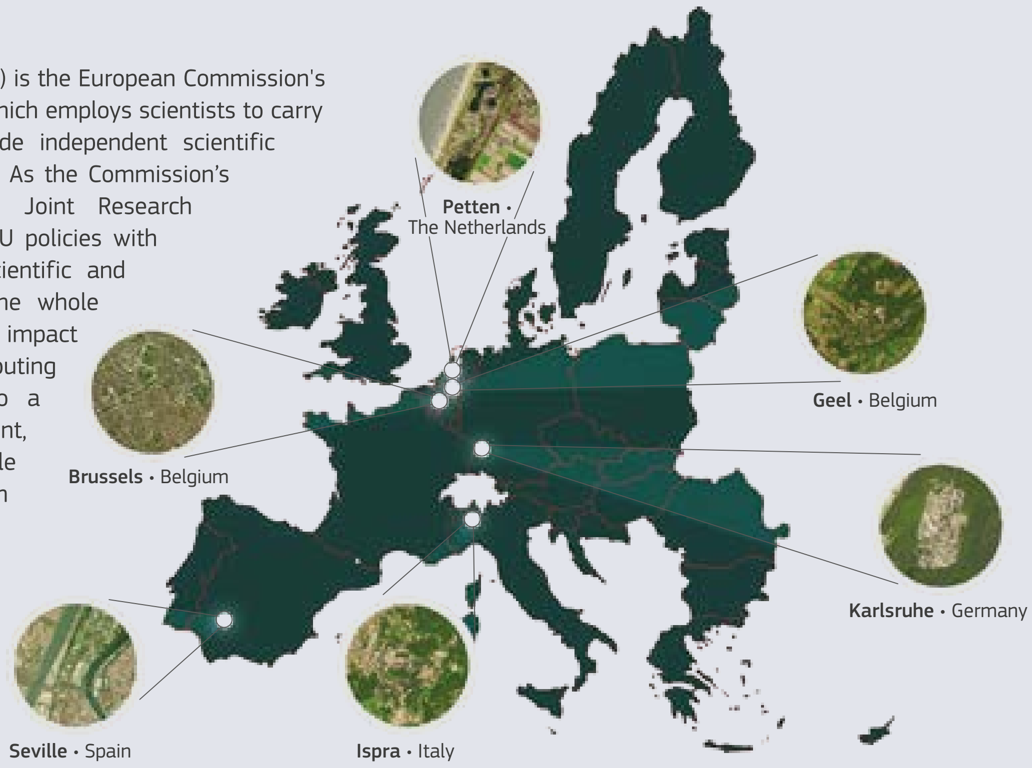
Directorate for Nuclear Safety and Security

The mission of the JRC Directorate G for Nuclear Safety and Security to implement the JRC Euratom Research and Training Programme, to maintain and disseminate nuclear competences in Europe, serving both "nuclear" and "non-nuclear" Member States.

A strong cooperation and complementarity with their national organisations is of key relevance.

Directorate G supports the relevant policy DGs with independent, technical and scientific evidence in the areas of nuclear safety, security and safeguards.

Directorate G is also an active key partner in international networks and collaborates with international organisations and prominent Academia and Research Institutes.



Location of the directorates and headquarters of the JRC.

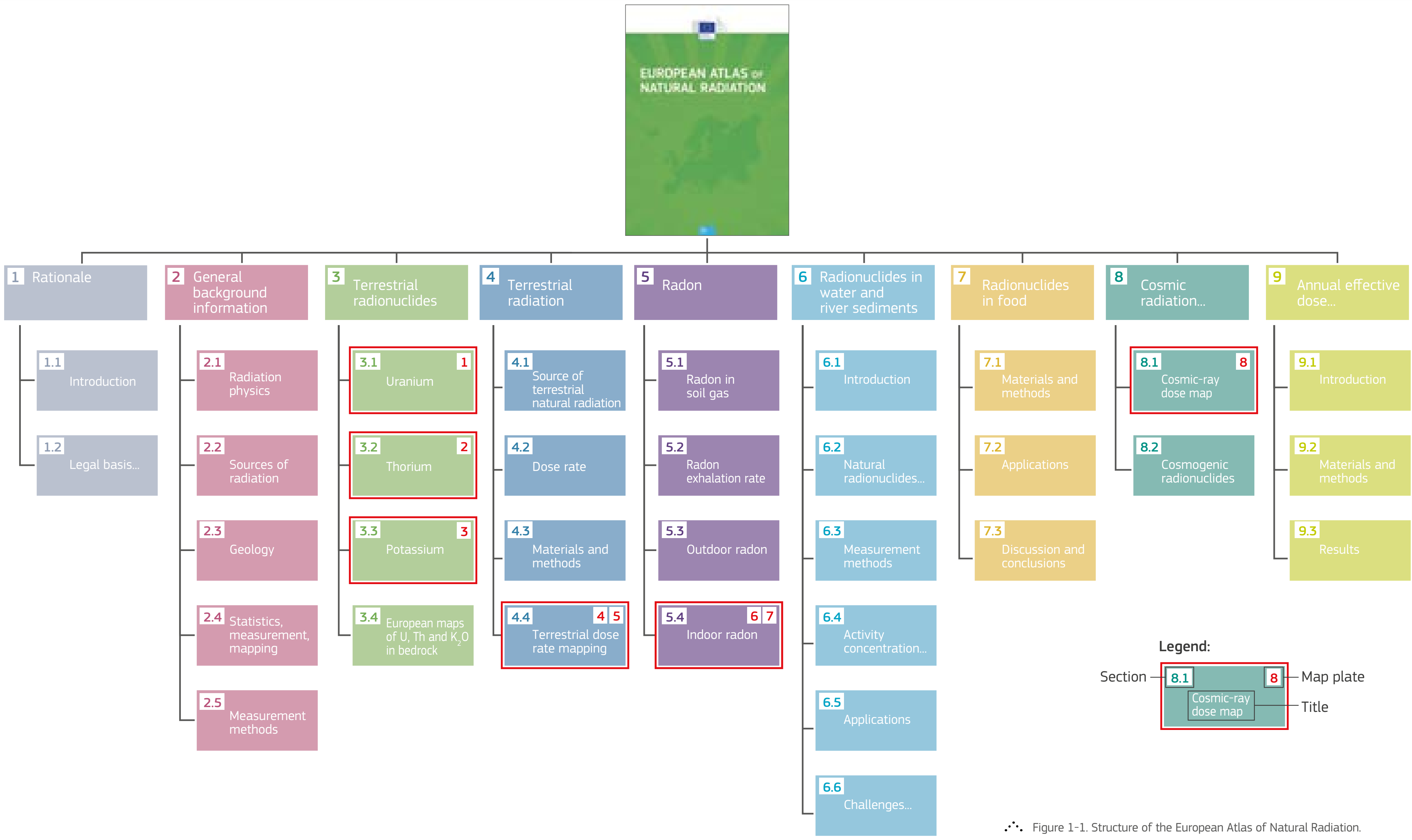


Figure 1-1. Structure of the European Atlas of Natural Radiation.

the ^{238}U progeny, is the major contributor to the total dose.
Indeed, this Atlas is intended as a tool for the public to:

- familiarise itself with natural radioactivity;
- be informed about the levels of natural radioactivity caused by different sources;
- have a more balanced view of the annual dose received by the world's population, to which natural radioactivity is the largest contributor; and
- make direct comparisons between doses from natural sources of ionising radiation and those from man-made (artificial), and hence to better understand the latter.

JRC mission statement

JRC in brief

- As the European Commission's science and knowledge service, the Joint Research Centre (JRC) supports EU policies with independent scientific evidence throughout the whole policy cycle.
- The JRC creates, manages and makes sense of knowledge and develops innovative tools and makes them available to policy makers.
- The JRC anticipates emerging issues that need to be addressed at EU level and understand policy environments.
- The JRC collaborates with over a thousand organisations worldwide whose scientists have access to many JRC facilities through various collaboration agreements.
- JRC's work has a direct impact on the lives of citizens by contributing with its research outcomes to a healthy and safe environment, secure energy supplies, sustainable mobility and consumer health and safety.
- The JRC draws on over 50 years of scientific experience and continually builds its expertise in knowledge production and knowledge management.
- The JRC hosts specialist laboratories and unique research facilities and is home to thousands of scientists.

Moreover, it provides reference material and generates harmonised data for the scientific community and national competent authorities. The latter could use the information to implement the Basic Safety Standard Directive (European Union, 2013b) regarding aspects linked to natural radiation (e.g. to develop national radon action plans).

Therefore, the EANR is in line with the mission of the European Commission, based on the Euratom Treaty (European Union, 2016), which is to collect, check and report information on radioactivity levels in the environment.

c. What does the EANR contain?

The European Atlas of Natural Radiation could be considered as an encyclopaedia of natural radioactivity. It describes the different natural sources of natural radioactivity, cosmic and terrestrial, in detail and represents the present state-of-the-art of this topic.

Moreover, it contains a collection of maps of Europe showing the levels of natural sources of radiation.

Europe: geographical area

In the EANR, Europe has been considered with the geographical extension of the continent defined as

'bordered in the North by the Arctic Ocean, on the west by the Atlantic Ocean, and on the south (west to east) by the Mediterranean Sea, the Black Sea, the Kuma-Manych Depression, and the Caspian Sea. The continent's eastern boundary (north to south) runs along the Ural Mountains and then roughly southwest along the Emba (Zhem) River, terminating at the northern Caspian coast.' (Encyclopædia Britannica, 2019).

The spatial coverage of the maps shown in the Atlas varies from map to map, depending on the data that were available to create the maps. For some maps, European-wide databases have been used, while for others the national authorities that agreed to join the Atlas project have provided the data.

d. How is the EANR structured?

The European Atlas of Natural Radiation is structured as depicted in Figure 1-1, namely:

Chapter I – Rationale

It presents the rationale behind the EANR, giving an overview of the European institutions involved in this project. Moreover, the legal basis and requirements on protection from exposure to natural radiation sources are described in detail.

Chapter 2 – General background information

It provides the background information necessary to understand:

- how ionising radiation works;
- why it is present in our environment; and
- how it can be represented on a map.

Chapter 3 – Terrestrial radionuclides

It gives a detailed description of the three main terrestrial radionuclides: uranium and thorium, with their decay chains, and potassium-40. Moreover, it explains the materials and methods used to produce European maps of radionuclide concentration in soil and in bedrock and and displays these maps.

Chapter 4 – Terrestrial radiation

It describes the gamma radiation from terrestrial sources (uranium and thorium with their decay chains and potassium) that represents an important component to the natural radiation environment. The methodologies used to map the terrestrial gamma dose rate are described and the European Annual Terrestrial Gamma Dose Map is displayed. It shows the annual effective dose rate that a person would receive from terrestrial radiation, if she/he spends all the reference time in a location in which the soil has fixed uranium, thorium and potassium concentrations.

Chapter 5 – Radon

It focuses on the noble, naturally occurring radioactive gas called radon (^{222}Rn), which is the largest contributor to the dose due to natural radiation received by the global population.

The chapter is divided into the following sections that describe the different steps from radon source to its accumulation in indoor space: radon in soil gas; radon exhalation; outdoor radon;

and indoor radon.

Finally, based on survey data received from 35 European countries participating on a voluntary basis, a European map of indoor radon concentration has been created. It shows the arithmetic means over 10 km × 10 km grid cells of annual indoor radon concentration in ground-floor rooms.

Chapter 6 – Radionuclides in water and river sediments

It describes in detail the natural radionuclides, released from rock surfaces, present in water and river sediments. Besides radionuclides in the uranium and thorium series (including radon), potassium-40 (^{40}K), tritium (^{3}H), carbon-14 (^{14}C) and other natural radionuclides may occur in water. The European legislation on the level or natural radionuclides in water, as well as the international recommendation, is explained.

Moreover, the main measurement techniques used to detect radionuclides in water are described.

Chapter 7 - Radionuclides in food

This chapter describes the pathways of natural radionuclides from soil to food, the radionuclides of interest as well as measurements of radioactivity in foodstuffs. Furthermore, typical activity concentrations in various foodstuffs in European countries are given, and finally the main factors controlling the dose due to ingestion of food are illustrated.

Chapter 8 – Cosmic radiation and cosmogenic radionuclides

This chapter addresses the effects from cosmic radiation. Cosmic rays are atomic nuclei accelerated to high energy levels, creating electrons, gamma rays, neutrons and mesons when interacting with atmospheric nuclei. The flux of cosmic radiation highly depends on the altitude above the Earth's surface. The European cosmic-ray annual dose map has been developed and displayed, as well as a detailed description of cosmogenic radionuclides, using beryllium-7 (^{7}Be) as an example.

Chapter 9 – Annual effective dose from natural environmental radiation

The overall goal of the Atlas is to estimate the annual effective dose that the European population may receive from natural radioactivity. Indeed, this final chapter reports on the population-weighted average of the annual effective dose due to natural sources of radiation estimated for each European country as well as for all of them together, giving, therefore, an overall European estimate.

Chapter 10 – References and Appendices

References
Appendix 1 - The International System of Units (SI)
Appendix 2 - Country ISO codes
Appendix 3 - List of national competent authorities that provided data for the European Indoor Radon Map
Appendix 4 - Periodic Table of Elements

The authors tried to explain the scientific jargon at their best. However, for further terms or explanations, the reader may wish to consult standard references such as the IAEA Safety Glossary (IAEA, 2019: IAEA Safety Glossary: Terminology used in nuclear safety and radiation protection, 2018 edition. International Atomic Energy Agency, Vienna. ISBN 978–92–0–104718–2.)

Explanation of bold/coloured text

The bold/coloured text indicates that this text is repeated more than once in the Atlas, providing general information (see example below):

3.2 Thorium

Thorium is an actinide series element with an atomic number of 90 and an atomic mass of 232. It is radioactive with one main natural isotope, the primordial long-lived radionuclide ^{232}Th, which has the longest half-life (1.41×10^{10} years) of all known radioactive isotopes of thorium and comprises 99.98 % of the total Th mass. Thorium decays through a long radioactive decay series ending with the stable lead isotope ^{208}Pb.

3.2.1 Thorium in rock minerals

Thorium (Th) is mainly present at minor to trace concentration levels (< 1 g/100 g) in accessory minerals such as zircon, sphene,

The parent
reservoir of th
which are r
(Cicchella et
the soil profil
concentrates
and zircon.
the cationic
charged clay
thorium is re
transported ir
insoluble in s
Thorium ha
taken up by p

1.2 Legal basis and requirements on protection from exposure to natural radiation sources

Introduction

Radiation protection has a long tradition in Europe. Based on the Euratom Treaty (European Union, 2016), the European Atomic Energy Community has established a comprehensive set of legislation for the protection against the danger arising from ionising radiation. While in the early days, this protection focused on protection from exposure to artificial 'man-made' ionising radiations, recent developments propose to extend the protection system to cover coherently exposure to natural radiation sources, such as exposure to indoor radon, exposure to cosmic rays, exposure to natural radioactive substances in drinking water and in building materials, and exposure to naturally occurring radioactive material. The extension of the system makes particular sense, as exposure to natural radiation is one of the most important contributors to the overall total exposure of members of the public and can lead to significant exposure of workers in specific workplaces. The recently modernised and consolidated Basic Safety Standard (BSS) Directive (European Union, 2013b) contains detailed provisions on the protection from all natural radiation sources, including radon, cosmic rays, natural radionuclides in building materials, and naturally occurring radioactive material. These provisions are complemented by the Drinking Water Directive (European Union, 2013a), laying down requirements on the protection of the health of the general public with regard to radioactive substances in water intended for human consumption, which addresses radioactive substances of both artificial and natural origin.

History and development of the Basic Safety Standards Directive

Articles 2 and 30 of the Euratom Treaty (European Union, 2016) empower the Community to establish uniform basic safety standards to protect the health of workers and the general public against dangers arising from ionising radiations. Article 31 of the Treaty stipulates the procedure to develop such basic safety standards, which includes the consultation of a group of scientific experts in the public health area. Already in 1959, the first Euratom Basic Safety Standards (BSS) Directive was adopted and has subsequently been repeatedly amended (in 1962, 1966, 1976, 1980, 1984 and 1996, respectively), taking account of the latest scientific findings and recommendations, to ensure the highest level of protection for workers, patients and members of the public. The Basic Safety Standards Directive from 1996 (European Communities, 1996), which already contained first elements on protection from natural radiation sources but still focussed on the protection of workers and members of the public from artificial radiation sources, has been supplemented in 1997 by a Directive for the protection of patients from medical exposures (European Communities, 1997).

In 2014, the Community published the latest Basic Safety Standards Directive, namely Directive 2013/59/Euratom, laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation (European Union, 2013b). The provisions in this Directive are based on the latest scientific findings and take account of technological progress and operational experience since 1996. At the same time, the Directive consolidates the previous set of Euratom radiation protection legislation by incorporating and repealing five Directives:

- the 1996 Basic Safety Standards Directive (European Communities, 1996);
- the Medical Exposure Directive (European Communities, 1997);
- the Outside Workers Directive (European Communities, 1990b);
- the Public Information Directive (European Communities, 1989); and the
- High Activity Sealed Sources Directive (European Union, 2003).

In addition, the Commission recommendation on indoor radon exposure (European Communities, 1990a) has been incorporated to become legally binding.

The main driver for the revision of the Basic Safety Standards Directive was the publication of The 2007 Recommendations of the International Commission on Radiological Protection (ICRP), ICRP Publication 103 (ICRP, 2007). In these recommendations, ICRP modifies the underlying radiation protection philosophy and proposes to categorise exposure situations in planned, existing and emergency situations. ICRP maintains the set of principles of radiation protection, justification of exposure, optimisation of protection and application of dose limits, emphasising their importance. Further to this ICRP recommends the consistent integration of natural radiation sources into the radiation protection system.

Following this ICRP philosophy, the 2013 Basic Safety Standards Directive applies to any planned, existing or emergency exposure situation, which involves a risk from exposure to ionising radiation, which cannot be disregarded from a radiation protection point of view. With this, the BSS applies to all relevant radiation sources with no distinction made between artificial 'man-made' radiation sources and natural sources of radiation.

The scope of the consolidated Basic Safety Standards Directive

As provided for in Article 2 of Directive 2013/59/Euratom (European Union, 2013b), the scope of the Directive has been extended to apply now to all human activities, including those which involve the presence of natural radiation sources and lead to a significant increase in the exposure of workers or members of the public. The human activities involving the presence of natural radiation sources include, inter alia, the operation of aircraft and spacecraft, in relation to the exposure of crews, the processing of materials with naturally occurring radionuclides, and workplaces involving exposure to indoor radon, the exposure of workers or members of the public to indoor radon, the external exposure from building materials, and cases of lasting exposure resulting from the after-effects of a past human activity.

Naturally occurring radioactive material

The 2013 BSS Directive introduces a graded approach to regulatory control of practices by way of notification, authorisation and appropriate inspections commensurate with the magnitude and likelihood of exposures resulting from the practice, and commensurate with the impact that regulatory control may have in reducing such exposures or improving radiological safety. Justified practices, if not exempted, need to be notified prior to the practice commencing and, if so decided, authorised. Authorisation can take the form of a registration or a license.

Following the above-mentioned philosophy, this system of regulatory control now equally applies to activities involving naturally occurring radioactive material (NORM). In a first step, the Member State shall identify, based on an indicative list given in Annex VI of the Directive, industrial sectors involving NORM which may lead to exposure of workers or members of the public which cannot be disregarded from a radiation protection point of view (Article 23). For identified sectors, a graded approach applies introducing exemption levels and decision criteria such as doses to workers and effluent releases to the environment.

Occupational exposure in NORM practices

Article 35 of the 2013 BSS Directive provides for the requirements on arrangements in workplaces introducing a graded approach. Paragraph 1 requires that radiation protection arrangements are made for all workplaces where workers are liable to exceed one of the dose limits for the public. The arrangements shall be appropriate to the nature of the installations and sources and to the magnitude and nature of the risks. It is worth noting that this requirement applies to all workplaces involving natural radiation sources extending a similar requirement which had been included in 1996 BSS Directive.

Exposure to radon

The exposure of members of the public or of workers to indoor radon is now explicitly taken up in the scope of Council Directive 2013/59/Euratom (Article 2 (2d)) (European Union, 2013b). Based on this, the Directive introduces, for the first time, legally binding requirements on protection from exposure to radon.

As major provision with regard to the radon protection strategy, the 2013 BSS Directive requires in Article 103 that Member States establish a national radon action plan addressing long-term risks from radon in dwellings, buildings with public access and workplaces for any source of radon ingress, whether from soil, building materials or water. Annex XVIII offers a detailed list of items to be considered in preparing the national action plan. Further to this, Article 103 requires specifically that appropriate measures be in place to prevent radon ingress into new buildings. These measures may include specific requirements in national building codes. Finally, Article 103 requires Member States to identify areas where the radon concentration (as an annual average) in a significant number of buildings is expected to exceed the relevant national reference level.

Indoor exposure to radon

Article 74 of the 2013 BSS Directive requires that Member States establish national reference levels for indoor radon concentrations. For the annual average activity concentration in air, the reference level shall not be higher than 300 Bq/m^3. Member States can choose more challenging reference levels and have the possibility to define different reference levels for existing buildings and for newly built ones (of maximum 300 Bq/m^3).

Member States have to promote actions to identify buildings with radon concentrations exceeding the national reference level. This can be done by establishing a radon measurement campaign. For buildings exceeding the national reference level, radon-reducing measures shall be encouraged. This encouragement can mean that technical measures are promoted or that financial support is offered to those building owners investing in these radon-reducing measures.

At the same time, Member States need to ensure that the population is informed, on a national level and even more on a local level in radon-prone areas, about indoor-radon exposure, the associated health risks, and the importance of performing radon measurements, as well as on the technical means available for reducing existing radon concentrations. An important stakeholder in these activities is the building industry, e.g. architects, and construction companies.

Radon in workplaces

Article 54 of the 2013 BSS Directive contains specific requirements on radon in workplaces. It requires the establishment of a national reference level for indoor radon concentration in workplaces. The reference level for the annual average activity concentration in air shall not be higher than 300 $Bq\,m^{-3}$, unless it is warranted by national prevailing circumstances. Member States are free to establish different reference levels for workplaces and for buildings, as long as they are not higher than 300 $Bq\,m^{-3}$.

Member States are requested to establish programmes to carry out radon measurements in workplaces within the areas identified under the national radon action plan (see also Article 103(3)), and in specific types of workplaces also identified in the national action plan (see point 3 of Annex XVIII). Workplaces with radon concentrations above the reference level shall undergo appropriate remedial actions. If, despite all actions to optimise, the radon concentration in a workplace remains above the national reference level, this workplace needs to be notified to the competent authority (according to Article 25 (2)) and the relevant occupational radiation protection requirements may apply (see Article 35(2)).

In this context, is it worth noting that Article 31 paragraph 3c clearly recognises the responsibility of the employer or the undertaking to protect workers who are exposed to radon at work, in the situation specified in Article 54(3).

Article 35 paragraph 2 sets out the graded approach for workplaces with exposure to indoor radon as specified in Article 54(3). Workplaces where the exposure of workers is liable to exceed an effective dose of 6 mSv/a or a corresponding time-integrated radon exposure value shall be managed as a planned exposure situation, and the Member States shall determine which requirements set out in Chapter VI Occupational Exposure of the 2013 BSS Directive are appropriate. For workplaces where the effective dose to workers is less than or equal to 6 mSv/a or the exposure less than the corresponding time-integrated radon exposure value, the competent authority shall require that exposures are kept under review.

Finally, it should be noted that for workplaces where workers are exposed to authorised practices and radon, Article 9 stipulates that the dose limits for occupational exposures apply to the sum of annual occupational exposures from all authorised practices, occupational exposure to radon in workplaces requiring notification in accordance with Article 54(3), and other occupational exposure from existing exposure situations in accordance with Article 100(3).

Cosmic radiation

Already the 1996 BSS Directive (European Communities, 1996) introduced with Article 42 the protection of aircrew from exposure to cosmic radiation and requested that undertakings operating aircraft assess the exposure of the crew concerned, optimised through the organisation of working schedules, information of the crew of the health risks, and the application of special protection during pregnancy. The 2013 BSS Directive (European Union, 2013b) took these requirements with Article 35 (3) up and embedded them coherently in the overall system of protection from natural radiation sources. Recital (26) specifies 'The exposure of air crew to cosmic radiation should be managed as a planned exposure situation. The operation of spacecraft should come under the scope of this Directive and, if dose limits are exceeded, be managed as a specially authorised exposure.' Provisions on specially authorised exposures are laid down in Article 52 of the 2013 BSS Directive.

It is worth noting that the 2013 BSS Directive explicitly excludes exposure of members of the public or workers other than air or space crew to cosmic radiation in flight or in space from the scope of the Directive.

Building materials

All building materials contain various amounts of natural radioactive nuclides. Materials derived from rock and soil contain mainly natural radionuclides of the uranium (^{238}U) and thorium (^{232}Th) series, and the radioactive isotope of potassium (^{40}K). In the uranium series, the decay chain segment starting from radium (^{226}Ra) is radiologically the most important and, therefore, reference is often made to radium instead of uranium.

The 2013 BSS Directive (European Union, 2013b) introduces, for the first time, binding requirements on building materials. In Article 75 (1), it establishes a reference level of 1 mSv/a applying to indoor external exposure to gamma radiation emitted by building material in addition to outdoor external exposure.

Member States will have to identify building materials, which are of concern from a radiation protection point of view with regard to their emitted gamma radiation, taking into account the indicative list of materials which is set out in Annex XIII of the Directive. The annexed list contains natural materials and materials incorporating residues from NORM industries, which may require a link to the requirements on NORM industries. For identified building materials, Member States need to ensure that before these materials are placed on the market, the activity concentrations of certain radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) are determined and the results of these measurements together with the corresponding activity concentration index, as defined in Annex VIII of the Directive, are communicated to the competent authority. Member States may also need to decide on an appropriate labelling of the materials before placing them on the market. For types of building materials which were identified and are liable to give doses exceeding the defined reference level of 1 mSv/a, the Member State needs to decide on appropriate measures on the further use of these materials – e.g. through specific requirements in building codes or restrictions on the use of these materials.

It should be noted that the provisions of the 2013 BSS Directive should be without prejudice to the provisions of Regulation (EU) No 305/2011 laying down harmonised conditions for the marketing of construction products (European Union, 2011), in particular on the declaration of performance, the establishment of harmonised standards or the means and conditions for making available the declaration of performance or with regard to CE marking.

Drinking water

Water is one of the most comprehensively regulated areas of the EU environmental legislation. Early European water policy began in the 1970s with the adoption of political programmes as well as legally binding legislation. Council Directive 98/83/EC, namely the EC Drinking Water Directive (European Communities, 1998), lays down the essential standards at EU level for the quality of water intended for human consumption. Its objective is to protect human health from adverse effects of any contamination of water by ensuring that it is wholesome and clean. Forty-eight microbiological, chemical and indicator parameters must be monitored and regularly tested.

In order to account for the potential presence of radioactive substances in drinking water, the EC Directive has been supplemented by Council Directive 2013/51/Euratom (European Union, 2013a), establishing requirements relating to the protection of the health of the general public against radioactive substances in water intended for human consumption.

The Council Directive 2013/51/Euratom (European Union, 2013a) applies to tap water and to water in bottles or containers intended for human consumption; it does not apply to natural mineral waters and to small private supplies. It lays down parametric values for radon, tritium, and – covering many other naturally occurring and artificial radionuclides – the indicative dose (ID). It is worth noting that the values given have an indicative function and are not meant to be limits. The Directive also lays down general principles for monitoring, including technical details (frequencies of sampling, analysis methods, measuring methods, etc.).

In its annexes, the Directive proposes as parametric values an indicative dose of 0.1 mSv/a over one year consumption of drinking water, and activity concentrations of 100 Bq/l for radon and tritium.

For the monitoring of radioactive substances in drinking water samples, the Directive proposes a graded assessment methodology: All drinking water samples shall undergo an initial screening for gross-alpha and gross-beta activity. If the measured activity concentrations are below the screening levels of 0.1 Bq/l for gross-alpha activity and 1 Bq/l for gross-beta activity, no further action is required. If either of the screening levels is exceeded, the concentrations of individual radionuclides should be determined and compared with the guidance levels provided in the annexes of the Directive. The outcome of this further evaluation may indicate that no action is required or that further assessment is necessary before a decision is taken on the need for remedial measures.

Résumé

Natural sources of ionising radiation are amongst the most important contributors to the overall total exposure of members of the public and can lead to significant exposures of workers in specific workplaces. Europe has established a comprehensive set of legislation for the protection against the dangers arising from ionising radiation, which, in its recent development, coherently covers the protection from exposure to natural sources of ionising radiation. This system of protection includes, in particular, protection from exposure to indoor radon, exposure to cosmic rays, exposure to natural radioactive substances in drinking water and in building materials, and exposure to NORM.