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CODEX ALIMENTARIUS COMMISSION

Food and Agriculture Organization of the United Nations

World Health Organization

Viale delle Terme di Caracalla, 00153 Rome, Italy - Tel: (+39) 06 57051 - E-mail: codex@fao.org - www.codexalimentarius.org

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February 2023

TO: Codex Contact Points
Contact Points of international organizations having observer status with Codex

FROM: Secretariat, Codex Alimentarius Commission,
Joint FAO/WHO Food Standards Programme

SUBJECT: **Request for comments on natural radioactivity in feed, food and drinking-water**

DEADLINE: **30 June 2023**

BACKGROUND[1]

CCCF13 (2019)[2]

1. In relation to IAEA's work on radioactivity in food, the Representatives from the International Atomic Energy Agency (IAEA) and the Joint FAO/IAEA Division (now redesignated as the Joint FAO/IAEA Centre) provided the background to and timeline for its ongoing work on radionuclides in food in non-emergency situations. Historically, IAEA safety standards addressed radionuclides in food only in the context of responding to a nuclear or national emergency, however this had now been extended to address radionuclides in food in non-emergency situations. IAEA also discussed the difference between naturally-occurring and human-made radionuclides in food, the variability observed in the concentrations of the different radionuclides in different foods and the general approach to dose assessments.

2. The Representatives explained that this work had been carried out in collaboration with FAO and WHO and would also require careful consideration regarding any impact on food standards, food safety and trade aspects for which feedback from Codex members was very important and could be gathered through CCCF. The Representatives further noted that such work would not entail the establishment of MLs for radionuclides in food in normal situations but would provide guidance to food safety authorities for increased understanding of radioactivity in food and related food safety and trade issues.

3. CCCF agreed to establish an Electronic Working Group (EWG) on radioactivity in feed and food to produce a discussion paper for consideration at its next session, chaired by the European Union (EU), co-chaired by Japan to (i) provide factual information on the radioactivity of both human-made and natural origin that can be found in feed and food (including drinking-water) in normal circumstances (i.e. not in an emergency exposure situation following a nuclear or radiological emergency) and (ii) identify the issues related to the presence, in normal circumstances, of radioactivity of both human-made and natural origin in feed and food (including drinking-water), such as feed and food safety, transfer of radioactivity from feed to food of animal origin, possible public health risks via intake of food, trade issues, etc.

4. CCCF noted that this discussion paper would (i) result in an increased understanding of the presence of radioactivity in feed and food (including drinking-water) in normal circumstances and related issues, and (ii) provide the Committee with the appropriate information enabling CCCF14 to take an informed decision on possible follow-up actions.

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1 To access CCCF documents relevant to this item please check the Codex/CCCF website: https://www.fao.org/fao-who-codexalimentarius/committees/committee/related-meetings/en/?committee=CCCF

2 REP19/CF13, paras. 21-27

CCCF14 (2021)[3]

5. The Representative of the Joint FAO/IAEA Centre drew the attention of CCCF to the ongoing work in IAEA on radionuclides in food, feed and drinking-water and the linkages with the information presented in the discussion paper on radioactivity in feed, food and drinking-water in normal circumstances for consideration by this Session of the Committee.

6. The Representative mentioned that work at the international level in this area is currently developing methodologies that can be used to produce criteria to assess these radionuclides in food. This work involved FAO, IAEA and WHO. The Representative further noted that naturally occurring radionuclides in food, feed and water do not seem to be an issue for food safety and trade. The IAEA could also commit to producing any necessary information or documents that might be helpful to food authorities in this regard and thanked the EWG, the Chairs of the EWG and the Codex Secretariat for the excellent discussion paper.

Radioactivity in feed, food and drinking-water in normal circumstances

7. The European Union, as Chair of the EWG, recalled that, following information provided by the Representative of the Joint FAO/IAEA Centre, CCCF13 had agreed that explorative work should be undertaken on food safety and trade issues associated with radionuclides in food (including drinking-water) and feed in non-emergency situations. The EWG had prepared a discussion paper to increase the understanding of the presence of radioactivity in food and feed in non-emergency situations to enable CCCF to take an informed decision on possible follow-up actions.

8. The EWG Chair noted that the discussion paper concluded that naturally occurring radionuclides (i.e. mainly ^{40}K, ^{210}Po, ^{210}Pb, ^{228}Ra and ^{226}Ra) are found in many different foods and tend to give radiation doses higher than those provided by artificially produced radionuclides (such as ^{134}Cs, ^{137}Cs, ^{131}I and ^{90}Sr) in situations not affected by a nuclear emergency situation in the past, but no specific safety problem for food, feed or drinking-water due to the presence of naturally occurring radionuclides had been identified. Furthermore, no international trade issues had been identified due to the presence of naturally occurring radionuclides in food, feed and drinking-water.

9. Following comments, the Representative of the Joint FAO/IAEA Centre clarified that the informative document would be presented to CCCF before publication. The EWG Chair further clarified that the informative document would focus on naturally occurring radionuclides, shall inform on regional variations in presence of naturally occurring radionuclides in food (including drinking-water) and feed, uptake variations depending on the type of food, and that the regular update on any development in the field of radioactivity will relate to naturally occurring and artificially produced radionuclides.

10. CCCF agreed that no further work was required to be done by CCCF at this time given that naturally occurring radionuclides in food, feed and water did not seem to be an issue for food safety and trade and welcomed the offer of IAEA to elaborate, with the collaboration of FAO and WHO, an informative document for the food safety regulators community, providing the state of the art of natural radioactivity in food/feed/water, thereby also reflecting regional variations.

11. CCCF further agreed to request IAEA to keep CCCF informed of any development in the field of naturally occurring and artificially produced radioactivity, in particular on the FAO/IAEA/WHO work to develop methodologies that could be used to produce criteria with which to assess radionuclides in food.

CCCF15 (2022)[4]

12. The representative of the Joint FAO/IAEA Centre provided an update on the ongoing international work on radionuclides in food, feed and drinking-water in non-emergency situations. This technical work was concluding. Three documents were in preparation, one was already published online as preprint FAO, IAEA and WHO Safety Report 114 '*Exposure due to Radionuclides in Food Other Than During a Nuclear or Radiological Emergency. Part 1: Technical Material*'. It includes information on the observed distributions of concentrations of key natural radionuclides in various foods, the use of dietary surveys to assess ingestion doses arising from exposure to radionuclides and it also provides information on radionuclide concentrations in natural mineral waters, in aquaculture and in other foods collected from the wild. A part 2 document was*in press*. It will put forward proposals that competent authorities could use to implement radiation safety standards as they relate to radioactivity in food in existing exposure situations. The third document in preparation is the information document that will be presented at the next CCCF after circulation to Codex Members for comments.

3 REP21/CF14, paras. 15-17, 181-185
4 REP22/CF15, paras. 40-41

Additional information

13. The "Part 2 Document" is jointly sponsored by FAO, IAEA and WHO. It was published after the CCCF15 in the IAEA Technical Documents series of reports (IAEA-TECDOC-2011). This part 2 publication is intended to support regulatory bodies, policy makers and others with responsibilities relating to the management of exposures where radionuclides are, or could be, present in food, but it excludes nuclear or radiological emergencies. Building on the information provided in Safety Report 114, the focus of the TECDOC is on technical considerations for the implementation of Requirement 51 of Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, in the area of food safety. In particular, this publication provides a proposed approach for the management of radionuclides in food for consideration in implementing Requirement 51 in GSR Part 3. The publication will be of practical value to all those with roles in food safety or radiation protection.

14. The "third document" has now been produced in collaboration with the FAO, IAEA and WHO; input was also provided by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). This third document is the informative document for the food safety regulators community, that is intended to provide the state of the art of natural radioactivity. It is this third document that is being circulated for comments. The UNSCEAR were involved because this document heavily references their previous reports on public exposure to natural radionuclides. Note that the new activity concentration in food data (Tables 3–7) are generated from the statistical analysis of approximately 8,000 individual measurements of natural radionuclides in food in the time period 1998 to 2017. Although these data comprise observations of natural radioactivity in food from many different regions of the world, analysis in terms of the variables of "Region" or "Country" where the samples were collected did not prove to be useful. It was found that the variables of most use were "Radionuclide" (e.g., ^{210}Po), "Food Subcategory" (e.g., edible parts of molluscs) and, in some cases, "Food Product" (e.g., edible parts of bivalve molluscs such as clams, mussels, oysters and scallops). Analysis in terms of these latter variables resulted in skewed distributions that could be described as log-normal distributions of activity concentrations for specific radionuclides in specific food subcategories or food products. The data do not provide evidence of regional variations in activity concentrations. Therefore, the document provided for CCCF comment cannot reflect regional variations in natural radionuclide activity concentrations in foods (as originally requested at CCCF15) because none were observed in the statistical analysis. For more detail on the statistical analysis please see Section 5, and also Annex II and Annex III of Safety Report 114.

REQUEST FOR COMMENTS

15. Taking into account the background provided in paragraphs 1–14 above and the purpose and users of the document, Codex members and observers are invited to provide:

    i. General comments on the approach, structure and overall content of the document

    ii. Specific comments on paragraphs 1–23 of the document presented in the Appendix.

16. The paper as presented in the Appendix is uploaded to the Codex Online Commenting System (OCS): https://ocs.codexalimentarius.org/. Comments provided through the OCS should follow the guidance provided in paragraphs 18-22.

17. Comments submitted in reply to this Circular Letter[5] will be considered by the Joint FAO/IAEA Centre to prepare a revised version for consideration by CCCF17 (2024).

GUIDANCE ON THE PROVISION OF COMMENTS

18. Comments should be submitted through the Codex Contact Points of Codex members and observers using the OCS.

19. Contact Points of Codex members and observers may login to the OCS and access the document open for comments by selecting "Enter" in the "My reviews" page, available after login to the system.

[5] Codex webpage/Circular Letters:
http://www.fao.org/fao-who-codexalimentarius/resources/circular-letters/en/
Codex webpage/CCCF/Circular Letters:
http://www.fao.org/fao-who-codexalimentarius/committees/committee/related-circular-letters/en/?committee=CCCF

20. Contact Points of Codex members and observers organizations are requested to provide proposed changes and relevant comments/justifications on a specific paragraph (under the categories: editorial, substantive, technical and translation) and/or at the document level (general comments or summary comments). Additional guidance on the OCS comment categories and types can be found in the OCS Frequently Asked Questions (FAQs)[6].

21. Other OCS resources, including the user manual and short guide, can also be found on the Codex website[7].

22. For questions on the OCS, please contact Codex-OCS@fao.org.

[6] http://www.fao.org/fileadmin/user_upload/codexalimentarius/doc/OCS/Codex_OCS_FAQs_2017-11-06.pdf
[7] https://www.fao.org/fao-who-codexalimentarius/resources/ocs/en/

APPENDIX

NATURAL RADIOACTIVITY IN FOOD, FEED AND DRINKING-WATER

(For comments)

INTRODUCTION

1. The purpose of this publication is to provide the food safety regulatory community with information on radioactivity in food, feed and drinking-water. It has been written to update and summarize key information contained in a discussion paper that was presented to the 14th Session of the Codex Committee on Contaminants in Foods. The intention is to: (a) provide an overview of internal radiation doses typical of exposure by ingestion; (b) specify the key radionuclides that in general contribute most to the ingestion dose and give typical concentrations of the most prevalent radionuclides found in foods, and; (c) discuss and give references to international standards and guidance related to radioactivity in food, feed and drinking-water. In general, it is the ingestion of naturally occurring radionuclides that gives rise to almost all of the assessed internal radiation dose by ingestion. Therefore, this publication focuses on naturally occurring radioactivity. However, further technical information on levels of naturally occurring radionuclides and of human-made radionuclides in food may also be found in a recent technical publication [1] produced by the FAO, IAEA and WHO.

2. It is normal for air, soil, food, feed and drinking-water to contain low levels of radioactivity caused by the ubiquitous presence of radionuclides in all substances. Radionuclides in food, feed and drinking-water are mostly of natural origin but can also include human-made radionuclides. With the exception of a radioisotope of potassium (^{40}K), all of the radionuclides in these commodities are amenable to being controlled in some way. In this respect, radiation safety standards use the concept of an "existing exposure situation"; this refers to a situation where an exposure to sources of ionising radiation already exists at the time a decision on control is being taken (i.e., in ordinary circumstances that are not emergencies). Existing exposure situations involve exposure to natural sources and human-made sources of ionising radiation. The definition is broad, for example, it includes but is not limited to exposure to residual radioactive material after a nuclear or radiological emergency has been declared to have ended.

INTERNAL RADIATION DOSE BY INGESTION

3. Radionuclides are present in the Earth's crust and oceans. People have always been exposed to radiation and this includes radiation emitted by radionuclides in the foods that they eat. Although food and drinking-water can contain radioactive substances, the levels are in general relatively low, and are expected to remain at low levels except in extreme circumstances (e.g., major accidents or malicious events that could result in some food becoming contaminated with large amounts of radioactive material).

> BOX 1: Radiation Dose
>
> The biological effects of ionising radiation vary with the type (alpha, beta, gamma etc.) and energy of the radiation. The risk of biological harm is related to the radiation dose that the tissues receive. The unit of effective radiation dose is the sievert (Sv). Since one sievert is a large quantity, radiation doses normally encountered are expressed in millisievert (mSv) or microsievert (µSv) which are one-thousandth or one millionth of a sievert. For example, one chest X ray would typically give about 0.1 mSv of radiation dose.

Although concentrations of radionuclides in food, feed and drinking-water are typically low, the ionizing radiation emitted by ingested radionuclides can make a significant contribution to the overall radiation dose [Box 1] that we receive from the many different sources of radiation to which we are exposed in our everyday lives. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in its report of 2000 [2] calculated that the world-wide annual ingestion dose from natural sources can typically range from 0.2–0.8 mSv, with an average of about 0.31 mSv or about 12% of the total worldwide average annual dose from all natural sources of 2.4 mSv (typical range of 1–10 mSv) (Fig. 1). In its later report in 2008 the UNSCEAR reassessed the world-wide annual ingestion dose from natural sources as typically ranging from 0.2–1.0 mSv with an average annual ingestion dose of 0.29 mSv [3].

What are the key radionuclides responsible for this dose?

4. There are five key radionuclides that make significant contributions to the radiation dose from the ingestion of food and drinking-water and these all occur naturally. These radionuclides have been present in the environment since the earth was formed and include a radioisotope of potassium, ^{40}K, plus radioisotopes of lead, polonium and two different isotopes of radium: ^{210}Pb; ^{210}Po; ^{226}Ra, and; ^{228}Ra. A small proportion (0.012%) of all naturally occurring potassium is present as radioactive ^{40}K, whereas the latter four heavy isotopes occur during the natural radioactive decay of uranium and thorium.

5. The human body maintains tight homeostatic control of potassium levels. Thus, as a direct result of homeostasis, a rather constant and evenly distributed amount of ^{40}K is maintained in the body and the radiation it emits gives rise to an annual radiation dose of about 0.17 mSv per person, approximately 55% of the world-average annual ingestion dose. The dose from ingestion of ^{40}K in foods is an example of an exposure to ionising radiation that is relatively constant and uniform for all individuals everywhere. A healthy body needs potassium for its wellbeing, and the potassium content (including ^{40}K) is kept constant by normal physiological processes of regulation. This is why the ingestion dose from ^{40}K is not amenable to being controlled.

6. The radionuclides ^{210}Po, ^{210}Pb, ^{228}Ra and ^{226}Ra are together assessed as accounting for almost all of the remaining average annual ingestion dose with all other remaining radionuclides making a minor contribution (<1%). However, these four (and other) radionuclides are not maintained under homeostatic control. The amount of these radionuclides in the human body and therefore the radiation dose they impart, is related to how much of the radionuclide is ingested. Therefore, ^{210}Pb, ^{210}Po, ^{226}Ra and ^{228}Ra can be detected in different amounts in humans because they are found in varying quantities in food and drinking-water. The levels present in humans reflect the levels found in the diet and variations are ultimately due to the varying concentrations of these radionuclides in different soils and waters of the environments where the foods are produced, or the drinking-water is obtained.

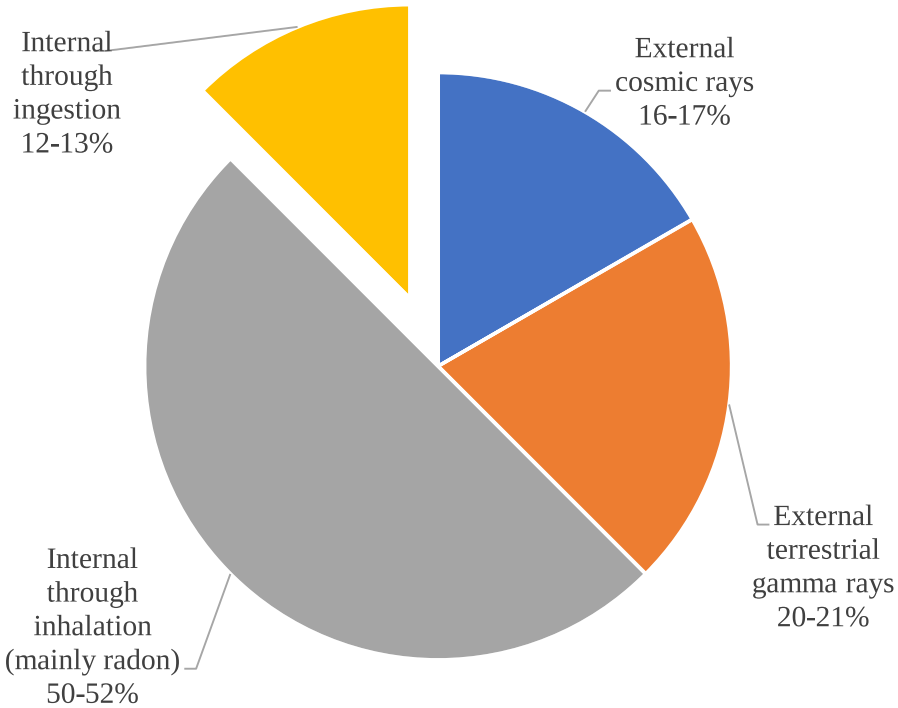

Fig. 1. The contribution of different radiation exposures to the worldwide average annual effective dose of 2.4 mSv from natural sources [2, 7]

7. At the time of writing, UNSCEAR has established an expert group to update its public exposure assessment from all sources, including food and drinking-water[1]. The UNSCEAR 2000 report [2] is the most recent report by the committee that presents representative values for nine of the most prevalent naturally occurring radionuclides generally found in food and drinking-water. The technical data published by UNSCEAR in 2000 on the different concentrations of natural radionuclides in different foods and drinking-waters from different countries and regions were used by the committee to generate single representative values for concentrations of the nine most prevalent radionuclides (^{210}Po, ^{210}Pb, ^{228}Ra, ^{226}Ra, ^{230}Th, ^{232}Th, ^{238}U, ^{228}Th, ^{235}U) in several food categories and drinking-water. These global representative concentrations, together with the dose contribution from ^{40}K were used by UNSCEAR to calculate a worldwide averaged (age-weighted) annual effective dose from the ingestion of natural radionuclides in food and water of 0.31 mSv (typical range of 0.20–0.80 mSv) in their 2000 report.

[1] The UNSCEAR expert group is reviewing the UNSCEAR representative values used for assessing radiation doses from radionuclides in food and drinking-water, this is scheduled to be completed in 2024, in close cooperation with the FAO, IAEA and WHO.

8. Most (>95%) of the 0.31 mSv annual ingestion dose presented in UNSCEAR 2000 is from food ingestion, whereas the ingestion of natural radionuclides in drinking-water typically accounts for less than approximately 0.01 mSv (<5%) of this averaged annual dose. The 0.31 mSv world-averaged annual ingestion dose is almost entirely due to ^{40}K, ^{210}Po, ^{210}Pb, ^{228}Ra and ^{226}Ra. The annual dose from ^{40}K contributes approximately 0.17 mSv and, as discussed earlier, is relatively constant and uniform for all individuals everywhere. However, the dose from ingestion of other radionuclides will vary according to how much is ingested. The radionuclides ^{210}Po, ^{210}Pb, ^{228}Ra and ^{226}Ra were together assessed as adding a further 0.14 mSv/year. Radionuclides, other than these account for less than 0.02 mSv/year on average (<6% of the total annual ingestion dose or <14% of the total annual ingestion dose excluding the dose contribution from ^{40}K). Human-made radionuclides in food contribute very little to the world-average annual ingestion dose in normal circumstances (existing exposure situations). However, some monitoring programmes are established to ensure that the levels of specific human-made radionuclides in food and agricultural products are low; for example, for products that originate from areas affected by nuclear or radiological accidents at some time in the past.

9. Human-made radionuclides (e.g., from industrial, medical, nuclear and research establishments and other uses of radioactive materials) may enter food, feed and drinking-water supplies. However, the contributions to ingestion dose from these sources of human-made radionuclides in planned exposure situations are limited by regulatory control of the source or practice in the specific discharge authorization. Should such sources of human-made radionuclides be regarded as important, it is normally through such regulatory mechanisms that action is taken to prevent or limit the radionuclide(s) from entering the environment and transferring into food, feed and water.

10. The UNSCEAR 2000 and UNSCEAR 2008 reports present estimates of worldwide averaged (age-weighted) annual effective dose and there will be significant variations for individual doses. Many national dietary studies make estimates of ingestion dose for specified populations. In general these ingestion doses are in reasonable agreement with the world-wide average assessments of UNSCEAR. This is discussed further in the following paragraphs.

What about national dietary studies and assessed ingestion doses?

11. In 2021, the FAO, IAEA and WHO published a report [1] that contained a literature survey that identified scientific papers and reports on ingestion dose from radionuclides in the diet at national levels. Many of the reviewed literature sources contained sufficient information and data for further evaluations to identify at the national level what were the most significant natural and human-made radionuclides contributing to dose from radionuclides in the diet and the variability of ingestion dose as a function of age or dietary study type. Table 1 presents a summary of these national estimates of total annual dose from all radionuclides (excluding the dose from ^{40}K). The FAO, IAEA and WHO concluded that these studies indicate that more than approximately 90% of the assessed ingestion dose (excluding ^{40}K dose) is due to ^{210}Po, ^{210}Pb, ^{228}Ra and ^{226}Ra. This is in general agreement with the assessments of UNSCEAR, for example in UNSCEAR 2000 these four radionuclides are assessed as contributing to more than 86% of the worldwide averaged ingestion dose excluding ^{40}K. Most of the assessed annual ingestion doses in these national studies fall within the range 0.03–0.63 mSv, and the median (and geometric mean) value of these data is 0.19 mSv/year; this observed range and median are also in good agreement with the UNSCEAR 2000 and UNSCEAR 2008 assessed world-averaged ingestion doses[2].

What about animal feed?

12. Animal feed may contain radionuclides that could present a risk to human health through the ingestion of foods of animal origin. Therefore, in normal circumstances the key radionuclides of interest are no different to those in foods (i.e., ^{210}Po, ^{210}Pb, ^{228}Ra and ^{226}Ra). However, some monitoring programmes are established to check levels of specific human-made radionuclides in feeds (e.g., ^{90}Sr, ^{137}Cs and ^{134}Cs), for example, to monitor feeds that originate from areas affected by nuclear or radiological accidents where significant amounts of radionuclides were accidentally released into the environment at some time in the past.

13. Just like humans, animals can accumulate radionuclides in their bodies by ingestion, inhalation, and absorption through skin. Radionuclides can originate from feed, soil, agricultural water etc. Ingestion of contaminated feed and soil is the most important route for the uptake of radionuclides into the animal. Radionuclides associated with soil are in general less available for absorption, it is the levels of the radionuclides in feed and the processes influencing the absorption and retention of radionuclides associated with feeds that generally determine the radionuclide content in animals.

[2] Subtracting the annual ingestion dose contribution from ^{40}K (0.17 mSv) from the UNSCEAR 2000 world averaged annual effective ingestion dose of 0.31 mSv (0.2–0.8 mSv typical range) yields an annual ingestion dose of approximately 0.14 mSv with a typical range of 0.03–0.63 mSv (excluding ^{40}K). Similarly, subtracting the ^{40}K dose contribution from the UNSCEAR 2008 assessed world average annual ingestion dose gives approximately 0.12 mSv with a typical range of 0.03–0.83 mSv (excluding ^{40}K).

RADIONUCLIDE CONCENTRATIONS

14. Ingestion dose cannot be measured directly, but it can be calculated from radionuclide activity. Activity can be easily measured and internationally accepted dose conversion factors that are specific to each radionuclide can be used to convert activity (Bq) to dose (Sv). Although activity is a rate, it can be used as a proxy for the amount of radionuclide [Box 2]. Therefore, surveillance and dose assessments are based on activity concentrations (Bq/kg or Bq/L). As mentioned in the previous section, data published by UNSCEAR in 2000 [2] presented activity concentrations that were considered to be representative values for the most prevalent radionuclides in several different categories of food and in drinking-water (reproduced in Table 2). Although these data were produced by UNSCEAR to assess public exposure, the representative activity concentration values in Table 2 are also used by laboratories to place their analytical results into context. A document published by the FAO, IAEA and WHO in 2021 [1] also provides data on activity concentrations of key natural radionuclides in different foods and gives data that can be used to place monitoring results into context.

BOX 2: Activity and activity concentration

The becquerel (Bq) is the unit of radionuclide activity (radioactivity), corresponding to one disintegration per second. Although the becquerel is a rate (per second) it can be used as a proxy for the amount of radionuclide present when the measurement was taken (e.g. Bq/kg or Bq/L). This is because radioactive decay is a first order process where “substance A” directly transforms into “substance B” at an exponential rate. The rate of disintegration at any given time is directly proportional to the amount of “substance A” present at that time.

15. The FAO, IAEA and WHO publication [1] includes activity concentration data derived from information published in scientific publications between 1998 and 2017 and from IAEA Member State surveillance measurements over the same period. These collated data were quality checked and used in statistical analyses to estimate various parameters, namely the median activity concentration (for lognormal distributions the median and geometric mean are identical), the arithmetic mean and 95th percentile of the distribution for key radionuclides in food. These estimates were used as part of a project to generate data that can be used as a basis for guidance relating to natural radionuclides in food. The median, confidence interval for the arithmetic mean and upper 95th percentile values are reported in Bq/kg, fresh weight for ^{210}Po, ^{210}Pb, ^{226}Ra and ^{228}Ra and are reproduced in Tables 3–6 respectively. In addition, median activity concentrations are also derived for ^{228}Th, ^{230}Th, ^{232}Th, ^{235}U, ^{238}U. Also, Table 7 provides a summary of fresh-weight median activity concentrations for all of these nine radionuclides in different food categories.

16. The radionuclides mentioned in the two preceding paragraphs occur naturally, but radionuclides such as ^{14}C, ^{90}Sr, ^{137}Cs and ^{134}Cs have also been found to contribute to ingestion dose in some instances. For example, although ^{14}C occurs naturally in the environment, it is also produced by the nuclear industry and therefore surveillance monitoring can sometimes detect enhanced ^{14}C levels in some foods. Similarly, concentrations of a few Bq/kg or less of human-made radionuclides such as ^{137}Cs, ^{134}Cs and ^{90}Sr may sometimes be found in foods, for example due to authorized discharges from nuclear facilities or from fallout due to past testing of nuclear weapons. However, in areas affected by a past nuclear accident ^{137}Cs, ^{134}Cs and ^{90}Sr concentrations in some foods could be higher by up to an order of magnitude.

INTERNATIONAL STANDARDS AND GUIDANCE

17. Up until 2014, international radiation safety standards did not explicitly address criteria for controlling public exposure to radiation from radionuclides in food and drinking-water in the context of existing exposure situations. This changed with the publication of a new edition of the International Basic Safety Standards and the inclusion of Requirement 51 in the General Safety Requirements Part 3 (GSR Part 3) [4].

BOX 3: Requirement 51 of GSR Part 3 [4]

The regulatory body or other relevant authority shall establish reference levels for radionuclides in commodities.

5.22. The regulatory body or other relevant authority shall establish specific reference levels for exposure due to radionuclides in commodities such as construction materials, food and feed, and in drinking-water, each of which shall typically be expressed as, or be based on, an annual effective dose to the representative person that generally does not exceed a value of about 1 mSv.

5.23. The regulatory body or other relevant authority shall consider the guideline levels for radionuclides in food traded internationally that could contain radioactive substances as a result of a nuclear or radiological emergency, which have been published by the Joint Food and Agriculture Organization of the United Nations/World Health Organization Codex Alimentarius Commission [7]. The regulatory body or other relevant authority shall consider the guideline levels for radionuclides contained in drinking-water that have been published by the World Health Organization [5].

18. Requirement 51 [Box 3] states that the regulatory body or other relevant authority shall establish reference levels[3] for exposure due to radionuclides in commodities including food and drinking-water. Therefore, radiation exposure from the consumption of food and drinking-water in non-emergency situations is required to be managed as an existing exposure situation through the establishment and use of reference levels and needs to consider both natural and human-made radionuclides.

19. **Drinking-water**: International Guidelines for Drinking-water Quality [5] and guidance on the management of radioactivity in drinking-water [6] establish criteria with which to determine the quality and safety of both natural and human-made radionuclide levels in normal circumstances (i.e., planned and existing exposure situations). The approach for managing radionuclides in drinking-water also considers an annual reference level of about 1 mSv from all radionuclides in drinking-water, consistent with international radiation safety standards (Requirement 51 of reference [4]). Part of the approach in these guidelines involves screening levels and guidance levels of activity concentrations expressed as becquerels per litre for different radionuclides in drinking-water. This internationally accepted approach for screening levels and guidance levels is based on an 'individual dose criterion' (IDC) per radionuclide of 0.1 mSv/year.

20. **Food**: The international food standards of the Codex Alimentarius provide guidance for the radiological safety of food in terms of international trade with areas not directly affected by a nuclear accident [7]. This focuses on human-made radionuclides (i.e., the presence of radionuclides as the result of an accidental or malicious release). Guideline Levels are provided for 20 radionuclides, most important for uptake into the food, in foods destined for human consumption and traded internationally, which have been contaminated following a nuclear or radiological emergency.

[3] A reference level is not a limit. For an existing exposure situation, a reference level is the level of dose, risk or activity concentration above which it is not appropriate to plan to allow exposures to occur and below which the process of determining what level of protection and safety is as low as reasonably achievable, would continue to be implemented (economic and social factors being taken into account). The value chosen for a reference level will depend upon the prevailing circumstances for the exposure under consideration.

21. More general international guidance [1, 8] has recently been developed to assist national authorities in establishing reference levels for radionuclides in food in non-emergency situations. As a first step, the FAO, IAEA and WHO have produced Safety Report No. 114 [1] with technical information that can be used to assess and manage radionuclides in food in existing exposure situations. In addition, another joint FAO, IAEA, WHO document [8] puts forward an approach for managing radionuclides in food that considers an annual reference level of about 1 mSv from all radionuclides in the food supply, consistent with international radiation safety standards (Requirement 51 of reference [4]). This involves using dietary surveys to monitor the food ingestion dose due to radionuclides in the food supply. Part of guidance also addresses the issue of assessing individual food products using guidance levels of activity concentrations for different radionuclides in food products (rather than the annual food supply as a whole). With some foods where natural levels of ^{210}Po, ^{210}Pb, ^{226}Ra or ^{228}Ra may be enhanced, the approach recommends using guidance levels based on the upper 95th percentile activity concentration values given in reference [1] and reproduced in Tables 3–6. For foods where these four radionuclides are not expected to be naturally enhanced, and for all other radionuclides (except ^{40}K) these guidance level activity concentrations are based on an 'individual dose criterion' (IDC) per radionuclide of 0.1 mSv/year. The technical information is consistent with that used for drinking-water [5] and also for foods in international trade affected by a nuclear or radiological emergency [7].

22. Safety Report No. 114 [1] includes information on the observed distributions of concentrations of natural radionuclides in various food products, the use of 'total diet' and other studies to assess ingestion doses from radionuclides in general. It also reviews and analyses studies of radionuclides in aquaculture, food collected from the wild, and natural mineral waters sold as foods. TECDOC-2011 [8] is intended to provide guidance in relation to the management of food in various circumstances where radionuclides are, or could be, present, excluding any nuclear or radiological emergency. Together, these two documents [1, 8] establish a scientific and technical foundation for implementing Requirement 51 of reference [4] as it relates to radionuclides in food.

23. **Feed:** International guidance is not available to assist national authorities in establishing reference levels for radionuclides in feed for food producing animals in non-emergency situations. Although there is international trade in animal feed, few monitoring programmes measure levels of both natural and human-made radionuclides in this commodity. As mentioned earlier, some monitoring programmes are established in areas affected by nuclear or radiological accidents at some time in the past. Their focus is detecting relatively persistent human-made radionuclides in feed in order to prevent uptake into the food supply.

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TABLES
(For information)

TABLE 1. TOTAL ANNUAL EFFECTIVE INGESTION DOSE FROM IMPORTANT RADIONUCLIDES IN THE DIET (EXCLUDING ^{40}K)

Country	Age Group	Total dose (mSv/year)*	Comment
Australia	Infant (< 1 year)	0.26	Fed with milk formula
	Infant (< 1 year)	0.02	Fed with breast milk
	Child (1 – 2 years)	0.30	-
	Child (2 – 7 years)	0.18	-
	Child (7 – 12 years)	0.19	-
	Child (12 – 17 years)	0.22	-
	Adult (> 17 years)	0.06	-
Austria	Adult (> 17 years)	0.33	99.6% from natural radioactivity
Brazil	Adult (> 17 years)	0.44	São Paulo region
	Adult (> 17 years)	0.43	Rural areas
	Adult (> 17 years)	0.29	Urban areas
France	Adult (> 17 years)	0.32	Typical seafood consumer nationally
	Adult (> 17 years)	0.19	Light seafood consumer nationally
	Adult (> 17 years)	0.73	Typical seafood consumer at a coastal location.
	Adult (> 17 years)	≤ 2.6	High-rate seafood consumer at a coastal location
Germany	Infant (< 1 year)	0.27	-
	Child (1 – 2 years)	0.18	-
	Child (2 – 7 years)	0.14	-
	Child (7 – 12 years)	0.14	-
	Child (12 – 17 years)	0.16	-
	Adult (> 17 years)	0.04	-
Ireland	Adult (> 17 years)	0.10	95% from natural radioactivity
Japan	Adult (> 17 years)	0.43	96% from natural radioactivity
New Zealand	Child (1 – 2 Years)	< 0.12	86% from natural radioactivity
	Child (2 – 7 years)	< 0.09	85% from natural radioactivity
	Child (12 – 17 years)	< 0.07	Female, 82% from natural radioactivity
	Child (12 – 17 years)	< 0.05	Male, 81% from natural radioactivity
	Adult (> 17 years)	< 0.09	Female, 85% from natural radioactivity
	Adult (> 17 years)	< 0.15	Male, 90% from natural radioactivity
Norway	Infant (< 1 year)	0.34	98% from natural radioactivity
	Child (12 – 17 years)	0.25	98% from natural radioactivity
	Adult (> 17 years)	0.19	98% from natural radioactivity
	Infant (<1 year)	0.39	99% from natural radioactivity
	Adult (> 17 years)	0.29	95% from natural radioactivity
UK	Adult (> 17 years)	0.19	92% from natural radioactivity
Viet Nam	Adult (> 17 years)	0.20	Red River Delta region

* Adapted from Table 10 in Section 4 of [1]

** For comparison the UNSCEAR 2000 world averaged annual effective ingestion dose is calculated as 0.14 mSv with a typical range of 0.03–0.63 mSv (excluding the ^{40}K dose of 0.17 mSv). Similarly, the UNSCEAR 2008 assessed world average annual ingestion is calculated as 0.12 mSv with a typical range of 0.03–0.83 mSv (excluding ^{40}K).

TABLE 2. REPRESENTATIVE ACTIVITY CONCENTRATIONS OF THE MOST PREVALENT RADIONUCLIDES IN FOOD CALCULATED BY THE UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION AND PRESENTED IN THEIR 2000 REPORT*

Food category	Radionuclide activity concentration (Bq/kg)								
	^{210}Po	^{210}Pb	^{228}Ra	^{226}Ra	^{230}Th	^{232}Th	^{238}U	^{228}Th	^{235}U
Milk products	0.015	0.015	0.005	0.005	0.0005	0.0003	0.001	0.0003	0.00005
Meat products	0.06	0.08	0.01	0.015	0.002	0.001	0.002	0.001	0.00005
Grain products	0.06	0.05	0.06	0.08	0.01	0.003	0.02	0.003	0.001
Leafy Vegetables	0.1	0.08	0.04	0.05	0.02	0.015	0.02	0.015	0.001
Root vegetables and fruits	0.04	0.03	0.02	0.03	0.0005	0.0005	0.003	0.0005	0.0001
Fish products	3.3*	0.2	-	0.1	0.01	0.01	0.03	0.1	-
Drinking-water	0.005	0.01	0.0005	0.0005	0.0001	0.00005	0.001	0.00005	0.00004

* Adapted from Table 15 in Annex B of [2]

** The value of 3.3 Bq/kg ^{210}Po is for fresh fish products as an aggregate food category. An alternative value of 2.0 Bq/kg can be used as a decay corrected value to account for a proportion of fish products that are stored as canned, frozen etc. before they are consumed. This is based on a reduction factor of 0.6 for the radioactive decay of ^{210}Po (half-life 138 days). Representative ^{210}Po activity concentrations for the three disaggregate food categories of fresh fish, fresh crustaceans and fresh molluscs are given as 2.4 Bq/kg, 6.0 Bq/kg and 15.0 Bq/kg respectively (fresh and therefore not decay corrected).

TABLE 3. SUMMARY OF ^{210}Po ACTIVITY CONCENTRATIONS IN FOOD* (FRESH WEIGHT).

Food	Number of data points (N) above detection limits.	Median and Geometric Mean (Bq/kg)	Arithmetic Mean (Bq/kg)		95th Percentile (Bq/kg)
			Lower Confidence Interval	Upper Confidence Interval	
^{210}Po Aquatic Food					
Mollusc Bivalves	663	40.37	49.47	55.97	134.0
Mollusc Gastropods	292	17.48	17.89	19.49	32.0
Crabs	191	16.40	17.10	19.80	37.0
Lobster	143	12.74	12.95	14.91	25.0
Prawns and Shrimp	59	6.40	6.89	12.60	32.0
Saltwater Fish	386	5.79	6.38	9.70	36.0
Mollusc Cephalopods	25	2.35	2.27	5.76	11.6
Scampi (Norwegian Lobster)	38	2.00	1.94	2.90	5.3
Seaweed	43	1.70	1.68	2.42	4.3
Freshwater Fish	222	0.99	1.63	2.42	6.7
^{210}Po Terrestrial Food					
Grain	119	0.14	0.20	0.41	1.50
Non-root vegetables	216	0.12	0.28	0.55	2.00
Fruit	161	0.12	0.20	0.33	0.87
Meat	203	0.10	0.12	0.15	0.37
Liquid Milk	57	0.07	0.15	0.75	1.50
Root Vegetables	46	0.04	0.05	0.10	0.25

* Adapted from Tables 24 and 25 in Section 5 of [1]

TABLE 4. SUMMARY OF ^{210}Pb ACTIVITY CONCENTRATIONS IN FOOD* (FRESH WEIGHT)

Food	Number of data points (N) above detection limits.	Median and Geometric Mean (Bq/kg)	Arithmetic Mean (Bq/kg)		95th Percentile (Bq/kg)
			Lower Confidence Interval	Upper Confidence Interval	
^{210}Pb Aquatic Food					
Mollusc Non-bivalves	18	2.00	1.71	5.78	11.24
Mollusc Bivalves	351	1.99	2.52	3.05	7.40
Seaweed	27	0.62	0.57	0.78	1.19
Freshwater Fish	59	0.23	0.30	0.69	1.50
Saltwater Fish	330	0.20	0.30	0.40	1.40
Crustaceans	129	0.14	0.16	0.22	0.53
^{210}Pb Terrestrial Food					
Mushrooms	132	0.32	0.42	0.66	1.73
Grain	153	0.15	0.24	0.43	1.50
Meat	60	0.15	0.18	0.34	0.79
Fruit	160	0.14	0.23	0.38	1.10
Non-root vegetables	235	0.13	0.26	0.45	1.50
Root Vegetables	90	0.07	0.14	0.36	0.88
Liquid Milk	71	0.06	0.06	0.09	0.18

* Adapted from Section 5, Tables 26 and 27 of [1]

TABLE 5. SUMMARY OF ^{226}Ra ACTIVITY CONCENTRATIONS IN FOOD* (FRESH WEIGHT)

Food	Number of data points (N) above detection limits.	Median and Geometric Mean (Bq/kg)	Arithmetic Mean (Bq/kg)		95th Percentile (Bq/kg)
			Lower Confidence Interval	Upper Confidence Interval	
Freshwater Fish	59	0.48	0.48	0.63	1.10
Saltwater Fish	95	0.27	0.35	0.67	2.00
Mollusc Bivalves	37	0.16	0.18	0.50	1.10
Grain	292	0.12	0.25	0.39	1.50
Leafy vegetables	324	0.11	0.39	0.77	2.40
Root vegetables	239	0.11	0.33	0.68	2.10
Fruit	193	0.08	0.19	0.37	1.10
Crustacean	20	0.06	0.18	0.50	0.58
Liquid Milk	147	0.05	0.16	0.35	0.77
Meat	90	0.04	0.05	0.09	0.22

* Adapted from Section 5, Table 28 of [1]

TABLE 6. SUMMARY OF ^{228}Ra ACTIVITY CONCENTRATIONS IN FOOD* (FRESH WEIGHT)

Food	Number of data points (N) above detection limits.	Median and Geometric Mean (Bq/kg)	Arithmetic Mean (Bq/kg)		95th Percentile (Bq/kg)
			Lower Confidence Interval	Upper Confidence Interval	
Saltwater Fish	43	1.75	1.76	2.80	5.5
Freshwater Fish	32	0.84	0.80	0.93	1.2
Root Vegetables	82	0.31	0.70	2.54	6.1
Mollusc Bivalves	19	0.17	0.15	0.35	0.68
Non-root Vegetables	188	0.12	0.35	0.80	2.1
Grain	90	0.12	0.15	0.27	0.67
Fruit	94	0.11	0.21	0.54	1.4
Meat	46	0.09	0.10	0.22	0.50
Liquid Milk	101	0.04	0.04	0.05	0.10

* Adapted from Section 5, Table 29 of [1]

TABLE 7. A SUMMARY OF MEDIAN ACTIVITY CONCENTRATIONS (FRESH-WEIGHT) FOR VARIOUS FOOD SUB-CATEGORIES, ADAPTED FROM TABLE II.1, ANNEX II OF [1]

Food	Median activity concentration (Bq/kg)								
	^{210}Pb	^{210}Po	^{226}Ra	^{228}Ra	^{228}Th	^{230}Th	^{232}Th	^{235}U	^{238}U
Beverages	0.115	0.042	0.211	0.415	4.650	ID	0.025	ID	0.004
Bivalve molluscs	1.99 [a]	40.37 [b]	0.16 [c]	0.17 [d]	0.471	0.545	0.326	0.031	0.824
Crustacean	0.14 [a]	2.00–16.40**	0.06 [c]	0.398	0.043	0.016	0.017	ID	0.034
Eggs	0.090	0.069	0.109	0.090	0.043	0.249	0.005	ID	0.081
Freshwater Fish	0.23 [a]	0.99 [b]	0.48 [c]	0.84 [d]	0.655	0.310	2.810	2.505	0.012
Fruit	0.14 [a]	0.12 [b]	0.08 [c]	0.11 [d]	0.026	0.040	0.007	0.000	0.011
Grain	0.15 [a]	0.14 [b]	0.12 [c]	0.12 [d]	0.090	0.002	0.400	0.025	0.124
Herbs	0.569	0.882	0.326	0.180	2.900	0.557	0.058	0.003	0.091
Honey and Sugar	0.107	0.230	0.049	0.188	0.142	0.014	0.002	ID	0.008
Non-root Vegetables	0.13 [a]	0.12 [b]	0.11 [c]	0.12 [d]	0.042	0.060	0.027	0.014	0.029
Liquid Milk	0.06 [a]	0.07 [b]	0.05 [c]	0.04 [d]	0.033	0.230	0.038	0.011	0.130
Meat	0.15 [a]	0.10 [b]	0.04 [c]	0.09 [d]	0.040	0.004	0.008	0.021	0.019
Milk Products	0.388	0.150	0.078	0.139	0.113	0.020	0.150	0.002	0.013
Mushrooms	0.32 [a]	0.580	0.300	0.260	ID	0.073	0.048	0.007	0.037
Non-bivalve molluscs	2.00 [a]	2.35–17.48**	0.230	0.210	ID	ID	0.060	ID	0.549
Nuts	0.126	0.101	0.231	0.530	12.600	0.011	9.408	ID	0.006
Offal	0.520	0.719	ID	ID	ID	ID	0.026	ID	0.023
Root Vegetables	0.07 [a]	0.04 [b]	0.11 [c]	0.31 [d]	0.042	0.008	0.179	0.010	0.089
Saltwater Fish	0.20 [a]	35.79 [b]	0.27 [c]	1.75 [d]	0.028	0.010	0.090	0.001	0.013
Seaweed	0.62 [a]	1.70 [b]	0.360	0.140	0.389	0.044	0.031	ID	0.375

ID, insufficient data.

[a–d] Medians from Tables 4, Table 3, Table 5 and Table 6 respectively.

** Median values of ^{210}Po in different subgroups of crustaceans and subgroups of non-bivalve molluscs are given in Table 3 and this represents the spread of median values for these subgroups.