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Report of the United Nations Scientific Committee on the Effects of Atomic Radiation

Seventy-first session
(20–24 May 2024)

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Note

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Chapter I

Introduction

1. The mandate of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was first established in General Assembly resolution 913 (X), adopted in 1955. In Assembly resolution 3154 A–C (XXVIII), adopted in 1973, the Committee was further requested to consider the risks of ionizing radiation from all sources.[1] In pursuit of its mandate, the Committee thoroughly reviews and evaluates global and regional exposures to radiation. The Committee also evaluates evidence of radiation-induced health effects in exposed groups and advances in the understanding of the biological mechanisms by which radiation-induced effects on human health or on non-human biota can occur. Those evaluations provide the scientific basis used, inter alia, by the relevant agencies of the United Nations system in formulating international standards for the protection of the public, workers and patients;[2] those standards, in turn, are linked to important legal and regulatory instruments.

2. Exposure to ionizing radiation arises from naturally occurring sources (such as radiation from outer space and radon gas emanating from rocks on the Earth) and from sources with an artificial origin (such as medical diagnostic and therapeutic procedures; radioactive material resulting from nuclear weapons testing; electricity generation, including by means of coal, natural gas, oil, nuclear power, and geothermal and other energy sources; unplanned events; and workplaces where there may be increased exposure to artificial or naturally occurring sources of radiation).

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[1] The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was established by the General Assembly at its tenth session, in 1955. The terms of reference of the Committee are set out in resolution 913 (X). The Committee was originally composed of the following Member States: Argentina, Australia, Belgium, Brazil, Canada, Czechoslovakia (later succeeded by Slovakia), Egypt, France, India, Japan, Mexico, Sweden, Union of Soviet Socialist Republics (later succeeded by the Russian Federation), United Kingdom of Great Britain and Northern Ireland and United States of America. The membership of the Scientific Committee was subsequently enlarged by the Assembly in its resolution 3154 C (XXVIII) to include the Federal Republic of Germany (later succeeded by Germany), Indonesia, Peru, Poland and the Sudan. By its resolution 41/62 B, the Assembly increased the membership of the Committee to 21 members and invited China to become a member. In its resolution 66/70, the Assembly further enlarged the membership of the Committee to 27 and invited Belarus, Finland, Pakistan, the Republic of Korea, Spain and Ukraine to become members. In its resolution 76/75, the Assembly further enlarged the membership of the Committee to 31 and invited Algeria, Iran (Islamic Republic of), Norway and the United Arab Emirates to become members.

[2] For instance, relevant international safety standards that take into account the findings of the Scientific Committee include: (a) the international Fundamental Safety Principles, which are jointly sponsored by the European Atomic Energy Community, the Food and Agriculture Organization of the United Nations (FAO), the International Atomic Energy Agency (IAEA), the International Labour Organization (ILO), the International Maritime Organization, the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), the Pan American Health Organization (PAHO), the United Nations Environment Programme (UNEP) and the World Health Organization (WHO); and (b) the *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards – General Safety Requirements Part 3*, which are co-sponsored by the European Commission, FAO, IAEA, ILO, OECD/NEA, PAHO, UNEP and WHO. Both international standards were established under the aegis of IAEA.

Chapter II

Deliberations of the United Nations Scientific Committee on the Effects of Atomic Radiation at its seventy-first session

3. The Scientific Committee held its seventy-first session in Vienna from 20 to 24 May 2024. The following were elected to serve as officers of the Committee for its seventy-first and seventy-second sessions: Sarah Baatout (Belgium) as Chair; Anssi Auvinen (Finland), Reiko Kanda (Japan) and Aayda Al Shehhi (United Arab Emirates) as Vice-Chairs; and Carol Robinson (Norway) as Rapporteur.

4. The Scientific Committee took note of General Assembly resolution 78/71 on the effects of atomic radiation. The Committee heard statements from five member States, Argentina, Belgium, Iran (Islamic Republic of), the Russian Federation and the United Arab Emirates, and from the following observers: the International Atomic Energy Agency (IAEA), the Scientific Advisory Group for the Treaty on the Prohibition of Nuclear Weapons and the World Health Organization. Assistant Secretary-General of the United Nations and Deputy Executive Director of the United Nations Environment Programme (UNEP), Elizabeth Mrema, also addressed the Committee. The recorded statements are available from the Committee's secretariat.

5. The Scientific Committee also noted and discussed other issues addressed in the resolution. Those discussions are summarized in chapter II, section E (Administrative issues), of the present report.

A. Completed evaluations

6. The Scientific Committee discussed in detail the evaluation of second primary cancer after radiotherapy and the evaluation of public exposure to ionizing radiation, adopted the scientific reports based on the findings of those evaluations (see chapter III) and requested that the scientific annexes be published in the usual manner, subject to the agreed modifications.

1. Second primary cancer after radiotherapy

7. At its sixty-sixth session, the Scientific Committee endorsed the plan to initiate an evaluation of second primary cancer after radiotherapy. The aim of the evaluation was to raise awareness in the scientific and medical communities and in national authorities with respect to the fact that cancer treatment by radiation, while contributing to the effective treatment of increasing numbers of patients, can involve off-target exposures which may, in some patients, result in second primary cancer several years later. Quantification of the risk of second primary cancer after radiotherapy and evaluations of the factors affecting that risk require data (e.g. on dose distributions) that are often difficult to obtain retrospectively.

8. At its seventy-first session, the Scientific Committee expressed its gratitude for the significant work of the expert group[3] in the preparation of its evaluation of second primary cancer after radiotherapy. In response to numerous constructive comments, the technical evaluation of radiation oncology, biology, dosimetry and epidemiology relevant to the development of second primary cancer after radiotherapy was revised substantially. The Committee discussed and approved for publication the scientific annex on second primary cancer after radiotherapy. In addition, the Committee reviewed and endorsed the three electronic attachments to that annex for presentation on the UNSCEAR website.

[3] The expert group comprises 37 experts (including four critical reviewers) from 17 Member States and four observers from IAEA, the International Commission on Radiological Protection (ICRP) and WHO.

2. Evaluation of public exposure to ionizing radiation

9. In pursuit of its mandate, the Scientific Committee regularly reviews and evaluates global and regional exposures of the public to radiation. At its sixty-sixth session, the Committee agreed to update annex B to its 2008 report[4] and in 2020 it commenced the evaluation of public exposure to ionizing radiation. At its sixty-ninth session, the Committee supported the application of the methodology for estimating exposures of the public due to radioactive discharges as presented in its 2016 report.[5] At its seventieth session, the Committee endorsed further updates to the methodology and approach regarding quality criteria to be applied in the evaluation as presented in the appendix to annex B to the present report.

10. At its seventy-first session, the Scientific Committee expressed its gratitude for the significant work of the expert group[6] in considering the data on public exposure to ionizing radiation submitted by 61 Member States as at December 2023, the review of relevant literature published since 2007, and relevant data from eight regional and international organizations. The Committee discussed and approved for publication the scientific annex on evaluation of public exposure to ionizing radiation. In addition, the Committee reviewed and endorsed the six electronic attachments to that annex for presentation on the UNSCEAR website.

B. Present programme of work

1. Epidemiological studies of ionizing radiation and cancer

11. At its sixty-sixth session, the Scientific Committee agreed to update annex A to its 2006 report[7] and commenced its evaluation of epidemiological studies of radiation and cancer by establishing an expert group and initiating a comprehensive literature review based on the principles and criteria for ensuring the quality of the Committee's reviews of epidemiological studies of radiation exposure.

12. At its seventy-first session, the Scientific Committee acknowledged the significant progress made by the expert group[8] in drafting the scientific annex on the selected cancer sites and in summarizing the literature review on epidemiological studies of radiation and cancer. In addition, the Committee endorsed the methodology for lifetime cancer risk calculations for four proposed scenarios, which combines approaches used in annex A to its 2006 Report [9] and the risk projections and comparative analysis presented in annex A to its 2019 Report,[10] using extensive demographic data obtained on five geographical regions. The Committee also acknowledged the timely development of the evaluation, which is scheduled for approval at its seventy-second session, in 2025.

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[4] *Sources, Effects and Risks of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation 2008 Report to the General Assembly,* vol. I (United Nations publication, 2010), annex B.

[5] *Sources, Effects and Risks of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation 2016 Report to the General Assembly with Scientific Annexes* (United Nations publication, 2017).

[6] The expert group comprises 57 experts (including four critical reviewers) from 20 Member States and four observers from the European Commission, IAEA, OECD/NEA and WHO.

[7] *Effects of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation 2006 Report to the General Assembly*, vol. I (United Nations publication, 2008), annex A.

[8] The expert group includes 27 experts (including four critical reviewers) from eight Member States and one observer from the International Agency for Research on Cancer.

[9] *Effects of Ionizing Radiation: UNSCEAR 2006 Report*, vol. I, annex A.

[10] *Sources, Effects and Risks of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation 2019 Report to the General Assembly with Scientific Annexes,* (United Nations publication, 2020, and corrigendum), annex A.

2. Effects of ionizing radiation on the circulatory system

13. At its sixty-seventh session, in 2020, the Scientific Committee agreed to commence an evaluation of diseases of the circulatory system resulting from radiation exposure. At its sixty-eighth session, it endorsed the project plan for commencement in 2021. At its seventieth session, the Committee welcomed the considerable work carried out by the expert group[11] and discussed the first results of the literature review. It provided feedback on the scope of topics to be included in the review and endorsed the proposed structure of the evaluation.

14. At its seventy-first session, the Scientific Committee welcomed the progress made by the expert group and reviewed the first draft annex. The Committee accepted that the expert group would not attempt to make lifetime risk projections, given the marked heterogeneity of the available data. The Committee requested the expert group to prepare a progress report and finalize the draft of the scientific annex, including the results of the review of new literature published up to 2023 and the group's conclusions on diseases of the circulatory system caused by radiation exposure, and to present the annex for approval by the Committee in 2025.

3. Effects of ionizing radiation on the nervous system

15. At its sixty-seventh session, the Scientific Committee agreed to commence an evaluation of the effects of ionizing radiation on the nervous system, when the necessary resources became available. At its seventieth session, the Committee noted the establishment of the expert group and endorsed the revised timelines for the implementation of the evaluation, with approval of the report expected in 2027. At its seventy-first session, the Committee took note of the updated content of the report and noted the progress reported with regard to expanding the expert group[12] and developing literature searches, also noting that the literature review was in progress, with the first draft of the annex expected to be available for the seventy-second session, in 2025.

4. Strategy to improve collection, analysis and dissemination of data on radiation exposure, including consideration of the Committee's ad hoc working group on sources and exposure

16. At its seventy-first session, the Scientific Committee endorsed the proposed actions by the ad hoc working group on sources and exposure and agreed to: (a) endorse the proposal for a new UNSCEAR Global Survey on Medical Exposure, to be initiated in 2026 and carried out in two phases; (b) continue outreach efforts with the network of national contact persons to promote dialogue with a view to addressing common issues and concerns among Member States and provide related training and tools; and (c) request the secretariat to review and update the UNSCEAR online global survey platform, including with regard to the availability of questionnaires in languages other than English.

17. The Scientific Committee expressed appreciation for the work performed by the ad hoc working group on sources and exposure and approved the extension of its work until the Committee's seventy-second session, in 2025. The ad hoc working group currently consists of two small groups of experts, one on medical exposure and one on occupational exposure, and it was agreed that a new small group of experts would be created on public exposure. The purposes of these groups are to monitor the implementation of the recommendations outlined in the 2022 strategy to improve the collection, analysis and dissemination of data on radiation exposure and to advise the Committee on future data collection and exposure assessments.

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[11] The expert group comprises 20 experts (including two critical reviewers) from 12 Member States and one observer from ICRP.

[12] The expert group comprises 36 experts (including five critical reviewers) from 13 Member States and two observers from ICRP and OECD/NEA.

18. The Scientific Committee re-emphasized the need for Member States to provide data on public, occupational and medical exposures to ionizing radiation in order to ensure that future assessments are as comprehensive as possible. Furthermore, the Committee welcomed the growing number of national contact persons (currently 112) and alternate national contact persons and expressed appreciation for the participation of national contact persons in the webinars, surveys and meetings organized by the secretariat and the ad hoc working group on sources and exposure and conducted since the seventieth session.

5. Implementation of the public information and outreach strategy for the period 2020–2024 and adoption of the public information and outreach strategy for the period 2025–2029

19. At its seventy-first session, the Scientific Committee noted the secretariat's progress report on public information and outreach activities in the period 2020–2024 and endorsed the public information and outreach strategy for the period 2025–2029. The strategy is aimed at disseminating, in particular among the scientific community, decision makers, the general public, young professionals, students and the media, the Committee's findings on levels, effects and risks of exposure to ionizing radiation. The main elements of the strategy are:

(a) Strengthening the Committee's input to the science-policy interface within and outside the extensive United Nations network;

(b) Enhancing engagement with scientific, diplomatic, academic and professional communities;

(c) Encouraging the involvement of young professionals in the work of the Committee.

20. The Scientific Committee welcomed the online publication of the UNEP booklet entitled *Radiation: Effects and Sources* in Italian, bringing the total number of language editions of the booklet to 16,[13] and also welcomed the planned publication of the booklet in Bulgarian in 2024 and in Urdu in 2025. The Committee urged the secretariat to update the booklet on the basis of its reports and annexes published since the most recent update, issued in 2016 (including those referred to in chapter III of the present report), with the goal of publishing the updated booklet in order to mark the seventieth anniversary of the Committee. It also encouraged the secretariat to further translate and promote the booklet.

21. The Scientific Committee welcomed the publication, in all six official languages of the United Nations, of the summary of its findings as contained in annex B to its 2020/2021 report. All the Committee's publications are available on the UNSCEAR website.[14] The Committee welcomed the ongoing work of the secretariat to publish the website in all six official languages of the United Nations in 2024.

22. The Scientific Committee invited member States to support the implementation of the public information and outreach strategy for the period 2025–2029 by undertaking outreach activities at the national and regional levels (e.g. dedicated UNSCEAR-related events and days).

C. Update on the Committee's long-term strategic directions

23. At its sixty-sixth session, the Scientific Committee approved its long-term strategic directions and plan for the period 2020–2024. An update on progress in that regard is set out below.

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[13] The 16 languages include the six official languages of the United Nations (Arabic, Chinese, English, French, Russian, Spanish) and 10 other languages (Czech, Dutch, German, Hindi, Indonesian, Italian, Japanese, Korean, Persian and Portuguese) (see www.unscear.org/unscear/en/publications/radiation-effects-and-sources.html).

[14] www.unscear.org/unscear/en/publications/index.html.

1. Establishing working groups on sources and exposure and on effects and mechanisms

24. At its seventy-first session, the Scientific Committee prolonged the mandate of the ad hoc working group on effects and mechanisms to continue its activities until the Committee's seventy-second session, in 2025. The prolongation would enable the ad hoc working group to: (a) continue monitoring the progress of the ongoing scientific evaluations of effects and mechanisms; (b) support the timely finalization of those evaluations, as needed; (c) support and monitor progress in the implementation of both the present and future programme of work; and (d) evaluate new scientific developments.

25. Also at its seventy-first session, the Scientific Committee prolonged the mandate of the ad hoc working group on sources and exposure with a focus on the implementation of the updated strategy for improving the collection of data on radiation exposure and a focus on the establishment of a subgroup on public exposure. The Committee noted that the ad hoc working group, together with small groups of experts on, respectively, occupational exposure, medical exposure and public exposure, would continue to: (a) monitor the literature and provide advice to the Bureau and Committee for ongoing data collection; and (b) evaluate available and new data sources relevant to the Committee's exposure evaluation, in order to work with the secretariat in preparation for the Committee's future evaluation on medical exposure to ionizing radiation, in 2026, and subsequently, on occupational and public exposure to ionizing radiation.

2. Inviting, on an ad hoc basis, scientists from other States Members of the United Nations to participate in the Committee's evaluations

26. The Scientific Committee noted that the secretariat and the Bureau had taken steps to involve 30 additional scientists since its seventieth session, including scientists from other States Members of the United Nations,[15] in supporting the Committee in conducting ongoing evaluations. That was particularly relevant for the ongoing evaluations of the effects of ionizing radiation on the nervous system and of the effects of ionizing radiation on diseases of the circulatory system, and the approved evaluations of public exposure to ionizing radiation and of second primary cancer after radiotherapy.

3. Increasing the Committee's efforts to present its evaluations and summaries thereof in a manner that attracts readers without compromising scientific rigour and integrity

27. The Scientific Committee referred to the outreach activities reported in paragraphs 19 to 22 above.

4. While maintaining its lead in providing authoritative scientific evaluations to the General Assembly, liaising closely with other relevant international bodies to avoid duplication of efforts

28. The importance of the Scientific Committee's evaluations in providing the scientific basis to relevant entities of the United Nations system and other international bodies for establishing international safety standards has continued to be demonstrated in the period since the seventieth session of the Committee. The Committee noted that its secretariat was a member of the Inter-Agency Committee on Radiation Safety, and that the current scientific basis provided by the Scientific Committee for the international safety standards remained valid. The Committee also noted that the secretariat continued to collaborate with IAEA, participating as an observer to the IAEA Commission on Safety Standards and Radiation Safety

[15] Austria, Italy, Netherlands (Kingdom of the) and Switzerland.

Standards Committee, and that the secretariat cooperated with several other international organizations[16] and regional organizations.[17]

29. The Scientific Committee welcomed and supported the continued cooperation of the secretariat with entities within the United Nations system and with other intergovernmental organizations with a view to promoting the Committee's work and exploring synergies and joint activities that would contribute to that work and support the collection and analysis of scientific data. The Committee specifically acknowledged the research framework agreement signed with the European Commission in June 2023, the memorandums of understanding signed with the International Commission on Radiological Protection (ICRP) in May 2024 and the ongoing dialogue with the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development and the International Labour Organization, and requested the secretariat to report on cooperation with other entities at the seventy-second session.

D. Future programme of work

30. Established by the Scientific Committee at its sixty-fifth session, in 2018, the ad hoc working group on effects and mechanisms supports the Bureau and the secretariat in monitoring the progress of the ongoing scientific evaluations and in evaluating new scientific developments between the sessions for consideration by the Committee.

31. At its seventy-first session, the Scientific Committee noted that, owing to considerable delays caused by the limited availability of resources in the secretariat, three scientific evaluations that had been planned to begin in the period 2020–2024 had not yet started. Among those was the new evaluation of the effects of ionizing radiation on the eye, which is now planned to begin in early 2025. The Committee confirmed the importance of the planned evaluation of the effects of ionizing radiation on the immune system and the overview on non-cancer health effects of exposure to ionizing radiation, the starting dates of which will be set in accordance with the availability of resources in the period 2025–2029.

32. Also at its seventy-first session, the Scientific Committee identified priorities for its future programme of work for the period 2025–2029 by discussing the assessment reports provided by the ad hoc working group on effects and mechanisms on three potential topics identified at the seventieth session. Of those, the evaluation of levels of radiation exposure to and effects on wildlife populations and ecosystems was considered to be urgent and should, if possible, be initiated early in the programme period 2025–2029. The ad hoc working group on effects and mechanisms was asked to assess to what extent the other two topics, the effects of prenatal exposure to ionizing radiation and the effects of ionizing radiation on ageing and lifespan, could be included in the planned overview on non-cancer health effects of exposure to ionizing radiation. In addition, as requested by the ad hoc working group on sources and exposure, the commencement of a new evaluation of medical exposure to ionizing radiation is planned for the period 2025–2029. Lastly, the Committee considered three topics for potential white papers – namely: (a) biomarkers and signatures of radiogenic diseases; (b) dose-effect relationships; and (c) survey of biophysical models of radiation action currently in use and their biological relevance – which may be initiated by the secretariat as resources allow.

33. However, given the current budgetary constraints and liquidity issues faced by the United Nations, it was not possible to establish a detailed programme timeline.

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[16] Including the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, the International Civil Aviation Organization, ILO, UNEP, the Office for Outer Space Affairs, WHO, the International Agency for Research on Cancer, OECD/NEA, ICRP, the International Radiation Protection Association, the International Organization of Medical Physics and the Scientific Advisory Group for the Treaty on the Prohibition of Nuclear Weapons.

[17] Including the European Commission and the Ibero-American Forum of Radiological and Nuclear Regulatory Agencies.

34. Bearing in mind the high-quality and important scientific work conducted by the ad hoc working group on effects and mechanisms in monitoring the Scientific Committee's programme of work, the Committee extended the mandate of the ad hoc working group for one year to support and monitor progress in the implementation of the present and future programme of work and to evaluate new scientific developments.

E. Administrative issues

35. The Scientific Committee welcomed the increased regular budget allocation for 2024 approved by the General Assembly and the Assembly's approval of two new staff positions in the secretariat.[18] However, the Committee expressed concern with respect to the reduction in the regular budget allotment in 2024, which had been affected by the liquidity challenges faced by the United Nations. The 2024 allotment of 60 per cent of the regular budget allocation for non-staff implementation costs had allowed the minimum resources necessary to prepare, organize and hold the seventy-first session of the Committee in accordance with its mandate. The Committee welcomed the voluntary financial support and in-kind contributions of 16 member States who had funded their travel to attend the seventy-first session in those exceptional circumstances.

36. While the Scientific Committee acknowledged that the contributions made to the general trust fund by six Member States[19] had allowed work to progress in a number of areas, such a method of funding continued to be neither predictable nor sustainable. The Committee welcomed General Assembly resolution 78/71, in particular paragraph 23, in which the Assembly requested the Secretary-General to strengthen support for the secretariat of the Committee. The availability of the increased regular budget allocation for 2024, and of increased allocations in the future, is essential for enabling the secretariat to provide adequate and efficient long-term services to the Committee in a predictable, sustainable and independent manner. The resource requirements for the Committee's work have increased owing to the ever-increasing amount of literature to be covered and the more formal methods adopted for evaluation.

37. The Scientific Committee agreed to hold its seventy-second session in Vienna from 16 to 20 June 2025.

[18] See General Assembly resolutions 77/119, 78/71 and 78/254 A.

[19] Australia, Austria, Belgium, Germany, Norway and Spain.

Chapter III

Scientific reports

38. The following two scientific annexes were approved by the Scientific Committee at its seventy-first session: (a) second primary cancer after radiotherapy; and (b) evaluation of public exposure to ionizing radiation.

A. Second primary cancer after radiotherapy

39. At its seventy-first session, the Scientific Committee reviewed and approved for publication the annex on second primary cancer after radiotherapy. The conclusions reached by the Committee in that annex are summarized as follows:

(a) Ionizing radiation has been used to treat cancer for over a century. Treatment using radiation, which is primarily delivered through external beam technologies, comprises approximately 50 per cent of all cancer treatments. In general, 40 per cent of all cured cancer patients received radiotherapy as part of their treatment. As a result of improvements in cancer screening, treatment options and treatment efficacy, global cancer survival rates have increased, leading to an ever-expanding world population of cancer survivors;

(b) The evolution of radiotherapy and imaging has allowed better targeting of tumouricidal doses to the tumour and reductions in doses to surrounding tissues. Nevertheless, some undesired radiation doses are still delivered to surrounding tissues and organs. Efforts to characterize and quantify radiation doses close to and at a distance from the primary tumour are necessary to improve treatment and facilitate future epidemiological analyses of second primary cancer risk. Although it is generally understood that, for a given radiation dose, children are generally at more risk of tumour induction than are adults, more study is required to fully understand the combined and independent effects of age at exposure and attained age;

(c) As cancer survival rates improve, a growing number of individuals are now living well beyond the completion of their primary cancer treatments. While a primary cancer relapse or metastatic spread is a main concern in the years immediately following treatment, a second primary cancer becomes an important issue in the long-term. Cancer survivors have a higher risk of developing a new primary cancer than does the general population. Contributors to this higher risk include genetic susceptibility to cancer development, behavioural and environmental factors, and treatment components such as chemotherapy and radiotherapy;

(d) It is important to note that second primary cancers causally linked to radiation exposure represent only a fraction of all second primary cancers, even in patients treated with radiotherapy. Only rarely, for a specific tumour type, is radiation an attributable cause with high probability (e.g. in the case of sarcomas arising in areas exposed to high radiation doses);

(e) To obtain information on risks of second primary cancer after radiotherapy, an extensive literature search was conducted, and a meta-analysis was performed on haematopoietic tissues, connective tissues, female breasts, lungs, gastrointestinal organs, thyroid and brain. Information on radiation-related cumulative second primary cancer rates and associated latency periods was also reviewed;

(f) The meta-analysis yielded risks per unit dose, which were then compared with cancer risks per unit dose from other radiation epidemiological studies, such as those based on data from Japanese atomic bomb survivors. The calculated excess relative risks per unit dose, derived from the meta-analyses of the seven second primary cancer sites, were generally lower than the risks reported in other types of radiation epidemiological studies. For sarcoma (connective tissues), such comparisons are statistically compatible. For thyroid cancer, statistical compatibility depends on the choice of the comparison study. For other sites (haematopoietic

tissues, female breasts, lungs, gastrointestinal organs and brain), the pooled estimates of risks from the radiotherapy cohorts are in general statistically significantly smaller than the corresponding risks from radiation studies of cohorts not subject to radiotherapy;

(g) On the basis of the relevant literature, the Committee is aware that between 5 and 15 per cent of cancer survivors may develop a second primary cancer. However, the Committee considered that only a small proportion of the total second primary cancers were likely to be attributable to radiotherapy. The annex on second primary cancer after radiotherapy has refined the Committee's general understanding of how many of the total second primary cancers can be attributed to radiotherapy. The absolute numbers depend upon the specific tissues at risk and the radiation doses received during radiotherapy treatment. In view of the significant benefit of radiotherapy, cancer patients should not be dissuaded from undergoing radiotherapy solely on the basis of concerns regarding the possible development of a second primary cancer. Nevertheless, the future design and development of radiotherapy should involve dedicated efforts to reduce second primary cancer induction.

B. Evaluation of public exposure to ionizing radiation

40. The Scientific Committee has conducted an evaluation of worldwide levels of, and trends in, public exposure to natural and human-made sources of radiation based on three sources: (a) data from the UNSCEAR global survey on public exposure; (b) reviews and analyses published in peer-reviewed literature since 2007; and (c) data from regional and international organizations. The evaluation was critically dependent on the availability of reliable national data. The Committee expressed its gratitude to the national contact persons in 61 Member States and the other national experts who were involved in collecting, submitting and checking national data. The Committee emphasized that Member States' efforts were needed in the future to maintain and further extend the Committee's network of national contact persons and improve reporting of public exposure data for enhanced quality and reliability of future evaluations of sources and levels of exposure to ionizing radiation, as well as to improve geographical representation in the datasets.

41. Internal exposure of the public to natural radiation sources arises from inhalation of radon and thoron and their decay products, and ingestion of uranium and thorium series radionuclides and potassium-40. External exposures arise from cosmic radiation and terrestrial radionuclides. On the basis of a large number of measurements of radionuclide concentrations in soil, air and food samples taken in many countries of the world, global average annual doses from natural radionuclides were estimated. Exposure from industries involving naturally occurring radioactive materials was assessed either on the basis of data on radionuclide discharges from facilities, provided through the global survey on public exposure, or on the basis of published papers and reports.

42. While radiation protection is not in the mandate of the Scientific Committee, the Committee uses, for practical and pragmatic reasons, the radiation protection quantities introduced by ICRP and the International Commission on Radiation Units and Measurements. These quantities are used and reported by Member States and have been used in previous UNSCEAR reports. The quantities have changed over time.

43. Exposures from radon and thoron were calculated using the same dose coefficients provided in previous UNSCEAR reports,[20] in accordance with the

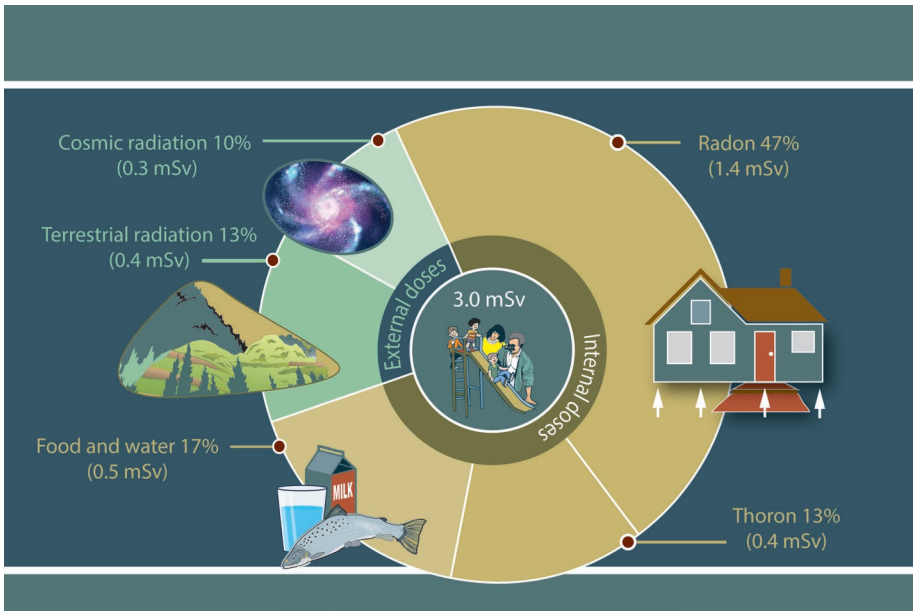
[20] *Sources, Effects and Risks of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation 2000 Report to the General Assembly with Scientific Annexes*, vol. I (United Nations publication, 2000), annexes A and B; and *Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2008 Report*, vol. I, annex B.

Scientific Committee's recent review.[21] Other components of public exposure were evaluated using dose coefficients currently used by ICRP.[22]

44. The range of the average annual effective dose to the public from natural radiation sources was estimated to be 1–14 millisieverts (mSv). That range remained consistent with previous estimates of 1–13 mSv.[23] In the scientific annex on evaluation of public exposure to ionizing radiation, the global annual average effective dose from natural sources was estimated to be about 3.0 mSv, of which the major contribution (60 per cent) was from inhalation of radon, thoron and their decay products, which represented about 1.8 mSv (see the figure below). The ingestion of uranium and thorium series radionuclides and potassium-40 represented a smaller contribution, of about 0.5 mSv. External exposure to terrestrial radionuclides and cosmic radiation contributed 0.40 mSv and 0.30 mSv, respectively.

45. While the estimate of the global annual average effective dose has changed from 2.4 mSv, provided in previous reports,[24] this change does not necessarily reflect an actual change in public exposure. It reflects methodological improvements and a greater diversity in the data available from different locations and regions, which were not available for previous Committee estimates. This has had the resultant effect of a changed global average value. For example, the updated estimates of exposure to radon and its decay products are now more robust, covering over 60 per cent of the world's population, whereas the previous estimate reflected less than 40 per cent of the world's population.

Global average annual effective dose from natural sources



Source: Adapted from UNEP, *Radiation: Effects and Sources.* Copyright 2016 by UNEP.

46. Compared with natural sources, exposure of the public from human-made sources is generally lower, except in the rare situation of major accidents.

47. Exposures to the public as a consequence of nuclear power production were evaluated on the basis of discharge information and by means of the assessment

[21] *Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2019 Report*, annex B.

[22] N. Petoussi-Henss and others, "ICRP Publication 144: dose coefficients for external exposures to environmental sources", *Annals of the ICRP*, vol. 49, No. 2 (October 2020) and K. Eckerman and others, "ICRP Publication 119: compendium of dose coefficients based on ICRP Publication 60", *Annals of the ICRP*, vol. 42, No. 4 (August 2013).

[23] *Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2000 Report*, vol. I, annexes A and B; and *Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2008 Report*, vol. I, annex B.

[24] *Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2000 Report*, vol. I, annexes A and B; and *Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2008 Report*, vol. I, annex B.

methodology from the UNSCEAR 2016 report,[25] with some minor modifications. While the Scientific Committee has updated its estimates of public exposure from electricity generated from nuclear power sources, it has not updated its evaluation of exposures from other forms of electricity-generating technologies, including those based on the combustion of coal, natural gas, oil and biofuels and on geothermal, wind and solar power, as reported in the UNSCEAR 2016 report. In that report, it was noted that, when considering the amount of electricity generated in the year 2010 by each technology, the coal cycle had resulted in the largest collective dose to the global public and workers combined, followed by the nuclear fuel cycle.

48. Estimated annual doses to members of the public from nuclear power production facilities generally did not exceed a few tens of microsieverts. The results were slightly higher than those presented in the UNSCEAR 2016 report,[26] owing to the use of updated discharge data and population distribution information, and the application of an approach that took into account differences in the age-related dose coefficients and the proportion of different age groups in the population.

49. The worldwide collective effective dose per unit of electricity generated from nuclear power plants, and from uranium mining and milling, was estimated and is presented in the annex on evaluation of public exposure to ionizing radiation.

50. On the basis of an analysis of data on public exposures from other applications of sources of ionizing radiation, including incidental exposures resulting from medical, industrial and research applications, and from the use of consumer products and other goods, it was concluded that average worldwide annual doses from those sources ranged from a few microsieverts to several hundred microsieverts. Such exposures, however, have affected a large proportion of the world population.

51. In the period since the publication of the UNSCEAR 2008 report,[27] estimates of past and current public exposure at nuclear weapons test sites have been updated at Marshall Islands; Mururoa and Fangataufa, French Polynesia (France); New Mexico, United States of America; and the Semipalatinsk region of Kazakhstan. Past exposures at many of those sites were estimated to have been well above natural background levels, immediately following the tests, and there remains the potential for significant exposures in certain circumstances. However, continuing public exposures at those sites have been found to be generally much lower than those from natural background radiation.

52. Public exposure relating to the legacy of other military applications of nuclear and radioactive material, such as nuclear weapons production, maintenance and decommissioning, was found to be generally negligible, except for the radiological consequences of major accidents.

53. The Scientific Committee has previously published detailed reports relating to the accidents that occurred at the Chornobyl nuclear power plant in 1986 and the Fukushima Daiichi nuclear power plant in 2011. In the affected areas, there has been a continuous reduction of radionuclide levels in soil, air, water bodies, vegetation and foodstuffs, owing to radionuclide decay and migration within ecosystems and to environmental countermeasures in those areas. Doses to members of the public residing in those areas have decreased accordingly, and current annual doses to members of the public residing in the areas surrounding the Chornobyl nuclear power plant, in areas of Belarus, the Russian Federation and Ukraine, range from tens of microsieverts to a few millisieverts. In the area of the Fukushima Daiichi nuclear power plant, current annual doses to residents in non-evacuated municipalities range from a few microsieverts to 0.3 mSv. Since late 2023, treated water has been routinely discharged from the Fukushima Daiichi nuclear power plant site. Those releases commenced after the submission period for data to be considered in this current evaluation had closed. The Committee has acknowledged that data from environmental

[25] *Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2016 Report*.
[26] Ibid.
[27] *Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2008 Report,* vol. I, annex B.

monitoring and assessments are now available. Those data and any subsequent publications in the scientific literature will be monitored under the Committee's ongoing programme of work and considered for inclusion in a future evaluation.

54. A comprehensive uncertainty analysis of public exposures could not be included in this evaluation of public exposure, owing to the nature of the available data. Descriptive statistics were used to quantify the distributions of the environmental activity concentrations and public exposures, where possible. However, an updated methodology to quantify uncertainties and variabilities in dose assessments has been proposed to guide future evaluations.

55. Databases of relevant data have been created by various international organizations, including the Scientific Committee. The success of such efforts depends on the voluntary submission by Member States of annual and other reports and relevant data. Ensuring wide geographical representation in the Committee's future reports will depend on Member States' greater involvement in such activities.

Appendix I

Members of national delegations attending the sixty-sixth to seventy-first sessions of the United Nations Scientific Committee on the Effects of Atomic Radiation in the preparation of its scientific reports for 2024

Algeria	S. Chelbani (Representative), Z. Lounis Mokrani (Representative), M. Ait-Ziane, D. T. Errahmani, A. Merad, M. Mezaguer
Argentina	A. J. González (Representative), D. Álvarez, A. Cánoba, M. Di Giorgio, M. G. Ermácora, A. E. Rossini
Australia	G. Hirth (Representative), C. Lawrence, S. Solomon, P. Thomas, I. Williams
Belarus	S. Sychyk (Representative), A. Stazharau (Representative), A. Ashurkevich, A. Avetisov, V. Drobyshevskaya, A. Nikalayenka, A. Rozhko, L. Sheuchuk, A. Yaumenenka
Belgium	S. Baatout (Representative), H. Vanmarcke (Representative), J. Vives i Batlle, G. Biermans, H. Bosmans, F. Dekkers, H. Engels, F. Jamar, M. Locquet, L. Mullenders, H. Slaper, P. Smeesters, P. Sonveaux, P. Willems
Brazil	L. Vasconcellos de Sá (Representative), D. de Souza Santos, P. Rocha Ferreira
Canada	J. Chen (Representative), D. Bracken Chambers, J. Burtt, P. Demers, J. Gaskin, R. Lane, K. Sauvé, B. Thériault, R. Wilkins
China	S. Liu (Representative), L. Chen, L. Dong, Y. Fa, Y. Gu, H. Guan, M. Huang, Y. Li, X. Lin, L. Liu, Q. Liu, Sh. Liu, J. Luo, L. Ma, G. Song, Q. Sun, J. Wang, Y. Wang, Q. Wu, X. Xia, S. Xu, D. Yang, L. Yuan, P. Zhou
Egypt	M. R. Ezz El-Din (Representative), M.A.M. Gomaa (Representative), A. A. Abdelaal, T. M. Morsi
Finland	A. Auvinen (Representative), S. Salomaa (Representative), R. Bly, E. Salminen, T. Siiskonen
France	D. Laurier (Representative), L. Lebaron-Jacobs (Representative), Y. Billarand, V. Blideanu, J.-M. Bordy, S. Candéias, J. Guillevic, C. Huet, A. Isambert, S. Jacob, J.-R. Jourdain, D. Klokov, K. Leuraud, F. Ménétrier, G. Pina, S. Roch-Lefevre, M. Simon-Cornu, R. Tamarat, J. Thariat
Germany	A. Friedl (Representative), P. Jacob (Representative), S. Baechler, L. Brualla, C. Engelhardt, C. Fournier, F. Gering, U. Gerstmann, T. Jung, J. C. Kaiser, K. Kammerlander, M. Kreuzer, R. Michel, W.-U. Müller, S. Neveling, W. Rühm, U. Schneider, S. Tapio, L. Walsh, W. Weiss, D. Wollschlaeger, H. Zeeb
India	A. Ghosh (Representative), S. K. Jha (Representative), A. Vinod Kumar (Representative), B. Das
Indonesia	N. R. Hidayati (Representative), E. Hiswara (Representative), T. Handayani, E. Kunarsih, E. D. Nugraha, D. H. Nugroho, T.B.M. Permata, H. Prasetio, N. Rahajeng, I. Untara
Iran (Islamic Republic of)	M. R. Kardan (Representative), K. Akbarzadeh, A. Rahimi Khoshmakani

Japan	M. Akashi (Representative), R. Kanda (Representative), T. Nakano (Representative), K. Akahane, K. Furukawa, T. Iwasaki, I. Kawaguchi, M. Kowatari, K. Ozasa, K. Tani, S. Yoshinaga
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Norway	C. Robinson (Representative), P. Strand (Representative), K. Gulliksrud, L. K. Juvet, D. Oughton
Pakistan	R. A. Khan (Representative), M. Usman (Representative)
Peru	P. Fuentes Rivera Carmelo (Representative), A. Lachos Dávila (Representative), V. A. Muñante
Poland	M. Waligórski (Representative), L. Dobrzyński, K. Fornalski, M. Janiak, D. Kluszczyński, M. Kruszewski, P. Olko, J. Welsh
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Ukraine	D. Bazyka (Representative)
United Arab Emirates	A. Al Shehhi (Representative), U. Al Bastaki, S. Al Mansoori, T. M. Almansoori
United Kingdom of Great Britain and Northern Ireland	S. Bouffler (Representative), A. Bexon, R. Haylock, R. Wakeford, W. Zhang
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Appendix II

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U. Schneider	K. Thiessen	L. Walsh

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A. Auvinen, Rapporteur (Finland)	L. Lebaron-Jacobs, Rapporteur (France)
Z. Lounis Mokrani (Algeria)	M. Di Giorgio (Argentina)
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N. Hidayati (Indonesia)	K. Ozasa (Japan)
K. M. Seong (Republic of Korea)	A. Akleev (Russian Federation)
V. Ivanov (Russian Federation)	A. Hernández Álvarez (Spain)
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D. Pawel (United States)	G. Woloschak (United States)

Members of the Committee's ad hoc working group on sources and exposure at the sixty-sixth to seventy-first sessions

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A. Ansari, Rapporteur (United States)	P. Thomas (Australia)
D. de Souza Santos (Brazil)	S. Liu (China)
U. Gerstmann (Germany)	A. Kryshev (Russian Federation)
S. Romanov (Russian Federation)	A. Almén (Sweden)
P. Hofvander (Sweden)	A. Al Shehhi (United Arab Emirates)
J. Alsuwaidi (United Arab Emirates)	A. Bexon (United Kingdom)
V. Holahan (United States)	

Secretariat of the United Nations Scientific Committee on the Effects of Atomic Radiation

B. Batandjieva-Metcalf (sixty-sixth to seventy-first sessions)

F. Shannoun (sixty-sixth to seventieth sessions)

M. Zimmermann (sixty-seventh to seventy-first sessions)

L. Beaton (sixty-ninth and seventy-first sessions)

J. Burtt (sixty-eighth and sixty-ninth sessions)

K. Randhawa (seventieth and seventy-first sessions)

A. Gaw (sixty-eighth session)

N. Bushra (seventieth and seventy-first sessions)