A/76/46 Part 1

United Nations

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

Sixty-seventh session
(2–6 November 2020)

General Assembly

Official Records
Seventy-sixth session
Supplement No. 46

General Assembly
Official Records
Seventy-sixth session
Supplement No. 46

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

Sixty-seventh session
(2–6 November 2020)

United Nations • New York, 2021

Note

Symbols of United Nations documents are composed of letters combined with figures. Mention of such a symbol indicates a reference to a United Nations document.

ISSN 0255-1373

[10 February 2021]

Contents

Chapter I

Introduction

1. Since the establishment of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) by the General Assembly in its resolution 913 (X) of 3 December 1955, the mandate of the Committee has been to undertake broad assessments of the sources of ionizing radiation and its effects on human health and the environment.[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 assessments provide the scientific foundation used, inter alia, by the relevant agencies of the United Nations system in formulating international standards for the protection of the general public, workers and patients against ionizing radiation;[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 in the Earth) and from sources with an artificial origin (such as medical diagnostic and therapeutic procedures; radioactive material resulting from nuclear weapons testing; energy generation, including by means of nuclear power; unplanned events such as the nuclear power station accident at Chernobyl in April 1986 and that following the great east-Japan earthquake and tsunami of March 2011; and workplaces where there may be increased exposure to artificial or naturally occurring sources of radiation).

[1] The United Nations Scientific Committee on the Effects of Atomic Radiation 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 Scientific Committee was originally composed of the following States Members of the United Nations: 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) of 14 December 1973 to include the Federal Republic of Germany (later succeeded by Germany), Indonesia, Peru, Poland and the Sudan. By its resolution 41/62 B of 3 December 1986, the General Assembly increased the membership of the Committee to 21 members and invited China to become a member. In its resolution 66/70, the General 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.

[2] For example, the International Atomic Energy Agency (IAEA) safety standard entitled *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards – General Safety Requirements Part 3*, co-sponsored by the European Commission, the Food and Agriculture Organization of the United Nations (FAO), IAEA, the International Labour Organization (ILO), the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (NEA/OECD), the Pan American Health Organization (PAHO), the United Nations Environment Programme (UNEP) and the World Health Organization (WHO).

Chapter II

Deliberations of the United Nations Scientific Committee on the Effects of Atomic Radiation at its sixty-seventh session

3. The Scientific Committee held its sixty-seventh session online from 2 to 6 November 2020.[3] The following served as officers of the Committee: Gillian Hirth (Australia), Chair; and Jing Chen (Canada), Anna Friedl (Germany) and Jin Kyung Lee (Republic of Korea), Vice-Chairs; and Anssi Auvinen (Finland) was elected as Rapporteur for the sixty-seventh session.

4. The Scientific Committee took note of and discussed General Assembly resolution 74/81 on the effects of atomic radiation, in which the Assembly, inter alia: (a) requested the United Nations Environment Programme (UNEP) to continue, within existing resources, to service the Committee and to disseminate its findings to Member States, the scientific community and the public and to ensure that the administrative measures in place are appropriate, including clear roles, so that the secretariat is able to adequately and efficiently service the Committee in a predictable and sustainable manner and effectively facilitate the use of the invaluable expertise offered to the Committee by its members in order that the Committee may discharge the responsibilities and mandate entrusted to it by the General Assembly; (b) welcomed the appointment of a new Secretary of the Committee by UNEP and urged UNEP to ensure that future recruitment processes are conducted in an efficient, effective, timely and transparent manner; (c) welcomed the establishment of the post of Deputy Secretary, which replaces the previous post of Scientific Officer, allows for the deputization of the Deputy Secretary as Secretary as appropriate and assists in the avoidance of disruptions in staffing; and (d) requested the Secretary-General to strengthen support for the Committee within existing resources, particularly with regard to the increase in operational costs in the case of a further increase in membership, and to report to the General Assembly at its seventy-fifth session on those issues.

5. In regard to points (c) and (d) above, the Scientific Committee's normal operation had been impacted by the coronavirus disease (COVID-19) pandemic. The Committee welcomed the establishment of the position of Deputy Secretary. However, the COVID-19 pandemic resulted in a delay in the appointment of an officer to the position of Deputy Secretary of the Committee, as the United Nations had implemented a recruitment freeze for all regular budget-funded United Nations posts. In addition, the Committee was unable to hold its sixty-seventh session in July 2020 as originally planned and postponed the session until 2–6 November 2020, when it was held online. Since it would not be timely to report to the General Assembly after the planned sixty-seventh session in November 2020, it was decided to report on the Committee's intersessional activities by means of a note by the Chair of the Committee (A/75/46) and an oral report before the conclusion of the seventy-fifth session of the General Assembly.

6. In regard to points (a), (b) and (c) above, the Scientific Committee heard a statement from the representative of UNEP, who acknowledged and thanked the Committee for its continued work and progress during the COVID-19 pandemic. He explained the budget difficulties leading to the freeze of all recruitments for posts under the United Nations regular budget, which had halted the recruitment of a Deputy Secretary for the Committee, and noted that UNEP was committed to

[3] The sixty-seventh session of the Scientific Committee was attended by 212 participants from 27 States members of the Committee, observers for Algeria, Iran (Islamic Republic of), Norway and the United Arab Emirates, in accordance with paragraph 23 of General Assembly resolution 74/81, and observers for the Comprehensive Nuclear-Test-Ban Treaty Organization, the European Union, the International Agency for Research on Cancer, IAEA, the International Commission on Radiation Units and Measurements, the International Commission on Radiological Protection (ICRP), FAO, ILO, NEA/OECD, UNEP and WHO.

completing the appointment of a Deputy Secretary for UNSCEAR as soon as the regular budget freeze was resolved. He expressed appreciation for the contributions to the UNSCEAR General Trust Fund that had been received from Australia, Belgium, Germany, Japan and Spain. The Committee also heard a statement from the representative of Indonesia. Issues raised by the Committee are reported in chapter II, section E ("Administrative issues").

A. Completed evaluations

7. The Scientific Committee discussed three scientific annexes to the present report (see chapter III), agreed on their findings and requested that the three scientific annexes be published in the usual manner, subject to the modifications agreed upon, and final adoption be conducted using a silence procedure due to the COVID-19 pandemic, as that procedure had been adopted by the Committee for use at the sixty-seventh session.

8. At its sixtieth session, the Scientific Committee had endorsed the plan for the collection and evaluation of data on medical exposure. Given that radiation exposures of patients worldwide are the main artificial source of human exposure to ionizing radiation, that there has been a continuing upward trend in collective doses to populations and that the pace of technological development in this field continues to accelerate, the Committee's regular evaluations of collective doses to populations and trends continue to be an important priority.

9. As at 30 September 2019, 58 countries had submitted data on medical exposures, and the Scientific Committee recognized the efforts of the expert group on medical exposure in carefully and systematically reviewing the submitted data and working with national contact persons to clarify any ambiguities.[4] The Committee discussed and approved for publication the scientific annex on the evaluation of medical exposure to ionizing radiation.

10. At its sixty-fifth session, the Scientific Committee considered the project plan to produce an update to annex A of the UNSCEAR 2013 report.[5] The aim was to produce a report summarizing all information that was available by the end of 2019, on levels and effects of radiation exposure due to the accident at the Fukushima Daiichi nuclear power station, and the implications of the new information for the UNSCEAR 2013 report. At its sixty-sixth session, the Committee endorsed having a more focused scope of the detailed analyses of doses to the public and concurred that the outreach material on issues of considerable media or public interest should be dealt with separately, as part of the secretariat's outreach plan. At its sixty-seventh session, the Committee discussed and approved for publication the scientific annex on the levels and effects of radiation exposure due to the accident at the Fukushima Daiichi nuclear power station: implications of information published since the UNSCEAR 2013 report.

11. At its sixty-third session, the Scientific Committee decided to compile an up-to-date overview of the following: up-to-date knowledge of biological mechanisms by which radiation influences the development of disease, in particular at low incremental doses and low dose rates; the implications for the dose-response relationships for health effects at low doses; and thus the relevance for estimating associated risks to health, as well as the relevance for the inference of cancer risks. An expert group was established that submitted progress reports to the Committee for consideration at its sixty-fourth, sixty-fifth and sixty-sixth sessions. At its sixty-seventh session, the Committee discussed and approved for publication the

[4] To put this in perspective, 58 countries is a small number of the total of 193 States Members of the United Nations.

[5] *Sources, Effects and Risks of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation 2013 Report to the General Assembly*, vol. I (United Nations publication, 2014), annex A.

scientific annex on the biological mechanisms relevant for the inference of cancer risks from low-dose and low-dose-rate radiation.

B. Present programme of work

12. The Scientific Committee took note of the progress report by the secretariat on the collection, analysis and dissemination of data on radiation exposures of the public, patients and workers, obtained from reviews of the scientific literature and the data submissions by Member States. The Committee recognized the efforts of the secretariat in: (a) conducting outreach about the global surveys, which has contributed to an increased number of nominations of national contact persons; and (b) supporting the production of a simplified questionnaire to assist in the preparation of data submissions, which has had a positive impact on the number of submissions on public, medical and occupational exposures. As at 30 September 2020, 90 countries had nominated national contact persons for public exposure; 87 countries in the field of medical exposure; and 68 countries in the field of occupational exposure. Although this is a significant increase in participation in recent years, more participation and contributions by Member States would be useful to ensure that the data are representative.

13. The Scientific Committee expressed its continued support for the creation of a network of national contact persons, using the UNSCEAR online platform as a tool for communication among them for exchanging experiences on the process of data collection. It also encouraged States Members of the United Nations to provide data on medical, occupational and public exposures and encouraged continued future cooperation of the Committee's secretariat with Member States and relevant international organizations, in particular in the new UNSCEAR Global Survey of Public Exposure, planned to commence in December 2020.

14. The Scientific Committee also noted that future evaluations of medical exposures should focus on motivating Member States not represented in the present global assessment to submit essential information. Actions should target, in particular, countries with developing levels of health care and those with large populations because those countries are potentially significant contributors to global medical exposure practice. A regional approach that facilitates data collection for the assessment of population dose could form the basis for surveys in regions whose countries have similar health and economic indicators, such as in Africa, Asia and Latin America; that regional approach could include training and support on data collection and evaluation for national contact persons. Data collection could be focused on the types of examinations that contribute most to the overall population dose, which could help to increase future participation in the UNSCEAR Global Survey of Medical Exposure.

1. Occupational exposure to ionizing radiation

15. The Scientific Committee's evaluations of worldwide occupational exposure to ionizing radiation provide information relevant for policy and decision-making regarding the use and management of radiation. The resulting dose distributions and trends give insight into the main sources and situations of exposure and provide information about the main factors influencing exposures. The evaluations assist in identifying emerging issues and may indicate situations that should be subjected to more attention and scrutiny.

16. The Scientific Committee has conducted evaluations of worldwide occupational exposure and trends on the basis of two sources: (a) data from the UNSCEAR Global Survey of Occupational Exposure; and (b) reviews of analyses published in peer-reviewed literature. At its sixty-sixth session, the Committee agreed to extend the deadline for data collection to 30 September 2019. This resulted in data being submitted by an additional 18 countries between April 2019 and October 2020.

17. The Scientific Committee acknowledged the work of the expert group in conducting its systematic review of the literature and that the work of the expert group had been delayed by one year owing to both the insufficient data provided by Member States and the extended quality checks and corrections of available data. The report on the evaluation of occupational exposure to ionizing radiation is envisaged to be prepared for approval for publication at the Committee's sixty-eighth session, in June 2021.

2. Public exposure to ionizing radiation

18. The Scientific Committee recalled that at its sixty-fourth session, the proposal to evaluate public exposure to ionizing radiation had been discussed. The Committee decided at that time to postpone project initiation until its evaluation of lung cancer from exposure to radon had been completed. At its sixty-sixth session, the Committee decided to commence its evaluation of public exposure to ionizing radiation, including quality criteria for sources and exposure.

19. The Scientific Committee noted the commencement of the evaluation in 2020 and discussed the progress report. It recognized the progress made and agreed the proposed revised plan for completion in 2024. The Committee noted the increased importance and broad interest in this new evaluation, which will review and analyse scientific information since 2007. As of October 2020, 36 experts from 17 Member States and observers from four international organizations were working on the update of the methodologies to be applied and the literature review.

20. The Scientific Committee encouraged all Member States to participate and respond to the UNSCEAR Global Survey of Public Exposure that is planned to commence at the end of 2020.

3. Second primary cancer after radiotherapy

21. At its sixty-third session, the Scientific Committee considered the issue of second primary cancer after radiotherapy and discussed preliminary plans to launch a project based on a proposal by the delegation of France. After further discussions at the sixty-fourth session, the Committee reached agreement at its sixty-fifth session on a project plan to evaluate second primary cancer after radiotherapy, emphasizing that while the project was a priority, the work could not be started until after the appointment of the new Secretary. At its sixty-sixth session, the Committee endorsed the plan presented by the expert group for initiating the work in late 2019 and requested that the expert group provide a progress report at its sixty-seventh session, including a first selection of literature on second primary cancer after radiotherapy, an updated timetable and an advanced table of contents.

22. At its sixty-seventh session, the Scientific Committee took note of the launch of the evaluation in 2019 and of the progress made to date and agreed with the updated timetable for completion. That progress report included a description of the literature research process and an update of the table of contents to include risk projections based on patient-specific organ doses, meta-analyses to provide site-specific pooled risk estimates and an assessment of the quality of dosimetry reporting. The expert group will provide a progress report at the next session.

4. Epidemiological studies of radiation and cancer

23. At its sixty-third session, the Scientific Committee discussed a preliminary plan to provide a comprehensive scientific review of epidemiological studies of radiation and cancer to update annex A of the UNSCEAR 2006 report.[6] The Committee agreed at its sixty-fifth session to initiate the comprehensive scientific review after both the appointment of the new Secretary and the initiation of the project on second primary cancer after radiotherapy are finalized.

[6] *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.

24. At its sixty-sixth session, the Scientific Committee approved the project plan, requesting that the final report also include a summary written in language that could be understood by members of the public. The Committee noted that the expert group would commence work in the third quarter of 2019 and requested that the expert group provide a progress report at its sixty-seventh session, including a first selection of literature on epidemiological studies on radiation and cancer, an updated timetable and an advanced table of contents.

25. At its sixty-seventh session, the Scientific Committee took note of the launch of the project in 2019 and the progress report on the project. That report included a description of the literature search process and a revised workplan in which a report would be submitted for approval in 2024. The Committee confirmed that the evaluation should be limited to cancer and not consider other health effects.

5. Public information and outreach strategy (2020–2024)

26. At its sixty-sixth session, the Scientific Committee endorsed the secretariat's proposal for a new strategy on outreach activities for the period 2020–2024. The latter complements the secretariat's planned outreach activities on the update of annex A of the UNSCEAR 2013 report on the levels and effects of radiation exposure due to the accident at the Fukushima Daiichi nuclear power station.

27. At its sixty-seventh session, the Scientific Committee took note of a progress report of the secretariat on the implementation of outreach activities in the period 2020–2024. That report included a summary of: (a) ongoing and future activities for the dissemination of the Committee's findings to a broader audience; (b) the strengthening of collaboration and development of framework agreements with international organizations; and (c) improvement of the UNSCEAR website (including its translation into all official languages of the United Nations). The Committee acknowledged the postponement of outreach activities on the update of the UNSCEAR 2013 report due to the COVID-19 situation and encouraged close collaboration with international organizations to further promote the Committee's findings. It also took note of the plans of the secretariat related to the celebration of the sixty-fifth anniversary of UNSCEAR in 2021 and noted that the dissemination of the Committee's findings[7] is increasingly dependent on the availability of extrabudgetary funds.

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

28. At its sixty-sixth session, the Scientific Committee approved its long-term strategic directions and plan for the period 2020–2024. That plan included the following:

(a) Establishing working groups focused on sources and exposure, and effects and mechanisms;

(b) Inviting, on an ad hoc basis, scientists from other States Members of the United Nations to participate in the Committee's evaluations;

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

[7] For example, the translation of the UNEP booklet entitled *Radiation: Effects and Sources* and participation in international events such as the International Conference on a Decade of Progress After the Fukushima-Daiichi: Building on the Lessons Learned to Further Strengthen Nuclear Safety, originally to be held on 22–25 February 2021 and now rescheduled for 8–12 November 2021.

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

(a) Establishing working groups focused on the areas of sources and exposure, and effects and mechanisms

29. At its sixty-sixth session, the Scientific Committee: (a) established the ad hoc working group on sources and exposure; and (b) prolonged the activities of the ad hoc working group on effects and mechanisms until the Committee's sixty-seventh session in 2020, in order to finalize the proposal for the future programme of work on effects and mechanisms of radiation exposure for the period 2020–2024.

30. Bearing in mind the high-quality, important work conducted by the ad hoc working group on effects and mechanisms in developing the Scientific Committee's future programme of work (2020–2024), the Committee, at its sixty-seventh session, extended the mandate of the ad hoc working group on effects and mechanisms for one year to support and monitor progress in the implementation of the programme of work and to evaluate new scientific developments relevant for the Committee at its sixty-eighth session in 2021.

31. At its sixty-seventh session, the Scientific Committee also acknowledged the high-quality, important work by the ad hoc working group on sources and exposure and endorsed the proposal for an extension of the work of the ad hoc working group on sources and exposure for one more year to continue support and guide the implementation of the processes for collection, analysis and dissemination of data on radiation exposures of the public, patients and workers. Both working groups will continue to consist of scientists selected for their competence, commitment and objectivity.

32. The Scientific Committee emphasized that, except for the administrative support from the secretariat, the extension of the work of the ad hoc working groups would incur no additional costs for the United Nations.

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

33. The Scientific Committee noted that the secretariat and the Bureau had taken steps to involve scientists from other States Members[8] of the United Nations in supporting the secretariat in conducting ongoing evaluations. This is particularly relevant for the ongoing evaluation of public exposure to ionizing radiation from natural and other sources.

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

34. The Scientific Committee referred to the outreach activities reported in section B.5 above.

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

35. The importance of the Scientific Committee's findings in providing the scientific evidence upon which decisions are made by the international community and the safety standards are developed was also demonstrated in the period since the sixty-fifth session. The Committee noted that in 2020, UNSCEAR was invited to participate as an observer of the International Atomic Energy Agency (IAEA) Commission of Safety Standards and as a member of the Steering Committee of the

[8] Austria, Italy, Norway, Singapore and Switzerland.

Global Nuclear Safety and Security Network of IAEA. UNSCEAR is also cooperating with a number of organizations, including IAEA, the International Commission on Radiological Protection (ICRP) and the International Radiation Protection Association in relation to the dissemination of the UNSCEAR 2020 report on the Fukushima accident. In addition, the 2019 report of the Secretary-General highlighted the importance of the Committee's work for the scientific evaluation of radiation exposure and the health effects of the Chernobyl accident.[9]

36. The Scientific Committee welcomed and supported the continued cooperation of the secretariat with the United Nations and other international organizations[10] 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.

D. Future programme of work

37. At its sixty-fifth session, the Scientific Committee established the ad hoc working group on effects and mechanisms. Since the sixty-fifth session, the ad hoc working group has collected and analysed the experience of and lessons learned by the Committee in recent years and developed a draft future programme of work for the period 2020–2024, which was first discussed by the Committee at its sixty-sixth session. The ad hoc working group on effects and mechanisms also supported the Bureau and the secretariat in monitoring progress on the current projects and in evaluating new scientific developments that occurred between the sessions, for consideration by the Committee.

38. At its sixty-seventh session, the Committee reviewed the draft future programme of work for the period 2020–2024 and agreed that priority should be given to evaluations already initiated or planned to be started in 2020. This includes an evaluation of diseases of the circulatory system from radiation exposure, which, due to the delay of the sixty-seventh session caused by the COVID-19 pandemic, is now planned to begin in 2021. In approving the new programme of work, the Committee agreed, in order to achieve a more balanced workload for the Committee and its secretariat, to follow a general principle of starting one evaluation per year. Therefore, the Committee is planning to initiate the evaluation of radiation effects on the nervous system in 2022 and the evaluation of eye lens opacities from radiation exposure in 2023. In 2024, however, to ensure thematic consistency, the evaluation of radiation effects on the immune system will start simultaneously with an overarching evaluation of non-cancer effects, which will include the following topics: acute radiation syndrome, respiratory disease, endocrine disease, transgenerational effects and other relevant non-cancer effects.

39. The Scientific Committee emphasized that timely programme implementation in the period 2020–2024 depends on having sufficient available resources in the secretariat. The Committee acknowledged the request of the Executive Director of UNEP for support in the form of financial contributions to the General Trust Fund.[11] Therefore, the Committee welcomed the contributions of five States members of the Committee and encouraged other Member States to make use of the possibility to strengthen the secretariat's capacity through regular voluntary contributions to the General Trust Fund and/or in-kind contributions, for example, experts working as non-reimbursable loans, junior professional officers or United Nations volunteers.

[9] See A/74/461.

[10] For example, UNEP, IAEA, the European Union, the International Civil Aviation Organization, NEA/OECD, the Inter-Agency Committee on Radiation Safety, the International Radiation Protection Association, ICRP and the International Commission on Radiation Units and Measurements.

[11] The programme for the UNSCEAR General Trust Fund for the period 2019–2021 has been prepared, and a note verbale in that regard has been sent to the Member States.

40. The Scientific Committee requested the two ad hoc working groups to develop a proposal for the scope and contents of a guidance document detailing the principles and criteria for ensuring the quality of the Committee's use of radiation protection quantities and units (including the use of collective effective doses), with a view to holding a discussion at the sixty-eighth session on how this guidance could be published in the future.

E. Administrative issues

41. The Scientific Committee took note of General Assembly resolution 74/81 on the effects of atomic radiation, in which the Assembly:

(a) Requested UNEP to continue, within existing resources, to service the Committee and to disseminate its findings to Member States, the scientific community and the public and to ensure that the administrative measures in place were appropriate, including clear roles, so that the secretariat is able to adequately and efficiently service the Committee in a predictable and sustainable manner and effectively facilitate the use of the invaluable expertise offered to the Committee by its members in order that the Committee might discharge the responsibilities and mandate entrusted to it by the General Assembly;

(b) Welcomed the appointment of a new Secretary of the Scientific Committee by UNEP and urged UNEP to ensure that future recruitment processes were conducted in an efficient, effective, timely and transparent manner;

(c) Welcomed the establishment of the post of Deputy Secretary, which replaces the previous post of Scientific Officer, allows for the deputization of the Deputy Secretary as Secretary as appropriate, and assists in the avoidance of disruptions in staffing;

(d) Requested the Secretary-General to strengthen support for the Committee within existing resources, particularly with regard to the increase of operational costs in the case of a further increase in membership, and to report to the General Assembly at its seventy-sixth session on those issues.

42. In considering the requests of the General Assembly, the Scientific Committee noted the statement by UNEP and strongly encouraged the finalization of the post of Deputy Secretary as soon as possible. The Committee also noted that the budget of the UNSCEAR secretariat was at its lowest level ever, and expressed concern about the Committee's ability to successfully implement its future programme of work, particularly with regard to the increase in the number of experts involved in the ongoing evaluations and the operational costs in the case of further membership. The Committee also noted the statement by the representative of Indonesia and welcomed the ongoing commitment of Indonesia to the Committee's work and outreach activities in that country.

43. The Scientific Committee acknowledged the significant effort of the Chair and secretariat to conduct the sixty-seventh session and adopted a procedure for taking decisions during the COVID-19 pandemic. The Committee also agreed to hold its sixty-eighth session in Vienna from 21 to 25 June 2021, or, if required to be online, an extension of the session duration will be considered, if necessary.

Chapter III

Scientific reports

44. The following three scientific annexes were approved by the Committee at its sixty-seventh session: (a) evaluation of medical exposure to ionizing radiation; (b) levels and effects of radiation exposure due to the accident at the Fukushima Daiichi nuclear power station: implications of information published since the UNSCEAR 2013 report; and (c) biological mechanisms relevant for the inference of cancer risks from low-dose and low-dose-rate radiation.

A. Evaluation of medical exposure to ionizing radiation

45. The Scientific Committee expresses its gratitude to the expert group which conducted the evaluation of medical exposure to ionizing radiation and to delegations for the technical discussions on this subject. The Committee also expresses its gratitude to the national contact persons and the national experts who were involved in collecting, submitting and checking the national data. Without reliable national data, it would not have been possible to conduct the evaluation. The Committee emphasizes that Member States' efforts are needed in the future to maintain and further extend the UNSCEAR network of national contact persons and improve reporting of medical exposure data for enhanced quality and reliability of future evaluations of sources and levels of exposure to ionizing radiation.

46. The Scientific Committee has considered the results of the evaluation of medical exposure in the light of its past UNSCEAR 2008 report[12] and has reached the following conclusions contained in paragraphs 47–53 below.

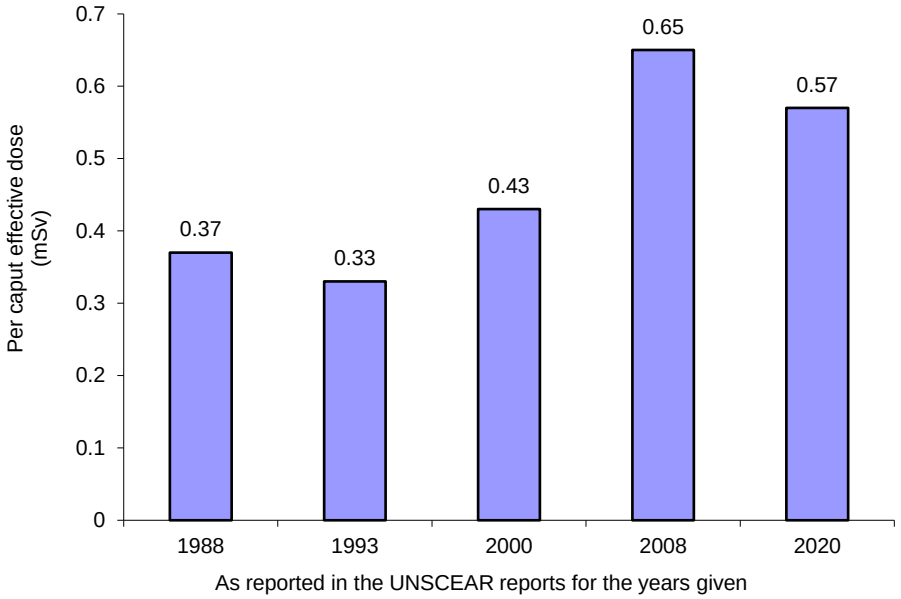
47. Medical exposure remains by far the largest human-made source of radiation exposure of the population. In the period 2009–2018, about 4.2 billion medical radiological examinations were performed annually. The collective effective dose was estimated to be 4.2 million man sieverts (man Sv) for the global population of 7.3 billion people, resulting in an effective dose per caput of 0.57 mSv (excluding radiotherapy). In addition, an estimated 6.2 million courses of radiation therapy treatment were performed each year, about 5.8 million by external beams and 0.4 million by brachytherapy. An estimated 1.4 million radionuclide therapy treatments were performed each year. Doses from radionuclide therapy and radiation therapy treatments were not included in the global estimate of collective effective dose, because effective dose is not an appropriate measure for these types of procedures. Uncertainties in the overall number of examinations and in the collective effective dose were estimated at ±30 per cent. The main sources of uncertainty were the gaps in the knowledge of both the number of examinations and the dose per examination, especially where no data were provided and modelled estimates were used instead, and the variations in dose per procedure both within and between countries.

48. The estimated annual effective dose per caput from medical radiological examinations has fallen slightly compared with the Committee's previous UNSCEAR 2008 report (from 0.65 to 0.57 mSv). The difference is, however, within the bounds of the estimated uncertainty. This trend stands in contrast to the trends observed in the previous two UNSCEAR reports, which showed notable increases (see figure I).

[12] *Sources and Effects 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), annexes A and B.

Figure I

Annual effective dose per caput from different UNSCEAR medical exposure evaluations

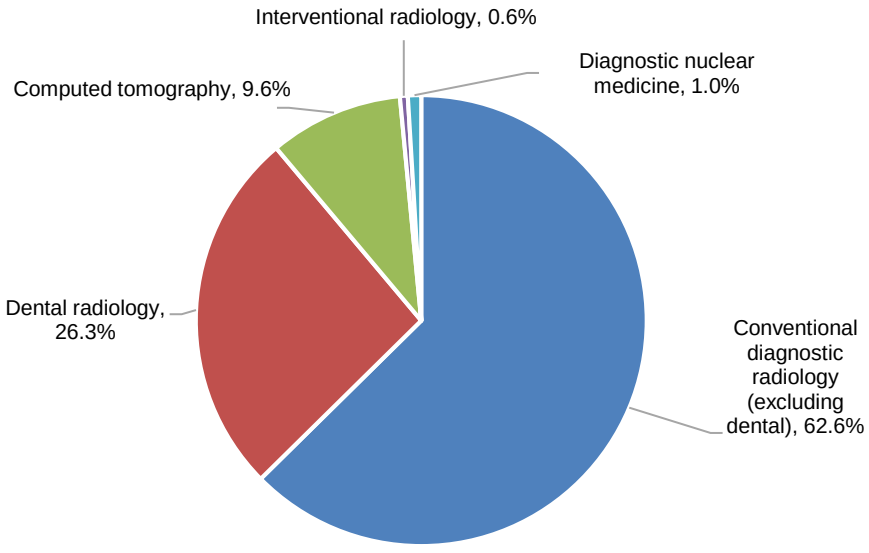


49. Conventional radiology (excluding dental examinations) accounts for 63 per cent of procedures and 23 per cent of the collective effective dose. Dental radiology accounts for 26 per cent of procedures, but only 0.2 per cent of the collective effective dose. Computed tomography makes the largest contribution (about 62 per cent) to the collective effective dose but accounts for only about 10 per cent of all procedures. Interventional radiology accounts for only 0.6 per cent of all procedures but contributes 8 per cent of the collective effective dose. Diagnostic nuclear medicine accounts for about 1 per cent of all procedures and about 7 per cent of the collective effective dose (see figure II).

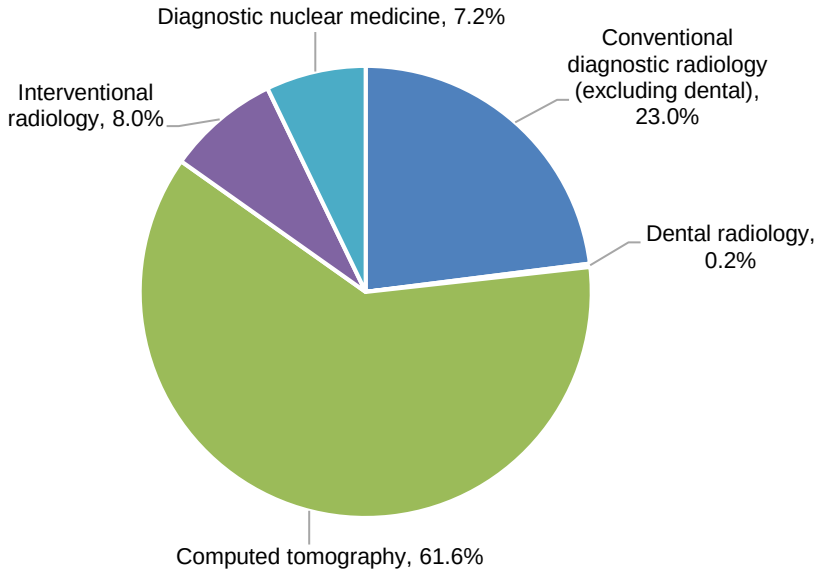
Figure II

Distribution of (a) examinations/procedures by imaging modality and their contribution to (b) the collective effective dose from medical exposures (excluding radiotherapy)

(a) Examinations/procedures



(b) Collective effective dose



50. The use of computed tomography has continued to expand and has replaced some of the older radiography and fluoroscopy examinations. The total number of computed tomography examinations has increased by about 80 per cent, and its contribution to the collective effective dose has increased from 37 per cent to 62 per cent. However, a major reduction has been reported in radiography and fluoroscopy examinations of the gastrointestinal tract (about 90 per cent), as well as a reduction in fluoroscopy examinations of the biliary and urinary systems and of the chest region. Overall, the number of conventional radiology examinations has decreased by 10 per cent, and the collective effective dose has fallen by 60 per cent. The contribution of interventional radiology procedures has increased considerably and now accounts for 8 per cent of the collective effective dose (compared with 1 per cent in the previous assessment), despite accounting for only 0.6 per cent of the total number of procedures. Nuclear medicine continues to account for about 1 per cent of all procedures, and its contribution to the collective effective dose has risen from 5 per cent to 7 per cent. The number of radionuclide therapy treatments is estimated to have increased by 60 per cent since the previous UNSCEAR report, while the number of courses of radiation therapy has increased by 22 per cent.

51. The table below shows the breakdown of the annual number and frequency of medical radiological examinations by the World Bank classification of income levels and the associated annual collective effective dose and annual effective dose per caput.

Table
Estimated average annual per caput dose and annual collective effective dose from reported medical radiological examinations in the 2009–2018 period by income level

Category by income level	*Population (millions)*	*Number of examinations (millions)*	*Frequency (per 1,000 population)*	*Annual per caput dose (mSv)*	*Annual collective effective dose (1,000 man Sv)*[a]
High	1 149	1 852	1 612	1.71	1 966
Upper-middle	2 619	1 197	457	0.46	1 195
Lower-middle	2 882	1 044	362	0.31	902
Low	662	101	153	0.13	89
Global	**7 312**	**4 194**	**574**	**0.57**	**4 152**

[a] Values have been rounded.

52. The use of medical radiation for diagnosis and therapy continues to be strongly weighted towards high- and upper-middle-income countries. Those countries account for around 70 per cent of all medical radiological examinations and 75 per cent of the collective effective dose. This disparity is even more noticeable in nuclear medicine, where high- and upper-middle-income countries account for over 90 per cent of procedures and more than 95 per cent of the collective effective dose. Access to radiation therapy is similarly concentrated, with around 95 per cent of all treatments occurring in high- and upper-middle-income countries.

53. The Committee underlines that the compilation of a global assessment of medical exposure is a complex task and relies on the collection of quality-assured data from Member States. As national surveys of medical exposure require adequate planning and significant time and resources, the Committee recommends the use of its survey questionnaires (especially the essential data sets) to collect such information on a regular basis. Also, the Committee intends to update its assessments more often by focusing on the essential data.

B. Levels and effects of radiation exposure due to the accident at the Fukushima Daiichi nuclear power station: implications of information published since the UNSCEAR 2013 report

54. The Scientific Committee has considered the implications of the significant amount of relevant information that has been published since the UNSCEAR 2013 report and reached the following conclusions.

1. The accident and the releases of radioactive material into the environment

55. The Fukushima Daiichi nuclear power station lies in Fukushima Prefecture of the Tōhoku region in Japan. It is located about 230 km north-east of Tokyo on the east coast of Japan. On 11 March 2011, an earthquake with a magnitude of 9.0 occurred along the Japan Trench. The earthquake and the following tsunami triggered a severe nuclear accident at the Fukushima Daiichi nuclear power station. The measures taken by the Japanese authorities included immediate (pre-emptive) and late (deliberate) evacuation, sheltering in homes, restricting distribution and consumption of contaminated foodstuffs (milk, vegetables, grains, meat, fish, etc.) and water, instructions to take stable iodine, and the remediation of affected areas. These actions were supported by radiation surveys of people and places.

56. More recent estimates of the total releases to the atmosphere from the accident using all the information now available remain consistent with the total release of ^{131}I being within the range of about 100 to about 500 PBq, and that of ^{137}Cs being within the range of 6 to 20 PBq, namely the same ranges as estimated in the UNSCEAR 2013 report. About 20 per cent of the total release to the atmosphere was estimated to have been dispersed over land, and a substantial fraction of this was deposited on land; and about 80 per cent was dispersed over, and deposited in, the Pacific Ocean. The estimated releases of these radionuclides from the Fukushima Daiichi nuclear power station accident (based on the averages of the ranges) were about 10 per cent (^{131}I) and 20 per cent (^{137}Cs) of the releases estimated for the Chernobyl accident.

57. There were also direct releases to the ocean (from leakage and deliberate release of water containing radionuclides) of about 10 to 20 PBq of ^{131}I and 3 to 6 PBq of ^{137}Cs in the first one to three months after the accident, followed by lower amounts thereafter.

2. Levels in the environment and food

58. The Scientific Committee has evaluated the information on the transfers of released radioactive material through the terrestrial, freshwater and marine environments. Some of the more pertinent findings are:

(a) Measurements of ^{137}Cs in seawater around the Fukushima Daiichi nuclear power station site, across the Pacific Ocean and in neighbouring seas showed rapid dispersion and dilution of the released material in seawater and its general movement eastwards. By 2012, the concentrations of ^{137}Cs, even in the coastal waters off the Fukushima Daiichi nuclear power station site, were little above the levels prevailing before the accident;

(b) Extensive monitoring programmes that began immediately after the accident enabled timely restrictions to be applied to prevent the sale of foodstuffs from areas where the radionuclide concentration exceeded provisional regulation values and standard limits[13] established by the Government of Japan. The radionuclide concentrations in most monitored foodstuffs have declined rapidly since the accident. Since 2015, no samples of livestock and crop products and only a few samples of monitored wild food and of freshwater and marine fish products have been found to exceed the limits established by the Government of Japan to apply as of 1 April 2012. It is noteworthy that the Japanese standard limit for caesium radionuclides is an order of magnitude lower than the levels recommended by the Codex Alimentarius Commission for the purpose of international trade.

3. Dose assessment

(a) Members of the public

59. Because of the availability of much more information than was available at the time of the UNSCEAR 2013 report, the Scientific Committee has been able to make more realistic and robust estimates of doses to members of the public, avoiding the need for the conservative assumptions applied in its earlier assessment.

60. In updating its dose assessment, the Scientific Committee has chosen to rely, to the extent possible, on measurements of ambient levels of radiation, as well as of radioactive material in people and the environment.

61. The main changes and/or improvements in the approach adopted by the Scientific Committee and their implications were as follows:

(a) An improved estimate of the temporal pattern of releases to the atmosphere (the “source term”) derived from the totality of measurements in the environment was used, together with an improved atmospheric transport, dispersion and deposition model, to estimate the concentrations of radionuclides in the air, for which only limited measurements were available; this resulted in a different spatial and temporal pattern of concentrations of radionuclides in the air compared with those in the UNSCEAR 2013 report;

(b) A new, validated model was developed to estimate external doses from radionuclides deposited on the ground based on extensive measurements of the variation of dose rate over time in the conditions in Japan; this resulted in a moderate increase in estimated external doses, typically by several tens of per cent compared with the UNSCEAR 2013 report, and a slower decrease in the dose rates with time;

(c) Revised and improved modelling of inhalation and ingestion doses, including more realistic factors and elements of data specific to the affected Japanese population, resulted in decreases in some estimated doses. These changes resulted in a decrease in the estimated thyroid doses in the first year after the accident by a factor of about two and a decrease in the estimated average doses from the inhalation of radionuclides by a factor of about two compared with the UNSCEAR 2013 report;

[13] The terms “provisional regulation value” and “standard limit” are those used in the English version of handbooks providing information on the effects of the Fukushima Daiichi nuclear power station accident published by the Radiation Health Management Division, Ministry of the Environment of the Government of Japan and the National Institute for Quantum and Radiological Science and Technology of Japan. The terms used in Japan may not correspond exactly with the Japanese translation of these terms.

(d) Improved information about people's actual diet, purchases and consumption of food and drink in Japan was used as a basis for revised dose estimates from ingested radionuclides. Over the longer term, the estimates were based on measurements made over 45 years of radiocaesium in food products and the whole diet in Japan from fallout from atmospheric nuclear weapons testing. These changes have reduced the estimated doses received from ingestion of food and drinking water by a factor of at least 10 compared with the UNSCEAR 2013 report.

62. Taken together, these changes led to a reduction in the estimated average doses in the first year compared with the estimated doses in the UNSCEAR 2013 report for the more highly exposed municipalities and groups of evacuees by a few tens of per cent for effective doses and by up to about a factor of two for thyroid doses. The general reduction in the current estimates of effective doses in the first year compared with those in the UNSCEAR 2013 report are largely due to the more realistic and lower estimates of doses from ingestion, and consideration of specific conditions in Japan and the use of dose coefficients that are specific to the Japanese population. However, estimated effective doses to adults over a lifetime remain similar to the estimated doses in the UNSCEAR 2013 report for many municipalities, but for municipalities with higher doses the current estimates are higher (by up to 30 per cent). Over the longer term, those decreases in the estimated effective doses in the first year are counterbalanced by an increase in the estimated dose from external exposure to deposited radionuclides.

63. Groups of evacuees were estimated to have received average effective doses in the first year of up to about 8 mSv and average absorbed doses to the thyroid of up to about 30 mGy. These doses are additional to those doses from natural sources of exposure that are estimated to result in average effective doses to the Japanese population of around 2 mSv.

64. Residents of municipalities in Fukushima Prefecture were estimated to have received average effective doses in the first year of up to about 5 mSv and average absorbed doses to the thyroid of up to about 20 mGy. Average effective doses due to the accident in the first year in other prefectures were estimated to be less than about 1 mSv and absorbed doses to the thyroid less than about 6 mGy. By 2021, annual average effective doses were estimated to have declined to less than 0.5 mSv in areas that were not evacuated, and, following remediation work and the lifting of evacuation orders, to less than 1 mSv in areas that were evacuated. Average effective doses over a lifetime due to the accident were, in all municipalities and prefectures, estimated to be less than 20 mSv; and were highest for residents of Fukushima Prefecture.

65. The Scientific Committee estimated the distributions of doses among individuals within a municipality or prefecture, taking account of all major sources of uncertainty and variability. In general, 90 per cent of the individuals in each population group were estimated to have received doses within a range from about three times lower than the average dose to about three times higher.

66. The Scientific Committee's estimates of radiation exposures in countries neighbouring or close to Japan have not changed: effective doses were less than 0.01 mSv.

67. While the uncertainties in the estimated doses remain large, the Scientific Committee does not believe that further research is likely to reduce them significantly or change the central estimates, except in specific circumstances (e.g., to take account of better information on the efficacy of remediation).

(b) Workers

68. Although the reported doses to workers as a result of the Fukushima Daiichi nuclear power station accident have been subject to some revision since the UNSCEAR 2013 report, the general findings of that report remain valid: the average effective dose of the 21,135 workers involved in mitigation and other activities at the Fukushima Daiichi nuclear power station site from March 2011 to the end of March 2012 was about 13 mSv, while 174 workers (0.8 per cent) received doses of more than

100 mSv. Annual effective doses have been considerably lower since April 2012, with average annual effective doses declining from about 6 mSv in the year ending March 2013 to 2.5 mSv in the year ending March 2019, and no individual has received an annual effective dose of more than 50 mSv since April 2013.

69. For the period March–December 2011, 1,757 workers (8.3 per cent) received absorbed doses to the thyroid greater than 100 mGy, with an average dose for this group of 370 mGy, and 13 workers were estimated to have received thyroid doses of 2 Gy or more.

70. A recent re-evaluation of the absorbed doses to the thyroid of the six workers who received the highest doses has revealed that their absorbed doses to the thyroid, estimated using individual-specific measurements of thyroid size, are, with one exception, higher than previously reported (using population average thyroid size), in one case by a factor of almost three. The highest assessed absorbed dose to the thyroid due to internal exposure from inhalation of ^{131}I is now 32 Gy. However, the Committee believes that the absorbed doses to the thyroid reported in the UNSCEAR 2013 report for the workers as a whole remain valid because there is evidence indicating that the mean thyroid volumes for adults in Japan do not differ significantly from the standard reference values used in dosimetry.

4. Health implications

71. In the years since the UNSCEAR 2013 report, no adverse health effects among Fukushima residents have been documented that are directly attributable to radiation exposure from the Fukushima Daiichi nuclear power station accident. The updated estimates of doses to members of the public have either decreased or are comparable with the Scientific Committee's previous estimates. The Committee therefore continues to consider that future health effects directly related to radiation exposure are unlikely to be discernible.[14]

72. Although approximately 200 cases of thyroid cancer have been detected by three rounds of screening among exposed children, the Scientific Committee believes that, on the balance of evidence, these cases are not the result of radiation exposure. Rather, their detection is the result of sensitive ultrasound screening procedures which have detected cases of latent disease that would not have been diagnosed in the absence of screening, as has been observed in other populations without any increased radiation exposure. The Committee has assessed the incidence of thyroid cancer that could be inferred from the estimated radiation exposures and has concluded that this is not likely to be discernible in any of the age groups considered.

73. While the updated estimated doses to the red bone marrow have not increased, the Scientific Committee's estimate of leukaemia risk per mGy has increased somewhat compared with what was stated in the UNSCEAR 2013 report. However, any increased incidence of leukaemia is still unlikely to be discernible among Fukushima residents of any age. Likewise, the levels of exposure of members of the public have been too low for the Committee to expect discernible increases in the incidence of breast cancer or other solid cancers.

74. There has been no evidence of excess congenital anomalies, stillbirths, preterm deliveries or low birthweights among newborns related to radiation exposure. Increases in the incidence of cardiovascular and metabolic conditions have been observed among adults evacuated following the accident, but they are probably associated with

[14] As stated in the UNSCEAR 2013 report (annex A, appendix E), the Committee considers quantitative and qualitative estimates of potential disease outcomes among the exposed populations that may or may not be observable in future disease statistics. For the purpose of this study, the Committee has also used the phrase "no discernible increase" where, although a disease risk in the longer term can be theoretically inferred on the basis of existing risk models, an increased incidence of effects is unlikely in practice to be observed in future disease statistics using currently available methods, because of the combination of the limited size of population exposed and low exposures, i.e., consequences that are small relative to the baseline risk and their uncertainties.

concomitant social and lifestyle changes and are not attributable to radiation exposure. Excess psychological distress also occurred in the aftermath of the combined earthquake, tsunami and Fukushima Daiichi nuclear power station accident.

75. The health of the Fukushima Daiichi nuclear power station emergency workers is being monitored in the nuclear emergency workers study sponsored by the Ministry of Health, Labour and Welfare of Japan. The majority of workers received effective doses within the first year of less than 10 mSv, and only a small fraction of workers received effective doses within the first year of 100 mSv or more. Thus, a discernible increase in the incidence of leukaemia or solid cancers is unlikely. Approximately 1,750 workers received absorbed doses to the thyroid greater than 100 mGy, and 13 workers received thyroid doses greater than 2 Gy. Because these thyroid doses were received by adults rather than children, an excess of thyroid cancers in the workers is also unlikely to be discernible.

5. Radiation exposures and effects on non-human biota

76. The Scientific Committee continues to consider that regional impacts on wildlife populations with a clear causal link to radiation exposure resulting from the Fukushima Daiichi nuclear power station accident is unlikely, although detrimental effects on individual organisms might have been possible. Indeed, various cytogenetic, physiological and morphological (sublethal, individual-level) effects in some plants and animals have been observed in areas of enhanced radiation levels following the Fukushima Daiichi nuclear power station accident, in the absence of any reported wide-scale group impacts. In contrast, substantial population-level impacts on biota were observed following the Chernobyl accident. A few studies have indicated population impacts on selected wildlife groups following the Fukushima accident. However no strong conclusions can be made from these studies, as there is also radiobiological evidence to the contrary, and doubts remain about the robustness of those findings, including uncertainty about reproducibility and control of confounding factors.

C. Biological mechanisms relevant for the inference of cancer risks from low-dose and low-dose-rate radiation

77. Since the establishment of the Scientific Committee in 1955, its mandate has been to undertake broad estimates of the sources of ionizing radiation and its effects on human health and the environment. In 1973,[15] the mandate was expanded to include scientific estimates of radiation risk. These assessments of the Committee provide the scientific foundation used, inter alia, by the relevant agencies of the United Nations system in formulating international standards for the protection of the general public and workers against ionizing radiation.[16] Those standards, in turn, are linked to important legal and regulatory instruments.[17] In its 2012 report to the General Assembly, the Committee considered the attribution of health effects and the inference of risks from radiation exposure,[18] as well as on the uncertainties in risk estimates. The understanding of the biological mechanisms by which radiation-induced effects such as cancer may occur is a relevant element for the inference of radiation risk. This report is intended to synthesize the current knowledge on biological mechanisms of radiation actions at doses mostly in the low to moderate range relevant for cancer risk inference. It is emphasized that this is not a report on radiation effects; in particular, it is not a report on cancers that can be attributed to radiation exposure situations.

---

[15] General Assembly resolution 3154 (XXVIII).

[16] The European Atomic Energy Community (Euratom), FAO, IAEA, ILO, the International Maritime Organization, NEA/OECD, PAHO, UNEP and WHO, “Fundamental safety principles: safety fundamentals” (IAEA, Vienna, 2006), para. 1.6.

[17] Ibid., para. 1.5.

[18] *Official Records of the General Assembly, Sixty-seventh Session, Supplement No. 46* (A/67/46).

78. In its annex on biological mechanisms relevant for the inference of cancer risks from low-dose and low-dose-rate radiation, the Scientific Committee has undertaken a comprehensive evaluation of the biological mechanisms that are considered to contribute to or modulate carcinogenesis following radiation exposure, particularly at low exposure levels (dose of 100 mGy and below for low-linear energy transfer (low-LET) radiation (X- and gamma-rays) and at dose rates of 0.1 mGy/min and below). The understanding of the mechanisms and modulators of carcinogenesis following low-dose and low-dose-rate radiation exposures remains incomplete. An appendix that considers principles and criteria for ensuring the quality of the Committee's reviews of experimental studies of radiation exposure is included, which serves as a companion to the "Principles and criteria for ensuring the quality of the Committee's reviews of epidemiological studies of radiation exposure" (annex A to the UNSCEAR 2017 report).[19]

79. There is very robust and reliable evidence that incomplete, failed or otherwise dysfunctional responses to DNA damage contribute to induced mutation and chromosome damage and thereby affect the occurrence of cancers after exposures at all doses and dose rates studied. These responses relate to: (a) direct damage to DNA; and (b) damage attributable to the generation of reactive oxygen and related species, both of which can contribute to double-strand breaks, complex lesions and effects on mitochondria.

80. The Scientific Committee concluded the following:

(a) There are limited robust data that can be identified at this time that would prompt the need to change the current approach taken for low-dose radiation cancer risk inference as used for radiation protection purposes and in consideration of the allocation of resources in health-care settings, as well as for the purpose of comparison with other risks. The potential contributions of phenomena such as transmissible genomic instability, bystander phenomena, induction of abscopal effects and adaptive response remain unclear. The dose-response relationships for mutations and micronuclei are linear in form in the low-dose region down to at least 50 and 10 mGy low-LET radiation, respectively. Similarly, the dose-response for DNA damage response activation is best represented by a linear form down to 10 mGy low-LET radiation. It is notable that since the Committee's last major evaluation of contributory mechanisms for radiation oncogenesis (UNSCEAR 1993 report),[20] there have been substantial new data on low-dose and low-dose-rate radiation risk from epidemiological investigations, in particular of occupational and medical cohorts. These studies have added to the epidemiological evidence underpinning low-dose and low-dose-rate cancer risk estimation and are supported by the mechanistic findings in this annex;

(b) There remains good justification for the use of a non-threshold model for risk inference for radiation protection purposes, given the present robust knowledge on the role of mutation and chromosomal aberrations in carcinogenesis. However, there are ways that radiation could act that might lead to a re-evaluation of the use of the Committee's approach to inference of radiation cancer risks. Some experimental animal studies indicate that low-dose and low-dose-rate exposures can shorten lifespan and possibly increase tumour burdens, but others indicate the extension of lifespan and reduced tumour burdens. The Committee also noted that generally, there is insufficient mechanistic understanding of these observations. This situation may be improved if, for example, low-dose exposures were shown consistently and unequivocally to stimulate DNA damage response/repair, or immune responses modulating cancer development; such a consistent evidence base has not been found

[19] *Sources, Effects and Risks of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation 2017 Report to the General Assembly* (United Nations publication, 2018).

[20] *Sources and Effects of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation 1993 Report to the General Assembly* (United Nations publication, 1994), annex E.

in this review. In this case, some elements of risk reduction might have to be taken into consideration alongside the established DNA damage – mutational damage and potential promotional pathways. Other examples where additional evidence would help the assessment of risk include the findings relating to the stimulation of tumour vascularization by low-dose exposures, where there is greater consistency and coherence of the available data. Stimulation of tumour vascularization would be expected to serve to promote tumour development;

(c) There is long-standing evidence that the number of mutational steps required for leukaemia is less than in the case of solid cancers, and this impacts on the time to presentation of leukaemia by comparison with solid cancers.

81. As mentioned above, the implications of the studies on the induction of transmissible genomic instability, bystander effects, abscopal effects and adaptive responses are still not clear. Some studies suggest thresholds for the induction of transmissible genomic instability and bystander effects at around 100 mGy low-LET radiation; if confirmed, this would indicate that the phenomena are not relevant for low-dose cancer risk inference. Adaptive response studies remain without a confirmed mechanistic basis and are of mixed outcome; similarly, studies of samples from persons inhabiting areas with high natural background radiation levels that are interpreted by some as providing evidence for adaptive response are insufficiently coherent to be adopted for risk assessment purposes.

82. Looking to the future, the recommended approach for combining a mechanistic understanding of low-dose radiation carcinogenesis with epidemiological studies is to use mathematical modelling integrating data from experimental systems (e.g., dose-response data for induction of key mutations or epimutations). For this purpose, there exist good multistage model frameworks that have the flexibility to include data on somatic events and germline influences on risk. These approaches may be used to test hypotheses and provide further insights for risk inference. Consideration should be given to the use of adverse outcome pathway approaches, as applied in chemical toxicology and risk assessment, to help define and formalize key mechanistic steps in carcinogenesis following low-dose exposures. In addition, experimental investigations may identify cancer risk indicators that, when validated, could be integrated into epidemiological investigations to improve statistical power or be used for population screening.

Appendix I

Members of national delegations attending the sixty-fourth to sixty-seventh sessions of the United Nations Scientific Committee on the Effects of Atomic Radiation in the preparation of its scientific reports for 2020

Argentina	A. J. González (Representative), D. Álverez, A. Cánoba, P. Carretto, M. Ermacora, M. di Giorgio
Australia	G. Hirth (Representative), C. Lawrence, P. Thomas, S. Solomon, A. Wallace
Belarus	A. Razhko (Representative), A. Stazharau (Representative), S. Sychik (Representative), V. Drobyshevskaya, A. Nikalayenka, L. Sheuchuk, V. Ternov
Belgium	H. Vanmarcke (Representative), S. Baatout, H. Bosmans, F. Dekkers, H. Engels, F. Jamar, L. Mullenders, H. Slaper, P. Smeesters, P. Willems
Brazil	L. Vasconcellos de Sá (Representative), D. de Souza Santos
Canada	J. Chen (Representative), P. Thompson (Representative), J. Burtt, D. Bracken Chambers, P. Demers, J. Gaskin, R. Lane, K. Sauvé, R. Wilkins
China	S. Liu (Representative), Z. Pan (Representative), L. Chen, L. Dong, T. Fang, D. Huang, Z. Lei, Y. Li, X. Lin, J. Liu, L. Liu, S. Liu, J. Mao, G. Song, Q. Sun, X. Xia, M. Xu, S. Xu, D. Yang, F. Yang, L. Yuan, X. Wu, G. Zhou, P. Zhou
Egypt	M.A.M. Gomaa (Representative), W. M. Badawy (Representative), T. M. Morsi
Finland	S. Salomaa (Representative), A. Auvinen, E. Salminen
France	L. Lebaron-Jacobs (Representative), J.-R. Jourdain (Representative), Y. Billarand, V. Blideanu, J.-M. Bordy, S. Candéias, I. Clairand, J. Guillevic, C. Huet, A. Isambert, D. Klokov, D. Laurier, K. Leuraud, F. Ménétrier, S. Roch-Lefevre, M. Tirmarche
Germany	A. Friedl (Representative), P. Jacob (Representative), S. Baechler, A. Böttger, L. Brualla, C. Engelhardt, C. Fournier, K. Gehrcke, U. Gerstmann, T. Jung, M. Kreuzer, R. Michel, W.-U. Müller, C. Murith, W. Rühm, L. Walsh, W. Weiss, D. Wollschlaeger, H. Zeeb
India	A. Vinod Kumar (Representative), K. S. Pradeepkumar (Representative), B. Das, A. Ghosh
Indonesia	N. R. Hidayati (Representative), E. Hiswara (Representative), D. H. Nugroho, T.B.M. Permata, H. Prasetio, N. Rahajeng
Japan	M. Akashi (Representative), T. Nakano (Representative), K. Akahane, S. Akiba, R. Kanda, I. Kawaguchi, K. Kodama, M. Kowatari, K. Ozasa, S. Saigusa, K. Tani, H. Yasuda, Y. Yonekura, S. Yoshinaga
Mexico	J. Aguirre Gómez (Representative), M. Cuecuecha Juárez
Pakistan	R. A. Khan (Representative)

Peru	A. Lachos Dávila (Representative), B. García Gutérrez
Poland	M. Waligórski (Representative), L. Dobrzyński, M. Janiak, M. Kruszewski, P. Olko
Republic of Korea	H. S. Kim (Representative), B. S. Lee (Representative), J. Jang, K.-W. Jang, M.-S. Jeong, J. K. Kang, B. S. Kim, J.-I. Kim, J. K. Lee, R. Lee, E. K. Paik, S. W. Seo, K. M. Seong, M. C. Song
Russian Federation	A. Akleev (Representative), T. Azizova, S. Geraskin, S. Fesenko, D. Ilyasov, V. Ivanov, L. Karpikova, S. Kiselev, A. Koterov, A. Kryshev, E. Melikhova, S. Mikheenko, S. Romanov, S. Shinkarev, R. Takhauov, V. Usoltsev, V. Uyba
Slovakia	L. Auxtová (Representative), M. Berčíková, A. Ďurecová, K. Petrová, L. Tomášek
Spain	A. M. Hernández Álvarez (Representative), M. J. Muñoz González (Representative), C. Álvarez García, M. T. Macías Domínguez, J. C. Mora Cañadas, E. Vañó Carruana
Sudan	R.O.A. Alfaki (Representative), E.H.O. Bashier (Representative), N. M. Hassan
Sweden	E. Forssell-Aronsson (Representative), I. Lund (Representative), A. Almén, P. Hofvander, A. Wojcik
Ukraine	D. Bazyka (Representative), V. Chumak, N. Gudzenko
United Kingdom of Great Britain and Northern Ireland	S. Bouffler (Representative), A. Bexon, R. Wakeford, W. Zhang
United States of America	V. Holahan (Representative), A. Ansari, W. Bolch, H. Grogan, N. Harley, B. Napier, D. Pawel, G. Woloschak

Appendix II

Scientific staff and consultants cooperating with the United Nations Scientific Committee on the Effects of Atomic Radiation in the preparation of its scientific reports for 2020

A. Aroua	M. Balonov	V. Berkovskyy
S. Candéias	L. Chipiga	M. Eidemüller
C. Estournel	G. Etherington	B. Howard
G. Ibbott	H. Järvinen	N. Kelly
L. Mullenders	E. Nekolla	M. P. Hande
E. Samara	R. Shore	P. Shrimpton
R. Smart	S. Solomon	G. Woloschak

Members of the Committee's ad hoc working group on the effects of radiation exposure and the biological mechanisms by which they occur at the sixty-sixth and sixty-seventh sessions

A. Friedl, Chair (Germany)	A. Auvinen, Rapporteur (Finland)
J.-R. Jourdain (France)	L. Lebaron-Jacobs (France)
K. Ozasa (Japan)	K. M. Seong (Republic of Korea)
A. Akleev (Russian Federation)	S. Bouffler (United Kingdom)
D. Pawel (United States)	

Members of the Committee's ad hoc working group on supporting the Committee's work on improving data collection, analysis and dissemination of levels of radiological exposure at the sixty-sixth and sixty-seventh sessions

J. Chen, Chair (Canada)	A. Ansari, Rapporteur (United States)
P. Thomas (Australia)	L. Vasconcellos de Sá (Brazil)
U. Gerstmann (Germany)	A. Kryshev (Russian Federation)
S. Romanov (Russian Federation)	J. Al Suwaidi (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 and sixty-seventh sessions)

M. J. Crick (sixty-fourth session)

F. Shannoun (sixty-fourth to sixty-seventh sessions)

E. Korneva (seconded)

Y. Shimizu (seconded)