United Nations

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

Fifty-ninth session (21-25 May 2012)

General Assembly
Official Records
Sixty-seventh session
Supplement No. 46

General Assembly
Official Records
Sixty-seventh session
Supplement No. 46

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

Fifty-ninth session
(21-25 May 2012)

United Nations • New York, 2012

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

[14 August 2012]

Contents

Chapter I

Introduction

1. Since the establishment of the United Nations Scientific Committee on the Effects of Atomic Radiation 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, and also evaluates evidence of radiation-induced health effects in exposed groups, including survivors of the atomic bombings in Japan and people exposed after the reactor accident at Chernobyl. The Committee also reviews 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 and workers against ionizing radiation;[2] those standards, in turn, are linked to important legal and regulatory instruments.

2. Exposure to ionizing radiation arises from sources such as natural background radiation, including from radon; medical diagnostic and therapeutic procedures; nuclear weapons testing; electricity generation, including by means of nuclear power; events such as the nuclear power plant accidents at Chernobyl in 1986 and following the great east-Japan earthquake and tsunami of March 2011; and occupations that increase exposure to artificial or natural 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. Its terms of reference 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 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 Assembly increased the membership of the Committee to a maximum of 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.

[2] For example, the international basic safety standards for protection against ionizing radiation and for the safety of radiation sources, currently co-sponsored by the International Labour Organization, the Food and Agriculture Organization of the United Nations, the World Health Organization (WHO), the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency of the Organization for Economic Cooperation and Development and the Pan American Health Organization.

Chapter II

Deliberations of the United Nations Scientific Committee on the Effects of Atomic Radiation at its fifty-ninth session

3. The Committee held its fifty-ninth session in Vienna from 21 to 25 May 2012.[3] Wolfgang Weiss (Germany), Carl-Magnus Larsson (Australia) and Leif Moberg (Sweden) served as Chair, Vice-Chair and Rapporteur, respectively. It welcomed representatives and delegations from the six new States members: Belarus, Finland, Pakistan, Republic of Korea, Spain and Ukraine.

A. Completed evaluations

4. The Committee discussed substantive documents on the attribution of health effects to different levels of exposure to ionizing radiation, and on uncertainties in risk estimates for cancer due to exposure to ionizing radiation. The principal findings on these subjects are summarized in a scientific report (see chap. III below) and, together with the two detailed scientific annexes that underpin them, will be published separately in the usual manner.

B. Present programme of work

1. Nuclear accident following the great east-Japan earthquake and tsunami in 2011

5. At its fifty-eighth session, the Scientific Committee had decided to carry out, once sufficient information was available, an assessment of the levels of exposure and radiation risks attributable to the nuclear power plant accident following the great east-Japan earthquake and tsunami of March 2011. It had envisaged a preliminary document for consideration at the fifty-ninth session of the Committee, and a more complete report for its sixtieth session, in 2013. The General Assembly had endorsed that decision in its resolution 66/70. The Committee discussed the preliminary document that summarized the planning, organization and technical progress of the work, as well as interim technical findings. The assessment is a major undertaking and requires extensive quality-assurance checks of the data to ensure that the final report will be authoritative.

6. States members and observers of the Committee and other selected countries had been invited to nominate experts to conduct the assessment at no cost to the United Nations. As of 18 March 2012, 72 experts from 18 countries had been offered, and they are now engaged in the work. In addition, three countries had made financial contributions to the general trust fund established by the Executive Director of the United Nations Environment Programme (UNEP) to receive and manage voluntary contributions to support the work of the Committee. Finally, in response to a request to consider offering an expert under a non-reimbursable loan

[3] The fifty-ninth session of the Committee was also attended by observers for WHO, the World Meteorological Organization (WMO), IAEA, the European Commission and the International Commission on Radiological Protection.

arrangement, an expert from the Government of Japan had been offered and was now serving with the secretariat in Vienna.

7. Five international organizations are participating in the work: the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, the Food and Agriculture Organization of the United Nations, the International Atomic Energy Agency (IAEA), the World Health Organization (WHO) and the World Meteorological Organization (WMO). The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization has shared from its global network relevant data on measurements of radionuclides in the air. FAO is making available a database on radioactivity levels in foodstuffs since March 2011 and is assisting in the interpretation of relevant data for the assessment of radiation exposures resulting from food consumption. IAEA made available results of measurements that its monitoring teams had conducted in Japan. WHO made available a preliminary dose assessment based on official information available up to mid-September 2011, and agreed to share its expertise particularly for the assessment of radiation exposures due to food consumption. WMO will gather relevant meteorological data and related information, and develop a set of suitable meteorological analyses that can be used to estimate the atmospheric concentration and surface deposition of radionuclides released.

8. Work so far has been focused on collecting and reviewing the material published in the scientific literature, defining the assessment methodologies and working arrangements, and defining processes for quality assurance of the data and assessment. There are many sources of data for the Committee’s evaluation: (a) specific datasets in electronic formats, together with supplementary information, requested from the Government of Japan and authenticated Japanese sources; (b) information on measurements made by other United Nations Member States, especially all other States members of the Scientific Committee, as well as Malaysia, the Philippines, Singapore and Thailand, and solicited by the secretariat; (c) compiled and checked datasets that are being made available by other United Nations organizations, including the Comprehensive Nuclear-Test-Ban Treaty Organization, FAO, IAEA, WHO and WMO; (d) information and independent analyses that are being published in peer-reviewed scientific journals; and (e) crowdsourcing websites, where the public can upload their own measurements, which have also sprung up in Japan (while the use of such data calls for caution, they are nevertheless seen as having some value because they are independent from government sources).

9. The Committee is currently reviewing information that has been reported to it (in particular, the numerical data have not as yet been verified), which includes the following:

(a) To date, there have been no health effects attributed to radiation exposure observed among workers, the people with the highest radiation exposures. To date, no health effects attributable to radiation exposure have been observed among children or any other member of the population;

(b) As of 31 January 2012, a total of 20,115 occupationally exposed people, comprising company workers (17 per cent) and external contractors (83 per cent) of the Tokyo Electric Power Company (TEPCO), were involved in the on-site mitigation activities. About 66 per cent of the workforce are reported to have received effective doses equal to or below 10 millisieverts (mSv). In addition, rescuers and volunteers were occupationally exposed. Six TEPCO workers received effective doses above 250 mSv (the maximum reported dose as of 31 January 2012 was 679 mSv); the largest part of those doses resulted from intakes of 131I, 134Cs and 137Cs. About 170 occupationally exposed people received effective doses above 100 mSv. It should be emphasized that there are no data available in the open literature that allow estimates to be made of thyroid dose for occupationally exposed people. The Committee has requested further information from the Japanese authorities on worker doses and monitoring data;

(c) A system was established on 20 May 2011 for the management of radiation exposures and medical monitoring of occupationally exposed people involved in dealing with the emergency situation. As of 10 March 2012, none of the six deaths noted since 11 March 2011 had been attributed to exposure to ionizing radiation;

(d) Although there were several cases of occupationally exposed people with exposure to radiation from documented skin contamination, no clinically observable effects were reported;

(e) Thyroid monitoring of 1,080 children aged 15 years or younger in Iitate village, Kawamata town and Iwaki city (which are outside the 30-km zone) found no individual exceeding a screening level that was derived from a thyroid dose of 100 mSv (the maximum thyroid dose reported was 35 mSv). Some of the details of those measurements still need to be reviewed by the Committee. The Committee will assess the thyroid doses of the exposed populations, particularly of young children;

(f) In late June 2011, the government of Fukushima Prefecture (2 million residents) initiated a survey of residents of Iitate village, Namie town and the Yamakiya district of Kawamata town. The survey is being extended to people living in other parts of the Prefecture. Its aim is to evaluate radiation exposure levels for all the people who were living in the Prefecture on 11 March 2011;

(g) Since March 2011, a database has been compiled on radionuclide concentrations in foodstuffs, under the guidance of FAO and IAEA and in collaboration with the Japanese authorities, including the Ministry of Agriculture, Forestry and Fisheries. As of 23 May 2012, approximately 165,000 records on food monitoring were available, including data for over 500 types of foodstuffs, sampled in 47 prefectures in Japan. The Committee will analyse that database for use in assessing the radiation exposure of the general public from food consumption;

(h) Only a few studies have been published on exposure to non-human biota arising from the releases of radionuclides in which dose rates to biota have been estimated explicitly. Those studies show somewhat contrasting results. The highest exposures of wildlife appear to be associated with the marine environment.

2. Radiation exposure from electricity generation and an updated methodology for estimating human exposures due to radioactive discharges

10. The Committee reviewed documents on radiation exposure from electricity generation and an updated methodology for estimating human exposures due to radioactive discharges. While primarily for underpinning the Committee's

assessments, the methodology will be made available to the public. The Committee noted that the review of the existing methodology had been completed and several elements had been updated. In addition, electronic spreadsheets were being developed that would implement the methodology for use in conducting the assessment of exposures of populations from electricity generation. The work is expected to be finished by the sixty-first session.

3. Effects of radiation exposure on children

11. The Committee discussed a document that represented an extensive review of the effects of radiation exposure during childhood. Owing to the importance of this subject, given the public concerns following the 2011 nuclear accident in Japan, the Committee acknowledged that its goal was to finish the work by its sixtieth session.

4. Biological effects from selected internal emitters

12. The Committee discussed a document on the biological effects of exposure to selected internal emitters, with two parts addressing two specific radionuclides: tritium and uranium. It considered that further work was needed on that document, but that it would be finalized for approval by the Committee at its sixty-first session.

5. Epidemiology of low-dose-rate exposures of the public to natural and artificial environmental sources of radiation

13. The Committee discussed a document on the epidemiology of low-dose-rate exposures of the public to natural and artificial environmental sources of radiation. It recognized that the work was at an early stage and foresaw that the document would be further developed with a view to approval by the Committee at its sixty-first session.

6. Biological mechanisms of radiation actions at low doses

14. The Committee considered a short review document on the biological mechanisms of radiation actions at low doses. That document, unlike the Committee’s standard full evaluations, was not intended to be comprehensive; it was rather intended to highlight major advances in the field that would provide guidance for developing the Committee’s future programme of work. Because the document would be of wider interest, the Committee requested the secretariat to investigate means to issue it as a public document on its website.

15. The document concludes that understanding of the mechanisms of so-called non-targeted and delayed effects is improving and that there is some evidence for differential responses in gene and protein expression for high- and low-dose radiation exposures, but there is a lack of consistency and coherence among reports. There is as yet no indication of a causal association of those phenomena with radiation-related disease. With regard to immune response and inflammatory reactions, there is a clearer association with disease, but there is no consensus on the impact of radiation exposure, particularly at low doses, on those physiological processes. While the document focuses on mechanisms relevant to carcinogenesis, some of the processes considered may be relevant for tissue reactions, and improved

understanding may therefore be helpful for assessing the potential risk of non-cancer diseases at low and protracted exposures. The Committee agreed to:

(a) Continue to encourage research into the mechanistic understanding of low-dose radiation action that may contribute to disease in humans;

(b) Consider further developing biologically based risk models and a systems biology framework to integrate mechanistic data into risk assessment;

(c) Make the document publicly available;

(d) Review the subject again in three to four years, as appropriate.

C. Future programme of work

16. Regarding its future programme of work, the Committee acknowledged the significance of its evaluations of uncertainties in risk estimates for cancer due to exposure to ionizing radiation, which summarize the present methodologies to estimate health risks from exposure to ionizing radiation, including their uncertainties (see chap. III, sect. 2, below). The Committee considered that it might be worthwhile to extend the use of the methodologies to other sets of health-risk evaluations, but given the existing programme of work and its critical nature, decided to consider this matter at a later session.

17. The Committee took note of progress reports by the secretariat on public information and on improving the collection, analysis and dissemination of exposure data. Because (a) radiation exposures of patients undergoing medical procedures represented the most significant source of artificial exposures, (b) technology and practices in this area changed rapidly and (c) this was a thematic priority of the Committee's strategic plan (2009-2013), the Committee requested the secretariat to prepare for its sixtieth session a detailed plan for a report on this subject. It also requested the secretariat to initiate the Committee's next Global Survey of Medical Radiation Usage and Exposures and to cooperate closely with other relevant international organizations (such as IAEA and WHO), as appropriate. The Committee suggested that the General Assembly might (a) encourage Member States, the organizations of the United Nations system and other pertinent organizations to provide further relevant data about doses, effects and risks from various sources of radiation, which would help greatly in the preparation of future reports of the Committee to the Assembly; and (b) encourage IAEA, WHO and other relevant organizations to further collaborate with the Committee secretariat to establish and coordinate the arrangements for the periodic collection and exchange of data on radiation exposures of the general public, workers and, in particular, medical patients.

18. The Committee intends to formulate a strategic plan to guide its work for the period 2014-2020, for consideration at its sixtieth session.

D. Administrative issues

19. The Committee suggested that the General Assembly might request the United Nations Secretariat to continue to streamline the procedures for publishing the

Committee's reports as sales publications, recognizing that, while maintaining quality, the timeliness of their publication is paramount to fulfil expected accomplishments approved in the programme budget, and expecting that the report ought to be published within the same year as approval.

20. The Committee recognized that because of the need to maintain the intensity of work of the Committee, voluntary contributions to the general trust fund established by the Executive Director of UNEP to receive and manage voluntary contributions to support the work of the Committee would be beneficial. The Committee suggested that the General Assembly might encourage Member States to consider making voluntary contributions to the general trust fund for this purpose or to make contributions in kind.

21. The Committee agreed to hold its sixtieth session in Vienna from 27 to 31 May 2013.

Chapter III

Scientific report

1. Attributing health effects to radiation exposure and inferring risks

22. In its resolution 62/100 of 17 December 2007, the General Assembly, in recalling the intention of the Committee "to clarify further the assessment of potential harm owing to chronic low-level exposures among large populations and also the attributability of health effects",[4] encouraged the Committee "to submit a report on that issue at its earliest convenience".

23. Furthermore, the General Assembly, in its resolution 63/89, endorsed the Committee's strategic plan for its activities during the period 2009-2013. The strategic objective for the period was "to increase awareness and deepen understanding among authorities, the scientific community and civil society with regard to levels of ionizing radiation and the related health and environmental effects as a sound basis for informed decision-making on radiation-related issues".[5] That strategic objective highlighted the need for the Committee to provide information on the strengths and limitations of its evaluations, which are often not fully appreciated. This involves avoiding unjustified causal associations (false positives) as well as unjustified dismissal of real health effects (false negatives). Specifically, there was a need to clarify the degree to which health effects could be attributed to radiation exposure.

24. Moreover, the Assembly, in its resolution 66/70, called upon the Committee to submit to it at its sixty-seventh session the report requested by the Assembly on the attributability of health effects from radiation exposure.

25. The Committee has addressed the attribution of health effects to different levels of exposure to ionizing radiation, and has reached the following conclusions:

(a) An observed health effect in an individual could be unequivocally attributed to radiation exposure if the individual were to experience tissue reactions (often referred to as "deterministic" effects), and differential pathological diagnosis were achievable that eliminated possible alternative causes. Such deterministic effects are experienced as a result of high acute absorbed doses (i.e. about one gray or more), such as might arise following exposures in accidents or in radiotherapy;

(b) Other health effects in an individual that are known to be associated with radiation exposure — such as radiation-inducible malignancies (so-called "stochastic" effects) — cannot be unequivocally attributed to radiation exposure, because radiation exposure is not the only possible cause and there are at present no generally available biomarkers that are specific to radiation exposure. Thus, unequivocal differential pathological diagnosis is not possible in this case. Only if the spontaneous incidence of a particular type of stochastic effect were low and the radiosensitivity for an effect of that type were high (as is the case with some thyroid cancers in children) would the attribution of an effect in a particular individual to

[4] *Official Records of the General Assembly, Sixty-first Session, Supplement No. 46* and corrigendum (A/61/46 and Corr.1), para. 5.

[5] Ibid., *Sixty-third Session, Supplement No. 46* (A/63/46), para. 8.

radiation exposure be plausible, particularly if that exposure were high. But even then, the effect in an individual cannot be attributed unequivocally to radiation exposure, owing to competing possible causes;

(c) An increased incidence of stochastic effects in a population could be attributed to radiation exposure through epidemiological analysis — provided that, inter alia, the increased incidence of cases of the stochastic effect were sufficient to overcome the inherent statistical uncertainties. In this case, an increase in the incidence of stochastic effects in the exposed population could be properly verified and attributed to exposure. If the spontaneous incidence of the effect in a population were low and the radiosensitivity for the relevant stochastic effect were high, an increase in the incidence of stochastic effects could at least be related to radiation, even when the number of cases was small;

(d) Although demonstrated in animal studies, an increase in the incidence of hereditary effects in human populations cannot at present be attributed to radiation exposure; one reason for this is the large fluctuation in the spontaneous incidence of these effects;

(e) Specialized bioassay specimens (such as some haematological and cytogenetic samples) can be used as biological indicators of radiation exposure even at very low levels of radiation exposure. However, the presence of such biological indicators in samples taken from an individual does not necessarily mean that the individual would experience health effects due to the exposure;

(f) In general, increases in the incidence of health effects in populations cannot be attributed reliably to chronic exposure to radiation at levels that are typical of the global average background levels of radiation. This is because of the uncertainties associated with the assessment of risks at low doses, the current absence of radiation-specific biomarkers for health effects and the insufficient statistical power of epidemiological studies. Therefore, the Scientific Committee does not recommend multiplying very low doses by large numbers of individuals to estimate numbers of radiation-induced health effects within a population exposed to incremental doses at levels equivalent to or lower than natural background levels;

(g) The Scientific Committee notes that public health bodies need to allocate resources appropriately, and that this may involve making projections of numbers of health effects for comparative purposes. This method, though based upon reasonable but untestable assumptions, could be useful for such purposes provided that it were applied consistently, the uncertainties in the assessments were taken fully into account, and it were not inferred that the projected health effects were other than notional.

2. Uncertainties in risk estimates for cancer due to exposure to ionizing radiation

26. Cancer risks from ionizing radiation are better understood than those from other carcinogens, largely because it is possible to quantify exposures and doses. Many studies of health effects from exposures to ionizing radiation exist, including the study of the Japanese survivors of the atomic bombings and studies of population groups that have been exposed at work or by medical procedures. However, differing estimates of radiation risks from low-dose exposures frequently give rise to controversy about the safe use of radionuclides and ionizing radiation in society. If uncertainties are not addressed properly by the scientific community,

apparent differences in risk estimates can cause anxiety and undermine confidence among the public, decision-makers and professionals. In order to provide a more rational basis for expressing radiation risk, the Committee has reviewed the state of science on analysing uncertainties in estimates of risks due to exposure to ionizing radiation.

27. Knowledge has reached a level where uncertainties in the risk estimates can be quantified. The concept "uncertainty" is used here to mean the distribution of possible true values of a quantity of interest and is often expressed as the range of likely values of that quantity. Uncertainty in radiation risk estimation arises from several sources, such as uncertainties in dose estimation, natural variation of disease occurrence in populations, limited information on exposed populations and incomplete understanding of the origins and development of cancer.

28. There are two general areas of interest. The first involves the characterization and quantification of uncertainties that arise in developing estimates of risk from a specific study or group of studies. Many epidemiological studies of health effects of radiation exposures report risk estimates with confidence levels that express the impact of statistical fluctuations of the data. However, there are various other types of uncertainties that are not usually expressed. These relate to information about health effects, estimates of radiation exposures and doses, and the models and methods used in evaluating epidemiological data. The second area of interest concerns risk projection, that is, when radiation risk estimates derived from specific studies are used to describe potential effects of radiation exposure in other populations of interest, such as workers exposed occupationally to radiation, people affected by an accidental release of radioactive material, or participants in a disease-screening programme involving radiation exposure.

29. In epidemiological studies, uncertainty and variability should be separated in dose quantification to account for their different effects on the estimate of risk. It is essential that common sources of mistakes associated with programming, data input and computation be identified and corrected prior to using dose estimates for epidemiological evaluation. In general, for external exposure to high-energy photons, the uncertainty in the estimation of an individual's organ dose will be less than that for exposure to internal emitters. For external exposures to low-energy gamma radiation, however, the uncertainty in dose estimates can be considerable, depending on the energy and other variables. For internal exposures, doses are often evaluated using mathematical models that describe the distribution of radionuclides in the human body and the related delivery of dose to the various organs and tissues. In an optimal setting, internal doses are determined from individual whole body, partial body or excretion measurements. If such measurements are not available, then the intake has to be assessed on the basis of environmental measurements. The largest uncertainties exist when such concentrations have to be estimated by simulating the transport of radioactive material through the environment. Various computational methods have been used to quantify the uncertainties that are present at each stage of the exposure and dose calculation.

30. Neglecting uncertainties in estimating doses not only results in underestimating the uncertainty of the risk estimates, but may also lead to an underestimate of the risk itself. (If dose dependencies are non-linear, neglecting dose uncertainty can, under some conditions, lead to an overestimate of risk.) Various methods have been developed to account for these effects. For example,

dose estimates may be adjusted on the basis of assumptions about the distribution of doses in the study population. In a European study of lung cancer risk due to indoor radon exposure, making such an adjustment doubled the estimate of risk.

31. In an analysis of epidemiological data, various models may approximate the data set equally well but give different risk estimates. At low doses, the impact of the model assumptions is large. There are methodologies to combine risk estimates from various models. The first applications in the field of radiation risk analysis demonstrated that the estimates of uncertainties derived by multi-model inference are larger than those derived from well-fitting descriptive models by up to a factor of two, or even more.

32. Depending on the problem under consideration, there are a number of factors that can dominate the uncertainty in projecting risk:

(a) Transfer of risk estimates from one population to another;

(b) Extrapolation from acute to chronic and fractionated exposures;

(c) Extrapolation from moderate- or high-dose to low-dose exposures; dose response may not be linear over the dose range of interest;

(d) Extrapolation to different radiation types;

(e) Absorbed dose values in the population of interest.

33. The Committee had informed the General Assembly at its sixty-first session that when its models were applied to the populations of any of five specific countries (China, Japan, Puerto Rico, United Kingdom of Great Britain and Northern Ireland, United States of America) of all ages, the lifetime risk of death from all solid cancers together following an acute dose of 1 sievert was estimated to be about 4.3 to 7.2 per cent, noting that those values varied among different populations and with different risk models.[6] The additional insight provided by the current evaluation has now allowed the Committee to estimate that the uncertainty bounds of its calculations are approximately a factor of three larger or smaller than the best estimate.

---

[6] Ibid., *Sixty-third Session, Supplement No. 46* and corrigendum (A/61/46 and Corr.1), para. 22.

Appendix I

Members of national delegations attending the fifty-seventh to fifty-ninth sessions of the United Nations Scientific Committee on the Effects of Atomic Radiation

Argentina	A. J. González (Representative), A. Canoba, M. di Giorgio
Australia	C. M. Larsson (Representative), P. Johnston, S. B. Solomon, R. Tinker
Belarus	J. Kenigsberg (Representative)
Belgium	H. Vanmarcke (Representative), H. Bijwaard, H. Bosmans, G. Eggermont, H. Engels, F. Jamar, L. Mullenders, P. Smeesters, A. Wambersie
Brazil	D. R. Melo (Representative), M. Nogueira Martins (Representative), M. C. Lourenço
Canada	B. Pieterson (Representative), D. Boreham, K. Bundy, D. B. Chambers, J. Chen, N. E. Gentner (Representative), R. Lane, C. Lavoie, E. Waller, D. Whillans
China	Pan Z. (Representative), Chen Y., Du Y., Liu J., Liu S., Liu Y., Pan S., Qin Q., Su X., Sun Q., Wang Y., Yang H., Yang X., Zhang W., Zhu M.
Egypt	T. S. Ahmed (Representative), M.A.M. Gomaa (Representative)
Finland	S. Salomaa (Representative), E. Salminen
France	A. Rannou (Representative), A. Flüry-Hérard, J. R. Jourdain, L. Lebaron-Jacobs (Representative), R. Maximilien, F. Ménétrier, E. Quémeneur, M. Tirmarche
Germany	W. Weiss (Representative), A. A. Friedl, P. Jacob, G. Kirchner, J. Kopp, R. Michel, W. U. Müller
India	K. B. Sainis (Representative), P. C. Kesavan, Y. S. Mayya
Indonesia	S. Widodo (Representative), Z. Alatas (Representative), G. Witono, B. Zulkarnaen
Japan	Y. Yonekura (Representative), S. Akiba, N. Ban, K. Kodama, M. Kowatari, M. Nakano, O. Niwa, S. Saigusa, K. Sakai, G. Suzuki, M. Takahashi, Y. Yamada
Mexico	J. Aguirre Gómez (Representative)
Pakistan	M. Ali (Representative), Z. A. Baig
Peru	A. Lachos Dávila (Representative), L. V. Pinillos Ashton (Representative), B. M. García Gutiérrez

Poland	M. Waligórski (Representative), L. Dobrzyński, M. Janiak, M. Kruszewski
Republic of Korea	S. H. Na (Representative), K.-W. Cho, J. K. Lee
Russian Federation	M. Kiselev (Representative), A. Akleyev, R. Alexakhin, T. Azizova, V. Ivanov, N. Koshurnikova, A. Koterov, I. Kryshev, B. Lobach, O. Pavlovsky, A. Rachkov, S. Romanov, A. Sazhin, S. Shinkarev
Slovakia	E. Bédi (Representative), M. Chorváth, Ž. Kantová, L. Tomášek, I. Zachariášová
Spain	M. J. Muñoz (Representative), B. Robles, E. Vañó
Sudan	I. Salih Mohamed Musa (Representative), E.A.E. Ali (Representative), A. E. Elgaylani (Representative)
Sweden	L. Moberg (Representative), A. Almén, L. Gedda, L. Hubbard
Ukraine	D. Bazyka (Representative)
United Kingdom of Great Britain and Northern Ireland	J. Cooper (Representative), S. Bouffler, J. Harrison, J. Simmonds
United States of America	F. A. Mettler Jr. (Representative), L. R. Anspaugh, J. D. Boice Jr., N. H. Harley, E. V. Holahan Jr., R. J. Preston

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 report for 2012

F. O. Hoffman

P. Jacob

C. Land

W. U. Müller

C. Muirhead

D. Preston

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

M. J. Crick

F. Shannoun