UNSCEAR United Nations Scientific Committee on the Effects of Atomic Radiation

DEVELOPMENTS SINCE THE 2013 UNSCEAR REPORT ON THE LEVELS AND EFFECTS OF RADIATION EXPOSURE DUE TO THE NUCLEAR ACCIDENT FOLLOWING THE GREAT EAST-JAPAN EARTHQUAKE AND TSUNAMI

A 2015 white paper to guide the Scientific Committee's future programme of work

EVALUATING RADIATION SCIENCE FOR INFORMED DECISION-MAKING

UNITED NATIONS

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EXECUTIVE SUMMARY

This summary is extracted from the report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the seventieth session of the United Nations General Assembly.[1]

[…]

5. Following its assessment of the levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami, as presented in its 2013 report to the General Assembly (A/68/46) and the supporting detailed scientific annex,[2] the Committee had put in place arrangements for follow-up activities to enable it to remain abreast of additional information as it was published in the scientific literature. A considerable amount of additional relevant information had already been published or become available before the publication of the scientific annex. New material is still being published and will continue to be in the foreseeable future, including under international and national initiatives.[3]

6. The Committee identified a large number of new publications that had become available between the time it conducted its assessment and the end of 2014, and systematically appraised about 80 of those in the lead-up to its sixty-second session. More than half of those 80 publications corroborated one or another of the major assumptions made by the Committee in its 2013 report. None of them challenged the report's major assumptions or affected its main findings, while some needed further analysis or more conclusive evidence from additional research. The Committee, as part of its continued efforts to identify and systematically evaluate new information as it came to light, would appraise other publications already identified and evaluate and periodically report how those publications affected the conclusions reached in its 2013 report. Depending on the outcome, the Committee expected to consider, at an appropriate time, the need to update that report.

7. The Committee expressed its gratitude to organizations and individuals that had engaged in the debate on the Committee's findings, and in some cases had publicized critiques of the 2013 report. It discussed and endorsed a commentary on the main themes appearing in those critiques to provide greater clarity where its judgement and/or impartiality had been questioned. The Committee considered the debate on its findings an important element of transparency and had therefore engaged in scientific forums, public dialogues and other outreach activities (see also section 6, entitled "Outreach activities").

8. The Committee requested the secretariat to make the findings of its review of new scientific literature and its commentary on the critiques available as a non-sales publication in both English and Japanese.

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[1] *Official Records of the General Assembly, Seventieth session, Supplement No. 46 (A/70/46).*

[2] United Nations publication, Sales No. E.14.IX.1.

[3] At the time of the sixty-second session, the International Atomic Energy Agency report on the accident, entitled "The Fukushima Daiichi accident: report by the Director General", had not been made public, and had thus not been evaluated by the Committee for the purposes of the present report.

I. INTRODUCTION

1. The Committee had assessed radiation exposures of the public, workers and non-human biota that resulted from the 11 March 2011 accident at the Fukushima Daiichi nuclear power station (FDNPS), discussed the health implications, and presented its findings in its annual report to the United Nations General Assembly in August 2013.[4] The United Nations subsequently published the Committee's findings and the detailed scientific annexes underpinning them on 2 April 2014 [U6]. The publication (referred to hereafter as the "2013 Fukushima report") was well received by the General Assembly, governments, the scientific community and the media/public in Japan.

2. The Committee's assessment had, in general, been based on information disclosed or published before the end of October 2012. Subsequently, much additional relevant information has been published or become available and this activity is likely to continue for the foreseeable future. The Committee intends to remain abreast of such developments because they may have implications for the results of its assessment (for example in corroborating, challenging or refining its findings and/or contributing to addressing identified research needs); doing so will enable the Committee to take informed and timely decisions on the need to refine or update its findings. The Committee expects that providing sound scientific appraisal of new material will also help *(a)* those affected by the accident to better understand the situation and *(b)* inform decision-making.

3. Accordingly, at its sixty-first session (21–25 July 2014), the Committee had requested the secretariat to "submit for consideration at its sixty-second session (1-5 June 2015) preliminary plans […] for follow-up activities to update and consolidate some of the findings and conclusions of the Committee's assessment of the radiological consequences of the Fukushima Daiichi nuclear accident". It also asked the secretariat to "promptly develop a standing mechanism to stay aware of new scientific developments in the follow-up to the accident. That mechanism should be based on the special arrangements that had been developed for conducting its recent assessment of the accident. The Committee also asked the secretariat to report annually on the implications for the Committee's programme of work".

4. In response, the secretariat developed a project plan of follow-up activities, which has since been endorsed by the Committee and is being implemented. The project comprises two phases: Phase I, a systematic and ongoing review of new information; and Phase II, an update of the 2013 Fukushima report at an appropriate time. The overall aim of Phase I (up to at least 2016 and beyond) is to "keep the Committee regularly apprised of the implications of new publications and research activities related to the accident with a view to initiating a formal update of the 2013 Fukushima report (i.e. Phase II) at an appropriate time". The more specific objectives of Phase I include:

(a) To systematically keep the overall radiological situation on the FDNPS accident under review by collecting and appraising published information;

(b) To collect and evaluate progress made in, and plans for, major research projects and programmes related to pending questions;

[4] *Official Records of the General Assembly, Sixty-eighth Session, Supplement No. 46 and corrigendum (A/68/46 and Corr.1).*

(c) To promptly identify inconsistencies between information issued after October 2012 and the 2013 Fukushima report;

(d) To conduct ad hoc analyses to help clarify the situation and which could be used subsequently in any update of the 2013 Fukushima report;

(e) To respond to questions and critiques of the 2013 Fukushima report;

(f) To report annually to the Committee at its regular sessions on the outcomes of the above.

5. This white paper describes progress with the initial implementation of the project plan and presents a summary of the main outcomes of the initial follow-up activities that underpins the findings reported by the Committee to the General Assembly. The initial follow-up activities were largely confined to addressing objectives *(a)* and *(e)* above, that is the systematic collection and appraisal of new information, and responding to questions and critiques on the 2013 Fukushima report. The new information screened and appraised in this initial stage has, with a few exceptions, been limited to peer-reviewed publications in English-language journals; the scope will be extended in future years to other sources of new information relevant to the FDNPS accident and, in particular, those that could have implications for the findings of the 2013 Fukushima report. These will include data compilations, evaluations and reports prepared or carried out by national and inter-governmental bodies, including organizations in the United Nations system.[5]

6. The white paper comprises a digest of new information and its implications for the 2013 Fukushima report, set out in chapters II to VIII, together with an appendix that contains a commentary on broad themes included in the few critiques that had been made of the 2013 Fukushima report. In addition, two electronic attachments have been developed to provide technical information that supplement the 2013 Fukushima report and address key technical issues for which there had been requests: the first provides information on power calculations for epidemiological studies that underpin the analyses carried out and reported in appendix E (Health implications) of [U6]; and the second summarizes the underlying methodology and data used in developing isodose maps of annual external exposure in Japan and their variation with time.

II. EVALUATION OF NEW INFORMATION

7. The scope of new information analysed by the Committee in this first digest was necessarily more restricted than expected for future years. This was, firstly, because the initial period to be covered (27 months, from October 2012 to December 2014) significantly exceeded that foreseen for subsequent annual digests (i.e. 12 months); secondly, the appraisals covered by this report had to be completed within a relatively short time period (3 months compared with about 9 months expected for subsequent years). In this first digest, the Committee has, with three exceptions, limited its analysis to publications in English in peer-reviewed journals. One exception was an article on the distributions of bird species, which was published in a book; this was included because of its relevance to an issue of some scientific debate. The other two exceptions comprised a report by the Japanese

[5] Inter alia, data and reports issued by the Fukushima Medical University (e.g. the Fukushima Health Management Survey), and the International Atomic Energy Agency's report on the accident ("The Fukushima Daiichi Accident: Report by the Director General"), which had not yet been published at the time of the Committee's sixty-second session.

Ministry of Health, Labour and Welfare (MHLW) on re-assessment of doses to workers, and a peer-reviewed publication in a Japanese-language journal on dietary intakes following the accident. These two publications were identified, from systematic searches of peer-reviewed publications in Japanese-language journals and of reports issued by Japanese Ministries or governmental organizations, as new information that might have a significant impact on the assumptions and/or findings of the 2013 Fukushima report.

8. The Committee developed and implemented a systematic approach to identify, screen and appraise new information for the purposes of this white paper. The Committee identified several hundred new publications. In selecting publications for screening review and for more detailed appraisal, particular consideration was given to whether:

- The publication significantly challenged the assumptions in the 2013 Fukushima report;
- It materially affected the conclusions of the 2013 Fukushima report;
- It had the potential to address research needs identified in the 2013 Fukushima report.

As a result, this digest focuses almost exclusively on new information that has significant implications for the 2013 Fukushima report; it is not intended, and should not be interpreted, as providing a new overview of all relevant information relating to the FDNPS accident. The lack of reference to any particular publication in this digest is not a reflection on its worth or quality; it merely indicates that it was not considered to have significant implications for the 2013 Fukushima report.

9. The numbers of publications in each topical area that were selected for screening and/or more detailed appraisal are indicated in table 1. For some topical areas (particularly, releases to atmosphere, dispersion and deposition, and doses and effects for non-human biota), the Committee was unable to screen and/or appraise all potentially relevant publications because of time and resource constraints; those not included in this digest are planned to be included in the next review.

10. The following chapters describe the main outcomes of the screening and appraisal of new sources of information for each topical area in turn. In each case, a brief recapitulation is provided of some of the main assumptions, findings and research needs set out in the 2013 Fukushima report to highlight those of particular relevance to the sources of new information reviewed. This is followed by a summary of the outcomes of the appraisals, and conclusions about the implications both for the 2013 Fukushima report and any follow-up activities. Finally, chapter IX sets out overall conclusions from this first digest and includes some tabular summaries which focus on those sources of new information which challenge (or could potentially challenge, subject to further analysis) the assumptions/findings of the 2013 Fukushima report, or where the contribution to addressing identified research needs has been judged to be significant.

Table 1. Numbers of new sources of information screened and appraised by topical area

Topical area	*Screened*	*Appraised*
Releases to atmosphere, dispersion and deposition	126[a]	12[b]
Releases to water,[c] dispersion and deposition	43	18
Doses to members of the public	17	12
Doses to workers	26	7
Health effects for workers and the public	24	10
Doses and effects for non-human biota	61[d]	20[e]

[a] *The outcomes of screening of a further 16 sources of information are planned to be reported in the second digest.*
[b] *These new sources of information were selected for appraisal based on their potential impact on the assumptions and findings of the 2013 Fukushima report; the outcome of appraising the remainder screened for appraisal is planned to be reported in the second digest.*
[c] *Consideration was limited to information on releases to and subsequent dispersion in the marine environment. The transfer of radionuclides to, and their dispersion in, freshwater systems (e.g. from run off from catchments) was excluded from consideration in this review, other than the contribution such sources or pathways make to the continuing release of radionuclides to the marine environment.*
[d] *The outcomes of screening of a further 29 sources of information are planned to be reported in the second digest.*
[e] *These new sources of information were selected for appraisal based on their potential impact on the assumptions and findings of the 2013 Fukushima report; the outcome of appraising the remainder screened for appraisal is planned to be reported in the second digest.*

III. UPDATES ON RADIONUCLIDE RELEASES TO ATMOSPHERE, DISPERSION AND DEPOSITION

A. Recapitulation of 2013 Fukushima report

11. The Committee had reviewed estimates of total releases to the atmosphere of ^{131}I and ^{137}Cs (the two most significant radionuclides from the perspective of exposures of people and the environment); these estimates ranged generally from 100 to 500 petabecquerels (PBq) for ^{131}I and from 6 to 20 PBq for ^{137}Cs. The averages of the published estimates were about 10% and 20%, respectively, of the corresponding releases to the atmosphere estimated for the Chernobyl accident. On a number of occasions, the meteorological conditions were such that radionuclides released to the atmosphere were dispersed over mainland Japan, and then were deposited on the ground by means of *(a)* dry deposition, and *(b)* wet deposition with rain and snow. The main deposition occurred to the north-west of the FDNPS site, but significant deposition also occurred to the north, south and west of the FDNPS site.

12. In general, the Committee had relied on measurements of the deposition densities of radionuclides as the basis for its estimates of doses to the public from external exposure and from inhalation. However, in order to estimate doses where measurement data were unavailable for the periods when exposures occurred (e.g. for evacuees) and could no longer be obtained, the Committee had needed to use an estimate of the source term (including the temporal patterns of release rates) together with appropriate atmospheric transport, dispersion and deposition modelling (ATDM) to estimate levels in the environment and resulting doses to people. The Committee had chosen a published source term for this purpose [T4]. The releases of the radiologically dominant radionuclides ^{131}I and ^{137}Cs in this source term were 120 and 8.8 PBq, respectively. While at the lower end of the range of published estimates, and possibly an underestimate of the total release, the Committee had considered this source term as the most appropriate for estimating doses incurred as a result of dispersion over the land mass of Japan (see paragraphs B15–B16 in [U6]).

B. Findings of review of new publications

13. Based on its appraisals, the Committee noted the following in particular:

(a) None of the 12 publications appraised materially affected the main findings or challenged the major assumptions of the 2013 Fukushima report, and five provided confirmation of the assumptions in whole or part;

(b) Several publications [A1, C1, K4, W3] demonstrated that inverse or reverse modelling can reasonably be applied to reconstruct the source term confirming the assumption made in [U6];

(c) New estimates [A1, C1, K4, W3, Z1] of the total amounts of ^{137}Cs, ^{131}I and ^{133}Xe released were broadly consistent with the ranges quoted in [U6], although tending to be at the lower end of the ranges;

(d) More detailed information about the temporal pattern of the release has been reported [K4, W3]. This new information was the result of considering new datasets (e.g. dose rate measurements, and new data on ^{137}Cs concentrations in air with high temporal resolution [T12]) and using inverse or reverse modelling;

(e) Several new studies have been published which investigated levels of radionuclides other than isotopes of tellurium, iodine and caesium in the environment and confirm the assumption in [U6] that those other radionuclides do not significantly contribute to the exposure of the population [H8, S3, T5, Z1];

(f) The absence of significant quantities of fuel materials and radionuclides of low volatility in the release and accordingly in environmental media has been confirmed [S3, T5, Z1];

(g) The findings of the 2013 Fukushima report [U6] relating to a narrow region along the coast to the south of FDNPS in which the ratio of ^{131}I relative to ^{137}Cs was significantly elevated have been confirmed [H8], and it has been noted that the ^{135}Cs/^{137}Cs ratio was also different in this area [Z1];

(h) One study [Z1] identified the release from the Unit 2 reactor as the major contribution to the total release based on the ratios of various isotopes of caesium and plutonium.

14. In its 2013 Fukushima report [U6], the Committee had used the Terada et al. [T4] source term to estimate levels of radionuclides in the environment where measurements were not available or could no longer be made. This source term was the last but one (then available) in a series of estimates made by a group of researchers at the Japan Atomic Energy Agency (JAEA), in which each estimate was a refinement of the one before. Katata et al. [K4] is the latest estimate in this series and has been derived using improved atmospheric and oceanic transport, dispersion and deposition models, as well as new information on measured levels of radiation dose or radionuclides in the environment. The total releases of ^{131}I and ^{137}Cs estimated by Katata et al. were 151 and 14.5 PBq, respectively, compared with the previous estimates of Terada et al. of 120 and 8.8 PBq. While these differences in total releases are relatively small in the context of the ranges of releases quoted in [U6] (100–500 PBq for ^{131}I and 6-20 PBq for ^{137}Cs), they disguise more substantive differences (of an order of magnitude or more) over particular periods of time.

C. Potential implication of new publications

15. The Committee has taken note of the refinements made to the source term estimate used in [U6]. In any further or updated assessment, the Committee would, therefore, recommend the use of the latest estimate in preference (together with consistent ATDM). The Committee does not, however, expect that use of this latest source term estimate would alter significantly the doses it estimated in [U6], with the possible exception of estimated doses to evacuees (see paragraph B16 of [U6]). The impact on the estimated doses to evacuees would be influenced by detailed differences between the Terada et al. [T4] and Katata et al. [K4] source term estimates over the periods before and during evacuation when people may have been exposed (see chapter V).

16. The Committee has identified that research in the following specific areas would have the greatest potential to contribute to addressing the needs identified in the 2013 Fukushima report:

(a) Further in-depth studies of the wet deposition schemes used in ATDM and of the effects of grid sizes;

(b) Inverse and reverse modelling to estimate the source term making use of all available measurement data (in particular, the more recently available hourly ^{137}Cs concentrations in air derived from filter tapes in instruments monitoring suspended particulate matter [T12]).

IV. UPDATES ON RADIONUCLIDE RELEASES TO WATER, DISPERSION AND DEPOSITION

A. Recapitulation of 2013 Fukushima report

17. The Committee had concluded that the direct discharge and releases from FDNPS to the ocean mainly occurred during the first month following the accident, and that the continuing releases were unlikely to affect the Committee's assessment of doses to the public significantly. The Committee had concluded that these direct releases were about 10-20 PBq for ^{131}I and 3–6 PBq for ^{137}Cs, mainly on the basis of estimates derived using three-dimensional modelling. In addition, the Committee had found that the release to the ocean from deposition from the atmosphere was about 60–100 PBq for ^{131}I and 5−8 PBq for ^{137}Cs, with only a small percentage of this occurring within a radius of 80 km from FDNPS. The Committee had concluded that measured levels of ^{137}Cs in seawater near the FDNPS site declined rapidly from a peak of 68,000 Bq/L on 7 April 2011 and were generally below 200 Bq/L by the end of April, after which the rate of decrease was much smaller. Concentrations decreased rapidly with distance from the coast: at 15 km and 30 km offshore from the FDNPS site, they were about 100 times and 1,000 times lower, respectively, than near the FDNPS site. The measured levels of ^{137}Cs in sediment generally lay between 10 and 1,000 Bq/kg of dry sediment, except in the port of FDNPS, where measured levels were much higher.

18. At the time the 2013 Fukushima report [U6] was finalized, radioactive water had still been leaking on the site, and groundwater had been transporting radionuclides into the aquatic environment. The Committee had also noted the appearance of significant amounts of fission and activation products in stagnant water in the basements of the reactor and turbine buildings. The Committee had identified that key priorities for scientific research

were to improve the characterization of the leaks and releases to the aquatic environment, and forecasting and quantifying the long-term transport and mixing of these releases.

B. Findings of review of new publications

19. Of the 18 publications appraised,[6] none materially affected the main findings or challenged the major assumptions of the 2013 Fukushima report. Several publications addressed the identified research needs and their contributions are summarized in the following paragraphs.

20. The estimates of direct discharges and releases to the marine environment and of indirect input from deposition from the atmosphere have not been significantly challenged by recent publications. Kanda [K3] estimated continuing releases of ^{137}Cs between June 2011 and September 2012 totalling 20 TBq, less than 1% of the total release before June 2011. Tsumune et al. [T11] suggested that deposition to the ocean surface from the atmosphere could have been underestimated, because no measurements were available to constrain this term in atmospheric dispersion models. Bu et al. [B7] considered the release of plutonium isotopes to the marine environment to be negligible, because no concentrations attributable to FDNPS were detected in marine sediments.

21. None of the papers dealing with the dispersion of radionuclides in seawater challenge the general finding that concentration of radionuclides were very low other than relatively close to FDNPS. They do, however, enable improved specification of the spatial and temporal scales of the dispersion. This is particularly true for coastal waters, where Oikawa et al. [O2] made a major effort to reanalyse the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) dataset, which had initially reported high detection limits: the levels in most samples outside a radius of 30 km from FDNPS were initially reported as not detectable (less than about 6–9 Bq/L), whereas the new more sensitive analysis has identified the variations of ^{137}Cs concentration at the surface, intermediate and bottom depths, with detectable levels between 0.1 and 1 mBq/L. This has demonstrated a downward transport of ^{137}Cs from spring to winter (2011), likely due to physical oceanic processes. More generally, as initially reported, observations and models have indicated that ^{137}Cs concentrations in seawater decreased rapidly with time: one year after the accident, levels associated with direct discharges and releases remained significantly higher than the pre-accident levels only in the coastal zone around FDNPS [T11]. At a larger scale, numerical models have indicated that the levels of ^{137}Cs in seawater had decreased to the pre-accident levels 2.5 years after the accident [K7]. While initial measurements, which were mostly restricted to the ocean surface, pointed to a major eastward dispersion of released radionuclides with the Kuroshio Current, observations at depths of 100−500 m have identified a southward transport of a significant amount of caesium [K1, K10].

[6] Consideration was limited in this first review to publications addressing releases and deposition to, and dispersion in, the ocean. The transfer to and dispersion in freshwater bodies of radionuclides (e.g. run off from catchments) is being addressed in an increasing number of publications and is an important element of the F-TRACE programme (Long Term Assessment of the Transport of Radioactive Contamination in the Environment of Fukushima) [I1]. The Committee will continue to monitor developments in this area but does not expect its main conclusions in the 2013 Fukushima report to be challenged by any new findings in this field – albeit, without negating the importance of ongoing research in this area and its possible relevance to future mitigation activities.

22. Analysis of a large set of sediment cores has led to estimates of the inventory of ^{137}Cs in ocean sediments of between 38 and 200 TBq for the coastal region around FDNPS [B4, K12, O3], corresponding to about 1% of the total release. The penetration of ^{137}Cs into the sediment was found to be deeper than 0.14 m (14 cm) for water depths less than 150 m. The spatial repartition of ^{137}Cs in the sediment seemed to be driven by several factors. First, the distance from FDNPS dominated within the 3 km zone; beyond this zone, the ^{137}Cs inventory [B4] and concentration at the surface [A2] seemed to be related to the sediment grain size (with larger values associated with finer grained sediments). This picture, drawn from low resolution sampling, must be tempered by the results of high resolution measurements that revealed strong heterogeneities of ^{137}Cs concentrations in the sediment at the small scale (1 m to 100 m), with isolated peak values larger than 5,000 Bq/kg [T6].

23. Extreme weather events such as typhoons could lead to the transfer of significant quantities of radionuclides associated with sediment drained from river basins to the coastal zone. Observations [Y2] indicate that the largest river system affected by deposition from FDNPS (the Abukuma river basin) discharged about 5 TBq of ^{137}Cs from August 2011 to May 2012 (about 1% of the total deposition over the basin catchment). Yamashiki et al. [Y2] estimated that 61% of this 10-month transfer occurred during an 8-day period, corresponding to the passage of Typhoon Roke. These sediments were responsible for an increase in the concentrations of ^{137}Cs in the marine sediment mostly confined near the river mouth.

C. Potential implication of new publications

24. The Committee has concluded that its findings in this area of the 2013 Fukushima report remain valid and are largely unaffected by new information that has since been published. The observed southward transport of caesium at deeper ocean levels has indicated that the barrier afforded by the Kuroshio Current is not as significant as initially thought. The Committee has noted several publications that will contribute to an improved understanding of the release and subsequent dispersion of radionuclides in the marine environment.

V. UPDATES ON EVALUATION OF DOSES FOR THE PUBLIC

A. Recapitulation of 2013 Fukushima report

25. The Committee's aim had been to make realistic estimates of doses to defined groups of individuals considered representative of the different subsets of the Japanese population. For the assessment of doses to the public from external exposure, the Committee had used models with parameter values mostly derived from European studies after the Chernobyl accident, and validated with numerous individual thermoluminescent dosimeter measurements conducted in the affected Bryansk region of Russia. The Committee had used these models in its 2013 Fukushima report in combination with population-averaged deposition densities of radionuclides for Japanese districts or prefectures, derived by combining measurements of radionuclide deposition densities with data on the age compositions and typical occupancy factors of different groups of the Japanese population based on the 2010 Japanese census.

26. For the assessment of doses to the public from internal exposure, the Committee had considered two exposure pathways, inhalation and ingestion. Exposure from inhalation had been assessed only from radionuclides in the passing radioactive plume, with subsequent

inhalation of resuspended radionuclides considered insignificant. Exposure from inhalation of radionuclides in the passing plume had been estimated from deposition density measurements using ratios of the concentrations of radionuclides in air to deposition density levels derived using the assumed source term and atmospheric transport, dispersion and deposition modelling.

27. Intakes of radionuclides in food and drinking water in the first year following the accident had been assessed using the database of food and drinking water measurements carried out in Fukushima Prefecture and other prefectures of Japan. This database included many measurements made for food inspection purposes and therefore had some bias associated with the sampling: samples with potentially elevated activity concentrations were more likely to have been selected. However, at the time of preparation of the 2013 Fukushima report, no other food measurements had been available.

28. For subsequent years, a modified form of the recognized European model, FARMLAND [B6], had been applied for estimating the transfer of radionuclides through terrestrial food chains, with some transfer coefficients adjusted for the conditions and agricultural practices of contemporary Japan. The model had been used in combination with input data on population-averaged deposition densities of radionuclides for Japanese districts or prefectures.

29. For residents of evacuated communities, where it had not been possible to use measurements of radionuclide concentrations in the environment, the Committee had estimated time-varying concentrations of radionuclides in the environment using the assumed source term for releases to atmosphere and ATDM. Doses from external exposure and from inhalation had then been estimated for the periods before, during and after evacuation using scenarios representing the movements of residents derived from the results of a survey using questionnaires.

30. Measurements of radionuclides in people, such as whole-body-counter (WBC) and thyroid measurements, provide a direct source of information on internal exposure. However, at the time of preparation of the 2013 Fukushima report, the number of thyroid measurements had been limited (about 1,100 persons) and these data had been able to be used only to corroborate doses to the thyroid in a few settlements estimated using numerical models. In addition, data from WBC measurements had become available to the Committee only at a late stage of report preparation, and comprehensive data analysis had not been possible. Nevertheless, some assessment of doses from internal exposure based on human measurements had been carried out by the Committee and were presented in the 2013 Fukushima report (see paragraphs 116–118 of [U6]).

B. Findings of review of new publications

31. Of the 12 publications appraised, none materially affected the main findings of the 2013 Fukushima report, while 10 provided confirmation of the main assumptions in whole or part.

1. External exposure

32. External exposure of the public has been considered to different extents by Harada et al. [H1], Ishii et al. [I6], Koike et al. [K8], Nagataki et al. [N1] and Takahara et al. [T2].

33. Harada et al. [H1] demonstrated a correlation between outdoor dose rate (ambient dose equivalent rate from deposited radionuclides) and personal dose rate (personal dose equivalent rate due to external exposure) that might be used to reconstruct doses for groups and individuals and therefore validate estimates of doses from external exposure (see figure I).

34. Another large series of individual measurements by Optically Stimulated Luminescent Dosimeter (OSLD) of dose to more than 1,000 students from external exposure over a two-year period, as well as forecasts of doses for the next 10 years, was presented by Koike et al. [K8]. The Committee has some reservations about calibration and the statistical processing of the data. However, the measurements are in good agreement with the estimates of doses from external exposure for Miharu town set out in the 2013 Fukushima report.

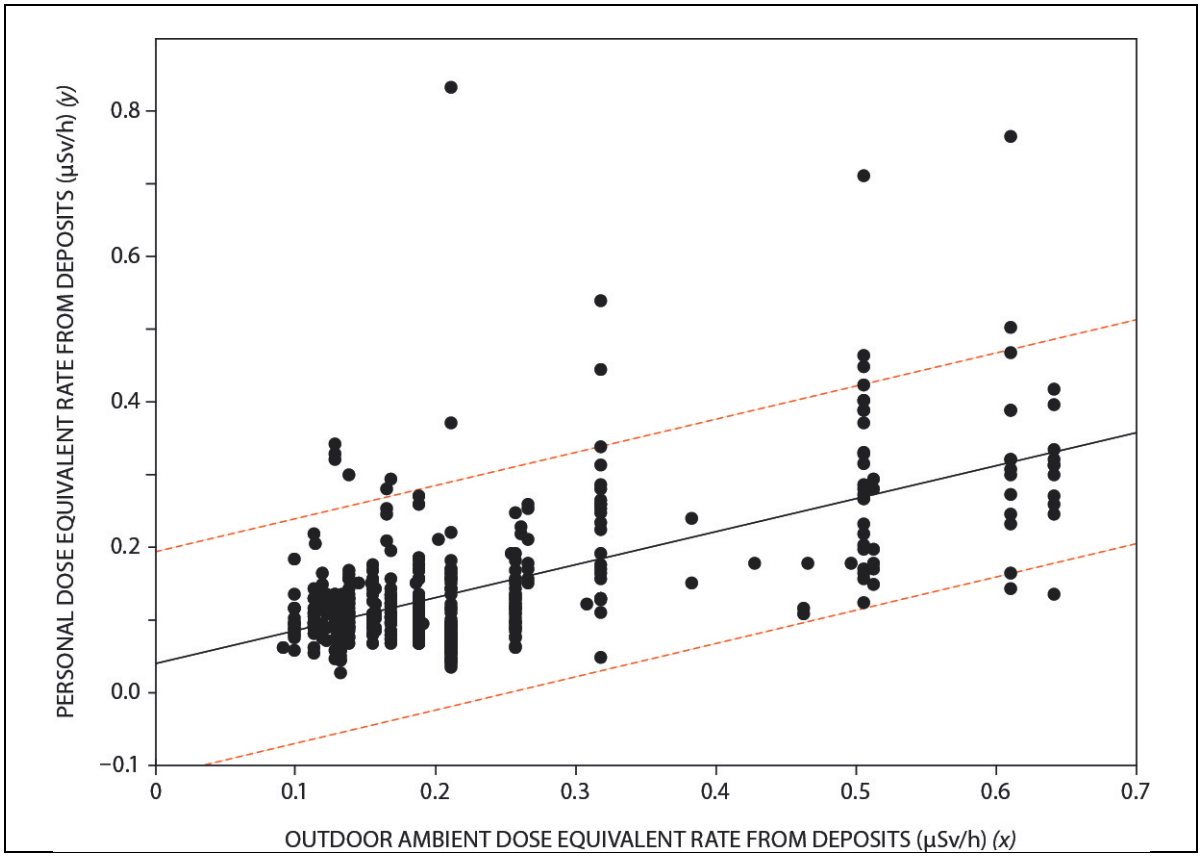
35. A review of estimated doses to individuals from external exposure, based either on personal measurements or interviews conducted by Japanese experts between 2011 and early 2013, was reported by Nagataki et al. [N1]. There is reasonable agreement between the data reported in the paper and that used in the 2013 Fukushima report, supporting the assumptions in the latter. Data of this type are potentially useful for reconstruction of doses to individuals and for epidemiological studies, and to improve national models for assessing doses.

36. Takahara et al. [T2] reported on the development of a probabilistic model for dose assessment based on measurements conducted in early 2012. They studied doses to residents of Fukushima Prefecture from external exposure by measuring ambient dose equivalent rates and monthly doses to 500 individuals, as well as behaviour patterns of various population groups, including indoor and outdoor workers, and pensioners. The paper contributes to both independent assessment of model parameters for estimating doses from external exposure, and validation of the results. It also partially confirms the model parameters used in the 2013 Fukushima report.

37. The Committee has noted significant progress in a number of areas that will contribute to enhancing the quality and reliability of estimated doses from external exposure. These include: the further clarification of patterns of external exposure; the validation of dose estimates with individual measurements; and the development of a national probabilistic model for estimating doses from external exposure. It has also noted that there was little new information (at least not reported in peer-reviewed publications) available in other areas, including: the migration of caesium radioisotopes in various environments; the determination of shielding parameters for Japanese buildings; the assessment of the effectiveness of urban decontamination; and long-term dose rate measurements in inhabited areas.

Figure I. Correlation between outdoor ambient dose equivalent rate and personal dose equivalent rate from deposited radionuclides

The fitted line corresponds to a relationship where y = 0.0403 + 0.4534x; r = 0.6274, p < 0.0001



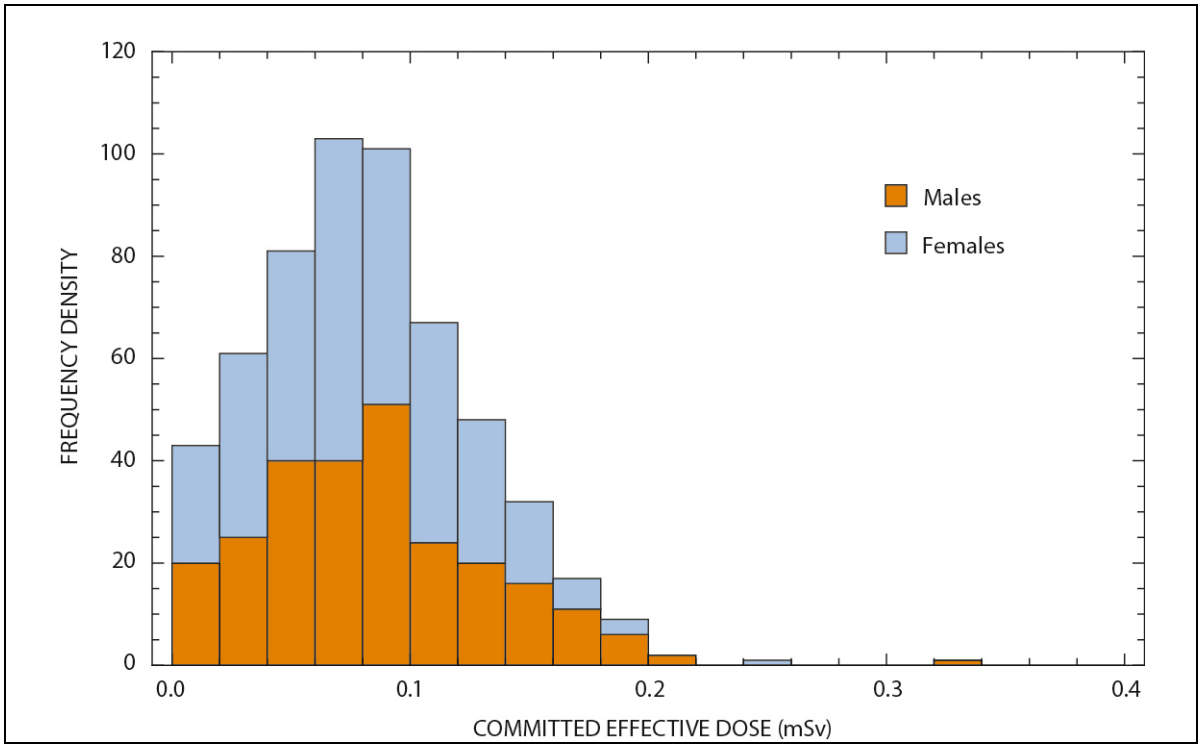
2. Internal exposure

38. Internal exposure of the public has been considered to different extents by Harada et al. [H1], Hayano et al. [H3], Ishii et al. [I6], Matsuda et al. [M1], Nagataki et al. [N1], Sato et al. [S2] and Torii et al. [T7]. Some relevant information has also been presented by Hirakawa et al. [H5] and Tsubokura et al. [T9].

39. Two papers [H3, M1] focused on early WBC measurements that provided the most reliable retrospective assessment of dose from internal exposure due to early inhalation and/or ingestion of caesium radionuclides (see figure II). Some uncertainty associated with the results presented by Hayano et al. [H3] should be noted because of the methodology used and assumptions made. The Committee converted the WBC measurement data to committed effective dose assuming early acute intake, regardless of whether this was by ingestion or inhalation. The resulting doses from internal exposure to caesium radionuclides were about three times lower than those estimated in the 2013 Fukushima report using the database on measurements in foodstuffs and inhalation modelling.

40. The review paper of Nagataki et al. [N1] also contains data on WBC measurements that imply low effective doses from internal exposure to the residents of Fukushima Prefecture in later periods of time, mostly in 2012.

Figure II. The estimated committed effective dose to adult residents of Minamisoma City based on WBC measurements conducted 110–140 days after the FDNPS accident assuming early intake of caesium radionuclides [H3]



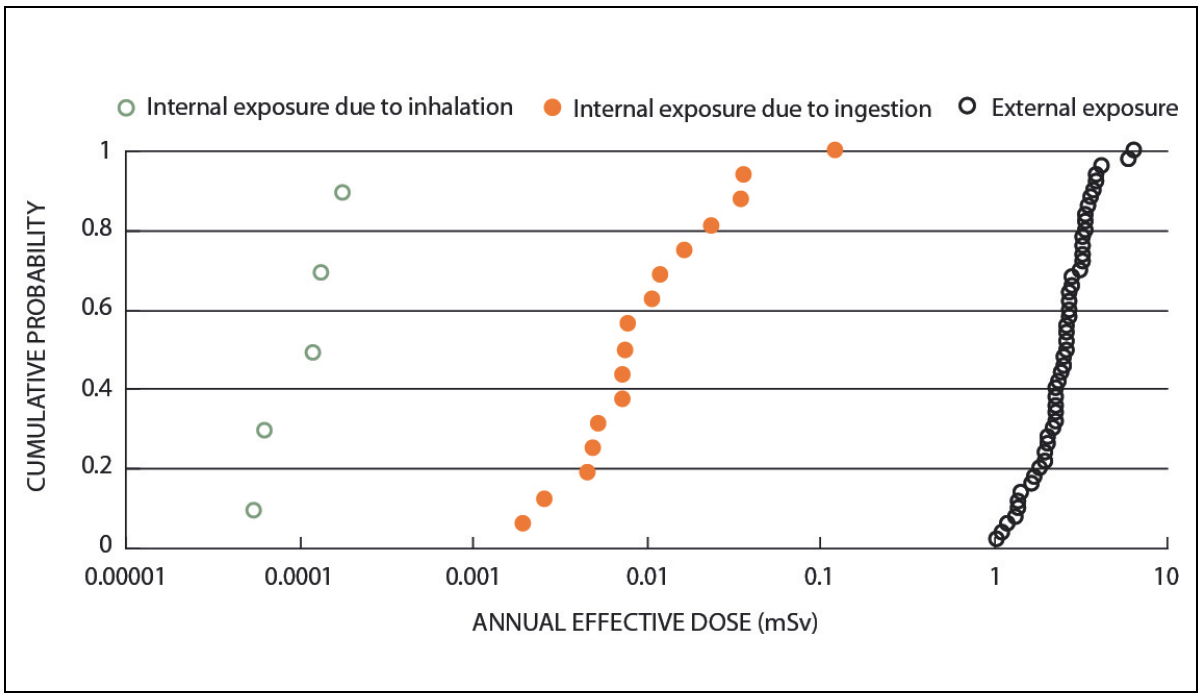
41. Harada et al. [H1] estimated doses from internal exposure to residents in three areas within 20–50 km of FDNPS resulting from intakes of caesium radionuclides during the summer of 2012 by ingestion (based on analysis of meal duplicates) and by inhalation (based on analysis of air dust). The results demonstrated that, in the summer of 2012, the doses from internal exposure were two orders of magnitude lower than the doses from external exposure as measured by personal OSLD (see figure III). The estimated doses from internal exposure due to inhalation of resuspended materials were two orders of magnitude lower than those due to ingestion.

42. A low ingestion rate of caesium radionuclides by residents of Fukushima Prefecture in the winter of 2011–2012 and the summer of 2012 was corroborated by analysis of meal duplicates collected from 200 families by Sato et al. [S2], although details of sampling and measurement procedures used were lacking. Among 200 meals analysed, only 12 were found to have average concentrations of more than 1 Bq/kg. For the highest measured caesium radionuclide levels in food, the assessed annual effective dose from ingestion did not exceed 0.1 mSv.

43. Hirakawa et al. [H5] summarized information from interviews with municipal staff and a collection of government documents relevant to bans on food and drinking water in Fukushima Prefecture during the first weeks after the nuclear accident. They confirmed that early evacuees from the 20-km zone were fed before and during the evacuation with stored foods or supplies from unaffected areas, and that consumption of fresh food was unlikely, clarifying conditions during the first weeks after the accident. It should be noted, however, that tap water and river water was consumed during the period before drinking water measurements were started. Furthermore, they confirmed that the fraction of local foods on markets in Fukushima Prefecture was about 15–30%, in agreement with the 25% figure assumed in the 2013 Fukushima report for estimating doses due to ingestion after the first year.

44. The Committee has noted significant progress in a number of areas that will contribute to enhancing the quality and reliability of estimates of doses from internal exposure; these include: the further clarification of internal exposure patterns; validation of dosimetric models with individual WBC measurements; and confirmation that doses from internal exposure due to ingestion and inhalation of resuspended radionuclides are much smaller than doses from external exposure. It has also noted that there was little new information (at least not reported in peer-reviewed publications) in other areas that have the potential to further enhance the quality and reliability of estimates of doses from internal exposure including: the dynamics of the variation over time of the concentration of caesium radionuclides in various foods (agricultural and wild) and in a staple food basket; and the development of deterministic and probabilistic models for the assessment of doses from internal exposure.

Figure III. Cumulative probability plot of annual effective doses in 2012 to adult residents of the Tamano area of Soma City from external exposure, and from internal exposure due to ingestion and due to inhalation of resuspended materials [H1]



3. Countermeasures (early and intermediate)

45. The Committee has so far found no peer-reviewed publications in English on the effect of countermeasures or remediation of contaminated areas on doses. Several potentially relevant publications were identified in Japanese, but time and resource constraints did not allow for these to be translated and appraised for this digest; it is envisaged to include them in the next digest. Dose estimates presented in the 2013 Fukushima report did not take account of longer-term remedial measures to reduce doses from external exposure to deposited radionuclides and doses from internal exposure due to ingestion of foodstuffs; they may, therefore, have been overestimates of the actual doses that have been or will be received in practice. Measurements of dose rates have been made before and after decontamination of settlements in the evacuated Special Decontamination Area, but the measurements have not yet been reported in peer-reviewed literature. Access to these data or their publication in the peer-reviewed literature would enable improvements to be made in the quality and reliability of the dose estimates in the 2013 Fukushima report. Similarly, information on the extent of remedial measures in the agricultural environment and their

impact on the transfer of radionuclides to foodstuffs would allow further improvement in the estimation of doses due to ingestion.

C. Potential implication of new publications

46. The Committee has concluded that its findings in this area of the 2013 Fukushima report remain valid and are largely unaffected by new information that has since been published. Further whole body measurements have given added weight to the statement in the 2013 Fukushima report (based on the more limited measurements then available) that effective doses from ingestion of radionuclides in foodstuffs may, in practice, have been much lower than those estimated theoretically (and reported generally in the 2013 Fukushima report) using the database on food measurements; analyses based on studies of duplicate meals further support this statement. By far the majority of the new publications broadly support or confirm the main assumptions made in, and the findings of, the 2013 Fukushima report, in particular:

(a) That doses to the general public in Japan decreased substantially after 2011 as foreseen in the 2013 Fukushima report;

(b) That the contribution to the total effective dose from internal exposure due to continuing intakes of radionuclides in foodstuffs is small, and the contribution of exposure from inhalation of resuspended caesium radionuclides is negligible;

(c) That doses from external exposure as measured by personal dosimeters or estimated from dose rate measurements and personal interviews are in broad agreement with the information reported in the 2013 Fukushima report.

47. The Committee has identified research in the following specific areas as having the greatest potential to contribute to addressing the research needs identified in the 2013 Fukushima report:

(a) Continuation of studies of migration of caesium radionuclides in urban, agricultural and forest environments and their transfer to various foods (agricultural and wild);

(b) Determination of parameter values necessary for regional and national models of doses (e.g. shielding parameters of buildings; time spent outdoors and indoors in various building types, in different seasons, and as a function of age and social group; and parameters related to the system of food distribution and consumption habits of cultivated and wild foods).

48. In chapter III, the Committee highlighted the new estimate of the source term for releases to atmosphere and its potential implications for the assessment of doses to evacuees presented in the 2013 Fukushima report. It would be beneficial if the Japanese authorities were to carry out a detailed evaluation of the doses received by those evacuated using this new source term, with consistent meteorological data and ATDM, and a detailed analysis of the movements and behaviours of those residents of evacuated communities.

VI. UPDATES ON EVALUATION OF DOSES FOR WORKERS

A. Recapitulation of 2013 Fukushima report

49. The main aim of the Committee's work had been to judge the extent to which the individual doses reported in Japan provided a true and reliable measure of the doses actually incurred by workers, and therefore the extent to which the reported doses could support a reliable commentary on the implications for health. By the end of October 2012, the Tokyo Electric Power Company (TEPCO) had reported statistics on doses to about 25,000 workers at the FDNPS site, most of whom were employed by contractors. According to TEPCO's reports, the average effective dose to FDNPS workers over the first 19 months after the accident had been about 10 mSv. About 34% of the workforce had received effective doses over this period above 10 mSv, while 0.7% of the workforce (corresponding to 173 individuals) had received effective doses more than 100 mSv. The highest reported effective dose was 679 mSv for the TEPCO worker who also had received the highest reported committed effective dose due to internal exposure (590 mSv). Dose statistics had been reported separately for a few hundred emergency services workers.

50. The Committee's independent assessments of the doses due to internal exposure for twelve workers (out of a total of thirteen) who had committed effective doses due to internal exposure higher than 100 mSv had confirmed that they had received absorbed doses to the thyroid due to inhalation of ^{131}I in the range of 2 to 12 Gy.

51. The reliability of the internal exposure assessments for the much larger number of workers with lower assessed internal exposures had been evaluated by performing independent assessments for randomly selected samples of workers.

52. The Committee had confirmed the reliability of assessments reported by TEPCO for those of its workers where a positive measurement of ^{131}I in the body had been made. However, for most of the workers, in vivo monitoring of ^{131}I in the thyroid had not started until mid- to late-May 2011, and in many cases this delay had meant that ^{131}I could no longer be detected. For the same reason, the contribution to internal exposure from intakes of shorter-lived radionuclides such as ^{132}Te and ^{133}I had not been able to be reliably assessed. The Committee had not been able to confirm the reliability of assessments reported by TEPCO for those of its workers for whom ^{131}I had not been detected in the body, nor the reliability of the internal exposure assessments reported by contractors for their workers.

53. The Committee had judged that the major factor potentially affecting the reliability of external exposure assessments had been the sharing of electronic personal dosimeters during March 2011, with only one worker in a team wearing a dosimeter for many missions.

54. The Committee had had insufficient information on beta irradiation to make an informed assessment of doses to the eye lens of workers (paragraph 143 in [U6]).

B. Findings of review of new publications

55. Of the seven publications appraised, two had the potential (albeit unlikely) to materially affect the main findings of the 2013 Fukushima report, while all seven provided some confirmation of one or other of the report's major assumptions.

56. Kurihara et al. [K11] reported results of measurements of ^{131}I in the thyroid of 560 FDNPS workers which provide committed effective dose estimates that are consistent with those presented in the 2013 Fukushima report.

57. Suto et al. [S5] presented results of dicentric chromosome assay for 12 workers. This work was known of at the time of preparation of the 2013 Fukushima report, although the work was unpublished at that time. The aim was to perform medical triage and planning for the selected workers. The results presented show that estimated whole body absorbed doses were less than 300 mGy for all 12 workers, and that no acute radiation syndrome effects were expected for the workers examined.

58. Naoi et al. [N3] reported doses from external exposure, and from internal exposure to radiocaesium, for Self-Defense Force (SDF) personnel. The reported doses from external and internal exposure were broadly consistent with those reported in the 2013 Fukushima report.

59. Tsubokura et al. [T10] presented the first results of in vivo measurements of ^{134}Cs and ^{137}Cs for workers who were not emergency workers, but who were performing decontamination tasks (during 2012) in villages near FDNPS. Measured levels of ^{134}Cs and ^{137}Cs in the whole body were below the detection limit of 300 Bq in all cases, and the authors concluded that, while the results may not be completely representative of all decontamination workers, resuspension of radioactive materials led to minimal intakes of radionuclides.

60. Yasui [Y4] reported on a re-evaluation of worker doses, carried out in July 2013. The Committee had been aware of this re-evaluation at the time of its 2013 Fukushima report, but had not been able to take full account of it at that time. The need for the re-evaluation arose because of significant discrepancies between doses from internal exposure assessed by TEPCO and those assessed by contractors of TEPCO, resulting from differences in the methods adopted for dose assessment. These discrepancies prompted new guidance from the Japanese Ministry of Health, Labour and Welfare (MHLW) on the standard methods to be used, which resulted in a revision of committed effective doses for a few hundred workers. Yasui [Y4] reported that, as a result of this re-evaluation, the numbers of workers found to have received committed effective doses (from internal and external exposure)[7] in the dose ranges 50−100 mSv and over 100 mSv increased by a few per cent. Yasui [Y4] also reported that the standard methods it had prescribed were considered by MHLW to be sufficient to account adequately for the contribution of the short-lived radionuclides ^{132}I and ^{132}Te. MHLW estimated the contribution from ^{132}Te to the committed effective dose, given the uncertainties, to be approximately 10% of the contribution from ^{131}I; in the 2013 Fukushima report, the Committee had estimated the contribution from short-lived radionuclides in total (including, for example, ^{133}I) to be in the order of 20% relative to that from ^{131}I.

61. The re-evaluation reported by Yasui [Y4] only concerned workers where significant differences were found between doses assessed by TEPCO and those assessed by contractors, and where there were doubts over the validity of the assessment. MHLW [M3] reported that, following the identification by TEPCO in January 2014 that the committed effective doses of nine workers had been assessed by methods other than the standard methods defined by MHLW, it had carried out a re-examination of the data for all workers, other than those re-assessed in the first re-evaluation. It concluded that the committed

[7] In both Yasui [Y4] and MHLW [M3] the time period used to present the results of the re-evaluations of doses was 11 March to 31 December 2011.

effective doses for 1,536 workers may have been assessed by a method other than the standard methods. The MHLW therefore instructed TEPCO and primary contractors to carry out a further re-evaluation of the committed effective doses.

62. MHLW [M3] reported that, as a result of this second re-evaluation, estimates of committed effective dose have been increased for 142 workers. Increases in the estimates of committed effective dose range from 1 mSv to 90 mSv. As a result there have been further small increases (that is by one or two) in the numbers of workers with committed effective doses above 100 mSv, and with doses between 50 and 100 mSv. Most of the increases occurred in workers with committed effective doses less than 50 mSv.

C. Potential implication of new publications

63. While significant changes have been made to doses estimated for some workers in the first and second re-evaluations reported by Yasui [Y4] and MHLW [M3], the Committee does not expect that these will materially affect its main findings in the 2013 Fukushima report [U6]. This would, however, need to be confirmed by a fuller analysis of the data and methodologies adopted in the re-evaluations of doses requested by MHLW.

64. The Committee did not find any new information that would enable it to reach informed judgments on the exposure of the lens of the eye or on improving the quality of its dose estimates in the various areas identified in the 2013 Fukushima report (e.g. exposures to radionuclides not detected by in vivo measurements, and reliability of using shared dosimeters).

VII. UPDATES ON HEALTH IMPLICATIONS FOR WORKERS AND PUBLIC

A. Recapitulation of 2013 Fukushima report

65. The Committee had found that health risks resulting from the Fukushima accident were expected to be far lower than those for the Chernobyl accident, owing to the substantially lower doses received by the public and workers. No deterministic effects from radiation exposure had been observed among the public and none had been expected. No increase in spontaneous abortions, miscarriages, perinatal mortality, birth defects or cognitive impairment had been expected from exposures during pregnancy. Nor had a "discernible increase in heritable disease among the descendants of those exposed from the accident" (paragraph 224 of [U6]) been expected. No discernible radiation-related increases in rates of leukaemia or breast cancer (two of the most radiogenic cancer types), nor in other types of solid cancer besides possibly thyroid cancer, had been expected. A large excess of thyroid cancer due to radiation exposure, such as occurred after the Chernobyl accident, had been able to be discounted, because the estimated thyroid doses due to the FDNPS accident were substantially lower than those sustained around Chernobyl. However, the sensitive ultrasound-based thyroid screening of those under 18 years old at the time of the accident had been expected to detect a large number of thyroid cysts and solid nodules, including a number of thyroid cancers "that would not normally have been detected without such intensive screening" (paragraph 225 of [U6]). However, similar or even slightly higher rates of cysts and nodules were found in the prefectures of Aomori, Yamanashi and Nagasaki that had not received significant radionuclide deposition from the accident. The substantial numbers that

had already been observed in the Fukushima Health Management Survey (FHMS)[8] had been considered likely due to the sensitivity of the screening and not to radiation effects.

66. Among FDNPS emergency workers, deterministic effects had been considered unlikely, but the Committee had not been able to preclude the possibility of hypothyroidism, nor assess the risk of cataracts due to insufficient information on doses to the lens of the eye from beta irradiation. Although 2−3 excess cancers could be inferred over the lifetime among workers with doses greater than 100 mSv (mainly from external exposure), the Committee had considered it unlikely that such increased incidence of cancer due to irradiation would be discernible. The Committee had judged the magnitude of any inferred risk of thyroid cancer among workers to be such that any increase in incidence due to radiation exposure would likely not be discernible.

67. The Committee had noted that the most important health effects that had been observed among the general public and among workers were considered to be on mental health and social well-being [W2], but that estimation of the occurrence and severity of such health effects was outside of the Committee's remit.

B. Findings of review of new publications

68. None of the 10 publications appraised challenge the assumptions or findings of the 2013 Fukushima report; instead they served to strengthen or complement those findings.

69. Nagataki and Takamura [N2] reported that (as of March 2014) 51 out of the 287,056 individuals (177 per million) in the FHMS screening programme had a diagnosis of thyroid cancer. The study of thyroid screening results in areas where people were not exposed to radiation resulting from the accident that is most comparable to the FHMS programme is that of young people in Aomori, Nagasaki and Yamanashi prefectures [H4]. This study, using instrumentation and methodology similar to the FHMS study, found rates of thyroid nodules and cysts that were nominally somewhat higher than the FHMS study. One thyroid cancer was found among the 4,365 children (prevalence of 230 per million) screened at ages 3–18 years. A relatively small study (1,214 screened individuals) by Iwaku et al. [I7] of children in the Kanto region found rates of thyroid nodules or cysts nominally higher than those in the FHMS study, and also found no differences in rates for those screened before or after the Fukushima accident. Nagataki and Takamura [N2] summarized thyroid cancer results from three other thyroid screening studies of non-exposed young people. In two university screening programmes the results were: 3 among 9,988 (300 per million) Japanese students at Chiba University and 3 among 2,307 (1,300 per million) at Okayama University were diagnosed with thyroid cancer. At Keio High School, 1 among 2,868 (350 per million) female students was diagnosed with thyroid cancer. As a supplement to the thyroid nodule/cancer data, Watanobe et al. [W1] reported no indication of excess hypothyroidism, immune thyroiditis or other thyroid dysfunction among children of the Fukushima Prefecture.

70. Taking all of the screening studies in non-exposed areas or times together indicates a prevalence of thyroid cancer of 380 per million compared to 177 per million in the FHMS. The Committee recognizes that the prevalence rates are not fully comparable, because the

[8] The Fukushima Health Management Survey is a large programme of health questionnaires and health screening conducted by Fukushima Medical University with Japanese government funding. The screening has two primary components: thyroid disease screening among those exposed at ages 0–18 years, and screening of women who were pregnant or breast-feeding at the time of the FDNPS accident and their offspring.

age distribution of those screened in the FHMS was younger than those of most of the comparison studies, and the degree of comparability of the screening methods is unknown except for the Hayashida et al. study [H4]. However, the studies are supportive of the suggestion that the apparent increased thyroid cancer rate among young people in Fukushima Prefecture was probably due to screening, at least at the time of the reported FHMS results in March 2014. Furthermore, the typical delay or latent period between exposure and appearance of thyroid cancer is an additional indicator of the apparent increase being due to screening.

71. Significant excess rates of non-cancer health end points because of radiation exposure are not expected in the Fukushima Prefecture population because of the relatively low exposures and limited population sizes, but actual data to support or refute those assumptions are needed. Three other publications are therefore worthy of mention here as they provide information on heart disease, reproductive outcomes and other non-cancer health assessments.

72. Some of the first information regarding pregnancy and birth outcomes was reported by Fujimori et al. [F1]. Compared to all Japan, the rates of untoward pregnancy outcomes in their survey of 8,600 women in Fukushima Prefecture pregnant at the time of the FDNPS accident were slightly lower for stillbirths, preterm births, and low birthweight, and slightly higher for birth defects. They concluded that there was no clear evidence of excess adverse birth outcomes in Fukushima Prefecture.

73. Yamaki et al. [Y1] obtained information from hospital registries in Fukushima Prefecture on the numbers of admissions for acute myocardial infarction (AMI) during the two years before and two years after the triple disaster of earthquake, tsunami and nuclear accident. Overall, there was no greater frequency of AMI admissions after the disaster, although they reported a suggestive post-disaster excess frequency in one of the six districts of Fukushima Prefecture. They attributed the possible excess frequency to the distress associated with the aftermath of the earthquake and tsunami. A radiation aetiology for AMI would be most unlikely within two years after exposure.

74. Yamashita [Y3] reported that rates of obesity, glucose metabolic dysfunction, hyperlipidaemia, and liver dysfunction after the triple disaster were high compared with those before, but he attributed the increase to changes in lifestyle, diet and exercise after the evacuation.

C. Potential implication of new publications

75. The Committee has concluded that its findings in this area of the 2013 Fukushima report remain valid and are largely unaffected by new information that has been published so far. Rather, the new information has given added weight to its statement that the high detection rate of nodules, cysts and cancer in thyroid surveys was a consequence of the intensive screening and highly sensitive nature of the equipment being used, and not of additional radiation exposure resulting from the accident.

76. The Committee has noted, and will remain abreast of, ongoing research and investigations into the health implications of the accident and, in particular, the health survey being carried out in the Fukushima Prefecture. It has identified the following specific areas where further data or information would have the greatest potential to contribute to addressing the research needs identified in [U6]:

(a) Ideally, further thyroid screening data from non-exposed Japanese young people for comparison with the FHMS thyroid nodule and cancer rates would be valuable, if such a study were deemed ethically appropriate;

(b) In the absence of further screening data, publication of the FHMS numbers of screened individuals, thyroid nodules and thyroid cancers by age and sex, because this would permit more accurate comparisons with the existing data from those unexposed, and with observations made after the Chernobyl accident;

(c) Where practicable, making available further data on the FHMS screening study, for example, on estimates of doses, which would permit a comparison of dose groups, and on the incidence of other health effects (such as childhood leukaemia, other solid cancers, birth defects among those conceived after the accident), which would, in time, provide indications of whether the frequency of health conditions varied by radiation dose;

(d) Making available data pertaining to the health of the FDNPS emergency workers, especially among those who received higher doses.

VIII. UPDATES ON EVALUATION OF DOSES AND EFFECTS FOR NON-HUMAN BIOTA

A. Recapitulation of 2013 Fukushima report

77. The Committee had estimated radiation doses due to the accident to non-human biota through the application of suitable models. The corresponding estimates of effects due to the radiation exposure had then been inferred through synthesis of the Committee's generic evaluations of dose–effects relationships. Exposures of both marine and terrestrial non-human biota following the accident had been, in general, too low for acute effects to be observed, although some exceptions had been considered possible because of local variability. The Committee had concluded that, in general, population-relevant effects on non-human biota in the marine environment would have been confined to areas close to where highly radioactive water was discharged and released into the ocean. Although the Committee had not been able to exclude a risk of effects to individuals of certain terrestrial species, in particular mammals, it had considered observable effects at the population level to be unlikely. It had concluded that any radiation effects would have been constrained to a limited area where the deposition density of radioactive material was greatest, and that, beyond this area, the potential for effects on biota was insignificant.

78. The Committee had made reference to studies in which effects in various terrestrial biotas had been observed in areas contaminated by the FDNPS accident [H6, M4, M5]. It had noted that the substantial impacts reported for populations of wild organisms from these studies were inconsistent with the main findings of the Committee's theoretical assessment. The Committee had expressed reservations about these observations, noting that uncertainties with regard to dosimetry and possible confounding factors made it difficult to substantiate firm conclusions from the cited field studies.

B. Findings of review of new publications

79. Of the 20 publications appraised, the Committee identified eight that were inconsistent with the main findings of the 2013 Fukushima report; nine provided confirmation of the major assumptions in whole or part.

80. Several new publications provided information on radionuclide activity levels in non-human biota (e.g. [H2, K2, T3, T8]) and on processes influencing transfer (e.g. [K5, K6, O1]). The results from these studies appeared to have no major repercussions for the findings of the 2013 Fukushima report, although synthesis of the newly published data could help refine the transfer models originally applied. Exposures derived for non-human biota in recent studies [F2, K9] generally corresponded closely to the estimates made in the 2013 Fukushima report, providing support for the robustness of the Committee's assessment approach and the validity of the associated exposure calculations. An exception possibly existed for the marine environment where elevated concentrations of caesium radionuclides in benthic marine fish were found to persist [S4].

81. The Committee's reservations about the field studies reporting observed effects on terrestrial biota [H6, M4, M5] have been reflected in comments on these studies in the intervening period from other scientists (e.g. [B2, B3]). Notwithstanding these reservations, the work cited, and more recent and related publications by the same groups, remained (as of end 2014) the only analyses of data pertaining to population-relevant environmental effects.

82. Several publications by Mousseau and Møller [M2, M6, M7, M8, M9] provided additional information on their original studies [M4, M5] by, inter alia, presenting more details on the statistical models applied and dismissing the influence of certain confounding factors, such as the effect of the tsunami itself. There was no change to the authors' original conclusions that abundances of butterflies, cicadas and birds decreased with increasing radiation levels, although the authors agreed that the original dose measurements may not have provided an accurate measure of the actual doses received by mobile animals [M7]. In contrast, a recent study [I5], found distributions of two bird species which were uncorrelated with radiation levels for areas affected by the FDNPS accident. Ishida [I5] noted that these results were inconsistent with the conclusions of Møller et al. [M4] about birds in the FDNPS area and that the design of the bird count survey by Møller et al. was inappropriate for discriminating the effects of radiation exposure from other environmental factors.

83. Several papers [H7, N4, T1] provided a comprehensive defence of an earlier publication cited in the 2013 Fukushima report concerning the impacts of radionuclide releases on the Pale Grass Blue Butterfly *(Pseudozizeeria maha)* [H6]. The authors provided an in-depth description of the methods applied and more detailed data analyses. Furthermore, one particular study [N4] augmented the general findings by studying the impact of ingestion of leaves on the larvae of the aforementioned butterfly species. The authors of this suite of publications maintained that exposures due to releases from the FDNPS accident would have led to mortality and abnormalities in the studied butterfly species, that mutations would have been passed on to the progeny and that populations would have decreased considerably in areas close to FDNPS. They further rejected the possibility of confounding factors such as the impact of the tsunami itself. Whilst noting some technical errors, where doses were wrongly specified in units of becquerels and reference was made to dose–response models that were inappropriate for the end points being studied in some of these publications (e.g. Nohara et al. [N4]), the observations indicating increases in particular effects that were correlated with indicators of radiation dose under field-relevant conditions merit further investigation. The publications cannot be

easily dismissed nor, accepting the integrity of the datasets, can the results be convincingly explained using existing understanding of radiation effects on environmental systems.

84. The Committee had assessed exposures of non-human biota and associated effects in general in its scientific annexes to the 1996 and 2008 reports [U3, U5]. The benchmarks set out and used in those annexes, and in the 2013 Fukushima report itself, were based on a large synthesis of information derived primarily from radiobiological literature spanning many decades of experimental work and (to a limited extent) including analyses of field observations from earlier accidents. They thus constituted the most profound insight that could be achieved into the doses at which biological effects were likely. However, this information, in large part, pertained to exposures of small groups of individuals, maintained in isolation and under controlled laboratory conditions. There will clearly be some limitations to the applicability of this information when extrapolating to infer effects for ecosystems exposed to ionizing radiation. Disturbances induced by stressors cannot be entirely grasped from knowledge of the stressor's effects on individual organisms, considering that such effects may act as triggers of perturbation, which propagate through higher levels of biological organization within ecosystems [B5]. This view appears to be supported by recent meta-analysis of effects data, suggesting that organisms in their natural environment were more sensitive to radiation than those tested under laboratory conditions [G1].

C. Potential implication of new publications

85. The Committee has concluded that its findings in this area of the 2013 Fukushima report remain broadly supported by the available evidence. However, it recognizes potential limitations in its approach (e.g. the benchmarks used) owing to reliance largely on laboratory-based rather than field studies. Field studies, tailored to analyse the impacts of exposure to ionizing radiation on populations of wild organisms interacting under the conditions prevalent within contaminated ecosystems, are required. Such studies would need to be multidisciplinary, involving not just radioecologists and radiation specialists but also ecologists, population biologists and geneticists.

IX. CONCLUSIONS

86. Of the 79 new sources of information appraised for this first annual digest, more than half confirmed one or other of the major assumptions in the 2013 Fukushima report. None materially affected the main findings in, or challenged the major assumptions of, the 2013 Fukushima report but twelve were identified that had the potential to do so, albeit subject to further analysis or confirmation from studies of better quality. Those publications judged to have the potential to challenge one or other assumption or finding in the 2013 Fukushima report are summarized in table 2. In each case an indication is given of what further work or analysis may be needed before informed judgements could be reached on the significance or otherwise of an identified potential challenge.

87. Eight of the publications highlighted in table 2 relate to a series of field studies reporting population-level effects on invertebrates and birds that were different from what could be inferred from the Committee's assessment. The results from these studies are not conclusive, and the findings in this area of the 2013 Fukushima report remain broadly supported by the available evidence. Further research would be needed to resolve these apparent differences.

88. One publication on levels of radionuclides in foods (supplemented by further whole-body measurements reported elsewhere) has provided support to the statement already made in the 2013 Fukushima report (based on the then limited whole-body measurements available) that doses to the public from ingestion may have been significantly overestimated in the 2013 Fukushima report. The magnitude of any overestimation needs to be further investigated. Any overestimation, in the 2013 Fukushima report, of doses via ingestion would, in general, have little impact on estimates of total doses as these are dominated by external exposure to radiation from deposited radionuclides.

89. Two of the twelve new sources of information concern two re-evaluations of doses to workers requested by the Japanese Ministry of Health, Labour and Welfare. These have resulted in significant changes (generally increases) to the doses estimated for some workers. These changes are judged unlikely to materially affect the main findings of the 2013 Fukushima report, but this would need to be confirmed by a fuller review of the data and methodologies adopted.

90. The final new publication concerns the latest in a series of estimates of the source term for releases to atmosphere by a group of researchers at the JAEA. In any further or updated assessment by the Committee, the use of this latest estimate would be preferable to that used in the 2013 Fukushima report. However, its use would not be expected to alter significantly the doses estimated in the 2013 Fukushima report, with the possible exception of estimated doses to evacuees. The impact on the estimated doses to evacuees would depend on detailed differences between the source terms over the periods before and during evacuation when people may have been exposed at levels depending on their locations. This would need more detailed analysis.

91. The Committee encourages the Japanese authorities to carry out a detailed evaluation of the doses received by those evacuated using this new source term, with consistent meteorological data and atmospheric transport, dispersion and deposition modelling, and a detailed analysis of the movements and behaviours of those residents of evacuated communities.

92. Table 3 summarizes those publications that have been judged to make a significant contribution to addressing the research needs identified in the 2013 Fukushima report. Many of the research needs identified in that report have yet to be addressed (at least in peer-reviewed publications). Through this and subsequent digests, the Committee intends to keep under review progress in addressing its identified research needs. Progress made may influence the Committee’s decision on when it would be most appropriate to update the 2013 Fukushima report.

Table 2. Publications identified as challenging or potentially challenging the assumptions and/or findings of the 2013 Fukushima report [U6]

Reference	*Challenge[a] to assumptions / findings of [U6]*	*Potential challenge[b] to assumptions / findings of [U6]*	*Further work required to assess potential challenge*	*Comments*
RELEASES TO ATMOSPHERE, DISPERSION AND DEPOSITION				
[K4]	None	Further refinement of source term estimate used in [U6] with detailed different temporal pattern that may have implications in particular for dose estimates for evacuees	Need to assess the implications of the temporal distribution of release for estimates of doses to evacuees	Based on source term estimation of Terada et al. [T4] but uses improved ATDM and additional and extensive data sets, some not published or used before. Methodology seems appropriate
RELEASES TO WATER, DISPERSION AND DEPOSITION (NO PUBLICATIONS IDENTIFIED)				
Doses to the public				
[S2]	None	Food measurement data are consistent with those reported [U6], strengthening the statement that doses for ingestion estimated using the database on food measurements may be significant overestimates	Needs to be confirmed by further studies	Methodological deficiencies cannot be ruled out
Doses for workers				
[M3, Y4]	None	Dose estimates have been revised for 621 workers	Findings of the 2013 Fukushima report not likely to be materially affected, but further detailed evaluation is needed	The need for this re-analysis arose inter alia from the shortcomings in individual monitoring discussed in the 2013 Fukushima report
HEALTH IMPLICATIONS (NO PUBLICATIONS IDENTIFIED)				
Doses and effects for non-human biota				
[H7, N4, T1]	None	Observations of population-level and transgenerational effects in invertebrates reported, which is not consistent with 2013 Fukushima report	Needs confirmation through multidisciplinary field studies	Concerns over quality of Taira et al. [T1] and Nohara et al. [N4] because of lack of or poor dosimetry and reference to non-applicable models
[M2, M6, M7, M8, M9]	None	Observations of population-level effects in invertebrates and birds reported, which is not consistent with 2013 Fukushima report	Needs confirmation through multidisciplinary field studies	Concerns over quality because of insufficient dosimetry and unclear accounting for confounding factors

[a] *Denotes a challenge to the assumptions and findings set out in the 2013 Fukushima report sufficient to warrant the Committee considering issuing an addendum to the report.*
[b] *Denotes a potential challenge to the assumptions and findings set out in the 2013 Fukushima report that, if confirmed, would be sufficient to warrant the Committee considering issuing an addendum to the report.*

Table 3. Publications considered to make a significant contribution to one or other identified research need

Research need	*Publications making a high contribution to research need*	*Publications making a medium contribution to research need*
RELEASES TO ATMOSPHERE, DISPERSION AND DEPOSITION		
Improve estimates of amount and characteristics of releases to atmosphere as function of time	[A3, K4, T12, W3, Z1]	[S3, T5]
RELEASES TO WATER, DISPERSION AND DEPOSITION		
Measure and improve characterization of leaks of radioactive water and releases to aquatic environment over time	[Y2]	[B7, K3, T11]
Forecast and quantify long-term transport and mixing of releases and consequent exposures through aquatic pathways	[A2, B4, K7, O2]	[K1, K10, O3, R1, R2, T6]
DOSES TO THE PUBLIC		
Measure dose rates due to external exposure to deposited material in various environments, forecast and track changes over time and quantify impact of environmental remediation programmes		[H1, T2, T7]
Conduct in vivo measurements of radionuclides in people to support refinement in the estimation of doses and their distribution, and to estimate current and future levels of exposure		[N1]
DOSES FOR WORKERS		
Elucidate the reasons for the differences between internal dose assessments performed by TEPCO and its contractors for some workers		[Y4]
HEALTH IMPLICATIONS		
Analyse and quantify the impact of ultrasonographic surveys on the apparent incidence of thyroid cancer in Fukushima Prefecture (surveys of thyroid cancer incidence in areas unaffected by the accident would be useful in this regard)	[H4]	[I7, N2, W1]
DOSES AND EFFECTS FOR NON-HUMAN BIOTA		
Measure and assess the environmental exposures typical for certain species of non-human biota, and further analyse whether radiation exposure was an important factor in causing environmental effects reported in field studies but which were inconsistent with the Committee's assessment	[H7, S4, T1]	[H2, K5, K6, O1]

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APPENDIX A. COMMENTARY ON COMMON THEMES IN CRITIQUES OF THE 2013 FUKUSHIMA REPORT

I. INTRODUCTION

A1. The responses to the 2013 Fukushima report [U6] have been generally positive. However, some critiques have been published. This appendix sets out a commentary by the Committee that addresses common themes in these critiques. Its aim is to promote better understanding of the scope, purpose and findings of [U6].

A2. Some of the critiques were based on the relevant findings in the Committee's report to the United Nations General Assembly[9] and/or the associated press release rather than on the Committee's full report [U6], which was published later, and some reflected a misunderstanding of the Committee's mandate. In most cases, the 2013 Fukushima report itself provides an answer to the critique, and, where relevant, the commentary below includes a reference to the relevant paragraph number of the full report where more detail can be found.

A3. The Committee recognized that there were uncertainties associated with many aspects of its assessment. The 2013 Fukushima report included a review of the main uncertainties, and identified some of the key priorities for scientific research to extend, corroborate and increase confidence in the Committee's evaluations (see paragraph 230 in [U6]).

II. ESTIMATES OF THE RELEASES OF RADIONUCLIDES FROM THE ACCIDENT

A. Validity of choice of estimate of releases to the atmosphere

A4. The 2013 Fukushima report has been criticized for choosing the estimate of releases of radionuclides to the atmosphere over time developed by scientists from the Japan Atomic Energy Agency rather than other available, and arguably more impartial, estimates, particularly those with larger estimates of the release [B1, I2, I4].

A5. The Committee had based its estimates of doses to the public in the 2013 Fukushima report primarily on measurements of the levels of radionuclides deposited on the ground and in foodstuffs in Japan. It only used its chosen estimate of the magnitude, time profile and nature of the release of radionuclides to the atmosphere (the "source term"), together with calculations of the subsequent dispersion of the radionuclides in the environment using atmospheric transport, dispersion and deposition modelling (ATDM) for the following purposes:

[9] *Official Records of the General Assembly, Sixty-eighth Session, Supplement No. 46 and corrigendum (A/68/46 and Corr.1).*

- Directly to estimate levels of radionuclides in the air and on the ground to which evacuees were exposed during the early stages of the accident;

- To estimate ratios of levels of radionuclides in the air to their levels on the ground in order to scale measured densities of radionuclides on the ground to infer concentrations of radionuclides in the air.

A6. The Committee had reviewed estimates of the source term published up to the end of March 2013, and made its choice in the light of how it intended to use the source term estimate (see paragraphs 45 and B11 to B16 in [U6]). It had chosen a source term derived by reverse modelling from, and optimized to fit, measurements of radioactive material in the terrestrial environment of Japan.

A7. The Committee acknowledged (see paragraphs 45 and B15 to B16 of [U6]) that it had adopted a source term for which the total releases of iodine-131 and caesium-137 were both at the lower end of the ranges of published values. However, if a larger source term had been used with ATDM, the resulting levels of radioactive material in the terrestrial environment would have been overestimated and this would have been contrary to the Committee's intent of making realistic estimates.

A8. The Committee recognized the uncertainties associated not only with the choice of source term but also with the subsequent ATDM. Its 2013 Fukushima report included an analysis of the robustness and implications of its choice of source term and ATDM (see paragraphs B52 to B59 and C118 to C119 in [U6]).

A9. Several more recent estimates of the source term tend to favour the lower ends of the ranges of releases given by the Committee in the 2013 Fukushima report (see chapter III of this white paper).

B. Validity of choice of radiologically significant radionuclides for releases to the atmosphere

A10. The 2013 Fukushima report has been criticized for not including other potentially significant radionuclides (such as isotopes of strontium and plutonium) in the source term for releases to the atmosphere [B1, I3].

A11. The Committee had based its choice of radiologically significant radionuclides on a consideration of the chronology of the accident, the conditions in the three reactors that led to releases, measured levels of radionuclides in the environment, and knowledge and experience from extensive theoretical and experimental investigations of a wide range of postulated accident conditions (see paragraphs 46 and B17 to B18 of [U6]). The significance of very short-lived radionuclides in the FDNPS accident was greatly reduced by the delay between reactor shutdown and when the releases occurred. The fractional release (and therefore significance) of isotopes of elements such as strontium, barium and plutonium was much lower than those of isotopes of elements that were included because of their much lower volatilities. This has been confirmed by measurements in the environment.

A12. The Committee's quantitative analysis had explicitly included all radionuclides that could have made a material contribution to the doses estimated and presented in [U6]. This is further supported by more recent evidence (see chapter III of this white paper).

III. SOURCES OF DATA AND THEIR IMPARTIALITY

A13. The 2013 Fukushima report has been criticized for its use of data from organizations (such as the Tokyo Electric Power Company (TEPCO), the operator of the FDNPS, and the International Atomic Energy Agency (IAEA)), which are claimed not to be impartial, in particular being perceived by some as having an interest in minimizing the impacts of the accident [I2, I3, J1].

A14. The Committee described the sources of data and the processes used to assure the scientific quality and relevance of each dataset for its purposes in its 2013 Fukushima report (see paragraph 4 and appendix A of [U6]). The sources included non-governmental organizations as well as a wide range of national and international bodies. The processes included reviewing the methods used to collect the data and the quality assurance procedures followed, as well as comparisons and cross-checking between datasets from different sources. Only information that had been deemed of acceptable quality and fit for the purpose of the Committee's assessment was used.

A15. In the few specific instances for which the Committee had any reason to question the validity of the data, it had clearly indicated this in its report (e.g. see below – reliability of doses to workers).

IV. AVERAGE DOSES AND VARIABILITY BETWEEN INDIVIDUALS

A16. The 2013 Fukushima report has been criticized for presenting average doses to broad groups of the population of Japan and not indicating the variability about the average or the higher doses to which many people would have been exposed [B1, I2, I3, J1, P1].

A17. The 2013 Fukushima report made clear that the Committee's aim was to make realistic estimates of doses and, to that end, its main focus had been on estimating doses to defined groups of individuals considered to be representative of the different subsets of the Japanese population. Accordingly, the report generally presented average doses, at different spatial resolutions, to different age groups in the population.

A18. The report also included a discussion of the variation about these average doses between individuals depending on their location and habits. In particular, the spatial variability in both the measured radionuclide deposition densities and the concentrations of radionuclides in air was such that the estimates of both effective doses and the absorbed doses to the thyroid from inhalation could be from 30–50% of the district-average dose up to about two to three times higher than the district-average dose (see paragraph 98 in [U6]).

A19. The Committee also stated that there was significant variability in measured levels of radionuclides in different foodstuffs. It could not exclude the possibility that some individuals, particularly those in the deliberate evacuation areas, might have consumed locally-grown food or collected mushrooms or wild plants, or caught or hunted local fish and game with high concentrations of radionuclides before their evacuation. Such food habits had the potential to increase the estimates of effective dose from ingestion for these individuals by up to perhaps ten times, however there was no evidence of such higher doses in the extensive sets of in vivo whole-body measurements of the general public. Also, because of the time of year of the accident, locally-grown food was limited, and many people in Japan took measures to reduce

their intake of radionuclides in food by avoiding fresh produce or anything that might have come from Fukushima Prefecture. For those people, doses due to ingestion would have been significantly lower than those estimated by the Committee (see paragraphs 100–101 in [U6]).

V. FETAL DOSES AND EFFECTS

A20. The 2013 Fukushima report has been criticized for not specifically assessing doses and effects to the fetus [I2, I3].

A21. The Committee had not explicitly estimated doses to the fetus but did provide an indication of their magnitude. This was considered sufficient because the doses to the fetus would have been similar to those to other age groups for which doses were explicitly assessed (adults, children and infants, where 1-year-old infants were used to represent all infants younger than 5 years old). The Committee had judged that the doses to the fetus from external exposure were approximately the same as those to adults, and that those from internal exposure were lower than, or within the range of, doses estimated for the three main age groups (see paragraphs 80, C32, C80 and C97 in [U6]).

A22. In discussing the health implications of the estimated doses, the Committee had recognized that relative risks in certain population groups (notably following exposure as fetus, or during infancy and childhood) are higher than for the population average, and had considered the risk to those exposed as fetuses during pregnancy (see paragraphs 221 to 224 and E37 in [U6]).

VI. RELIABILITY OF WORKER DOSES

A23. The 2013 Fukushima report has been criticized for basing its assessment of doses to workers on data provided by the Tokyo Electric Power Company (TEPCO), the operator of FDNPS, which should not be relied on because of the company's perceived interest in minimizing the impacts of the accident. In addition, the 2013 Fukushima report did not adequately address numerous reports of shortcomings in TEPCO's monitoring arrangements, including missing dosimeters, tampering with dosimeters and faulty radiation measuring instruments, or the lack of information about possible intakes of shorter-lived radionuclides [I2, I3].

A24. The Committee had to rely on data provided, not only by TEPCO, but also by the Japanese authorities, for the assessment of doses to workers, because there were no other, independent, sources of relevant information. One of the aims of the Committee's work was to judge the extent to which the individual doses reported in Japan provided a true and reliable measure of the doses actually incurred. The Committee's assessment therefore comprised, firstly, a review of the methodologies used in Japan for assessing doses and, secondly, independent dose assessments for defined groups of workers (including individuals randomly selected by the Committee) which were then compared with the values reported in Japan.

A25. Further details of its approach and the results were set out in the 2013 Fukushima report (see paragraphs 145 to 155, and appendix D of [U6]). In general, the process had resulted in good agreement between the dose assessments of the Committee and the Japanese government, but better information was needed in some areas. The Committee also made clear that, because of the use of shared dosimeters and a lack of information about whether conditions for the use of shared dosimeters had been met, it had some reservations about the reliability of the external dosimetry carried out before 1 April 2011. The Committee also provided an indication of the impact on the

assessed doses of the delay in starting in vivo monitoring based on a detailed assessment of the potential additional doses arising from intakes of shorter-lived radionuclides (see paragraphs D38 to D40 and attachment D−1 of [U6]).

VII. INCONSISTENCIES BETWEEN FINDINGS AND PUBLISHED FIELD STUDIES ON NON-HUMAN BIOTA

A26. The 2013 Fukushima report has been criticized for not taking adequate account of evidence from field studies from both the Fukushima-Daiichi and Chernobyl accidents of observed effects on non-human biota [I4].

A27. The 2013 Fukushima report included a summary of the findings of a few field studies published up to December 2012 (see paragraphs 197 and F4 to F6 of [U6]). However, the Committee noted that uncertainties with regard to dosimetry and possible confounding factors (including the impact of the tsunami itself) made it difficult to substantiate firm conclusions on a causal relationship with radiation exposure. Furthermore, the main body of existing scientific data did not support the appearance of the observed effects at the dose rates recorded. The Committee identified the need for further analyses of whether radiation exposure was an important factor in causing the environmental effects reported in field studies as a priority for future research. This need is reinforced by more recent publications (see chapter VIII of this white paper).

VIII. HEALTH RISKS

A. Discernibility

A28. The 2013 Fukushima report has been criticized for stating that no discernible increases in the future incidence of health effects due to radiation exposure would be expected either among workers or the public. Some critics stated that the concept of "no discernible increase" in risk is not valid from a public health perspective and is inconsistent with the international scientific consensus that there is no threshold below which radiation poses no harm [B1, I2, I3, P1]. At the same time, other critics [S1] called on the Committee to make a firm, unconditional statement to the Fukushima residents that returning to their homes would not increase their risk of cancer and thereby overcome the "disastrous consequences" of the use of the linear no-threshold model for radiation-induced cancers and its associated no-safe-dose mantra.

A29. The 2013 Fukushima report included a commentary on the immediate and long-term health implications of exposures to ionizing radiation resulting from the accident at FDNPS (see paragraphs 156 to 167 and appendix E in [U6]). The Committee estimated risks due to exposure for members of various exposed groups based on its own dose estimates, its estimates of disease risks from exposures to ionizing radiation, and the results of the WHO report [W2]. The Committee's commentary considered qualitative and quantitative estimates of potential disease outcomes among the exposed populations that may or may not be observable in future disease statistics. Further analysis of the power of epidemiological studies to detect increases in the frequency of disease occurrence given the numbers of people exposed as a result of the FDNPS accident can be found in electronic attachment 1 to this white paper.

A30. In its commentary, the Committee used the phrase "no discernible increase" to express the idea that currently available methods would most likely not be able to demonstrate an

increased incidence in the future disease statistics (i.e. an increased frequency of disease occurrence) due to irradiation. The 2013 Fukushima report made clear that the use of this phrase did not equate to absence of risk or rule out the possibility of excess cases of disease due to irradiation, nor to the possibility of detection of a biomarker for certain types of cancer in certain subgroups being identified in the future that could be associated with radiation exposure; moreover, it was not intended to disregard the suffering associated with any such cases should they occur.

A31. The Committee is a body dealing with science alone; it does not have the mandate to take that science and develop public health policy. It has recognized that public health authorities may calculate risks based on certain assumptions at doses well below the levels at which effects have been observed.

B. Non-cancer diseases and hereditary effects

A32. The 2013 Fukushima report has been criticized for not assessing the risks of non-cancer health effects, such as cardiovascular diseases, endocrinological and gastrointestinal disorders, infertility, genetic mutations in offspring and miscarriages [I2, I3].

A33. The 2013 Fukushima report included a brief recapitulation of knowledge on health effects and risks from exposure to ionizing radiation that covered all known effects (see paragraphs 164 and E4 to E14 in [U6]). The Committee had concluded that exposure of members of the public fell well below the thresholds for deterministic effects (see paragraph 168 in [U6]). It had also concluded that exposure during pregnancy was not expected to increase the incidence of spontaneous abortion, miscarriages, perinatal mortality, congenital effects or cognitive impairment (see paragraphs 178 and 224 in [U6]).

A34. No early deterministic health effects had been observed among the workers with the highest doses to the thyroid, but the Committee could not preclude the possibility of hypothyroidism among the most exposed workers. The Committee had concluded that risks for circulatory disease resulting from radiation exposure were very low for those most exposed. However, the Committee had had insufficient information on exposures of the eye lens to reach an informed judgement on the risk of cataracts (see paragraphs 184 and 186 in [U6]).

A35. An increased incidence of hereditary effects has not been reliably demonstrated in humans for any level of exposure, and it was not expected to be possible to demonstrate this among the general public or workers following the FDNPS accident (see paragraph 166 in [U6]).

C. Effects from combined exposure to radiation and other pollutants

A36. The 2013 Fukushima report has been criticized for not considering the possibility that exposure to hazardous chemical contamination, resulting from the effects of the earthquake and tsunami on other industrial facilities, may severely confound the relationship between radiation exposure and carcinogenic effects [I4].

A37. The Committee considered the issue of the combined effect of ionizing radiation with other physical, chemical and biological agents in its reports of 1982 and 2000 [U2, U4]. The 2000 report [U4] included a detailed review of the available evidence on combined effects. It concluded that, except for radiation and smoking, there was no evidence that low-level exposures to multiple agents yielded combined effects far from additivity (i.e. from what

would be expected from adding the effects of each agent separately), or above the estimates resulting from linear extrapolation of single agent effects to lower doses.

D. Thyroid anomalies

A38. The 2013 Fukushima report has been criticized for deficiencies in its discussion of the apparently high prevalence of thyroid anomalies that are being found in the health screening being carried out in Fukushima Prefecture, specifically over "assurances" based on comparisons with a cohort of Ukrainians and the results of a survey carried out in prefectures largely unaffected by the accident [I2, I3].

A39. In the 2013 Fukushima report, the Committee concluded that most of the absorbed doses to the thyroid of members of the public were in a range for which an excess incidence of thyroid cancer had not been observed in epidemiological studies, although doses towards the upper bounds of the ranges could imply an increased risk for individuals that among sufficiently large population groups might lead to discernible increases in the incidence of thyroid cancer due to radiation exposure. The Committee concluded that a large number of radiation-induced thyroid cancers as had been observed after the Chernobyl accident, could be discounted because doses were substantially lower (see paragraph 175 in [U6]).

A40. The Committee did not provide any "assurances". It reviewed the information available at the time from the thyroid ultrasound examinations that were being carried out for individuals in Fukushima Prefecture and noted that thyroid nodules had been detected in about 1% of those surveyed and thyroid cysts in about 40% of those surveyed. It further noted that, in a survey using similar equipment that had been made in prefectures largely unaffected by the accident, the observed prevalence of thyroid nodules and cysts was even larger, suggesting that the intensive screening and the highly sensitive nature of the equipment being used could explain the high detection rate of nodules and cysts. The prevalence of some types of asymptomatic thyroid cancers (that would remain latent, but would be detectable in the surveys being conducted) could be as high as 35% in many parts of the world, according to findings from autopsies (see paragraphs 180 to 181 and E48 in [U6]). This interpretation is supported by more recent evidence (see chapter VII of this white paper).

E. Collective dose

A41. The 2013 Fukushima report has been criticized for presenting estimates of the collective doses to the Japanese population from the accident, but not presenting estimates of the expected cancer cases that would result based on "internationally accepted", no-threshold models [B1, I3, I4, J1, P1].

A42. The Committee's views on the usefulness of collective dose estimates were recently summarized in its report to the sixty-seventh session of the United Nations General Assembly.[10] The Committee had concluded, inter alia, that "an increased incidence of stochastic effects in a population could be attributed to radiation exposure through epidemiological analysis — provided that, inter alia, the increased incidences 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

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

exposure". "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 [i.e. estimating collective dose, and using this] 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." The Committee noted, however, that "public health bodies need to allocate resources appropriately, and that this may involve [estimating collective dose and/or] 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 was 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".

IX. UNSCEAR COMMITTEE

A. Composition

A43. The Committee has been criticized for not being balanced in respect of pro- and anti-nuclear sympathies and for not being clearly free from conflicts of interest or bias [B1, C2].

A44. The Committee's mandate in the United Nations system (as set out by the General Assembly in resolution 913 (X) of 3 December 1955) is the science of the matter – it is neither pro- nor anti-nuclear nor, indeed, pro- nor anti- any other activity that involves the use or production of radiation or radioactive material (e.g. in medicine, research or industry). The Committee assesses and reports on the levels and effects of exposure to ionizing radiation from all sources, including natural sources.

A45. The governing principles of the Committee place expectations on its members to be free of conflict of interest. All those working on the 2013 Fukushima report signed a formal declaration of any potential conflicts of interest. The selection of those involved in the assessment work was based on proposals made by the national representatives to UNSCEAR; the key selection criteria were scientific excellence and competence in the relevant scientific fields.

B. Japanese funding

A46. The Japanese government made a voluntary contribution to support "the vital role UNSCEAR plays in the safety of nuclear energy" [U1]. This contribution has been claimed to have been made for the purposes of "removing unnecessary concerns about radiation effects" [I3].

A47. The Secretariat of the Committee is financed by the United Nations and administered through its environment programme (UNEP). In May 2007, in response to a resolution of the United Nations General Assembly urging UNEP to review and strengthen the funding of UNSCEAR, the Executive Director of UNEP, in common with practice in other areas of UNEP's work, had established a general trust fund to receive and manage voluntary contributions to support the work of the Committee. Since the establishment of this trust fund, the United Nations General Assembly had regularly encouraged Member States to consider making voluntary

contributions to the trust fund. Several countries have contributed (namely, Australia, Canada, Germany, Indonesia, Sweden, and Switzerland) and Japan and Spain are recent additions.

A48. The trust fund is intended to support the Committee in fulfilling its mandate, which is to undertake scientific assessments of the sources of ionizing radiation and its effects on human health and the environment. The Committee's reports are based on science and are neutral with respect to policy. The Committee does not develop policy or provide advice to governments or regional or international bodies. However, many governments and relevant bodies choose to make use of the Committee's scientific evaluations for their own development of policies and thus the Committee may be considered to play a "vital role" in the safety of nuclear energy.

A49. For the purposes of the 2013 Fukushima report, the contributions in kind of more than 80 experts at no cost to the United Nations, and their support staff in national institutes, were more significant than the financial contributions to the trust fund.

C. Delay in publishing the report

A50. The Committee has been criticized because of the delay between the review of the report by the Committee and its publication, which has been attributed to "disputes between members of the committee" and "the need for the report to be worded correctly" [B1].

A51. The main findings of the assessment were approved by the Committee and submitted to the United Nations General Assembly in October 2013. This was in line with the Committee's planned schedule. The full report with supporting scientific annex and appendices was published in April 2014. The six-month period was taken up with further extensive and detailed checking of the data, the assumptions and the methods used to assure the quality and robustness of the assessment, and publication matters. This period was not excessive, given that the report extended to nearly 300 pages, was supported by 28 electronic attachments and involved the work of more than 80 scientific experts from around the world, a significant number of whom were involved in reviewing and checking drafts of the document for quality assurance purposes.

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In 1955 the United Nations General Assembly established the Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in response to concerns about the effects of ionizing radiation on human health and the environment. At that time fallout from atmospheric nuclear weapons tests was reaching people through air, water and food. UNSCEAR was to collect and evaluate information on the levels and effects of ionizing radiation. Its first reports laid the scientific grounds on which the Partial Test Ban Treaty prohibiting atmospheric nuclear weapons testing was negotiated in 1963.

Over the decades, UNSCEAR has evolved to become the world authority on the global level and effects of atomic radiation. UNSCEAR's independent and objective evaluation of the science are to provide for—but not address—informed policymaking and decision-making related to radiation risks and protection.

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