United Nations Scientific Committee on the Effects of Atomic Radiation

ATTACHMENT 2

DEVELOPMENT OF ISODOSE MAPS REPRESENTING ANNUAL EXTERNAL EXPOSURE IN JAPAN AS A FUNCTION OF TIME

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

Notes

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This publication has not been formally edited.

Contents

I. INTRODUCTION

1. In its 2013 Fukushima report [UNSCEAR, 2014], the Committee had made estimates *(a)* of district- and prefecture-average doses and *(b)* of accumulated doses in the first year after the accident, over the first 10 years, and up to age 80 years. The Committee has since further analysed the data and results presented in the 2013 Fukushima report to produce an animated map of the estimates of annual adult effective dose from external exposure into the future. The values for annual dose from external exposure per unit deposition density of ^{137}Cs in figure C-IX of [UNSCEAR, 2014] have been interpolated to derive estimates for each year up to 10 years after deposition, and for every tenth year up to 100 years after deposition. The data and methods used are described in this attachment.

II. ESTIMATES OF EFFECTIVE DOSE FROM EXTERNAL EXPOSURE INTO THE FUTURE

2. The estimates of doses from external exposure in [UNSCEAR, 2014] were based mainly on data for measured ground deposition density and ambient dose equivalent rate provided by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). MEXT had compiled data on measured ambient dose equivalent rates and soil samples collected between 6 June and 8 July 2011 for areas within 100 km of the Fukushima Daiichi Nuclear Power Station (FDNPS). Out to 80 km from FDNPS these had been undertaken for 2 km × 2 km grids. Soil samples had been collected at five points for each location. Around 11,000 soil samples had been taken; and the deposition densities of five gamma-emitting radionuclides (^{110m}Ag, ^{129m}Te, ^{131}I, ^{134}Cs and ^{137}Cs) had been measured using germanium semiconductor detectors. The Committee reproduced the data it had used from the MEXT survey of ^{137}Cs deposition density in attachment C-2 of the 2013 Fukushima report [UNSCEAR, 2014] as an Excel® workbook with geospatial information on a 1 km grid.

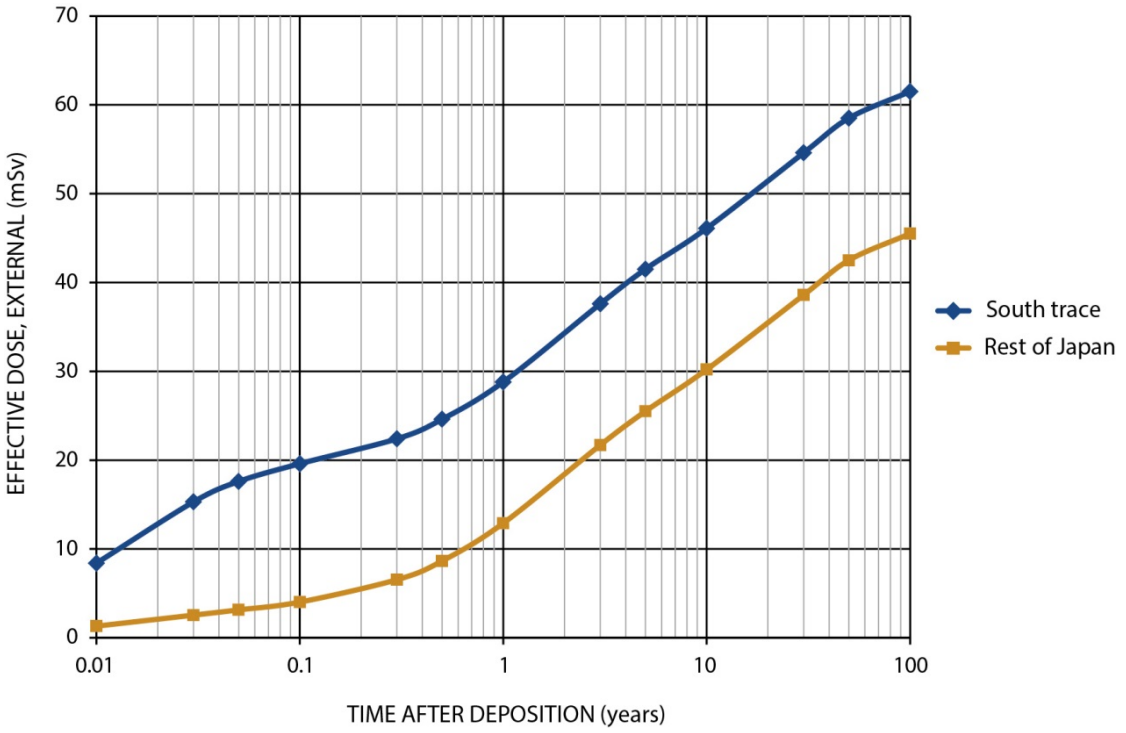
3. In [UNSCEAR, 2014], the Committee had made estimates *(a)* of district- and prefecture-average doses and *(b)* accumulated doses in the first year after the accident, over the first 10 years, and up to age 80 years. The Committee had estimated doses from external exposure for future years using similar dosimetric methods as for the first year, but taking

account of the reduction in dose rate due to radioactive decay and the implied effects of removal of radionuclides by natural physico-chemical processes over the period of exposure. The detailed methodology used was presented in attachment C-12 to [UNSCEAR, 2014].

4. Figure C-IX in [UNSCEAR, 2014], reproduced in figure I below, provides estimates of the accumulated effective dose from external exposure, projected forward over 100 years after the accident. The estimates of how the contributions from ^{134}Cs and ^{137}Cs fall with time take account of radioactive decay and the natural movement of caesium into surfaces assumed to be similar to that derived from data collected over the years since the Chernobyl accident. Because detailed information was lacking on the implementation and effectiveness of remediation at specific locations, no account was taken of the possible reduction in exposure from future remediation. The estimates of accumulated dose from external exposure used to prepare figure I are tabulated in table 1.

Figure I. Estimated accumulated effective dose per unit deposition density from external exposure of typical adults living in areas covered by the south trace and in the rest of Japan (figure C-IX [UNSCEAR, 2014])

The estimated doses are normalized to a deposition density of 1 MBq m^{-2} of ^{137}Cs



5. The values in table 1 were interpolated to derive estimates of the annual dose from external exposure, for each year up to 10 years after the initial deposition, and for every tenth year up to 100 years after deposition. These estimates are summarized in table 2 and are derived for the locations outside of the south trace. However, after the first year and following the radioactive decay of the short-lived radionuclides, these values are applicable for locations in both the south trace and the rest of Japan.

Table 1. Estimated accumulated effective dose to adults from external exposure per unit ^{137}Cs deposition density, for locations in the south trace and for the rest of Japan (derived from figure C-IX of [UNSCEAR, 2014])

The number of significant figures presented in the table are used for calculational purposes only; they do not imply such a degree of accuracy in the underlying quantities

Time after deposition (years)	*Accumulated effective dose from external exposure, south trace (mSv/MBq m^{-2})*	*Accumulated effective dose from external exposure, rest of Japan (mSv/MBq m^{-2})*
0.01	8.4	1.31
0.03	15.3	2.55
0.05	17.6	3.14
0.1	19.6	4.02
0.3	22.4	6.54
0.5	24.6	8.64
1	28.8	12.9
3	37.6	21.7
5	41.5	25.5
10	46.1	30.2
30	54.6	38.6
50	58.5	42.5
100	61.5	45.5

Table 2. Interpolated values of annual effective dose and accumulated effective dose from external exposure per unit ^{137}Cs deposition density, derived for locations outside of the south trace (derived from figure C-IX of [UNSCEAR, 2014])

Time after deposition (years)	*Annual effective dose (mSv/MBq m^{-2})*	*Accumulated effective dose (mSv/MBq m^{-2})*
1	12.9	12.9
2	5.5	18.4
3	3.3	21.7
4	2.2	23.9
5	1.6	25.5
6	1.2	26.7
7	1	27.7
8	0.90	28.6
9	0.85	29.5
10	0.75	30.2
20	0.49	35.1
30	0.35	38.6
40	0.23	40.9
50	0.16	42.5
100	0.03	45.5

III. PREPARATION OF ISODOSE MAPS REPRESENTING ANNUAL EFFECTIVE DOSE TO ADULTS FROM EXTERNAL EXPOSURE

6. The Committee had presented the data from the MEXT survey of ^{137}Cs deposition density for a 1 km grid as an Excel® workbook with geospatial information in attachment C-2 of [UNSCEAR, 2014]. This workbook provided the values for the ^{137}Cs ground deposition density (as at 14 June 2011) for approximately 2,200 grid cells, together with the latitude and longitude values for the grid. This dataset had been spatially interpolated using an Inverse Distance Weighting algorithm to estimate ground deposition density values for all the 1 km grid cells in Fukushima Prefecture and neighbouring prefectures.

7. For each grid cell, the adult effective dose from external exposure, as a function of time after initial deposition, was estimated from the product of the ^{137}Cs deposition density on the ground and the conversion factor for annual effective dose per unit deposition density on the ground (table 2). The annual effective dose to adults from external exposure was thus estimated for each 1 km grid cell and for each year from years 1 to 10, then at every 10 years from years 10 to 50.

8. The estimates of annual effective dose from external exposure for each year were analysed to derive an isodose line representing a dose of 1 mSv in a year. These isodose lines were then overlaid on a portion of the World Topographical map covering Fukushima Prefecture, or exported as shape files for use in other geospatial information systems. Maps showing the isodose lines for years 1, 3, 10 and 50 are shown in figure II. The maps and isodose curves for each year have been combined into a single file to provide an animated map of the change in the isodose curve for an annual effective dose of 1 mSv from external exposure into the future. This animation can be downloaded from http://www.unscear.org/unscear/en/publications/Fukushima_WP2015.html.

ACKNOWLEDGEMENTS

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REFERENCE

UNSCEAR. Sources, Effects and Risks of Ionizing Radiation. Volume I: Report to the General Assembly and Scientific Annex A. UNSCEAR 2013 Report. United Nations Scientific Committee on the Effects of Atomic Radiation. United Nations sales publication E.14.IX.1. United Nations, New York, 2014.

Figure II. Maps showing the isodose line for an annual effective dose of 1 mSv from external exposure to adults in years 1, 3, 10 and 50 after deposition