Potential internal radiation dose from inhalation in the vicinity of the Fukushima NPP on 14th and 15th March 2011

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Potential radiation doses in the vicinity of the Fukushima NPP

In March 2011, a catastrophic accident occurred in the nuclear power plant Fukushima. Not all people in the vicinity of the plant were evacuated in time, i.e. before there were massive releases of radiation. In this paper, the possible radiation doses for these people are roughly estimated. The objective of this assessment is to show, that:

1. these persons received a significant radiation dose, and
2. sufficient data for such a calculation are available.

In May 2012, a preliminary report from the World Health Organisation (WHO) estimated the radiation doses that residents of Japan have received in the year following the accident at Fukushima Daiichi.[1] But this report does not include doses within a radius of 20 km from the Fukushima site. According to the WHO, such an assessment would have required more precise data than were available.

In this paper, the basis of the calculation is a publication of the Japanese operator TEPCO from May 2012: "Estimation of Radioactive Material Released to the Atmosphere during the Fukushima Daiichi NPS Accident." [2] In this publication, TEPCO lists 37 different releases. There were two massive releases, with wind blowing from the sea to the land: release No. 13 on the 14th of March 2011 between 9:20 and 10:20 p.m. and release No. 15 on the 15th of March 2011 between 7:20 and 10:20 a.m. The evacuation of the population was only completed by 12:00 on the 15th of March 2011.

1 Calculation of atmospheric dispersion

First, the activity concentrations in the air were calculated on the basis of the data provided by TEPCO for the releases No. 13 and 15 at a distance of 10, 15 and 20 km from the Fukushima NPP. For larger distances, the modelling programme provides only very rough values; nevertheless, the values for 40 km are calculated comparatively.

The atmospheric dispersion programme HOTSPOT (V. 2.06) is used for the calculations. This programme was developed by the renowned US-American Lawrence Livermore National Laboratory (LLNL) for the purpose of determining values for orientation.[3] The calculation of this programme is based on the same model (Gaussian Plume Model) that has to be

[1] Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami; World Health Organisation (WHO); May 2012; http://www.who.int/ionizing_radiation/pub_meet/fukushima_dose_assessment/en/

[2] http://www.tepco.co.jp/en/press/corp-com/release/betu12_e/images/120524e0205.pdf

[3] Lawrence Livermore National Laboratory (working on behalf of the U.S. Department of Energy): HotSpot Health Physics codes; Livermore (California), www.llnl.gov, viewed in August 2008

used to determine the potential distribution of radioactive substances during a nuclear accident in Germany, to comply with the applicable incident calculation bases.[4]

Hotspot was created to provide emergency response personnel and emergency planners a fast, field-portable set of software tools for evaluating incidents involving radioactive material. The software is also used for safety-analyses of facilities handling nuclear material.

Dispersion calculation parameters

Source terms

For the calculations, the source terms of Iodine-131 provided by TEPCO are used. The activity of the released Iodine-131 is 40 PBq (No. 13) and 60 PBq (No. 15).

Wind velocity

During release No. 13 the wind velocity most of the time was 1 – 2 m/s; at the end of the time period wind velocities of 4 – 5 m/s were measured. During release No. 15, a wind velocity of about 2 m/s was specified, in short time periods higher or lower velocities were measured.

For the calculation of both scenarios, an average wind velocity of 2 m/s is assumed. This wind velocity is relatively low, meaning that the radioactive cloud moved rather slowly. As a result, more radioactive substances were inhaled than with a fast-moving radioactive cloud.

Wind direction

During release No. 13, there was wind from the north, so the radioactive cloud moved southwards. Although other wind directions (south-east to south-west) also occurred every now and then during this release, the dispersion calculation is based on the assumption that a north wind blew over the entire release period.

During release No. 15, the winds blew mainly from the north-east, and also partly from the north or east. As a result, the radioactive cloud moved to the south-west. For the estimated calculation, it was assumed that a north-east wind blew during the entire release.

Air stability category

For the dispersion calculations for both scenarios, the neutral-to-stable air stability category D was used. In their publication, TEPCO do not provide any information about air stability categories, but on the basis of the available data the use of this category appeared appropriate. D is an air stability category with medium-sized air turbulence. Air stability categories with higher air turbulence (A, B, C) lead to a larger spatial extent of the cloud, but the air concentrations of radioactive substances and, thus, the resulting doses are lower. Air stability categories with lower turbulence (E, F) lead to a lower spatial extension of the radioactive cloud, but the resulting doses are higher.

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[4] Strahlenschutzkommission (SSK): Störfallberechnungsgrundlagen zu § 49 StrlSchV, Neufassung des Kapitels 4: Berechnung der Strahlenexposition, verabschiedet auf der 186. Sitzung der SSK am 11.09.2003

Release height

TEPCO stated concerning release No. 13 that a release from the Unit 1 and Unit 2 stacks is assumed, although the exact release location is unclear. A release from the stacks corresponds to a release height of 120 m. For release No. 15, the height of the reactor building (30 m) is specified as the release height, the exact release height is also unclear.

Despite the existing uncertainty, the release heights provided by TEPCO are used as a parameter for the dispersion calculation.

The parameters of the dispersion calculation are summarised in Table 1:

Table 1: Parameters of the dispersion calculation

Parameter	Unit	Release No. 13	Release No. 15
Source term	[PBq]	40	60
Release height	[m]	120	30
Air stability category		D	D
Wind velocity	[m/s]	2	2

2 Determination of the radiation dose

From the determined air activity concentrations the possible radiation doses for people who stayed outdoors or in buildings with negligible shielding effects during the passage of the radioactive cloud were calculated. Radioactive substances can contribute to the doses via different exposure pathways. The most important pathways are external exposure to radiation from the radioactive cloud and the ground, and internal exposure by inhalation of radionuclides from the radioactive cloud and ingestion of food.

For this calculation only the internal exposure by inhalation of the radioactive cloud is considered. In addition, only the nuclide (iodine 131) with the largest contribution to the exposure is considered.

On the basis of inhalation rates and dose coefficients, the effective doses for children (1 – 2 years) and for adults (aged 18 years and over) are calculated. The inhalation rates and dose coefficients used are summarised in Table 2:

Table 2: Inhalation rates and dose coefficients

	Unit	Adults (from 18 years)	Children (1 – 2 years)
Inhalation rates	[m^3/s]	2.60 E-04	6.00 E-05
Dose coefficients	[Sv/Bq]	2.00 E-08	1.60 E-07

3 Discussion of the results

The results of the calculations are given in Tables 3 and 4. At a distance of 10 to 20 km from the NP the calculated radiation doses are relatively high. For children from 1 – 2 years, the calculated effective doses in the south-west of the nuclear power plant Fukushima are between 580 and 1580 mSv, for adults aged 18 years and over between 310 and 860 mSv.

Table 3: Effective doses after release No. 13 in the vicinity of the Fukushima NPP

Distance	[km]	10	15	20	40
Effective doses adults (from 18 years)	[mSv]	380	240	170	70
Effective doses children (1 – 2 years)	[mSv]	710	450	320	130

Table 4: Effective Doses after release No. 15 in the vicinity of Fukushima NPP

Distance	[km]	10	15	20	40
Effective doses adults (from 18 years)	[mSv]	860	470	310	120
Effective doses children (1 – 2 years)	[mSv]	1580	860	580	220

This rough estimation shows that the WHO would have sufficient data to calculate the radiation doses of people who were not evacuated in time. More accurate calculations using the existing meteorological data and with all nuclides and exposure pathways will determine similar doses. These calculations should urgently be performed by the WHO, so that the affected people will receive the necessary health care. Not calculating radiation doses for the most-exposed people appears to be a deliberate downplaying of the consequences of this catastrophic accident. The WHO identified 50 mSv as the highest effective dose that people received within the first year after the accident.[5]

[5] Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami; World Health Organisation (WHO); May 2012; http://www.who.int/ionizing_radiation/pub_meet/fukushima_dose_assessment/en/