

Health consequences of the Fukushima accident
Situation of the workers involved in the mitigation activities
carried out at the Fukushima Dai-ichi nuclear power plant
Report on the situation in March 2016

Doses received by TEPCO workers and subcontractors

The main information currently available on the doses received by workers involved in the operations carried out at the Fukushima Dai-ichi nuclear power plant is that provided by TEPCO, which has been publishing a monthly report since April 2011. It concerns only the employees of TEPCO and its subcontractors. The latest report, published on 29 February 2016, concerns 4 687 TEPCO employees and 41 803 employees of subcontractors (i.e. a total of 46 490 employees) who worked at the Fukushima Dai-ichi power plant between 11 March 2011 and 31 January 2016 (Table I).

Table I: Breakdown of the total doses received by the employees of TEPCO and its subcontractors between 11 March 2011 and 31 January 2016 (report published by TEPCO on 29 February 2016)

Cumulative dose	TEPCO	Subcontractors	Total
> 250 mSv	6	0	6
200 - 250 mSv	1	2	3
150 - 200 mSv	26	2	28
100 - 150 mSv	117	20	137
75 - 100 mSv	316	279	595
50 - 75 mSv	328	1 745	2 073
20 - 50 mSv	633	6 410	7 043
10 - 20 mSv	621	5 671	6 292
5 - 10 mSv	496	5 405	5 901
1 - 5 mSv	887	9 584	10 471
< 1 mSv	1 256	12 685	13 941
Total	4 687	41 803	46 490
Maximum (mSv)	678.80	238.42	-
Average (mSv)	22.44	11.61	12.70

The average dose received between 11 March 2011 and 31 January 2016 by these workers is 22.44 mSv for TEPCO employees and 11.61 mSv for subcontractors' employees. As compared to the report published in February 2015, this shows a slight reduction for TEPCO employees (-0.67 mSv), but an increase for subcontractors' employees (+0.76 mSv).

Putting the recorded doses into perspective with respect to exposure limits

At the time of the Fukushima accident, the workers' exposure limit was 50 mSv per year, and could not exceed a dose of 100 mSv over five years. Pursuant to Japanese legislation, the exposure dose limit for an emergency situation was set at 100 mSv at the time of the accident. It was raised to 250 mSv by the order dated 14 March 2011, which entered into force on 15 March 2011, and later reduced to 100 mSv per year for all workers involved in these emergency works, as from 1 November 2011. The reduction did not apply to the fifty or so workers involved in operations to maintain reactor cooling functions, for whom the exposure dose limit remained at 250 mSv until 30 April 2012.

Currently, the maximum recorded dose is 678.80 mSv for a TEPCO worker. Since the accident, six workers have received a total dose above the 250 mSv limit and 174 have received a total dose of more than 100 mSv. Analysis of changes in received doses shows that the total number of workers who received a dose of more than 100 mSv has not changed since April 2012 (150 TEPCO workers and 24 subcontractors'). Between November 2011 and April 2012, only one worker received a total dose of more than 100 mSv. Finally, analysis of this data shows that the average internal dose received by these workers fell from 8 mSv in March 2011 to 0.13 mSv in May 2011. No internal dose has been recorded since June 2011.

Exposure of other categories of workers

In August 2012, the Japanese authorities sent information pertaining to the exposure of other categories of exposed workers (fire fighters, policemen, municipal employees, self-defence force personnel) to the group of experts in charge of drafting the chapter of the UNSCEAR report on doses to workers. This information was published in the UNSCEAR 2014 report, but is unfortunately very scattered and not very accurate.

Since the report was published, few studies on the exposure of workers who were affected without necessarily having worked at the Fukushima nuclear power plant have been published in scientific papers. One study published in 2014 shows the results of the monitoring set up in July and August 2011 on 101 employees of the municipal general hospital of Minamisoma (located 25 km to the north of the nuclear power plant). The health professionals concerned by this monitoring cared for patients who were hospitalised or who had come for examinations between 11 and 20 March 2011, which were when all of the hospitalised patients were evacuated.

Protective measures implemented to minimise the external and internal exposure of these employees in contact with patients included distributing stable iodine tablets to them on 14 March 2011 in order to mitigate the risk of thyroid cancer, and asking them to wear chemical protective clothing.

According to the results of the measurements taken, caesium-134 was detected in 24 of the 101 employees, but at concentrations corresponding to internal doses of less than 1 mSv. However, the publication surprisingly makes no reference to possible exposure to caesium-137, which is always present with caesium-134.

Nevertheless, this publication is noteworthy as it is only the second report since the accident that analyses effective doses estimated on the basis of measurements taken from health professionals in direct contact with potentially contaminated patients. The first study on the same subject, published in 2013, showed the results of measurements performed on five members of an emergency medical team from Nagasaki University which is specialised in the care of radiation victims (REMAT). The study concluded that the five persons in question had received doses of less than 0.1 mSv due to the incorporation of very low quantities of iodine-131, caesium-134 and caesium-137.

Observed effects and health monitoring of workers

Observed effects

To date, at least ten deaths of workers have been recorded, none of which can be attributed to exposure to ionising radiation according to the information provided by the Japanese authorities:

- Two workers aged between 20 and 30 years died on 11 March 2011 while they were in one of the Fukushima Dai-ichi buildings flooded after the tsunami.
- Three workers aged between 50 and 60 years died of heart attack, the first on 14 May 2011, the second on 9 January 2012 and the third on 22 August 2012.
- One worker, aged about forty, died of acute leukaemia in August 2011, although he had never been exposed to ionising radiation before the accident. Between March and August 2011, he received an external dose of 0.5 mSv. Moreover, a whole-body radiation measurement confirmed the absence of internal contamination on 7 August 2011. This additional information helped in confirming the absence of a cause and effect relationship between exposure to ionising radiation and the leukaemia that caused the death of this worker.
- One worker, aged about fifty, died of septic shock caused by a retroperitoneal abscess, on 6 October 2011. As was the case of the worker who died of acute leukaemia, this death cannot be attributed to ionising radiation as the worker had never been exposed before the accident. He received an external dose of 5 mSv after the accident and a whole-body radiation measurement conducted on 9 September 2011 confirmed the absence of internal contamination.
- Two workers were fatally injured on the power plant site. The first was buried in sediment during excavation works in March 2014, the second fell into a storage tank of contaminated water in January 2015.
- A worker, aged about thirty and employed by a subcontractor of TEPCO, died of unknown causes in August 2015, after having worked for approximately three hours on the construction site of an ice wall meant to stop the flow of contaminated water.

Report on the situation of a former TEPCO employee to whom the Japanese health ministry granted a financial compensation on 20 October 2015

The 41-year-old worker from the city of Kita-Kyushu (Prefecture of Fukuoka) was employed at several Japanese nuclear sites between November 2011 and December 2013. In particular, between October 2012 and December 2013, TEPCO assigned him to the works for covering reactor buildings 3 and 4 of the Fukushima nuclear power plant. Note that this worker was not present at the site during the initial weeks that followed the accident in March 2011.

In January 2014, the worker was diagnosed as suffering from acute myeloid leukaemia. According to the dosimetry reports, he had received a dose of 15.7 mSv while working at the Fukushima nuclear power plant, in addition to a dose of 4.1 mSv received during inspection work conducted for a period of three months at the Genkai nuclear power plant in 2012 (i.e. a total dose of 19.8 mSv between 2012 and 2013).

The worker submitted a claim for compensation to the labour inspectorate to cover his medical expenses and compensate for his incapacity to work. This compensation was granted by the Japanese government after consulting with a panel of experts under the aegis of the Ministry of Health, which nevertheless stated that the cause and effect relationship between the exposure of the worker and the leukaemia that he developed was uncertain.

The decision of the Ministry of Health was based on a government text of 1976, which states that any worker exposed to an annual dose equal to or greater than 5 mSv, and who developed leukaemia during the first year following his or her assignment to works likely to expose him or her to ionising radiation, must receive financial compensation for the damage incurred. The text specifies that its provisions do not apply if it is proven that the leukaemia developed by the worker was due to another cause, especially a viral infection. According to this approach, the worker must always be given the benefit of the doubt in any other situation. These provisions have benefited 13 other Japanese workers since they were established in 1976.

According to the Japanese Ministry of Health, since 2011, eight workers from the Fukushima nuclear power plant have submitted claims for compensation for pathologies that they believe attributable to exposure to ionising radiation. Three of the eight claims have been rejected and one was eventually withdrawn by the worker. The other claims are still being examined.

Health monitoring

A worker health monitoring database has been set up. Each worker, including those who are no longer involved in on-going operations at the Fukushima Dai-ichi nuclear power plant, benefits from a basic medical check-up that includes eye, ear, chest, cardiovascular and digestive examinations, as well as biological analyses and an evaluation of his or her psychological and psychiatric condition.

Moreover, workers who have received a dose of more than 50 mSv undergo special monitoring to detect the possible occurrence of a cataract. Those who received a dose of more than 100 mSv undergo additional examinations to monitor the possible onset of thyroid disorders and certain cancers (lung, stomach, colon).

To the best of our knowledge, no specific and complete assessment of this health monitoring has been published to date by the Japanese authorities or by TEPCO or its subcontractors (who are responsible, as employers, for monitoring their employees' health).

The recent IAEA report published in 2015 indicates that TEPCO conducted thyroid ultrasound examinations on 672 workers who had received, over the course of 2011, an equivalent dose of more than 100 mSv, as well as on 1 437 other workers who had received lower doses. The results of these thyroid ultrasound examinations showed that there was no significant difference between the two groups of workers. This is not very surprising considering the short period of time between the examination and the exposure (thyroid cancer can take up to several decades to appear after exposure to ionising radiation), and the fact that the risk of an adult developing radiation-induced thyroid cancer is extremely low compared to that of exposed children.

Additional information collected following the publication of the WHO and UNSCEAR reports (the information given below comes from the notice published by IRSN in March 2015, as the situation has not changed since then)

Administration of stable iodine to workers

The administration of stable iodine is a preventive countermeasure aimed at saturating the thyroid with non-radioactive iodine in order to prevent, as far as possible, the accumulation of radioactive iodine in the thyroid gland in the event of exposure and thereby limit the risk of thyroid cancer in the long term.

According to the information collected by the working group chaired by an IRSN's representative as part of the work of UNSCEAR, approximately 17 500 stable iodine tablets (each containing 50 mg of iodine) have been distributed since 13 March 2011 to some 2 000 workers, including employees of TEPCO, the subcontractors, fire fighters, policemen and self-defence force personnel.

No side effect resulting from the administration of stable iodine was observed in the workers concerned, including the 230 of them who were given stable iodine tablets for more than 14 days, or those who were given more than 20 tablets during the period for which this preventive measure was implemented. Note that one worker was given a total of 87 stable iodine tablets, without any noteworthy adverse effect being observed, apart from a temporary disorder of thyroid function (hypothyroidism), which was reported in three workers.

Short-term health risks

In its report published in 2014, UNSCEAR confirmed that no acute radiation syndrome was observed or expected, given that the doses received by even the most exposed workers always remained below the detection threshold of such effects.

Long-term health risks

The potential long-term consequences of the Fukushima accident on the health of workers were assessed by the WHO. Its conclusions, published in February 2013, can be summarised as follows:

- It seems unlikely that a statistically significant increase in cataracts will be seen in the few individuals who received a dose of more than 100 mSv.
- Workers who received a dose of more than 500 mSv are at an increased risk of long-term cardiovascular disorders.
- For two-thirds of the workers (who received low whole-body doses), the risks of cancer are at a level comparable to fluctuations in the baseline rate.
- For approximately one-third of the workers (who received moderate doses to the thyroid, lower doses in the other tissues), the relative increase in thyroid cancer compared to the baseline rate is estimated to be between 1.4% (workers aged 60 years) and 20% (workers aged 20 years).
- For fewer than 1% of workers (those who received the highest doses), the relative increase in leukaemia and thyroid cancer with respect to the baseline rate is estimated at 28% in the youngest workers.
- For workers who received very high doses to the thyroid (>10 Sv), the risk of a significant increase in the incidence of thyroid cancer has been estimated, especially in the youngest workers (attributable lifetime risk of 356 in 10 000).

Based on dose estimations performed using the most recent and consolidated data, UNSCEAR also evaluated the long-term risks to workers' health in its report published in 2014. Its conclusions, which more or less match those of the WHO, are as follows:

- For the group of 174 workers who received more than 100 mSv (140 mSv on average), two or three cases of cancer may occur in addition to the 70 or so cancers expected in the absence of exposure. This increase in the risk of cancer is low compared to natural fluctuations, and has very little chance of being detected. In the same individuals, one case of leukaemia could be induced by exposure (relative risk = 1.20 for an average exposure of 140 mSv at the age of 20 years), but even here, there is little chance of this being detected in an epidemiological study.
- Approximately 2 000 workers received a dose to the thyroid of more than 100 mGy (average value about 400 mGy). The ultrasound examinations conducted on these individuals are likely to lead to a substantial increase in the detection of cases making up the baseline rate and in that of radiation-induced cancers, compared to the number of cases expected on the basis of the reported baseline rate for non-exposed persons. It is not very likely, however, that any increased incidence of radiation-induced cancer will be detectable. On the other hand, possible cases of hypothyroidism (reduction in the thyroid function) cannot be ruled out.
- For workers who received the highest effective doses, there is a slight probability of excess cases of circulatory disorders, at least theoretically according to current scientific knowledge.
- The data is not statistically sufficient (too few workers concerned) to make a judgement concerning a possible increase in the incidence of cataract.
- There are risks of Post Traumatic Stress Disorder (PTSD). A survey conducted two to three months after the accident revealed the appearance of such disorders in certain workers.