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5 Years Living With Fukushima

Summary of the health effects of the nuclear catastrophe

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5 Years Living With Fukushima

Summary of the health effects of the nuclear catastrophe



On March 11, 2011, Japan and the world will commemorate the beginning of the Fukushima nuclear disaster. More than 200,000 people were evacuated from Fukushima Prefecture to makeshift camps, where about one hundred thousand are still living today. But the effects of the disaster extend far beyond the borders of the prefecture. Since the onset of the disaster, millions of people have been exposed to increased radiation doses – mainly in areas with higher nuclear fallout. Radioactive fallout affects people from air exposure during releases or storms raising radioactive dust as well as direct exposure to contaminated soil and surfaces. All people including those in less contaminated parts of the country have also had to deal with radioactively contaminated drinking water and food. This exposure is gravely concerning as radioactive particles can be integrated into internal organs and tissues and continue to emit ionizing radiation for decades.

According to Japan’s Prime Minister at the time, it was only by “divine providence” that the Greater Tokyo Area with more than 30 million people was spared contamination and evacuation. As a result of the authorities’ failure to distribute iodine tablets, the population was left unprotected from radioactive iodine which can cause thyroid cancer and hypothyroidism. And the tragedy continues to the present day. Approximately 300 tons of radioactive wastewater flows unchecked into the ocean every day. The Fukushima disaster already created the most severe radioactive contamination of the oceans in human history.

Five years after the nuclear meltdown there is still uncertainty about its effects on the health of the Japanese population. First, it is unclear just how much radiation was actually released in March and April of 2011, and how much has since leaked from the reactor

ruins and the plant site. Reasons for this include:

- Independent studies in some cases show significantly higher radioactive emissions
- Not all radioactive isotopes were measured, especially not strontium-90;
- Initial releases were not included in estimation of health impacts.

This means that basic information about the contamination of soil, ocean and food is still a disputed issue between the nuclear lobby and independent scientists. Secondly, the pro-nuclear Japanese government and the country’s influential nuclear lobby are doing everything in their power to play down and conceal the effects of the disaster. Even Fukushima Medical University, where the thyroid cancer screening program is coordinated, has links to the nuclear lobby and received money from the International Atomic Energy Agency (IAEA). The aim seems to be to ensure the Fukushima file is closed as soon as possible and the Japanese public returns to a positive view of nuclear power.

But the data shows a rather different picture. Not only are there continued periodic radiation leaks from the wrecked reactors and recontamination events in the entire region, but the perception of nuclear energy has also changed and a majority of the Japanese people now rejects nuclear power. The controversial thyroid cancer study has not brought the all-clear signal, the nuclear lobby had hoped for. Instead, 116 children in Fukushima Prefecture have already been diagnosed with aggressive and fast-growing, or already

metastasizing, thyroid cancer – in a population this size about one case per year would normally be expected. For 16 of these children a screening effect can be excluded as their cancers developed within the last two years.

Even more disturbing than the study’s findings so far is the fact that, apart from the incidence of thyroid cancer among children in Fukushima Prefecture, Japan has not begun any other large-scale scientific investigations into radiation-related diseases. Cancer does not carry a seal of origin and the cause of an individual cancer case cannot be causally linked to a specific incident. The Japanese authorities are well aware of this fact and have not looked for increases in the incidence of miscarriages, fetal malformations, leukemia, lymphomas, solid tumors or non-cancerous diseases among the population affected by radioactive fallout. These were all known to have increased significantly from the Chernobyl accident.

When we are talking about the affected population in Japan, we differentiate between four sub-groups:

- More than 25,000 cleanup and rescue workers received the highest radiation dose and risked their health, while preventing a deterioration of the situation at the power plant site. If data supplied by the operator TEPCO is to be believed, around 100 workers are expected to contract cancer due to excess radiation, and 50% of these will be fatal. The real dose levels, however, are most likely several times higher, as the operator has had no qualms in manipulating the data to avoid claims for damages – from hiring unregistered temporary employees to tampering with radiation dosimeters and even crude forgery.
- The evacuated population numbering 200,000, which was initially exposed to considerable radiation doses, now mostly lives outside Fukushima prefecture.
- Populations not evacuated from irradiated areas are still being exposed to increased radiation doses every day.
- The population in the rest of Japan is exposed to increased radiation doses from minor amounts of radioactive fallout, as well as contaminated food and water. Calculations of increased cancer cases overall in Japan range from 9,600 to 66,000 depending on the dose estimates.

What is badly needed now is a series of epidemiological studies to investigate the health consequences of the excess radiation exposure - especially diseases that can be detected and treated early. These studies should be guided by published investigations, outlined in this report, of affected animals, birds, and insects which show hematologic effects, higher mutation rates in second generations and higher mortality rates. But as such studies, and the negative image of nuclear energy they would convey, are not politically desirable, we will likely never actually know the true dimensions of the health effects of the Fukushima nuclear disaster and will have to limit ourselves to making estimates based on known or assumed radiation emissions and exposure pathways.

Based on the figures of the pro-nuclear UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), which estimated a collective lifetime dose of approximately 48,000 Person-Sievert and using the internationally acknowledged risk factors of the BEIR-VII report, just under 10,000 excess cases of cancer are to be expected in Japan in the coming decades (confidence interval 4,300 – 16,800). If independent data and more modern risk factors are used, estimates of the rise in cancer incidence are significantly higher at around 66,000 additional cancer cases, approximately half of which would be fatal.

Is this a lot? Surely not in relation to a population of just under 127 million people and a ‘normal’ lifetime cancer risk of 50%. Is it negligible? In light of ten thousand people who will develop cancer solely as a result of the “manmade disaster” in Fukushima (to quote the Fukushima Nuclear Accident Independent Investigation Commission of the National Diet of Japan) – no. The fates of these people and their families are neither “negligible” nor “insignificant”, as the Japanese authorities or institutions of the nuclear power lobby, IAEA and UNSCEAR, would have us believe.

Public discourse on the Fukushima disaster should not be guided by economic profit and political influence, but should focus on the health and fate of the affected populations – those who lost everything, who fear for their health and that of their children, who ask for nothing more than a life without the constant fear of radiation. The risks to the health of the Japanese population must be investigated by independent scientists and in a way that excludes any undue influence by the nuclear power industry and their political supporters. Extensive studies are required to understand the health consequences for the affected population, to identify disease at an early stage and improve protection for future generations by learning more about the effects of ionizing radiation. The debate on the effects of the Fukushima nuclear disaster is about far more than the principle of independent research and taking a stand against the influence of powerful lobby groups. It is about the universal right of every human being to health and a life in a healthy environment.

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5 Years Living With Fukushima

Summary of the health effects of the nuclear catastrophe

Executive Summary	4
Abbreviations	9
Introduction	10
1. The beginning of the nuclear catastrophe	11
2. Radioactive emissions and contamination	13
2.1. Atmospheric emission	15
2.2. Discharge into the Pacific Ocean	16
2.3. Radioactive contamination of food products	18
3. Consequences of the nuclear disaster for human health	22
3.1. Health effects in occupationally exposed people	23
3.2. Health effects on the general public	24
4. Thyroid screening in Fukushima Prefecture	26
4.1. Preliminary baseline screening	27
4.2. Full-scale screening	27
4.3. Screening summary	28
5. Consequences of the nuclear disaster on the non-human biota	29
6. Outlook	31
7. Recommendations from IPPNW and PSR	33

Abbreviations

BEIR	Biological Effects of Ionizing Radiation report series of the American Academy of Sciences
Bq – Becquerel	A basic international (SI) measure of radioactivity. Defined as decay of one radioactive nucleus per second
Gy – Gray	An international (SI) measure for radiation dose absorbed by matter. Used in context of high doses at which all tissues and organs would be always be affected (deterministic). Defined as the amount of energy (in Joules) absorbed per mass (in kg)
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
JAEA	Japanese Atomic Energy Agency
PBq	PetaBecquerel (10^{15} Bq)
Person-Sv	Collective equivalent dose of a population (number of people x average individual dose in Sv)
SI	International System of Units (<i>Système international d'unités</i>)
Sv – Sievert	An international (SI) measure similar to Gy but adjusted for biologically equivalent radiation dose absorbed by a particular tissue type or organ. Used in context of relatively low doses where effects variable & less certain (stochastic). Defined as the amount of energy absorbed per unit of mass. In Germany, the threshold value 0.001 Sv (1 mSv) per year is officially considered safe for humans.
TBq	TeraBecquerel (10^{12} Bq)
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WHO	World Health Organization



Introduction

On March 11, 2011, Japan and the world will commemorate the beginning of the Fukushima nuclear catastrophe five years ago. Enormous amounts of radioactive substances entered the environment due to the meltdown of 3 nuclear reactors at the Fukushima Daiichi nuclear power plant, several explosions breaching the containment vessels, fires, leaks and the controlled release of radioactive discharge. More than 200,000 people were evacuated from Fukushima Prefecture to makeshift camps, where about one hundred thousand still live as refugees today. But the effects of the nuclear catastrophe extend far beyond the borders of the prefecture. Since the onset of the disaster, millions of people have been exposed to elevated doses of radiation – mostly in areas with higher nuclear fallout, and people in less contaminated parts of the country have to deal with radioactively contaminated drinking water and food.

International Physicians for the Prevention of Nuclear War (IPPNW), is well aware of the close links between the civilian and military nuclear industries and of the risks inherent in both. We are committed to a scientific assessment of the health effects of the entire nuclear chain – from uranium mining to nuclear waste. In this respect, civilian nuclear disasters such as Three Mile Island, Chernobyl or Fukushima provide particularly striking

examples of the nuclear industry's harmful impact on public health. As physicians and scientists we must ask the following questions to fully examine the Fukushima nuclear disaster:

- How could this disaster occur?
- How much radioactivity was released?
- How will it affect the environment?
- What health consequences are to be expected in the affected population?

These are the issues we aim to address with this publication.

1. The beginning of the nuclear catastrophe



On March 11, 2011, an earthquake with magnitude 9 on the Richter scale occurred just off Japan's eastern coast. The Tohoku Earthquake triggered a tsunami that caused severe devastation along the coastline. More than 15,000 people died as a direct result of the earthquake and the tsunami, and more than 500,000 others had to be evacuated. The natural disaster affected several nuclear power plants on the coast of Japan. The other plants automatically underwent shutdown but did not lose back up cooling. However, the earthquake severely damaged the Fukushima Daiichi nuclear power plant by interrupting the power supply to the plant including the cooling system.

The tsunami generated by the earthquake caused loss of the emergency diesel electric generators. This failure of backup electric power to keep cooling water circulating to the reactors and spent fuel pools, resulted in core meltdowns in reactor units 1, 2 and 3. The power plant operator, Tokyo Electric Power Company (TEPCO), began to vent steam from the reactor buildings to reduce the increasing pressure in the reactors to prevent larger explosions. But the steam also transported large amounts of radioactive particles into the atmosphere – a risk believed at the time to be the lesser evil. Despite this, there were numerous explosions in the three reactors.

Although Japan's disaster management contingency plans for earthquakes and tsunamis are among the best in the world, the Japanese authorities were hopelessly overwhelmed by three nuclear meltdowns and the release of radioactive clouds. The first evacuation order was given for a 3 km zone on the evening of March 11. On the evening of March 12, this was extended to a 12 km zone around the stricken reactors. By this time, the first hydrogen explosion had already destroyed reactor 1. A total

of 200,000 people were ordered to leave their homes.¹ Naoto Kan, Japan's Prime Minister at the time, later stated that the 30 million people of the Tokyo Metropolitan area had been spared radioactive contamination "by a hair's breadth".

In the first days of the nuclear disaster the wind was mostly blowing east, allowing an estimated 76% of the radioactive fallout to disperse over the Pacific.² On just one day, March 15, 2011, the wind turned towards the northwest, distributing radioactive contamination all the way to the small village of Iitate, more than 40 km (25 miles) away. If the wind had come from the north on just one single day, large areas of Tokyo would have been contaminated and the government would have been forced to evacuate the capital city. Former Prime Minister Kan admitted, this would have meant "the collapse of our country", and cited "a series of fortunate coincidences" he called, "divine providence" as reasons why this did not occur.³

On March 14 and March 15, reactors 2 and 3 were destroyed by a number of explosions that also caused a fire in the spent fuel pool of reactor 4. To cool the fuel rods inside the reactors, TEPCO chose the controversial decision to pump seawater into the reactor building. This, however, did little to prevent further temperature rise as the fuel rods were already exposed. According to TEPCO and scientists from Nagoya University, 100% of

1 International Atomic Energy Agency (IAEA). "Fukushima Nuclear Accident Update", 12.03.11. www.iaea.org/newscenter/news/2011/fukushima120311.html.

2 Evangeliou N et al. "Global deposition and transport efficiencies of radioactive species with respect to modelling credibility after Fukushima (Japan, 2011)". *J Environ Radioact.*, 2015 Nov;149:164-75. <http://www.ncbi.nlm.nih.gov/pubmed/26254209>

3 Wagner W. „Ex-Premier Kan über Fukushima-Katastrophe: ‚Die Frage war, ob Japan untergeht‘“. *Spiegel Online*, 09.10.15. <http://www.spiegel.de/politik/ausland/ex-premier-ueber-fukushima-die-frage-war-ob-japan-untergeht-a-1056836.html>

the fuel rods in reactor 1 melted, 70-100% of the fuel rods melted in reactor 2 and 63% of the fuel rods melted in reactor 3.^{4,5} Cooling water was contaminated with radiation in the reactor before flowing back into the sea in large quantities via groundwater aquifers.

On March 25, people living within a 30 km radius of the nuclear power plant were asked to leave their homes and the contaminated area voluntarily. On April 12, the nuclear meltdown in Fukushima was upgraded to severity level 7 on the International Nuclear Event Scale INES, the highest possible rating, previously only assigned to the Chernobyl disaster. On April 22, the Japanese government finally extended their evacuation recommendation to cover the municipalities of Katsurao, Namie, Iitate and parts of Kawamata and Minamisoma, within a 50 km area around the wrecked reactor buildings.

At the time of the accident, the authorities decided not to distribute iodine tablets that would have prevented uptake of damaging radioactive iodine-131 into the thyroid, leaving the population unprotected. The World Health Organization (WHO) criticized this omission in their Fukushima Report, stating that the anticipated incidence of thyroid cancer among the general public had increased because this vital preventive measure had been neglected.⁶ In their official report of June 2012, the National Diet of Japan Nuclear Accident Independent Investigation Committee (NAIIC) found that the Fukushima nuclear accident was not simply the result of a natural disaster, but was profoundly man-made.



“The commission concludes that the situation continued to deteriorate because the crisis management system of the Kantei, [Prime Minister’s office] the regulators and the other responsible agencies did not function correctly. Residents’ confusion over the evacuation stemmed from regulators’ negligence and failure over the years to implement adequate measures against a nuclear accident, as well as a lack of action by previous governments and regulatory authorities focused on crisis management. The crisis management system that existed for the Kantei and the regulators should protect the health and safety of the public, but it failed in this function.”⁷

4 Japanese Atomic Information Forum (JAIF). “TEPCO: Melted fuel ate into containment vessel”. Earthquake Report No. 278, 01.12.11. www.jaif.or.jp/english/news_images/pdf/ENGNEWS01_1322709070P.pdf.

5 Kumai H. „Researchers: More than 70% of No. 2 reactor’s fuel may have melted“. Asahi Shimbun, 27.09.15. <http://ajw.asahi.com/article/0311disaster/fukushima/AJ201509270023>

6 World Health Organisation (WHO). “Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami”. 23.05.1212, p.49. http://whqlibdoc.who.int/publications/2012/9789241503662_eng.pdf

7 The National Diet of Japan. „The official report of The Fukushima Nuclear Accident Independent Investigation Commission of the National Diet of Japan“. 05.07.12, p 18–19. http://www.nirs.org/fukushima/naaic_report.pdf

2. Radioactive emissions and contamination



The multiple meltdowns in Fukushima constituted the biggest nuclear disaster since Chernobyl in 1986. The wrecked reactors have been leaking radioactive discharge since March 2011, despite assurances by the nuclear industry and institutions of the nuclear lobby such as the International Atomic Energy Organization (IAEA) that a singular incident occurred in spring 2011, which is now under control. This statement ignores the continuous emission of long-lived radionuclides such as cesium-137 or strontium-90 into the atmosphere, the groundwater and the ocean. It also ignores frequent recontamination of affected areas due to storms, flooding, forest fires, pollination, precipitation and even clean-up operations, which cause radioactive isotopes to be whirled into the air and spread by the wind.¹ Thus, several incidents of new contamination with cesium-137 and strontium-90 have been discovered during the past years, even at considerable distance beyond the evacuation zone.²

Even now, 30 years after the Chernobyl disaster, wild game and mushrooms in southern Germany are still found to contain so much radioactive cesium-137 that they are classified as radioactive waste. 30 years constitutes just the first half-life of cesium-137, meaning that only half of the radioactivity has

dissipated.^{3,4} It can be safely assumed that a similar development will be seen in the flora and fauna of the affected areas in Japan. As attempts to decontaminate woodland areas, mountain ranges or other areas of dense vegetation would be futile, such efforts are currently not even considered and the danger of radioactive exposure in Fukushima and the neighboring prefectures will persist for decades to come. Japanese authorities have already abandoned the original aim of rendering all contaminated regions habitable again.⁵

An additional threat to the local population is posed by the practice of leaching radioactive substances from the soil into groundwater reservoirs in the process of decontamination. Disposal issues have also come up. In an intensive and expensive attempt to decontaminate the homes, farmlands and even forests, workers have been bagging up soil, leaves and debris from more contaminated areas in the evacuated zone costing over \$13.5 billion as of 2014. The tons of bagged debris is planned to be moved to temporary storage near the Fukushima plant.⁶ In areas with lesser radiation the ground has been turned over to bury the radioactive soil up to a foot deeper.

Finally, there are frequent leaks at the power plant itself – par-

1 Higaki S, Hirota M. „The reductive effect of an anti-pollinosis mask against internal exposure from radioactive materials dispersed from the Fukushima Daiichi Nuclear Disaster“. *Health Phys.* 2013 Feb;104(2):227-31, February 2013. www.ncbi.nlm.nih.gov/pubmed/23274827.

2 Steinhauser G et al. „Post-Accident Sporadic Releases of Airborne Radionuclides from the Fukushima Daiichi Nuclear Power Plant Site“. *Environ. Sci. Technol.* 2015, 49, 14028–14035. <http://pubs.acs.org/doi/pdf/10.1021/acs.est.5b03155>

3 Bundesministerium für Gesundheit. „Radioaktive Belastung von Wildschweinen“. 08.04.11. http://bmg.gv.at/home/Schwerpunkte/VerbraucherInnenengesundheit/Radioaktive_Belastung_von_Wildschweinen.

4 Hawley C. „A Quarter Century after Chernobyl: Radioactive Boar on the Rise in Germany“. *Spiegel Online*, 30.07.10. www.spiegel.de/international/zeitgeist/a-quarter-century-after-chernobyl-radioactive-boar-on-the-rise-in-germany-a-709345.html.

5 Aoki M et al. „Government secretly backtracks on Fukushima decontamination goal“. *The Asahi Shimbun*, 16.06.13. <http://ajw.asahi.com/article/0311disaster/fukushima/AJ201306160022>.

6 Makinen, Julie, „After 4 years, Fukushima cleanup remains daunting, vast.“ March 3, 2015. <http://www.latimes.com/world/asia/la-fg-fukushima-nuclear-cleanup-20150311-story.html>

ticularly from the cracked underground vaults of the reactor buildings and from containers holding radioactive contaminated water, which were hastily welded together and already exhibit numerous defects. According to TEPCO, 300 tons of radioactive wastewater still flow unchecked into the ocean every day – more than 500,000 tons since the beginning of the nuclear disaster.⁷ The amount and composition of radioactive isotopes fluctuate widely so that it is not possible to ascertain the actual effect this radioactive discharge will have on marine life. What is clear, however, is that increasing amounts of strontium-90 are being flushed into the sea. Strontium-90 is a radioactive isotope that is incorporated into living organisms in a similar way to calcium - in bones and teeth. As it travels up the marine food chain, it undergoes significant bioaccumulation and, because of its long biological and physical half-lives, will continue to contaminate the environment for the next hundreds of years.⁸

An estimated 23% of nuclear fallout from the Fukushima disaster occurred over mainland Japan.⁹ The most severely affected regions are located in the eastern half and center of Japan's main island Honshu. The island's west coast, however, remained largely unaffected by nuclear fallout due to the island's mountainous topography that, which forms a meteorological divide. Increased dose rates were also found in the far south and north of Japan, however.¹⁰ People throughout the country came into contact with radioactive isotopes – via radioactive air, water and contaminated food. For this reason it is crucial to consider not only the radioactive exposure of the population in Fukushima and the neighboring prefectures Chiba, Gunma, Ibaraki, Iwate, Miyagi and Tochigi, but also that of the more distant prefectures affected by nuclear fallout. On March 15 and 21, for example, high amounts of fallout not only landed in Tokyo, but also in the prefectures of Kanagawa, Saitama, and Shizuoka.¹¹ Tea plantations in Shizuoka Prefecture, 400 km south of Fukushima, and 140 km from Tokyo, were so heavily contaminated that the 2011 tea harvest had to be withdrawn from the market.¹² The following map created by a researcher

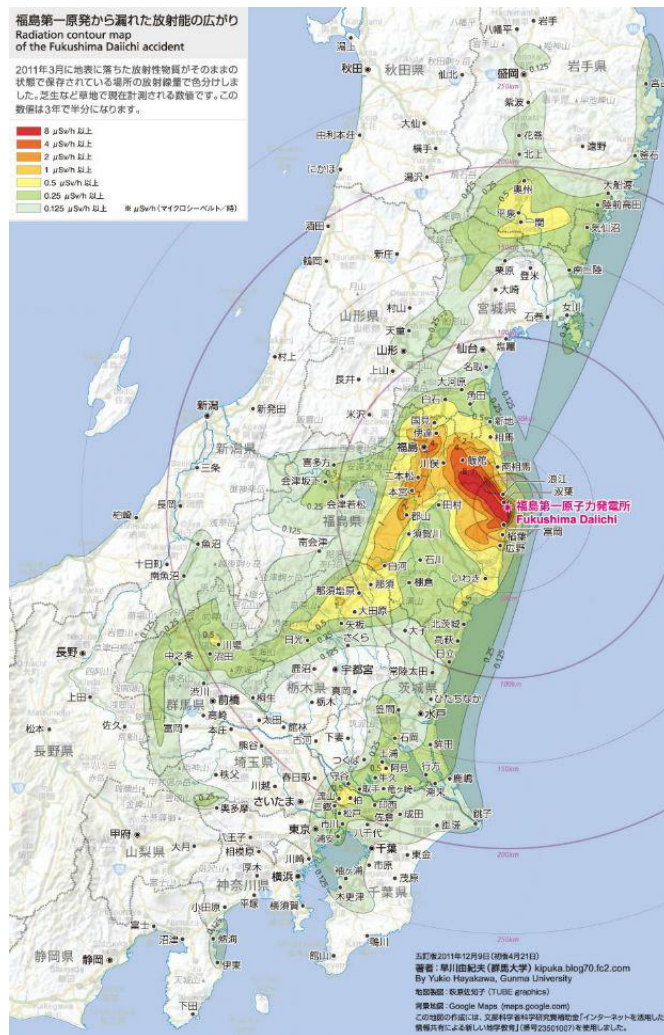


Figure 2-1: Map of radioactive contamination in northern Japan

at Gunma University shows the radioactive contamination of Honshu Island at the end of 2012.

There are principally five pathways by which humans come into contact with radioactivity during and after a nuclear disaster:

- External radiation exposure to ‘cloudshine’: direct irradiation from the radioactive cloud. This can involve all types of radioisotopes, such as xenon-133, iodine-131 or cesium-137.
- External radiation exposure to ‘groundshine’: is direct irradiation from terrestrial radioactive particles, particularly gamma emitters like barium-137m, a decay product of cesium-137.
- External radiation via superficial contamination of skin, hair and clothing, particularly by beta emitters like cesium-137, strontium-90 or iodine-131. Beta radiation is blocked by clothing but with direct contact can penetrate the skin.

7 Tsukimori O, Hamada K. “Japan government: Fukushima plant leaks 300 tpd of contaminated water into sea | Reuters”. Reuters, 07.08.13. <http://www.reuters.com/article/2013/08/07/us-japan-fukushima-water-idUSBRE9760AU20130807>.

8 Kiger PJ. “Fukushima’s Radioactive Water Leak: What You Should Know”. National Geographic, 09.08.13. <http://news.nationalgeographic.com/news/energy/2013/08/130807-fukushima-radioactive-water-leak/>

9 Evangeliou N et al. “Global deposition and transport efficiencies of radioactive species with respect to modelling credibility after Fukushima (Japan, 2011)”. J Environ Radioact. 2015 Nov;149:164-75. <http://www.ncbi.nlm.nih.gov/pubmed/26254209>

10 Hirose K. “Fukushima Dai-ichi nuclear power plant accident: summary of regional radioactive deposition monitoring results”. J. Environ. Radioact. 111, 13-17. <http://dx.doi.org/10.1016/j.jenvrad.2011.09.003>

11 Priest ND. “Radiation doses received by adult Japanese populations living outside Fukushima Prefecture during March 2011, following the Fukushima 1 nuclear power plant failures”. J Environ Radioact 2012 Dec; 114:162-170. www.ncbi.nlm.nih.gov/pubmed/22770771.

12 Shizuoka Prefectural Government. “Test Results for Radioactivity on Tea Produced in Shizuoka Prefecture”. 20.05.11. www.pref.shizuoka.jp/sangyou/sa-340/20110520_test_results_radio_activity.html.

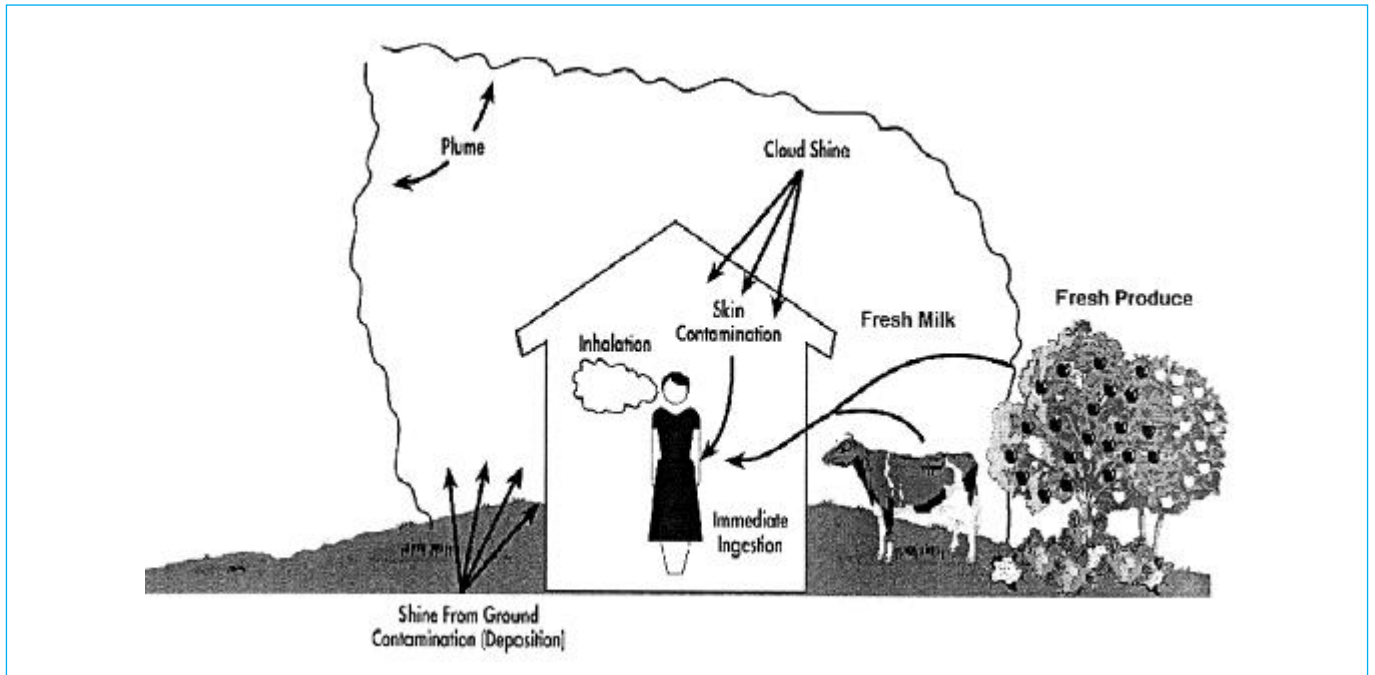


Figure 2-2: Illustration showing the different radiation exposure pathways

- Internal radiation exposure can be due to inhaled radioactive particles, particularly alpha emitters like plutonium, or beta emitters like cesium-137, strontium-90 and iodine-131.
- Internal radiation can be due to exposure to radioactive particles ingested with food or drinking water, particularly alpha emitters like plutonium, or beta emitters like cesium-137, strontium-90 and iodine-131.

In order to calculate individual and collective radiation doses it is therefore important to know not only the total amount of radioactive emissions, but also the radiation concentrations in air, water and food. The following chapters will take a look at the available data regarding emissions and contamination.

2.1 Atmospheric emissions

Radioactive isotopes were repeatedly released into the atmosphere with the smoke and fumes from explosions and the fire in the spent fuel pool of reactor 4, through the evaporation of cooling-water, as well as through the deliberate venting of the reactors. Even today, the magnitude of the total emissions, also referred to as ‘source term’ in scientific literature, is just as contentious as in the Chernobyl disaster. While calculations by scientists from independent institutions indicate higher levels, the World Health Organization (WHO) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) cite the much lower numbers propagated by the

Japanese Atomic Energy Agency JAEA.¹³

Stohl et al. at the Norwegian Institute for Air Research (Norsk Institutt for Luftforskning – NILU) calculated that in the period between March 12 and March 19, the Fukushima power plant released 35.8 PBq of cesium-137 (confidence interval CI 23.3 – 50.1).¹⁴ Japanese Atomic Energy Agency (JAEA), however, published significantly lower cesium-137 emissions of only 13 PBq.¹⁵

It appears reasonable to look for a reliable meta-analysis of all available source term calculations. The most extensive summary of all emission estimates is the study by Aliyu et al, which compares the data from 14 different scientific papers and sub-

13 Terada H et al. “Atmospheric discharge and dispersion of radionuclides during the Fukushima Dai-ichi Nuclear Power Plant accident. Part II: verification of the source term and analysis of regional-scale atmospheric dispersion”. *J Environ Radioact* 2012 Oct; 112: 141–154. www.sciencedirect.com/science/article/pii/S0265931X12001373.

14 Stohl A et al. “Xenon-133 and cesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition”. *Atmos. Chem. Phys. Discuss.* 11, Nr. 10 (20.10.11): 28319–28394.

15 Terada H et al. “Atmospheric discharge and dispersion of radionuclides during the Fukushima Dai-ichi Nuclear Power Plant accident. Part II: verification of the source term and analysis of regional-scale atmospheric dispersion”. *J Environ Radioact* 2012 Oct; 112: 141–154. www.sciencedirect.com/science/article/pii/S0265931X12001373.

jects them to critical analysis.¹⁶ The authors estimate the emissions of the major radioisotopes as follows:

Radioisotope	Amount released	Sources
Iodine-131	150-160 PBq	Masson 2011
Cesium-137	12-55 PBq	IRSN 2012, Masson 2011, Kantei 2011, Stohl 2012
Strontium-90	0.01-0.14 PBq	Povinec 2012

Table 2.1: Estimated atmospheric emissions following the Fukushima disaster

The way emissions are calculated is highly relevant for estimating radiation doses and therefore for predicting health effects in the affected population. It should go without saying that, in the interests of public health, the most trustworthy and reliable data should be used if the objective is effective protection from the impact of radiation. It is therefore incomprehensible that, instead of also drawing on data from independent and neutral institutions, the WHO and UNSCEAR apply the lowest estimates possible. This exclusive reliance on JAEA data is astonishing, given that the Japanese parliament accused precisely this agency of contributing to the catastrophe through corruption, collusion and negligent conduct. Citing the JAEA as a neutral source in this matter should therefore be out of the question.

Furthermore, all release amount estimates only cover the first three days after the onset of the nuclear disaster, despite the release of further radioactivity from the reactors every day since – mainly through evaporation of radioactive contaminated cooling water. At this point it must also be mentioned that, in addition to the well-known radioactive substances iodine-131, cesium-137 and strontium-90, short-lived radioisotopes like iodine-133, cesium-134 and strontium-89 were also released – in the case of radioactive cesium for example, the ratio of cesium-134 to cesium-137 is 1:1. This means, release amounts given for cesium-137 only constitute half of the actually released relevant substances. Furthermore, a large number of radioactive particles, whose effects on human health are not sufficiently known, were also emitted. According to Japanese government sources, relevant amounts of the following substances

were released during the nuclear disaster: plutonium-239 and -240, barium-140, tellurium-127m, tellurium-129m, tellurium-131m, tellurium-132, Ruthenium-103, ruthenium-106, zirconium-95, cerium-141, cerium-144, neptunium-239, yttrium-91, praseodymium-143, neodymium-147, curium-242, iodine-132, iodine-135, antimony-129, molybdenum-99 and xenon-133.¹⁷ Although they were found in groundwater, sediment and soil samples, these substances are not included in JAEA's emission estimates.¹⁸ By restricting emission estimates to JAEA data, both WHO and UNSCEAR may be systematically underestimating the health effects.

Finally, not only the total amounts of individual isotopes are relevant, but also their spatial distribution. Greek and French researchers found that most (approx. 76%) of the radioactive fallout occurred over the Pacific Ocean and about 23% over mainland Japan. As a result of radioactive fallout over the main island Honshu, the local dose rate rose from an average of 0.05 µSv/h before the onset of the nuclear disaster to levels 10 to 760 times higher, with values between 0.5 and 38 µSv/h.¹⁹ The remaining 2% of radioactive emissions were distributed over Canada (40 TBq), the US (95 TBq), Greenland (5 TBq), the North Pole (69 TBq), Europe (14 TBq), especially Russia, Sweden and Norway, as well as other parts of Asia (47 TBq), particularly Russia, the Philippines and South Korea.²⁰ Although the fact that most fallout occurred over the ocean can be viewed as a blessing for the population of the surrounding prefectures, this by no means implies that their health is not endangered, as will be shown in the following chapters.

2.2 Discharge into the Pacific Ocean

Possibly the most serious ecological damage caused by the nuclear disaster was the radioactive contamination of the Pacific Ocean off the Japanese coast. In addition to radioactive fallout over the sea, a further factor in the radioactive pollution of the Pacific was the continuous discharge of contaminated water from the wrecked nuclear reactors. In the last three years, enormous volumes of water have been continuously pumped

17 Nuclear Emergency Response Headquarters. "Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety – The Accident at TEPCO's Fukushima Nuclear Power Plant", 07.06.11. www.iaea.org/newscenter/focus/fukushima/japan-report/.

18 Zheng J et al. "Isotopic evidence of plutonium release into the environment from the Fukushima DNPP accident". *Sci. Rep.* 2 (08.03.12). doi:<http://www.nature.com/srep/2012/120308/srep00304/full/srep00304.html>.

19 Aliyu AS et al. « An overview of current knowledge concerning the health and environmental consequences of the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident". *Environ. Internat.* 85 (2015) 213-228. <http://cricket.biol.sc.edu/chernobyl/papers/Sadiq-et-al-EI-2015.pdf>

20 Evangeliou N et al. "Global deposition and transport efficiencies of radioactive species with respect to modelling credibility after Fukushima (Japan, 2011)". *J Environ Radioact.* 2015 Nov; 149:164-75. <http://www.ncbi.nlm.nih.gov/pubmed/26254209>

16 Aliyu AS et al. "An overview of current knowledge concerning the health and environmental consequences of the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident". *Environ. Internat.* 85 (2015) 213-228. <http://cricket.biol.sc.edu/chernobyl/papers/Sadiq-et-al-EI-2015.pdf>

into the reactor buildings in an attempt to cool them. Large amounts of radioactive wastewater are generated every day as a result and are discharged into the sea and groundwater depots, or evaporate into the atmosphere. Regarding the question of the total extent of radioactive contamination of the Pacific Ocean, Kawamura et al. from JAEA calculated a total of 124 PBq of iodine-131 and 11 PBq of cesium-137. The JAEA study, however, only analyses the extremely short period between March 21 and April 6, 2011. With regard to the radioactivity released between March 11 and 21, i.e. the first ten days after the first explosion in the nuclear power plant, the authors write, “no direct release into the ocean was assumed before March 21 because the monitoring data were not available during this period.” A similar approach is applied to radioactive fallout after April 6, 2011 when the authors state “There is no information on the amounts released into the atmosphere after April 6. It was assumed, therefore, that the radioactive materials were not released into the atmosphere after April 6.”²¹

The continuing radioactive contamination of the ocean is therefore entirely ignored, despite the disclosure by the operator TEPCO that 300 tons of contaminated wastewater were discharged into the sea every day. Researchers from the French atomic agency IRNS estimated that between March and July of 2011 the amount of cesium-137 released into the Pacific amounted to 12-41 PBq.²² The majority of studies also fail to include strontium-90 emissions, which were also released into the ocean in significant quantities and now pose an additional hazard to the marine food chain. An exception is the research group around Povinec from the University of Bratislava, which calculated total emissions of strontium-90 into the Pacific to be 0.1-2.2 PBq.²³

Radioisotope	Amount released	Sources
Iodine-131	124 PBq	Kawamura 2011
Cesium-137	12-41 PBq	Bailly du Bois 2012
Strontium-90	0.1-2.2 PBq	Povinec 2012

Table 2.2: Estimated amounts discharged into the Pacific as a result of the Fukushima disaster

21 Kawamura H et al. “Preliminary Numerical Experiments on Oceanic Dispersion of 131-I and 137-Cs Discharged into the Ocean because of the Fukushima Daiichi Nuclear Power Plant Disaster”. *Journal of Nuclear Science and Technology*, 01.11.11. www.tandfonline.com/doi/pdf/10.1080/18811248.2011.9711826.

22 Bailly du Bois P et al. “Estimation of marine source-term following Fukushima Dai-ichi accident.” *J Environ Radioact.* 2012 Dec;114:2-9. <http://www.ncbi.nlm.nih.gov/pubmed/22172688>

23 Povinec PP et al. “Radiostrontium in the western North Pacific: characteristics, behavior, and the Fukushima impact”. *Environ Sci Technol.* 2012 Sep 18;46(18):10356-63. <http://www.ncbi.nlm.nih.gov/pubmed/22873743>

Despite such grave shortcomings in the calculation of total emissions into the Pacific Ocean and the ongoing discussion among scientists about realistic estimates, there is broad agreement that the Fukushima nuclear disaster already constitutes the most serious radioactive contamination of the world’s oceans in human history – comparable with the effects of atmospheric nuclear weapons tests and surpassing the radioactive fallout from Chernobyl or discharge from nuclear reprocessing plants like Sellafield and La Hague.^{24,25,26}

IAEA analyzed seawater in the vicinity of the Fukushima nuclear power plant and published concentrations of 130,000 Bq/l for radioactive iodine and up to 63,000 Bq/l for radioactive cesium.^{27,28, 29}

The nuclear industry tries to argue that dilution decreases the effect of radioactive waste on the marine environment and food chain. Radioactive particles do not disappear but are merely distributed over a larger area. This is dangerous for two reasons: first, as there is no safe threshold of ionizing radiation, the spread of radioactive contamination in the Pacific Ocean leads to a greater number of people being affected.³⁰ Even the smallest amount of radiation has the potential to cause disease if ingested with water or food. Second, the repeated distribution of long-lived radioisotope sediments, such as cesium-137 and strontium-90, which can also be stirred up by seaquakes or storms, leads to bioaccumulation of radioactivity in marine animals through the trophic cascade: numerous plankton samples taken from the coast of Fukushima Prefecture in 2012 already

24 Institut de Radioprotection et de Sûreté Nucléaire (IRSN). «Synthèse actualisée des connaissances relatives à l’impact sur le milieu marin des rejets radioactifs du site nucléaire accidenté de Fukushima Dai-ichi.» 26.10.11. www.irsn.fr/fr/actualites_presse/actualites/documents/irsn-ni-impact_accident_fukushima_sur_milieu_marin_26102011.pdf.

25 Woods Hole Oceanographic Institution (WHOI). “Researchers Assess Radioactivity Released to the Ocean from the Fukushima Daiichi Nuclear Power Facility”. 06.12.11. www.whoi.edu/page.do?pid=7545&tid=282&cid=123049&ct=162.

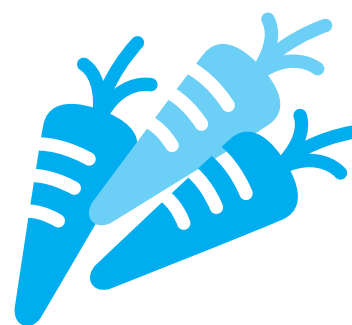
26 IAEA. “Worldwide marine radioactivity studies (WOMARS) - Radionuclide levels in oceans and seas”. Januar 2005. www-pub.iaea.org/MTCD/publications/PDF/TE_1429_web.pdf.

27 IAEA. “Fukushima Nuclear Accident Update”. 31.03.11. www.iaea.org/newscenter/news/2011/fukushima310311.html.

28 Weiss D. “Contamination of water, sediments and biota of the Northern Pacific coastal area the vicinity of the Fukushima NPP”. *Gesellschaft für Anlagen- und Reaktorsicherheit*, 31.10.11. www.eurosafe-forum.org/userfiles/2_2_%20paper_marine%20environment_Fukushima_20111031.pdf.

29 Buesseler K et al. “Impacts of the Fukushima nuclear power plants on marine radioactivity”. *Environ Sci Technol.* 2011 Dec 1;45(23):9931-5. 01.12.11. www.ncbi.nlm.nih.gov/pubmed/22013920.

30 National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). “BEIR VII report, phase 2: Health risks from exposure to low levels of ionizing radiation”. 2006. www.nap.edu/openbook.php?record_id=11340&page=8.



exhibited increased concentrations of cesium-137.³¹ Cesium-137 in plankton is ingested by smaller fish, which are eaten in turn by larger fish, which are then caught and sold on the fish markets in the Pacific region.³² Thus, bone-seeking radioactive strontium with its long biological half-life as well as the radioactive isotopes of cesium endanger the population of coastal regions, as well as potential consumers of algae, seafood and fish from the affected zone. Especially in a country like Japan where these food products constitute a substantial part of the regular diet, the long-term radioactive contamination of seafood and algae is a significant health risk, as will be shown in the following chapter.

2.3 Radioactive contamination of food products

In addition to the source term, the radioactive contamination of food and drinking water is also important for calculating the total radioactive dose that a person is exposed to after a nuclear accident. As noted above, there simply is no ‘safe threshold’ of radioactivity in food and drinking water. Even the tiniest amounts of radioactivity have the potential to cause tissue damage, genetic mutations and cancer.³³ According to the German Society for Radiation Protection (GRS), it is estimated that a person is normally exposed to about 0.3 mSv per year by ingesting radionuclides in food and drink. This can be considered the ‘permissible level’ of radioactivity ingested with food and drink to avoid excessive health risks. In order not to exceed this level, the amount of radioactive cesium-137 should not exceed 8 Bq/kg in milk and baby formula and 16 Bq/kg in all other foods. Because of its short half-life, radioactive iodine should not be permitted in food at all. In Japan however, the permissible level of radioactive cesium-137 in milk and baby formula is 50 Bq/kg and 100 Bq/kg for all other foods. For radioactive iodine-131 the permissible level is 300 Bq/kg for milk and other liquids and 2,000 Bq/kg for solid foods.³⁴ Japanese threshold values are therefore stricter than those in the European Union (see table), but still not low enough to effectively prevent excessive health risks.

	Baby formula and milk products	Other foods
Japan	50 Bq/kg	100 Bq/kg
EU	370 Bq/kg	600 Bq/kg
IPPNW recommended	8 Bq/kg	16 Bq/kg

Table 2.3: Safe exposure levels for radioactive cesium (Cs-134/Cs-137)³⁵

	Baby formula	Milk and other liquids	Solid foods
Japan	100 Bq/kg	300 Bq/kg	2,000 Bq/kg
EU	150 Bq/kg	500 Bq/kg	2,000 Bq/kg
IPPNW recommended	0 Bq/kg	0 Bq/kg	0 Bq/kg

Table 2.4: Safe exposure levels for radioactive iodine (especially iodine-131)³⁶

The Fukushima nuclear meltdown caused major contamination of food and drinking water, particularly during the first months. According to the IAEA, nearly all vegetable and milk samples taken in Ibaraki and Fukushima Prefectures one week after the earthquake revealed levels of iodine-131 and cesium-137 above the radioactivity thresholds specified for food and drink in Japan.³⁷ Over the course of the following months, food was often found to be contaminated:

31 Aliyu AS et al. “An overview of current knowledge concerning the health and environmental consequences of the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident”. *Environ. Internat.* 85 (2015) 213-228. <http://cricket.biol.sc.edu/chernobyl/papers/Sadiq-et-al-EI-2015.pdf>

32 Buesseler KO et al. “Fukushima-derived radionuclides in the ocean and biota off Japan.” *Proc. Natl. Acad. Sci. USA* 109, 5984-5988. www.pnas.org/content/109/16/5984.full.pdf

33 National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). “BEIR VII report, phase 2: Health risks from exposure to low levels of ionizing radiation”. 2006. www.nap.edu/openbook.php?record_id=11340&page=8

34 Foodwatch. *Kalkulierter Strahlentod*. 20.09.11. www.foodwatch.org/uploads/tx_abdownloads/files/foodwatch_report_kalkulierterStrahlentod_20110920.pdf

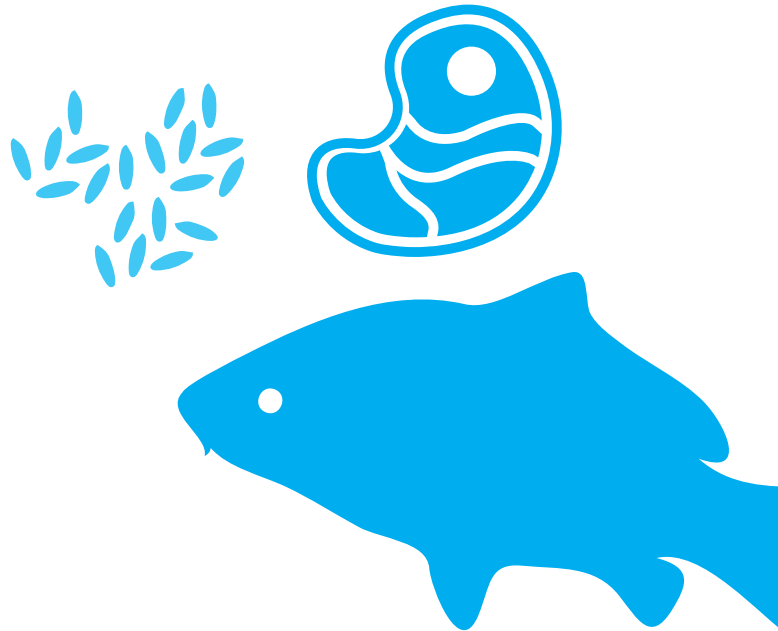
35 Foodwatch. “Strahlen-Grenzwerte für Lebensmittel”. 23.10.2012. <https://www.foodwatch.org/de/informieren/strahlenbelastung/mehr-zum-thema/eu-grenzwerte>

36 Foodwatch. “Strahlen-Grenzwerte für Lebensmittel”. 23.10.2012. <https://www.foodwatch.org/de/informieren/strahlenbelastung/mehr-zum-thema/eu-grenzwerte>

37 IAEA. “Fukushima Nuclear Accident Update”, 24.03.11. www.iaea.org/newscenter/news/2011/fukushima240311.html

- Fruit and vegetables: A survey by the Japanese Science Ministry (MEXT), which was conducted outside the Fukushima Prefecture evacuation zone one week after the earthquake, found contaminated vegetables in the municipalities of Iitate, Kawamata, Tamura, Ono, Minamisoma, Iwaki, Date, Nihonmatsu, Shirakawa, Sukagawa, Ootama, Izumizaki and Saigou, some with iodine-131 concentrations as high as 2,540,000 Bq/kg and cesium-137 concentrations up to 2,650,000 Bq/kg. One month after the meltdowns, iodine-131 concentrations in some regions were still above 100,000 Bq/kg and cesium-137 above 900,000 Bq/kg.³⁸ In Ibaraki Prefecture, about 100 km south of the Fukushima plant, the prefectural government discovered spinach with radioactive iodine levels of up to 54,100 Bq/kg and radioactive cesium up to 1,931 Bq/kg. In addition to spinach, most other vegetable samples also contained radioisotopes, most notably mustard plants 1,200 Bq/kg iodine-131, parsley 12,000 Bq/kg iodine-131 and 2,110 Bq/kg cesium-137 and Shiitake mushrooms 8,000 Bq/kg cesium-137. Lesser amounts of radiation were found on lettuce, onions, tomatoes, strawberries, wheat and barley.³⁹
- Milk: In the first weeks of the nuclear catastrophe, even the IAEA issued a warning not to drink milk from Fukushima Prefecture as it contained dangerous levels of iodine-131 and cesium-137.⁴⁰
- Beef: The sale of beef was temporarily regulated when radioactivity levels in beef from Fukushima, Tochigi, Miyagi and Iwate Prefectures exceeded the permitted tolerance limits.⁴¹
- Rice: According to the Fukushima prefectural government, contaminated rice with up to 1,050 Bq/kg cesium was found in Onami District, as well as in the city of Date.⁴² To this day, rice samples from Fukushima still regularly exceed official limits.⁴³
- Drinking water: In spring of 2011, the IAEA warned that permissible levels of iodine-131 were exceeded in drinking

water samples taken in the prefectures of Fukushima, Ibaraki, Tochigi, Gunma, Chiba and Saitama between March 17th and 23rd.⁴⁴ Even in the northern districts of Tokyo, tap water was found to contain 210 Bq/L iodine-131 and residents were warned not to drink it.⁴⁵



- Fish and seafood: Even today, fish and seafood caught in the vicinity of the Fukushima Daiichi plant still contain high levels of cesium, more than 10,000 Bq/kg – in extreme cases even up to 740,000 Bq/kg.^{46,47,48,49}
- Tea: According to the Shizuoka prefectural government, tea leaves harvested 400 km south of Fukushima contained 679 Bq/kg cesium-137. In June of 2011, radioactive green tea from Japan was discovered in France.⁵⁰

38 Ministry of Education, Culture, Sports, Science and Technology (MEXT). "Important Information from Japanese Government, Readings of Dust Sampling". 18.04.11. http://eq.wide.ad.jp/files_en/110418dust_1000_en.pdf

39 Ibaraki Prefectural Government. "Ibaraki Prefecture Agricultural Products Test Results". 08.08.11. www.pref.ibaraki.jp/bukyoku/seikan/kokuko/en/links/agriculture_radiation.html

40 IAEA. "Fukushima Nuclear Accident Update". 20.03.11. www.iaea.org/newscenter/news/2011/fukushima200311.html

41 TEPCO. "Current Status of Fukushima Daiichi Nuclear Power Station". 27.01.12. www.tepco.co.jp/en/nu/fukushima-np/f1/images/f12np-gaiyou_e_3.pdf

42 Japanese Atomic Information Forum (JAIF). "Cesium detected from more Fukushima rice". Earthquake Report No. 276, 29.11.11. www.jaif.or.jp/english/news_images/pdf/ENGNEWS01_1322541949P.pdf

43 Ministry of Health, Labour and Welfare. "Emergency monitoring test results". Juli 2015. <http://www.mhlw.go.jp/file/04-Houdouhappyou-11135000-Shokuhinzenbu-Kanshianzenka/0000091483.pdf>

44 IAEA. "Fukushima Nuclear Accident Update", 20.03.11. www.iaea.org/newscenter/news/2011/fukushima200311.html

45 "Regarding the Limitation of Tap Water for Infants to Intake - Disaster Information 65th - Translation Edition". Multilingual Support Center for the Tohoku Earthquake out at Pacific Ocean, 23.03.11. <http://eqinfo.jp.net/?p=2999>

46 Weiss D. "Contamination of water, sediments and biota of the Northern Pacific coastal area the vicinity of the Fukushima NPP". Gesellschaft für Anlagen- und Reaktorsicherheit, 31.10.11. www.eurosafe-forum.org/userfiles/2_2_%20paper_marine%20environment_Fukushima_20111031.pdf

47 TEPCO. "Nuclide Analysis results of seafood, 20 km from Fukushima Daiichi nuclear power plant". 15.03.13. http://www.tepco.co.jp/nu/fukushima-np/f1/smp/2013/images/fish_130315-j.pdf

48 World Health Organization (WHO). "Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami". 23.03.12. http://www.who.int/ionizing_radiation/pub_meet/fukushima_dose_assessment/en

49 TEPCO. "Analyzed result of nuclide in fish - Port in Fukushima Daiichi NPS". 18.08.15. http://www.tepco.co.jp/en/nu/fukushima-np/f1/smp/2015/images/fish01_150818-e.pdf

50 Shizuoka Prefectural Government, "Test Results for Radioactivity on Tea Produced in Shizuoka Prefecture".

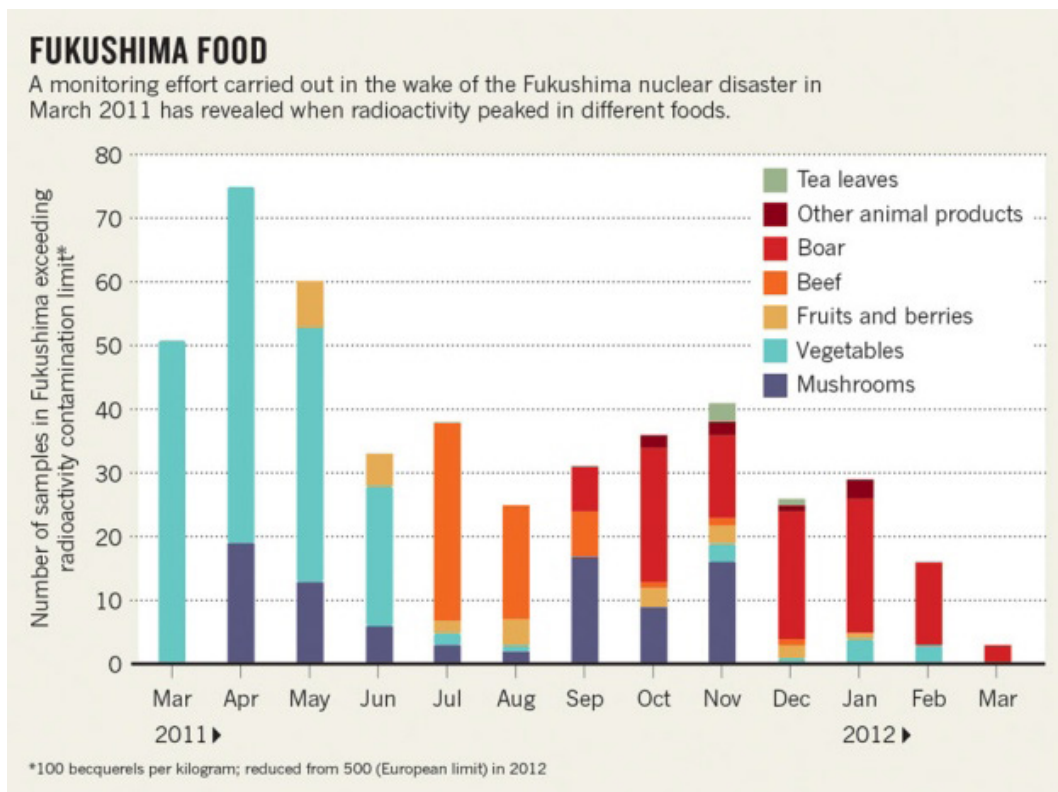


Figure 2.1: Evaluation of food radioactivity 2011/2012

Figure 2.1 from Nature magazine⁵¹ shows the number of food samples exceeding permitted values and illustrates the course of radioactive contamination in selected foods in the year following the nuclear meltdowns.

Natural decay of radioactivity, trade restrictions and preventive measures allowed the gradual reduction of radioactivity in most foods in Japan, except fish, seafood, game, forest fruits and homegrown crops from contaminated areas. But there was still relevant absorption of radioactivity through food and drinking water, particularly in the first year of the nuclear disaster. A scientific estimate of the individual and collective radiation doses ingested with contaminated food would be required to assess the overall health risk to the affected population.

But the reports of the responsible international institutions, WHO and UNSCEAR, only draw on the food database of the IAEA – an organization set up to “promote the safe, secure and peaceful use of nuclear technologies” and “to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world.”⁵² IAEA officials are nominated by national nuclear energy organizations, which means that when it comes to assessing the effects of nuclear disasters, the IAEA has a profound conflict of interest. The IAEA database contains 125,826 food samples that were collected in the first year of the nuclear disaster, two thirds (66.9%) of which, how-

ever, are beef samples.⁵³ Although the remaining 40,000 samples are roughly classified according to the month and location of collection, they can hardly be considered representative of the huge quantities of food consumed in the contaminated areas.

If, in a country like Japan with a population of more than 120 million, between 6 and 81 eggs are tested each month, this does not allow any meaningful conclusions to be drawn about the overall contamination of eggs in the country. The same applies to the ridiculously small sample size for freshwater fish (eleven) or fruit juice (sixty-three) that were analyzed by the IAEA during the course of the first year. From a total of 135 radioactive isotopes, samples were only taken for iodine-131 and cesium-137. Strontium-90 – a particular cause of concern for human health – was ignored altogether. Nor is it entirely clear if these samples were collected in areas of low, middle or high contamination. The level of radioactivity in the food samples collected by the Japanese authorities exceeded those of the IAEA database samples many times over. The following table gives maximum values for vegetable samples in the IAEA database (taken from the 2012 WHO Fukushima Report)⁵⁴ and comparable samples collected by MEXT, Japan’s ministry of

51 Gibney E. “Fukushima Data show rise and fall in food radioactivity.” Nature, 27.02.15. <http://www.nature.com/news/fukushima-data-show-rise-and-fall-in-food-radioactivity-1.17016>

52 IAEA. “Atoms for Peace”. 1957. www.iaea.org/About

53 UNSCEAR. “2013 Report, Annex A - Levels and effects of radiation exposure due to the nuclear accident after the 2011 great East-Japan earthquake and tsunami - Attachment C-8: FAO/IAEA food database”. July 2014. http://www.unscear.org/docs/reports/2013/UNSCEAR_2013A_C-8_FAO_IAEA_food_database_2014-07.pdf

54 WHO. “Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami”. 23.03.12, S.106, Table A8.2. http://whqlibdoc.who.int/publications/2012/9789241503662_eng.pdf

science and technology.⁵⁵ Neither IAEA nor the WHO has explained why these samples were not included in the IAEA database.

Radioisotope	WHO/IAEA	MEXT
Iodine-131	54,100 Bq/kg	2,540,000 Bq/kg
Cesium-131	41,000 Bq/kg	2,650,000 Bq/kg

Table 2.5: Differing values for vegetable samples

The estimation of health effects can only be as accurate as the data it is based upon. The method of choosing food samples and the sample size influence the results of the data and therefore the calculations of possible health effects. To this day, a scientifically sound estimate of individual and collective radiation doses ingested through contaminated food in Japan is neither possible nor politically desired.

55 MEXT. "Important Information from Japanese Government, Readings of Dust Sampling". 18.04.11. http://eq.wide.ad.jp/files_en/110418dust_1000_en.pdf

3. Consequences of the nuclear disaster for human health



The carcinogenic nature of ionizing radiation has been known for a long time.¹ People exposed to radiation at the workplace become ill significantly more often than non-exposed people. A meta-analysis of data from 15 countries in 2007 was able to show a significant correlation between the radiation dose and the incidence of cancer, with no lower threshold dose in persons exposed to radiation.² The US National Academy of Sciences' Advisory Committee on the Biological Effects of Ionizing Radiation states in its BEIR VII report that there is no lower threshold dose and that even small amounts of radiation have the potential to cause tissue damage and genetic mutations. Exposing a large population to low-dose radiation can therefore have a similar effect as the exposure of a small population to a high radiation dose. The dose-risk model of the BEIR-VII report states that exposure of a population of 100,000 to an average 1 mSv would result in an average of 20 (confidence interval CI 9 to 35) persons developing cancer. The same number of cancer cases would be expected if 1,000 people were exposed to 100 mSv radiation. In both cases, the risk factor 0.2 per Person-Sievert is assumed for the cancer incidence (CI 0.09-0.35).³ The WHO also uses a cancer risk factor of 0.2/PSv in their 2013 Fukushima Report.⁴ The risk factor for cancer mortality is about half as high (0.1/PSv, CI 0.05-0.19).

If this model is applied to the situation in Japan in the aftermath of the Fukushima nuclear disaster, the following picture emerges: clean-up workers at the plant were probably exposed to the highest doses. This was, however, a comparatively small group. Radioactive fallout and the continuous contamination of the ocean, drinking water and food means that an even greater proportion of the Japanese population is being exposed to low-dose radiation, especially in the most heavily contaminated areas. But people living in the greater Tokyo area are also affected, as are the consumers of products with increased radiation throughout the entire country. This radioactive contamination will continue to have an effect on the population for a long time to come – strontium-90 and cesium-137 have physical half-lives of 28 and 30 years respectively; it will be 300 years before decay brings radiation down to an acceptable level.

The greatest challenge for public health policy in the coming decades will be the chronic exposure of large parts of the population to low-dose radiation. As cancer carries no seal of origin, the cause of a specific cancer case cannot be causally linked to a specific event. Moreover, Japan already has a relatively high 'natural' cancer incidence – approximately every second person in Japan will develop cancer in the course of a lifetime. Despite this, appropriate epidemiological studies could differentiate excess radiation-induced cancer cases from the 'background noise' of the natural cancer incidence. This was clearly demonstrated in the study of childhood leukemia and cancers near German nuclear reactors, which found a significant increase of childhood cancers in areas around NPPs.⁵ But such studies do not serve the interests of the Japanese authorities and the powerful nuclear lobby. Their organizations therefore contend that

1 WHO. "Cancer prevention". www.who.int/cancer/prevention/en

2 Cardis E et al. «The 15-Country Collaborative Study of Cancer Risk among Radiation Workers in the Nuclear Industry: estimates of radiation-related cancer risks». *Radiat Res.* 2007 Apr;167(4):396-416, April 2007. www.ncbi.nlm.nih.gov/pubmed/17388693

3 National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). "BEIR VII report, phase 2: Health risks from exposure to low levels of ionizing radiation". 2006, S. 279, Tabelle 12.5. www.nap.edu/openbook.php?record_id=11340&page=8

4 WHO. "Global report on Fukushima nuclear accident details health risks". 28.02.13. www.who.int/mediacentre/news/releases/2013/fukushima_report_20130228/en/index.html

5 Kaatsch P et al. "Leukaemia in young children living in the vicinity of German nuclear power plants". *Int J Cancer.* 1220:721-726, 2008. www.rachel.org/lib/leukemias_near_german_nukes.080215.pdf

“a discernible increase in cancer incidence in this population that could be attributed to radiation exposure from the accident is not expected.”⁶ In the following two chapters this claim will be examined on the basis of the two mainly affected populations: the clean-up workers and the general public. This paper will then go into the results of the ongoing thyroid cancer study by the Fukushima Medical University as this is the only study so far, which looks into a possible link between increased cancer incidence and the Fukushima nuclear disaster.

3.1 Health effects in occupationally exposed people

The people most acutely affected by high radiation doses in Fukushima were, like in Chernobyl, the members of the power plant workforce and emergency services. According to the authors of the UNSCEAR report on Fukushima from autumn 2013, a total of 25,000 persons were deployed at the Fukushima Daiichi site since the beginning of the disaster.⁷ Only about 15% of these were actually employed by TEPCO, the rest were temporary workers, volunteers or sub-contracted workers. Hardly any of them were adequately qualified to work with hazardous radioactive substances and were neither prepared nor equipped to work in a nuclear disaster area.

In its report from February 2013, the WHO reported about 23,172 workers:

- Around 67% of these (approx.15,500) were exposed to radiation doses of about 5 mSv during the first year of the nuclear disaster (March 2011-April 2012).⁸ According to current WHO risk models (risk factor for cancer incidence 0.2/PSv, CI: 0.09-0.35/PSv), approximately 15 (CI: 7-17) radiation-induced excess cancer cases can be assumed for this group during the first year of the disaster, half of these fatal. The additional risk of developing cancer due to radiation for each individual worker is therefore 0.1% (CI: 0.05-0.17%).
- In the first year of the disaster, 33% of the workers, i.e. 7,600 persons, were exposed to 30 mSv of radiation. It must be assumed that as a result of radioactive contamination during deployment on the power plant site during the first year of the disaster, this group will incur around 46

(CI: 20-80) excess cancer cases, half of them fatal. The additional risk of developing cancer due to radiation for each individual worker in this group is therefore 0.6% (CI: 0.3-1.0%).

- According to the WHO, 75 workers were exposed to radiation doses between 100 and 199 mSv. As individual dose values were not published, the expected cancer rate for this group can only be a rough estimate. The number of excess cancer cases in this group can be expected to lie somewhere between 1 and 5. The additional risk of these workers to develop cancer is therefore between 1% and 7%, depending on the level of contamination.
- According to the WHO, 12 workers were exposed to internal radiation with individual doses ranging between 100 and 590 mSv, as well as approximately 100 mSv external radiation. As no individual dose values were published for this group, the expected cancer incidence can only be given as a rough estimate. Between 0 and 3 excess cancer cases should be expected in this group. The additional risk of these workers to develop cancer is therefore between 0 and 25%, depending on the contamination level.

To sum up the WHO data, it can be said that of the 23,172 workers deployed on the power plant site during the first year of the disaster, an estimated 28-115 are expected to develop radiation-induced cancer as a result and 14-58 will die of it.

It must be emphasized that these estimates are not only based on provisional figures from just the first year of the disaster, but they are also disputed:

- Short-lived radioisotopes like iodine-132 or iodine-133 were not included in the estimates so that even UNSCEAR has to admit that the figure for internal contamination could be as much as 20% higher.⁹
- According to UNSCEAR, even the corrected dose rates would lead to a systematic underestimation, as most radiation was no longer detectable at the actual time of measuring due to the rapid decay, for example of iodine-131.¹⁰
- Moreover, the fact that organizations like the WHO and UNSCEAR rely exclusively on data provided by TEPCO certainly warrants criticism. It is a known fact that employees of a number of sub-contractors were not included in

6 UNSCEAR. “Report of the United Nations Scientific Committee on the Effects of Atomic Radiation - Sixtieth session”. UN General Assembly Official Records, 68th session, supplement No. 46, 27.05.13. www.un.org/Docs/journal/asp/ws.asp?m=A/68/46

7 UNSCEAR. “Report of the United Nations Scientific Committee on the Effects of Atomic Radiation - Sixtieth session”. UN General Assembly Official Records, 68th session, supplement No. 46, 27.05.13. www.un.org/Docs/journal/asp/ws.asp?m=A/68/46

8 WHO. “Global report on Fukushima nuclear accident details health risks”. 28.02.13. www.who.int/mediacentre/news/releases/2013/fukushima_report_20130228/en/index.html

9 UNSCEAR. “Report of the United Nations Scientific Committee on the Effects of Atomic Radiation - Sixtieth session”. UN General Assembly Official Records, 68th session, supplement No. 46, 27.05.13. www.un.org/Docs/journal/asp/ws.asp?m=A/68/46

10 UNSCEAR. “Report of the United Nations Scientific Committee on the Effects of Atomic Radiation - Sixtieth session”. UN General Assembly Official Records, 68th session, supplement No. 46, 27.05.13. www.un.org/Docs/journal/asp/ws.asp?m=A/68/46

the plant operator's official figures, their data was probably not even collected.^{11,12}

- A number of workers complained that they had never been given a medical examination. Reports of missing, faulty or manipulated dosimeters (e.g. by encasing them in lead covers) and fake measurements have done little to enhance the credibility of the TEPCO data.^{13,14,15}
- The focus on the effects of radioactive iodine has meant that the health effects of radioisotopes like cesium-137, strontium-90 or plutonium have been neglected. In its Fukushima report, the WHO even assumed that internal contamination was exclusively due to iodine-131 and categorically excluded the possible incorporation of any other radioisotopes – despite the vast amount of available data showing relevant contamination and experiences gained from Chernobyl.¹⁶

The sum of these factors has resulted in the systematic underestimation of the health risk to the thousands of people exposed to radiation while working at the power plant – oftentimes without qualifications or adequate protection. Also to be taken into consideration are the tens of thousands of cleanup and decontamination workers who swept radioactive dust from rain gutters, removed contaminated soil or washed down treetops, often in perilous working conditions or even voluntarily, wearing only the simplest of face masks to protect themselves. In summary, it is safe to say that the health risks for workers exposed to radiation during the Fukushima disaster cannot be adequately assessed using the available data.

3.2 Health effects on the general public

Unlike workers who were and are still exposed to high levels of radiation, the larger part of the Japanese public was exposed to smaller doses, mainly from contaminated food, water, soil and

air. Nonetheless, by far the greatest number of actual health effects is to be expected in this group due to its size. This can be illustrated with an example: if the UNSCEAR figures are used, Japan's population of 127 million people will be exposed to a lifetime dose of around 48,000 Person-Sievert (PSv), the majority of which will affect the population in the most heavily contaminated prefectures. By applying the risk factor 0.2/PSv (CI: 0.09-0.35) proposed in the BEIR VII report, which is now even used by the WHO, the estimated total number of radiation-induced cancer cases in Japan is 9,600 (CI: 4,300-16,800), around half of which will be fatal.

This figure is even higher if the dose calculations of the WHO Fukushima report are used. The WHO assumes that the individual dose in the first year of the nuclear disaster was about 3-25 mSv for the population in the most heavily contaminated areas (just under 1 million people), and 0.316 mSv (CI: 0.1-1 mSv) for the remaining population (about 126 million people).¹⁷

Depending on the factor used to calculate lifetime dose (double or triple the first-year dose), one arrives at a collective lifetime dose of 110,000-165,000 PSv. Using the cancer incidence risk factor of 0.2/PSv (CI: 0.09-0.35), around 9,900-57,000 additional cancer cases can be expected for the whole of Japan. Other calculation models that apply the higher risk factor of 0.4/PSv for cancer incidence arrive at a figure between 22,000 and 66,000 cancer cases.¹⁸ Recent epidemiological studies suggest that this risk factor more reliably reflects the actual cancer risk than the lower risk factor applied in the BEIR VII report.¹⁹

Irrespective of which dose estimates, lifetime dose calculations or risk factors one is inclined to believe – there can be no doubt that the radioactivity released through the Fukushima nuclear disaster will result in a significant number of cancer cases in Japan – leukemia, lymphoma and solid tumors – while the individual cases will not be attributable to Fukushima or any other singular cause. No mass screenings or special prevention programs are planned for the general public, with the exception of regular thyroid tests for children in Fukushima Prefecture.

It has also been acknowledged that ionizing radiation not only causes cancer, but also cardiovascular diseases, as well as a number of other health issues – in some cases with similar risk

11 Hackenbroch V et al. "A Hapless Fukushima Clean-Up Effort". *Der Spiegel*, 05.04.11. www.spiegel.de/international/world/a-hapless-fukushima-clean-up-effort-we-need-every-piece-of-wisdom-we-can-get-a-754868-2.html

12 Sato J, Tada T. "TEPCO fails to submit dose data on 21,000 Fukushima plant workers". *The Asahi Shimbun*, 28.02.13. <http://ajw.asahi.com/article/0311disaster/fukushima/AJ201302280086>

13 Sato J et al. "TEPCO subcontractor used lead to fake dosimeter readings at Fukushima plant". *The Asahi Shimbun*, 21.07.12. <http://ajw.asahi.com/article/0311disaster/fukushima/AJ201207210069>

14 McCurry J. "Life as a Fukushima clean-up worker". *The Guardian*, 06.03.13. www.theguardian.com/environment/2013/mar/06/fukushima-clean-up-radiation-public-criticism

15 "TEPCO subcontractor tries to underreport workers' radiation exposure". *Kyodo News*, 21.07.12.

16 WHO. "Global report on Fukushima nuclear accident details health risks". 28.02.13, S. 48-49. www.who.int/mediacentre/news/releases/2013/fukushima_report_20130228/en/index.html

17 WHO. "Health risk assessment from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami based on a preliminary dose estimation". 2013. S. 39. www.who.int/iris/bitstream/10665/78218/1/9789241505130_eng.pdf

18 Paulitz H et al. "Auf der Grundlage der WHO-Daten sind in Japan zwischen 22.000 und 66.000 Krebserkrankungen zu erwarten" IPPNW, 14.03.13. www.ippnw.de/commonFiles/pdfs/Atomenergie/Fukushima/Fukushima_Erwartete_Krebserkrankungen_Japan_mit_WHO-Daten.pdf

19 Thiel et al. "Gefahren ionisierender Strahlung: Ergebnisse des Ulmer Expertentreffens vom 19. Oktober 2013". IPPNW, 15.01.14. www.ippnw.de/strahlung

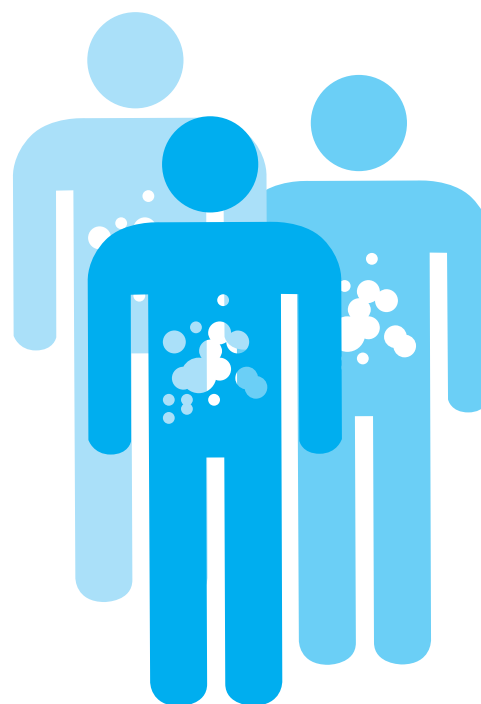
factors to those for cancer.^{20,21} In addition, a great deal is known about genetic damage and the transgenerational effects of ionizing radiation today, examples for which can be found in a recent overview article by Scherb et al.²² In particular, a shift in the sex ratio has been seen in newborn children when populations were exposed to ionizing radiation. With fewer girls being born, the sex ratio shifts towards males. Whether or not this effect will also become apparent in Fukushima over the course of the next few years remains to be seen, but certainly warrants closer examination. In a statistical analysis of Japanese birth records, Körblein found a significant 20% increase in perinatal mortality in the contaminated regions in 2012 and 2013, corresponding to about 140 excess cases of perinatal death.²³

It must be noted that the calculation of disease rates and health effects is based on a great number of assumptions, such as the source term, the ingestion of radioactive particles in food and certain risk-relevant behaviors.²⁴ The calculations in this chapter are based on dose calculations by the WHO and estimates of collective lifetime doses by UNSCEAR. It has already been shown that this information is so fraught with uncertainties and subject to systematic underestimation that the collective doses and with it the number of cancer cases and deaths are likely to be several times higher. Reasons for this include:

- The total amount of radioactive particles that were released is probably far greater than the numbers used for the WHO and UNSCEAR reports (see chapter on atmospheric emissions).
- Exposure of the population in the 20-km zone prior to and during evacuation was not included in dose estimates.²⁵
- The quantity and choice of food samples for calculating internal radiation doses was inadequate or biased (see chapter on radioactive contamination of food).

- The independence of the authors of both reports is questionable. IAEA representatives wrote essential sections of the WHO report, even though the agency's main aim is the promotion of nuclear energy around the world.²⁶

Calculations of health risk can naturally only be as accurate as the assumptions they are based upon. An assessment based on data of questionable objectivity, selective sampling, biased data and the misappropriation of relevant information does not provide an acceptable basis for health policy recommendations.



20 Little MP et al. „Systematic review and meta-analysis of circulatory disease from exposure to low-level ionizing radiation and estimates of potential population mortality risks“. *Environ Health Perspect* 2012, 120, 1503-1511.

21 Shimizu Y et al. “Radiation exposure and circulatory disease risk: Hiroshima and Nagasaki atomic bomb survivor data, 1950-2003“. *BMJ* 2010, 340, b5349.

22 Scherb, H et al. “Ionizing radiation and the human gender proportion at birth - A concise review of the literature and complementary analyses of historical and recent data“, *Early Human Development* 91 (2015) 841–850. <http://www.ncbi.nlm.nih.gov/pubmed/26527392>

23 Körblein A. „Perinatal mortality in Japan after Fukushima: an ecological study“. Submitted to *Environmental Health Journal*, 26. January 2016.

24 WHO. “Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami“. 23.03.12. http://www.who.int/ionizing_radiation/pub_meet/fukushima_dose_assessment/en

25 WHO. “Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami“. 23.03.12. http://www.who.int/ionizing_radiation/pub_meet/fukushima_dose_assessment/en

26 IAEA. “Atoms for Peace“. 1957. www.iaea.org/About

4. Thyroid screening in Fukushima Prefecture

An increase in thyroid cancer is to be expected in the regions affected by radioactive iodine contamination. According to UNSCEAR, the thyroid glands of infants in Fukushima Prefecture were exposed to a dose of 15-83 mGy in the first year of the nuclear disaster, “as much as one half of which arose from the ingestion of radioactivity in food.”^{1,2} In comparison, the average annual thyroid dose from natural background radiation is normally 1 mGy.³ These dose calculations are, of course, just estimates, as actual doses depend on a number of dietary and habitual variables, individual exposure well as specific health factors. As radioactive fallout does not stop at prefectural borders and radioactive iodine was found in milk, seafood, meat, drinking water, vegetables and rice, infants in other parts of the country were also affected. It is estimated that in the first year of the nuclear disaster, infants in the rest of Japan received an average thyroid dose of 2.6-15 mGy. UNSCEAR estimates the collective lifetime thyroid dose for the whole of Japan to be

112,000 Person-Gy.⁴ If the Dose and Dose Rate Effectiveness Factor (DDREF) of 0.009/pGy from the BEIR-VII report is applied to calculate the number of expected thyroid cancer cases due to radioactivity from the nuclear disaster in Japan, one arrives at the number of 1,000 excess cases.⁵ In view of the numerous problems with the UNSCEAR data that have already been addressed above, it is safe to assume that this figure is actually far too low.

To monitor the development of thyroid cancer cases in the affected population, the Fukushima Medical University (FMU) initiated the Fukushima Health Management Survey. This prospective study is the largest scientific investigation of long-term effects of the Fukushima nuclear disaster and warrants a brief analysis.

The study was initiated by the controversial Japanese scientist Shunichi Yamashita, known among other things for his advice to the people of Fukushima to smile more, as this would minimize the effects of radiation, as well as for trivializing the effects of ionizing radiation on health, contrary to scientific knowledge.⁶ Perhaps even more critically, he was instrumental in preventing the distribution of iodine tablets in his role as consultant to the responsible emergency au-

1 UNSCEAR., “Sources, effects and risks of ionizing radiation – UNSCEAR 2013 Report; Volume I – Report to the General Assembly – Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami“. 02.04.14, S. 9, Paragraph 30. www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf

2 UNSCEAR., “Sources, effects and risks of ionizing radiation – UNSCEAR 2013 Report; Volume I – Report to the General Assembly – Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami“. 02.04.14, S. 87, Tabelle 10. www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf

3 UNSCEAR., “Sources, effects and risks of ionizing radiation – UNSCEAR 2013 Report; Volume I – Report to the General Assembly – Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami“. 02.04.14, S. 86, Paragraph 211. www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf

4 UNSCEAR., “Sources, effects and risks of ionizing radiation – UNSCEAR 2013 Report; Volume I – Report to the General Assembly – Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami“. 02.04.14, S. 198, Tabelle C16. www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf

5 National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). “BEIR VII report, phase 2: Health risks from exposure to low levels of ionizing radiation“. 2006, S. 279, Tabelle 12.5. www.nap.edu/openbook.php?record_id=11340&page=8

6 Yamashita, S. “Rede vom 21.03.11“. <https://www.youtube.com/watch?v=UOgaBUDFeb4>

thority - a decision that he later recognized as wrong.⁷ In this light, the results of a study led by him must be viewed critically due to a probable lack of objectivity. In 2012, it also became known that the international nuclear lobby organization IAEA had financial relations with the Fukushima Medical University, which casts further doubt on the study's scientific neutrality.⁸ Parent organizations in Fukushima also criticized the hasty and superficial nature of FMU thyroid exams, which lasted no longer than 2-3 minutes, the practice of withholding ultrasound images from the children's families and the fact that general practitioners had received written warnings not to perform follow-up examinations of children taking part in the study or to provide secondary opinions. Children living outside the prefecture were excluded from the study, as were a large numbers of children whose parents had left the prefecture after the onset of the disaster. Despite such criticism, the Fukushima Prefecture thyroid study is the world's most extensive study of radioactively contaminated children and warrants discussion. The FMU study comprises two separate parts: the preliminary baseline screening and the full-scale screening.

4.1 Preliminary baseline screening

Preliminary baseline screening was carried out between October 2011 and March 2014 to determine the thyroid cancer prevalence, i.e., the natural frequency of thyroid cancer in the pediatric population of Fukushima Prefecture. At the time of the nuclear meltdowns, around 360,000 children between the ages of 0 and 18 were living in the prefecture. Japan's Ministry of Health puts the annual rate of new cases (incidence) of thyroid cancer in children under 19 in Japan at 0.35 per 100,000.⁹ In a population of 360,000 children, one could therefore expect about one new case of thyroid cancer per year to be diagnosed either because the illness exhibited symptoms or due to incidental findings. A known phenomenon is the so-called 'screening effect', whereby healthy subjects who would normally not have become symptomatic until much later are diagnosed at an early stage of the disease as a result of mass screenings. It can be assumed that in the three and a half years of the baseline study, the cancer incidence would actually have been higher than the 3-4 statistically predicted cases. It was expected that these additional cases would be diagnosed at a very early stage and therefore present no acute danger for the patient.

7 "Authorities jump gun on iodine pills / Premature distribution risked ill effects on health, depleted emergency supplies". The Yomiuri Shimbun, 22.03.11. <http://www.nationmultimedia.com/2011/03/21/headlines/Authorities-jump-gun-on-iodine-pills-30151398.html>

8 MOFA. "Practical arrangements between Fukushima Medical University and the International Atomic Energy Agency on Cooperation in the area of human health". 15.12.12. http://www.mofa.go.jp/policy/energy/fukushima_2012/pdfs/fukushima_iaea_en_06.pdf

9 Katanoda K et al. "An updated report of the trends in cancer incidence and mortality in Japan". *Jpn J Clin Oncol*. 43(5):492-507, May 2013. www.ncbi.nlm.nih.gov/pubmed/23493744.

The actual picture presented by the baseline study, however, was altogether different: the ultrasound tests of 537 of the children showed such abnormal results that fine needle aspiration biopsy was required. Microscopic analysis resulted in a total of 116 suspected cases of cancer. A large majority of these were found to be malignant, and based on the limited information available, 101 children required surgery mostly because of metastasis, large tumor size, or tumor's proximity to other vital structures. In surgery, one case was found to be a benign lesion, while cancer was confirmed in 100 cases (97 papillary thyroid carcinoma and 3 poorly differentiated thyroid carcinoma).¹⁰ Awkward questions about the possible causes of such an unexpected high rate of malignant thyroid cancer were already asked by the end of the preliminary baseline study.

4.2 Full-scale screening

Full-scale screening is the second phase of thyroid screening and was begun in April 2014. It involves a follow-up thyroid ultrasound examination of the children from the baseline study plus a baseline thyroid ultrasound examination of children born shortly after the nuclear disaster. The target group is therefore slightly larger than that of the baseline study. The aim is to examine these children every 2 years up to the age of 20, then every 5 years for the rest of their lives. Full-scale screening involved the thyroid ultrasound examination of 381,261 children, of which 236,595 (62.1%) were examined between April 2014 and December 2015. Validated results are only available for 220,088 children (57.7%) at this time. 157 children required fine-needle aspiration biopsy because of lesions found on ultrasound examination. Microscopic analyses resulted in a total of 51 new suspected cases of cancer. 16 of the children required surgery, mostly because of metastasis, large tumor size, or tumor's proximity to other vital structures, and papillary thyroid carcinoma was confirmed in all cases.¹¹

Thus, the total number of children with confirmed thyroid cancer is now 116 (February 2016). All of them required surgery, some for metastasis, large tumor size, or tumor's proximity to other vital structures. A further 50 children have been diagnosed with suspected thyroid carcinoma. They are still awaiting surgery.

At this point it should be noted that although thyroid cancer

10 Fukushima Medical University. "Final Report of Thyroid Ultrasound Examination (Preliminary Baseline Screening)". 31.08.15. <http://fmu-global.jp/?wpdmdl=1222>

11 Fukushima Medical University. "The 22nd Prefectural Oversight Committee Meeting for Fukushima Health Management Survey". 15.02.16. <http://fmu-global.jp/survey/proceedings-of-the-22nd-prefectural-oversight-committee-meeting-for-fukushima-health-management-survey>

is generally considered a cancer with favorable outcome, such a diagnosis is always a personal tragedy for the patients and their families. Following surgery, which of course always involves a certain degree of risk itself, patients have to endure lifelong follow-up examinations, permanent medication with thyroid hormones, regular visits to the doctor, blood tests and both clinical and sonographic examinations. There is also the perpetual fear of a relapse, metastasis or renewed tumor growth. Thus, there is no justification for treating thyroid cancer lightly.

Particularly alarming is the fact that 16 new proven carcinoma cases have developed in the period between the first and the second round of screenings. The incidence of other thyroid lesions also increased: while the incidence of thyroid nodules and cysts in the first screening was 48.5%, the incidence for such changes in the second screening was 59.3%. This means that in the second screening, cysts and nodules were found in 36,408 children that had not exhibited thyroid anomalies in the first screening. In 348 children, these lesions were so unusual that further examinations were required. A further 782 children with small cysts or nodules in the first screening exhibited such rapid growth rates of these lesions at a follow-up examination that further evaluation had to be initiated. In the years to come, the families of these children must live in fear of their child developing cancer. They blame themselves and are tormented by the question of why more was not being done to protect their children.

The data from full-scale screening now allows for a calculation of the incidence, i.e. the number of new cases per year. Unfortunately, because the authorities are withholding data related to newly diagnosed cases of thyroid cancer, the exact period of time between the first and second screenings are not known for the individual cancer case. If the time between the two screenings was 2 years as scheduled, then we can assume an incidence of 3.6 new cases per year among 100,000 children. Prior to the Fukushima nuclear meltdowns, the annual incidence of thyroid cancer among children in Japan was 0.35 per 100,000 children. This ten-fold increase in the incidence of thyroid cancer in children can no longer be explained by the so-called 'screening effect'.

4.3 Screening summary

The number of children that were not examined suggests that the increased incidence of thyroid cancer could be even higher. More than 67,000 children from Fukushima Prefecture who were exposed to radiation were not included in the study and more than 160,000 are still on the waiting list for full-scale screening. A further cause for alarm is that children living outside Fukushima Prefecture are not being systematically examined or screened – although it is generally known that radioactive fallout containing iodine-131 occurred as far away as the northern districts of Tokyo and hundreds of thousands of additional children were exposed to increased radia-

tion levels in the first days and weeks of the nuclear disaster and not screened. Without mass screenings it will not be possible to establish a causal link between excess cancer cases and radiation exposure, and cancer cases may have delayed diagnosis with worsened outcomes.

At this point it is important to remember that the authorities, against better judgment, did not distribute iodine tablets to protect the population from the harmful effects of iodine-131. The report by the Japanese parliament's Independent Investigation Committee states that "although the positive effects of administering stable iodine and the proper timing were fully known, the government's nuclear emergency response headquarters and the prefectural government failed to give proper instructions to the public."¹² It is also difficult to understand why, on April 19, 2011, the Japanese government raised the permissible level of radiation exposure of children to 3.8 µSv per hour (equivalent to about 20 mSv per year with an average exposure of 14 hours per day).¹³ Following protests by parent organizations, scientists and doctors, the government withdrew the new guideline on May 27, 2011 and returned to the old standard of 0.2 µSv/hour (equivalent to about 1 mSv/year).¹⁴ In the first weeks and months of the disaster the change in standard will have certainly contributed to children in the affected areas being exposed to higher doses of radiation .

In summary, it can be said that mass screenings can contribute to documenting the incidence of thyroid carcinoma and result in treatment at an earlier stage with more likely positive outcomes.

In view of the experience of Chernobyl, it is incomprehensible that, apart from thyroid screenings, there have been no other mass screenings of children in the contaminated prefectures. Evaluation and screening for other radiation induced conditions such as solid tumors, leukemia, lymphoma as well as non-cancer health effects like cataracts, endocrine and cardiovascular diseases and genetic consequences of radiation exposure should have been or could still be undertaken. Extensive research by independent scientists is necessary to quantify the true extent of the disease burden on the affected population.

¹² The National Diet of Japan. "The official report of The Fukushima Nuclear Accident Independent Investigation Commission of the National Diet of Japan". 05.07.12. http://www.nirs.org/fukushima/naic_report.pdf

¹³ MEXT. "Notification of interim policy regarding decision s on whether to utilize school buildings and outdoor areas within Fukushima Prefecture". 19.04.11. www.mext.go.jp/english/incident/1306613.htm

¹⁴ MEXT. "Immediate Measures toward Reducing the Radiation Doses that Pupils and Others Receive at Schools, etc. in Fukushima Prefecture". 27.05.11. http://radioactivity.mext.go.jp/en/important_imfor mation/0001

5. Consequences of the nuclear disaster on the non-human biota

In addition to the effects on humans in contaminated areas, a closer look should also be taken of the effects of increased radiation on the non-human biota, i.e. plants and animals. Plants and animals belong to the same ecosystem as humans and have numerous interdependencies with us, the most obvious being the fact that our diet consists almost entirely of animal and plant products. But apart from this, we co-exist in a complex symbiosis with numerous species and are therefore also affected by changes in these complex systems. Also, we may be able to learn more about the effects of chronic exposure to low-dose radiation from its effects on plants and animals. As many living organisms have a more rapid generational turnover than humans, genetic effects can be easily observed and investigated both *in vitro* and *in vivo*. The investigation of the non-human biota is therefore an important aspect in the analysis of the consequences of a nuclear disaster. During the last five years, several scientific papers have addressed the morphological, genetic and physiological effects of ionizing radiation on the non-human biota in Fukushima, the most relevant of which will be discussed in this chapter.

In 2015, for example, the research group around Watanabe found a significant correlation between radiation dose and morphological abnormalities in native Japanese fir trees in the contaminated area around the wrecked power plant.¹ The closer the trees were to the wrecked reactor, the more pronounced were the changes, suggesting a dose-effect correlation. Temporal progression could also be observed, as the most serious mutations of main shoots were found on trees that began growing in spring 2012, i.e. one year after the onset of the nuclear disaster. As trees live and grow their entire lives in one place,

they provide us with an excellent demonstration of local effects.

This is not the case with animals that run free and are therefore unsuitable for demonstrating local effects. However, the lycaenid butterfly, a native species that spends its entire life within an extremely limited radius was evaluated for radiation impacts. In a study in 2012, Hiyama et al. were able to demonstrate a significant increase in pathologies that was directly proportional to the radioactive contamination of the food source: reduced body and wing size, greater number of morphological mutations and increased mortality rate (18.5%).² Laboratory examinations confirmed the radiation-induced increase in genetic mutations and morphological changes in the butterflies.³ It was also found that later generations of butterflies exhibited higher mutation rates than the first generation. This suggests that mutations can be passed on and accumulate over generations.⁴

In well-designed studies, larger animals can also be an important source of information. Murase et al. observed a species of goshawk that tend to return to their same nest year after year. The goshawks were studied before and after the Fukushima nuclear disaster up to 100-120 kilometers from the Fukushima site. Murase et al. found that the bird's reproductive capacity was directly proportional to the level of radiation measured di-

1 Watanabe Y. et al. "Morphological defects in native Japanese fir trees around the Fukushima Daiichi Nuclear Power Plant". *Sci. Rep.* 5, 13232. <http://dx.doi.org/10.1038/srep13232>

2 Hiyama A et al. "The biological impacts of the Fukushima nuclear accident on the pale grass blue butterfly". *Nature Scientific Reports* 2, Art 570 (2012). www.nature.com/articles/srep00570

3 Møller AP, Mousseau TA. « Low-dose radiation, scientific scrutiny, and requirements for demonstrating effects". *BMC Biol.* 2013 11:92. <http://bmcbiol.biomedcentral.com/articles/10.1186/1741-7007-11-92>

4 Taira W et al. "Fukushima's Biological Impacts: The Case of the Pale Grass Blue Butterfly". *J Hered* (2014) 105 (5): 710-722.

rectly beneath the nest.⁵ These results indicate that radiation has an effect on the bird's germ line. Overall success of birds leaving the nest dropped from pre-Fukushima rates of 79% to 55% in 2012 and 50% in 2013 which may be related to the level of radioactive substances in their food. There was also an overall reduction in the number of birds, butterflies and cicadas proportional to the ambient radiation of the study area.^{6 7}

A study of primates in the contaminated areas is even more significant in terms of the possible inferences about the effects on humans. In April 2012, pathological blood counts were found in wild monkeys in the Fukushima forests about 70 kilometers from the nuclear plant. As a control group, a monkey population about 400 kilometers north of Fukushima was also analyzed. While the concentration of radioactive cesium in the muscles of Fukushima monkeys was found to be between 78 and 1,778 Bq/kg, cesium concentrations in the control group were below the detectable level. In the Fukushima monkeys, the reduction in the number of red and white blood cells was directly proportional to the cesium concentration in the muscles, so that a dose-effect correlation can be assumed.⁸

It would be unscientific to draw direct conclusions about the effects of ionizing radiation for humans from such plant- and animal-studies. Nonetheless, the research findings cannot be disregarded, particularly regarding the question of genetic and transgenerational effects of radiation. In this respect, animal models with their rapid generational succession can help us fill knowledge gaps and attain a better understanding of the complex interaction between ionizing radiation and living tissue in general, and the DNA of germ line cells in particular. Thus, the investigation of the non-human biota in Fukushima is a field of research that could provide a wide range of important findings in the future.

5 Murase K et al. „Effects of the Fukushima Daiichi nuclear accident on goshawk reproduction“. *Sci. Rep.* 2015, 5. <http://dx.doi.org/10.1038/srep09405>

6 Mousseau TA et al. „Genetic and Ecological Studies of Animals in Chernobyl and Fukushima“. *Journal of Heredity*, Volume 105, Issue 5. S. 704-709.

7 Aliyu AS et al. „An overview of current knowledge concerning the health and environmental consequences of the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident“. *Environ. Internat.* 85 (2015) 213-228. <http://cricket.biol.sc.edu/chernobyl/papers/Sadiq-et-al-EI-2015.pdf>

8 Ochiai K et al. „Low blood cell counts in wild Japanese monkeys after the Fukushima Daiichi nuclear disaster“. *Nature Scientific Reports* 2014:4:5793. <http://www.nature.com/srep/2014/140724/srep05793/pdf/srep05793.pdf>

6. Outlook

From the findings cited above it is clear that the nuclear catastrophe of Fukushima is still not under control and the process of dealing with the consequences for humans and the environment has only just begun. At the same time, basic information about the source term and the contamination of soil, ocean and foods is still being disputed between the nuclear lobby and its institutions on one side and independent scientists and physicians on the other, even five years after the onset of the disaster. The health effects for occupationally exposed workers and the general public are being systematically played down by the nuclear industry and their lobby organizations such as the IAEA or UNSCEAR. With eloquent statements and palliative reports, particularly on the part of the Japanese authorities, persistent attempts are undertaken to end all discussion about the Fukushima nuclear disaster.

It must be clearly stated that the discussion is far from over. According to TEPCO, every day, approximately 300 tons of radioactive wastewater flow into the sea.¹ Decontamination efforts have stalled and are being continuously countered by recontamination. The decontamination of mountain ranges, forests and fields has proven to be impossible, even for a country like Japan. The authorities optimistically assume a 'shielding effect' due to the washout of radionuclides in the ground and leaching of radioactive particles into deeper layers of soil, but forget to account for the increased exposure of the public through radio-

active cesium-137 in the groundwater and food chain.² It will take decades and cost many billions of tax dollars to salvage the radioactive materials from the wrecked reactor blocks.³ The half-life of cesium-137 is about 30 years. This means that relevant amounts of radiation will remain in fields, pastures and forests for the next three hundred years and more. The fact that the forests of southern Germany are still radioactively contaminated 30 years after Chernobyl is a case in point.

It would be unscientific to formulate a concluding statement about the long-term effects of a nuclear disaster just five years after it began, especially as the main issues are cancer and cardiovascular disease which take years and decades to manifest themselves. But this is precisely what the Japanese authorities, IAEA and UNSCEAR are attempting to do by stating that there will be no 'relevant' or 'discernible' radiation effects in the exposed population. What people in the affected areas need is credible information, guidance and support, not deception, manipulated studies and false hopes. Organizations like the IAEA are not motivated to protect the health of the population; their interests lie largely in protecting the profits and political influence of the nuclear industry in Japan and the world. While the Japanese nuclear power sector has generated immense profits with its aging reactors for decades, the cost of the extensive decontamination and clean-up attempts in Fukushima will be shouldered by generations of Japanese taxpayers – a major-

1 Tsukimori O, Hamada K. „Japan government: Fukushima plant leaks 300 tpd of contaminated water into sea | Reuters“. Reuters, 07. 08.13. <http://www.reuters.com/article/2013/08/07/us-japan-fukushima-water-idUSBRE9760AU20130807>.

2 MAFF. „Towards the recovery and restoration of the Great East Japan Earthquake disaster area“. MAFF Topics, Dezember 2011. http://www.maff.go.jp/j/pr/aff/1112/mf_news_00.html

3 „IAEA calls for improvements at Japan's Fukushima plant“. BBC News Asia, 22.04.13. <http://www.bbc.co.uk/news/world-asia-22246464>.

ity of which now have grave doubts about nuclear power. In Japan, a huge system of deception has been installed to protect the nuclear power industry. Undesirable reports can be declared a 'betrayal of state secrets' and are punishable by law.⁴

Public debate on Fukushima should not be focused on profits, power and political influence of the nuclear industry, but center around the situation and health of the affected population – those who lost everything, who fear for their health and that of their children, who ask nothing more than a life without fear of radiation. The risks to the health of the Japanese population must be investigated by independent scientists, positively excluding any undue influence by the nuclear industry and their political supporters. Extensive studies are required to understand the public health consequences, to identify diseases at an early stage and improve preventive measures for future generations by learning more about the effects of ionizing radiation. The debate on the health effects of the Fukushima nuclear disaster is about far more than the principle of independent research and taking a stand against the influence of powerful lobby groups. It is about the universal right of every human being to health and life in a healthy environment.

4 Sieg L, Takenaka K. "Japan secrecy act stirs fears about press freedom, right to know". Reuters, 24.10.13. <http://www.reuters.com/article/2013/10/25/us-japan-secrecy-idUSBRE99N1EC20131025>.

For Europe and the United States:

- There are still almost 300 nuclear reactors in Europe and the United States with an average age of 30 to 40 years.
- IPPNW and PSR urge all States with nuclear power plants to begin closure and decommissioning of reactors and to move to sustainable renewable energy and energy efficiency. There is a broad global consensus that fossil fuels cannot and should not play any role in the energy production of the future. But nuclear is not an acceptable alternative.
- IPPNW and PSR recommend that a global energy transition towards 100% renewable energy, coupled with energy efficiency and conservation and the decentralization of energy production should be the only reasonable political consequence of the nuclear disasters at Chernobyl and Fukushima.

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