Critical Analysis of the UNSCEAR Report "Levels and effects of radiation exposure due to the nuclear accident after the 2011 Great East-Japan Earthquake and tsunami"

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Outline

I) Introduction

The International Physicians for the Prevention of Nuclear War (IPPNW) is a global federation of doctors working towards a healthier, safer and more peaceful world. In more than 60 countries, our national affiliates are acting as advocates of nuclear abolition and proponents of a nuclear-free world. For its work, IPPNW was awarded the Nobel Peace Prize in 1985.

In 2011, the IPPNW Board of Directors unanimously agreed to adopt a more encompassing stance towards the goal of a nuclear weapons-free world by addressing the strong interdependency between the military and civilian branches of the nuclear chain. A world without nuclear weapons will only be possible if we also phase out nuclear energy. As physicians, we are also concerned about the environmental and health implications of all aspects of the nuclear chain – from the public health impact of uranium mining and the creation of large amounts of radioactive tailings, the inherent dangers of processing and transporting fissile material around the globe, the uncontrollable risks attached to the civil use of nuclear energy, the dual use capability of fissile material for both civilian and military purposes and the ensuing proliferation risk, all the way to the global health impact of nuclear weapons testing and the unsolved problem of nuclear waste. Every human being has the right to live in an environment free of radioactive contamination, compatible with health and well-being.

After the Fukushima nuclear meltdowns in March of 2011, IPPNW physicians were approached by many affected families, local politicians and doctors in Fukushima and were asked for their expertise on the health effects of radioactive fallout. In the past three years, IPPNW physicians have been helping the people of the contaminated regions gather valid scientific information and protect their children from the harmful effects of radiation. In many instances, IPPNW has had to confront and publicly criticize attempts by the nuclear industry and its lobby groups to downplay the consequences of the catastrophe. We supported the families, doctors and scientists who opposed the government's decree to raise the permissible annual radiation exposure level for children from 1 to 20 mSv and took a strong stance against the proponents of the Japanese "nuclear village" who publicly proclaimed that the increased radiation exposure would pose no harm to human health.

After the IPPNW World Congress in Japan in August of 2012, IPPNW physicians visited the contaminated regions in Fukushima and participated in scientific conferences, public meetings and university lectures. Like Anand Grover, the UN Special Rapporteur on the right to health to the Human Rights Council, we are concerned that the people affected by Fukushima radioactive fallout are systematically deprived of their right to a standard of living adequate for their health and well-being.

On April 2nd, 2014, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) published its complete report "Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami". In its press release, UNSCEAR uses the following phrase to sum up its findings: "No discernible changes in future cancer rates and hereditary diseases are expected due to exposure to radiation as a result of the Fukushima nuclear accident".[1] This echoes the UNSCEAR press release from May 31st, 2013, which stated: "Radiation exposure following the nuclear accident at Fukushima-Daiichi did not cause any immediate health effects. It is unlikely to be able to attribute any health effects in the future among the general public and the vast majority of workers".[2]

Current research gives no justification for such optimistic presumptions. Although UNSCEAR's evaluations of the complex data may be useful in assessing the consequences of the Fukushima nuclear catastrophe, we also feel that the report does not reveal the true extent of the consequences of the disaster. The Belgian Association for Radiation Protection, a member of UNSCEAR, criticized that the report has even retreated from the lessons of Chernobyl[3] UNSCEAR draws mainly on data from the nuclear industry's publications rather than from independent sources and omits or misinterprets crucial aspects of radiation exposure. In question are also some of the assumptions, which UNSCEAR's calculations are based on. Even a month after publication of the report, the important appendices containing the raw data have still not been made accessible, preventing independent verification of UNSCEAR's conclusions. For these reasons, doctors from 19 affiliates of IPPNW have found the need to issue this critical analysis of the UNSCEAR report.

We are concerned that the apparently systematic underestimations and questionable interpretations in the report will be used by the nuclear industry to downplay the expected health effects of the nuclear catastrophe in Fukushima. Furthermore, public authorities need reliable interpretations of scientific data in order to act in the best interest of the public, as well as an honest assessment of the limitations and uncertainties of available data and assumptions. The "precautionary principle" as defined by the Declaration of Rio in 1992 dictates, that in situations of scientific uncertainty, the worst possible outcome should be presumed and acted upon. However, we feel that the UNSCEAR report, which will most likely be considered by most public authorities as a reliable and scientifically sound basis for their policies, is over-optimistic and misleading. This could negatively affect future public policy, scientific research, social support and health services for the affected population in Japan. We are also worried that the unsubstantiated and unreliable conclusions of the UNSCEAR report could have negative long-term impacts on international radiation safety standards and emergency response guidelines and risk higher exposure to future generations. For these reasons, we present our medical and scientific insight on the UNSCEAR report, noting first the points with which we agree, followed by our ten main points of criticism.

II) Where we agree with the UNSCEAR report

The UNSCEAR report represents an extensive project, dealing with a multitude of data. In particular, we are pleased to note the following four points:

1 Calculating collective effective doses for all of Japan

UNSCEAR estimated the collective effective life-time dose of the entire Japanese population due to the Fukushima nuclear catastrophe to be 48,000 Person-Sv and the collective absorbed life-time thyroid dose of the entire Japanese population to be 112,000 Person-Gy.[4] This calculation represents a substantial step forward from the World Health Organization (WHO) health assessment, which restricted itself to calculating average individual life-time doses. With the collective effective life-time doses, health effects in large populations can be calculated. It is appreciated that UNSCEAR acknowledges the linear non-threshold model and thereby rejects the use of a threshold for radiation effects of 100 mSv, used by the International Atomic Energy Agency (IAEA) in the past. However, there are serious doubts regarding the estimations behind the collective dose calculations in the UNSCEAR report, which we believe results in systematic underestimations. This will be further elaborated on in section III.

2 Estimating radiation doses for non-evacuated districts and neighboring prefectures

UNSCEAR estimated the total effective dose[5] and absorbed dose[6] to the thyroid for non-evacuated districts of Fukushima Prefecture and six neighboring prefectures in the first year following the accident. The UNSCEAR report acknowledges that "the deposition of radionuclides in the ground at locations within the South trace (Tomioka, Naraha, Hirono Towns and Iwaki City) was significantly enriched in tellurium-132, iodine-132 and iodine-131 compared with the rest of Japan."[7] As a result, the highest first-year thyroid dose in non-evacuated districts was determined to be 52 mGy for a 1-year-old infant living in Iwaki City.[8] This is 52 times the annual absorbed dose to the thyroid from natural background radiation (~ 1 mGy).[9] UNSCEAR has furthermore calculated the average absorbed thyroid doses for the six neighboring prefectures Chiba, Gunma, Ibaraki, Iwate, Miyagi and Tochigi, acknowledging that radioactive fallout did not just affect people in Fukushima Prefecture, but people all over Japan who came in contact with airborne or ingested radionuclides.[10] Contaminated rice, beef, sea-food, milk, milk-powder, green tea, vegetables, fruits and tap water were found all over mainland Japan and even in Japanese food exports.[11,12,13,14,15,16,17,18,19,20,21,22] However, UNSCEAR stopped short of estimating doses for Tokyo and Saitama in the Kanto region, immediately south of Chiba, which also received a significant fallout both on March 15th and 21st, 2011.[23] Since produce as far as Shizuoka Prefecture, 140 km south of Tokyo, was found to be contaminated,[24] not considering the radioactive fallout in the prefectures of Tokyo, Saitama, Kanagawa and Shizuoka reduces the estimated radiation doses of the population in these regions and ultimately leads to an underestimation of the total collective lifetime dose of the Japanese population.

3 Describing a much higher marine discharge than previously reported

TEPCO's initial estimates of the total radioactive contamination of the Pacific Ocean due to the Fukushima nuclear disaster came to 4.7 PBq. By far the biggest marine contamination, however, occurred from radioactive fallout in the days and weeks following the initial nuclear meltdowns and was not considered in the TEPCO estimate. Scientists from the Japanese Atomic Energy Agency (JAEA) and Kyoto University subsequently calculated the total amount of marine contamination from iodine-131 and cesium-137 to be 15 PBq.[25] In October of 2011, calculations by the French Institute for Radioprotection and Nuclear Safety (IRSN) topped this number by determining 27 PBq of cesium-137 marine contamination alone.[26]

According to the current UNSCEAR report, however, all of these estimates were still far too low. In determining marine contamination, the authors rely mostly on a study by Kawamura et al from August of 2011, calculating the total amount of radiation that entered the Pacific Ocean by deposition from the atmosphere to be 5 PBq for cesium-137 and 57 PBq for iodine-131 in the period of time between March 12th and April 30th and an additional 4 PBq of cesium-137 and 11 PBq of iodine-131 that were directly released during the period of time from March 21st to April 30th.[27]

However, even these figures most probably do not describe the full extent of marine contamination. Regarding radioactive discharge before March 21st, Kawamura states that "no direct release into the ocean was assumed before March 21st because the monitoring data were not available during this period".[28] Also, his calculations do not take into account any atmospheric emission after April 6th, taking the questionable stance that "there is no information on the amounts released into the atmosphere from April 6. It was assumed, therefore, that the radioactive materials were not released into the atmosphere from April 6."[29] Most incomprehensibly, however, all radioactive discharge after April 30th, 2011 is ignored, despite TEPCO's recent revelation that since the beginning of the disaster, about 300 tons of radioactive discharge reached the ocean every day, amounting to a total of about 346,500 tons during the past 38 months. Kawamura's study at least concedes that "it will probably be necessary to estimate the source term on oceanic and atmospheric releases more accurately at some point in the future."[30]

Given all the uncertainties and underestimations explained above, it can be summarized that UNSCEAR assumes marine contamination of 68 PBq iodine-131 and 9 PBq cesium-137. This figure exceeds JAEA's estimate by more than 5 times and TEPCO's initial calculations by more than 15 times. Hence it is clear that Fukushima fallout constitutes the single highest radioactive discharge into the oceans ever recorded.[31,32] According to the IAEA, Fukushima nuclear fallout already ranks as one of the prime radioactive pollutants of the world's oceans, together with the atmospheric nuclear weapons tests, the fallout from Chernobyl and the radioactive discharge of nuclear reprocessing plants like Sellafield, UK or La Hague, France.[33]

4 Correctly portraying the Fukushima catastrophe as an ongoing process rather than a singular event

The nuclear industry commonly portrays the nuclear catastrophe in Fukushima as a singular event, not taking into consideration the continued emissions of radioactivity after the initial meltdowns in March 2011. In particular, there is usually no consideration of the continued dispersion of radioactive particles, leaks into soil and groundwater from radioactive storage tanks and the destroyed reactor cores, as well as the radioactive contamination of soil and groundwater due to washout of radioactive isotopes in fields, forests and urban settlements. Decontamination efforts have proven to be only temporary measures, as radiation is redistributed over previously decontaminated areas from natural reservoirs such as forests or fields during rainy and typhoon season, on windy days or during spring, when the flight of pollen can contribute to the spread of radioactive particles.[34, 35]

In the UNSCEAR report, the Fukushima nuclear disaster is recognized as an ongoing catastrophe, requiring constant reevaluation of the cumulative extent of contamination. UNSCEAR notes that "releases to the marine environment were ongoing at the end of December 2013" and that "this may warrant further follow-up of exposures and trends in the coming years."[36] UNSCEAR also reports that "groundwater, contaminated by numerous sources of radioactive material on site (e.g. leaks from storage tanks, dispersal of contaminated reactor coolant, and deposition of radionuclides released to the atmosphere), represents a continuing source of release to the ocean" and that "further releases could not be excluded in the future, either inadvertently (e.g. from water continuing to be released from the reactor buildings into groundwater) or as part of the waste management strategy adopted in the remediation of the FDNPS [Fukushima Dai-ichi Nuclear Power Station] site."[37] In the long run, this may lead to an increase in internal exposure in the general population through radioactive isotopes from ground water supplies and the food chain. This scenario is a realistic assessment, considering that in many places in Eastern and Central Europe, radioactive cesium-137 contained in mushrooms and wild game still poses a public health concern, almost three decades after the Chernobyl nuclear meltdown.[38, 39] Unfortunately, these precautionary aspects were not stated in the UNSCEAR press release and seem to be ignored by most media reports about the findings of the committee.

III) Main points of criticism

While we believe that parts of the UNSCEAR report may be useful in future assessments of the environmental and public health consequences of the Fukushima nuclear meltdowns, we are concerned that this report could lay the groundwork for a systematic underestimation of the true extent of the nuclear catastrophe. In its report to the UN General Assembly, UNSCEAR states that "no discernible increased incidence of radiation-related health effects are expected among exposed members of the public or their descendants".[40] To many people this statement could be understood as a prediction that no health effects are to be expected, when in reality, it is merely suggesting that the health effects (e.g. cancer cases, non-cancer diseases, genetic malformations and stillbirths) will be too small to manifest themselves in epidemiological surveys of the entire Japanese population. While we share the view that many of the expected health effects cannot be unambiguously attributable to the radioactive contamination in north-eastern Japan, this is not true for rare diseases such as childhood thyroid cancer, the incidence of which can be significantly increased in the aftermath of a nuclear catastrophe.[41] It is commonly accepted that the exposure of a large population to even small amounts of ionizing radiation leads to a predictable number of cancer cases, a fact also stated in the UNSCEAR report. In the case of Fukushima, this affects not only the population in the immediate vicinity of the nuclear plants, but also people in other prefectures who can be affected by internal radiation through contaminated food, water, air-borne radioisotopes or the growing amounts of nuclear waste.

UNSCEAR bases many of its assumptions regarding medical radiation effects and dose estimates on the WHO/IAEA reports published in May of 2012 and in February of 2013.[42,43] The WHO reports were criticized for misrepresenting the true extent of radiation exposure, following faulty assumptions on the vulnerability of the unborn child to radiation and ignoring the ongoing emissions of radioactivity from the damaged nuclear reactors. Also, they excluded non-cancer effects of radiation without a critical discussion and were influenced to a large extent by scientists with conflicts of interests because of close ties to the nuclear industry.[44,45]

Regarding the current UNSCEAR report, the established scientific principle still holds true that any assessment can only be as good as the data and the assumptions that it is based upon. Accordingly, our main points of criticism can be summed up under these ten arguments:

1. The validity of UNSCEAR's source term estimates is in doubt
2. There are serious concerns regarding the calculations of internal radiation
3. The dose assessments of the Fukushima workers cannot be relied upon
4. The UNSCEAR report ignores the effects of fallout on the non-human biota
5. The special vulnerability of the embryo to radiation is not taken into account
6. Non-cancer diseases and hereditary effects were ignored by UNSCEAR
7. Comparisons of nuclear fallout with background radiation are misleading
8. UNSCEAR'S interpretations of the findings are questionable
9. The protective measures taken by the authorities are misrepresented
10. Conclusions from collective dose estimations are not presented

1 The validity of UNSCEAR's source term estimates is in doubt

Several studies have dealt with the calculation of the Fukushima 'source term' – the total amount of radioactivity released by the nuclear disaster.[46] Even without addressing the fact that the emissions of radioactive particles from Fukushima Dai-ichi continue unabated and that the available source term estimates only deal with the emissions during the first weeks of the disaster, there are still various concerns regarding the source term assumptions used in the UNSCEAR report. The authors state that they base their calculations on the source term estimate of Terada et al,[47] but fail to mention that this study was undertaken by the Japanese Atomic Energy Agency (JAEA), which was severely criticized by the Fukushima Nuclear Accident Independent Investigation Commission of the Japanese Diet [parliament] for its collusion with the nuclear industry and its carelessness in the field of nuclear safety.[48] JAEA has a clear conflict of interest when it comes to assessing the effects of the nuclear disaster and cannot be considered a neutral source of information in this regard.

UNSCEAR argues that JAEA's study, published on May 22nd, 2012, represents the most current assessment, although the renowned Norwegian Institute for Air Research (NILU) published its findings just three months earlier, in February of 2012, and found a release of cesium-137 four times higher than the JAEA estimate (37 PBq instead of 9 PBq). Furthermore, TEPCO's own estimates of the release of iodine-131 from May 2012 were also more than four times higher (500 PBq vs. 120 PBq).[49] If the primary concern is to adequately assess possible health effects on the population, it is not clear why UNSCEAR relies on the significantly lower source term estimates of the controversial Japanese Atomic Energy Agency rather than those of neutral international institutions or of TEPCO itself.

Radioisotope	TEPCO	JAEA	NILU
Iodine-131	~500 PBq	120 PBq	-
Cesium-137	~10 PBq	9 PBq	37 PBq

Table 1: Source term estimates cited in UNSCEAR report 49

Another contentious issue regarding source term estimates is the release of other radioisotopes, such as radioactive strontium (Sr-89/-90). Upon ingestion, strontium can accumulate in bone tissue, as it is very similar to calcium, and can cause bone marrow cancer and leukemia. It is therefore a highly relevant environmental toxin and its effects on human health have been demonstrated in numerous nuclear accidents in the past decades. In its report, UNSCEAR states that radioactive strontium isotopes were detected in concentrations that were higher by four orders of magnitude [i.e. more than 10,000 times] than those that preceded the accident.[50] The report goes on to say that radioactive strontium concentrations were always less than 1/10 of Cs-137 concentrations, except in December 2011, when radioactive strontium was directly released into the ocean.[51] With a marine release of Cs-137 in the magnitude of about 9 PBq, even one tenth of this still amounts to a significant amount of radioactive strontium released into the Pacific Ocean. And while most of the initial radioactive fallout from Fukushima has gone into the ocean, strontium was also detected in soil, groundwater and sediment samples in different parts of Fukushima Prefecture.[52]

Radioactive strontium isotopes should therefore be included in the assessment of radiation doses to the general population. However, UNSCEAR states in its report that "Sr-89 and Sr-90 deposited on the ground were significantly lower than those of Cs-137 and these radionuclides were therefore not included in the Committee's estimation of doses to the public." This unfortunate omission is justified in the rapporteur's report of UNSCEAR's May 2012 session as follows: "The first strontium measurements were received after the deadline and therefore they are not included".[53] Between May of 2012 and April of 2014, almost two years passed, but still, the health effects of radioactive strontium emitted by the crippled power plant in Fukushima were not taken into consideration. The same is true for more than two dozen other radionuclides emitted in the course of the disaster, most notably Xenon-133 or plutonium.

While we realize the difficulties in assessing the true extent of radiation emissions after such a catastrophic event, we have doubts as to the validity of the UNSCEAR source term estimates due to the arguments listed above. It is not clear why UNSCEAR decided against the more conservative approach and instead chose to rely on the lowest published source term estimates and to omit relevant radioisotopes due to 'deadline' issues.

On a side note, the aftermath of the Tohoku earthquake and tsunami included environmental pollution from fires at oil refineries and industrial areas, releasing numerous toxic chemicals into the air.[54] These chemicals can be harmful to humans and other living organisms, causing respiratory, dermatological and hematological problems, as well as carcinogenic and teratogenic effects. UNSCEAR should acknowledge that exposures of individuals to hazardous chemical contamination due to the earthquake and the tsunami may severely confound the relationship between radiation exposure and carcinogenic effects. The coexistence of radiation and chemical exposures could have synergistic effects, possibly leading to earlier and more severe health consequences. Health services in Fukushima should be aware of this possibility so that proper monitoring is conducted in all those who were exposed to radioactive fallout.

2 There are serious concerns regarding the calculations of internal radiation

Similar to the source term, the estimated uptake of radioactive isotopes with food and drink significantly influences the total radiation dose an individual is exposed to after a nuclear catastrophe. No matter how expertly undertaken, any assessment of health risks due to internal radiation can only be as exact as the assumptions it is based upon. Furthermore, any dose calculation is influenced by the method of choosing food samples and of determining sample size. Estimates based on data whose validity has to be questioned on the grounds of selective sampling, distortion and omission are not acceptable as a basis on which to make predictions and health policy recommendations.[55]

Such concerns undermine the conclusions of the UNSCEAR report. Regarding radiation doses in foodstuff, UNSCEAR uses, as its one and only source, the still unpublished database of the IAEA and the Food and Agriculture Organization (FAO).[56] The IAEA was founded with the specific mission to "promote safe, secure and peaceful nuclear technologies" and to "accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world."[57] It therefore has a profound conflict of interest. The reliance on food sample data from the IAEA is not advisable, as it discredits the assessment of internal radiation doses and makes the findings vulnerable to claims of manipulation.

There are several contentious issues regarding the IAEA/FAO foodstuff database. First of all, it only includes measurement data for I-131, Cs-134 and Cs-137 and so the UNSCEAR report only considered these three radionuclides in the assessment of doses from ingestion.[58] Other radionuclides, such as Sr-89/90 were not taken into account. Also, no comment is made in the UNSCEAR report regarding the sites where and how the IAEA food samples were collected, raising the suspicion that selective sampling may have taken place.

To give a concrete example, we cite from a recent analysis of the WHO/IAEA dose assessment report from May of 2012, which also bases its estimates on the IAEA/FAO foodstuff database. The quantity and selection of food samples used in the calculations of the internal radiation dose in the WHO/IAEA report were shown to be inadequate and in stark contrast to samples published by the Japanese authorities early during the disaster.[59] While the highest level of radioactive contamination of vegetables included in the WHO/IAEA report were samples with 54,100 Bq/kg of iodine-131 (incidentally found outside of Fukushima Prefecture) and 41,000 Bq/kg of cesium-137,[60] the Japanese Ministry for Science and Technology (MEXT) found contaminated weed/leafy vegetable samples with iodine-131 concentrations as high as 2,540,000 Bq/kg (more than 40 times higher than the most contaminated vegetable sample mentioned in the WHO/IAEA report) and cesium-137 concentrations of up to 2,650,000 Bq/kg (more than 60 times higher than the most contaminated vegetable sample mentioned in the WHO/IAEA report). Such high levels of radiation in weeds/leafy vegetables would suggest that produce grown in the same area would have accumulated similar radiation doses. Even one month after the meltdowns, MEXT scientists still found maximum concentrations above 100,000 Bq/kg for iodine-131 (almost twice as high as in the WHO/IAEA report) and 900,000 Bq/kg for cesium-137 (more than 20 times higher than in the WHO/IAEA report) in weeds/leafy vegetables.[61] Why are such highly contaminated samples not found in the WHO/IAEA report and could this indicate a selection bias? No explanation was offered by WHO or IAEA why these MEXT samples, readily available on the website of the ministry and cited by numerous publications, were omitted in their database. By relying solely on the IAEA/FAO foodstuff database, UNSCEAR repeats the approach of the WHO/IAEA report, discredits its assessment of internal radiation doses and makes its findings vulnerable to the suspicion of selective data sampling.

Radioisotope	WHO/IAEA	JAEA
Iodine-131	54,100 Bq/kg	2,540,000 Bq/kg
Cesium-137	41,000 Bq/kg	2,650,000 Bq/kg

Table 2: Maximum radiation dose readings in plants 60, 61

Another important issue is the assumption of dietary habits, which play a large part in estimating internal radiation exposure. The authors of the UNSCEAR report assumed that "the majority of people in Japan obtain their food from supermarkets where food is sourced from the whole of the country" and calculated the amount of internal radioactive exposure accordingly.[62] This may seem logical, but ignores the overwhelmingly rural character of the affected region, where many people rely on farmer markets and home-grown produce. The principle of 'chisan-chisho' or 'consuming the food produced locally' was widely encouraged in Fukushima to the point where municipalities encouraged or decreed the use of local Fukushima products in school lunches.[63] UNSCEAR admits that people eating locally produced food "could have received exposures significantly higher than those presented".[64] Also not taken into consideration was the nationwide governmental campaign 'tabete ouen shiyou', which promotes the purchase of food produced in Fukushima as an act of solidarity.[65] Therefore, the assumption that people in Fukushima eat food from the entire country probably leads to an underestimation of the actual consumption of contaminated food.

It also needs to be recalled that at the beginning of the nuclear catastrophe, residents suffered from shortage of fresh food and water due to the earthquake and the tsunami. During this period, there was no possibility for testing crops for radiation. People may therefore have consumed highly contaminated local food or water before proper testing and regulation came into effect. This fact receives no mention in the UNSCEAR report, which merely states that "there were insufficient data in the first months following the accident to adopt a fine spatial resolution for the assessment of the ingestion doses."[66] This may present an additional source of error in the calculation of the internal radiation dose.

3 The dose assessments of the Fukushima workers cannot be relied upon

The UNSCEAR report lists 24,832 people who were employed on the site of the nuclear catastrophe as plant workers, emergency personnel and clean-up staff. Regarding their radiation exposure, UNSCEAR relies solely on data received from TEPCO itself.[67] The report lists 173 workers exposed to effective doses greater than 100 mSv and about 24,659 workers who received effective doses of less than 100 mSv. Additionally, thirteen of these workers received thyroid doses in the range of 2 to 12 Gy.

The Japanese Diet's Fukushima Nuclear Accident Independent Investigation Commission accused TEPCO of collusion with the authorities and of ignoring warnings about the possibility of Tsunamis damaging coastal nuclear power plants and gives the company a large part of the responsibility for the nuclear disaster.[68] It is therefore only natural to assume that TEPCO has a conflict of interest when it comes to divulging facts and figures about radiation doses to its employees. There is no meaningful control or oversight of the nuclear industry in Japan and data from TEPCO has in the past frequently been found to be tampered with and falsified.[69]

Also, UNSCEAR states that only 15% of the total number of affected workers were directly employed by TEPCO,70 while the rest (about 20,000) was employed by an obscure network of subcontractors and sub-sub-contractors. Many of these sub-contracted companies employ temporary workers who are unaccounted for in the official statistics.[71,72] There are also numerous reports about missing dosimeters, deliberate lead casing of dosimeters to disable measurement and faulty radiation measuring instruments.[73,74,75]

Finally, short-lived radioisotopes such as tellurium-132, iodine-132, iodine-133 and xenon-133 were excluded from the calculations of workers' exposure doses. As an example, the report states that "no account was taken of the potential contribution from intakes of shorter-lived isotopes of iodine, in particular iodine-133; as a result, the assessed doses from internal exposure could have been underestimated by about 20 per cent. For many workers, because of the long delay before monitoring, iodine-131 was not detected in their thyroids; for those workers the internal doses estimated by TEPCO and its contractors are uncertain."[76]

For all of these reasons, it is difficult to accept the data provided by TEPCO as a representative and valid basis for prognostic calculations. The UNSCEAR report, however, bases its health assessments entirely on the data from TEPCO, most probably underestimating health effects in this population.

We also disagree with the assessment of UNSCEAR that "studies would lack sufficient statistical power to assess the risk of cancer due to irradiation; the doses would be too low and the population size too small".[77] Numerous studies have shown significant health effects from low-level radiation exposure in very diverse populations who were exposed to very different levels of radiation: from uranium miners,78-83 downwinders of nuclear tests,84-86 workers in nuclear factories,[87-90] to people living in the vicinity of power plants[91] and the clean-up workers (liquidators) in Chernobyl.[92-94] In the end, it is a question of study design and strict adherence to scientific principles, which in the case of TEPCO cannot be assumed, judging from the unwarranted magnitude of data manipulation in recent years.[78,79,80,81,82,83, 84,85,86, 87,88,89,90, 91, 92,93,94]

4 The UNSCEAR report ignores the effects of fallout on the non-human biota

Observed effects of low-level radiation on non-human biota can help to understand the consequences to humans. In its Fukushima report, UNSCEAR disregards current scientific fieldwork on actual radiation effects by stating that "the observations are not consistent with the Committee's assessment"[95] and rather refers to its own reports on the effects of radiation on non-human biota from 1996 and 2008.[96,97]

This implies that no new knowledge has been acquired since then, even though a growing number of published ecological and genetic studies from both Chernobyl and Fukushima find substantial evidence for low dose rate radiation effects generating genetic damage such as increased mutation rates, as well as developmental abnormalities, cataracts, tumors, smaller brain sizes in birds and mammals and further injuries to populations, biological communities and ecosystems.[98,99,100]

Unlike older radiation studies conducted under laboratory settings for short periods of time and focusing on acute responses to relatively high doses of radiation, the scientific studies of Mousseau, Møller, Lindgren and others address the much more complex question of whether or not there are measurable effects in natural populations following multiple generations of chronic exposure to low doses of ionizing radiation.

As such, their observations reflect cumulative effects under natural conditions - effects that cannot be observed under the artificial conditions used by most conventional toxicology studies. Underlining this point, a recent review in the Journal of Environmental Radiology suggested that responses by organisms in Chernobyl were about eight times larger than predicted by conventional models.[101]

UNSCEAR should include the findings of the current field-studies from Chernobyl and Fukushima, given their publication in peer reviewed scientific journals. Ignoring such studies gives the appearance of bias or a lack of rigor by the UNSCEAR proceedings that can only serve to undermine any constructive or useful advice the committee might have.

5 The special vulnerability of the embryo to radiation is not taken into account

The UNSCEAR report divides the affected population into three age groups: adults, children and infants. The special situation of the unborn child was specifically not taken into consideration: "The Committee did not explicitly estimate doses to the fetus or breast-fed infants because they would have been similar to those to other age groups for both external and internal radiation exposure."[102]

This approach goes against basic principles of neonatal physiology and radiobiology, as the special vulnerability of the unborn child is completely ignored. While it is known that the radiation dose for an embryo from external exposure is lower than for children and adults due to the additional shielding of the mother's skin, abdominal muscles and uterus, this is not true for internal radiation, which is the much more relevant factor in a nuclear catastrophe. Iodine-131, ingested or inhaled by the mother, accumulates in the fetal thyroid gland and can lead to the development of thyroid diseases and cancer after birth. Another radioisotope, cesium-137, freely passes the developing placenta into the embryo, and also accumulates in amniotic fluid and the bladder, affecting the unborn child from all sides with beta- and gamma-radiation. Most importantly, the effect of a given dose of radiation poses a much greater risk for an embryo than it would in children: high tissue-metabolism and mitosis rates of cells increase the chance for mutations of the genome. As the immune system and cell-repair mechanisms of the unborn child are not yet fully developed, they cannot adequately prevent malignancies from developing.[103] UNSCEAR does state that "previous experience indicates that the relative risks for certain cancers in certain population groups (notably following exposure as fetus, or during infancy and childhood) are higher than for the population average", but gives no special consideration to unborn children in its assessments.[104]

It is widely accepted that "in utero exposure to ionizing radiation can be teratogenic, carcinogenic or mutagenic. The effects are directly related to the level of exposure and the stage of fetal development. The fetus is most susceptible to radiation during organogenesis (two to seven weeks after conception) and in the early fetal period."[105] Every exposure to ionizing radiation carries a quantifiable risk, as numerous studies since the late 1950's were able to show:

Dr. Alice Stewart undertook the first epidemiological studies of childhood cancers caused by in utero x-ray exposure. She was able to show that a single x-ray to the abdomen of a pregnant woman could result in a 50% increase in childhood cancer incidence. Also, her studies showed that the risk of childhood cancer increases linearly with the number of in utero x-ray exposures. No confounding variables could be identified that could offer alternative explanations to these effects.[106, 107]

In 1997, Doll and Wakeford concluded that "a consistent association has been found in many case-control studies in different countries. The excess relative risk obtained from combining the results of these studies has high statistical significance and suggests that, in the past, a radiographic examination of the abdomen of a pregnant woman produced a proportional increase in risk of about 40%. [...] It is concluded that radiation doses of the order of 10 mGy received by the fetus in utero produce a consequent increase in the risk of childhood cancer."[108]

Numerous large-scale studies from around the world confirmed the findings of Stewart et al and have led to a much more careful approach towards antenatal radiation exposure.[109, 110, 111]

It is therefore not acceptable to arbitrarily have a reference 1-year-old infant represent all infants younger than 5, including the unborn child.[112] In dismissing the effect of the physiological differences between an unborn and an infant, the authors of the report effectively underestimate the health risks of this particularly vulnerable population.

6 Non-cancer diseases and hereditary effects were ignored by UNSCEAR

Non-cancer health effects such as cardiovascular diseases, endocrinological and gastrointestinal disorders, infertility, genetic mutations in offspring and miscarriages have been reported in medical literature but are not considered in the UNSCEAR report. Instead, the authors cite the WHO/IAEA health risk assessment, which "did not expect any deterministic effects in any of the various groups". Also, they "did not expect prenatal exposure to increase 'the incidence of spontaneous abortion, miscarriages, perinatal mortality, congenital effects or cognitive impairment.'"[113]

This position takes for granted that non-cancer effects of radiation would have to be deterministic, while it is just as reasonable to assume that they may be stochastic in nature, similar to the cancer-effects of radiation. Large epidemiological studies have shown undeniable associations of low dose ionizing radiation to non-cancer health effects. As these associations have not been scientifically challenged, the internationally acknowledged precautionary principle in public health dictates that broad preventive measures should be taken to minimize radiation exposure of all persons at risk.

One striking example of non-cancer diseases associated with ionizing radiation is the group of cardiovascular disorders. There are numerous studies that suggest a stochastic risk of ionizing radiation for the cardiovascular system, possibly through radiation damage to the epithelial lining of blood vessels, similar to the effects of high blood sugar, cholesterol, fats, blood pressure or other independent risk factors:

Little et al proposed a plausible model for cardiovascular disease due to fractionated low-dose ionizing radiation exposure and suggests a linear correlation between radiation dose and effects, similar to the model used for estimating cancer cases.[114]

A Swedish study on women who received radiotherapy due to breast-cancer showed a radiation-induced increase of cardiovascular diseases.[115]

A Japanese study on the Hibakusha of Hiroshima and Nagasaki found increased risks of heart disease and stroke in a radiation dose range of 0-2 Gy, supporting a linear model similar to the one used in cancer rate estimation and suggesting excess risk even at lower doses.[116]

7 Comparisons of nuclear fallout with background radiation are misleading

The UNSCEAR report concludes that "for the general public of Japan, inhabiting areas where exposures from the FDNPS accident in the first year were of the order of or below annual background exposure to natural sources of radiation (and lifetime exposures are expected to be much below those incurred from background radiation), the Committee estimated that risks over their lifetimes were so low that no discernible increase in the future incidence of health effects due to radiation exposure would be expected among the population or their descendants."[117] This comparison is often brought up to downplay the health impact of low-level radiation and apart from being misleading, can cause systematic underestimations of the public health impact of a nuclear disaster.

First of all, it is important to realize that some forms of radiation affect the whole body (terrestrial or cosmic radiation), while ingested or inhaled radioactive particles may only affect particular organs: iodine-131, for example, is mainly incorporated in the thyroid gland and can cause malignancies in this location, while strontium-90 is mainly deposited in bones, causing leukemia or bone cancers. Cesium-137, on the other hand, is distributed fairly evenly in most soft tissues, leading to the development of solid tumors. However, all of them have one thing in common: they deliver their radioactive dose directly and continuously to the surrounding tissue and therefore pose a much larger danger to internal organs than external background radiation. Organ doses are therefore a better tool for predicting cancer incidence than whole-body doses.

To put this in perspective, the average natural background radiation that an individual in Japan receives in the course of a year amounts to ~1.5 mSv and consists of ~0.3 mSv cosmic background radiation, ~0.4 mSv terrestrial radiation from radioisotopes in the ground, such as potassium-40 or uranium-238, ~0.4 mSv per year from the inhalation of airborne radioactive isotopes (mostly radon gas in houses) and ~0.4 mSv per year from ingestion, because most foods contain at least some amount of inherent radiation.[118] This natural background radiation is not harmless. Numerous well-designed studies have shown significant associations between cancer levels and background radiation[119, 120, 121], most notably naturally occurring radiation in groundwater122, soil123, radon levels in homes[124, 125, 126, 127, 128, 129], as well as the exposure to cosmic background radiation in airplanes.[130] It can be assumed that a certain proportion of the 'naturally' occurring cases of cancer are caused by exposure to natural background radiation.

The international scientific consensus is that there is no threshold below which radiation poses no harm. Instead, there is a linear relationship between radiation dose and cancer incidence. According to the comprehensive report, published in 2006 by the US National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR-VII), full-body exposure of 10,000 people with 1 mSv of radiation stochastically leads to one excess case of cancer. Put differently, a person exposed to a full-body dose of 1 mSv has a 1/10,000 chance of developing cancer because of this exposure. At a dose of 10 mSv, this risk is already increased to 1/1,000 and with 100 mSv the risk is 1/100 or 1%. This calculation is true for natural background radiation, medical radiation and radioactive fallout from a nuclear catastrophe.

It is therefore not scientific to argue that natural background radiation is safe or that excess radiation from nuclear fallout that stays within the dose range of natural background radiation is harmless. If this were true, then doctors should have no qualms about placing a child or a pregnant woman under an x-ray and irradiate them with 1.5 mSv, the equivalent dose of Japanese background radiation (that would be approximately 3 x-ray examinations of the abdomen or 75 x-ray examinations of the chest)[131]. The medical profession, however, is well aware of the harmful effects of ionizing radiation even at dose levels comparable to background radiation. Large epidemiological studies were able to show significant medical effects of low-level ionizing radiation. A strong correlation between in utero x-ray exposure and childhood cancers was already found in the 1950's.[132] More current studies were able to show that the average cancer risk of people who underwent CT-scans with an average dose of 4.5 mSv rose by 24% for the first CT and by 16% for every subsequent examination. The highest increase in cancer risk was seen in young children.[133,134] Avoiding unnecessary medical radiation from CT scans or x-rays are therefore important public health measures, which can help prevent excess cancer cases. This principle of minimization must also be applied to nuclear fallout.

8 UNSCEAR's interpretations of findings are questionable

The authors of the UNSCEAR report state that their job was to assess only radiation-related health effects.[135] Apart from these, it is important to realize that a nuclear catastrophe such as the one in Fukushima has a severe impact on population health for a number of reasons, be it the acute stress on people during the evacuation process, psychosomatic effects and post-traumatic stress disorder, chronic effects on people in the contaminated zone due to lack of physical exercise outdoors, etc. These factors should not be used to dismiss the effects of radiation exposure, however. Even after the Chernobyl disaster, the health effects on the group of liquidators were blamed on "stress and unhealthy lifestyle".[136] This should not be repeated in Fukushima.

In its press release, UNSCEAR comes to the conclusion that "no discernible changes in future cancer rates and hereditary diseases are expected due to exposure to radiation as a result of the Fukushima nuclear accident; and, that no increases in the rates of birth defects are expected."[137] It is important to realize that this statement is not saying that there will be no health effects, only that commonly used epidemiological methods will not be able to find them. This is an old strategy, already used for decades by tobacco companies or the automotive industry in order to argue against scientific evidence showing a causal link between cigarette smoke or unfiltered exhaust fume and lung disease. A cancer does not carry a label of origin and can never be attributed to a single cause. However, when epidemiological evidence becomes overwhelming, causal links can be established with reasonable certainty.

The report itself states that "the Committee has used the phrase "no discernible increase" to express the idea that currently available methods would most likely not be able to demonstrate an increased incidence in disease statistics due to radiation exposure. This does not rule out the possibility of future excess cases or disregard the suffering associated with any such cases should they occur."[138]

However, most people reading the report, its brief executive summary or the press release, will understand that no health effects are to be expected. By phrasing its conclusion in such a way that would most likely be misunderstood by most people, the authors are putting a 'spin' on their report. The report's findings, however, give no justification for such an optimistic conclusion. The report does not adhere to scientific standards of neutrality, but systematically underestimates the health risks for the affected population.

Also, it is worrying that when comparing the complete 292-page report with the short 22 page summary for the UN General Assembly and the one-page press release, the level of certainty with which interpretations are presented seems to increase, the more succinct the text becomes. While the complete report, supposedly written by scientists for scientists, includes a large number of uncertainties, these are not carried through to the more widely read, shorter documents, aimed at policy-makers, media and the general public. In its complete report, UNSCEAR admits to "incomplete knowledge about the release rates of radionuclides over time and the weather conditions during the releases."[139] The authors go on to state that "there were insufficient measurements of gamma dose rate and of radionuclides in air during the passage of the radioactive plumes for an assessment to be made of external exposure based on environmental measurements."[140] Also, "relatively few measurements of foodstuff were made in the first months" and that there "was insufficient information on the transfer of radionuclides to food as a function of time for foods produced in Japan."[141] With these uncertainties, how can the collective dose estimates be presented with the level of certainty employed in the executive summary?

9 The protective measures taken by the authorities are misrepresented

In its report and press releases, UNSCEAR frequently applauds the protective measures taken by the authorities. Without wanting to underestimate the laudable efforts of many tens of thousands of emergency workers, relief coordinators and others involved in the operations aimed at preventing even higher radiation exposure in the general population, it seems odd that a scientific body like UNSCEAR would turn a blind eye to the many grave mistakes of the Japanese disaster management, which have rightly been criticized not only by citizens, journalists, doctors, scientists and politicians in the affected prefectures, but also by the Fukushima Nuclear Accident Independent Investigation Commission of the Japanese Diet:

"The central government was not only slow in informing municipal governments about the nuclear power plant accident, but also failed to convey the severity of the accident. […] Specifically, only 20 percent of the residents of the town hosting the plant knew about the accident when evacuation from the 3km zone was ordered at 21:23 on the evening of March 11. Most residents within 10km of the plant learned about the accident when the evacuation order was issued at 5:44 on March 12, more than 12 hours after the Article 15 notification [nuclear disaster response] - but received no further explanation of the accident or evacuation directions. Many residents had to flee with only the barest necessities and were forced to move multiple times or to areas with high radiation levels. […] Some people evacuated to areas with high levels of radiation and were then neglected, receiving no further evacuation orders until April. […]

The Commission concludes that the situation continued to deteriorate because the crisis management system of the Kantei [office of the Japanese prime minister], the regulators and other responsible agencies did not function correctly. […]

Residents' confusion over the evacuation stemmed from the regulators' negligence and failure over the years to implement adequate measures against a nuclear disaster, as well as a lack of action by previous governments and regulators 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. [...] the government and the regulators are not fully committed to protecting public health and safety; [...] they have not acted to protect the health of the residents and to restore their welfare."[142]

The distribution of stable iodine right after the nuclear meltdown illustrates quite vividly how UNSCEAR's praises of the protective measures taken by Japanese authorities are often ill-deserved. According to UNSCEAR, "medical countermeasures included the use of stable iodine for thyroid blocking."[143] Only careful readers will notice that stable iodine was only prescribed to about 2,000 workers involved in the emergency response and not to the general public.[144] In fact, the Japanese Diet's Fukushima Nuclear Accident Independent Investigation Commission concluded 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."[145] This grave error caused thousands of children to become irradiated with iodine-131. The WHO/IAEA report on Fukushima concluded that due to the lack of stable iodine distribution, the estimated thyroid doses of the affected population would be "higher than those expected in people who have undergone thyroid blocking to reduce the uptake of radioactive iodine."[146]

Unlike the members of UNSCEAR, we are disturbed by the evidence that the authorities have not made public health and safety their top priority. The Japanese government has failed in the paramount duty of protecting its citizens. By raising the permissible annual exposure limits to 20 mSv on April 19th, 2011, the authorities have effectively forced many children to live in radioactively contaminated areas.[147] Only after protests by parent organizations, scientists and doctors, the government advised to use 1-20 mSv per year in schools as a guide level with the aim of reducing the annual dose to 1 mSv or less. Unfortunately, this recommendation is not mandatory and has not been fully implemented.[148] The Japanese Ministry of Education made a decision to restart schools in Fukushima soon after the accident without providing air conditioning units for classrooms so that windows could remain shut to keep radioactive dust from drifting in.[149] School officials have been ignoring radiation hot spots just a few feet outside of school premises and are reintroducing Fukushima rice to school lunches.[150] None of these issues are talked about in the UNSCEAR report.

Finally, it is important to realize that the people of Japan have been spared the worst-case scenario, as about 80% of the radioactive fallout of the nuclear meltdowns dispersed over the Pacific Ocean and not over large municipal areas.[151] The reason for this were not the "number of measures to protect the public, including immediate and late ('deliberate') evacuation, sheltering in homes, restricting distribution and consumption of contaminated foodstuffs"[152], as the UNSCEAR report implies, but rather sheer luck that the wind turned toward the northeast and not towards the south, where Metropolitan Tokyo, with a population of more than 35 million people, was at risk of heavy contamination. One single day of wind blowing towards the coast, however, led to a large radioactive trace reaching dozens of kilometers inland from the crippled plant, forcing tens of thousands of people to evacuate from small towns and villages. Fukushima clearly showed that even a highly industrialized country such as Japan is unable to control the inherent dangers of nuclear energy.

10 Conclusions from collective dose estimations are not presented

The UNSCEAR report includes a number of dose estimations, which can help understand the expected health effects of the nuclear catastrophe in Japan. While the scientific basis of the calculations underlying these estimates is questionable, as was illustrated in previous chapters, it is the interpretation of the results that is most critical. UNSCEAR lists collective doses in its report, but does not explain the expected cancer cases that would result from these doses. In the following chapter, we will try to explain in layman' terms, which health consequences can be expected for the population of Japan, based on the UNSCEAR calculations – keeping in mind that these most probably represent underestimations for the reasons listed above. We will restrict ourselves to cancer cases, while we have already stated above that non-cancer diseases also represent a substantial part of the total health effects of a nuclear catastrophe such as the one in Fukushima.

Overall cancer cases

Today we know that there is a linear relationship between the dose of radiation exposure and the risk of developing cancer, with no threshold under which radiation doses would be harmless. This model is called the linear non-threshold model and is internationally accepted by organizations such as UNSCEAR or the WHO. In order to calculate how many cases of cancer are to be expected in an irradiated population, it is necessary to know two variables: the total collective lifetime effective dose and the attributable cancer risk for a defined effective dose.

Starting with the collective lifetime effective dose, UNSCEAR calculates that in the first year of the catastrophe, infants in Fukushima Prefecture were exposed to whole-body radiation doses of 1.6 to 13 mSv.[153] To put this in perspective, the average annual dose from natural background radiation in Japan is about 1.5 mSv, so that even the least exposed children in Fukushima still received more than twice their normal radiation dose in the first year. These and all other estimates regarding radiation doses are average calculations. True doses depend on a large number of lifestyle and dietary habits, as well as individual health factors, so that certain people, especially children, may have incurred higher doses. Because radioactive fallout and food contamination extended beyond the boundaries of Fukushima Prefecture, people all over Japan were exposed to increased levels of radiation. According to UNSCEAR, infants in other parts of the country received whole-body doses of 0.2-2.5 mSv in the first year of the catastrophe.[154] In general, adults received lower first-year doses than children: 1.0 to 9.3 mSv in Fukushima Prefecture and 0.1 to 1.4 in the rest of Japan, according to UNSCEAR's estimations.[155] From these average whole-body exposure data, UNSCEAR calculated the collective life-time effective dose for the entire Japanese population to be 48.000 Person-Sv.[156] We will use this figure in our assessment, keeping in mind that due to the reasons listed in the previous chapters and because of UNSCEAR's conservative method of calculating lifetime dose, this figure most probably represents a systematic underestimation.

The second important variable in estimating cancer incidences is the risk factor for a given radiation dose. The most widely used source of such risk factors is the BEIR VII report. In this report, the age- and sex-averaged life-time attributable risk of cancer is calculated to be 1,190 (615-2,305) cases per 10,000 Person-Sv (~ 0.06-0.23/PSv), and the age- and sex-averaged lifetime attributable cancer mortality risk 610 (305-1240) cases per 10,000 Person-Sv (~ 0.03-0.12/PSv).[157] The BEIR VII report still uses an arbitrary reduction factor for low-dose ionizing radiation (DDREF) of 1.5, however. This factor has been deemed obsolete by recent studies, referenced in the latest WHO publication on Fukushima, which states that "a DDREF of 1 would be reasonable."[158] So without the DDREF of 1.5, the age- and sex-averaged lifetime attributable risk of developing cancer derived from the BEIR VII report is 1.785 (923-3,458) cases per 10,000 Person-Sv (~ 0.09-0.35/PSv), and mortality risk 915 (458-1,860) cases per 10,000 Person-Sv (~0.05-0.19/PSv). Recent studies that analyze the effects of low-dose ionizing radiation on down-winders of nuclear tests or radiation workers in over 15 countries showed that risk factors of 0.4/PSv for cancer incidence and 0.2/Sv for cancer mortality were even more realistic in assessing the relationship between radiation dose and cancer.[159,160,161] Nevertheless, in this paper we will use the widely accepted numbers from the BEIR VII report and hence a range of 0.09-0.35/PSv for estimating cancer incidence and a range of 0.05-0.19/PSv for estimating cancer mortality.

BEIR VII risk factors	Incidence	Mortality
With DDREF	0.06 – 0.23 / Psv	0.03 – 0.12 / Psv
Without DDREF	0.09 – 0.35 / Psv	0.05 – 0.19 / Psv

Table 3: Cancer risk factors from BEIR VII report 158

Bringing together the estimated total collective dose of 48,000 Person-Sv and the risk factors explained above, we arrive at an estimated 4,300 to 16,800 excess cases of cancer due to the Fukushima nuclear catastrophe in Japan in the coming decades, with mortality figures ranging between 2,400 and 9,100. UNSCEAR may call these numbers insignificant and with Japan's relatively high baseline incidence of cancer (approximately 630,000 new cases of cancer per year)[162], it can rightly be assumed that the additional 4,300-16,800 Fukushima-associated cancer cases may not be noticed in national epidemiological statistics. From an individual's perspective however, every case of cancer is one too many and we as doctors know the tragic consequences that cancer has on a person's physical and mental health, as well as the situation of the entire family. In the case of a nuclear catastrophe, these excess cancer cases represent preventable and man-made diseases and should be given special attention by public health institutions.

Radiation exposure of the thyroid

The thyroid gland is of special interest after a nuclear catastrophe, because one of the main isotopes of radioactive fallout after nuclear meltdowns is iodine-131. If ingested, iodine-131 behaves like normal iodine and is incorporated into the thyroid gland. Here, it damages surrounding tissue with beta- and gamma-radiation until its full decay (it has a half-life of 8 days), causing thyroid cancer.[163] After Chernobyl, the most prominently observed type of malignancy was thyroid cancer. A study published in the International Journal of Cancer in 2006 predicted more than 15,000 excess cases of thyroid cancer due to nuclear fallout.[164]

The topic of thyroid cancer is predominantly a pediatric issue, as children's susceptibility to radioactive fallout is proportionally higher than that of adults due to their playing and eating habits. In addition, their mucous membranes have a greater permeability and their respiratory minute volume is higher so that larger amounts of fallout are absorbed. Above-average tissue-metabolism and high rates of mitosis increase the chance that mutations cause malignancies before they can be stopped by the body's self-regulatory mechanisms. As the children's immune systems and cell-repair mechanisms are not yet fully developed, these mechanisms cannot adequately prevent the development of cancer. A recent meta-analysis found that “qualitative and quantitative physiological and epidemiological evidence supports infants being more vulnerable to cancer” and estimated that infants have about 10 times higher radiation risks per unit dose when it comes to radioactive fallout than adults,[165] while the more conservative International Commission on Radiological Protection (ICRP) assumes that the sensitivity to ionizing radiation in young children and fetuses is higher than in adults by only a factor of 3.[166] Several international studies also found that thyroid nodules in children have a much higher malignancy rate than in adults, between 2 and 50%.[167,168,169] It becomes clear that any assessment of thyroid pathologies in the wake of a nuclear disaster needs to adopt a differentiated approach towards the different age groups. Looking at the methodology of the UNSCEAR dose assessments, it is highly questionable whether all of these factors were appropriately taken into consideration.[170]

In the first three months of the Fukushima nuclear disaster, radioactive iodine was detected in milk, drinking water, vegetables, rain and groundwater, as well as soil samples around Northeastern Japan,[171] including parts of downtown Tokyo, were iodine-131 levels reached 36,000 Bq/m2 on March 23rd, 2011.[172] In this context, it is important to recall that the national emergency authorities in Japan did not give the order to administer iodine prophylaxis to the general population, potentially exposing many children to radioactive iodine-131. According to the WHO, it can be assumed that “stable iodine tablets were not taken by members of the public, either in Japan or elsewhere. Therefore the estimated equivalent thyroid doses are higher than those expected in people who have undergone thyroid blocking to reduce the uptake of radioactive iodine.”[173]

Like all forms of malignancies, radiogenic thyroid cancer rates show a linear relationship with radiation exposure doses. In order to calculate how many cases of thyroid cancer are to be expected in an exposed population, we again need to know two figures: the total collective lifetime organ dose of the Japanese population and the attributable thyroid cancer risk for a defined organ dose.

Starting with the collective lifetime organ dose, UNSCEAR has looked at the thyroid exposure from external and internal radiation in Fukushima Prefecture and the rest of the country. Most affected by radioactive fallout are the children. According to UNSCEAR, in the first year of the catastrophe, the thyroids of infants in Fukushima Prefecture were exposed to radiation doses between 15 and 83 mGy, “as much as one half of which arose from the ingestion of radioactivity in food”.[174, 175] To put this in perspective, “the average annual absorbed dose to the thyroid from naturally occurring sources of radiation is typically of the order of 1 mGy”.[176] That means that in the first year of the catastrophe alone, the thyroids of infants in Fukushima Prefecture were exposed to harmful radiation 15 to 83 times higher than natural background radiation. These and all other estimates regarding radiation doses are average calculations. True doses depend on a large number of lifestyle and dietary habits, as well as individual health factors, so that certain people may have incurred higher thyroid doses. Because radioactive iodine did not stop at the prefectural borders of Fukushima and was found in milk, seafood, meat, water, vegetables and rice from the region, infants in other parts of the country were also exposed to radioactive iodine-131 and received thyroid doses about 2.6 to 15 times the normal annual dose. In general, adults received lower first-year doses: 7.2 to 35 mGy in Fukushima Prefecture and 0.5 to 5.1 mGy in the rest of Japan. Extrapolating the data of the average thyroid exposure, UNSCEAR calculated the collective absorbed life-time dose to the thyroid for all of Japan to be 112,000 Person-Gy[177]. We will use this figure in our assessment, keeping in mind that due to the many reasons listed above and the very conservative way of calculating lifetime doses employed by UNSCEAR, this number most probably represents a systematic underestimation and may in fact be significantly higher.

Regarding the risk factor, we again draw from the BEIR VII report, which calculates the age- and sex-averaged lifetime attributable risk of thyroid cancer to be 60.5 cases per 10,000 Person-Gy (~0,006/PGy).[178] As this figure still includes the obsolete DDREF of 1.5, the corrected age- and sex-averaged lifetime attributable risk of thyroid cancer derived from the BEIR VII report is 90.75 cases per 10,000 Person-Gy (0,009/PGy).

Taking this number and the collective absorbed life-time dose of 112,000 PGy, we arrive at an estimated 1,016 cases of thyroid cancer due to the nuclear catastrophe in Fukushima. UNSCEAR may be right that this number does not constitute a “discernible increased incidence”[179] of thyroid cancer, but to us doctors, it means that for more than 1,000 people, mostly children, the direct consequence of the multiple meltdowns, the uncoordinated evacuations, the failure to distribute stable iodine tablets and the continuing cover-up of the risks of radioactive contamination will be thyroid cancer.

While it is often claimed by the nuclear lobby that the rise of thyroid cancer is of relatively small concern due to good treatment options, we should not underestimate the impact of such diseases on children and their families. The necessary operation and removal of the entire thyroid carries with it not just a psychological impact, but also certain perioperative risks connected with general anesthesia and the close proximity of the vagus nerve to the operation field. The lifelong need to take artificial thyroid hormones, frequent medical follow-ups, blood tests, ultrasounds, possibly fine-needle biopsies and the constant fear of a possible relapse are all very serious issues for the individual patients and their families. The US National Council on Radiation Protection and Measurements (NCRP) estimates that 7% of thyroid cancers caused by radiation would be fatal.[180] This would mean that of the approximately 1,000 estimated excess cases of thyroid cancers, about 70 would lead to death. The number of non-fatal cases, which lead to substantial hospitalization and loss of quality of life cannot be adequately assessed, but also have to be taken into consideration.

In addition to the predictions of future thyroid cancer cases on the basis of dose estimates, there is already epidemiological data available from the first round of thyroid examinations on children aged 18 or less on 11 March 2011, performed between October 2011 and March 2014.[181] It is important to note that from this first round of screening, it is not possible to make assertions regarding the incidence of thyroid cancer, as the screening of the entire cohort of children in the prefecture yields the prevalence (i.e. the total number of cases in the population) of thyroid cancers and only future screenings will reveal the incidence (i.e. the rise in numbers from year to year). So far, the prevalence of tumor-suspect thyroid biopsies in Fukushima is 29.1 per 100,000 children under the age of 18 (absolute number: 74) and the prevalence of confirmed cases of thyroid cancer 13.0 per 100,000 (absolute number 33).[182] In comparison, the incidence of thyroid cancer in Japanese youths (< 19 years) in the years 2000 to 2007 was 0.35 per 100,000.[183] While we cannot directly compare the prevalence found in the screening program to the incidence levels before the Fukushima disaster, this is nonetheless a worrying number, with the numbers of detected thyroid cancers higher than expected.

The assurance in the UNSCEAR report that these cases of thyroid cancer in Fukushima are "consistent with results from a study of a cohort of Ukrainians (the "UkrAm cohort") who had been exposed during childhood or adolescence to 131I from the Chernobyl accident"[184] is difficult to accept, as it is not explained how supposed "non-radiation-related" thyroid cancer cases were differentiated from those with a "radiation-relation" in a population of irradiated children in the Soviet Union in the late 1980's, when modern ultrasound devices were not available and where, due to governmental restrictions and limited resources, little scientific workup actually took place.

There are also some other inconsistencies in the UNSCEAR report regarding the Fukushima thyroid examinations. While the report was released in April of 2014, it only used the data of the thyroid examinations up to July 31st, 2013. More current publications by Fukushima Medical University from November 12th, 2013 and February 7th, 2014 were not included, even though the number of diagnosed thyroid cancers has increased from the 9 cases mentioned in UNSCEAR's report to the current number of 33, with another 42 suspect malignancy cases waiting for further diagnostics. Even with an understanding that the Fukushima thyroid examination is an ongoing process and that secondary examination for the first round is not yet complete, UNSCEAR could strive to incorporate the latest results with an accurate number of cancer cases, instead of mentioning just part of the available results.

Moreover, UNSCEAR cites an ultrasound examination in the prefectures of Aomori, Nagasaki and Yamanashi as a comparison study, supposedly representing the normal baseline risks.[185] UNSCEAR fails to mention, however, that the cohorts were not matched for age, sex or other demographic characteristics and consisted primarily of students from institutions associated with national universities, not representative of the general population. In addition, the length of ultrasound examination was said to be longer for this study, potentially leading to more detailed examination than the Fukushima examination.

Instead, UNSCEAR cited a review article published on December 3rd, 2013, stating, "The prevalence of clinically occult small papillary thyroid cancers could be as high as 35% in many parts of the world," suggesting that the high rates of cancers found in the Fukushima thyroid examinations are simply screening effects and that other pediatric populations would have similar rates of cancer if screened.[186] This statement, however, is solely based on a Finnish autopsy study, which, interestingly enough, mentions a prevalence of 27% and not 35% and specifically found no clinically occult thyroid cancers in children under the age of 18. This fact is not mentioned by UNSCEAR, as it contradicts the screening effect hypothesis.[187]

IV) Conclusion

The Fukushima nuclear disaster is far from over. Despite the declaration of "cold shutdown" by the Japanese government in December of 2011, the crippled reactors have not yet achieved a stable status and even UNSCEAR admits that emissions of radioisotopes are continuing unabated.[188] TEPCO is struggling with an enormous amount of contaminated water, which continues to leak into the surrounding soil and sea. Large quantities of contaminated cooling water are accumulating at the site. Failures in the makeshift cooling systems are occurring repeatedly. The discharge of radioactive waste will most likely continue for a long time.

Both the damaged nuclear reactors and the spent fuel ponds contain vast amounts of radioactivity and are highly vulnerable to further earthquakes, tsunamis, typhoons and human error. Catastrophic releases of radioactivity could occur at any time and eliminating this risk will take many decades. Moreover, many of Japan's other nuclear power stations are just as sensitive to seismic catastrophes as the Fukushima Dai-ichi plant.

Attempts to make reliable forecasts for the next decades seem futile against the backdrop of so much uncertainty. While much of the UNSCEAR report represents useful and important groundwork for future assessments, it does not in any way justify the type of 'all-clear' that UNSCEAR is proposing.

It is impossible at this point to come up with an exact prognosis of the effects that the Fukushima nuclear disaster will have on the population in Japan. However, based on the arguments presented in this paper, it has to be stated that the UNSCEAR report represents a systematic underestimation and conjures up an illusion of scientific certainty that obscures the true impact of the nuclear catastrophe on health and the environment.

In its report, UNSCEAR calculates the collective effective doses and absorbed thyroid doses for the Japanese population. However, the admitted uncertainties regarding exposure doses, questionable data selection, faulty assumptions and the fact that ongoing radioactive emissions were not considered undermine the validity of these calculations. The resulting dose estimates are most likely underestimated and do not reflect the true extent of radiation received by the affected population.

By utilizing more neutral sets of data, acknowledging inherent uncertainties in dose estimates, citing the full range of possible exposure rates rather than the best-case scenarios, and by incorporating the latest information about ongoing radioactive emissions, UNSCEAR could have presented a more realistic picture of what effects people can expect from the radioactive fallout in the coming decades, including thyroid cancer, leukemia, solid tumors, non-cancer diseases and genetic defects, all of which have been found in the population affected by the Chernobyl nuclear catastrophe.

Even with more realistic data, however, the number of cancer cases induced by Fukushima radioactive fallout may still be considered insignificant to the members of UNSCEAR, especially given the relatively high baseline incidence of cancer in Japan. From a physician's perspective however, every preventable case of cancer is one too many and the tragic consequences that cancer has on a person's physical and mental health, as well as the situation of the entire family have to be considered.

To reduce the horrible effects of the Fukushima nuclear disaster on tens of thousands of families to a statistical problem and to dismiss these individual stories of suffering by stating that "radiation exposure following the nuclear accident at Fukushima-Daiichi [...] is unlikely to be able to attribute any health effects in the future among the general public and the vast majority of workers"[189] is inappropriate for a committee of the United Nations, an organization that prides itself on the Declaration of Universal Human Rights.

Through the combination of a man-made nuclear disaster, corrupt operators, regulatory institutions and politicians, inadequate emergency measures, and finally through the systematic underestimation of radiation doses and expected health effects, the people of Fukushima are being deprived of their right to a standard of living adequate for their health and well-being.

As physicians, primarily concerned with the health of the people affected by the nuclear disaster, we urge the United Nations General Assembly and the government of Japan to realize that the affected population needs protection from further radiation exposure. In our opinion, the following issues need to be addressed:

» All available expertise should be used for the tremendous tasks of minimizing ongoing radioactive emissions from the damaged reactors and spent fuel pools and preventing larger emissions in the future.

» According to UNSCEAR, more than 24,000 workers have worked on the premises of the crippled reactors since the start of the disaster. Tens of thousands more will be required over many decades. In addition to the provision of adequate radiation protection, monitoring and health care for these workers, a national lifetime radiation exposure register for all workers in the nuclear industry is required in Japan. This must include subcontractors as well as utility employees. Individual workers should have ready access to their results.

» The issue of functioning registries is also important for the civilian population. Currently, the absence of both effective cancer registries in most prefectures in Japan and comprehensive registers of exposed persons with dose estimates that can be used to assess long term health outcomes means that potential impacts will go undetected. Such registries should be created so that future health effects of the radioactive contamination can be properly assessed.

» It is unacceptable that people are currently being encouraged to return to some areas where they can be expected to receive up to 20 mSv in additional annual radiation exposure. We see no adequate alternative to minimize such unacceptable exposures other than more relocations than have currently occurred. Logistic and financial support for families living in the radioactively affected municipalities who want to move to less contaminated regions should be offered to reduce the risk of future health effects. Evacuees should not be pressured or bribed into returning to contaminated regions.

» Decontamination on the scale that would be required to sufficiently and sustainably reduce radiation exposures has not proven feasible. Also, radioactive contamination knows no boundaries, and fallout has not been confined to Fukushima Prefecture alone. Parts of Tochigi, Miyagi, Ibaraki, Gunma, Saitama and Chiba have also been contaminated. At present, government programs responding to the nuclear disaster are largely limited to Fukushima Prefecture. A national approach based on contamination levels, not prefectural boundaries is needed.

» We ask the United Nations General Assembly and the Japanese Government to study the report of the UN Special Rapporteur on the right of everyone to the enjoyment of the highest attainable standard of physical and mental health, Mr. Anand Grover, and heed his constructive suggestions.[190] The precautionary principle should be employed in radiation protection policies.

The people of Fukushima are not being helped by false claims and premature reassurances that no health effects are to be expected. They need proper information, health monitoring, support and most of all, they need acknowledgment of their right to a standard of living adequate for their health and well being. This should be the guiding principle in evaluating the health effects of the nuclear catastrophe:

"The number of children and grandchildren with cancer in their bones, with leukemia in their blood, or with poison in their lungs might seem statistically small to some, in comparison with natural health hazards. But this is not a natural health hazard - and it is not a statistical issue. The loss of even one human life, or the malformation of even one baby - who may be born long after we are gone - should be of concern to us all. Our children and grandchildren are not merely statistics toward which we can be indifferent." John F. Kennedy, July 26th, 1963

V) List of acronyms and abbreviations

BEIR US National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation

CT Computer Tomography

FDNPS Fukushima Dai-ichi Nuclear Power Station

IAEA International Atomic Energy Agency

IPPNW International Physicians for the Prevention of Nuclear War

IRSN French Institute for Radioprotection and Nuclear Safety

JAEA Japanese Atomic Energy Agency

LNT Linear no-threshold

MAFF Japanese Ministry Agriculture, Forestry and Fisheries

MEXT Japanese Ministry of Education, Culture, Sports, Science and Technology

NILU Norwegian Institute for Air Research

PSR Physicians for Social Responsibility

TEPCO Tokyo Electric Power Company

UNSCEAR United Nations Scientific Committee on the Effects of Atomic Radiation

WBC Whole Body Counter

WHO World Health Organization

Scientific units

Bq = Becquerel; unit for radioactivity in the International System of Units (SI)
Defined as the number of disintegrations per second
Former unit: Curie (Ci): 1 Bq = 2.7×10^{-11} Ci

Examples used in the text:
MBq = Megabecquerel (1×10^{6} Becquerel)
PBq = Petabecquerel (1×10^{15} Becquerel)

Gy = Gray; SI unit for absorbed dose by matter
Defined as the amount of energy (in Joules) absorbed per mass (in kg)
Former unit: Radiation absorbed dose (rad): 1 rad = 0.01 Gy

To convert Bq into Gy, it is necessary to know the dose conversion factor relevant to the isotope in question and the specific irradiation pathway

Examples used in the text:
mGy = Milligray (1×10^{-3} Gray)
Person-Gy = collective absorbed dose of a population (number of people x average individual dose)

Sv = Sievert; SI unit for equivalent dose by tissue
Defined as the amount of energy (in Joules) absorbed per mass (in kg)
Former unit: Roentgen equivalent man (rem): 1 Sv = 100 rem

To convert Gy into Sv, the absorbed dose is multiplied with the radiation weighting factor W_R (W_R = 1 for x-ray, g- and b-radiation; W_R = 20 for a-radiation)

Examples used in the text:
mSv = Millisievert (1×10^{-3} Sievert)
µSv = Microsievert (1×10^{-6} Sievert)
Person-Sv = collective equivalent dose of a population (number of people x average individual dose)

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