2015/05/28

The IAEA Fukushima Daiichi Accident Summary Report: A preliminary analysis

Jan Vande Putte
Kendra Ulrich
Shaun Burnie

"Since the accident, Japan has reformed its regulatory system to better meet international standards. It gave regulators clearer responsibilities and greater authority...I am confident that the legacy of the Fukushima Daiichi accident will be a sharper focus on nuclear safety everywhere. I have seen improvements in safety measures and procedures in every nuclear power plant that I have visited."
Yukiya Amano, IAEA Director General,
The Fukushima Daiichi Accident Report, 2015

GREENPEACE

IAEA Fukushima Daiichi Accident, Summary Report by the Director General

Greenpeace
Summary

"an authoritative, factual and balanced assessment, addressing the causes and consequences of the accident, as well as lessons learned" IAEA Director General Amano

The principal conclusion of the Greenpeace review of the IAEA Fukushima Daiichi Report is that it has failed to achieve the ambitions of its Director General. Uncertainties and unknowns are presented as facts, critical evidence is ignored, and it can in no way be considered balanced.

Radiation and Health – lead author Jan Vande Putte

- The IAEA confirms: ***"The quantification and characterization of the source term of the accident at the Fukushima Daiichi NPP proved to be difficult.***

- The IAEA confirms that radiation dose estimates to the affected population in Fukushima have a high level of uncertainty. One of the principle reasons for the uncertainty is that in the early days of the accident radiation monitoring systems were not properly functioning.

- The IAEA Report is flawed when its states no discernible radiation related effects on human health are expected, not only because the estimated dose to the population is uncertain, but also because the estimated collective dose is still significant. Health effects to thousands of people should be expected based on Linear No Threshold (LNT) model, the basis for radiation protection to quantify radiation exposure and set regulatory limits.

- The IAEA acknowledges the importance of 'stakeholder involvement' but ignores the reality in Fukushima prefecture, where people are effectively forced return to contaminated land as a result of deliberate Japanese government policy such as in the villages of Tamura (Myakoji) or Kawauchi where the evacuation order was lifted in 2014 and in the future in Iitate.

Environmental consequences – lead author Kendra Ulrich

- The IAEA Fukushima Report utterly fails to address the magnitude, scope, and complexity of the terrestrial radiological contamination resulting from the Fukushima Daiichi nuclear disaster, and dismisses, without supporting evidence, its impact on non-human biota.

- The IAEA confirms extremely high levels of radioactive caesium were deposited northwest of the reactor site: respectively, in this area, it states that deposition densities between 1000 kBq/m^2 and 10 000 kBq/m^2 were recorded.[1] The IAEA's average deposition density for

1 Fukushima Daiichi Accident, Summary Report by the Director General, Board of Governors May 14 2015, IAEA 2015, pg. 131

caesium 137 throughout Fukushima Prefecture, is 100 kBq/m².[2] This is an astounding figure, given that these numbers far exceed IAEA's own benchmark of 40 kBq m² for contaminated land.

- In contrast to the superficial dismissal of radiation impacts on the environment by the IAEA Fukushima Report, scientists actually investigating those impacts have concluded that there are measurable impacts on animal life due to radiation exposure.

Failure of safety risk analysis – lead author Shaun Burnie

- The IAEA fails in fundamental areas to accurately reflect the consequences for nuclear safety of the Fukushima Daiichi accident and provides no evidence that nuclear regulation in Japan, now being overseen by the Nuclear Regulation Authority (NRA), is anywhere near the worlds highest standard.

- The IAEA Fukushima Report fails to acknowledge the unknowns and uncertainties about the causes of the accident despite evidence of seismic impact on the Fukushima nuclear plant – with much of the critical equipment and piping inside the reactors, and relevant to understanding the accident, yet to be inspected. Incredibly, the IAEA describes the nuclear plant as having "a conservative approach to earthquake design and construction of NPPs in Japan, resulting in a plant that was provided with sufficient safety margins."

- While justifiably critical of both Tokyo Electric Power (TEPCO) and the Nuclear and Industrial Safety Agency (NISA), the regulator overseeing the Fukushima Daiichi nuclear plant in 2011, the IAEA makes no mention of the current flaws within the new seismic regulatory requirements in Japan nor their mis-application.

- Despite warnings of weak nuclear regulation, the NRA is not following international practice, including recommendations made by the IAEA. The NRA review of nuclear plants planned for restart, specifically the Sendai nuclear reactors, has accepted the violation of the post-Fukushima regulations, and thus has approved an inadequate seismic standard essential for the safety of the nuclear plant.

For further information:

Jan Vande Putte – Greenpeace Belgium - jan.vande.putte@greenpeace.org
Kendra Ulrich – Greenpeace Japan - kendra.ulrich@greenpeace.org
Shaun Burnie – Greenpeace Germany - sburnie@greenpeace.org

2 IAEA Fukushima Report, pg. 131

Introduction

Greenpeace has had the opportunity to review the Summary Fukushima Daiichi Accident Report compiled by the International Atomic Energy Agency (IAEA), and to be discussed from June 8th-12th at the IAEA Board of Governors Meeting. A full report from the IAEA will be presented to the General Conference of the member states at their annual meeting in Vienna in September 2015.

This preliminary analysis of some sections of the 238 page report focus on:

1 – Radiation and Health
2 – Environmental Consequences
3 – Failure of Safety Risk Analysis

During the coming weeks and months Greenpeace aims to provide additional analysis of the IAEA Fukushima Report.

1 - RADIATION AND HEALTH

Uncertainty on actual effective doses to the population of Fukushima

The IAEA Fukushima Report recognizes that the radiation dose estimates to the affected population in Fukushima have a high level of uncertainty, in particular because in the early days after the accident no monitoring system was properly functioning. Several isotopes have a short half-life, such as Iodine-131 and Xenon-133, which makes a precise reconstruction of the original exposure impossible. The IAEA Fukushima report states:

"There are uncertainties concerning the iodine intakes immediately following the accident due to the scarcity of reliable personal radiation monitoring data for this period".

Furthermore the IAEA Fukushima Report states,

"The quantification and characterization of the source term of the accident at the Fukushima Daiichi NPP proved to be difficult. Prompt monitoring of the environment provides confirmation of the levels of radionuclides and establishes the initial basis for protecting people"

The IAEA Fukushima Report herewith confirms the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) report of 2013[3], on which the IAEA Fukushima Report is largely based, and which lists a number of factors leading to uncertainty, including the ***"incomplete knowledge of the release rates of radionuclides over time and the weather conditions during the releases".***

3 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, United Nations Scientific Committee on the Effects of Atomic Radiation, http://www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf

In the UNSCEAR report of 2013, the collective dose to the Japanese population over a period of 80 years is estimated at 48,000 man-Sv.

Table 8. Estimated collective effective dose and collective absorbed dose to the thyroid for the population of Japan (approximately 128 million in 2010)

Dose category	*Exposure duration*		
	Over first year	*Over ten years*	*Up to age 80 years*
Collective effective dose (thousand man-sieverts)	18	36	48
Collective absorbed dose to the thyroid (thousand man-grays)	82	100	112

[UNSCEAR, 2013]

If we would apply a risk factor of 10% per man-Sv[4], the number of fatal cancers in the Japanese population can be estimated at 4800. This does not include the number of non-fatal cancers and non-cancer illnesses.

IAEA concludes: "no discernible health effects" without knowing radiation dose

The IAEA Fukushima Report states: ***"However, given the low levels of doses reported among members of the public, the conclusions of this report are in agreement with those of the UNSCEAR to the UN General Assembly. UNSCEAR found that no discernible increased incidence of radiation-related health effects are expected among exposed members of the public and their descendants."***

Such a statement is problematic for many reasons. Not only because the estimated dose to the population is uncertain, but also because the estimated collective dose is still significant, and health effects to thousands of people should be expected based on Linear No Threshold (LNT) model. LNT is the basis for radiation protection to quantify radiation exposure and set regulatory limits.[5] Also, non-discernible or noticeable health effects as the IAEA Fukushima Report states, is not the same as no health effects.

Personal radiation monitoring

The IAEA Fukushima Report states: ***"the early assessments of radiation doses used environmental monitoring and dose estimation models, resulting in some overestimations. For the estimates in this report, personal monitoring data provided by the local authorities were also included to provide more robust information on the actual individual doses".*** This refers to the use of thermoluminescent dosimeters (TLD), also called "glass badges" in Japan and distributed to the population in Fukushima prefecture.

As such, personal dosimetry is an important instrument in radiation protection. However, it should be complemented by environmental monitoring, as stated in the International Commission on

4 Based on LNT (Linear Non-Threshold) and a DDREF (Dose and Dose Rate Effectiveness Factor) of 1

5 Low-dose Extrapolation of Radiation-related Cancer Risk ICRP Publication 99 Ann. ICRP 35 (4), 2005, http://www.icrp.org/publication.asp?id=ICRP+Publication+99

Radiological Protection (ICRP) recommendation 111[6]. Both should be combined, because the use of personal dosimeters might, for example, involve some people not wearing them all the time when outside their residence and thus underestimate the risk.

Another issue is that data collected from glass badges could seriously underestimate the impacts on the population living in a contaminated area. This is because people might have changed their behavior and for example avoid being outside (including children not allowed to play outside, leading to health problems). The recorded doses will thus be lower than the dose they would have received leading a normal lifestyle. If such personal measurements would be taken as a reference to decide to send people back home, it would mean that such changed lifestyle is set as a standard. This leads to the contradiction that the more people make an effort to avoid risk, the higher the radiation level can be in the area they are sent back to. This raises a fundamental question on the quality of life.

The IAEA Fukushima Report implies that data collected from glass badges provide a good reference to decide on evacuation orders. The report first states it that environmental monitoring ***"overestimates"*** actual doses and badges offer ***"more robust information"***, followed by the statement that ***"conservative decisions related to specific activity and activity concentrations in consumer products and deposition activity led to extended restrictions and associated difficulties"***. The Japanese authorities can conclude from the IAEA Fukushima Report that they should rely on badge readings as a ***"more robust"*** source of data to decide on lifting the evacuation order, without taking potential underestimations and impacts on people's quality of life into account.

Glass badges are suitable for the use of personal dosimetry for personal protection, and but should not be regarded a suitable method for deciding on levels to lift the evacuation order in municipalities.

Forced return to contaminated land - safety of the population is disregarded

ICRP 111 states, ***"In recent years, stakeholder engagement has moved steadily to the forefront***
of policy decisions. Such engagement is considered by the Commission as key to the development and implementation of radiological protection strategies for most existing exposure situations".

And furthermore, ***"It is the responsibility of the authorities, particularly at the regulatory level, to establish the conditions and to implement the means to allow affective engagement of the affected population in the protection strategies and more globally in the rehabilitation program. Past experience of the management of contaminated areas has demonstrated that the involvement of local professionals and inhabitants in the implementation of protection strategies is important for***

6 Application of the Commission's Recommendations to the Protection of People Living in Long-term Contaminated Areas after a Nuclear Accident or a Radiation Emergency ICRP Publication 111 Ann. ICRP 39 (3), 2009J. Lochard, I. Bogdevitch, E. Gallego, P. Hedemann-Jensen, A. McEwan, A. Nisbet, A. Oudiz, T. Schneider, P. Strand, Z. Carr, A. Janssens, T. Lazo, http://www.icrp.org/publication.asp?id=ICRP%20Publication%20111

sustainability of the rehabilitation program"

The IAEA Fukushima Report also refers to the importance of stakeholder involvement: ***"engagement of the affected population in the decision making process is necessary for the success…".***

However, the document fails to recognize the existing conflicts in Fukushima prefecture, such as in the village Tamura (Myakoji) or Kawauchi, where the evacuation order was lifted in 2014, and in Iitate where such a decision is being prepared. The government policy is to stop compensation payments to the evacuated population one year after the lifting of the evacuation order.[7] As most residents own their own home and lack sufficient financial resources to buy or rent another house by their own means, this practically means that those people are financially forced back to contaminated areas, even if they don't want to. Forcing people back can hardly be categorized as "stakeholder involvement". People should always have the choice whether they want to return to contaminated areas or not.

Limited application of the Optimization principle

According to the ICRP, in an ***"existing situation"***, which is the language referring to the period after the emergency phase, the basic principle of Optimization is crucial to reduce the dose to the population as far as ***"reasonably"*** possible. The ICRP 111 recommendation clearly explains that : ***"The objective is to implement optimized protection strategies, or a progressive range of such strategies, which aim to reduce individual doses below the reference level".***[8] Very importantly, the ICRP recommends that the reference levels should be reduced over time: ***"The optimization of protection is a forward-looking iterative process aimed at preventing or reducing future exposures"***

The IAEA Fukushima Report appears to contradict the ICRP 111 recommendation when it states that, ***"there is a need for consistency in the international standards for acceptable levels of radioactivity in products for public consumption in order to facilitate their application by regulatory bodies and their understanding by the public. National standards need to be in line with international standards".***

Today, the Japanese reference levels for food such as rice, which are set at 100Bq/kg for radioactive cesium, are indeed lower than the standard used in the European Union. However, the amount of rice harvested which measures above this reference level is very low, and removing this rice from the market has no negative impact on the Japanese agriculture or on the economy. Furthermore, a more stringent reference level would be easily feasible, and would be logical if Optimization were properly applied (it could easily be done, so it should be done). By suggesting that the Japanese reference levels are low, the IAEA Fukushima Report is undermining the principle of Optimization , which is the cornerstone of radiation protection in an "existing" situation such as in Fukushima.

---

7 "Ministry plans to end TEPCO compensation to 55,000 Fukushima evacuees in 2018", May 19 2015, https://ajw.asahi.com/article/0311disaster/fukushima/AJ201505190055

8 Application of the Commission's Recommendations to the Protection of People Living in Long-term Contaminated Areas after a Nuclear Accident or a Radiation Emergency ICRP Publication 111 Ann. ICRP 39 (3), 2009J. Lochard, I. Bogdevitch, E. Gallego, P. Hedemann-Jensen, A. McEwan, A. Nisbet, A. Oudiz, T. Schneider, P. Strand, Z. Carr, A. Janssens, T. Lazo, http://www.icrp.org/publication.asp?id=ICRP%20Publication%20111

The Justification principle protecting the interests of the nuclear industry, not the population

The IAEA Fukushima Report refers to the cost-benefit assessment for decision on protective measures, ***"the potential benefit from avoiding radiation doses must outweigh the individual and social detriment caused by the protective measures and actions themselves".***

The underlying assumption of weighting costs and benefits is that there is one calculation of common costs and common benefits equally shared by all citizens (benefit: saving someone's live, not getting cancer, not getting ill,... whereas cost = cost of measures, including radiation risks to implement those measures).

Apart from some more fundamental ethical questions one might have with such a utilitarian approach (cost-benefit), this clearly conceals very fundamental social conflicts. There are several conflicts of interest (asymmetry between costs and benefits) such as:

- **TEPCO vs population**: The benefit of a measure (e.g. to avoid dying) is to the person, whereas the cost (investing in measures) is to TEPCO (a private company responsible or liable for damage after an accident, or responsible to invest in preventive measures to avoid an accidental exposure).
- **Regional conflict**: there is a conflict between the population of the most affected region (Fukushima, Ibaraki, etc.) vs the total population of Japan. Another important issue in Japan is the conflict between the hosting municipality of a nuclear power plant (which receives compensation from the utility under normal operation and which had a role in approving construction) and the surrounding municipalities (which receive no payment and were never asked whether the plant could be build or not). Villages such as Namie and Iitate at 30-40km from the Fukushima Daiichi power plant were highly affected but historically have never received compensation. As a consequence they have only suffered the disadvantages, not the benefits (a limited municipal 'tax'). This is a key issue in the debate on the re-start of Japan's 43 shutdown reactors: which municipalities have a say over it restart, and how far does local approval extend ?
- **Socio-economic** conflict: the wealthier members of the affected population have more options to reduce their exposure (having the possibility to self-evacuate/relocate even without economic compensation)
- **Inter-generational**: there is an inter-generational conflict within the population: the potential benefit of protective measures is highest for young people, while the cost will be paid by the older generation, who have a relatively lower benefit. Furthermore, in Japan, the older population has been most reluctant to relocate. This has had the effect of keeping younger population in the area with higher contamination for a longer time as sought to support their elderly relatives. In emergency planning, there needs to be a very specific focus on children's rights.
- **Long-term intergenerational**: hereditary health effects, contaminated areas, radioactive waste management resulting from the accident will be inherited by future generations. It is ethically questionable to put future generations into a cost-benefit comparison.
- **High risk groups** vs lower risk groups: conflict between a (small) group that is highly exposed vs a (large) group that is exposed to low doses. A too linear interpretation of

cost-benefits, following the concept of collective dose, and optimization, could lead to the conclusion that mathematically, there could be a situation where it might be more effective to take measures to reduce the dose to the large and low-exposed population vs taking very expensive measures (eg relocation) to a small number of people to have for each individual a large reduction, but collectively a small reduction of the collective dose. From an ethical point of view, and taking socio-economic factors into account, it would be unfair to put such high burden on this small group (that is 'sacrificed') to have a larger collective benefit. This is why 'limitation' or reference levels have to play a role as well.

The IAEA Fukushima Report fails to recognize such cost-benefit conflicts. The consequence being that there is only very little accountability for those creating the risks (nuclear power utilities) compared to those bearing the consequences but having very little influence on decisions taken to build the reactors, how to operate them under poor safety conditions and how to manage the consequences of a severe accident.

2 – ENVIRONMENTAL CONSEQUENCES

Failing to address environmental contamination

"Country life is appealing because we can drink good water and eat wild foods from the mountains. If you put limits on that, you're not living; you're surviving," ~Kazuhiro Yoshida, chairman of the Namie town assembly

The Fukushima Daiichi accident released an enormous amount of radionuclides into the environment, both through atmospheric dispersion and liquid discharges into the Pacific Ocean. While much of the focus has justifiably been on the human impacts of the disaster, the environmental contamination – and the implications of that for both human beings and non-human animals and plants – warrants deeper consideration and concern than has been given thus far.

The IAEA defines protection of the environment as:

". . . the protection and conservation of: non-human species, both animal and plant, and their biodiversity; environmental goods and services. The term also includes the production of food and feed; resources used in agriculture, forestry, fisheries and tourism; amenities used in spiritual, cultural and recreational activities; media, for example soil, water and air; and natural processes, such as carbon, nitrogen and water cycles."[9]

Given the broadness of the definition, and the potential impacts on not only the non-human environment, but those natural resources which human beings use and contact daily – such as agricultural products, fish, water, and wood products – it would be prudent to be both cautious and thorough in the analysis of the impact of the Fukushima disaster on the natural environment and plant and animal species.

Despite this, the IAEA Fukushima Report utterly fails to address the magnitude, scope, and complexity of the terrestrial radiological contamination resulting from the Fukushima Daiichi

9 Fukushima Daiichi Accident, Summary Report by the Director General, Board of Governors May 14 2015, IAEA 2015, pg. 157

nuclear disaster, and dismisses, without supporting evidence, its impact on non-human biota.[10] In its summary of its analysis, the IAEA concludes, ***"Long term effects are also not expected as the estimated short term doses were generally well below levels at which highly detrimental acute effects might be expected and dose rates declined relatively rapidly after the accident."***[11]

As detailed below there is substantial evidence of the negative impacts of radioactive contamination of the environment, its just that the IAEA has chosen to not acknowledge its existence.

Terrestrial radiological deposition

In order to have a better understanding of potential impacts, it is necessary to have some background on the scale of the land contamination resulting from the disaster.

According to the IAEA's own definition, land that has surface radioactivity levels (for beta and gamma emitters) above 40 kBq m^2 is considered contaminated land (2005, 2009). And while the IAEA emphasizes repeatedly in the Fukushima Report that most of the atmospheric releases were carried out over the Pacific Ocean – and they were – that does not mean that there was an insignificant amount of land contamination.

According to the IAEA's Fukushima Report, extremely high levels of radioactive caesium were deposited northwest of the reactor site: respectively, in this area, it states that deposition densities between 1000 kBq/m^2 and 10 000 kBq/m^2 were recorded.[12] The IAEA's average deposition density for caesium 137 throughout Fukushima Prefecture, is 100 kBq/m^2.[13] This is an astounding figure, given that these numbers far exceed IAEA's own benchmark of 40 kBq m^2 for contaminated land.

To put this into further context, some of the most contaminated areas around Chernobyl range between 40 to more than 1480 kBq/m^2.[14]

And while the radioisotopes primarily discussed – Cs-134, Cs-137 and I-131 – are concerning, these are not the only dangerous radioactive elements released in the disaster. In addition to caesium and radioactive iodine, the accident released a large number of other dangerous radionuclides, such as Strontium-90 (which bioaccumulates in bones). Further, sample testing of black dust collected from roadsides and soil samples throughout Fukushima prefecture, and as far away as 25-45 km from the reactor site, in the heavily contaminated village of Iitate, showed transuranic contaminates that were confirmed to share the same transuranic profile as the fuel core and therefore could be confirmed as being in the environment as a result of the Fukushima Daiichi NPP disaster.[15]

These elements were detected in nearly all samples taken and included: Plutonium 238, 239 and

10 IAEA 2015, pg. 156
11 IAEA pg. 157
12 IAEA Fukushima Report, pg. 131
13 IAEA Fukushima Report, pg. 131
14 N. Evangeliou et al. (2015). Fire evolution in the radioactive forests of Ukraine and Belarus: future risks for the population and the environment. Ecological Monographs, 85(1), 2015, pp. 49–72.
15 M. Yamamoto, et al. (2014). Isotopic Pu, Am and Cm signatures in environmental samples contaminated by the Fukushima Dai-ichi Nuclear Power Plant accident. Journal of Environmental Radioactivity. 132 (2014) 31- 46.

240; Americium-241; and Curium-242, 243, and 244.[16] Although the amounts of these dangerous transuranic elements were low, their longevity and toxicity – even in extremely small amounts – makes them particularly harmful if inhaled, and potentially dangerous if ingested.

The impact of these elements in the environment and on non-human biota has not been explored – much less the potential exposure pathways for humans living in or using natural resources and/or agricultural products from these contaminated areas.

Radiation, Forests, and Fire

The Fukushima accident could have had an even greater impact on Japan if were not for the fact that due to the prevailing winds, most of the radioactive releases were carried eastward to the ocean, rather than inland.

However, the mountainous Tohoku region is heavily forested, predominately cool temperate and boreal forest[17], and thus the radioactivity that was deposited on land largely contaminated forested lands. In this regard, the vegetation is similar to that near the Chernobyl disaster site, which is predominately boreal forest.[18] And as such, Chernobyl provides a useful example for comparison.

In both disasters, large areas of forested land were heavily contaminated, which present a particularly difficult challenge for managing after the disaster. As one observer stated, ***"Japan's current recovery plan revolves around removing contamination from the landscape to allow residents to move back home. In this context [when compared with the Chernobyl exclusion zone], contaminated forests represent not a buffer but a threat to public health."***[19]

The IAEA has put forth that environmental contamination has rapidly decreased, and that weathering contributes in part or largely to this – in addition to radioactive decay. It is important to understand that while this is to some extent true – especially as it is related to radioactive iodine, which has a half-life of only 8 days – other longer-lived radionuclides, like caesium, strontium, and transuranics are still very much present in the environment.

In the first complete study about ecological loss of Cs-137[20], "the calculated effective half-lives of radiocesium in the surface soil layer vary across the sites from 10 to 30 years, which is equal to the physical half-life of Cs-137". N. Evangeliou et al. (2015) further states that, ***"effective half- life of Cs-137 combines its physical decay and also its ecological half-life (which includes all environmental removing processes, such as vertical migration, runoff to large reservoirs, soil erosion, etc) . . ."***[21] Thus, it cannot be assumed – unless proven by

16 M. Yamamoto, et al. (2014). Isotopic Pu, Am and Cm signatures in environmental samples contaminated by the Fukushima Dai-ichi Nuclear Power Plant accident. Journal of Environmental Radioactivity. 132 (2014) 31- 46.

17 J. Kolbek et al. (eds.), Forest Vegetation of Northeast Asia, 231-261. © 2003 Kluwer Academic Publishers.

18 N. Evangeliou et al. (2015). Fire evolution in the radioactive forests of Ukraine and Belarus: future risks for the population and the environment. Ecological Monographs, 85(1), 2015, pp. 49–72.

19 Bird, W.A and J.B. Little (2013). A Tale of Two Forests: Addressing Postnuclear Radiation at Chernobyl and Fukushima. Environmental Health Perspectives • volume 121 | number 3 | March 2013

20 Bergan, T. D. 2000. Ecological half-lives of radioactive elements in semi-natural systems. NKS(97)FR5, ISBN 87-7893-025-1.

21 N. Evangeliou et al. (2015). Fire evolution in the radioactive forests of Ukraine and Belarus:

measurement – that caesium contamination has decreased more rapidly than the half-life of the radionuclide due to weathering effects.

Further, the largely clay soils in the region both bind caesium and resists weathering effects.[22]

In an astounding move, though the Japanese government has restricted such activities as mushroom collection, gathering wild vegetables, firewood, and hunting, it has not restricted timber use in the contaminated areas.[23] The implications of this, and the potential for the spread of contaminated wood far from the reactor site, appears not not have been addressed either by the IAEA or the Japanese government.

Fire Risks in Radioactively Contaminated Forests

The IAEA's failure to examine or account for impacts of radioactive contamination, as it impacts a functioning and interconnected ecosystem, results in a significant underestimation of risks.

Studies in Chernobyl have demonstrated that both caesium and strontium remain in the uppermost topsoil layers, decades after the initial deposition. This is due to the natural living processes of vegetation (trees, grasses, and fungi). As plants lose water through transpiration, they pull in additional water from the soil via their root systems. Cesium and strontium are chemical analogues of potassium and calcium. These radioactive, water-soluble salts are taken up in place of these crucial nutrients.[24] They accumulate in the tree, including in leaves. When the tree loses leaves, the caesium and strontium they contain are returned to the soil.

This becomes particularly problematic when one considerations the impact of radiation on natural decomposers. Similar to the irradiation process that some vegetable and fruit foodstuffs are subjected to in order to preserve them for longer periods of time, the post-nuclear disaster contaminated forests around Chernobyl and Fukushima have experienced irradiation on an enormous scale.

Radiation kills many of the natural decomposers. And without these decomposers, leaf litter, branches, and dead vegetation that would normally break down year after year instead continues to pile up. In Chernobyl, this has been referred to as creating "fuel ladders" which increases the risk for forest fires to reach the canopy and become large crown fires – in addition to providing enormous amounts of kindling that can significantly increase the intensity of a fire and allow it to quickly spread. [25]

When contaminated forests burn, they release strontium, caesium and plutonium in fine

---

future risks for the population and the environment. Ecological Monographs, 85(1), 2015, pp. 49–72.

22 Bird, W.A and J.B. Little (2013). A Tale of Two Forests: Addressing Postnuclear Radiation at Chernobyl and Fukushima. Environmental Health Perspectives • volume 121 | number 3 | March 2013

23 Bird, W.A and J.B. Little (2013). A Tale of Two Forests: Addressing Postnuclear Radiation at Chernobyl and Fukushima. Environmental Health Perspectives • volume 121 | number 3 | March 2013

24 N. Evangeliou et al. (2015). Fire evolution in the radioactive forests of Ukraine and Belarus: future risks for the population and the environment. Ecological Monographs, 85(1), 2015, pp. 49–72.

25 N. Evangeliou et al. (2015). Fire evolution in the radioactive forests of Ukraine and Belarus: future risks for the population and the environment. Ecological Monographs, 85(1), 2015, pp. 49–72.

particulates that can be inhaled.[26] Crown fires are particularly problematic because the intensity of the fire can release up to 40% of the radionuclides contained in the forest into the atmosphere – and this release can enter the upper atmosphere, and be carried over long distances.[27] In addition, due to the low boiling point of caesium, it is partially volatilized in wildfires and transported in smoke, even when bound in soil.[28]

Thus, radionuclides previously sequestered in contaminated forests can be remobilized and redistributed – sometimes far from the initial site – via fire, and the very presence of radiation in the forest is disruptive to the ecosystem in such a way that it increases the likelihood, potential scope, and intensity of wildfires.

This concerning cycle has come to the fore of international attention in recent years, as increasing fires in the Chernobyl exclusion zone and contaminated areas threaten not only the safety of the reactor and temporary disposal sites, but also release radioactivity into the atmosphere.

Thus, radioactive forests cannot be regarded as a buffer, or a sequestration mechanism as such. And the problems arising from this forest contamination extends far beyond potential redistribution via wind and water weathering. Rather, they are tinderboxes that can re-release radiation leading to potentially significant human health impacts and/or redistribution onto agricultural lands.

Impacts on non-human animals

The IAEA's report summary does not address the impacts on non-human animals from the contamination released from the Fukushima Daiichi accident, other than to say they do not expect any health consequences and no acute effects were observed. Here again, Chernobyl provides a useful comparison for what might be expected in ecosystems around Fukushima.

Extensive long-term studies have shown developmental abnormalities in animal populations near Chernobyl. According to Moller, et al., highly radioactive environments increase oxidative stress on animals. Due to the fact that maintaining a large brain requires supplying it continuous large amounts of oxygen for normal functioning – meaning, maintaining a large brain is a highly oxidative process. When the background oxidative stress is also very high, as is the case in heavily contaminated areas, large-brained individuals are at an ecological disadvantage because their bodies are under more stress than those with less oxygen demands. This disadvantage leads to greater success for smaller brained individuals, leading to a decrease in brain size in long-term populations in contaminated areas. This abnormal brain phenomenon – the devolving of the brain, if you will – has been documented amongst Chernobyl bird populations. [29]

---

26 Hao, W. M., O. O. Bondarenko, S. Zibtsev, and D. Hutton. 2009. Vegetation fires, smoke emissions, and dispersio of radionuclides in the Chernobyl Exclusion Zone. Pages 265– 275 in A. Bytnerowicz, M. J. Arbaugh, A. R. Riebau, and C. Andersen, editors. Developments in environmental science. Volume 8. Elsevier, Amsterdam, The Netherlands.

27 N. Evangeliou et al. (2015). Fire evolution in the radioactive forests of Ukraine and Belarus: future risks for the population and the environment. Ecological Monographs, 85(1), 2015, pp. 49–72.

28 N. Evangeliou et al. (2015). Fire evolution in the radioactive forests of Ukraine and Belarus: future risks for the population and the environment. Ecological Monographs, 85(1), 2015, pp. 49–72.

29 Møller AP, Bonisoli-Alquati A, Rudolfsen G, Mousseau TA (2011) Chernobyl Birds Have Smaller Brains. PLoS ONE 6(2): e16862. doi:10.1371/ journal.pone.001686

In addition to smaller brains, birds near Chernobyl show increased cataracts[30], tumor incidence, albinism.[31]

Although it is too early to see such significant impacts on animal populations near Fukushima, similar studies have shown decreases in bird and insect diversity near Fukushima. A recent analysis concluded that in the case of Fukushima bird populations ***"The abundance of birds decreased with increasing levels of background radiation, with significant interspecific variation. Even though levels of background radiation decreased over time, the relationship between abundance and radiation became more negative over time. The relationship between abundance and radiation became less negative with increasing trophic levels. These findings are consistent with the hypothesis that the negative effects of radiation on abundance and species richness accumulate over time."*** [32]

In contrast to the superficial dismissal of radiation impacts on the environment by the IAEA Fukushima Report, scientists actually investigating those impacts have concluded, ***"we have shown substantial evidence based on rigorous and highly replicated observations across space and time that is consistent with the hypothesis that the species richness and abundance of different species of birds were suppressed at high levels of background radiation in Fukushima."***

This important research can be considered an early indicator of a stressed ecosystem.[33]

Conclusion

The IAEA Fukushima Report states that its conclusion is based on, "[a lack of] observations of direct radiation induced effects in plants and animals have been reported ***although limited observational studies were conducted in the period immediately after the accident***" [Bold and italics added]. And that: "***The overall uncertainties associated with the types of models applied in this assessment are large, particularly where assumptions about environmental transfers are involved***. These assessment methodologies tend to be based on simple assumptions and uncertainties are usually taken into account by the use of conservative assumptions. The benchmarks used to relate calculated doses to radiation effects are primarily related to chronic rather than acute exposures and to a ***limited range of individual organisms, rather than populations or 'ecosystems.'*** The current methodologies ***do not take account of***

30 A.P. Møllera and T.A. Mousseau. Elevated Frequency of Cataracts in Birds from Chernobyl. Published: July 30, 2013 DOI: 10.1371/journal.pone.0066939.

31 A.P. Møllera, A. Bonisoli-Alquatib, T.A. Mousseau. High frequency of albinism and tumours in free-living birds around Chernobyl. Mutation Research/Genetic Toxicology and Environmental Mutagenesis. Volume 757, Issue 1, 18 September 2013, Pages 52–59.

32 Cumulative effects of radioactivity from Fukushima on the abundance and biodiversity of birds A. P. Møller1 · I. Nishiumi2 · T. A. Mousseau, March 3 2015, Journal of Ornithology DOI 10.1007/s10336-015-1197-2, http://cricket.biol.sc.edu/chernobyl/papers/Moller-et-al-JO-2015b.pdf, also "...at higher levels of radioactive contamination the number of barn swallows declined and the fraction of juveniles decreased, indicating lower survival and lower reproduction and/or fledging rate. Thus, genetic damage to nestlings does not explain the decline of barn swallows in contaminated areas, and a proximate mechanism for the demographic effects documented here remains to be clarified. "Abundance and genetic damage of barn swallows from Fukushima", A. Bonisoli-Alquati, K. Koyama, D. J. Tedeschi, W. Kitamura, H. Sukuzi, S. Ostermiller, E. Arai, A. P. Møller & T. A. Mousseau, Scientific Reports 5, Nature, Article number: 9432 doi:10.1038/srep09432, April 2 2015, http://www.nature.com/srep/2015/150330/srep09432/full/srep09432.html

33 A.P. Møllera, et al., Differences in effects of Radiation on abundance of Animal in Fukushima and Chernobyl. Ecological Indicators 24 (2013) 75–81

interactions between components of ecosystems or the combined impact of radiation and other environmental stressors." [bold and italics added][34]

While reference biota may give an initial sense of potential impacts on specific plant or animal species, dismissing the future environmental impacts on living organisms as wholly unlikely, while also completely ignoring the way in which those organisms interact with one another and their environment – and thus both come into contact with, transfer, or bioaccumulate, environmental pollutants – is simply not credible. A conclusion cannot be drawn when there is not only a lack of understanding, but a complete lack of any effort to understand or analyze the subject of one's conclusion – in this case, the environmental impacts to be expected in the future from the enormous radioactive contamination resulting from Fukushima.

The IAEA's analysis that there will be no expected impacts from Fukushima's radiation on the nonhuman environment lacks all credibility. At best, it is merely a cursory glance in the direction of environmental concern. At worst, it deliberately oversimplifies complex system analysis, and ignores existing scientific evidence that points to real environmental and non-human animal impacts from radioactive contamination.

Given that the Fukushima Report is an attempt by the IAEA to frame the understanding and discourse on the impacts of radiation in the environment from the Fukushima Daiichi accident, the crippling shortfalls in its methods and conclusions can put the public at undue risk, as community members interact with the nonhuman environment, using its resources and eating food from agricultural land. In its dismissal of these very real issues, the IAEA has failed to put sound scientific analysis and public safety before rhetoric and empty reassurances.

3 – THE FAILURE OF SAFETY RISK ANALYSIS

The IAEA Fukushima Report is presented as the definitive report on the March 2011 nuclear accident, which would provide ***"an authoritative, factual and balanced assessment, addressing the causes and consequences of the accident, as well as lessons learned"***.

As with earlier IAEA reports that followed the Chernobyl nuclear accident in 1986,[35] the latest report has a clear objective, to present to (and convince) the world that the international body responsible for developing nuclear safety standards,[36] has the most comprehensive, and therefore reliable, understanding of a severe nuclear accident, and, that as a result, nuclear safety standards are being raised to a level that can provide confidence about avoiding future accidents. This is the message, but it does not mean it is based on reality, not in the past, the present or future.

The nuclear safety myth – Chernobyl through Fukushima to the present day

Over a period of five decades the IAEA has promoted the expansion of nuclear power. During the same time period it has proposed and developed nuclear safety standards which, it insisted, once adopted by its member governments into their national regulations, would provide assurances on nuclear safety. In the years following the Chernobyl nuclear accident, and prior to the Fukushima Daiichi nuclear accident, the IAEA claimed that nuclear power could be operated safely with the

34 IAEA Fukushima Report, pg. 157
35 See for examples, http://www-pub.iaea.org/MTCD/publications/PDF/Pub885e_web.pdf
36 https://www.iaea.org/about/mission

use of its evolving high standards.

"The IAEA Conference on "The Safety of Nuclear Power: Strategy for the Future" in 1991 was a milestone in nuclear safety. The objective of this conference was to review nuclear power safety issues for which achieving international consensus would be desirable to address concerns on nuclear safety and to formulate recommendations for future actions by national and international authorities to advance nuclear safety to the highest level."

Many of the same issues that are assessed in the Fukushima Report were reviewed and included in IAEA reports on Chernobyl – regulatory failure, consideration of external events, old reactor designs. In the area of nuclear safety, the shock to the international nuclear industry caused by the 1986 Chernobyl, evolved over the following years into a carefully managed communication. Safety standards would be improved, and that with lessons learned, this would translate into safe operation of nuclear power worldwide. The IAEA knew then that trust in nuclear regulators and regulations is correlated with public confidence that nuclear power plants can be operated safely. As the accident receded into history, the nuclear industry and IAEA have promoted this view while asserting the benefits of nuclear power, and emphasizing the low risk of severe accident[37]. In the event of a severe accident, communicating the minimal consequences in terms of human health and environmental impact has been standard operating procedure. The Fukushima Report is the next stage in their strategy.

In the immediate years prior to the Fukushima Daiichi accident, the IAEA had consistently reported that they were satisfied with overall nuclear safety standards worldwide, including in Japan.[38]

The Fukushima Daiichi accident therefore came as a devastating blow to the IAEA and the global nuclear industry. One month after the start of the accident, and at the conclusion of a nuclear safety conference, the IAEA and member states, for obvious reasons, removed reference to those satisfactory global safety standards.[39]

Being seen to be learning the lessons of Fukushima, as with Chernobyl before it, is a priority for the IAEA, regulators and industry. Without public perception of nuclear safety there can be no trust in nuclear regulation and therefore nuclear power operations are threatened. Nowhere more so is this true than in Japan where currently all 43 remaining commercial nuclear reactors remain shutdown.

The IAEA Fukushima Report is a central element in the strategy of restoring trust in Japan and internationally. But the report falls far short in assessing Fukushima and its consequences. The challenge for the IAEA is to reflect the clear failures of the past that led to accident, while also attempting to downplay the negative impacts of the accident in terms of radiation risks and environmental impact and to emphasize the positive in terms of progress made by TEPCO in managing the current crisis. Similarly, it is critical of former safety standards applied by Japan's

37 http://www-pub.iaea.org/MTCD/publications/PDF/TE_1661_Web.pdf
38 http://www-ns.iaea.org/downloads/ni/safety_convention/summary-report-april2008-final.pdf
39 http://www-ns.iaea.org/downloads/ni/safety_convention/sr2011/cns-rm5-summary-report_englsih_final_signed.pdf, While the IAEA did raise safety issues with Japanese regulators in the years prior to 2011, it did not publicly communicate that unless standards were raised there was a major risk of multiple reactor meltdowns.

regulators before 2011, but also it must emphasize the positive, in terms of the new regulations now being applied to Japan's nuclear reactors.

As this preliminary critique will seek to demonstrate, the IAEA fails in fundamental areas to accurately reflect the consequences of the Fukushima Daiichi accident and provides no evidence that nuclear regulation in Japan, now being overseen by the Nuclear Regulation Authority (NRA) is anywhere near the worlds highest standard.[40]

The false premise of the IAEA Fukushima Report and nuclear reactor restart

The declared mission for the IAEA Fukushima report is to provide an authoritative, factual and balanced assessment, addressing the causes and consequences of the accident. As detailed below we will see that there are major failings in the IAEA analysis, but even the mission itself is based on a false premise – that all necessary information is currently available to permit such an 'authoritative' assessment. There are multiple problems with this claim, not least that there remain many unknowns about the actual events that led to the multiple nuclear reactor meltdowns. The need to understand the details of the nuclear accident are fundamental for assessing nuclear safety both in Japan and worldwide.

As early as 2012 the Fukushima Nuclear Accident Independent Investigation Commission (NAIIC) prepared by the National Diet of Japan, raised the fact that, ***"a number of important factors relating to how the accident actually evolved remain unknown, mainly because much of the critical equipment and piping relevant to the accident are inside the reactor containment facility and are thus beyond the reach of inspection or verification for many years to come."***

The IAEA Fukushima Report expresses no such doubts, and joins the efforts of TEPCO,[41] the Japanese Government and the NRA, all of which have presented conclusions on the accident, its timeline and causes with the common aim of communicating that they fully understand the accident. There is a simple reason for this effort: unless they can demonstrate that they understand the accident, including its causes, any assurances to the Japanese people that they have learned from the accident and that the new regulations on nuclear safety can be relied upon, will be rejected. In this sense, the IAEA Fukushima Report is a central element in plans by the Japanese government to restart nuclear reactors over the coming years.

Ignoring uncertainties

In contrast to the narrative of the IAEA and Japanese authorities, and four years after the start of the accident, many of the issues raised by the Japanese Diet investigation and others remain unanswered.

The IAEA has adopted the same language of TEPCO which specified that equipment providing key safety features was not damaged by the earthquake, and that the main cause of the accident was

40 "We will be tireless in our efforts to improve our regulatory measures so that Japan's nuclear regulation standards will be among the world's highest." Shunichi TANAKA, Chair, Nuclear Regulation Authority, http://www.nsr.go.jp/english/e_nra/outline/02.html

41 Fukushima Nuclear Accident Analysis Report June 20, 2012 Tokyo Electric Power Company, Inc., http://www.tepco.co.jp/en/press/corp-com/release/betu12_e/images/120620e0104.pdf

the tsunami. The government also wrote a similar accident report that was submitted to the International Atomic Energy Agency (IAEA). This has now be incorporated into the Fukushima Report. ***"There were no indications that the main safety features of the plant were affected by the vibratory ground motions generated by the earthquake on 11 March 2011. This was due to the conservative approach to earthquake design and construction of NPPs in Japan, resulting in a plant that was provided with sufficient safety margins."***

A quite incredible statement by the IAEA - clearly the triple reactor meltdown at Fukushima Daiichi demonstrated that there were not sufficient safety margins.

The IAEA Fukushima Report fails to address issues raised by the Japanese Diet Investigation. As they concluded, "***TEPCO was too quick to cite the tsunami as the cause of the nuclear accident and deny that the earthquake caused any damage. We believe there is a possibility that the earthquake damaged equipment necessary for ensuring safety, and that there is also a possibility that a small-scale Loss of Coolant Accident occurred in (Fukushima Daiichi) Unit 1. We hope these points will be examined further by a third party."***

As with all of the NAIIC recommendations, third party examination of the seismic impact of the accident have been ignored by the Japanese government and nuclear industry. The future of nuclear power in Japan, already severely in doubt, would be dealt a fatal blow if it was confirmed that seismic impact was a critical cause of the accident. Focussing on the tsunami cause is essential if the nuclear industry and current Japanese government energy policy is to have any chance of a future. The NAIIC, in contrast to the IAEA Fukushima Report, raises this fundamental question:

"Although the two natural disasters—the earthquake and subsequent tsunami—were the direct causes of the accident, there are various points in the unfolding of the event that remain unresolved. The main reason for this is that almost all the equipment directly related to the accident is inside the reactor containers, which are inaccessible and will remain so for many years. A complete examination and full analysis are impossible at this time."[42]
The IAEA Fukushima Report does not even acknowledge these uncertainties but instead states definitively that the Fukushima Daiichi plant was seismically secure and with sufficient safety margins.

IAEA failure to address current regulation in Japan

"we will be tireless in our efforts to improve our regulatory measures so that Japan's nuclear regulation standards will be among the world's highest."

42 The Diet Investigation did reach the conclusion that, "the people involved were aware of the risk from both earthquakes and tsunami. Further, the damage to Unit 1 was caused not only by the tsunami but also by the earthquake, a conclusion made after considering the facts that: 1) the largest tremor hit after the automatic shutdown (SCRAM); 2) JNES confirmed the possibility of a small-scale LOCA (loss of coolant accident); 3) the Unit 1 operators were concerned about leakage of coolant from the valve, and 4) the safety relief valve (SR) was not operating. Additionally, there were two causes for the loss of external power, both earthquake-related: there was no diversity or independence in the earthquake-resistant external power systems, and the Shin-Fukushima transformer station was not earthquake resistant."

Shunichi Tanaka, chair, nuclear regulation authority,

The IAEA Report states in relation to Fukushima Daiichi that, ***"The regulations, guidelines and procedures in place at the time of the accident were not fully in line with international practice in some key areas, most notably in relation to periodic safety reviews, re-evaluation of hazards, severe accident management and safety culture."***

The Fukushima Report is justifiably critical of the regulator overseeing the Fukushima Daiichi nuclear plant in 2011, the Nuclear and Industrial Safety Agency (NISA). Unfortunately, the failure of Japanese nuclear regulation prior to the March 2011 Fukushima Daiichi accident, also applies in many areas to the current nuclear regulation overseen by the NRA. In important areas the NRA is not following international practice, including recommendations made by the IAEA. This is not addressed by the IAEA in the Fukushima Report. Instead, when considering nuclear safety, the Fukushima Report describes in a wholly superficial manner the establishment of the new regulator in Japan. Devoting less than one page to the NRA, the impression given by the IAEA is one where many of the failures of the former regulator, NISA, have been addressed in the new regulations and requirements for nuclear plant operators. The reality is very different.

To illustrate the weaknesses in current fundamental safety regulation in Japan today, and the failure of the IAEA Fukushima Report to address the current context, the example of the Sendai nuclear power plant highlights the future risk of a severe nuclear accident. The two pressurized water reactors at Sendai located in Kagoshima prefecture, and owned by Kyushu Electric, are the most advanced in the NRA review process and are scheduled to resume operation during the coming months, with plans to restart unit 1 in July 2015, to be followed by unit 2 from late September.

The IAEA Fukushima Report states,

"Comprehensive probabilistic and deterministic safety analyses need to be performed to confirm the capability of a plant to withstand applicable beyond design basis accidents and to provide a high degree of confidence in the robustness of the plant design.

Safety analyses can be used both to evaluate, and to develop response strategies for, beyond design basis accidents and may include the use of both deterministic and probabilistic methods. The probabilistic safety assessment studies conducted for the Fukushima Daiichi NPP were of limited scope and did not consider the possibility of flooding from internal or external sources. The limitations in these studies contributed to the limited scope of accident management procedures available to the operators."

The IAEA's call for Probabilistic Analysis (PRA) is nothing new, including in the years following the Chernobyl accident. It is widely adopted as a benchmark in nuclear regulation worldwide. However, the IAEA reliance on probabilistic analysis is in itself problematic. These include

- as noted by a MIT study[43], they cannot account for the indirect, non-linear, and feedback

43 The Future Of Nuclear Power An Interdisciplinary MIT Study, 2003,

relationships that characterize many accidents in complex systems;

- they do a poor job of modeling human actions and their impact on known, let alone unknown, failure modes.
- the U.S. Nuclear Regulation Commission (NRC) concluded[44], it is conceptually impossible to be complete in a mathematical sense in the construction of event-trees and fault-trees … This inherent limitation means that any calculation using this methodology is always subject to revision and to doubt as to its completeness.[45]

The IAEA Fukushima Report confirms that PRA was applied to the Fukushima Daiichi nuclear power plant prior to the accident in March 2011 but ***"some weaknesses which were not fully evaluated by a probabilistic safety assessment, as recommended by the IAEA safety standards."***

The IAEA Fukushima Report cites PRA almost as a cure all for assessing nuclear risk, and if only it were applied nuclear safety, could be ensured. But as one nuclear analyst concludes,

"If probabilistic risk assessments were just esoteric exercises performed by nuclear engineers for internal consumption, there would not be much reason to be concerned with their lack of reliability except that they create overconfidence among those designing and operating reactors. The problem is that the small numbers produced by this exercise, widely seen as involving complicated calculations, have the effect of what might be termed false or misplaced concreteness, especially on policy makers and the general public.",[46] *(page 82)*

The IAEA Fukushima Report PRA approach is about communicating lessons learned from the 2011 accident and rebuilding trust in nuclear regulation – but is no basis for ensuring nuclear safety in the real world.

The disconnect between the narrative of the IAEA Fukushima Report and the reality of current nuclear regulation in Japan is further illustrated by how the NRA has chosen to apply risk analysis of nuclear reactors seeking restart operation. Currently, 24 reactors are under NRA review.

The current Japanese regulator fails to apply IAEA recommendations.

The NRA has not required Japanese nuclear utilities, including the owner of the Sendai nuclear

---

http://web.mit.edu/nuclearpower/pdf/nuclearpower-full.pdf, as cited in "Beyond our imagination: Fukushima and the problem of assessing risk", M. V. Ramana, http://thebulletin.org/beyond-our-imagination-fukushima-and-problem-assessing-risk-0

44 Risk Assessment Review Group Report T O T H E U.S. Nuclear Regulatory Commission, H. W. Lewis, Chairman, NRC, 1978, http://www.osti.gov/scitech/servlets/purl/6489792

45 As one expert analyst has observed, "conclusions about overall accident probabilities derived from its use are far from dependable. Perhaps the only robust conclusion one can draw is that no two major accidents are alike. Historically, severe accidents at nuclear plants have had varied origins, progressions, and impacts. These have occurred in multiple reactor designs in different countries. This means, unfortunately, that while it may be possible to guard against an exact repeat of the Fukushima disaster, the next nuclear accident will probably be caused by a different combination of initiating factors and failures. There are no reliable tools to predict what that combination will be, and therefore one cannot be confident of being protected against such an accident.", "Beyond our imagination: Fukushima and the problem of assessing risk", M. V. Ramana, http://thebulletin.org/beyond-our-imagination-fukushima-and-problem-assessing-risk-0

46 "Beyond our imagination: Fukushima and the problem of assessing risk", M. V. Ramana, http://thebulletin.org/beyond-our-imagination-fukushima-and-problem-assessing-risk-0

plant, to perform comprehensive safety analyses as recommended by the IAEA.

The NRA requires that power companies prepare a Probabilistic Seismic Hazard Analysis (PSHA) and a Probabilistic Tsunami Hazard Analysis (PTHA). These have been completed for the Sendai nuclear reactors. Such probabilistic hazard analyses are intended to determine the scale or magnitude of a particular phenomenon, in this case seismic and tsunami, as a function of the frequency of occurrence.

However, under the revised post Fukushima guidelines, the NRA has not required Kyushu Electric, or other nuclear power companies, to conduct Probabilistic Risk Analysis (PRA) which the IAEA states would help determine the risk of occurrence of reactor core damage, so called core damage frequency, or the amount of radioactivity that would be released in a severe accident, so called Large Early Release Fraction (LERF).

The NRA have therefore accepted the lower standard probabilistic hazard analysis while not requiring a probabilistic risk analysis.

So we are left with a situation where a methodology that has major flaws, is recommended by the IAEA to be applied more comprehensively to correct the mistakes made prior the Fukushima Daiichi accident, but which in reality, are not applied by the NRA.

Underestimation of seismic risks and NRA failure

The IAEA Fukushima Report states,

"The assessment of natural hazards needs to be sufficiently conservative. The consideration of mainly historical data in the establishment of the design basis of NPPs is not sufficient to characterize the risks of extreme natural hazards. Even when comprehensive data are available, due to the relatively short observation periods, large uncertainties remain in the prediction of natural hazards. Extreme natural events that have a very low probability of occurrence can result in significant consequences, and the prediction of extreme natural hazards remains difficult and controversial due to the existence of uncertainties." *(page 80)*

The NRA review process of the Sendai nuclear power plant reveals that both the regulator and Kyushu Electric are not following a conservative approach as detailed by the IAEA.

The fault-line running through the NRA seismic safety guidelines, and their misapplication during the Sendai reactor review process, has recently been documented by one of Japan's leading critical seismologists and member of the Diet Investigation Committee, Professor Katsuhiko Ishibashi,[47] and former General Electric nuclear engineer Satoshi Sato.

As Professor Ishibashi reports, the NRA regulations stipulate that the Standard Seismic Motion (SSM) (horizontal and vertical motions on the free rock surface in the site) shall be formulated as the ***"earthquake ground motion formulated with a hypocenter specified for each site"***

47 Katsuhiko Ishibashi, Emeritus Professor at Kobe University, seismologist, member of NAIIC (the National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission), presentation to Foreign Correspondents' Club of Japan, April 27, 2015.

and the ***"earthquake ground motion formulated without a hypocenter."*** The ***"earthquake ground motion formulated with a hypocenter specified for each site"*** shall be formulated by selecting multiple earthquakes that are predicted to have significant effects on the site (Earthquakes for Investigation: EQFIs) as to inland crustal earthquakes, interplate earthquakes and oceanic intraplate earthquakes, and by implementing the evaluation of ground motions for each selected EQFI.

However, Kyushu Electric examined the effects of historical earthquakes on the Sendai reactors according to its own criterion. They concluded that the sources of the largest interplate and oceanic intraplate earthquakes are far from the nuclear plant site and therefore the maximum design earthquake (S1) would be lower. Kyushu Electric concluded that interplate and oceanic intraplate earthquakes need not to be selected as Earth Quakes For Investigation – they were screened out by the power company, and the NRA accepted this approach. But as Ishibashi points out the maximum design earthquake of some inland crustal earthquakes are larger than those included in the Sendai assessments submitted and subsequently approved by the NRA.

Also screened out by Kyushu Electric was consideration of the risk from the Nankai Trough seismic fault.[48] Taking the Nankai Trough earthquake into account is indispensable in the formulation of the Standard Seismic Motion for the Sendai nuclear reactors. The Nankai trough is estimated to be capable of a generating a category 9.1 magnitude seismic event. Ishibashi has documented that if the ground motion due to a Nankai Trough earthquake was formulated by setting up the possible maximum fault parameters, the ground motion may exceed the Sendai reactors maximum design earthquake. Yet the, the NRA requires that plate tectonics such as in the Nankai Trough should be comprehensively be considered when selecting the earthquakes for consideration by Kyushu Electric. Instead, four years after the Fukushima Daiichi nuclear disaster, the utility has excluded it.

Nuclear engineer Satoshi Sato has documented[49] that in contrast to the IAEA , which recommends determining a safe design-basis-earthquake based on seismic events occurring with a probability of once every 10.000 to 100.000 years (annual exceedance probability 1E-4 and 1E-5), the design-basis-earthquake, presented by Kyushu Electric for the Sendai reactors, indicates the probability of a higher frequency, with seismic events happening partially once every 1.000 - 10.000 years (annual exceedance probability 1E-3 and 1E-4). The NRA has thus not required Kyushu Electric to apply the recommended standard from the IAEA.

In the Construction Permit Application for the Sendai reactors, submitted and accepted by the NRA, only the continental crust was considered as a seismic source for non-seismic isolation buildings and not seismic sources at plate interface and within oceanic plate. As a result, the earthquake impacts from lower frequency (longer period) regions of vibration spectrum, which has caused serious consequences in past nuclear accidents, have been underestimated.

The lower frequency (longer period) region of vibration spectrum should not be underestimated as it

48 The Nankai Trough is an oceanic trench that stretches for about 700 kilometers off the coast of Shizuoka Prefecture in central Honshu to Kyushu. It is a region where quakes frequently occur when the oceanic plate slips under the continental plate, "Experts say M9 Nankai Trough earthquake would kill hundreds of thousands",August 30 2012, http://ajw.asahi.com/article/0311disaster/analysis_opinion/AJ201208300060

49 "Technical issues of Japanese seismic evaluations from the point of global and Japanese standards" Satoshi Sato, commissioned by Greenpeace, http://www.greenpeace.org/japan/Global/japan/pdf/20150428-seismic-evaluation-en.pdf

can lead to the destruction of tanks, pools and transformers in the reactor caused by swelling liquids (sloshing effects) as well as to great damage to machines, such as overhead polar cranes, lower pressure turbine rotors and underground pipes.

The IAEA Fukushima Report provides details of the weakness of the former regulator NISA in applying effective regulations against nuclear power companies who resisted more robust measures, the consequences of which contributed to the Fukushima Daiichi nuclear accident.

Yet, in 2015, as the NRA review process concludes with the final safety review of the Sendai nuclear reactor unit 1 - the NRA has accepted the Kyushu Electrics violation of the post-Fukushima regulations, and thus has accepted an inadequate seismic standard essential for the safety of the nuclear plant. The IAEA Fukushima Report makes no mention of the current flaws within the new seismic regulatory requirements in Japan nor their mis-application.
Professor Ishibashi, who resigned from the drafting committee of the 2006 seismic guidelines due to the failure to adopt the highest standards,[50] and who has warned for nearly two decades of the risk of a seismically inducted severe nuclear accident, has concluded that on the basis of the Sendai NRA Review,

"sometime at some nuclear power plant, it will be inevitable that there will be an earthquake that far surpasses the Standard Seismic Motion of that plant, and this could very well lead to a second Genpatsu Shinsai (Earthquake-Nuclear Combined Disaster)."[51]

Other external events – volcano

As noted, the IAEA Fukushima Report highlights the need to conservatively assess natural hazards. In the case of the Sendai reactors, and multiple other nuclear plants in Japan, one such hazard is the risk from major volcanic eruptions. The Sendai plant is located 50km from the active volcano at Mt Sakurjima. Here again during the past year the NRA has failed to apply standards recommended by the IAEA when considering volcanic hazards to the Sendai nuclear plant. Specifically, the NRA fails to adopt key recommendations of the 2012 IAEA volcano safety guidelines[52] —including a requirement that the nuclear plant operator modifies the plant to make it able to withstand extreme volcanic events—the so called *design basis.* Kyushu Electric has relied upon flawed historical analysis, underestimating the potential ash fallout that could reach the Sendai nuclear reactors and that could result in serious on-and off-site radiological consequences.

One of the severe consequences from major volcanic ash deposition is it can lead to a common-mode failure, which in turn results in failure of safety equipment and functioning and other day-to-day operations across and beyond the power plant site—any one affect of ash fall may not, in itself and alone, be sufficient to bring the plant down, but when acting in combination and possibly chaotically, the plant's overall resilience may fail. Inevitably, in the aftermath of major volcanic eruption, the impact of ash fallout will include short-circuiting (flashover) of electricity distribution networks and

50 Why Worry? Japan's Nuclear Plants at Grave Risk From Quake Damage Katsuhiko Ishibashi Why Worry? Japan's Nuclear Plants at Grave Risk From Quake Damage, August 11 2007, http://www.japanfocus.org/-Ishibashi-Katsuhiko/2495/article.html

51 Ishibashi, presentation to Foreign Correspondents' Club of Japan, April 27, 2015.

52 IAEA Volcanic Hazards in Site Evaluation for Nuclear Installations, Specific Safety Guide No SSG-21, IAEA 2012, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1552_web.pdf

switchgear, leading to loss of off-site electrical power (LOOP), for which the nuclear plant rely upon to cool both the reactors and the spent fuel in the storage ponds—this will place the two Sendai nuclear reactors and their spent fuel ponds in much the same risk situation as the Fukushima Daiichi reactors following the earthquake and before the arrival of the tsunami.[53]

The NRA and Kyushu Electric have failed to provide credible plans for how the deposited ash layer would be removed from key buildings, roofs and access routes, especially from the roofs of the buildings containing more than 800 tons of highly radioactive nuclear spent fuel, resulting in a heightened risk of roof collapse – Kyushu Electric acknowledges that the roofs of the spent fuel buildings have minimal reserve or safety margins against overloading by ash layers.
Once again it appears that pressure from the nuclear industry has played a decisive role in weakening both the drafting and application of the post-Fukushima safety regulations.

Nuclear engineer Dr John Large, who analysed the volcano hazard for Sendai and the process of NRA review, has concluded, ***"the NRA's original draft volcanic effect guide required the nuclear plant operator provide a risk-informed approach accounting for probabilities and 'off the cliff-edge' situations, requiring the Sendai plants be physically modified against these extremes by setting up and including volcanic design-basis resilience. However, the final NRA guide dropped all of these requirements thereby permitting Kyushu Electric not to include these common sense safeguards against the inevitable - as a result, the final Sendai volcanic site evaluation is weak, departing considerably from the International Atomic Energy Agency safety recommendations for evaluation of nuclear plant sites in the region of volcanic activity."***[54]

This is one further example where lessons that should have been learned from the regulatory failure that led to the Fukushima nuclear accident, are being ignored by the new regulator, nuclear industry and ultimately the Japanese government.

For further information:

Jan Vande Putte – Greenpeace Belgium - jan.vande.putte@greenpeace.org
Kendra Ulrich – Greenpeace Japan - kendra.ulrich@greenpeace.org
Shaun Burnie – Greenpeace Germany - sburnie@greenpeace.org

53 In this LOOP situation, the Sendai plants will be wholly dependent upon the emergency diesel generators, yet Kyushu Electric fails to adequately prepare for maintaining these generators in operation, especially in its plans for unblocking of the air filters (necessary for operation) —the utility plans to replace filters after 26.5 hours, whereas the U.S. NRC requires the replacing after 2.3 hours at the Columbia nuclear reactor; combined with LOOP, and other impacts, it would lead to Station Black Out (SBO) and loss of cooling function to the nuclear reactors and spent fuel pools, see, "Implications of Tephra (volcanic ash) fallout: On the operational safety of the Sendai nuclear power plant", Large & Associates, Greenpeace Commissioned report, February 26th 2015
http://www.greenpeace.org/japan/Global/japan/pdf/Volcano_Ash_report_by_John_Large.pdf, see also
https://www.greenpeace.de/sites/www.greenpeace.de/files/publications/r3229-e1-john-large-atomkraft-japan-20150128.pdf

54 http://www.greenpeace.org/japan/Global/japan/pdf/Volcano_Ash_report_by_John_Large.pdf