Implementing optimisation in post-accident situation: Some lessons from Fukushima

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Optimisation is one of the fundamental principles of radiological protection system by the ICRP.

The concepts of reference level are used in the process of optimisation of protection to assist in ensuring that all exposures are kept as low as reasonably achievable, societal and economic factors being taken into account.

The Fukushima Daiichi Nuclear Power Plant accident is the first experience using those for decision-making on protective actions after a nuclear accident.

To get insights on the choice and update of the reference level in post accident situation;
- Reviewing of the evolution of numerical criteria which were used for making decisions on protective actions after the Fukushima accident.
- Analyzing the data on confusions which were caused by the use of the reference level and other numerical criteria.
## Off-site protective actions in the Fukushima accident

<table>
<thead>
<tr>
<th>Time</th>
<th>Evacuation</th>
<th>Other actions (Sheltering, ITB, Restriction on foods, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 March</td>
<td>20:50 2 km radius of the NPP 21:23 3 km radius</td>
<td>Sheltering: within 3–10 km radius of the NPP</td>
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<tr>
<td>12 March</td>
<td>05:44 10 km radius of the NPP 18:25 20 km radius</td>
<td>Monitoring: 13000 cpm was used for evacuees</td>
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<tr>
<td>14 March</td>
<td></td>
<td>Monitoring: Criterion changed from 13000 cpm to 100000 cpm</td>
</tr>
<tr>
<td>16 March</td>
<td></td>
<td>Advice on implementing ITB</td>
</tr>
<tr>
<td>19 March</td>
<td></td>
<td>Food restriction: Activity in leafy vegetables and milk exceeding criteria to restrict food</td>
</tr>
<tr>
<td>21 March</td>
<td></td>
<td>Restrictions on certain foods</td>
</tr>
<tr>
<td>25 March</td>
<td>Voluntary evacuation within 20–30 km radius recommended (by whom?)</td>
<td></td>
</tr>
<tr>
<td>11 April</td>
<td>20 mSv/y criterion established to determine areas beyond 20 km evacuation area that will relocate</td>
<td>Re-opening of schools: 20 mSv/y criterion established to determined which schools will re-open (subsequently became lower to 1mSv/y)</td>
</tr>
<tr>
<td>19 April</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This table was made based on following references:
NAIIC, 2012 The official report of the Fukushima Nuclear Accident Independent Investigations Commission (NAIIC, 2012);
Evacuation

Earthquake (11 March 14:46)
11 March 20:50 2km radius from the past experience of emergency preparedness drill
11 March 21:23 3km radius from the past experience and International Standards (PAZ).

Delay of vent
12 March 05:44 10km radius from Emergency Planning Zone (EPZ).

Hydrogen explosion in the Unit 1
12 March 18:25 20km radius from some people’s subjective opinions.

A lot of times spent for:
- coordinating contradictory opinions between related organization.
- discussing the criteria to determine the new evacuation zone

19 April 20 mSv/y was applied for judging whether use of school grounds

22 April Deliberate Evacuation Area was designated based on 20 mSv/y.
Consideration on the deliberate evacuation zone

Contradictory opinions between related organizations

- Fukushima Prefecture (21 March)
  - “establishing evacuation zones would make residents anxious”
  - “changing the zones of evacuation orders was assumed to cause confusion among residents”

- Iitate village (27 March)
  - Mayor of Iitate village also commented that expanding the evacuation zones would make residents wary, which would not be favorable.

Discussion on the criteria to determine the new evacuation zone

- The National authority considered the reference levels should be adopted as criteria for the new evacuation zone.
  - How to choice the criteria from the dose band between 20 mSv/y and 100 mSv/y.
  - Decision makers considered on the premise that the previous dose criteria for evacuation is 50 mSv and this level is equivalent to 25 mSv/y.
Effective dose cannot be measured directly.

This scheme has some problems:

1. Dose conversion (effective dose or ambient equivalent dose)
2. Exposure pathway (only external exposure)
3. Time-dependence of dose did not take into account (physical decay, weathering)
4. Differences due to inter-individual variability.

Calculation scheme of 3.8 \( \mu \text{Sv/h} \)

Outdoor
- 8 hours
- 3.8 \( \mu \text{Sv/h} \) \times 8 hours = 54.7 \( \mu \text{Sv/day} \)

Indoor
- 16 hours
- 3.8 \( \mu \text{Sv/h} \) \times 0.4 \times 16 hours

54.7 \( \mu \text{Sv/day} \)

365 days

20 mSv/y

The ambient dose rate of 3.8 \( \mu \text{Sv/h} \) measured at outdoor is equivalent to 20 mSv/y
Dose criteria for evacuation in Japan

Before the accident:
- Intervention Level (Avertable dose): 20 mSv/y (3.8 µSv/h)
- Reference revel (Residual Effective dose): 50 mSv
- Dose limit: 11 April 2011

After the accident:
- Effective dose (Ambient dose rate): 1 mSv/y
- Chernobyl: 5 mSv/y

ICRP Publ. 63 (1991)
ICRP Publ. 103 (2007)
IAEA BSS 115 (1996)
Reopening of schools

Ministry of Education, Culture, Sports, Science and Technology (MEXT)

6–8 April
- **Schools should be reopened?**
  - How about the safety of reopening schools?
  - How to determine the contaminated area

9 April
- **School buildings and ground can be used?**
  - How about the use of 20 mSv/y for judging availability of school buildings and ground?

14 April
- Internal exposure can be negligible.

19 April
- Finally, MEXT decided to use **3.8 µSv/h**, which is equivalent to **20 mSv/y**, for restricting the outdoor activities at the schools.

Nuclear Safety Commission (NSC)

- MEXT have to establish benchmark for judgment by themselves.
- As reference, the dose limit for the public was **1 mSv/y**.
- The 20 mSv/year benchmark should be used on a limited basis;
- Even if this value is adopted, the doses from external and internal exposures should be considered.
MEXT confirmed the number of schools whose dose rate are exceeding 3.8 μSv/h (as of 8 April, 2011).

MEXT thought that if the selected dose criteria is below 20 mSv/y, many schools are not respecting this criteria (COGJ, 2011).

Note: Schools which are located within 20 km zone and in the deliberate evacuation zone is not included
Criticism against the dose criteria of Reopening of schools

- Comparison with the other standards
  - 1 mSv/y is used for dose limit

- Doubts remain about the extent to which MEXT considered the health and safety of children.

- Schooling provided under prohibits and restricts can ensure children a proper learning experience.

- Scientific and other basis for this dose criteria was not clear.

- MEXT aimed to keep the dose that children and students receive at schools 1mSv/y

- MEXT decided
  1. To distribute dosimeters to all schools in Fukushima Prefecture
  2. To offer financial support for schools whose the dose rate was more than 1µSv/h, in order to help the costs of decontamination.

- Parents in Fukushima
- Japan Federation of Bar Associations
- Japan Medical Association
Lessons learned

- Reasonableness of dose criteria
  - Reference level vs Operational quantity
  - Comparison with the past experience and other standards
  - Comparison with the criteria for other protective actions

- To Clarify the scientific and other basis for dose criteria, and the aim of dose criteria
  - How to derive the numerical criteria and the validity of the data which used for the calculations.
  - What is the target to achieve using the selected criteria.

- To clarify the role and responsibility for the choice and update of dose criteria
Thank you for your attention!

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