Cytogenetic analysis of restoration workers for Fukushima Daiichi Nuclear Power Station accident

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After 11 March 2011, the Great East Japan Earthquake affected the Fukushima Daiichi Nuclear Power Station (NPS) and caused serious damages to NPS, resulting in a large amount of radioactive materials being released into the environment.

- I-131 \(1.6 \times 10^{17}\) Bq
- Cs-134 \(1.8 \times 10^{16}\) Bq
- Cs-137 \(1.5 \times 10^{16}\) Bq

As of June 6, 2011
(by Nuclear and Industrial Safety)
NIRS activities for Fukushima NPP accident

- Assisting Government, local Gov
- Sending experts & equipment
- Dose assessment & health check of the restoration workers and residents
  - Residents’ temporary home-visit: contamination check / medical consultation
- International organization (WHO, UNSCER)
- Assisting other hospitals on WBC
- Accepting patients
- Surface screening
- Public information
- Telephone consultation to public
- Telephone consultation to relevant organizations
External exposure

Individual monitoring for exposure is done by:

- Clinical dosimetry
  * Medical symptoms, blood cell counts...

- Physical dosimetry
  * Personal dosimeter
  * Dose reconstruction

- Biodosimetry
  * Chromosome Analysis
  * ESR, new technologies...
**NIRS DCA System**

### Radiation Accident (24-h Emergency Call)

- **Day 0**
  - Blood collection, isolation of PBMCs, cell culture (48h, 1\(^{st}\) division)
  - Harvesting, fixation, chromosome preparation, staining

- **Day 1**
  - Automatic metaphase-finding → chromosome-image analysis
  - Medical triage scoring → report to the doctors

- **Day 3**
  - Biodosimetry scoring
  - → Upload the result to medical report

- **Day 4**
  - Explain to the patient at their next consult
  - FISH analysis
  - Genomic analysis

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**NIRS DCA System**
based on IAEA Manual 2011, ISO 19238, ISO 21243

- **Questionnaire & Informed consent**
- **Age, sex, alcohol, smoking, medicine, histories of medical and occupational exposures, etc.**
NIRS received 1F site-workers with suspected overexposure for medical care and physical and biological dosimetry

For biodosimetry, 12 individuals were received from 21 March to 1 July 2011.

I-131, I-133, Cs-134, Cs-137
→ External exposure (gamma-rays)

→ Patients were back every week for internal dose assessment.

Re-examination of DCA: after 3 months and 1 year
* Among the workers, no individuals showed values exceeding 300 mGy (95% upper confidence limit), which is lower than the lower limit level of medical triage for acute radiation syndrome (1 Gy).

* The results corroborate the fact that no acute radiation syndromes were observed among the workers examined.
Dose estimated by DCA (mGy)

Dose detected with alarm personal dosimeter (mSv)

The linear regression was obtained:
[physical dose (mSv)] = [biological dose (mGy)] × 1.032 - 7.067 (p < 0.05)

Effective dose by WBC was < 100 mSv.

* The estimated values were in good agreement with those of physically estimated doses by personal dosimeters.

(Suto et al., 2013)
Exposed dose to emergency workers at 1F NPP

* Six individuals took an annual health examination (29 July - 6 August 2012)

→ Every individual showed either a decreasing tendency or equal values to the results obtained from the initial examination.

(Suto et al., 2013)

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<tr>
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<th>Max (mSv)</th>
<th>Ave (mSv)</th>
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<td>Max (mSv)</td>
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<td>85</td>
</tr>
<tr>
<td>Ave (mSv)</td>
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(from TEPCO press release 2012.12.27)
NIRS’s current biodosimetric strategy for the suspected overexposure of ionizing radiation

Blood collection
Lymphocyte separation

Culture

G0/G1 PCC with PNA-FISH
Cell fusion-mediated prematurely condensed dicentric chromosome assay & a rapid procedure (5-h) by PNA-FISH
1-h analysis (30 fused cells)

Dose estimation

Harvesting and preparation

Dicentric chromosome assay

Slide ageing (1 day)

3-color FISH for translocation analysis

5 h

48 h

72 h

96 h

Triaging
Translocation analysis

M-FISH (multiplex fluorescence in situ hybridization)

3-color FISH [chromosomes 1, 2 and 4; 22.9% (males) and 22.5% (females) of human whole genome]

Examples of FISH to the restoration workers’ lymphocytes
We examined blood samples from a total of 12 restoration site-workers (March 21 to July 1, 2011) for biodosimetry.

1) The dicentric chromosome assay (DCA)

Among the workers, no individuals showed values exceeding the dose limit of 300 mGy (a 95% upper confidence limit), which is lower than the lower limit level of medical triage for acute radiation syndrome (1 Gy).

The results corroborate the fact that no acute radiation syndromes were observed among the workers examined.

The estimated values were in good agreement with those of physically estimated doses by personal dosimeters.
2) Translocation analysis by fluorescence in situ hybridization (M-FISH and 3-color FISH)

    Our tentative results suggest the frequency of translocations is considered to be 1.5 times higher in the workers than in the controls.

3) On this occasion, the need for improved cytogenetic research strategies adopted for mass-casualty management was reconsidered.