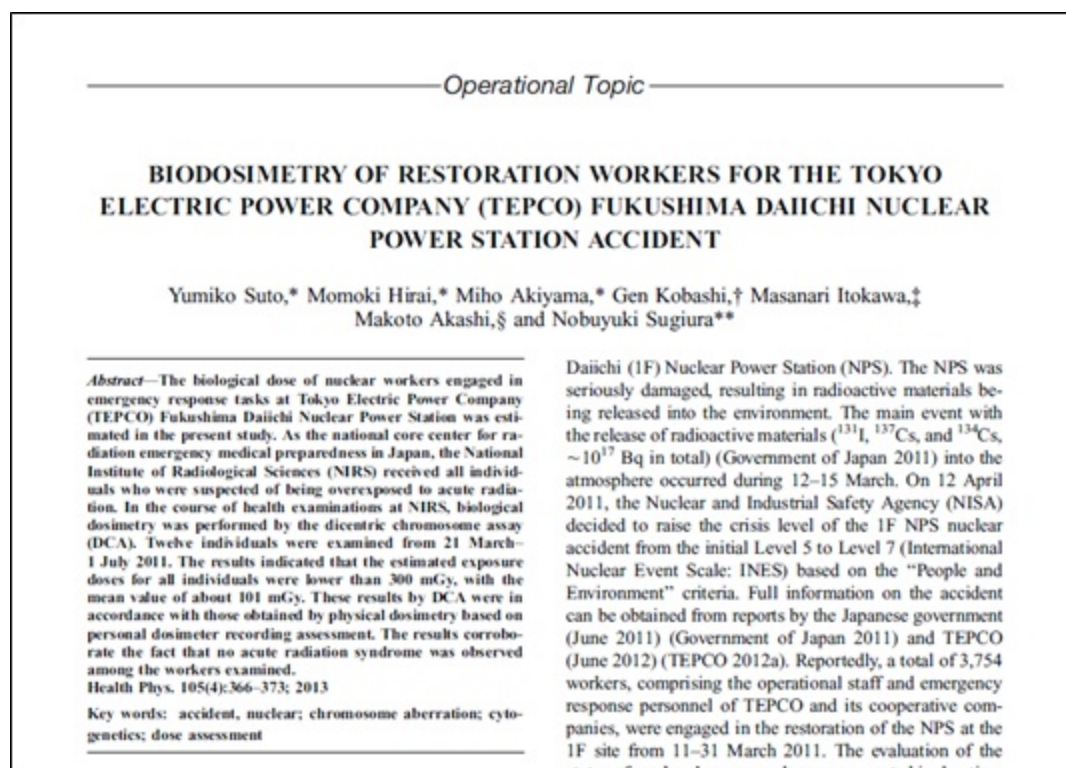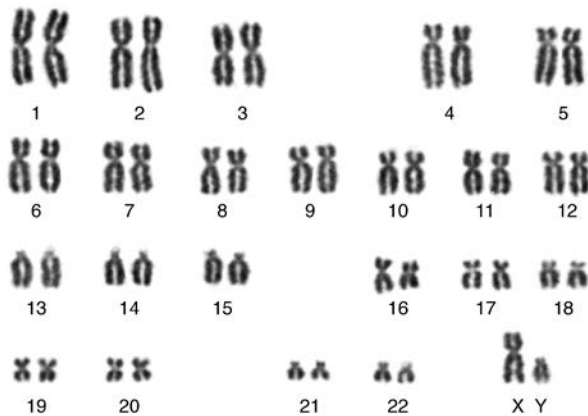# Biodosimetry of Restoration Workers for the Tokyo Electric Power Company (TEPCO) Fukushima Daiichi Nuclear Power Station Accident
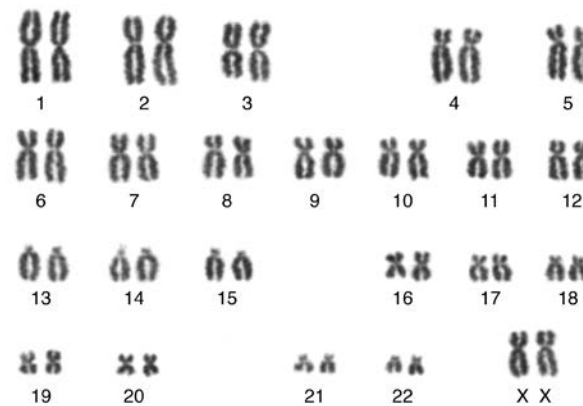

Health Physics 105(4): 366-373, October 2013.

National Institute of Radiological Sciences (NIRS)
Yumiko Suto
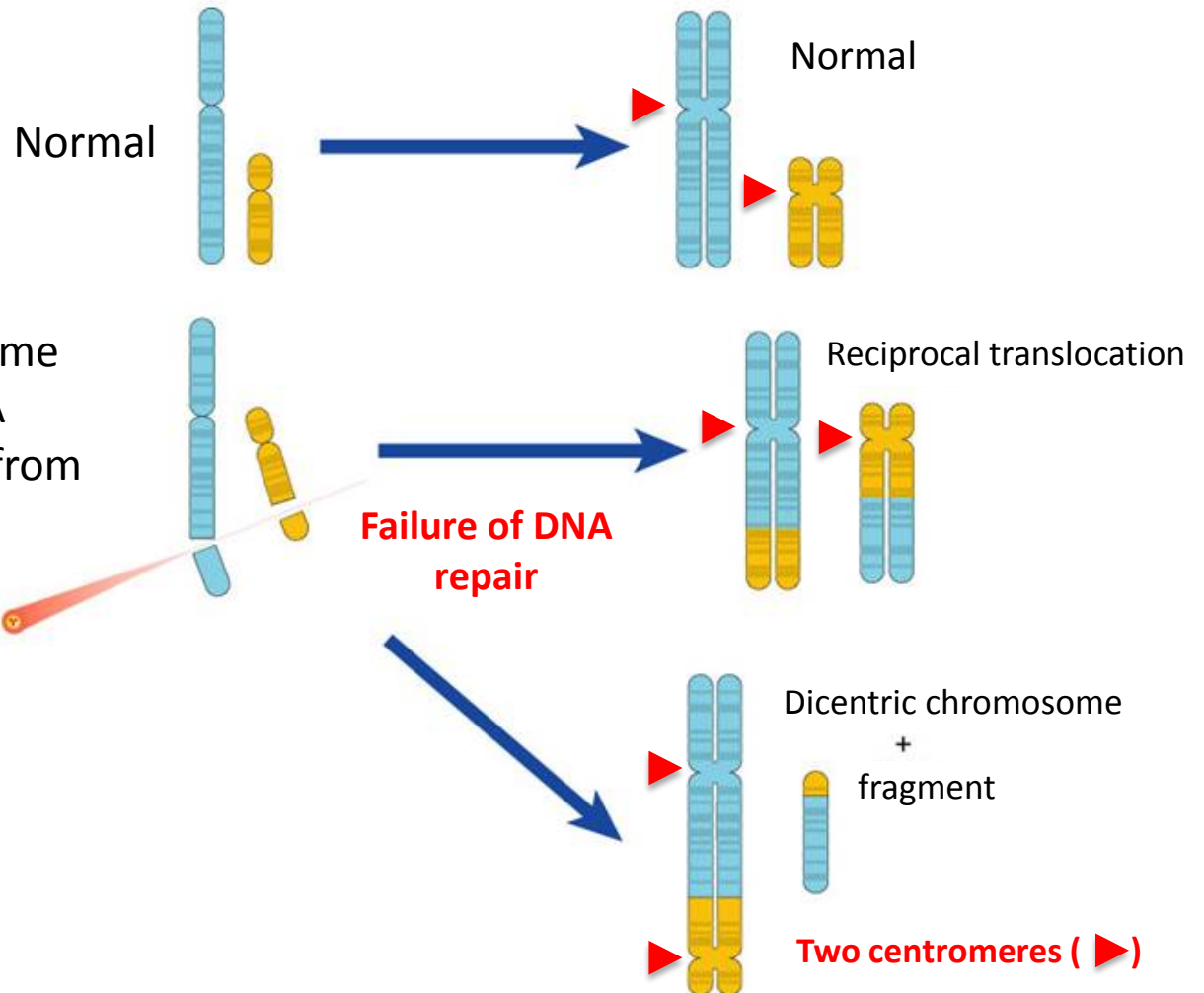
Normal male (2*N*=46, XY)   **Normal female (2*N*=46, XX)**

Normal human karyotypes

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Formation of chromosome aberrations as a result of radiation exposure

Normal

Normal

When a chromosome breaks due to DNA damage resulting from radiation...

Failure of DNA repair

Reciprocal translocation

Dicentric chromosome
+
fragment

Two centromeres (▶)

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Examples of chromosome aberrations in peripheral blood lymphocytes experimentally exposed to radiation

Dicentric chromosome

Ring chromosome

Calibration curve

[Suto et al., Health Physics, 2013]

$$Y = (0.00015 \pm 0.00017) + (0.0302 \pm 0.0044) \times D + (0.0588 \pm 0.0028) \times D^2$$

Y: Dicentric chromosome yield, D: Dose (Gy)

Table 2. Dose-response curve data for the dicentric chromosome assay (DCA).

Dose (Gy)	No. of cells	Dicentric equivalent counts[a]	Yield	V/m[b]
0	5,000	1	0.0002	1
0.1	5,003	11	0.0022	1.180
0.25	2,606	30	0.0115	0.989
0.5	2,107	68	0.0323	0.968
0.75	1,674	101	0.0603	0.980
1	1,112	102	0.0917	0.968
1.5	720	129	0.1792	0.993
2	415	128	0.3084	0.897
3	277	162	0.5848	0.776
4	117	122	1.0427	0.866
5	245	394	1.6082	0.816

[a]The number of centromeres minus one in a multi-centric chromosome equals dicentric equivalent count.
[b]Variance to mean ratio. The p values of goodness of fit test for the Poisson distribution at every dose point where $p > 0.05$, except for 0.1-Gy dose point ($p < 0.05$) at which one cell possessing two dicentrics was unexpectedly observed.

Dicentric chromosome yield vs Exposure dose (Gy)

The frequency of chromosome aberration and the dose are mathematically related to each other.
→ If a calibration curve is created in advance by an in vitro irradiation experiment, it will be possible to assess the dose of exposed patients and people subject to medical exposure and occupational exposure.

NIRS Biodosimetry System (As of 2011)

Time
Day 0 — Occurrence of a nuclear emergency or radiation exposure accident Suspected as an exposed patient (Radiation Emergency Call System)

Age, gender, consumption of alcohol, tobacco and medicine, medical or occupational history of radiation exposure

Cytogenetic Dosimetry: Applications in Preparedness for and Response to Radiation Emergencies

IAEA

Interview survey sheet & letter of consent

Day 1 — Blood sampling, lymphocyte isolation and cell culture (48 h, first division)

3-10 mL

Based on the IAEA Manual, 2011, ISO 19238 and ISO 21243

Day 3 — Harvesting/fixation/chromosome preparations

Automatic metaphase detection / image analysis system

Triage-mode scoring (reporting the results to the physician in charge)

Full-mode scoring
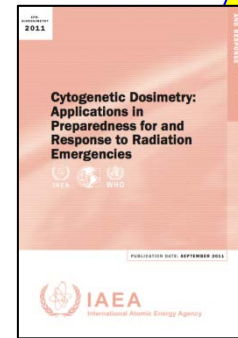Dose assessment (the results are entered in the medical record)

Day 4

To Day 7 — Test results are explained to the patient when the patient is seen by the physician the next time
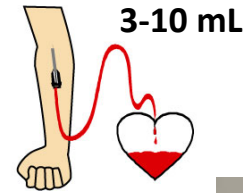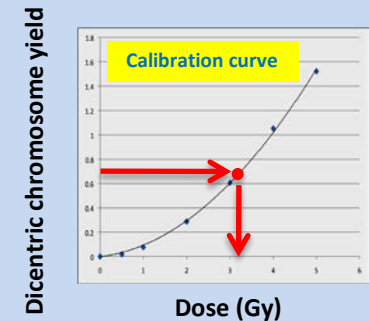
To FISH analysis
- Translocation
- Complex chromosome aberration, etc.

Dose assessment

Calibration curve

Dicentric chromosome yield

Dose (Gy)

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Table 3. Results of biological dosimetry of restoration workers for the Fukushima Daiichi Nuclear Power Station accident examined by the dicentric chromosome assay (DCA) and records of physical dosimetry detected with alarm personal dosimeters (APDs).

ID[a]	APD record (mSv)[a]	No. of metaphases scored	Dicentric equivalent counts (DIC)[b]	DIC per metaphase	Dose estimated by DCA (mGy)	95% LCL[c] (mGy)	95% UCL[d] (mGy)
Fu-3	179	1,003	7	0.00698	170	77	298
Fu-4	180	1,000	7	0.00700	171	77	299
Fu-5	173	1,000	5	0.00500	129	45	255
Fu-6	87	1,036	1	0.00097	26	0	137
Fu-7	38	1,005	4	0.00398	105	29	230
Fu-8	102	1,013	4	0.00395	105	29	229
Fu-9	unknown	1,035	6	0.00580	146	59	271
Fu-10	17	1,037	3	0.00289	79	14	199
Fu-11	4	1,042	1	0.00096	26	0	136
Fu-12	unknown	1,004	2	0.00199	55	3	174

[a]Detailed data and information of the alarm personal dosimeter (APD) record of each worker will be published elsewhere.
[b]The number of centromeres minus one in a multi-centric chromosome equals dicentric equivalent count.
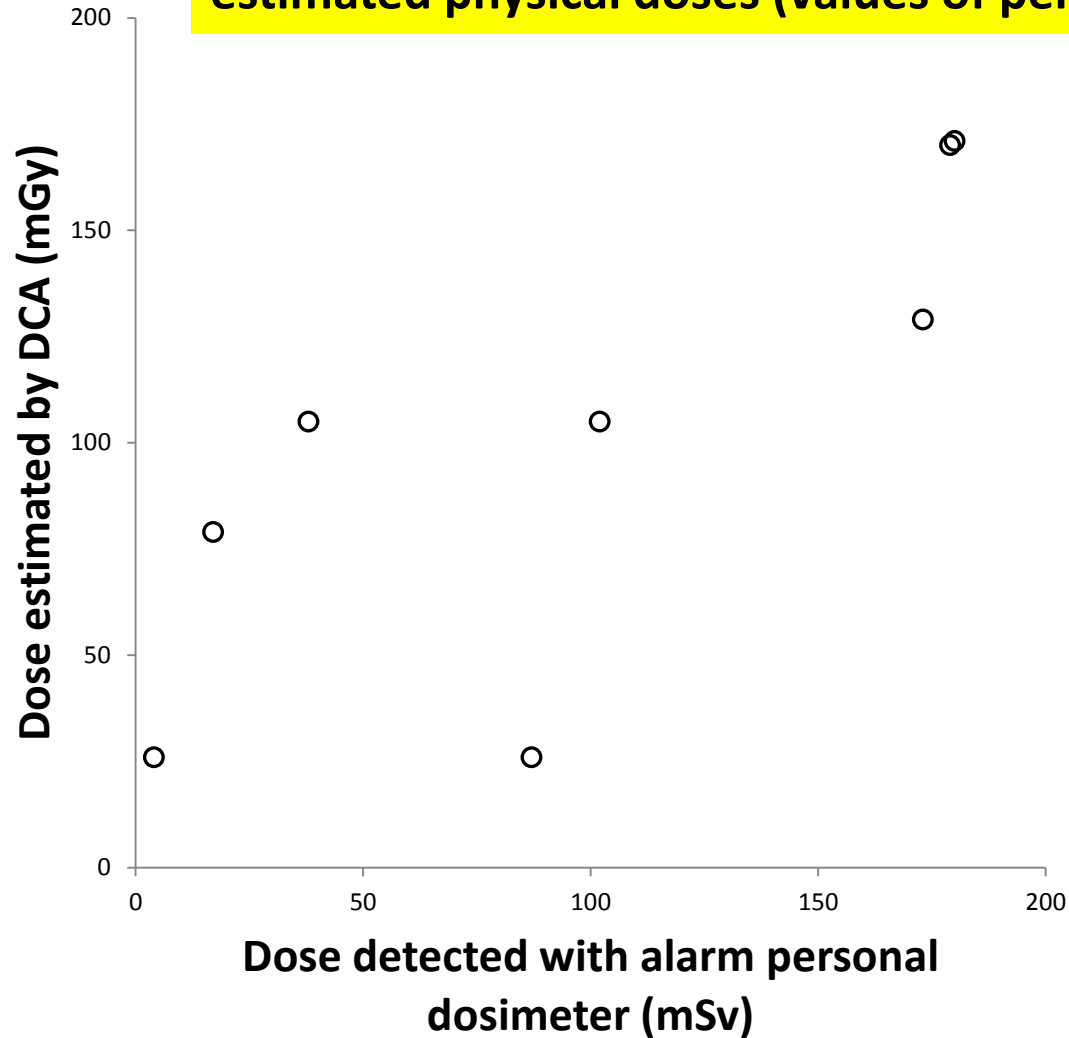[c]Lower confidence limit.
[d]Upper confidence limit.
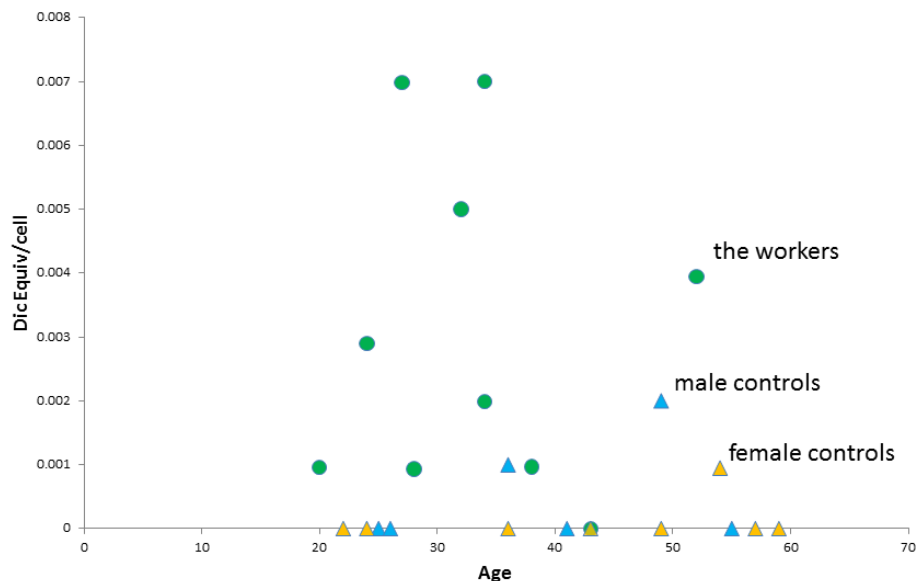
* < 300 mGy (95% UCL)

* None of the workers developed acute radiation syndrome.

The estimated biological doses coincided well with estimated physical doses (values of personal dosimeters).

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 ($p < 0.05$)

Summary

◆ The estimated doses for 10 restoration workers for the Fukushima Daiichi Nuclear Power Station accident were below 300 mGy (no acute radiation syndrome was observed).

◆ Good recovery was observed in the retesting (six workers) in the health checkup one year later.

◆ At present, analysis is conducted by using chromosome aberration in the form of translocation as an indicator, since it is suitable for a long-term follow-up survey.

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