

東電福島第一原発事故作業者の 染色体分析による線量評価

Operational Topic

BIODOSIMETRY OF RESTORATION WORKERS FOR THE TOKYO ELECTRIC POWER COMPANY (TEPCO) FUKUSHIMA DAIICHI NUCLEAR POWER STATION ACCIDENT

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Abstract—The biological dose of nuclear workers engaged in emergency response tasks at Tokyo Electric Power Company (TEPCO) Fukushima Daiichi Nuclear Power Station was estimated in the present study. As the national core center for radiation emergency medical preparedness in Japan, the National Institute of Radiological Sciences (NIRS) received all individuals who were suspected of being overexposed to acute radiation. In the course of health examinations at NIRS, biological dosimetry was performed by the dicentric chromosome assay (DCA). Twelve individuals were examined from 21 March–1 July 2011. The results indicated that the estimated exposure doses for all individuals were lower than 300 mGy, with the mean value of about 101 mGy. These results by DCA were in accordance with those obtained by physical dosimetry based on personal dosimeter recording assessment. The results corroborate the fact that no acute radiation syndrome was observed among the workers examined.

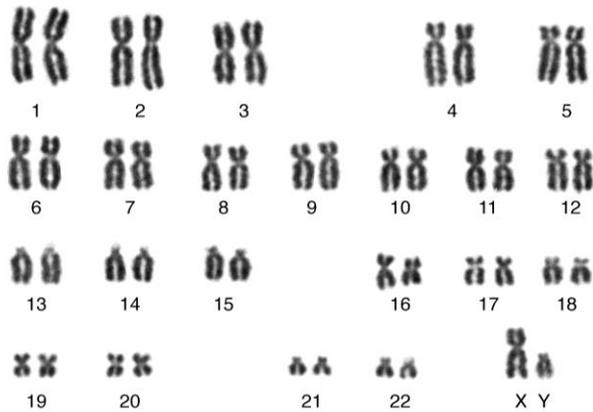
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Key words: accident, nuclear; chromosome aberration; cytogenetics; dose assessment

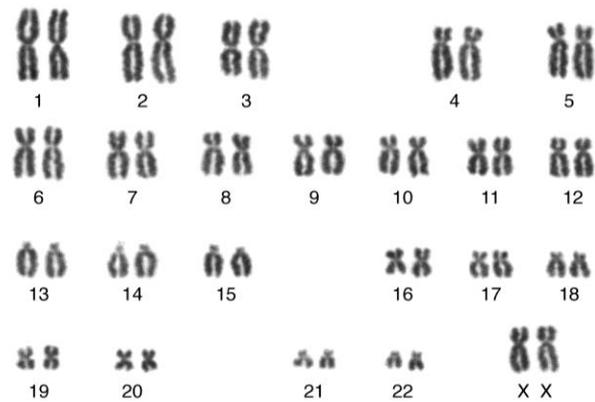
Daiichi (1F) Nuclear Power Station (NPS). The NPS was seriously damaged, resulting in radioactive materials being released into the environment. The main event with the release of radioactive materials (^{131}I , ^{137}Cs , and ^{134}Cs , $\sim 10^{17}$ Bq in total) (Government of Japan 2011) into the atmosphere occurred during 12–15 March. On 12 April 2011, the Nuclear and Industrial Safety Agency (NISA) decided to raise the crisis level of the 1F NPS nuclear accident from the initial Level 5 to Level 7 (International Nuclear Event Scale: INES) based on the “People and Environment” criteria. Full information on the accident can be obtained from reports by the Japanese government (June 2011) (Government of Japan 2011) and TEPCO (June 2012) (TEPCO 2012a). Reportedly, a total of 3,754 workers, comprising the operational staff and emergency response personnel of TEPCO and its cooperative companies, were engaged in the restoration of the NPS at the 1F site from 11–31 March 2011. The evaluation of the

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(独)放射線医学総合研究所
数藤由美子



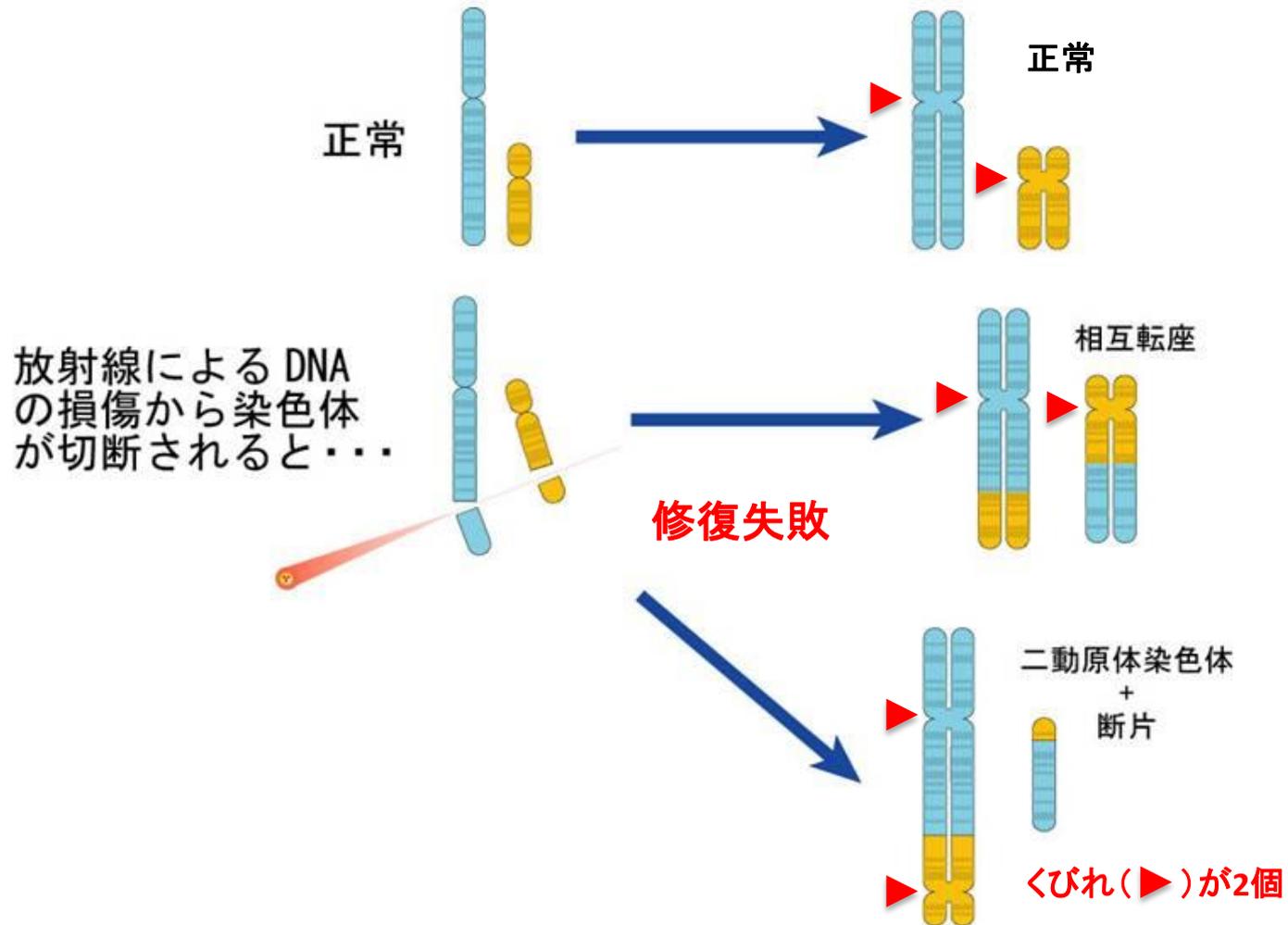
Normal male (2N=46, XY)



Normal female (2N=46, XX)

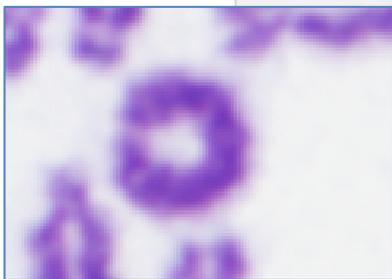
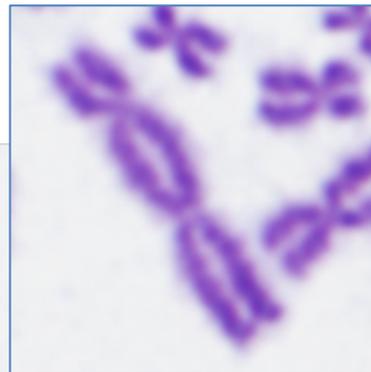
ヒト 正常核型

放射線被ばくによる染色体異常の形成



実験的照射をした末梢血リンパ球にみられる染色体異常の例

二動原体染色体



環状染色体

検量線

[Suto et al., Health Physics, 2013]

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

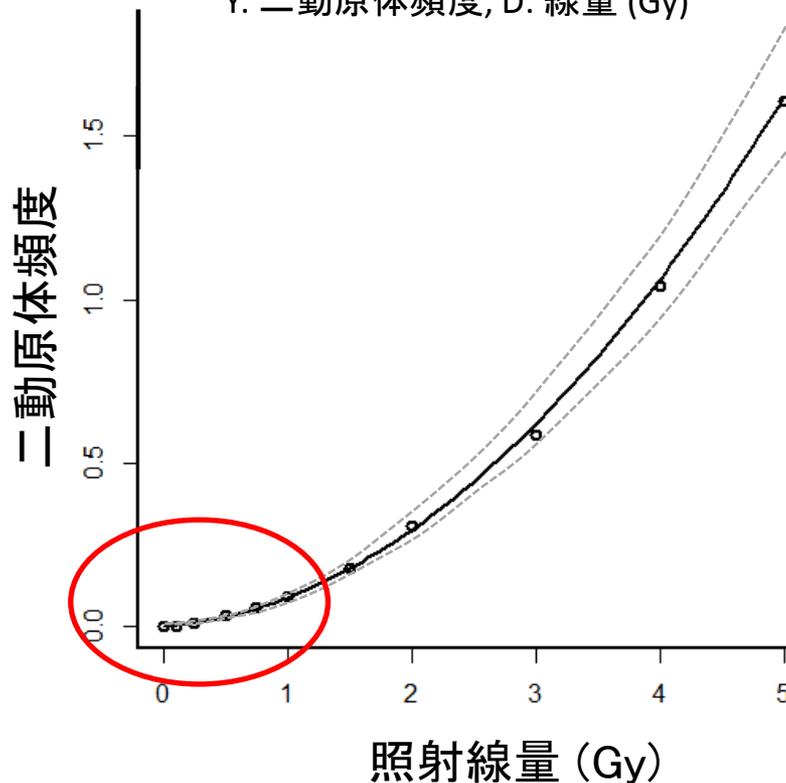
Dose (Gy)	No. of cells	Dicentric equivalent counts ^a	Yield	V/m^b
0	5,000	1	0.0002	1
0.1	5,003	11	0.0022	1.180
0.25	2,606	30	0.0115	0.989
0.5	2,107	68	0.0323	0.968
0.75	1,674	101	0.0603	0.980
1	1,112	102	0.0917	0.968
1.5	720	129	0.1792	0.993
2	415	128	0.3084	0.897
3	277	162	0.5848	0.776
4	117	122	1.0427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

^aThe number of centromeres minus one in a multi-centric chromosome equals dicentric equivalent count.

^bVariance 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.

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

Y: 二動原体頻度, D: 線量 (Gy)



染色体異常の頻度と線量には数理的な関係がある。

→ あらかじめ細胞の in vitro 照射実験で検量線を作製しておけば、被ばく患者や医療被ばく・職業被ばくを受けた人の線量評価ができる。

放医研の生物線量評価システム (2011年当時)

時間
Day 0

原子力災害・放射線被ばく事故発生
被ばく患者の疑い (緊急被ばく医療ダイヤル)

Day 1

採血, リンパ球分離, 培養 (48h, 1回目分裂)

Day 3

細胞の回収・固定・染色体標本作製

自動検出顕微鏡画像解析システム

トライージ・スコアリング (結果を担当医に報告)

Day 4

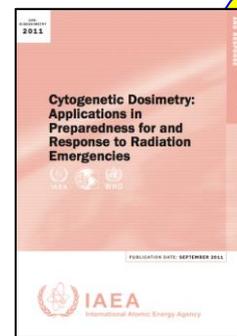
本スコアリング
線量評価 (結果をカルテに記載)

次回来院時
患者に検査結果を説明

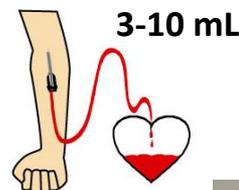
高精度 FISH 解析へ
・転座
・複雑な染色体異常, etc.

年齢・性別
飲酒・喫煙・薬
医療被ばく歴
職業被ばく歴

聴き取り
調査票
&
同意書



IAEA Manual, 2011, ISO 19238, ISO 21243 に準拠



線量評価

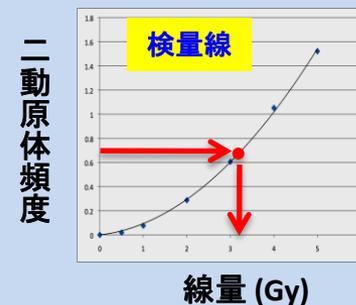


Table 3. Results of biological dosimetry of restoration workers for the Fukushima Daiichi Nuclear Power Station accident examined by the dicentric chromosome assay (DCA) and records of physical dosimetry detected with alarm personal dosimeters (APDs).

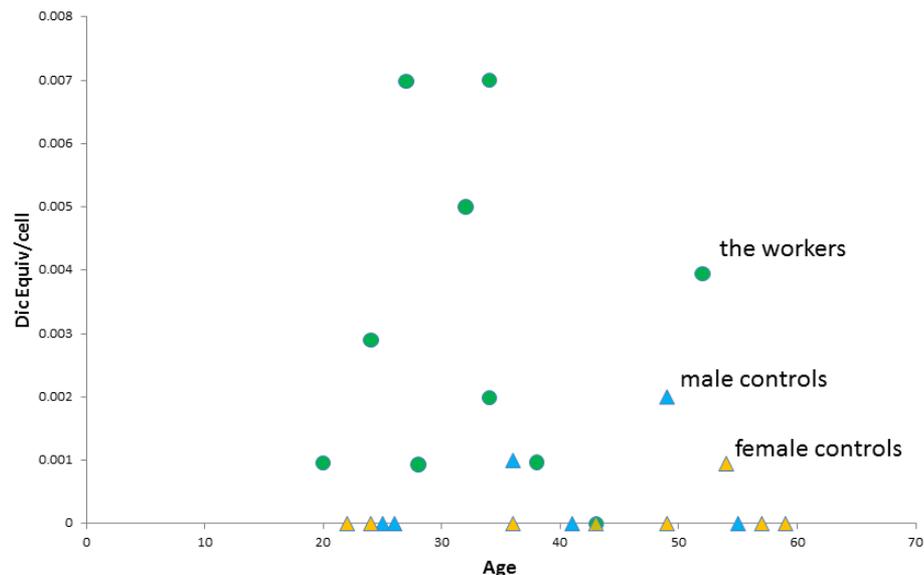
ID ^a	APD record (mSv) ^a	No. of metaphases scored	Dicentric equivalent counts (DIC) ^b	DIC per metaphase	Dose estimated by DCA (mGy)	95% LCL ^c (mGy)	95% UCL ^d (mGy)
Fu-3	179	1,003	7	0.00698	170	77	298
Fu-4	180	1,000	7	0.00700	171	77	299
Fu-5	173	1,000	5	0.00500	129	45	255
Fu-6	87	1,036	1	0.00097	26	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

^aDetailed data and information of the alarm personal dosimeter (APD) record of each worker will be published elsewhere.

^bThe number of centromeres minus one in a multi-centric chromosome equals dicentric equivalent count.

^cLower confidence limit.

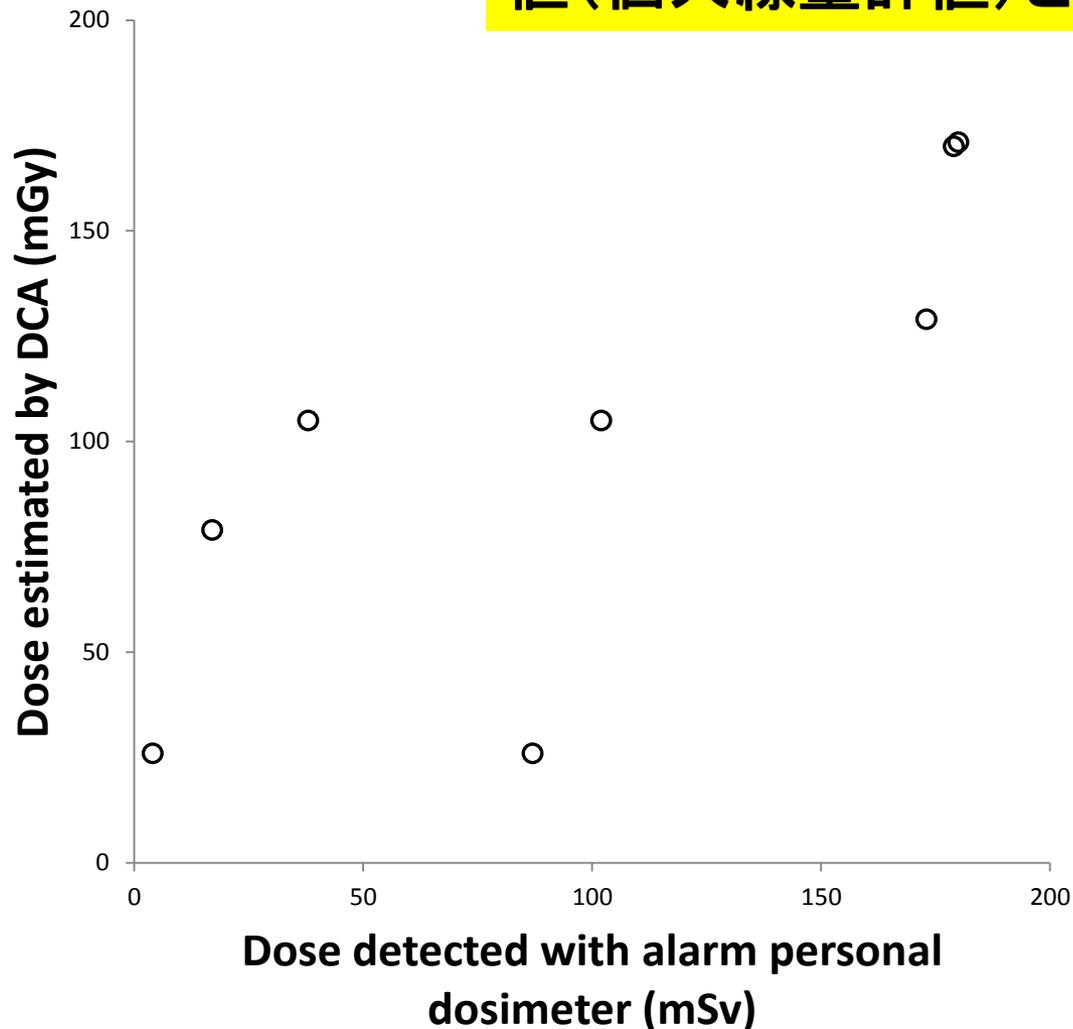
^dUpper confidence limit.



* < 300 mGy (95% UCL)

* 急性放射線症候群の発症者なし

生物線量推定値は物理線量評価の値(個人線量計値)とよく一致した。



The linear regression was obtained:

$$[\text{physical dose (mSv)}] = [\text{biological dose (mGy)}] \times 1.032 - 7.067 \quad (p < 0.05)$$

まとめ

- ◆ 福島第一原発事故の作業員12名のうち、10名の推定線量は 300 mGy 未満であった（急性放射線症候群はみられなかった）。
- ◆ 1年後健診における染色体再検査（6名）で着実な回復がみられた。
- ◆ 現在は長期追跡調査に適した転座染色体異常を指標にした解析を進めている。