(3) Historical Review of 23 Japanese Fishermen Accidentally Exposed to Radioactive Fallout on 1st March 1954

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I. Introduction

More than forty one years have passed since the 23 Japanese fishermen were accidentally exposed to radioactive fallout following the U.S. test detonation by a powerful thermonuclear device called "Bravo" at Bikini, March 1, 1954. Besides Japanese fishermen 239 Marshals and 28 Americans were exposed to the same sort of fallout at the almost same time. As Dr. Conard described, "this was the first time that a human population had been seriously exposed to radioactive fallout and carefully documented findings have formed an important basis for action in other types of accidents involving radioactive fallout, the most notable being the recent reactor accident at Chernobyl in Russia "

According to the BNL report, "the device, Bravo, in the Castle Series of tests at Bikini resulted in a serious fallout accident. The yield was about 17 megatons, considerably greater than expected, and an unpredicted shift inwinds in the atmosphere caused the radioactive cloud to drift over and deposit fallout on several inhabited atolls to the east "

The Japanese fishermen, aged 18-39, saw a huge red light in the west at 3:50 a.m (Japanese Time) while they were fishing tuna, and heard a few dull sounds several minutes later. The location of the vessel was long. 16658'E. and lat. 11 53'N. where the distance from the explosion centre was about 170 km At about 7:00 a.m. white ashes began to fall on the vessel, which continued for about 41/2 hours. They gave up fishing and returned to their base "Yaizu" on 14 March 1954.

After landing, all the fishermen were found to have been injured by the fallout They were hospitalized by 28 March, 7 of them to the Tokyo University Hospital, and the other 16 patients to the First National Hospital of Tokyo. They were discharged from both hospitals in May 1955, except one fatal case that died on 23 September 1954, i.e. the 206 day after detonation. After discharging, the follow-up studies have been performed on an annual basis. The number of persons who accepted the examination has been 10-20 in each year.

II. The Reproduction of Fallout Exposure

A try to reproduce the scene of exposure to fallout was performed in cooperation with the fishermen in August 1954. The diameter of original fallout ranged mainly 100~400 μm. The chemical composition of the powder is shown in Table 1.

Powder made from the same sort of non-radioactive coral reef was used. Photo 1 shows the scene of most intense period. At these time the fishermen were unable to keep their mouths and eyes open. Their footprints were clearly visible on the deck covered by the fallout (Photo 2) Clothes of the fishermen were cotton shirts, rubber boots, rubber apron, cotton glove, and they covered by cap (Photo 3). Photo 3 shows the white materials. It seems that the fishermen were unexpectedly well protected from β-ray irradiation.

III. Analyses of Fallout

The results of radiochemical analysis of fallout brought by the fishermen were performed at several laboratories. The data from Prof. Kimura's Laboratory of University of Tokyo proved 27 nuclides by 26 March. Rare-earth elements and uranium constituted about 50% and 20% of the gross beta activity respectively.

The specific activity of fallout was 13.69MBq/g on 23 April 1954. By extrapolation of this data, the specific activity of fallout at 7·00 a.m. on 1 March was estimated as 51.8GBq/g.

IV. Estimates of Radiation Dose

The fishermen were irradiated in the following ways on the vessel for two weeks;

1) from radioactive fallout adhered to the body surface
2) externally from the fallout deposited in the cabins, on the deck, etc.
3) internally from the incorporated radioactive materials.

IV-1. External Doses

External doses were estimated with the following surveys:

1) From the results of a reproduction of fallout exposure, a rough quantitative estimate of fallout on the deck was made.
2) Then, the measurement of dose rate at many places of the vessel were done at Yaizu repeatedly. From these data, the dose rate during the navigation was calculated.
3) The movements of each fishermen on the vessel were followed per every one hour.

Table 2 shows the estimated doses for two weeks. Biological effects by these dose will be equivalent to that of about half of dose in the case of single exposure.

IV-2. Internal Exposure

The internal deposition of radioactive materials was proved by the existence of radioactivity in urine, in thyroids, and in several organs of one fatal case.

(1) Radioactivity in Urine

Urine samples of the fishermen were collected and transferred to the Health and Safety Laboratory of U.S. AEC for radiochemical analysis. According to the information from Prof. M. Eisenbud of HASL, significant amount of radioactivity were found in urine samples at about four weeks after the initial exposure (Table 3). The radioactivity decreased rapidly, and about 4 months later the activity became barely detectable. The initial skeletal deposit of Sr-89 was estimated to be 18.5-185kBq.

(2) Radioactivity in the thyroid

External countings of radioactivity in the thyroid glands were performed on seven fishermen hospitalized in Tokyo University Hospital. From these observations the effective half-life of Iodine-131 on the patients counted two or three times was estimated as 4.8 - 7.0 days (cases T-2, T-6, T-7 and T-8).

The integrated doses from I-131 were approximately 0.2 - 1.2 Gy. Besides I-131, other iodine isotopes (I-132, I-133, I-135) may have been absorbed. Among them mainly I-133 and I-135 contributed to the thyroid irradiation. However, the dose estimate by these isotopes were very difficult. Assuming that the fishermen inhaled each radioiodine isotopes at 5 hrs after explosion, the thyroid dose by incorporated iodine were approximately 0.80 - 4.5 Gy. Considering the each external dose for 14 days, total thyroid dose may be 3.0 - 10 Gy (Table 4).

V. Progress of Clinical Observations and Laboratory Tests

V-1. Signs and Symptoms

Soon after the accident, prodromal syndrome and conjunctivitis were observed These were followed by skin lesions and epilations (Fig.1).

V-2 Skin Lesions

Skin lesions due to beta radiation occurred in the sequence of erythema, edema, vesicle, erosion and ulcer or necrosis mainly at the uncovered surface of the bodies.

Epilations were observed in 18 fishermen on occipital area.

However, complete epilation was seen in another 2 men who did not wear hats at the time of ashes-fall (Photo 4). Wooly hair, eyebrows, eyelashes, beard, axillary hair, and pubic hair were proved to have some radioactivity but were not epilated.

Acute skin lesions recovered in a few months. However, neurotic area had remained in one case (Photo 5). Residues of skin lesions are observed in the navel area and on the anterior surface of the ears, where atrophy of epidermis, pigmentation, depigmentation and capillary dilatation are macroscopically noted in 9 cases. However, these findings are becoming not apparent year by year and hard to observe at present in most of them. No sign of skin cancer is observed. Fig 2 shows the contaminated and injured area schematically.

V-3 Haematologic changes

Haematologic examinations were begun on 16 March 1954, i.e. 16 days after initial exposure.

(1) Leukocytes

The total numbers of leukocytes decreased gradually, showing the lowest count at about four to seven weeks after the exposure In 5 cases the counts was less than 2,000/mm^3, in 13 it was less than 3,000, and in 5 cases it was less than 4,000 In one case the number fell to 800.

A reverse correlation was found between these minimum count of total leukocytes as well as neutrophils and individual external radiation dose (Fig.3).

Lymphopenia was noted at two to eight weeks in all cases.

After eight weeks, recovery was clear. At that time in some cases immature neutrophils slightly appeared in peripheral blood. Most cases showed remarkable eosinophilia (maximum more than 40%) at that time, which continued several years in some cases with gradual depression. In a few cases, monocytosis was observed.

(2) Platelets

Platelets count decreased (15,000~100,000/mm^3). Slight coagulation disturbances were observed in several cases.

(3) Erythrocytes

A few cases showed slight anemia accompanied by remarkable depression of reticulocytes.

The colour indices were over 1.0. The Price Jones curves were displaced to the right of normal ones, and returned to normal after one year.

(4) Bone Marrow

In severe cases the bone marrow revealed hypoplasia at 4th~7th week (Fig.4), but it changed to slight hypoplastic and then became almost normoplastic. In some cases, the coexistence of hypoplastic and normo-or hyperplastic area was observed on the way of recovery.

(5) Morphological Abnormalities

Several morphological abnormalities, e.g. abnormal granules in lymphocytes or neutrophils,

vacuoles in various leukocytes and megakaryocytosis, giant nuclei and hypersegmentation of neutrophils, binuclear lymphocytes, abnormal mitosis of erythroblasts etc. were observed for about one year, especially at the critical and recovery stages.

(6) Recovering Process of Blood Cells

The cumulative distribution curves of the number of leukocytes, erythrocytes and platelets were displaced to the left of normal ones at the critical stage

Though the erythrocytes and platelets curves lay on the normal Japanese ones after two years, the leukocyte curve was still displaced slightly to the left of normal after six years (Fig.5, 6).

The changes of percent depression from normal average values of leukocytes and platelets are shown in the (Fig.7), which indicates the general tendency of haematopoietic recovery.

The assay of CFUc in bone marrow was performed with soft agar culture method at 24 years after exposure. Depression of CFUc were observed in three cases.

V-4. Chromosome Observations

Follow-up of chromosome observations in blood cells has been performed since 1964. In the 1969 examination the close correlation between the percentage of Cs cells and individual external dose shows the cytogenetic data observed in ten cases that have been examined three to five times since 1964. In comparison with the results obtained in 1967 and 1970 survey the frequency of dicentrics plus ring seems to be decreasing. On the other hand Cs cells remained fairly constant at the frequency of 2~3%.

In bone marrow cells, chromosome abnormalities, which were only stable aberration, were observed. In some case clone formation was proved.

V-5. Spermatopoiesis

The examinations of spermatopoiesis were performed on 21 cases among 23 cases, including 1 autopsy case.

The number of spermatozoa was depressed by June except five cases, which showed the depression at the next examination about four months later. Reduced motility of spermatozoa and increased percentages of morphologically abnormal spermatozoa were also noticed. Indications of recovery were seen at approximately two years after exposure, and most of the patients had healthy children (Table 5).

The testicle of the fatal case, who had three daughters at that time is remarkably atrophic and possessed the interstitial tissue composed of loosely arranged connective tissue. The basement membrane of the seminiferous tubules shows marked thickening Spermatogonia are decreased in number and in some are as they are completely lacking. No sperma is encountered within the lumen of either seminiferous tubules or epididymis. Serotoli's and Leidig's cells are essentially well preserved.

V-6 Ophthalmological Findings

In the evening of the day of exposure, lacrimation, eye wax, and pain in the eyeball annoyed most of them. Two weeks later, severe photophobia, hyperemia and edema of the conjunctiva were added to the above mentioned signs. By the treatment of ophthalmologist these signs disappeared before the middle of April.

Although slight lenticular opacities have been observed in several cases, no characteristics of radiation-induced cataracts as observed in some of A-bomb survivors.

V-7. Thyroid Findings

Thyroid disturbances of exposed Marshals were reported by Dr. R.A. Conard et al. However, in Japanese cases, in one case a nodule of rice corn size was found at left edge of thyroid in 1965. However, it was not observed at next year's examination. Since then it has never appeared. Though he showed lower border line value of T-3, any significant clinical changes were not observed.

V-8. Liver Functions

Since 1975, 5 cases died due to liver cancer with cirrhosis. Some of them did not participate in annual examination for a long time, and somebody drank much. Viral hepatitis could not be ignored but was negative. Taking above mentioned situation into consideration, it is difficult to prove the existence of a relationship between the exposure and liver damage. Besides these, one died due to traffic accident.

VI. Social Impacts in Japan After Accident

The accidental exposure of the 5th Fukuryu-Maru (Lucky Dragon) caused big social impacts

These are summarized as follows:

1) The accident proved that nuclear bomb will be able to bring about severe damages on many people, not with blast and heat but with radioactive fallout, even though at distant area from explosion point

2) The Japanese governmental authorities realized the importance of systematic research on radiation effects on human being. In consequence of it, National Institute of Radiological Sciences, and chairs or research institutes of radiation effects in several universities were established.

3) Researches and investigations on radioecology and radioactive contamination of environment were started.

4) It was recognized generally that periodical medical examinations of A-bomb survivors in not only Hiroshima and Nagasaki but also the whole country were indispensable. Furthermore, the supportive law for A-bomb survivors was consolidated.

5) In 1950s and 1960s laws related to radiation protection were established.

6) The large scale campaign for ban of nuclear weapons grew among the general public spontaneously.

VII. Summary

1) The present conditions of the Japanese fishermen recognized which are considered to be the effects of radiation are residual beta burns in several cases and the increase of chromosome abnormalities in peripheral lymphocytes and bone marrow cells. Hematologic changes have almost recovered. Radiation-induced cataract has not been proved.

However, the further investigation should be continued to detect subtle changes

2) Some social impacts in Japan due to the Bikini accident was described briefly

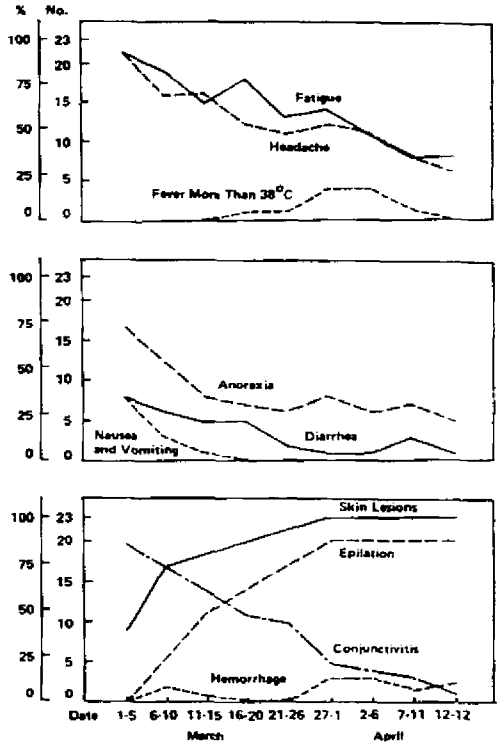


Fig.1 Symptoms and signs in the early stage.

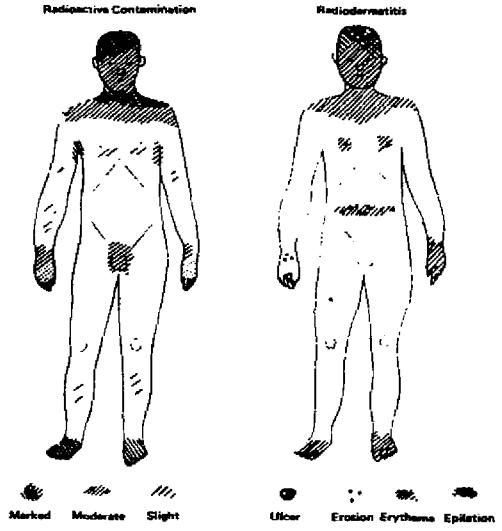


Fig.2 Contamination and lesions of body surface.
(By coutesy of Dr.K.Ishikawa)

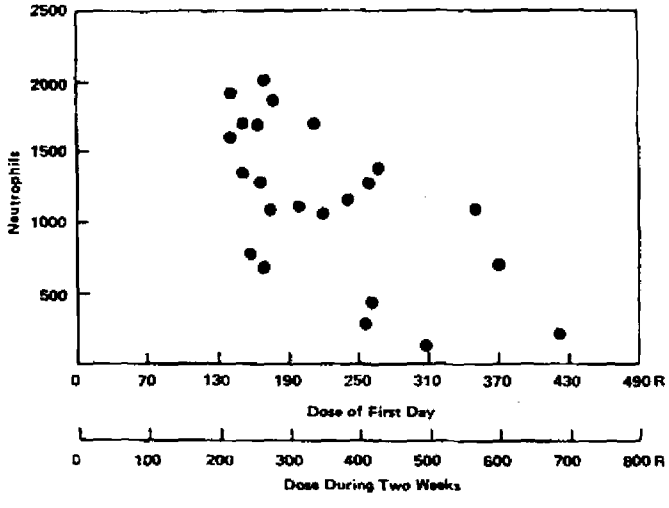


Fig.3 Correlation between minimum count of neutrophils and dose.

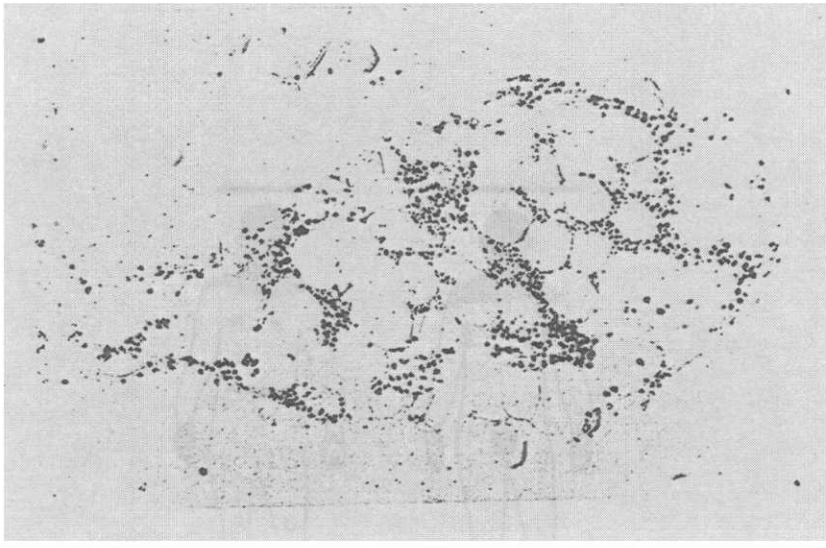


Fig. 4 Hypoplastic bone marrow. K-9, 32 days post detonation, 125 x .

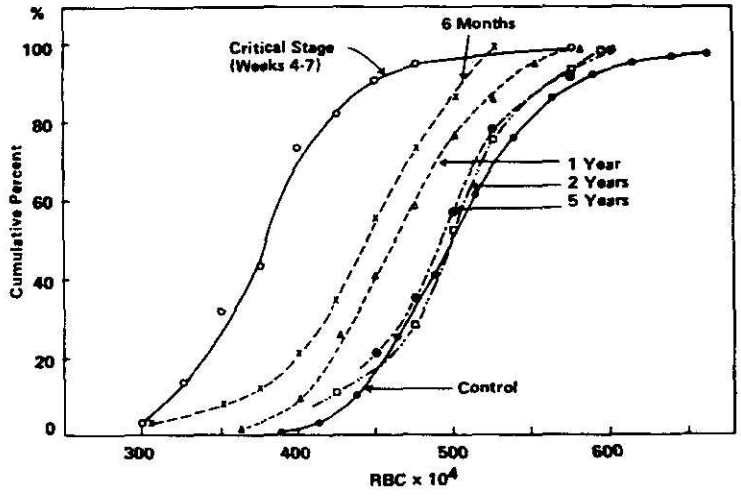
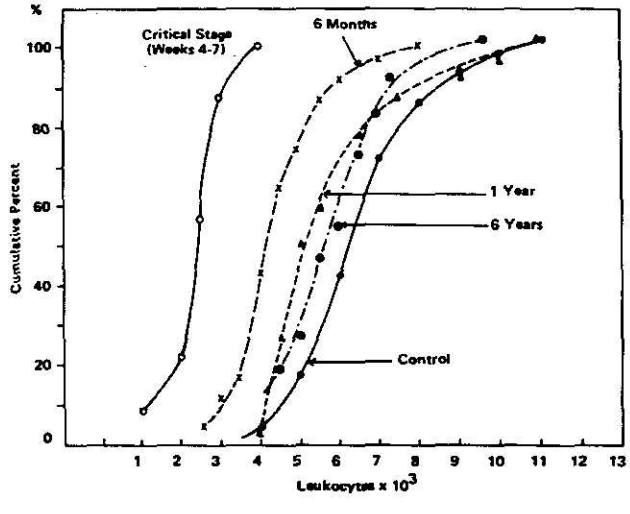


Fig. 5 Cumulative distribution curves of erythrocytes count.



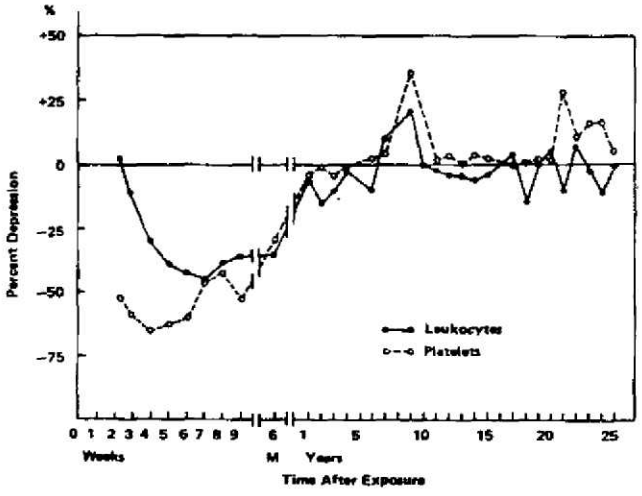


Fig.7 percentage depresion of leukocytes and platelets count.

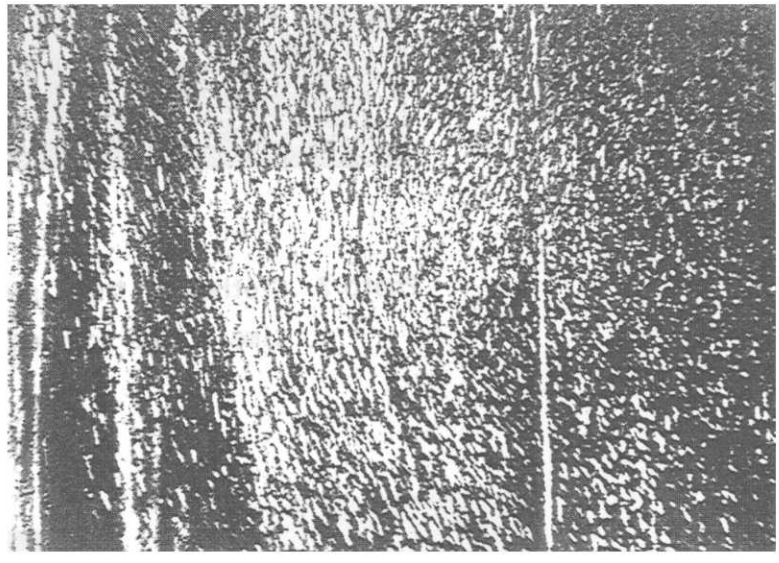


Photo 1. The falling ashes(experimentally reproduced)

Photo 2. Footprints on the deck(experimentally reproduced)

Photo 3. Clothes of the fishermen at the time of the accident

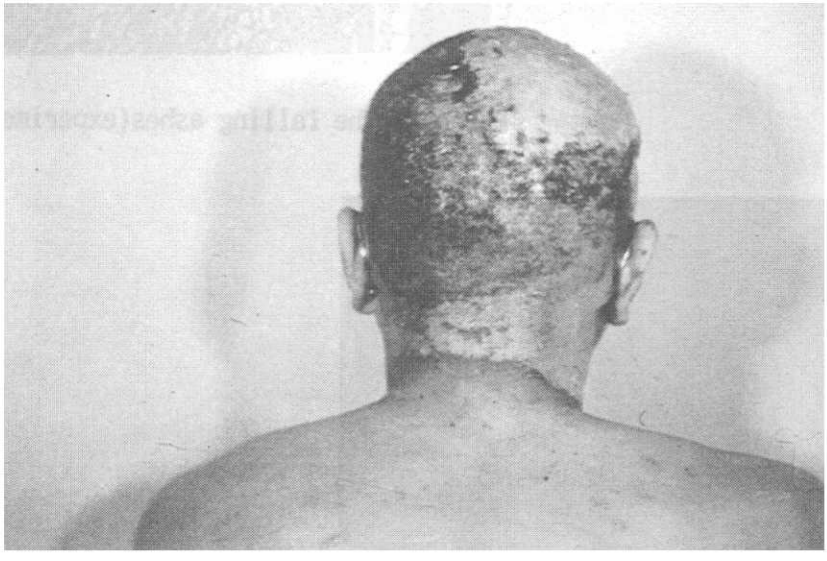


Photo 4. Wound observed in a patient who did not wear a hat at the time of accident.

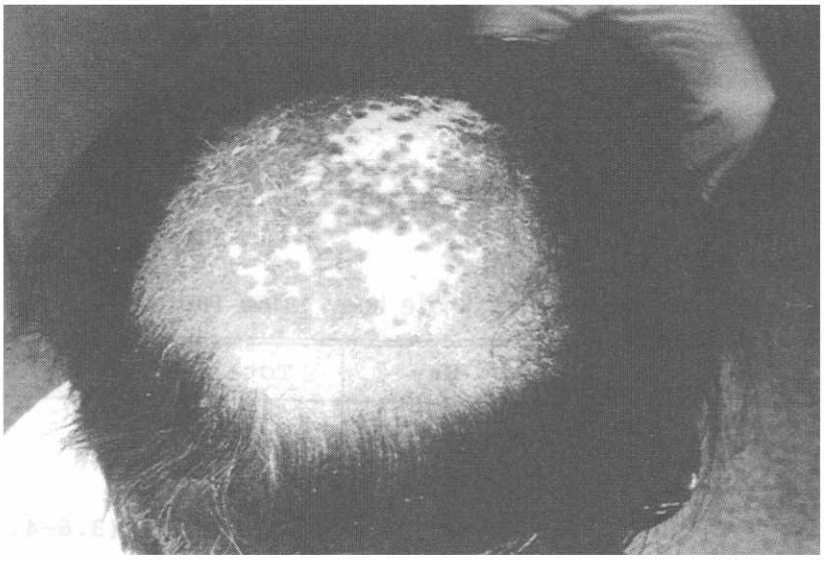


Photo 5. Neurotic area remained in a patient after acute skin lesions.

Table 1. Chemical composition of ashes

(25 May 1954)

	%
CaO	55.2
MgO	7.0
CO_2	11.8
H_2O (by difference)	26.0
	100.0

Table 2. Estimated doses of whole body gamma radiation.

Subject No.	1st Day	Total	
T- 1	2.4-2.9 Gy	4.5-5.0 Gy	
T- 2	2.1-2.6	3.9-4.4	
T- 3	1.5-2.0	2.6-3.1*	(3.6-4.1)
T- 5	4.0-4.3	6.6-6.9	
T- 6	1.3-1.8	2.0-2.5	
T- 7	1.4-1.9	2.2-2.7	
T- 8	3.1-3.6	5.2-5.7	
K- 1	1.9-2.2	3.1-3.4	
K- 2	1.3-1.8	2.0-2.5	
K- 3	1.4-1.9	2.3-2.8	
K- 4	1.2-1.7	1.9-2.4	
K- 5	1.4-1.9	2.2-2.7	
K- 6	1.8-2.3	3.0-3.5	
K- 7	2.3-2.8	3.4-3.9	
K- 8	2.2-2.7	3.8-4.3	
K- 9	3.1-3.6	5.5-6.0	
K-10	1.4-1.9	2.3-2.8	
K-11	1.2-1.7	1.7-2.2	
K-12	1.0-1.5	1.7-2.2	
K-13	2.5-3.0	3.7-4.2	
K-14	4.2-5.0	5.1-5.9	
K-15	1.4-1.9	2.1-2.6	
K-16	1.2-1.7	1.9-2.4	

*T-3 put the fall-out material close to his bed.
Therefore, about 1.0 Gy should be added in total .

Table 3. Radiochemical analysis of urine.

Case	Date of Sample	Total Products[a]	Total Activity/24 hr[b]	Percent Sr^{89}	Percent Ba^{140}
T-1	3/29/54	6,100	3,540	5	8.2
T-2	3/29/54	6,000	3,360	0.4	4.0
T-3	3/29/54	8.400	5.380	9	4.6
T-5	3/29/54	54,000	76,680	6.9[c]	
T-6	3/29/54	1,300	1,170		
T-7	3/26/54	550	495	18[c]	
T-8	3/26/54	230	300	21[c]	

[a] Disintegrations per minute per liter.

[b] Disintegrations per minute in 24-hr specimen. Corrected as "per 24h" by Kumatori.

[c] Sr + Ba.

Table 4. Doses to thyroid gland. The weight of thyroid is assumed as 20g.

Case	Dose (Gy)		
	Incorporated Iodine	External	Total
T-7	0.76	2.2-2.7	2.96- 3.46
T-2	0.99	3.9-4.4	4.89- 5.39
T-6	3.04	2.0-2.5	5.04- 5.54
T-8	4.56	5.2-5.7	9.76-10.26

[a]The weight of thyroid gland is assumed as 20gm.

Table 5. Marriage and children.

Case	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	Age in March 1954
T-1	M(2)[a]		A	f											27
2	M(3)														38
3	M(2)														28
5	M(4)														30
6	M(3)			f											28
7		M						f							27
8						M									26
K-1		M	m		m								m		22
2				M				f			f				25
3					M	f		m		m		f			25
4		M			m			f							24
5						M			m				f		22
+6		M		m	A	f		f		f					26
7									M			m	f		18
8				M						m					23
9							M	f		m					22
10			M	m		f								m	24
11				M					f			f			23
12							M			m					18
13			M			f		f							22
+14	M(3)														39
15	M(2)				f										27
16						M	S	f	m						20

[a] M, marriage; ( ), no. of children at the time of exposure; m, male; f, female; A, abortion; S, stillbirth; +, fatal case.