Uncertainties under Emergency Conditions in Hiroshima and Nagasaki in 1945 and Bikini Accident in 1954

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INTRODUCTION

The uncertainties under emergency conditions, in particular, the uncertainties in estimating dose-effect relationships in Hiroshima and Nagasaki have been repeatedly discussed by Nishiwaki since the first meeting on the medical and pathological effects of atomic bombings held at the Department of Pathology of the late Professor Ryojun Kinoshita, the then Professor of Pathology, Faculty of Medicine of Osaka Imperial University in 1945. Prof. Kinoshita was the first pathologist who guided the US experts to Hiroshima and Nagasaki when they visited Japan as the first American Medical Investigation Team of the Atomic Bomb Casualty Commission. Nishiwaki, the then assistant of department of physics of Osaka Imperial University, had the pleasure of working as the interpreter for the discussion at this first meeting. Prof. Kinoshita, later, became visiting professor at the Medical School of the University of California, Los Angeles, USA.

The survivors of atomic bombings and those who visited Hiroshima and Nagasaki immediately after the atomic bombing could have been subjected to a number of other possible noxious effects in addition to atomic radiation. Hospitals, laboratories, drugstores, pharmaceutical works, storehouses of chemicals, factories, etc. that were situated close to the hypocenter were all completely destroyed and various mutagenic, carcinogenic or teratogenic substances must have been released; many doctors, nurses and chemists were killed. There was no medical care and no food in the region of high dose exposure and the drinking water was contaminated. There would have been various possibilities of infection. Mental stress would also have been much higher in the survivors closer to the hypocenter. It is confusing which factor played a dominant role. In addition, there would be problems in accurately identifying the position of the exposed persons at the time of the atomic bombing and also in estimating the shielding factors. There may be considerable uncertainty in human memory under such conditions. It is also possible that there could have been a large storage of gasoline to be used for transportation of the army corps in Hiroshima. Therefore there is a possibility that various toxic substances, mutagenic or carcinogenic agents such as benzopyrene and other radiomimetic substances could have been released from various facilities which were destroyed at the time of the atomic bombing.

BACKGROUND INFORMATION

(I) Uncertainties in Hiroshima and Nagasaki (1-9, 13, 15, 18-24)

The enormous difference in dose rates between the atomic bombings and the radiation sources used for calibration experiments may also have some effect on some dosimetric systems or on some biological systems. Although it may be difficult to quantify some of these uncertainties, it is extremely important to keep all these and other uncertain factors in mind when analysing the atomic bomb effects of Hiroshima and Nagasaki.

In Japan, medical X-ray examination is widely used in schools, factories and companies. With certain diseases such as tuberculosis and some diseases of the lung and digestive systems extensive X-ray examinations may be conducted and periodically repeated. Survivors with a relatively low dose of high dose rate atomic bomb radiation must also have received some relatively low dose of low dose rate medical X-ray radiation. In other words, they must have received both high dose rate radiation and low dose rate radiation. There is a possibility of non-probabilistic uncertainties involved in estimation of the relative proportion of the two types of radiation and even greater uncertainties would be involved in the estimation of the organ doses.

In Hiroshima, it was reported by the anti-aircraft observation staff that the bomb was inclined quite a bit at the time of explosion. The angle of inclination was different from the estimation based on the film taken by the American plane. Hiroshima atomic bomb is a gun-type bomb, therefore the side of the bomb and the bottom and top of the bomb may have been made of different material. The top or the bottom of the bomb must have been made stronger. The neutron absorption by the side direction and that by the top-bottom direction may have been different because of the different composition of the material. Depending on the angle of the bomb at the time of detonation, the neutron and the neutron energy distribution may not have been uniform in all directions.

The measurement of the radioactivity induced by neutron in the sulphur used for insulation at the electric pole was also observed not uniform in all directions in case of Hiroshima. The Nagasaki bomb is an implosion type and therefore the construction material may be more or less uniform in all directions and the neutron distribution is also considered more uniform as compared with the Hiroshima bomb.

However, in Nagasaki, it seems to have been more difficult to estimate the dose of radiation accurately, because of the more mountainous terrain as compared with Hiroshima. In case of a person who was exposed on the third floor of the former Nagasaki Medical University Hospital, a reinforced concrete building located 691 meters from the hypocenter, the acute effects were slight diarrhoea and leucopenia. Many years later the person was still in good health. In this case, the estimated DS86 free-in-air tissue dose of gamma ray at a point 691 meters from the hypocenter was 32.80 Gy. The person donated shell buttons from the clothing he was wearing at the time of the bombing and a tooth extracted 37 years after the exposure to the atomic radiation. Based on these samples the gamma ray dose was estimated to be 1.80 Gy by Electron Spin Resonance spectroscopy (ESR). When the person was exposed to radiation, he was in the reinforced concrete structure and the walls and roof or ceiling acted as a shield. However, it seems to be difficult to estimate the distance of the radiation path in the concrete, through which the gamma ray passed and also, in addition to the direct radiation the degree of scattered radiation is difficult to estimate accurately.

In exploding an atomic bomb, in addition to ionizing radiation, strong non-ionizing radiation, such as infrared, ultraviolet light, visible light, electromagnetic pulse radiation, as well as heat and shock waves are produced. Combined with these factors, the action of ionizing radiation may be greatly enhanced.

Therefore, the possibility of the combined effects of all these direct factors and the indirect factors such as those mentioned above must be considered in interpreting the effect of the atomic bombing instead of ascribing all the effects solely to ionizing radiation.

In Hiroshima and Nagasaki, it was sometimes observed that in the same room of the same building some died and some survived. First, it was thought that it might be due to the individual differences. However, under the close examination of the position it was found that those who died were irradiated by strong visible light including ultraviolet and infrared in addition to the atomic radiation. At the meteorological observatory, some gentlemen who hid in the shadow at the instant of flash survived but those who were kept exposed to the strong light from the fireball died. Later it was found that the combined effects of skin burn and external irradiation by ionizing radiation caused high death rate with experimental animals (13, 16, 19).

Brooks, Evans, Ham and Reid (1952) conducted an experiment on combined effects of skin burn and ionizing radiation using dogs. When only 20% of the skin surface was burnt the lethality was 12%. When only 1 Gy (100 rad) of radiation was given to the dogs, the lethality was zero. When 20% skin burn and 1 Gy radiation were given, the lethality increased to 73%. Later it was found that the penicillin sensitive strain of bacteria was growing in the dead body of the experimental animal. When they gave penicillin to the dogs in addition to burn and radiation, then the lethality decreased to 14% (5).

Baxter, Drummond, Stephens-Newsham and Randall (1954) conducted an experiment with pigs. At 10 - 15% burn, the lethality was zero. When 4 Gy total body radiation was given, the lethality was 20%. When 10 - 15% burn plus 4 Gy radiation was given, the lethality increased to 90%, but the mortality was reduced by streptomycin (6).

Alpen and Sheline (1954) made an experiment with rats. When 31 - 35% was burnt, the lethality was 50%. When 2.5 Gy (250 R) whole-body X-irradiation was given the lethality was zero. At 5 Gy (500 R) radiation the lethality was 20%. At 31 - 35% burn plus 1 Gy (100 R), the lethality amounted to 65%. At 31 - 35% burn plus 2.5 Gy (250 R) the lethality was 95%. At 31 - 35% burn plus 5 Gy (500 R), the lethality was 100% (7).

According to Fujita, Kato and Shull, data on a total of 7,593 persons in Hiroshima who were in 2,518 wooden Japanese houses and exposed to A-bomb within 1.6 km from the hypocenter have been used to estimate the $LD_{50/60}$. The effect of radiation shielding for these people is relatively well-known in the revised dosimetry system DS86. A range of values were estimated varying slightly with the method of estimation. This range, deriving from DS86 marrow doses, and based on a linear fit to equally weighted estimates of the probabilities of death at various doses, is 2.3 - 2.6 Gy. A linear estimate in which the probabilities of death at the various doses are weighted by the inverse of their variances is somewhat lower, 2.2 Gy. These values may be under-estimations of $LD_{50/60}$ because of inclusion of deaths in the first day, and the severely injured (burns, traumata) who survived the first day but succumbed later to their injuries (14, 18).

There are still some discussions on the T65D and DS86 Dosimetry System. With T65 dose there are even lower estimates of $LD_{50/60}$ for Hiroshima, 1.3Gy by Silini and 1.54 Gy by Rotblat. This might be due to the various complicating factors in Hiroshima as mentioned above. It is difficult to say that the revised DS86 Dosimetry System is always better or more accurate than T65 dose. Every explosion is said to be different, even if it is made in the same way. In this respect, T65D and DS86 are two different estimations, only slightly differing from each other as compared with the range of large uncertainties of other complicating factors (13).

If one person in the family survives he could report the exact number of deaths in the family. However, if

the whole family or whole section or district is completely annihilated there is no one who can report the exact number of deaths. Intuitively, the A-bombing of Hiroshima and Nagasaki would appear to provide an unparalleled basis for the estimation of the $LD_{50/60}$. However, retrospective estimates of radiation-induced mortality following the A-bombing of these cities are plagued by three virtually insurmountable problems. First, there are no wholly reliable estimates of the number of individuals nor their age or sex who were exposed at a given distance or dose and hence no reliable estimate of the number at risk of death, save in selected circumstances. Even in these latter instances, the population at risk is unlikely to have been representative of the general population in age, sex, or possibly health status. Second, it is exceptionally difficult, if not impossible, to separate deaths due to exposure to ionizing radiation from those ascribable to other bomb-related causes, such as fire or the blast itself. The Joint Commission, for example, reported in its study of 20-day survivors that 48% of those surviving within 2,000 m had multiple injuries. Finally, other factors, such as age, sex, poor nutritional status and the occurrence of a devastating typhoon on 17 September 1945, undoubtedly contributed to the 60-day mortality rates; the contributions these factors have made to mortality, and hence to the obfuscation of the estimation of the $LD_{50/60}$ can only be conjectured.

(II) Uncertainties of Chemical Weapons (1, 10, 16, 17, 20)

Fifty years after the war Thomas B. Allen and Norman Polmer disclosed an unclassified US document on the operation “Olympic” planned for the occasion of the landing on Japan Mainland in November 1945 and operation “Coronet” planned for the second wave of attack in March 1946, with which USA was trying to make a massive use of chemical weapons on 25 major cities in Japan and it was estimated that about 5 million people would be killed and many more would be injured. The war ended on 15 August 1945 with two atomic bombings on Hiroshima and Nagasaki. Therefore, these operations were not put in practice. The Japanese Government strongly protested to the Headquarters of the International Red Cross in Switzerland that the atomic bomb is much more cruel and inhumane than chemical or biological weapons. We did not know, however, of such U.S. operations with chemical weapons during the war, but after the German surrender, in May 1945, it was reported in June, in Japan, that the USA might attempt landing on Japan mainland soon and that they might be planning massive use of chemical weapons all over Japan on that occasion. Preparing for such case chemical officers who were trained at Narashino (Chemical) School near Tokyo were assigned, at least one, to each unit of the Japanese Army. A special chemical weapons control unit was also organized.

At about 40 km east of Hiroshima City, there was a small island called “Oh-ku-no-jima” in the Inland Sea of Japan, off the coast of Tadano-umi in Hiroshima Prefecture. This island was erased from the map of Japan since 1929 when a chemical weapons producing facility of the former Japanese Army began to operate until the end of the World War II in 1945. Since the island was erased in the map during the war, the chemical weapons plant on Okunojima was referred to as Tadanoumi Factory. At the facility, Yperit of German type, Yperit of French type, Lewisite and other poison gases were produced. The facility was occupied by U.S. and British occupation forces after the war. Some chemical weapons were also found in Hiroshima City and in the adjacent Kure City where Army and Navy Headquarters for Pacific Operations were situated during the war. Some containers of mustard gas were found cracked and leaking after the war in the central part of Hiroshima at the location where Army Headquarters were located during the war.

The following major chemical weapons were produced by the Japanese Army in Japan.

(1)	Yperite of German type	Bis(2-chloro-ethyl) Sulfide
(2)	Yperite of French type	“ “ “ “
(3)	Yperite of non-freezing type	“ “ “ “
(4)	Lewisite	2-chlorovinyldichloro-arsine
(5)	Diphenylcyanoarsine	
(6)	Hydro cyanic acid	
(7)	Chloro acetophenone	
(8)	Phosgene	Carbonyl Chloride

After the war, Hiroshima was under the occupation of BCOF (British Commonwealth Occupation Forces). According to the report of January 1947, 26,872 tons of chemical weapons were found in the area of BCOF occupation. Most of these chemical weapons were produced by the Army.

After the first World War, the Japanese Navy once decided that the Navy would not use chemical weapons. However, in 1922 they decided to begin a study on chemical weapons and development of anti-chemical weapons equipment including anti-gas mask, anti-gas clothing, filters, and chemical weapons detecting equipment and also neutralising agents, etc. The Japanese Navy also built the Sagamihara Navy Arsenal to produce chemical weapons in 1943, but on a smaller scale as compared with the Army.

Prof.Yoshiaki Yoshimi of Chuo University in Tokyo obtained an unclassified report of BCOF on Disposal

Operation of Chemical Weapons of Okunojima island in Hiroshima while he was staying in USA. The report is entitled “Disposal Report, Chemical Munitions, Operation Lewisite, BCOF OCCUPATION ZONE JAPAN, 8 May 1946 to 30 November 1946. A part of the report, which gives a more or less general statement on disposal of chemical weapons of Okunojima Japanese Army Arsenal will be reproduced below (17).

“INTELLIGENCE - ACTIVITIES DURING OPERATION ‘LEWISITE’”

Experience gained from previous disposal operations during the Occupation of Japan indicated the advisability of stressing certain aspects of intelligence activity. Consequently, orders were issued at Tadanoumi requiring the Disposal Contractor to report by name all ex-military personnel employed for disposal work.

Many of these former military people were arsenal workers, Army Chemists, and Army Engineers who had served in several different arsenals. Their combined knowledge of the former Japanese Army Arsenal system provided a reasonably clear picture of the Chemical Munitions production by the former Japanese Army from 1925 through June of 1945.

As work progressed at Okunoshima, daily contact with these people relative to disposal problems brought much of their former experience to light, thus revealing some related information concerning the manufacture, storage and military use of chemical agents.

Prefectural Government Offices in the area were instructed to furnish inventories complete with maps for all CW storage and installations within the prefectural confines.

By cross-checking these two sources of information some unknown storage of mustard bombs, smoke shell and other CW munitions was disclosed.

Much of the history of the Japanese Army’s Chemical Warfare (CW) Manufacturing was likewise revealed from these information sources. The following conclusions are indicated:

1. The manufacture of chlorine, phosgene, chlorosulphonic acid, and perhaps some smoke mixtures was “farmed out” to civilian chemical plants.
2. The Tadanoumi Factory of the Tokyo Second Army Arsenal was the principal producing CW Arsenal of the Japanese Imperial Army.
3. The Sone Arsenal, near Kokura, Kyushu, was a smoke manufacturing and chemical filling plant. CW filling materials were supplied by the Tadanoumi Factory. Vesicants were shipped to this plant in 2-ton containers.
4. Plans for construction of a CW manufacturing arsenal at Arao on Kyushu were completed in 1945, but construction was interrupted by the surrender.
5. Dyphenylcynarsine production at the Tadanoumi Factory ceased in December 1944. This plant was converted to the manufacture of Dinitronapthalene explosives in February of 1945.
6. Production of all vesicants ceased at the Tadanoumi Factory in June 1944. There was no shortage of raw materials in the Arsenal and no critical deterioration of plant equipment at this time.
7. No evidence of shipment of vesicants or vesicant munitions from the Tadanoumi Factory to points outside the Japanese Islands proper has been discovered.
8. Moto Machi Depot in Hiroshima City was an Army Supply Depot to which vesicants were shipped in 200 kg containers from the Tadanoumi Factory. This installation was destroyed by the atomic bomb. No records of its activities are available in Hiroshima Prefecture. One 200 kg container of mustard gas was removed from these premises on 9 Sept 1946. This container is believed to have survived the atomic bomb burst because it was stored two feet below the earth’s surface. The container was ruptured, allowing vapours to escape, which led to discovery of same.
9. No storage or manufacture of CW munitions was maintained on Shikoku Island.
10. 10. Total vesicant production of the Tadanoumi Factory from 1927, when construction began, to June 1944, when production ceased, approximated 5100 metric tons, of which 2600 metric tons was in Arsenal storage when the war ended. Expansion of production capacity for both Mustard gas and Lewisite was completed in June 1937. Production records from this date on can be substantiated. Production for the period 1929 to June 1937 has been estimated on the basis of plant capacity rates -

    Mustard gas 1929 - June 1937 @ 2 tons per mth 200 tons
    Mustard gas June 1937 to June 1944 - 2850 tons
    Lewisite 1929 - June 1937 @ 8 tons per mth - 610 tons
    Lewisite June 1937 to June 1944 1450 tons
    Total vesicants: 5110 m/tons

As clearly stated in item (8) of the above, the Army Installation in the central part of Hiroshima to which vesicants (Yperite and Lewisite) had been shipped had been destroyed by the atomic bombing. Judging from these findings it may be possible that some chemical weapons were released to the environment from the military facilities on ground at the time they were destroyed by the atomic bombing and the survivors were exposed to

poison gases to a smaller or larger extent. There was no drinking water and they had to drink rain water which fell heavily soon after the atomic bombing. It is highly possible that the rainwater was also contaminated by various toxic substances including chemical weapons. These effects combined with the irradiation by atomic radiation are difficult to quantify accurately at present, many years after atomic bombings. But if all these adverse effects were ascribed solely to the ionizing radiation, the effects of radiation may be overestimated in Hiroshima and Nagasaki. In using the Hiroshima and Nagasaki data for establishing radiation standard in peaceful uses of atomic energy, we should keep these possibilities of over-estimation in mind.

According to Mr. Hatsuichi Murakami , ex-director of the Okunojima Chemical Weapons Museum, soon after the atomic bombing, some chemical weapons leaked into the sea from the facility on Okunojima and many fish were dead and floating on the water and washed to the shore. Normally, such contaminated dead fish are not consumed, but because of the extreme shortage of food at that time they were distributed in Hiroshima Prefecture. What effects it might have had is difficult to estimate (23).

(III) Uncertainties at Bikini Accident (2-4, 11, 12, 14, 21, 11)

An unusually large amount of strong radioactive ash was produced by the thermonuclear test conducted on March 1, 1954 at the Bikini Atoll in the Pacific by the United States Atomic Energy Commission.

A Japanese fishing boat called No. 5 Fukuryu Maru (Lucky Dragon) which was engaged in fishing about 150 km east of Bikini early in the morning of March 1 was showered by this ash. The boat, contaminated by the ash came back to Japan in the middle of March with the crew apparently injured by the strong radiation emitted from the ash. The contaminated fish brought back by this boat had been sent to various parts of Japan including Osaka and some of them had been distributed in the market before radiation monitoring.

Under such circumstances, to meet the urgent needs of public health, the studies on the radioactivity of Bikini ash and the radioactive contamination of environment were started, with the initiative of Nishiwaki, the then head of the Radiation Biophysics Laboratory of Osaka City University, Medical School, under close cooperation with the public health officers of local governments in Osaka district since the middle of March, 1954.

The estimation of the probable dose of radiation the crew might have received during their voyage and the accurate estimation of beta-ray energies and the detection of alpha-ray activity as well as the identification of various radioactive nuclides included in the Bikini ash were considered to be urgently needed items of information in estimating the possible hazard due to the internal as well as the external irradiation from the health physics point of view.

Because of the unexpectedly strong radioactivity detected on the contaminated fish in Osaka, it was felt to be very important to go down to the fishing port, Yaizu, immediately to examine the radioactivity of the No.5 Fukuryu Maru, the boat, on which the contaminated fish had been brought back to Japan. On the morning of March 17, Nishiwaki and his assistants arrived at Yaezu and collected some radioactive dust from the upper deck of the steering room of the boat. The lower deck seemed to be thoroughly washed, and yet strong radiation was being emitted at corners or joints where dust accumulates easily and it is difficult to clean.

With the ash brought back to the Laboratory a detailed analysis of the gamma radiation, alpha radiation, the analysis of beta rays with the beta spectrometer as well as radiochemical analysis were conducted by Nishiwaki, Kawai, Yamatera, Azuma, et al.

The beta ray spectrometer used in the work was the ordinary double-coil magnetic-lens type. The spectro-chamber was equipped with an aluminium buffle system. The beta-ray spectrum of the original sample prior to chemical analysis was studied on March 19, 1954. It is shown in Fig. 1 (2), however, there were so many groups of beta-rays and gamma rays that they could not be analysed reliably without chemical separation. A strong beta-ray activity was found in the CeO_2-fraction, about 40 - 50% of beta-activity of rare-earth elements mixture. From the animal experiments conducted by Prof. Nishiwaki and his staff of the Radiation Biophysics Laboratory of Osaka City University Medical School, the rare-earth elements were observed to accumulate first in the liver. The chemically separated CeO_2-fraction in powder form was put on a mica sheet and covered with a thin Zapon film. In operating the spectrometer, a resolution of about 5% was used to increase the transmission.

The measured beta-ray spectrum was analysed using the Fermi plot; that is, the plot of $(N/f_{(z,w)})^{1/2}$ against the total energy, where N is the number of counts per minute of beta-ray per unit momentum, and $f_{(z,w)}$ is the Fermi distribution function of transition probability, and w is the energy of emitted electrons in units of mc^2. In this analysis a better approximation for $f_{(z,w)}$ especially for large Z, as given by Bethe and Bacher, was used. The absorption curve of the CeO_2-fraction, on April 19, 1954, was compared with that of May 15, 1954, from which the apparent half-life of the higher energy part of beta-ray and that of the lower energy may be estimated separately.

In Fig. 2, the observed beta-ray spectrum of CeO_2-fraction is shown (2). The insert in the figure shows the internal conversion line of the 134 kev gamma-ray. The allowed Fermi plot of the higher energy part of the beta-ray is shown in Fig. 3, from which the end-point energy of 2.97 Mev can be obtained. This beta-ray group was then subtracted, and the remaining beta-ray groups were also analysed using the Fermi plot. It can be seen that

the measured beta-ray group is a complex consisting of six components with end points at 1.377-, 1.086-, 1.030-, 0.709-, 0.580, and 0.438 Mev. The data obtained in this work were compared with the momentum spectra of pure Ce-isotopes which have been reported in the past.

In this experiment, Ce^{144}-Pr^{144} was ascertained to exist in the sample, from the beta-ray spectrum of the highest energy and the internal conversion lines of 134 Kev gamma-ray. The half-life of Ce^{141} is short compared to that of Ce^{144}, but the existence of the element in lower concentration may be inferred from the beta-ray groups of 580 and 438 Kev. The energies of the internal conversion lines of Ce^{144} and Ce^{143} differ from each other by only 10 Kev, and they have spectra of similar shape. Therefore, these two could not be detected separately because of the low resolving power of the beta-ray spectrometer used in this work, but the possible existence of Ce^{143} may be inferred by the beta-ray group of 1.377-, 1.086-, and 0.709- Mev. The beta ray spectrometer analysis was conducted in cooperation with Prof. Azuma, Faculty of Engineering of Osaka Prefectural University and the radiochemical analysis in cooperation with Prof. Yamatera and his staff of the Faculty of Engineering of Osaka City University.

The probable dose of external gamma radiation the crew might have received during their two weeks' voyage may be estimated roughly about 500 - 800 rads. However, judging from the strong radioactive contamination of the boat, it may be inferred that the crew might have received a considerable degree of internal irradiation besides the external whole body gamma irradiation and the local beta irradiation on the skin where the radioactive dust directly contacted. The specific activity of the dust when it fell on the boat a few hours after the nuclear detonation may be estimated to be roughly about one curie per gram.

From the radiochemical analysis and the beta-ray analysis, the major part of the radioactivity included in the dust was found to be due to a mixture of various fission products, while the main chemical component of the dust (Bikini ash) itself consisted of a calcium compound.

The alpha-ray was also detected by the use of an ionization chamber in that portion where uranium and transuranium elements, if present, were collected by chemical analysis.

The tuna fish and the shark fins which were brought back to Japan by No.5 Fukuryu Maru in the middle of March, 1954 were most strongly contaminated on the skin, but the fish caught later in the Pacific were found to be contaminated more strongly in the internal organs rather than on the skin. The area in the Pacific where the radioactive contaminated fish were caught seemed to expand gradually with time. In the latter half of 1954, besides the ordinary fission products, the radioactive Zn^{65} which was not found in appreciable amount in the original Bikini ash has been detected from the internal organs of the contaminated fish. A possible production of Zn^{65} by the neutron activation of some metallic part of the bomb devices at the time of nuclear detonation may be inferred.

Based upon the results of the biological experiments conducted with the extract of Bikini ash using rats and the result of the radioactive analysis of some of the organs of Mr. Kuboyama, the chief wireless operator of No.5 Fukuryu Maru who died about 206 days after the nuclear detonation on March 1, 1954, an attempt has been made to estimate the internal dose of radiation. Although the accurate estimation seems to be extremely difficult, judging from the degree of strong radioactive fallout and the various conditions of the boat and the crew, the upper limit of the integral internal dose for the liver might be estimated in the range of the order of magnitude of about 760 - 81,500 rads, while that of the bone marrow in the range of about 3 - 60 rads. The main cause of the death was the liver trouble.

From the record of the microbarograph and mareograph and the degree of strong radioactive contamination of the boat and the results of the radiochemical analysis of the Bikini ash, the size of the nuclear detonation conducted on March 1, 1954 in Bikini was estimated to be roughly about the order of magnitude of 10 megaton TNT equivalent including fast neutron fission of the natural uranium or uranium 238. About 20% of the radioactivity, about 2 weeks after the accident, was found to be that of uranium 237 which was produced from U-238 by fast neutron. Therefore, it was imagined that the bomb might have been surrounded by natural or depleted uranium, a part of which also fissioned by fast neutron produced by H-bomb reaction. U-237 was first identified by Prof. Kimura and his associates of Tokyo University.

The analysis of radiation was made quite accurately, but it was extremely difficult to estimate the individual dose of radiation 23 members of the crew of the boat received during the two weeks voyage back to Japan. The amount of the radioactive ash that fell on the boat was roughly estimated based on the experiment conducted in the hospital by Dr. Miyoshi, chief doctor in charge of fishermen at the Tokyo University Medical School in the presence of the crew (11). However, it is not clear how soon and how thoroughly they washed all the ash from the deck. Some of the crew tasted the ash to see what it was. The exact amount the individual members of the crew ingested or inhaled is not accurately known. It would be greatly underestimated, if we assume the radioactive nuclides detected after the death of Mr. Kuboyama who died 206 days after the accident are the only source of internal irradiation. External dose would also be greatly underestimated if we assume the radioactivity remaining on the deck after return to the Japanese port is the only source of external irradiation. The crew said that they had washed the ash from the deck with sea water, but whether 90% or 99% of the ash

was washed away makes quite a bit of difference in the estimation of external dose. Stronger radioactivity was found on the upper deck where the room of Mr. Kuboyama, the wireless operator, was located. He might have received more external and internal radiation as compared with other crew members inside in the lower part of the ship. More radioactivity was remaining at the corners or joints, or with gloves, ropes, blankets and clothing which are likely to collect the dust usually. Our colleagues who visited the ship sometime later detected stronger radioactivity. It was found that some members of the crew brought back to the ship contaminated blankets and clothing when they learned by the newspaper that they might have been contaminated with the dangerous radioactive ash.

The radioactive nuclides detected in the Bikini ash at various institutions in Japan (Tokyo, Kyoto, Shizuoka, and Osaka City Universities) with the ordinary method of chemical analysis with carrier as well as with the ion exchange method may be summarized as follows:

Sr-89, Sr-90, Y-90, Y-91, Zr-95, Nb-95m, Nb-95,
Ru-103, Ru-106, Rh-106, Ag-111, Sb-125, Sb-127,
Te-127, Te-129m, Te-129, Te-132, I-131, I-132,
Ba-140, La-140, Ce-141, Ce-143, Ce-144, Pr-143,
Pr-144, Nd-147, U-237, Pu-239, Ca-45, S-35.

It is very probable that other radioactive nuclides may also have been included in the Bikini ash in smaller percentage.

From the highly radioactive rain in May 1954, the following radioactive nuclides had been detected:-

Ba-140, La-140, Sr-89, Ar-95, Nb-95, Y-91,
I-131, I-133, I-132, Te-129m, U-237, Np-239.

The decay of the gross activity of the original Bikini ash (greyish white) collected from No. 5 Fukuryu Maru was found to follow the following empirical curve as measured at about 2 cm from the 3.5 mg/cm^2 A1 window of the Lauritsen type electroscope:

$A=A_1t^{-1.59\pm0.02}$, 20 d < t < 60 d
$A=A_2t^{-1.22\pm0.03}$, 60 d < t < 170 d
$A=A_0t^{-1.38\pm0.05}$, 20 d < t < 170 d

(A_0, A_1, A_2: constants) (t : No. of days after the explosion of March 1st, 1954).

The estimation of test sites and explosion energy is already attempted based on the records of microbarometer, seismographe and mareographe at different places since the Bikini accident. However, possible effects on the climate and environment, possible disturbance of the balance of ecosystem through the circulation of radionuclides in the biosphere and biological, microbiological, molecularbiological and genetic effects, possible effects to the climate through the heating of atmosphere or wide area of earth above the tests and the possibility of triggering earthquake at active fault by underground tests are some of the problems yet to be clarified associated with nuclear tests and other nuclear applications from the point of view of global radiation protection of human environment..

CONCLUSION AND DISCUSSION (1-3, 14-17, 20-14)

In case of the atomic bombings in Hiroshima and Nagasaki, in addition to ionizing radiation, various other direct and indirect factors such as those mentioned above must be considered instead of ascribing all the effects solely to ionizing radiation. In applying the Hiroshima and Nagasaki data to establishing the radiation protection standard for peaceful uses of nuclear energy one must keep in mind that there would be a possibility of overestimation of risk. According to the BCOF report in 1946, “Moto Machi Depot in Hiroshima City was an Army supply Depot to which vesicants (Yperit or Lewisite) were shipped in 200 kg containers from the Tadanoumi Factory. This installation was destroyed by the atomic bomb.” As judged from this report, a substantial quantity of chemical weapons of the Army Headquarters in Hiroshima might have been released by the atomic bombing.

In case of the Bikini accident, a Japanese fishing boat No. 5 Fukuryu Maru (Lucky Dragon) was showered by strongly radioactive ash from H-bomb testing whilst engaged in fishing in the Bikini area on March 1, 1954 at about 150 km from the test site in the Pacific. Some members of the crew tasted the ash to test what it is. When the ship came back two weeks later, stronger radioactivity was found on such easily movable things as dust, gloves, ropes and clothing rather than on the solid smooth surface of the ship. The amounts of radioactive ash some members of the crew might have ingested or inhaled are not known accurately. Therefore, the exact dose of a particular person was extremely difficult to estimate.

Under these ill-defined conditions associated with risk estimation, the fuzzy set and fuzzy measure theories may be more appropriate for uncertainty analysis than the probabilistic approach.

In the UNSCEAR Report 1988, after detailed discussions on early effects in man of high doses of radiation the factors which might cause the $LD_{50/60}$ to be lower or higher are given as follows: (14)

Lower: Pre-1986 dosimetry for A-bomb tests;

contribution of extensive burns;	Young, female;
pre-existing illness;	radiation poorly penetrating;
chronic nutritional deprivation;	unilateral irradiation;
concurrent infections;	partial marrow shielding;
contribution of high LET radiation.	good medical support;

Higher: Protoracted irradiation.

In these or other factors, under emergency conditions of war-time or accidents, both randomness and fuzziness may be involved. Under such situations, it may be important to consider application of fuzzy theory to the uncertainty analysis of cause-effects relationships or to the estimation of the dose range.

Prof. Josef Rotblat of the University of London, in his paper entitled "Acute Radiation Mortality in a Nuclear War", writes as follows: "Estimates of radiation casualties in a nuclear war depend on assumptions made about the LD_{50} value for humans. In the absence of direct evidence, this value has been deduced from animal data and partly from a few radiation accidents, many victims of which have been receiving extensive medical treatment. The LD_{50} value thus deduced was very high, 600 rads bone marrow dose. The largest amount of data for humans - the 1945 inhabitants of Hiroshima and Nagasaki- has been rejected for a variety of reasons" (24). Under wartime conditions, even exposure to sublethal doses could give rise to fatalities, because the suppression of the immune system would reduce the chance of recovery from other normally non-lethal injuries. Apart from radiation, the conditions of impairment of immune response may be physical traumata. burns, and malnutrition, etc.

In this paper, the authors introduced another complicating factor of chemical weapons, which might have been released from the Japanese Army Installation in Hiroshima by atomic bombing. Mustard Gas, Yperite and Lewisite may be considered strong radiomimetic substances.

In these or other factors, under emergency conditions of war-time or accidents, both randomness and fuzziness may be involved.

The late Prof. Tsuzuki, who was the highest medical officer (rear-admiral) of the ex-Japanese Navy during the war and later became professor of surgery of Tokyo Imperial University Medical School after the war, gave a lecture entitled "On the so-called Atomic Bomb Injury" (countermeasures from the medical point of view) at a medical meeting in September 1945. In his lecture, he mentioned about the poison gas in Hiroshima after the atomic bombing (1). However, in the article of his lecture printed in the Japanese Journal of Medicine "Sogo-Igaku" (General Medicine), the part related to poison gas is erased out and deleted, possibly by censorship of the then Japanese Government under Occupation Forces. This poison gas is related to the problem of chemical weapons which Prof. Nishiwaki used to emphasise in the past and this is one of the most striking points of difference between Hiroshima and Nagasaki. Many medical data on the effects of atomic bombings in Hiroshima and Nagasaki are plotted as a function of atomic radiation dose. However, the estimated dose may not always be as accurate as the dose in carefully controlled radiological treatment or radiobiology experiments, and the medical effects observed in Hiroshima and Nagasaki may include influence of many complicating factors other than the effects of atomic radiation. Therefore, in interpreting the reports on the effects of atomic bombings in Hiroshima and Nagasaki one may have to keep in mind the possibility of these uncertain factors as mentioned in this paper and that these uncertainties are not necessarily always due to probabilistic uncertainties or randomness only, but that they might include both probabilistic and non-probabilistic uncertainties or both randomness and fuzziness.

During the initial period of Hiroshima and Nagasaki, many complicating factors may be identified qualitatively, but not estimated quantitatively with sufficient accuracy. Under these circumstances, there are many doubtful cases where one may not be able to say definitely that it is due to radiation, but at the same time one may not be able to say it is not due to radiation. To describe these situations, what is needed is not the "yes" or "no" judgement by conventional binary logic "0" or "1", but the fuzzy logic which allows the degree of expert judgement between "0" and "1".

Under these situations, the application of Fuzzy Theory may be more important for the analysis.

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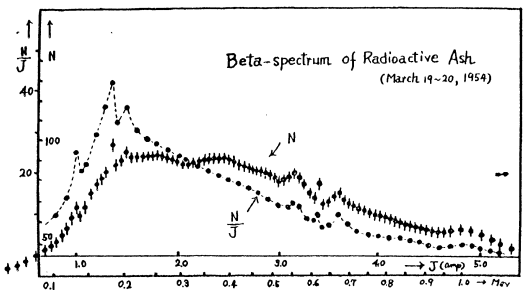

Fig. 1, Beta-ray spectrum of the original radioactive Bikini ash prior to chemical analysis. The radioactive ash was collected from the upper deck of No. 5 Fukuryu Maru (Lucky Dragon) at the fishing port Yaezu in Shizuoka Prefecture in the morning of 17 March 1954 by Prof. Nishiwaki and his assistants of the Radiation Biophysics Laboratory of the Osaka City University Medical School.

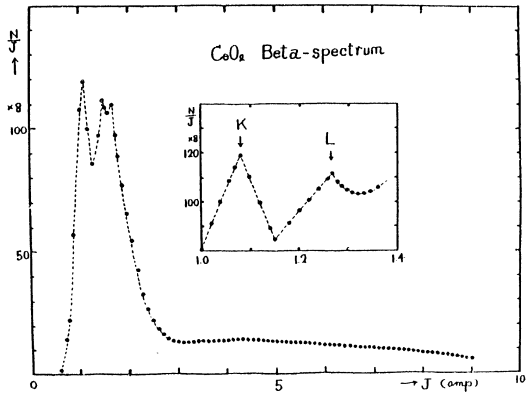

Fig. 2, Beta-ray spectrum of CeO_2-fraction. The insert shows an enlargement of the internal conversion line of the 134 kev gamma-ray from Ce^{144}-Pr^{144}. This is the most radioactive fraction in the rare earth elements mixture, which was observed to accumulate first in the liver by animal experiment (Nishiwaki).

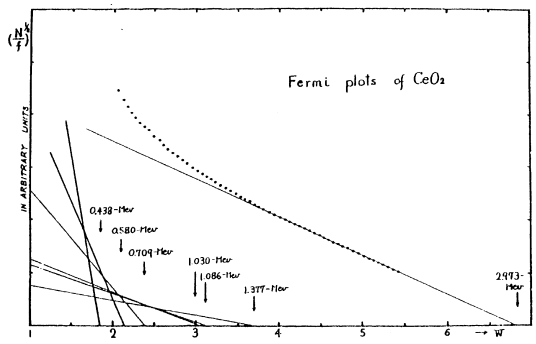

Fig. 3, Allowed Fermi plots constructed from the beta-ray spectrum of the CeO_2-fraction. The values of the maximum energies of the beta-ray groups are shown in the figure, based on which the redio nuclides were identified.

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