HANDLING OF RADIOACTIVE FALLOUT PROBLEMS AT CHERNOBYL ACCIDENT (1986) AS COMPARED WITH THAT OF BIKINI ACCIDENT (1954)

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I BIKINI ACCIDENT (1954)

We conducted an analysis in Japan of the highly radioactive fall-out on the Japanese fishing boat No.5 Fukuryu Maru that was engaged in fishing about 150 km east of Bikini at the time of the thermonuclear test conducted early in the morning of 1 March 1954, and which returned to Japan in the middle of the same month. According to the statements of some of the crew, a few hours after the thermonuclear detonation in Bikini the whitish dust began to fall on the boat so heavily that for a period they could hardly bear to open their eyes and mouth. It continued to fall for several hours. Some of the crew apparently tasted it, to see what it was, without knowing that it was highly radioactive. Owing to the difficulty of dose estimation without more accurate information on the initial condition, the radioactive fall-out conditions on the boat were experimentally reproduced by M. Miyoshi, the chief physician in charge of treatment of the exposed crew at the Tokyo University Hospital,using pulverized coral reef. This experiment was carried out in the presence of the crew as witnesses of the actual amount of ash which had fallen on the boat, This amount was then estimated to be about 3.38-8.52 mg/cm^2. The radioactivity of the ash was estimated by extrapolation to be about 1 Ci/g at the time it fell on the boat. Taking into consideration various possible exposure conditions of the crew during the voyage,the probable gamma dose was estimated to be in the range 170-600 rads. The degree of uncertainty was far greater for the internal dose. The long-lived radionuclides detected in organs such as the liver many weeks later could not be considered the only sources of internal exposure. Depending on the assumed degree of initial incorporation of short-lived radionuclides, a wide range of estimates was possible: for the liver, a few rads to a few tens of thousands of rads, the probable dose range being 10-10^4 rads; and for bone and bone marrow, a few rads to about 60 rads. If we assume a non-uniformity factor of five for bone, the local dose could be five times higher.The thyroid dose was estimated to be about 10-10^3 rads. Radiation syndromes such as radiodermatitis, epilation, decrease of leucocytes, decrease of spermatozoa, etc. were observed in the exposed.Some of the larger aggregates of the Bikini dusts collected from the fishing boat 'Fukuryu Maru' were found to have a size of about 0.1-0.5 mm. (0.3 mm in average). However these granules were found to consist of finer unit particles of the size 0.1-3 μm with cubic or spindle shapes. Some of the fine particles of indefinite shapes were found to have a size less than 0.1 μm on electron microscopic examination. From electron micro diffraction and X-ray diffraction studies,the Bikini dust was confirmed to have the crystal structure of calcite while the coral reef is aragonite. From these findings it may be inferred that the coral reef evaporated at the time of the H-bomb explosion and recrystallized in the air into calcite with the inclusion of radioactive nuclides produced by the explosion. Double-coil magnetic-lens type beta-ray spectrometer was used to identify some of the radionuclides. The beta-ray activity of the rare earth elements mixture was about 30-60% of the total beta-activity of the original Bikini ash while that of uranium 237amounted to as much as 10-20% at the end of March 1954. This suggests the existence of a large amount of uranium 238 in the March 1st bomb, if we assume uranium 237 were produced by (n-2n) reaction from uranium 238. The unexpectedly large amount of radioactivity release by Bikini test was officially announced by USAEC on January 15, 1955.

II CHERNOBYL ACCIDENT (1986)

The accident of Chernobyl Unit 4 took place on April 26, 1986. The Soviet experts calculated that the first power peak reached 100 times the nominal power within 4 seconds. Energy released in the fuel from the power excursion (>300 cal/g) suddenly disrupted part of the fuel into minute pieces. This disruption mechanism is known from experiments in safety research programmes. Small hot fuel particles may have caused a steam explosion. The energy release shifted the 1000 ton reactor cover plate and cut all cooling channels on both sides of the reactor cover. After 2 to 3 seconds a second explosion was heard and hot pieces of the reactor were ejected from the destroyed reactor building. It may be assumed that steam-zirconium and other exothermic reactions occur. Hydrogen and CO is produced and may explode. The destruction of the reactor allowed the ingress of air which led subsequently to graphite burning. Destruction of the Chernobyl containment and core structures led to release of radioactivity from the plant. The USSR experts estimated 100% of the noble gas radionuclides escaped the plant. Of the remaining, condensible, radionuclides the release amounted to about 5×10^7 curies or about 3-4% of the core inventory of radioactivity. This release was composed of about 10-20% of the Cs, I and Te inventories and about 3-6% of the inventories of other radionuclides.

The release of radionuclides from the Chernobyl plant did not occur as a single acute event. Rather, there was initial, intense release associated with the destructive events in the accident. Release rates decreased over the next few days probably as a result of accident management activities undertaken. Relèase rates were about 2×10^6 Ci/day five days after the accident initiation. At that point, the release rates began to increase and reached 8×10^6 Ci/day about nine days after the accident initiation. When UO_2 is further oxydized to U_3O_8, most of the fission products contained in UO_2 may be released. There was, then, a drop in the radionuclide release to 10^3 Ci/day. Release rates have continued to decline since that time. Radioactive releases corrected to 6 May and have an uncertainty range of $\pm$ 50%. In case of a nuclear bomb explosion, all the radioactive materials are instantaneously released to the environment. In case of Chernobyl Accident, volatile radionuclides such as I and Cs were more predominant.

On 3-4 May 1986, the radioactivity included in the surface air was observed to increase suddenly at the central part of Japan. The radioactivity detected in different parts of Japan was as follows: I-131, Te-132, Ru-103, Rh-106, Cs-134, Cs-137, Ba-140, La-140, Mo-99, Tc-99m. The radioactivity ratio Cs-137/Cs-134 observed in the dust and rainwater sampled by Morishima, et al. at Kinki University, Osaka, Japan, was about 2.0 ± 0.2 during the period 4-11 May, in good agreement with the ratio 2.0 ± 0.3 reported by Aoyama, et al. The air concentration of I-131 was observed to reach about 90 mBq/m^3 on 9 May at Kinki University, Osaka, and the percentage of I-131 was estimated to be over 50% of the total beta activity on 10 May. Kr-85 was estimated by cryogenic separation from air samples collected in an iron cylinder followed by gas chromatographic purification at the Geochemical Laboratory of Meteorological

Research Institute. Before Chernobyl Accident, Kr-85 was 0.9Bq/m^3, but increased to 1.04 Bq/m^3 on May 6, falling steadily to the normal. There is a possibility that a small fraction of Chernobyl radioactivity went up to the stratosphere, but this fraction would be very small as compared with that of Bikini H-bomb test. Because of the large explosion power of H-bomb, the global fallout of Bikini Accident was larger, but the local and regional fallout of Chernobyl Accident would be more significant.

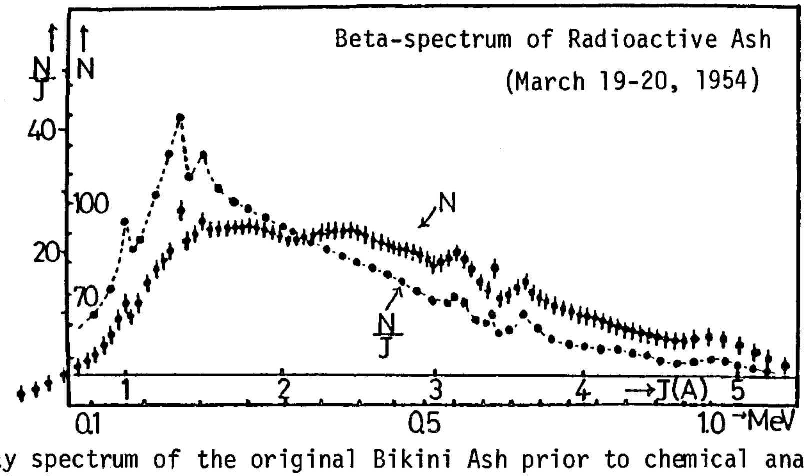
III RADIOACTIVE FALLOUT PROBLEMS AND INTERVENTION LEVELS

According to the USSR-Report, the released radioactivity of Cs-137 at the Chernobyl Accident (1986) is about one megacurie ($\pm$ 50%). The fraction of Cs-137 released is estimated to be about 13% of core inventory. The released radioactivity of Cs-137 at the Bikini Accident (1954) may be estimated to be about the same order of magnitude. Assuming 15 megaton TNT equivalent with fission and fusion energy about 50;50 and assuming U-238 fission spectrum the total Cs-137 released at the time of explosion is also estimated about one MCi. However, the local (30 km) close-in fallout of Cs-137 is estimated about 100-1000 times higher with the Chernobyl Accident and the fallout of Cs-137 in an area equivalent to Central Europe region is about 20 times higher with the Chernobyl Accident.

The fraction of radionuclides of refractory elements was more predominant in the thermonuclear test conducted at Bikini on March 1, 1954. The fission yield of Cs-134 is much lower than that of Cs-137, and it may be difficult to identify this nuclide in the fallout due to nuclear weapons test. However, fission yield of Cs-133 is much larger, and Cs-134 is produced by neutron capture of Cs-133 in the nuclear reactor. In case of Chernobyl accident, Cs-134/Cs-137 was about 0.5 which corresponds to the burnout of about 10,000 Mwd/t of nuclear fuel. A large number of highly contaminated tuna fish brought back by the fishing boat showered by strongly radioactive fallout of Bikini test were distributed in the market. Sometime later, milk and vegetables were also contaminated by the fallout all over Japan. A confusion was created about the handling of these radioactive fallout problems in Japan in 1954. The situation encountered in Japan very much resembles that in Europe after Chernobyl accident in 1986. The intervention level of foodstuffs was one of the most important items of discussion. The intervention level under initial emergency condition and that under more or less stabilized chronic situation should be distinguished. In the latter case we may have more time to discuss the matter. However, in the first case, it is not known at the beginning whether the contamination may increase or not, and the extent of increase of external dose and that of inhalation dose, etc. are all fuzzy. Under such circumstances the derived intervention level based on maximum permissible dose or body burden may not be used to the full. Whether we take 1/5, 1/10 or 1/100 is up to the subjective judgement based on intuitive optimization of the decision maker. This constitutes a most difficult case of optimization under fuzzy environment and decision making with fuzzy information. ICRP optimization technique may not be applicable in such cased. When non- or less-contaminated alternative foodstuffs are abundantly available, one may take very strict measures and very low intervention levels to compensate external and inhalation dose. On the other hand, when all available foodstuffs are contaminated, one may be obliged to take, at least temporarily, a highly intervention level for survival under emergency condition.

The first contaminated tuna fish which were brought back to Japan by No.5 Fukuryu Maru in the middle of March 1954 were found to be emitting much stronger radiation from the surface (0.1-1.0 $\mu Ci/cm^2$) than from the inside,and the government set the tentative discarding level of radioactive contaminated fish at 100 cpm as measured at 10 cm from the wet surface with the beta-ray counter with 3.5 mg/cm^2 mica window plus 2.5 mg/cm^2 plastic cover to protect the counter window. The natural counts of this counter were about 30 cpm. Geometry of this counting condition was estimated to be 1/400 and the beta-ray absorption by mica window and plastic cover and water and scale on the surface of the fish about 2.5. The overall efficiency of beta-counting may be estimated about 1/1000. Since the first contaminated fish had very strong radioactivity on the surface, the above emergency intervention level was adopted tentatively to screen the high surface-contaminated fish. The fish caught later had much weaker radioactivity mostly inside and much lower intervention levels based on the then ICRP recommended action for respective radionuclide identified in the fish. The tuna fish is an expensive fish and a balance between the risk due to economic loss, the risk due to consumption of contaminated food, the pressure of public opinion, the psychological and political effects, the effects on international relation and international trade, etc. may have to be considered in setting an intervention level. If the contaminated food constitutes a significant fraction of staple food of the people, nutritional problem must be considered. A simple cost-benefit analysis may create a confusion and socio-political problems. According to an USSR expert (1987), the initial emergency intervention level at Chernobyl (1986) was 5 rem for external and 5 rem for internal irradiation, but later the level was reduced to a lower level. When no alternate food is available, one must assume a higher level under emergency condition. Through these two accidents the necessity of internationalization of radiation protection and nuclear safety was strongly felt.

References: Y. Nishiwaki,"Studies on the radioactive contamination due to nuclear detonations" I-VI, 1954-1961, Kinki Univ. Press, Osaka, Japan;"Global contamination due to radioactive fallout", Progress in Nuclear Energy, Series XII, Health Physics, Vol.II, Pergamon Press, 1969; M. Morishima, H. Kawai, M. Aoyama, Y. Sugimura, et al, private communications 1986; USSR Report on Chernobyl Accident, 1986; Y. Nishiwaki, et al. Optimization of radiation Protection and the Possible Application of Fuzzy Set Theory,IAEA-SM-285/36,1986.



Beta-ray spectrum of the original Bikini Ash prior to chemical analysis March 1954. Double-Coil Magnetic-Lens type beta-ray spectrometer was used.