FIFTY YEARS AFTER HIROSHIMA AND NAGASAKI

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Fifty years ago, in 1945, the first three atomic bombs in human history were produced by the United States; one of these bombs was exploded experimentally at the testing ground in the desert 80 km from Alamogordo, New Mexico, on 16 July. The remaining two were used against Japan; the one called "Little Boy", using Uranium 235 was dropped on Hiroshima on 6 August, the other "Fat Man", using Plutonium 239 on Nagasaki on 9 August, 1945.

In the early morning, at 1:30 a.m. of 6 August 1945, a United States Army weather observation plane took off from the Tinian air base in one of the Mariana Islands in the Pacific towards Japan. As the plane approached Hiroshima, at an altitude of about 10,000 metres, it sent a message to the B-29 "Enola Gay" loaded with an atomic bomb, which was following it, "fair weather, ready for air raid." The "Enola Gay" took off from Tinian Island at 2:45 a.m. together with two observation planes on both sides, and invaded Hiroshima from the northeast and dropped the atomic bomb at 8:15:17 a.m., (Tinian time 9:15:17 a.m.), at an altitude of 9,600 metres. Records on the time of explosion range from 8:15 to 8:18 a.m., depending on the source of information. However, according to the Hiroshima City, the official time of explosion was announced to have been 8:15 a.m. The whole city was covered by a bluish-white glaze. The central part of the city was completely destroyed instantaneously.

The altitude of the explosion and the location of the hypocentre were estimated by the extrapolation of the lines connecting the shadows and the corresponding objects that were exposed to strong thermal radiation. The height of the epicentre was about 580 ± 15 m and the hypocentre at about longitude 132°27'29" E and latitude 34°23'29" N. This is on the ground of Shima Surgical Hospital, about 160 m southeast from the centre of the Atomic Bomb Dome, which is considered a symbol of Hiroshima at present.

Dr. Shima, a graduate of Osaka University, the then director of the Shima Hospital, was my personal friend and whenever I went to Hiroshima I used to stay at his home next to the hospital. The night before the atomic bombing, Dr. Shima visited his family evacuated to the outskirts of Hiroshima, and missed the last train back to Hiroshima because he was playing mahjong (a kind of Chinese card playing - small square tiles) with his friend until late at night. Because Dr. Shima was late he, fortunately, escaped the atomic bombing.

Dr. Shima, the current director of the hospital, is one of the former students of mine when I was the head of the radiation biophysics laboratory, School of Medicine of Osaka City University many years ago. His younger brother is also a medical doctor from Hiroshima University. About ten years ago he was studying at the Max Planck Institut für Hirnforschung in Köln with Humboldt Stiftung and visited me in Vienna with his family because his immediate boss in Köln was a graduate of the University of Vienna.

News of the atomic bombing was briefly announced at 6 p.m. by the Japan Broadcasting Corporation: "August the 6th. Hiroshima was attacked by B-29's this morning at about 8:20. The planes have turned back after dropping incendiary bombs. Damage is now being investigated." The news of the bombing was dispatched from Osaka, becausc mass media in Hiroshima were completely destroyed and did not function, and reported by newspapers throughout Japan on the following day. The first report appeared in the Osaka Asahi Newspaper was a relatively small article at about the centre of the front page.

There was also a shortwave radio news from the U.S. to the effect that President Truman had announced that an atomic bomb was dropped on Hiroshima.

It was a hot morning in Nagasaki on 9 August 1945. Two planes, B-29 "Bockscar" loaded with an atomic bomb and a weather observat ion plane, left the Tinian airbase early in the morning at 2:45 a.m. At 9:50 a.m. the plane flew into the sky above Kokura, the first bombing target, which is in the northeast of Fukuoka Prefecture on the island of Kyushu. It circled three times for about 10 minutes, but could not locate the target because of heavy clouds, and abandoned the first target for lack of fuel. It then turned towards

Nagasaki, the second bombing target. Taking a round-about way, it flew southward from Kokura via Kumamoto and the Shimabara peninsula and reached Nagasaki at 10:58 a.m. The sky over Nagasaki. was also covered by clouds and visibility was very poor. They prepared to drop the bomb using radar. The observation plane dropped a "sonde" by parachute. Just at this moment, the clouds opened up and the huge Nagasaki Mitsubishi Plant appeared. The atomic bomb was dropped at an altitude of about 9,000 m. The plane changed course immediately, and after confirming the flash and shock wave at 11:02 a.m. escaped to Okinawa, the closest base then occupied by the U.S. forces. The plane landed in Okinawa at 1 p.m. with only a few gallons of fuel left. The height of explosion in Nagasaki is estimated at about 503 ± 10 m and the hypocenter at longitude 129°51'56"4E and latitude 32°46'12"6 N. This site is about the place where the Hypocenter Monument is located at present at Heiwa Kōen (Peace Park) in Nagasaki.

My colleague, Prof. Hasegawa, the then professor of otorhinolaryngology of the Nagasaki University was staying in Osaka at the time of the atomic bombing on Hiroshima. On hearing about the atomic bombing on Hiroshima he hurried back to Nagasaki through Hiroshima on the following day and met the atomic bombing in Nagasaki. However, at the time of the atomic explosion he was in the toilet of the heavy concrete main building which is apparently well shielded from radiation, and, fortunately, he survived. He later became professor of otorhinolaryngology of Osaka University.

Next to the heavy concrete main building of the Nagasaki University Hospital there was a large wooden lecture hall. All students present at the lecture at the time of the atomic bombing were killed. Even now, in the list of the graduates of the Nagasaki Medical University there is a large blank space in the corresponding year and it is written "all died by the atomic bombing on Nagasaki in 1945".

The Nagasaki University Hospital was about 700 m southeast of the Hypocenter. At about 500 m northeast of the hypocenter there was a large Urakami Cathedral, the largest catholic church in Japan with a membership of about 14,000. The church was completely destroyed by the atomic bombing. Father Saburo Nishida and the parishioners present in the church were all killed. Only a part of the walls were standing in the ruins.

The atomic bomb differs from conventional explosions in that besides the shock wave or bomb blast it is accompanied by intense heat and radiation, with the dissipation of energy in the approximate ratio of bomb blast (50%), heat (35%), and radiation (15%).

Towards the end of the last war I was assistant professor of physics at the Osaka University of Science and Engineering (at present, Faculty of Science and Engineering of Kinki University).

Since the air raid on industrial areas was gradually intensified, one of the branch laboratories of the Nishina Research Project on nuclear energy was evacuated to the Yao High School near the university. I was assisting them in a preliminary study on the separation of uranium isotopes together with my students. When we heard about the atomic bombing, the liaison officer immediately flew to Hiroshima and Nagasaki by an ex-Japanese army plane. Although it was not possible to enter the central part of the city, we knew that it was the atomic bomb because all roentgen films stored in the basement of the Hiroshima Red Cross Hospital were exposed to radiation and unusable.

The explosion creates an extremely high pressure at the point of detonation equal to several hundred thousand atmospheres; the surrounding air expands greatly to form the bomb blast. It attains a velocity of 280 m/sec around the hypocenter and a velocity of 28m/sec at a point 3.2 km. The front edge of the bomb blast advances as a shock wave, which travels a distance of approximately 3.7 km in about 10 seconds, and reaches a distance of about 11 km after 30 seconds. The shock wave spreads outwards; at the instant when the wind abates, a blast blows inwards from the outside due to the reduced pressure at the hypocenter.

A fireball is created in the air at the same time as the explosion. At the instant of detonation the temperature at the center is estimated to correspond to several million degrees centigrade, with the temperature on the surface of the fireball about 7,000° C after 0.3 seconds; the heat energy is estimated at 99.6 cal/cm^2 in the vicinity of the hypocenter, and 1.8 cal/cm^2 at a point 3.5 km. Within 3 seconds of the explosion, 99% of the thermal radiation emitted by the fireball may affect the surface of the ground.The heat caused the scorching of wood for a distance of about 3 km. At the distance of 3.5 km the burning of human skin that was not covered with clothing was caused. The burns resulting from exposure to the strong thermal radiation proved fatal to any unprotected people within about 1.2 km; 20 -30% of the total deaths may be due to these burns.

It is possible to classify the radiation released by the atmospheric atomic explosion into two categories: the initial radiation, which was emitted within one minute of the explosion and which accounts for approximately 5% of the total energy, and the residual radiation, which was released later at ground level over a long period of time and which accounts for approximately 10% of the total energy.

The initial radiation was composed primarily of gamma rays and neutrons. Several estimates have in the past been advanced for the initial dose of radiation. The tentative T65D dose estimates (established in 1965) were revised in July 1987 by the US-Japan Committee for Reassessment of Atomic Bomb Radiation Dosimetry in Hiroshima and Nagasaki, and the new DS86 dosimetry system was adopted. However, there may still be various uncertainties involved.

The uncertaintes under emergency conditions, in particular, the uncerataintes in estimating dose-effect relationships in Hiroshima and Nagasaki have been repeatedly discussed by professor 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 University in 1945.

The survivors and those who visited Hiroshima immediately after the atomic bombing could have been subjected in a number of other possible noxious effects in addition to atomic radiation. Hospitals, laboratories, drugstores, chemists, 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. 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 recording 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.

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 uncertain factors in mind when analysing the atomic bomb effects of Hiroshima and Nagasaki.

In Japan, medical X-ray examination is compulsory 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 these uncertainties both randomness and fuzziness may be involved.Under such situation it may be important to consider application of fuzzy theory for the analysis of cause-effect relationships.

In exploding an atomic bomb, in addition to ionizing radiation, strong non-ionizing radiations, such as infrared, ultraviolet light, visible light, electromagnetic pulse radiation, as well as heat and shock waves are produced.

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. (1-10)

P.S.: Soon after the outbreak of the Pacific War in December 1941, we heard that the late Admiral Yamamoto of the ex-Japanese Navy was very angry when he heard that the transmission of the declaration of war from Japan to the United States was delayed at the Japanese Embassy in Washington D.C. and that he strongly opposed against the plan to bomb the pacific coast of the

United States following the attack on Pearl Harbour during the Christmas holiday season for the reason that it is an important religious holiday in U.S.A.

At about this time, we received a special Japanese navy information via Argentina that the United States had decided to establish a research project to develop atomic bomb because they were afraid that Germany might produce the atomic bomb first.

The Japanese Navy asked us a question whether it would be possible in the United States to develop an atomic bomb before the end of the war. After some discussion it was replied that it is theoretically possible but it would not be possible even in the United States to develop an atomic bomb before the end of the war.

From 1939 to 1940, Mr. Tadayoshi Hikosaka, a graduate of Tohoku Imperial University was a visiting scientist at the department of physics of Osaka Imperial University and made the following oral presentation at the colloquium meeting on nuclear physics. The absorption of slow neutrons by the absorption band of U-238 would be greatly reduced if the reactor is made heterogeneous, nuclear fuel and moderator, so that the neutron reaches the uranium fuel rod after the neutron velocity is slowed down sufficiently low in the moderator.

Mr. Hikosaka also presented a paper at one of the nuclear physics meetings in November 1944 on "a method of utilization of nuclear energy" in which a possibility of fast neutron reactor was discussed. This paper was submitted to Prof. Takahashi of Tohoku University as a doctoral thesis, but the original documents were burnt down by the air-raid during the war. Mr. Hikosaka then became a professor at the Ryojun Institute of Technology in Port Arthur, Manchuria, in May 1945, and returned to Japan in October 1949, but passed away some years ago. However, because of these presentations and discussions, we saw a real possibility of peaceful utilization of nuclear energy in future at that time, but never thought that the atomic bomb would be produced in the United States before the end of the war and dropped on Japan.

After the aromic bombing on Hiroshima, the U.S. plane distributed bills written in Japanese to the following effects:

> "The U.S. invented a powerful new atomic bomb. If you have any doubt about it, you should investigate the effects of a single atomic bomb on Hiroshima. One atomic bomb has the power equivalent to all bombs carried by 2,000 B-29 bombers. You should ask your emperor to stop this useless war by accepting 13 terms honorary capitulation.
>
> Unless Japan gives up military resistance immediately, the U.S. are determined to use these bombs and other superior weapons to terminate the war quickly and powerfully."

After the atomic bombing on Nagasaki, an English letter addressed to Prof. Sagane was recovered by an ex-Japanese navy officer. It was hidden in the "radiosonde" dropped by parachute at the time of atomic bombing which came down about 50 minutes later at Isahaya City 20 km northeast-east of Nagasaki. Prof. Sagane used to work at the Radiation Laboratory of the University of California before the war. The letter was hand-written. No signature, but it was written "from three colleagues".

The letter requests immediate stop of war by Japan and said to the effect that as scientists they regret that their beautiful scientific work was used for such a purpose as atomic bombing, but unless Japan surrenders immediately, more and more atomic bombs will continue to be dropped all over Japan in fury. The Japanese Government immediately protested about the atomic bombing to the headquarters of the International Red Cross in Switzerland for the reason that it is more inhumane than the chemical and biological weapons.

After the war, when Dr. Compton (brother of Dr. Arthur H. Compton of Compton Effect), the then president of the University of Washington in Seattle visited Japan, Prof. Sagane asked him to find out the three colleagues. Later, it was found that they are Dr. Louis W. Alvarez and two other scientists of the Radiation Laboratory. Prof. Sagane later became a member of the Board of Directors of the Japan Atomic Power Co. When he was a member of the Radiation Council of Japan, which is an advisory group to the prime minister on matters related to radiation, I was full professor of the Nuclear Reactor Research Laboratory of Tokyo Institute of Technology and also a member of the same Radiation Council. I used to cooperate with Prof. Sagane in the field of radiation protection. Unfortunately, he passed away already some years ago in Tokyo.

"LITTLE BOY" *(Hiroshima)* [1-3, 5, 6]

(Gun-type, U-235, 12-20 kt TNT equivalent)
3 m in length
0.7 m in diameter
4 tons in weight

Dropped at an altitude of about 9,600 m at 8:15 a.m.

Exploded 43 seconds later at an altitude of 580 ± 15 meters on 6 August, 1945.

The hypocenter is estimated at longitude 132°, 27' 29" E and latitude 34°, 23' 29" N.
(a difference in radius of about 15 meters)

This site is on the ground of the Shima Hospital, 160 meters southeast from the center of the Atomic Bomb Dome in Hiroshima.

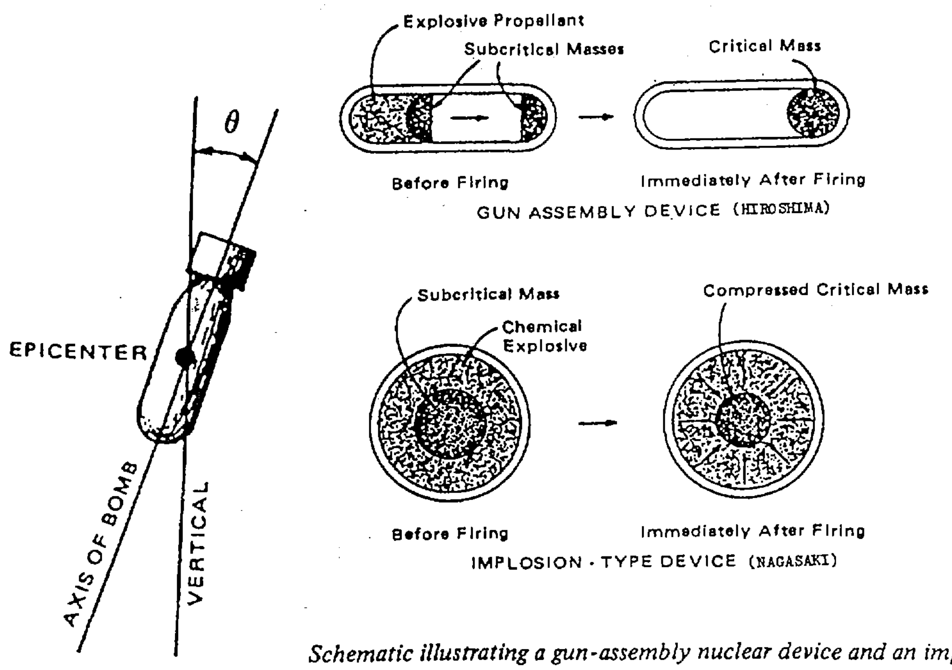
"FAT MAN" *(Nagasaki)* [1-3, 5, 6]

(implosion-type, Pu-239, 22 ± 2 kt TNT equivalent)
3.5 m in length
1.5 m in diameter
4.5 tons in weight

Exploded at 11:02 a.m. at an altitude of 503 ± 10 meters on 9 August, 1945.

The hypocenter is estimated at longitude 129°, 51' 56" 4 E and latitude 32°, 46' 12" 6 N.
(a difference in radius of about 7 meters)

This site is about where the Hypocenter Monument at Heiwa Koen (peace Park) is located at present in Nagasaki.



Schematic illustrating a gun-assembly nuclear device and an implosion-type nuclear device. [1-3]

θ : 15 ~ 17° (Angle at the time of explosion in Hiroshima)

Fig. 1: Schematic illustrating a gun-assembly nuclear device and an implosion type nuclear device [1-3]

Table 1: Total Number of Casualties due to the Atomic Bomb, Hiroshima, 10 August 1946 *(3-6).

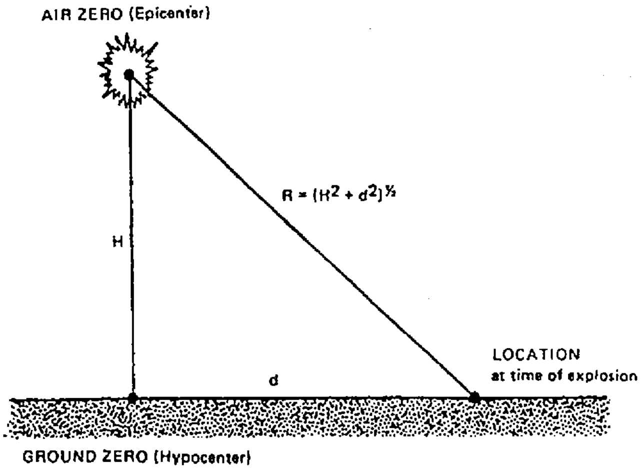
Distance from Hypocenter (km)	Killed	Severly Injured	Slightly Injured	Missing	Not Injured	Total
Under 0.5	19 327	478	338	593	924	21 622
0.5 - 1.0	42 271	3 046	1 919	1 366	4 434	53 036
1.0 - 1.5	37 689	7 732	9 522	1 188	9 140	65 271
1.5 - 2.0	13 422	7 627	11 516	227	11 698	44 490
2.0 - 2.5	4 513	7 830	14 149	98	26 096	52 686
2.5 - 3.0	1 139	2 923	6 795	32	19 907	30 796
3.0 - 3.5	117	474	1 934	2	10 250	12 777
3.5 - 4.0	100	295	1 768	3	13 513	15 679
4.0 - 4.5	8	64	373		4 260	4 705
4.5 - 5.0	31	36	156	1	6 593	6 817
Over 5.0	42	19	136	167	11 798	12 162
Total	118 661	30 524	48 606	3 677	118 613	320 081

* Military personnel not included (Population in Hiroshima about 330 000 in August, 1945)(4).
Source: Hiroshima Shiyakusho, *Hiroshima Genbaku Sensaish*, (Hiroshima, 1971), vol. I.

Table 2: Number of Casualties due to the Atomic Bomb in Nagasaki * as of 31 December 1945 (3-6).

Killed	73 884
Injured	74 909
Affected	120 820

* It is unknown whether floating population, such as military personnel and other volunteer corps, is included.
Source: Nagasaki City A-bomb Records Persevation Committee (Population in Hiroshima about 330 000 in August, 1945)(4).



Note: The term epicentre and hypocentre are used sometimes reversed in Ref. (4). (Comment by Y. Nishiwaki)

Fig. 2: Schematic illustrating the relationship between height of bomb, distance from hypocentre, and slant distance (1,2).

Table 3: Initial radiation doses (DS86) [(4)].

Distance from epicentre (m)		Distance from hypocentre (m)	Gamma-ray dose (Gy)	Neutron dose (Gy)
0	Hiroshima	580	-	-
	Nagasaki	503	-	-
500	Hiroshima	766	35.0	6.04
	Nagasaki	709	78.5	3.31
1 000	Hiroshima	1 156	3.93	0.227
	Nagasaki	1 119	7.83	0.143
1 500	Hiroshima	1 608	0.487	0.008
	Nagasaki	1 582	0.893	0.006
2 000	Hiroshima	2 082	0.071	0.0
	Nagasaki	2 062	0.127	0.0
2 500	Hiroshima	2 566	0.012	0.0
	Nagasaki	2 550	0.021	0.0

N.B. Since the above values are the mid-air doses, they can be deemed appropriate as values of the radiation dose absorbed by surface human skin in unshielded victims. For the effect on internal organs such as the bone marrow, it is necessary to convert the dose measured in grays into sieverts, taking into account of the dose reduction by shielding and radiosensitivity. Studies are still in progress with respect to distances greater than 2000 m from the hypocentre.

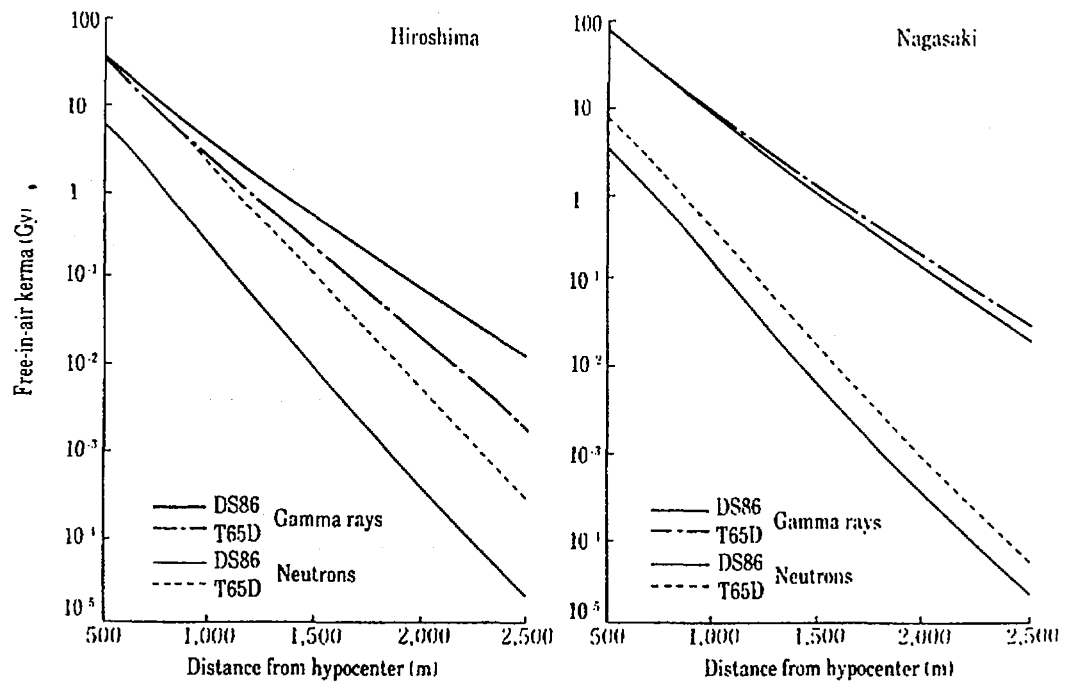


Fig. 3: Comparison of DS86 and T65D values of the free-in-air kerma of gamma rays and neutrons [(4)].

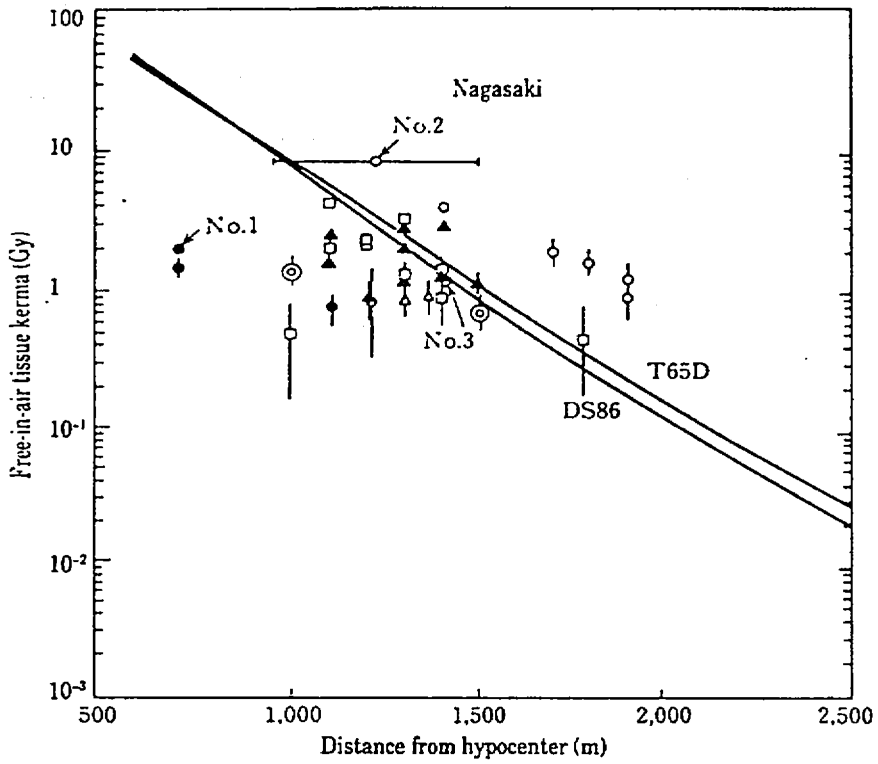


Fig. 4: Comparison of ESR-determined doses for Nagasaki atomic bomb survivors with calculated T65D and DS86 free-in-air tissue kermas [4]. (Gamma rays)
The solid lines represent calculated values; other symbols indicate shielding conditions:
○ = no shielding,
◎ = shielding by trees or brick walls,
□ = inside wooden structure,
△ = inside munitions factory with roofs of slates supported by iron frames etc.,
● = inside reinforced concrete structure.
The specimen for which there was a large margin of error in the distance (specimen No.2) was obtained from an individual who died within a week of the explosion from acute radiation illness, thus rendering ascertainment of the precise point of exposure impossible.

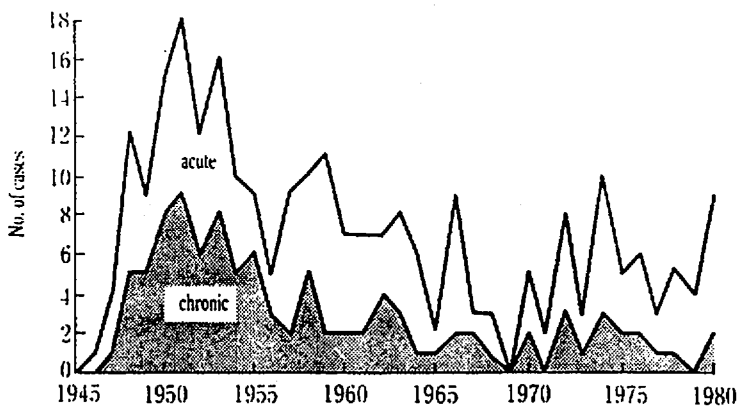


Fig. 5: Number of leukemia cases among Hiroshima atomic bomb survivors by year of onset (exposed within 2 000 m). Proportion of chronic myelocytic leukemia was high among Hiroshima survivors. [4]

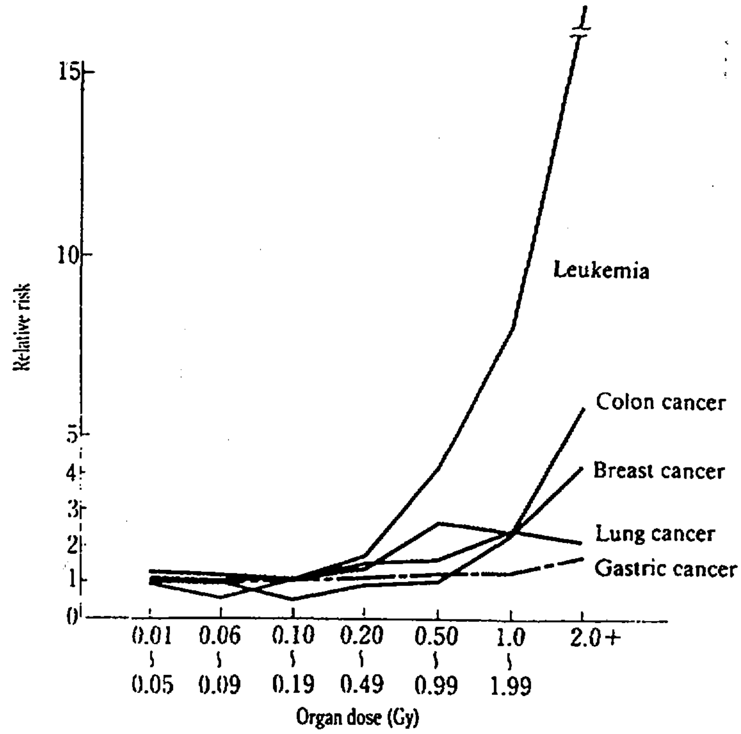


Fig. 6: Estimated relative risks for various malignant tumors observed in atomic bomb survivors (in comparison with the non-exposed (0 Gy) population) [4].

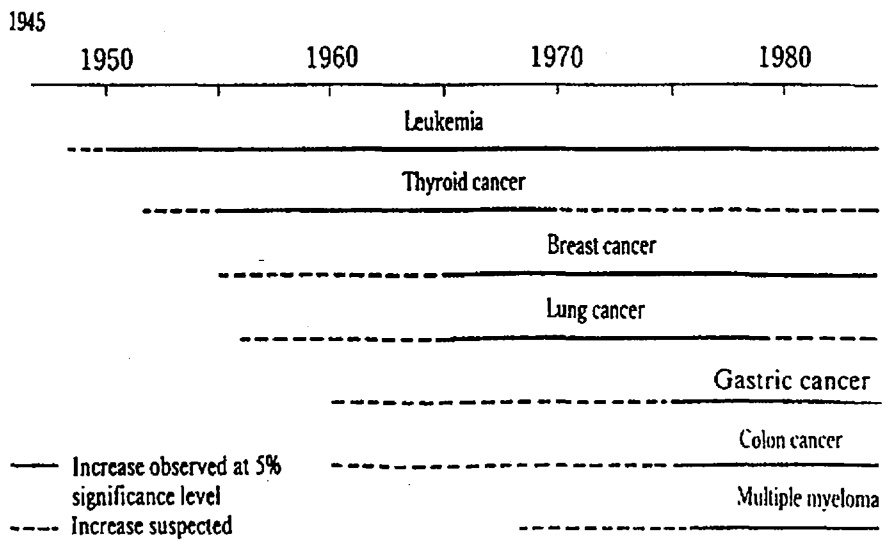


Fig. 7: Year of development of maligant tumors [4].

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9. Kawai, H., private communication: At Ohkuno Island, about 50 km south-east-east of Hiroshima, the following chemical weapons were produced: Yellow No. 1 Yperite, Yellow No. 2 Lewsite, Brown No. 1 Hydrogen Cyanide Gas, Red No.1 Diphenyl-Cyanoarsine, Green No. 1 Chloro-Acetophenone. At the end of the war, all stores were buried underground at the neighbouring island of Ohmi-jima.
10. Nishiwaki, Y., private communications with General Fukuda, et al: Towards the end of the war there was an unconfirmed information that the US might use chemical weapons on attacking Japan Mainland. Preparing for such case, the Gas Officer, a graduate of Narashino Chemical School, was assigned to each brigade and larger units. It seems to be highly probable that some chemical weapons were stored at the military headquarters about 700 m from the hypocentre in Hiroshima and were released by breakage of storehouse at the time of atomic bombing. If we use the data, which are correlated only with radiation, as a basis of radiation protection standard, it may be considered on a safer side, although exact quantitative estimation of all non-radiation effects and combined effects would be difficult.