SESSION VI

EDUCATION
FOR
GENERAL PUBLIC,
RISK COMMUNICATION
AND NUCLEAR PROBLEMS

WEDNESDAY, AUGUST 25

6.1 Radiation Application Contributing to Welfare of the Nation

国民の福祉に貢献する放射線利用

Kazuaki YANAGISAWA[1] and Ryuichi TANAKA[2]
柳澤和章[1]、田中隆一[2]

[1]Office of Planning, Japan Atomic Energy Research Institute
日本原子力研究所企画室
1233 Watanuki-cho, Takasaki-shi, Gunma 370-1292
〒370-1292 高崎市綿貫町 1233

[2] Radiation Education Forum
放射線教育フォーラム
3-3-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-0013
〒100-0013 東京都千代田区霞ヶ関 3-3-1

Abstract

Ionizing radiation has been widely applied in the fields of industry, agriculture, and medicine. Now, radiation application offers great benefit to people in various ways to improve quality of life, such as sterilization of disposable medical equipment, semiconductors, radiographic testing and radial tire in industry, food irradiation, sterile insect technique (SIT), mutation breeding (rice etc.) and radioisotope utilization in agriculture, diagnostic imaging, prostate cancer, FDG-PET, medical equipment, radioisotopes, radio pharmacy and contrast media in medicine. However, the benefit has not been so far estimated economically in Japan. In the present study, the concept of 'economic scale' was introduced as an economic measure indicating the magnitude of the market created by products manufactured by the utilization of radiation. The total economic scale of radiation application in Japan was evaluated 71b$ (billion dollars, 1$=121yen) for the fiscal year of 1997. This quantification of the benefit of radiation applications will greatly contribute to radiation education and risk communication for general public.

要旨

放射線は工業、農業及び医療の分野に広く利用されるようになった。いまや放射線利用は、生活の質を向上させるさまざまな手段よって人々に大きな便益をもたらしている。代表的な実例として、工業利用では、使い捨て用医療用具の滅菌、半導体、非破壊検査、ラジアルタイヤの生産が、農業利用分野では、食品照射、害虫駆除、突然変異育種（米等）、ラジオアイソトープ利用が、また、医療利用分野では、放射線関連画像診断、前立腺がん、FDG-PET、医療機器、RI、放射性医薬品、造影剤が挙げられる。しかしながら、こうした便益は経済的な尺度によって日本においてこれまで評価されなかった。この調査研究では、放射線の使用によって製造された製品によって創り出された市場の大きさを示す経済規模の概念を採用した。これをもとに、放射線利用の経済規模が各利用分野毎に評価され、その 1997 年度における総額は 71b$（1 ドル＝121 円で約 8 兆 6 千億円）とみなされた。この放射線利用の定量化は一般公衆への放射線教育やリスクコミュニケーションに大いに貢献すると考えられる。

Ⅰ. Introduction

In highly industrial countries, most people are exposed to unreliable information about radiation risk and nuclear energy mainly from electronic and printed media. They have a public sentiment of fear, antipathy and rejection against radiation and nuclear energy. Excessive information about the risk of radiation may cause public to have fears and doubts about the utilization of radiation that is the benefit of radiation. To improve the risk and benefit relation, we should emphasize quantification of the benefit to make risk communication more reliable and informative. Basically, the application of nuclear energy and radiation is so composed of variety of complicated components governed by different engineering mechanisms that it keeps the majority of people at a distance. To overcome this situation, the authors try to tell many teachers and specialists how radiation is useful and beneficial to people's lives. Hence, an economic scale of radiation application in the field of industry, agriculture and medicine is described here. All statistical data used are derived from the year of 1997. Obtained results are also comparable with those of nuclear energy.

Ⅱ. Method and Concept

Economic scale is defined here as economic index indicating the magnitude of the market created by products manufactured by the utilization of radiation or nuclear energy. Regarding the former, an amount of Market Creation Product (MCP) such as radial tire (industry), food irradiation (agriculture) and medical equipment (medicine) in Japan was studied by defining the factory production cost of each article as economic scale. It is usually referred to as the direct economic effect. Regarding the latter, the retail revenue from electricity generated from nuclear power stations was defined as the economic scale. It also has a direct economic effect. The sum of aforementioned two parameters was defined as the economic scale for the application of nuclear energy and radiation.

Ⅲ. Results and Discussion

1. Economic Scale of Radiation and Nuclear Energy in Japan

A lot of Japanese may be considering that radiation is like a forty-years-old shanty, hence that the economic scale of radiation is fairly small in magnitude than that of nuclear energy. The result of quantitative study made by the authors is very interesting [1]. Hence, as shown in **Fig. 1**, the total of 130b$ is composed of 71b$ (54%) radiation with a further 60b$ (46%) on nuclear energy. It points out that the use of radiation and nuclear energy in modern times are inseparable and the two exists like two wheels of a car.

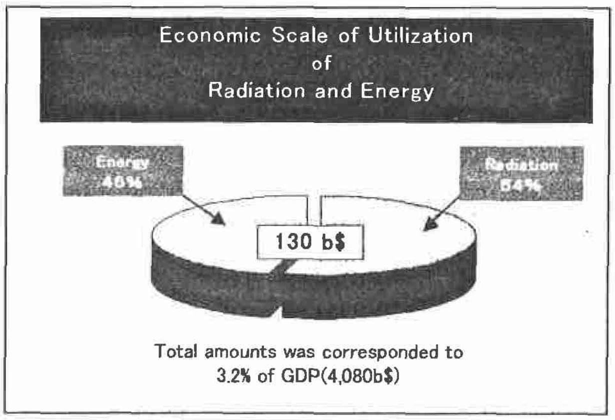


Fig.1 Economic scale of radiation and nuclear energy in Japan for 1977. 1$=121yen

2. Radiation Application Contributing to Welfare

Generally, the nuclear energy is recognized as one of important infrastructure in the nation, while radiation application is recognized as important tools for contributing the welfare of people's lives.

2.1 Industry

Regarding industry, the following seven areas are studied. In those, essential goods are produced by the whole or the partial utilization of radiation.

(1) Radiation Sterilization of Disposable Medical Equipment

Gamma radiation has the function of sterilizing microbes in and on medical equipments by inactivating the critical biomolecules in the cell, where the gamma source is usually the isotope Co-60. Revenue from sterilization of disposable medical equipments in Japan (12 major and 2,000 small companies) was 2.3b$ with the assumption of a share as γ : EB: EtO: autoclaving=0.59: 0.04: 0.27: 0.1, where γ means the gamma radiation process, EB the electron beam process, EtO the ethylene oxide gas process and autoclaving the steam autoclaving process, respectively. **Photo. 1** shows examples of radiation sterilization of medical equipments; dialyzer, syringe, injection needle, tubes and scalpel.

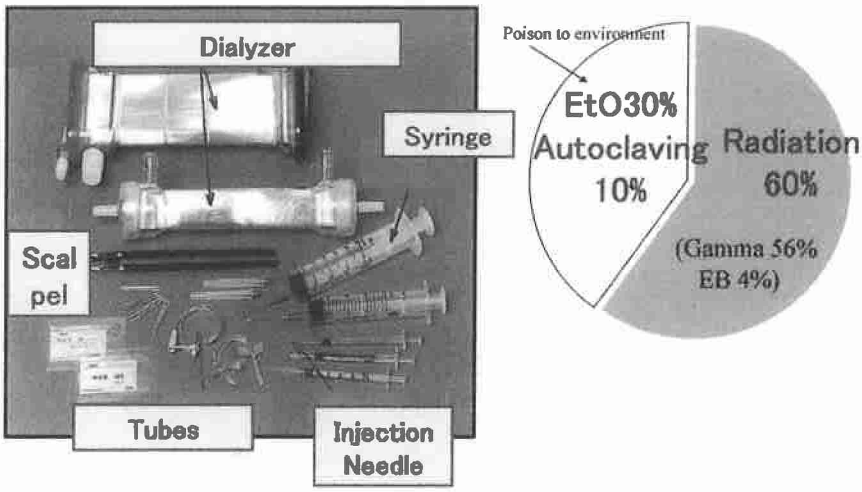


Photo.1 Sterilized disposable medical equipments, where the occupational ratio of radiation (γ and EB) is about 60%.

(2) Fabrication of Semiconductors

Microscopic fabrication in semiconductors consists mainly of elemental techniques such as lithography, etching, impurity doping and so on, where EB, X-ray, laser, ion beam and thermal neutrons are used as a variety of tools. This is shown in **Fig. 2.** The economic scale of semiconductor production (memory, system LSI, and other semiconductors) in Japan was revealed to be about 44.3b$. Revenue from 11 major Japanese companies such as NEC, Toshiba, Hitachi, Fujitsu and so on was accumulated. From a viewpoint of normal sense, about 44b$ is too big to imagine. People's suspicious of this big money should not run because of fact. A market of fabricating machines prepared for semiconductors (11b$) is excluded here. The semiconductor market in the world was about 147b$, of which about 45% was shared by the U. S. A. and Japan.

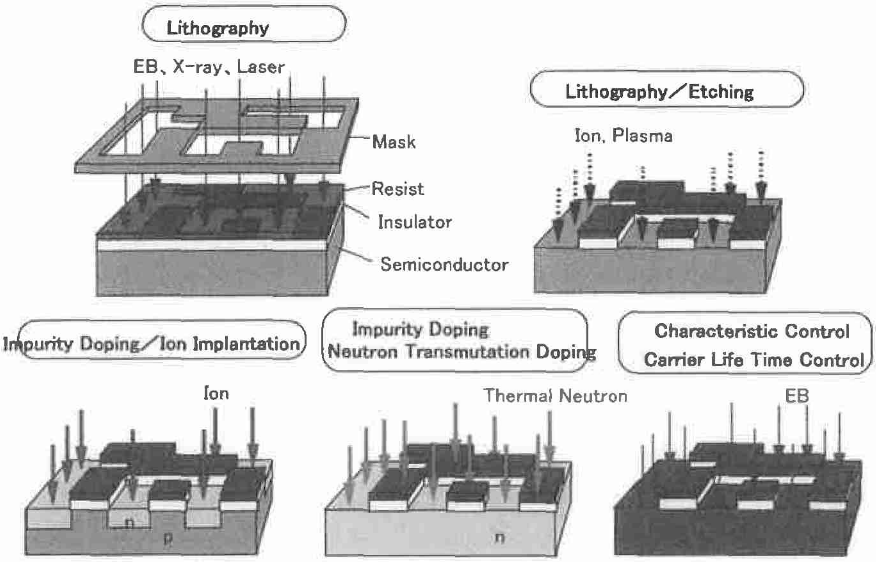


Fig.2 EB, X-ray, laser, ion beam and thermal neutrons are using in semiconductor fabrication.

(3) Accelerators

Electron accelerators are useful and powerful tools if the are applied to an industrial irradiation process such as the production of cross-linked wire, heat shrinkable film and tubing, sterilization and so on. Apart from the economic scale, the clarification of installed numbers of accelerators was shown in **Table 1** with data of North America involving the U. S. A., Canada and Mexico.

Table 1 Accelerators installed in Japan and North America during 1970-1998 (29 years)

Category / Energy level / Field in Industry	(1) Low ~300keV		(2) Medium 300keV~3MeV		(3) High 3MeV~10MeV		Sum (1)+(2)+(3)	
	Japan	NA	Japan	NA	Japan	NA	Japan	NA
Electric Wire & Cables	1	5	50	49	0	0	51	54
Polyethylene Foam	2	0	12	7	0	0	14	7
Heat Shrinkable Tubes & Film	10	24	17	202	1	1	28	227
Radial Tires	3	1	20	35	0	0	23	36
Curing (Coating, Laminating, etc.)	44	150	2	7	0	0	46	157
Exhaust Gas & Waste Water Treatment	0	0	4	5	0	0	4	5
Sterilization	3	8	2	1	6	5	11	14
Contract (Food irradiation, etc.)	3	18	10	16	3	10	16	44
Research & Development	112	100	2	2	1	2	115	104
Sum	178	306	119	324	11	18	308	648

NA: North America consisted of the U. S. A., Canada and Mexico

The total number of electron accelerators installed was 308 for Japan and 648 for North America. The latter was large in magnitude by a factor of about 2. The use of those accelerators in the field of curing (coating, lamination) as well as heat shrinkable tubes and film, has advanced significantly in the U. S. A.

(4) Radiographic Testing

The retail revenue of 310 companies related to non-destructive testing was about 1.1b$. The market share of radiographic testing (RT) of these was 24.6%; the revenue regarding RT was 1.1x0.246=0.26b$. **Photo 2** shows a testing of soundness of large diameter pipe by using X-ray inspection.

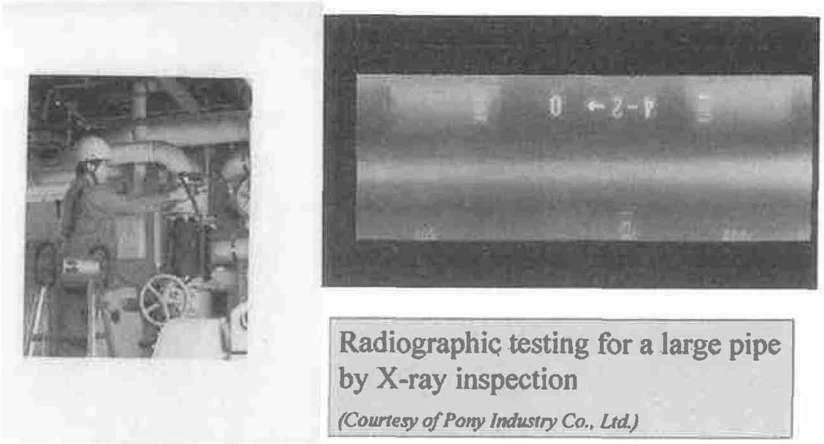


Photo.2 Radiographic testing of the large pipe by X-ray

(5) Radioisotope (RI) Applications and Radiation Protection for Facilities and Instruments

Due to wide and variety usage of RI in our country, the economic scale of it is very difficult to be evaluated. A preliminary study [2] reveals that it was roughly 540M$ for radiation protection related to facilities and instruments. This was obtained from questionnaires sent to 56 companies related. As for Japan, the Law Concerning Prevention from Radiation Hazards due to Radioisotopes, etc. (Law No. 167, June 10, 1957) exists, where the establishments which have been permitted by the authority (MEXT) to use radioisotopes and/or radiation generators, and the establishments that have been reported to and have been accepted by the authority to use only sealed radioisotopes of less then 3.7MBq (100 μ Ci) in all are listed in the statistical data. The readers should be understood how RI is useful and provided for our environment. **Fig. 3** shows a typical example of RI usage in our environment of life.

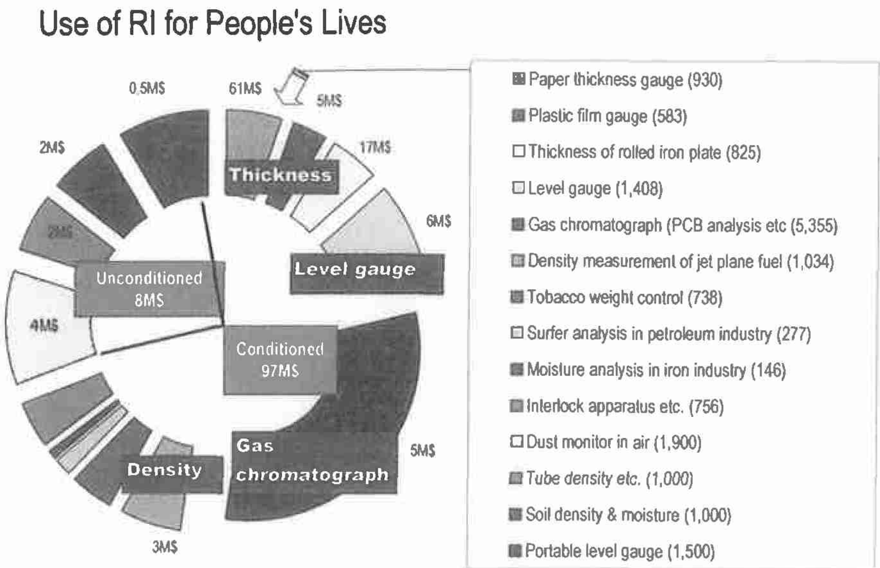


Fig.3 RI used for thickness gauge, level gauge, densitometer and dust monitoring etc.
Unconditioned means RI level below 3.7MBq

(6) Radiation Processing represented by the Cross-linking of Radial Tires

From an economical point of view, EB radiation is certainly competitive in the rubber industry. Basically, radiation processing of rubber appears good because partial curing of calendared fabric, reduction of rubber coating gauge, prevention of ply movement during final curing, reduction of operating costs and increase in production rates can occur. As for Japan, tire sales for 5 big companies (Bridgestone Corp., Yokohama Rubber Co, Ltd., Sumitomo Rubber Industries, Ltd., Toyo Tire & Rubber Co., Ltd., Ohtsu Tire & Rubber Co., Ltd.) were 9.2b$, where the share of radial tires made by EB vulcanization of tire components was 91%. Namely, the economic scale of radial tires in Japan was 8.4b$. It is worth mentioning that, according to an estimation by W. R. Scheerer [3], the liner cost for non-irradiation was 2.15$ a tire but the liner cost for irradiation was 1.80$ a tire, which gave a net savings of 16% by EB vulcanization. Hence, EB vulcanization saves about 1.3b$ a year. **Fig. 4** shows radial tires with those fabrication merits and economic scales.

•Annual tire sales in Japan
9.2b$

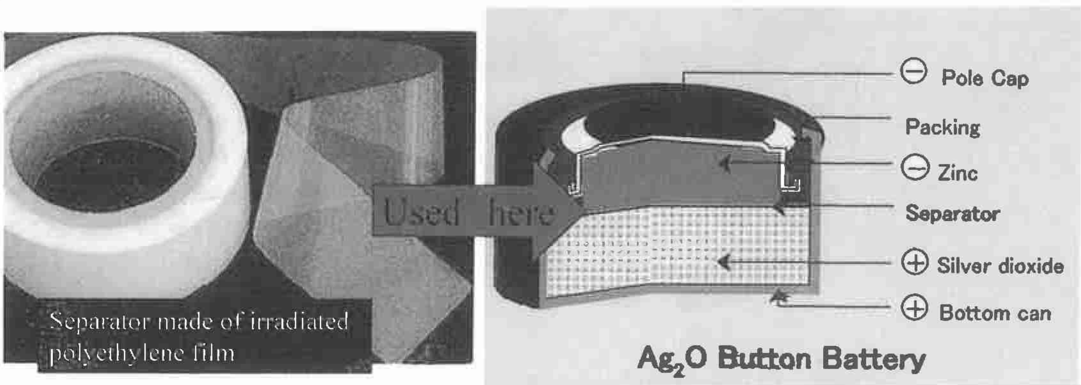
•Share of radial tire produced by radiation
91%

•Economic scale of radial tires
9.2x0.91=8.4b$

Characteristics of radiation usage for radial tire production:
(1) Partial curing of calendared fabric, (2) Reduction of rubber coating gauge,
(3) Prevention of ply movement during final curing, (4) Reduction of operating costs and (5) Increase in production rates

Fig.4 Fabrication of radial tires by radiation processing

Except for radial tires, radiation processing includes; 1) the cross-linking represented by wire and cabled (0.4b$), foam (0.15b$), heat shrink tube/film (0.14b$), 2) the degradation represented by PTFE (4M$), 3) the curing represented by coating and converting (25M$), and the graft represented by cell separator and so on (8M$), respectively. A total sum of those except radial tires is 0.7b$. **Fig. 5** shows the cell separator fabricated by the graft technique.



Conductive polyethylene film having thickness by 10 μ m fabricated by radiation graft technique

Fig.5 Cell separator (polyethylene thin film) fabricated by graft technique

(7) Purchase of Irradiation Facilities

Purchase of facilities, for example, cobalt 60 usage in industry as well as X-ray apparatus for diagnosis in medicine was studied. Obtained sales related to the former items was 0.48b$ and those related to the latter items was 3.0b$. Details with respect to studied items are described elsewhere [4].

Summary in Industry:

Obtained economic scales of aforementioned items are summarized in **Table 2**. The share of representative industrial fields is shown in **Fig. 6**. The largest is semiconductor (71%), followed by radiation processing (15%).

Table 2 Economic scale of radiation applications in industry in Japan (1997) 1$=121yen

Items in Industry	Sales(b$)
(1) Sterilization of Disposal Medical Equipments	2.3
(2) Fabrication of Semi-conductors	44
(3) Accelerators	-
(4) Radiographic Testing	0.26
(5) Radiation Protection for Facilities and Instruments	0.54
(6) Fabrication Process, Radial Tires(8.4b$) and Others (0.7b$)	9.1
(7) Purchase of Irradiation Facilities	3.5
Sum	60
Note: Economic scale of accelerators is omitted here	

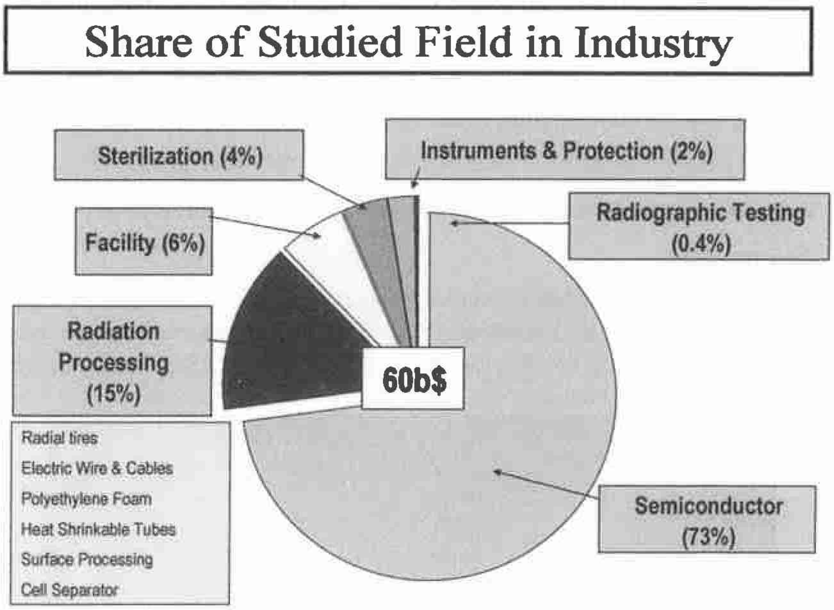


Fig.6 Share of industrial fields studied

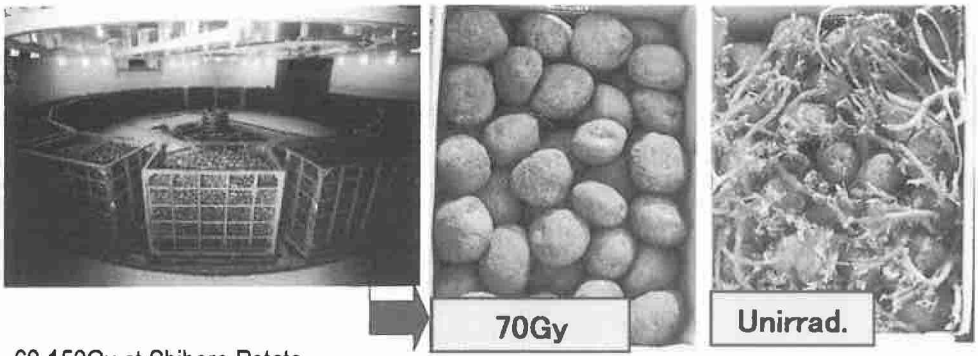
2.2 Agriculture

Regarding agriculture, the following three main fields are studied.

(1) Radiation processing

(i) Food irradiation

For the food irradiation in our country, only permitted by the government was the inhibition of sprouting in potatoes with run since 1974. Economic scale of potato irradiation was calculated to be 16M$ using the amount of 15,000 ton/y [5] with an associated cost of 128 yen/kg. The market share of irradiated potato is only 0.6% (15,000t / 2,440,000t). Irradiation is carrying out at Shihoro, Hokkaido as shown in **Fig. 7** for more than 25 years.



60-150Gy at Shihoro Potato Irradiation Plant

Sprout Inhibition of potato by irradiation, Storage 6 months at room temp.

Share in production of irradiated potato: 15,000 tons for Shihoro vs 2,440,000 tons for all countries.Hence, irradiated potato has a share by 0.6%. Share in sales of irradiated potato: 16M$ for Shihoro vs 2,579M$ for all countries, leading to 0.6% share

Fig. 7 Overview of the Shihoro potato irradiation facility located in Hokkaido [5]

(ii) SIT (Sterile Insect Technique)

SIT is an extremely useful technique for eradicating the fruit fly. In old days the islands of Okinawa have been infested with melon fly and local people were damaged and further prohibited the transport of agricultural products to the main islands of Japan. The SIT Project on the Okinawa islands was initiated in 1977 as shown in **Fig. 8**, and succeeded in eradicating the melon fly from the entire Okinawa region in 1993. The economic scale of the entire Okinawa region and Amami Islands (Kagoshima Prefecture) benefited by SIT is 69 M$. This increase resulted from an increase in the amount of agricultural products transported to the mainland of Japan as well as an increase in crop production within the islands.

Sterile of melon flies caused 1) increased crop production inside islands, 2) cost saving in analysis and fumigation, 3) increase of crop transport to outside Okinawa etc. Radiation benefits in total is 69M$, where 63M$ for Okinawa and 6M$ for Amami islands.

Fig. 8 A photograph of melon fly (about 8mm long) [6] and facilities for melon fly eradication belonged to the Office of Okinawa Prefecture Fruit Fly Eradication Project located in Naha.

(iii) Sterilization

Radiation sterilization relating to laboratory animal feed and food packaging materials is 50M$ consisting of 2M$ for the former and 48M$ for the latter. The bag in box (BIB) is the largest in the latter.

(2) Mutation breeding

(i) Rice

After the finding of induced mutation in *Drosophila* fly and maize plants, radiation induced plant mutation breeding has been a key topic investigated in many countries. In Japan, cytogenetic studies on a more fundamental level have been performed using X-rays. Using gamma-irradiation, the first practical and successful application to the case of rice was registered and opened to the public in 1961 more than ten years prior to a comparable variety in the U.S. rice variety, 'Calrose 76'. The very first mutant variety was named 'Reimei', which attained lodging resistance by induced semi-dwarfness as the mutant character.

(ii) Crop

Following this variety, 128 varieties have been developed in various crop species in Japan as of 1999. Among them, 55 varieties (including crossed offspring varieties derived from 'Reimei') were in rice, ten in barley, two in wheat, five mutant cultivars in soybean *etc.* as shown in **Table 3**. The induced mutation technique was also very effective for changing the flowering colors in *Chrysanthemums* and total of 19 varieties have been produced.

Table 3 Mutation breeding in Japan (1999)

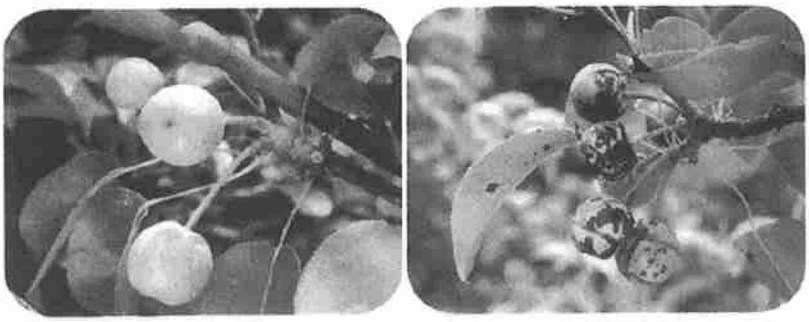
Category	Common Name	(1)Direct	(2)Indirect*
Cereals	Rice (Reimei,*etc*)	8	47
	Barley	6	4
	Wheat	2	
Beans	Soybean	9	1
	Others	2	
Fruits	Apple	1	
	Pear	3	
	Peach	1	
Grasses	Lawn	4	
Flowers	*Chrysanthemum* , *etc*	39	
Vegetables	Tomato, *etc*	6	
Subtotal		88	56
* Mutant in its pedigree		Sum:(1)+(2)=128	

(iii) Fruit

In fruit trees, the most effective case was a disease resistant mutant in a Japanese pear, 'Nijisseiki' (meaning 'twentieth century' in Japanese). The variety is highly evaluated in the market by its juicy high quality and dominated the domestic market for most of the twentieth century, as the name indicates. The variety, however, had a very significant weakness of being susceptible to black spot disease. Farmers tried to protect the high quality fruits from the disease by spraying fungicides almost every week. A disease resistant mutant of this product had been awaited for a long time. As shown in **Fig. 9**, chronic irradiation in the gamma-field (Institute of Radiation Breeding, the National Institute of Agrobiological Resources, Ibaraki) could induce a promising disease resistant twig, and after grafting of the mutant twig to separate it as a clone. Various tests were performed on it and finally the mutant clone was registered and released as 'Gold-Nijisseiki' in 1991 [7]. Revenue of this fruit is estimated to be about 25M$ a year.

As for the economic impact, the most effective crop group in Japan is rice. Rice with its 17 active mutant varieties was by far the largest, amounting to 774 M$ (96.3 %) followed by 25M$ (3.1%) of pear, 4M$ (0.5%) of various beans and 1M$ (0.1%) of others including peach and *Chrysanthemum*.

Chronic irradiation in the gamma-field, (Institute of Radiation Breeding, the National Institute of Agrobiological Resources) could induce a promising disease resistant twig, and after grafting of the mutant twig to separate it as a clone. Various tests were performed on it and finally the mutant clone was registered and released as 'Gold-Nijisseiki' in 1991



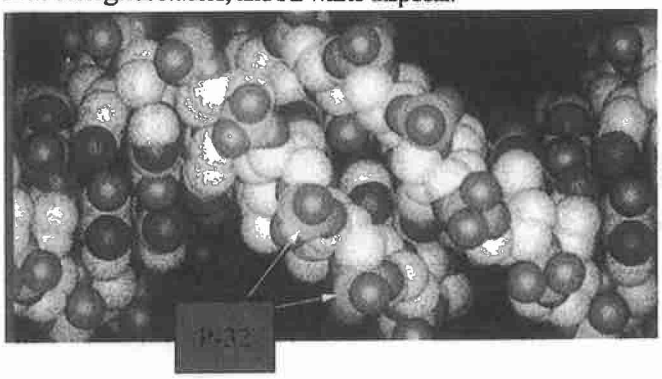
Gold Nijisseiki (mutant) Nijisseiki

Fig.9 Mutation Breeding, Japanese pear mutant cultivar resistant to black spot disease induced by chronic irradiation; 25M$ a year

(3) Research and Development by RI Utilization

(i) Laboratory work for RI provision in agricultural as well as biological studies, and RI waste disposal.

The total economic scale for this was about 4M$. Isotopes of ^{3}H, ^{14}C, ^{35}S and ^{125}I are important for agricultural and biological studies, while ^{137}Cs is useful for studying fall out. Economic scales of the first three are 0.5M$ 0.6M$ and 0.2M$, respectively. The latter two contribute a further 0.3M$ each. As shown in **Fig. 10**, the use of ^{32}P as a tracer is the largest and has increased in the area of gene engineering having a total retail cost of 1.6M$ per year. Japan Radioisotope Association treated RI wastes with a commission by 2M$.



^{32}P as a tracer has increased its usage in the area of gene engineering having a total retail cost of 1.6M$ a year.

Fig. 10 Use of ^{32}P as a tracer in gene engineering

(ii) Environmental protection of air pollution analysis The work is mainly addressed to chemical environmental analysis against materials released from air pollutant. Governmental sectors are mainly doing this job with economic scale by 17M$ as a total retail revenue.

(iii) Chronology for geology and archeology using ^{14}C

As shown in **Fig. 11**, ^{14}C usage for archeology is widely practiced. In Japan, a total of 9 private universities and agencies perform about 150 measurements a year with an average cost of about 500$. The total economic scale is 500$ x 150 x 9 or 0.68M$.

By using Tandetron (left), carbide (carbon-14) adhered on an earthenware vessel is analyzed to know its fabrication year. This case the stone (right) was estimated to be fabricated around years of 15,320-16,540 cal BP. (Ref: brochure issued by Nagoya University Center for Chronological Research)

Fig.11 ^{14}C usage for archeology

Summary in Agriculture:

Table 4 summarizes all components entering the economic scale [8]. The total cost of 964M$ consisted of 136M$ (14%) for radiation processing, 804M$ (83%) for mutation breeding and 24M$ (3%) for RI utilization. The share of studied three fields in agriculture is shown in **Fig. 12.** The largest is mutant breeding (83%).

Table 4 Annual economic scale for radiation applications in agriculture for Japan (1997)

Field	Item	Revenue	Field Sum
1. Radiation Processsing			136M$
(1) Food irradiation	Potatoes	16	
(2) SIT	Fruit flies	69	
(3) Sterilization	Bag-in-box	50	
	Feed for laboratory animals	2	
2. Mutation Breeding			804M$
	Rice (17 varieties)	774	
	Pear (Gold Nijisseiki and others)	25	
	Beans (4 varieties)	4	
	Others (Peach、*Chrysanthemum etc.*)	1	
3. Research & Development by RI Utilization			24M$
(1) Laboratory work	RI provision in Agro-Biological studies	4	
	RI depositions (solid, liquid etc.)	2	
(2) Environmental protection	Air pollution analysis	17	
(3) Chronology	Geology & Archeology by C-14 isotopes *etc.*	1	
Total Sum			964M$

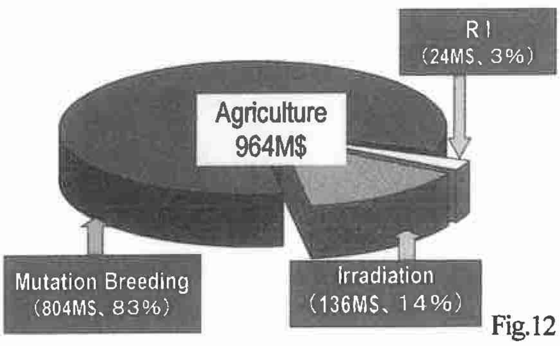


Fig.12 Share of agricultural fields studied

2.3 Medicine

Regarding medicine, the economic scale was decided by reimbursed receipts issued by hospitals and so on.

(1) National Health Expenditure to GDP

In Japan, national health expenditures were increased with every years and in 1997 it reached to 240b$. The figure is corresponding to 0.24% of Gross Domestic Products (GDP) and 1,903$ for personal expenditures of Japanese people [9].

(2) Radiological Usage in Medicine to National Healthcare Expenditures

A radiological use in medicine at the national healthcare expenditures (240b$) in Japan was about 4%, that is, about10 b$ [9]. The breakdown of 10b$ is listed in **Table 5.** It consists of 9b$ for medical care and 0.9b$ for dental care and very small amounts from charged particle therapy and boron neutron capture therapy (BNCT). Former two items were reimbursed but latter one was not. In medical and dental cares, radiological uses are, for example, diagnosis consisting of the X-ray diagnosis, the computed tomography (CT) and the nuclear medicine.

Table 5 Economic scale of medicine in studied fields in 1997 (Unit : M$)

Item		Reimbursement	Field Sum
1 Medicine			8,982
	1.1 Diagnosis (excluding MRI)		
	1) X-ray Inspection	4,192	
	2) Nuclear medicine	1,035	
	3) Computed Tomograph	3,287	
	1.2 Radiation Treatment	466	
	1.3 Inspection	2	
2 Dentistry			853
	2.1 Diagnosis	849	
	2.2 Radiation Treatment	4	
3 Sum of Medicine and Dentistry			9,835

Note:FDG-PET, proton treatment and boron neutron capture therapy (BNCT) are not reimbursed b public insurance. Cost of them known to date was 3M$ for proton treatment and 0.4M$ for BNCT. Cost for FDG-PET was not decided in the present study.

The share of individual items in medicine part (about 9b$ as mentioned in the above table) is shown in **Fig. 13.** X-ray diagnosis and computed tomography (CT) is large to the magnitude of 47% and 37%.

Followings are topics obtained from comparison between Japan and the U.S.A. [10].

(A1) Radiation Imaging

When one goes to a hospital as a patient, his first encounter may be a diagnostic imaging using radiation. According to our definition, magnetic resonance imaging (MRI) and ultrasonography were omitted because they are non-radiological modalities for imaging. The radiation imaging used here is X-ray diagnosis, CT and nuclear

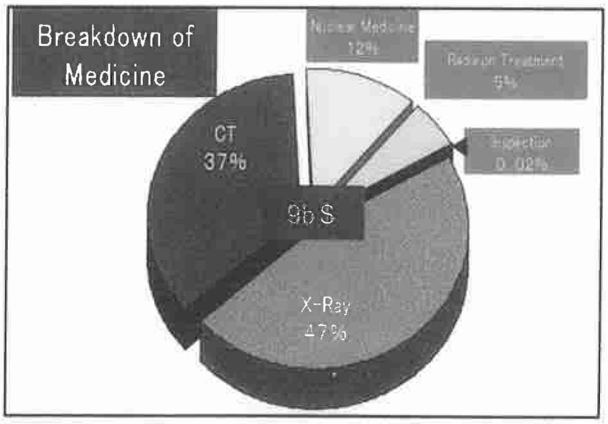


Fig.13 Share of the medical care at revenue by 9b$

medicine. Radiation imaging in the U. S. A. is 5 times that in Japan.

(A2) Cancer and Radiotherapy (RT)

RT is known as the one of the most useful treatments for various types of cancers. In old days, American patients rather than Japanese used RT aggressively to cure their diseases. The facts revealed are summarized in **Table 6.** Once Americans had any cancers (1.15million patients in 1994), 49% (560,262 patients) of those received RT. For Japanese, of the 440,001 new patients in 1995, only 15% (71,696 patients) received RT. Japanese patients are willing to have surgical operations than RT. This can be explained in various ways. With respect to cancer treatments, different attitudes exist between Americans and Japanese.

Table 6 Application rate of radiotherapy (RT) for patients with cancer

U. S. A.			Rate of RT(%)
Year	New patients	Patients treated by RT	
1994	1,150,000	560,262	49
1995	1,252,000		
Japan			Rate of RT(%)
Year	New patients	Patients treated by RT	
1994			
1995	440,001	71,696	15

(A3) Prostate Cancer

Prostate cancer is known to be a typical disease of males. This was the top malignant neoplasm among Americans in 1997. The rate of prostate cancer in the U. S. A. is 7 times higher than in Japan, implying that Americans have a constitutional predisposition to prostate cancer. Application of RT is 30% for Americans and only 5% for the Japanese. For the latter, hormone therapy is applied frequently.

(A4) Medical Equipment

During diagnostic imaging, a Japanese doctor uses X-rays, RT, nuclear medicine and CT. Additionally, an American doctor uses MRI and ultrasound having a respective share of 12% and 23% in the U. S. A. markets.

3. Economic scale comparison between industry, agriculture and medicine [11]

Results of the present study were summarized in **Fig. 14.** It revealed that the scale of utilization of radiation in that fiscal year stood at 71 b$ corresponding to about 1.7% of the gross domestic products (GDP). It consisted of 60 b$ for industry, 1 b$ for agricultural and 10 b$ for medicine, respectively.

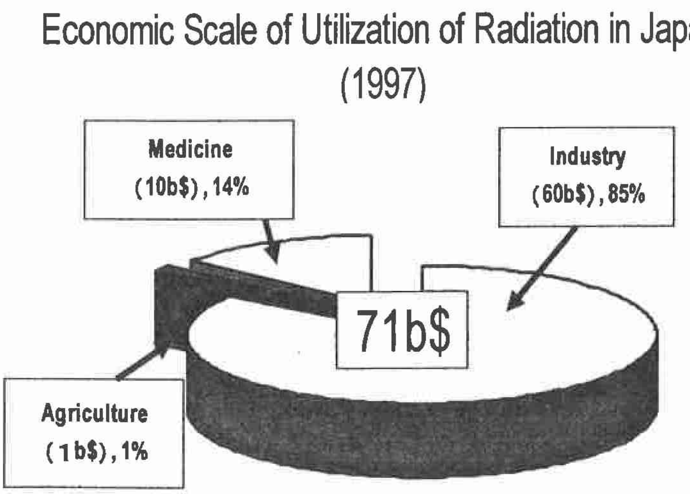


Fig. 14 Share of radiation in industry, agriculture and medicine. Total is 71b$.

IV. Conclusion

Scientific literacy in nuclear may be fostered by the correct understanding of radiation, especially in an age of compulsory education. Quantitative study revealed that the economic scale of radiation and nuclear energy in Japan is the total of 130b$, composing of 71b$ (54%) for the radiation with a further 60b$ (46%) on nuclear energy generated by 52 commercial nuclear power plants. The radiation is made of 60b$ for industry, 1b$ for agriculture and 10b$ for medicine. It should be emphasized that these are contributing to welfare of the nation in forms of sterilization of disposable medical equipments, semiconductors, radiographic testing and radial tire in industry, food irradiation, sterile insect technique (SIT), mutation breeding (rice etc.) and radioisotope utilization in agriculture, medicine and dentistry in radiological medicine. The fact shown by the present study should be used as a milestone of correct dissemination in the radiation education.

-Acknowledgment

Grateful acknowledgment is addressed to the Quantum and Radiation Research Division, Research Promotion Bureau, Ministry of Education, Culture, Sports, Science and Technology (MEXT) for their encouragement and permission to paper submission. The authors also appreciate assistance from Members of the Special Committee for Evaluation of Economy on Utilization of Radiation, for their excellent contributions to this work.

-References

[1] K. Yanagisawa, T. Kume, K. Makuuchi, S. Tagawa, M. Chino, T. Inoue, M. Takehisa, M. Hagiwara and M. Shimizu; "An Economic Index regarding Market Creation of Products obtained from Utilization of Radiation and Nuclear Energy (IV)-Comparison between Japan and the U. S. A. ", *J. Nucl. Sci. Technol.*,**39** [10], 1120(2002).

[2] K. Yanagisawa, T. Kume, K. Makuuchi: *Radioisotopes*, **50** [11], 21(2001).

[3] W. R. Scheerer : *Radiat. Phys. Chem.* **42**, [1-3], 535 (1993).

[4] S. Tagawa, M. Kashiwagi, T. Kamada, M. Sekiguchi, K. Hosobuchi, H. Tominaga, N. Ooka and K. Makuuchi: "Economic Scale of Utilization of Radiation (I): Industry-Comparison between Japan and the U. S. A. ", *J. Nucl.Sci. Technol.*, **39** [9], 1002 (2002).

[5] K. Makuuchi: Radiation Processing in the World, Proceedings of the 35th Annual Meeting on Radioisotopes in the Physical Sciences and Industries, pp.225-228 (1998). {in Japanese}.

[6] Okinawa Prefecture Fruit Fly Eradication Project Office: Eradication of Melon Fly from Japan (1993). {in Japanese}.

[7] T. Sanada and E. Amano: "Induced mutation in fruit trees", In "Somaclonal Variation and Induced Mutations in Crop Improvement." Kluwer Academic Publ., Dordrecht, pp.401-419 (1998).

[8] T. Kume, E. Amano, T. M. Nakanishi and M. Chino: "Economic Scale of Radiation (II):Agriculture-Comparison between Japan and the U. S. A. ", *J. Nucl.Sci. Technol.*, 39[10], 1106 (2002).

[9] Japan Atomic Energy Research Institute (JAERI): *Survey Report for Economic Scale of Utilization of Radiation*, (1999). {in Japanese}.

[10] T. Inoue, K. Hayakawa, H. Shiotari., E. Takada, M. Torikoshi, K. Nagasawa, K. Hagiwara and K. Yanagisawa: "Economic Scale of Utilization of Radiation(III): Medicine-Comparison between Japan and the U. S. A ", *J. Nucl. Sci.Technol.*, 39 [10], 1114(2002).

[11] Japan Atomic Energy Research Institute (JAERI): *Survey Report for Economic Scale of Utilization of Radiation [II]*, Report to MEXT (2000.3), [in Japanese].

6.2 Women's viewpoints on radiation and its applications
女性の視点から見た放射線とその利用

Tamiko IWASAKI
岩崎民子

National Institute of Radiological Sciences
放射線医学総合研究所
〒263-8555 千葉市稲毛区穴川 4-9-1
E-mail：tiwa@fml.nirs.go.jp

Abstract

The discoveries of X-ray by W. C. Roentgen and of radium by M. Curie were immediately followed by application of them to medical field. After the World War II, nuclear energy has been used as an energy source on the one hand, and radiations have been also applied to various familiar fields in daily life on the other hand. These are now being developed into essential technologies in our present life.

However, many people in general still fear nuclear power and radiation. There are numerous cases clearly indicating a widespread rejection of anything " nuclear" in the society as a whole.

People in "radiation" community have made great efforts to remove these unfortunate misunderstandings and negative images regarding the use of radiation, but these have not been satisfied. In this paper, I would like to reexamine possible factors that have been led to the dissatisfaction and do so from a different perspective from the standpoint of women.

1．緒言

19 世紀末、レントゲンによって発見されたX線とそれに続いてキュリー夫人によって発見されたラジウムは直ちに医学分野に利用された。第二次世界大戦後、エネルギー源としての原子力の利用が、一方、身近ないろいろな分野に放射線が利用されるようになった。現在我々の生活にとってこれらは欠かせないものになっている。然るに原子力・放射線に対して多くの人々は恐怖心を抱いており、時には拒否反応さえ示す。この分野に係わるものはこれらのイメージを払拭すべく多大の努力を今日まで払ってきたように思うが、その成果は必ずしも充分であるとは云えない。何故であろうか。私は長年女性、特に放射線とは殆ど縁の無い生活を送っている一般女性に放射線を正しく理解してもらうために努力してきた。この過程において私が経験したことの中、かれらが放射線をどう捉えているか、何が彼女たちを放射線から遠ざけているか、そして放射線の有用性をどの程度知っているだろうかという点について述べる。

2．放射線を分かり易く説明する

放射線に限らず、如何に正しい情報を社会に知らせるかは非常に大きな問題である。それを受け止める人々がある程度それについての知識を持っていて、理解できれば良いのだが、残念ながら、大抵の場合は理解不能とまではいかなくてもかなり困難である。その一つは言葉の問題である。 私が放射線とは全く関係のないある話を聞いた時である。そこで出会った最初の言葉が「コージョ・リョーゾク」であった。云われたときには見当もつかず、「それは英語ですか？」と聞き返したものである。これは我々の社会生活上欠くべからざる重要な基本理念で、民法第 90 条に出てくる言葉であり、「公序良俗（Public order and morals）」を意味する。こんな説明が無くても我々は不言実行しているのだが、法律書を紐解くとやたら難しい言葉が出てくる。

原子力・放射線の分野においても然りである。原子力・放射線は難しい、解からない、だから怖いと一般の人々は頭からそう思っている。何故解らないのか、専門家にとってはそれが解らない。だから幾ら同じ言葉を使って説明しても分かって貰えない。恐らく難解な「専門用語（言葉）」に一つはあると思われる。「放射線」、「被ばく」、「線量」、「グレイ或いはシーベルト」等々。この分野に関係のある仲間内ではこのような単純化した専門用語で通じるであろうが、一般公衆に説明する際には易しい別な言葉を使って、換言すれば一般の人々に解るような言葉へ「翻訳」することが絶対に必要だと思う。ちなみに、上記の「公序は公の秩序のことであり、良俗は善良の風俗」のことである。このように専門家の話す言葉を翻訳（通訳）するのが、原子力・放射線の分野ではマスコミであり、原子力の PA に携わっている人々であろう。

ここで女性の視点に立って、目線を同じレベルにおいてもう一度考え直してみよう。

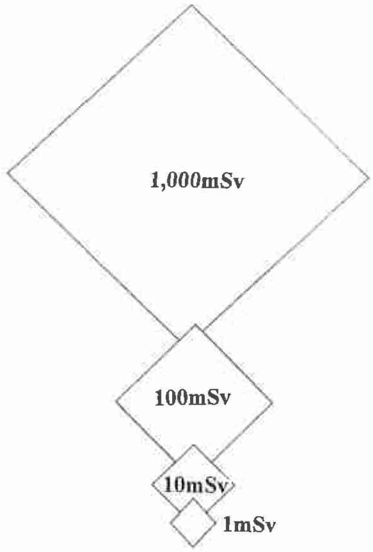
最近では、自然放射線は身の回りに存在すること、そしてそれらの放射線を我々は四六時中受けて（被ばくして）いることは、原子力・放射線の PA 活動によりかなり一般の人々が知っているようになった。だから余り自然放射線の被ばくのことは怖れてはいない。医療被ばくに関しては直接我々にとってメリットがあるので、被ばく線量が少々多くてもそれ程恐怖心を持たない。

さて、放射線はこのように四六時中環境からまた体内からも受けていて怖れることはないのだが、何が問題かというと「当たる量（被ばくする量）」が問題なのであると一般の人々には説明する。この際、まず用いる線量単位（グレイ、シーベルト、時にはベクレル）の説明から始めることが多い。このような言葉は日常生活にとっては必要ではなく、疎遠な単位である。一般の人々への「被ばく」と「線量」の説明には「ミリシーベルト」だけを用いれば充分であると考える。また、身近な被ばく線量として、1 年間に浴びる自然放射線の量（まるめて 1 ミリシーベルトとする）を基準にすることも良いかもしれない。しかしながら、そうはいっても長さや重さのように体感できるものではない。例えば、メートルの細かな定義は知らなくても、人々はメートルがどのくらいか、ミリメートルはどのくらいか実感として解っている。放射線の場合には、たとえ線量計をもってしても 1 ミリシーベルトを実感として捉えることは出来ない。

放射線の線量と人体影響（リスク）をよく図解で説明する。その際最も低い 1 ミリシーベルト（時には胸部 X 線の 0.05 ミリシーベルト）からヒトが死亡する 7,000-10,000 ミリシーベルト（7-10 シーベルト）までの線量を取り上げる。なんとそこには 4 桁以上の違

いがある。長さで言えば、1ミリメートルの大きさの話をしていて、急に10,000ミリメートル（10 メートル）の話に持っていくことになる。さて、それを図示しようとすると、従来のような対数目盛で表さざるを得ない。そうすると、1ミリシーベルトと10,000ミリシーベルト（10 シーベルト）はよくよく注意しないと 4 倍にしか捉えられない。専門家には対数目盛で表すことにはなんの抵抗もないが、一般の人々特に私が対象としている女性にとってはその大小関係が「容易に」明確に把握できない。このことは以前から私の脳裏を離れなかった。国連環境計画(UNEP)の PR 誌「放射線一その線量、影響、リスク」において面積や丸の数でその大小関係を表しているものがある（第１図）。これだとかなり線量の大小関係が視覚的に捉えられるが、この表し方では限度がある。そして、実感として捉え難い。

そこで日常生活の中で4桁もの違いを一つの単位で表すことが出来るものとして、例えば貨幣に例えたらどうであろうか。お金は最も身近にあるものであり、主婦にとっても馴染みやすい。1ミリシーベルトが1円、10,000ミリシーベルトが1万円になぞらえるわけである。そうすれば、「1年に自然放射線から浴びる量は1円ですよ、また一般公衆の線量限度も1年1円です」。「コインでは人体への影響はありません。」「お札になるような線量では人体に影響が見られます、そして10,000円では殆どの人々は死亡します。」というようにである。このアイデアを用いればグラフは不要であり、恐らく線量の大きさと障害リスクとの関係が「容易に」実感として理解できるのではなかろうか。



第１図　線量の大小比較

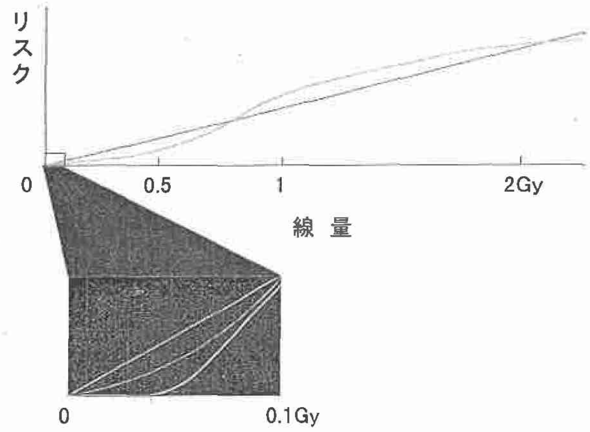
Comparison of dose

早速このアイデアを用いて一般女性に説明したところ、非常に分かり易い、線量の大小関係と障害の程度が直ぐに理解できるとの評価を得たのである。新聞報道などでは、「自然放射線の 2 倍にもなっている」といえば、「危ない」というイメージを持つ。しかし1円が2円になったと言えば、普段余り気に掛けるほどのものでなく、大したことはないと想像できる。これが同じ 2 倍でも、1,000 円の 2 倍となると貨幣価値に重さがでてくる。このようにある程度実感として捉えることが出来るのではなかろうか。

最近は“低線量の影響”についてもよく取り上げられる。これを図示したものが第２図である。こんなに低い線量の範囲についてしきい値の有無を論じているのである。“低線量”とはどのくらいの線量を指しているのであろうか。これも大雑把に「コイン程度の線量（100円以下）ですよ」といえば記憶に入り易いであろう。

このアイデアに対する評価は、一般人（女性）にとって分かり易く非常に評判が良かったのであるが、いろいろな制約もあり、専門家達の同意が得られなかった。放射線とお金がごっちゃになる、不遜である、というのである。ここで感ずることは、一般人の感じ方と、専門家のとらえ方のギャップである。即ち一般人に分かり易い表現が必ずしも専門家の評価とは異なることである。それではこれに代わる良い比喩があるだろうか、目下探索

中である。



第２図　低線量域での健康リスクと線量の一般的な関係
General relation between health risk and radiation dose in the low dose region

３．生活の中での放射線利用に関する認識度

放射線は管理しながら使うことで社会に対し多くの便益をもたらし、活力を与えてきた。今日、医療分野を初めとし、放射線プロセス、計測装置、半導体産業などの工業分野でもその利用が普及し、一般化しているのであるが、放射線利用の有用性に対する認識度が低いように思われる。著者は最近放射線利用に対する啓蒙書「知っていますか？　放射線の利用」を著したが、その際女性を対象として放射線利用についてどの程度の知識があったかを本書を手にした前後についてアンケート調査を行った。調査対象者数としては余り多いとは云えないが、その結果を纏めてここに紹介する。

対象者は100名で、全く放射線に関係のない一般女性（General public； 67名）と、放射線に関わり合いのある集団（Study group；33 名）として放射線に関心を持っていて勉強をしている主婦（23 名）と放射線関連施設に勤めている女性事務職員（10 名）の二群に分けた。

放射線利用の分野の区分については、 科学技術庁（現文部科学省）が日本原子力研究所に委託して平成９年度に放射線利用の経済規模を調査した時に用いた工業利用、医学利用及び農業利用の分類を参考にした（第１表）。ちなみに放射線利用における三分野の占める経済規模の割合はそれぞれ 85%、14%、1%であった（文献参照）。但し、その際には医療機器の滅菌や手荷物検査は工業利用に、文化財等への分析利用は農業利用に入れられている。

質問項目は、しかしながら、特に今回の調査は対象者が一般女性ということもあって、答えやすいように、食品照射とか、文化財等の研究、空港での手荷物検査などと具体的な項目も取り上げた（第２表）。このようにして得られたデータを第５図及び第３表に示す。

データからも明らかなように、工業利用（製造業、放射線プロセス等）については、我々日常生活の中で最も多く利用されており、その経済規模が最大であるにも拘わらず利用認識度は極めて低く（約１割）、本書を読んで初めて知った人達が９割も占めた。それは放射線に興味を持って勉強しているグループの人々でさえもそれほど高いとは云えない

（約 4 割)。それに反して、医学利用（診断・治療）は最も身近に全ての人々が恩恵を受けているため、本書を手にしなくてもほぼ全員がすでに知っていた。意外だったことは、文化財等の分析への利用については、かなりの人々が知っていた（約 9 割）。農業利用に含まれる食品照射、害虫駆除、品種改良になると、何れの項目も勉強グループが遙かに認識度が高かった。

調査対象者が全員女性であることから、特に食品照射について一歩踏み込んで、日本ではジャガイモの芽止めのためにのみ照射が認可されていること、それ以外の食品照射は許

第 1 表　放射線利用分野　（Various radiation application fields）

工業利用 Industry	：	製造業・半導体加工・放射線プロセス・放射線滅菌・非破壊検査等
医学利用 Medicine	：	各種病気の診断・がん治療
農業利用 Agriculture	：	食品照射・品種改良・害虫駆除・文化財等分析 年代測定

第 2 表　質問項目　（Items of questionnaire）

工業利用（Industry）：	
製鉄・製紙工業	（Manifacturing industry）
半導体加工	（Smicontacter processing）
滅菌	（Radiation sterilization）
手荷物検査	（Laggage check in air port）
医学利用（Medicine）：	
がん治療	（Cancer therapy）
病気の診断	（Diagnosis）
農業利用（Agriculture）：	
食品照射	（Food irradiation）
害虫駆除	（Sterile insect technique）
品種改良	（Improvement of breed）

第 3 表　放射線利用について既知の項目の割合
(Percentages of already known items on the various radiation applications in the different groups)

	一般公衆(%) Public	放射線関連(%) Study group
工業利用(Industry)		
製造業(Manufacture)	11.2	40.4
滅菌(Sterilization)	53.7	84.8
手荷物検査(Laggage)	97.0	97.0
医学利用(Medicine)		
治療(Therapy)	100	97.0
診断(Diagnosis)	91.0	93.9
農業利用(Agriculture)		
食品照射(Food irradiat.)	65.7	97.0
害虫駆除(Insect steril)	36.0	84.8
品種改良(Improve.breed)	21.9	60.6
文化財等(Culture)		
文化財(Cultural asset)	86.6	90.9
年代測定 (Dating)	61.2	87.9

第 4 表　食品照射　(Food irradiation in Japan)

	一般公衆(%) Public	勉強グループ(Study group) (%)	
		職員(Staff)	勉強(Study)
ジャガイモ可 Poteto	65.7	90.0	100
他の食品不可 Only poteto	20.9	30.0	82.6

可されていないことを知っているかどうか尋ねた（第4表）。勉強をしている主婦グループでは8割の人が正確な知識として知っていたが、その他のグループではジャガイモの照射可を知ってはいてもそれ以外は不許可であることを知っている人はさらにその中の三分の一にも満たなかった。回答者の中で、もっと食品照射を進めた方がよいという意見があったことは女性を対象とした今回の調査で記すべきことであろう。

今回のアンケート調査から、以下のようなことが云えよう。

1. 工業利用のような製品の製造過程において放射線がいろいろな方法で利用されているとはいえ、実態として捉えがたいため、その認識度は低い。

2. 医学利用や空港で手荷物検査のように人々が実際に身を以て体験しているものについては良く知っている。

3. 文化財等への調査利用に関しては、新聞等からの情報で既に知っている。

4. 対象グループ別には、普段放射線利用について関心の薄い一般公衆の認識度は医学利用及び手荷物検査を除けば、何れの項目においても低く、一方、放射線について関心が深く勉強しているグループは、すでに施設見学などで知見を広めているので、全ての項目について認識度が高かった。放射線関連施設に勤務している女子職員は周囲からの放射線に関する情報が幾分なりとも入ってくるため、全ての項目について認識度は一般女性と勉強グループの中間であった。

5. どのような分野に興味があるかを同時に尋ねたが、全体として、医療分野（診断、治療とも）、文化財研究への利用が多かったのに対し、工業利用に関しては関心度が低かった。これは調査対象者が女性であったためかもしれない。

本調査から、興味を持って放射線について勉強しているグループは顕著に成果が挙がっていることが明確に読みとれる。しかしながら、今まで関心が余り無かった一般女性もまた本書を読んで、多くの人達がこのようにいろいろな分野で、特に人々の目に触れないような分野（工業利用を指すが）で放射線が利用されているとは知らず、認識を新たにしたという感想が非常に多かったことは喜ぶべきことであろう。

4．むすび

放射線という言葉を聞くと、とにかく怖い、危険であるというイメージが先に立つ。利用などにはとても頭が回らないというのが多くの女性たちの感想であった。21 世紀は女性の時代である。最近では男性もかなり家庭の仕事を分担するようにはなってきたが、やはり子供に接する時間の長いのは女性のほうである。学校教育における放射線の学習もさることながら、女性への正しいそして易しい日常生活に直結した放射線の教育もまた考えるべきであると訴えたい。そして、彼女たちに放射線を知ってもらうため、私はインタープレッターとして、難しい言葉を易しい言葉に翻訳して、人々に理解できるような話し言葉に変えて、或いは文章にして語りかけたいと努力している。

参考文献

岩崎民子：「知っていますか？　放射線の利用」　丸善株式会社　(2003)

United Nations Environment Programme;：「Radiation　Doses, Effects, Risks」United Nations Publication　(1986).

ICRP Publication：「1990 Recomendations of the International Commission on Radiological Protection」　Pergamon press　(1990).

文部科学省：「放射線利用の経済規模」　(2000)
英訳版？

6.3 RISK COMMUNICATION - THE KEY OF THE POLICY SUCCESS

Valentina COVALSCHI
S.N. Nuclearelectrica S.A.
Bucharest, Romania

Abstract.

Today, in a democratic society, nuclear power development is subject to public acceptance. The acceptance of the nuclear activities development implies both the approval by the government's proper authorities and also the standpoints of the civil society, expressed in forms more or less institutionalized.

The public has an important role to play in addressing issues of health, safety and environment. Therefore, all activities of a nuclear organization need to be both transparent and should provide for the public's appropriate involvement, with input not only from the nuclear community, but also from members of the public, interested groups, media, as well as public representatives in local and national councils and groups. How to communicate clearly with the public is a very challenging job that requires special attention.

Risk communication is the art or practice of talking about scientific information and principles to a non - expert audience. Its goal is to convey accurate and trustworthy information about safety to decision – makers, the public, or anyone else with an interest in the safety of the public or themselves. The science of communication, public education for a proper perception of risks are the key for attaining social acceptance of any technology that is about to become part of the sustainable development process and hence, of nuclear energy.

The paper describes the way our nuclear organization is acting and the results in risk communication activity it achieves.

The Cernavoda Nuclear Power Plant Unit 1, the first nuclear reactor of 706 MWe CANDU 6 in Romania, has been operating since December 1996 as a result of the works carried out for the implementation and upgrading of the national nuclear programme.

Having as main mission the generation of electricity and heat as well as CANDU 6 nuclear fuel, our state-own company "Nuclearelectrica" has an active participation in the power development programme in Romania.

Today, in a democratic society, nuclear power development is subject to public acceptance. The acceptance of the nuclear activities development implies both the approval by the government's proper authorities and also the standpoints of the civil society, expressed in forms more or less institutionalized.

The public has an important role to play in addressing issues of health, safety and environment. Therefore, all activities of a nuclear organization need to be both transparent and should provide for the public's appropriate involvement, with input not only from the nuclear community, but also from members of the public, interest groups, media, as well as public representatives in local and national councils and groups. To be sure the public is informed, information needs to be technically coherent, clear, accurate, reliable and comprehensible to the public. If a communication gap between the nuclear organization and the public will manifest, this gap could be filled up with speculations, rumors or misinformation, leading to undesirable impact on the programme. How to communicate clearly with the public is a very challenging job that requires special attention.

Risk communication is the art or practice of talking about scientific information and principles to a non-expert audience. Its goal is to convey accurate and trustworthy information about safety to decision-makers, the public, or anyone else with an interest in the safety of the public or themselves.

Risk communication can be considered as a subset of the overall field of risk analysis. As NRC stated, there are three stages of risk analysis: risk assessment, risk management and risk communication.

We have set up a complex information programme on safety radiation, radioactive wastes and other issues on nuclear energy. The programme comprises a set of structured and systematic activities aiming at establishing or improving communications between the nuclear organization and target audiences.

Within the communication strategy, we have provided the opportunity for the members of the public to express their opinions and to provide information and comments to nuclear organization for major nuclear implementations. Various formats are used to invite public to make comments, such as informational public meetings, roundtable discussions and formal public hearings. The education and training integration will mitigate the barriers, which may inhibit the interaction and communication process. An effective way to avoid negative reactions consists of the extensive consultation to identify the public's concerns and needs, the access to suggestive and attractive programmes for education and training.

We have received a significant support in the communication activity from the worldwide scientific development. One of the most dramatic changes in the dissemination of scientific information has been the prolific use of the World Wide Web. Widespread distribution of scientific information has opened up unprecedent direct avenues of communication between the scientific community and the interested public, using this the most dynamic medium.

The Romanian experts in nuclear power, organized in associations like AREN (Romanian Association for Nuclear Energy) and ROMATOM (Romanian Atomic Forum – active FORATOM's member) pay permanent attention to the communication with the public. Thus, they add their competence, objectivity and credibility to the actions undertaken by the economic agents, institutes and organizations acting in the nuclear sector.

"The Days of Nuclear Energy" event is already traditional. This event is organized by AREN and it addresses to everybody taking interest in the domain, but mostly to the young people. The event has a great section dedicated to drawings and pictures on nuclear items made by children between 6 and 17 years old, on themes like: "What do we know about energy?", "The atom – our friend", "The energy of the new millenium".

It is very interesting to see their perception on the atom and the nuclear energy as life generating. We consider this event a very good way to educate the young people to understand the benefit of nuclear energy and application to mankind. They are encouraged by the awards offered by the "Alexandru Ene" Foundation, a foundation created to support the actions in favour of nuclear energy.

The "Ionel Purica" Foundation offers annualy the award "Ionel Purica" to a personality with special contribution in promoting the Romanian nuclear energy.

On an annual basis, these associations organize nuclear events as SIEN (International Symposium on Nuclear Energy), gathering Romanian and foreign specialists in the nuclear field, who present papers on items like: the functioning NPP in safety conditions, nuclear engineering, young generation – nuclear knowledge management, public acceptance.

The magazines "Energetica" and "Nuclear Energy" are other steps towards the dialog with the Romanian civil society. The papers on different items of nuclear energy can be considered an initiative of an effective campaign for the correct information of mass media and public opinion regarding the nuclear energy.

The magazines together with the Politechnica University – Bucharest, the Romanian National Committee of the World Energy Council are boosting round tables dedicated to nuclear power issues debates. These events are attended, besides specialists pertaining to kindred domains, by various representatives of civil society: people in the education area, members of non-governmental entities, persons working in central and local administration, ecologists etc.

Daily central magazines like "Economical True" or "The Economist" objectively present multiple aspects related to nuclear energy. The article "Nuclear Energy: Pros and Cons" published in "The Economist" magazine brings to the chief editor the prize for the most active journalist in the objective promotion and support of the nuclear energy, offered by ROMATOM. Starting with 1994, the Romanian national television broadcasted talk shows on nuclear energy.

Exhibitions are organized on a regular basis on nuclear energy addressing both to the specialists and to the general public, where informative materials, video records, computer modelling of nuclear themes, as well as panels showing Romanian and foreign companies involved in the nuclear energy are displayed. The public debates carried out last year at Constantza, Medgidia, Cernavoda and Bucharest concerning the results of the impact study of Cernavoda NPP's Unit 2 on the environment are typical for our transparency and openness towards civil society and for accepting democracy rules. In our country, this kind of debates becomes a mandatory stage, provided in the present Romanian legislation and applied in the completion of the works performed on the project.

Some actions are developing towards mass media and population to promote the use of nuclear energy by explaining the economic and environmental benefits, the positive contribution in avoiding the climate change, in the context of the sustainable development concept. Coming to better understand the benefits of nuclear science and technology may occur through more awareness of how nuclear activities contribute to our everyday life: how it helps us improve our activities, how it provides safe electricity, heating or potable water to our houses.

For Cernavoda community there are direct and indirect support programmes, including income increase activities, public works, educational activities such as scholarships for local students and local information program. Indirect support activities include employment of local population to work at the nuclear organization. The local community support provided through improving the living conditions in the town of Cernavoda started in 1991, including a number of 21 objectives related to the project of the Cernavoda NPP: urbanistic, social, cultural buildings, as well as dwellings for the operation and executive staff of the nuclear power plant. Two important objectives were completed and inaugurated in 2002: Cernavoda Town Hospital and "Saint Maria" bridge over the Danube – Black Sea Channel. There are other social and economic benefits for the regional public that should be underlined: provides over 1,300 jobs, provides activities for 15 contractor companies having over 350 jobs, provides accomodation for over 500 plant employees, provides heating for more than 60% of Cernavoda inhabitants at the lowest price in the country. The perception of the contribution of nuclear energy to regional prosperity is a very important indicator of a good communication activity.

The Cernavoda NPP has in its organizational chart an Information Centre having the supporting role of bringing to the public's attention the factual information and more awareness of how nuclear activities contribute to everyday life. A couple of thousands of visitors have visited the Unit 1 within the "Open doors" programme initiated by the plant. Students visits are often organized in Cernavoda for attracting the younger generation to join and keep the nuclear option alive. Special information seminars and workshops have been organized for the representatives of mass-media, followed by the plant tour.

A considerable amount of printed materials such as brochures, leaflets, information documents have been elaborated and distributed to public, policymakers, opinion leaders, media and non-governmental organizations. Information about events in the company are provided to the media within press releases, press conferences, interviews and by internet on the company's website www.nuclearelectrica.ro.

The science of communication, public education for a proper perception of risks are the key for attaining social acceptance of any technology that is about to become part of the sustainable development process and hence, of nuclear energy. At present, this science is an remarkable stage of development and progress. We have to assimilate it, including all new achievements. We must understand public points of view and address it using its own language. What we need is not only a unidirectional flow of information towards the public, but also an effective and steady dialog with representatives of the general public. It shows the change of culture from information to communication.

Public confidence, built on open, credible communication, patience and perseverance, will make a safe ground for social acceptance of nuclear energy.

REFERENCES

[1] U. S. National Research Council, 1989 – Improving Risk Communication

[2] Douglas Powell, 1996 – An Introduction to Risk Communication and the Perception of Risk

[3] Ioan Rotaru, 2002 – Nuclear Energy and Communication

6.4 Radiation Risks, Nuclear Power, and the Media

Klaus Becker
Radiation Science & Health
RSH, Boothstr. 27, D-12207 Berlin, Germany
e-mail: prof.dr.klaus.becker@t-online.de

In Western Europe as well as in some other highly industrialized parts of the world, most electronic and print media play a central role in creating an antinuclear public sentiment, largely without considering the actual technical and scientific facts. Even more than large-scale nuclear accidents, proliferation, and politically delayed waste disposal projects, fear-mongering about the risks of low-dose radiation exposures became a central acceptance issue. A typical example is the Chernobyl accident, for which German media regularly claim 10,000 to 100,000 radiation casualities, despite the well-established fact that their number is (and probably will remain, including the five child thyroid cases and long-term effects) below 40.

On media policies, the following opinions are generally acceptable:
(1) "The newspaper's role as the public educator has been diminishing. Its role is coming more that of entertainer like television. Education belongs to the schools and colleges." (J. W. Anderson, former Editor of Washington Post (IAEA Bull. 46/1, 32, 2004))
(2) "We are not a charitable trust. We print what people want to read and to buy."
(H. Nannen, ex-Publisher of STERN Magazine (personal communication to the author)
(3) "Journalists create public fears because of greed, lack of correct information, or ideological bias -- frequently in combination." (Kramer and G. Mackenthun, "The Panic Makers", Piper 2003)

Main reasons for this situation (excepting relatively few serious journalists) are:
1. Widespread lack of relevant technical or scientific education among the responsible editors and journalists, forcing them, frequently under substantial time pressure, to accept unreliable information. Sensationalistic doomsday stories are more in demand and sell better than carefully researched, well-balanced reports.
2. Immediate comments and explanations, e.g. after a nuclear accident or incident, is much easier to obtain from self-appointed antinuclear activists with no reputation to loose, than from serious technical and scientific experts or organisations, who require more time to analyze the facts and consequences, and are used to more carefully worded and less spectacular statements.
3. Ideologically prejudiced green environmentalists from the 1968 student movement dominate many key positions in the media. They are inclined not to publish material which disagrees with their old paradigms.
4. In some countries, e.g. Germany, official governmental antinuclear policies suppress on various levels factual information about radiation risks and nuclear energy, and promote instead expensive "alternative and/or sustainable" energy sources.

5. Widespread “Political Correctness” among so-called progressive intellectuals supports everything that appears to be natural and small, and distrusts deeply large and complex technologies, because they are not instantly comprehensible to them as well as to other technically less educated people.

The opinions can be summarized as : “Infotainment“, just bridging gaps between commercial efforts, is unlikely to contribute much valuable public education. They say that media reports are often distorted, and the reasons for distorted media report may be concluded as due to the following two problems.

One is the probelms with regulations. They are:

(1) Interpretation of very low dose and activity limits as threshold of serious health hazard.
(2) Estimates based on LNT and Collective Dose Hypothesis (multiplication of extremely low theoretical risks with high population numbers)
(3) Ignorance of recent research and results by regulators, based on outdated international recommendations (ICRP, IAEA, EU, etc.)

The other is journalistic/editorial problems. They are:

(4) Increasing commercial competition in TV and print media resulting in “infotainment” instead of seriously investigated information and education.
(5) Lack of journalists with sufficient technical and scientific background.
(6) Audience psychology: bad, frightening news get more attention, and are easier to sell than positive news.
(7) Instant comments are easier to get from anti-nuclear activists than from serious experts.

It may not be easy to alter this situation. However, increasing energy costs and economic problems on many of the countries concerned may provide a change in public opinion sooner than most producers of published opinions would nowadays expect.

Remark: This is a note for a presentation, and not a carefully polished scientific paper.

6.5 Information Treatment of Mass Media on Radiation-Related Issues

放射線に関わる事柄についてのマスメディアの情報処理

JunIchiro Tada
多田順一郎

Safety Office of SPring-8/JASRI, tada@spring8.or.jp
高輝度光科学研究センター

要旨

自然放射線はどこにでもあるものであり、文明生活は様々な面で人工放射線の利用と密接に関係している。それゆえ、誰ひとり放射線とかかわりなく生きることはできない。それにもかかわらず、多くの人々は、放射線を利用することに疑問とおそれを抱いている。

放射線や放射能に関する人々の主な情報源は報道である。それゆえ、報道記事の中での放射線や放射能の取り扱い方---言い換えるならば、報道機関の放射線や放射能に対する視点や理解---は、そうした問題に対する人々の意見に極めて強い影響を与えることになる。

NPO 放射線教育フォーラムでは、タスクフォースを編成し、放射線や放射能に関連する報道記事を調査して、そこから読み取れる報道機関の視点や理解の仕方を分析した。本報告では、その分析の結果を報告し、幾つかの問題点に対する改善を提案する。

Radiation is nothing but a component of existences in nature. It is a kind of energy transportation. In the beginning of the universe, only radiation existed there. Thus it is necessary to understand radiation as a subject of natural science just like as heat and electricity.

The necessity of promoting natural science education has been claimed in Japan for years. Relevant curricula for teaching ionising radiation *as a subject of natural science* in compulsory education system, however, have not yet been made.

In the course of social science, on the other hand, Japanese pupils are taught repeatedly the occurrences, related to ionising radiation or radioactivity, in which people lost lives, suffered from severe injury or serious illness, or deprived their wealth; *i.e.* atomic bombings at Hiroshima and Nagasaki, nuclear test at Marshall Islands that involved Japanese fishing boat, Chernobyl nuclear power plant accident, criticality accident of nuclear fuel plant at Tokaimura, and so on. To study these events, as subjects of social science, must be important though, pupils are seldom taught how such damages were caused by ionising radiation.

Consequently, most Japanese launch out into life with much information on the danger of ionising radiation, and with significantly poor scientific knowledge about radiation itself. So, it is not surprising that many Japanese keep away from ionising radiation as if it caused evil, and abominate radioactive material as if it were defilement.

Having very little chance to attend natural science education after the graduation from school, most Japanese obtain information about ionising radiation and radioactivity primary through mass media in their daily lives. Thus, the mass media have strong influence on the public perception of the Japanese on ionising radiation and radioactivity.

Upon this background, Radiation Education Forum (NPO) formed a taskforce to investigate the output of mass media relating to radiation and radioactivity. The taskforce has examined the *status quo* and studied whether any problems existed there.

More than a decade before, not a few news articles contained trivial mistakes from scientific viewpoint, for example, misuse of the word radioactivity instead of radiation and *vice versa*. However, such kinds of mistakes have decreased recently. This improvement must be a consequence of the efforts of mass media themselves, which we would like to appreciate.

Comments of the experts may have much contributed in reducing scientifically erroneous expression. However, mass media must take precautions in choosing the expert, for some of them may have biased opinions or the interests. Such "experts" often make inadequate comments into news articles, though their statements usually radical which mass media would feel the urge to hake comments.

For example, when a newspaper reported the issue of depleted uranium residue in Iraq, a professor of physics, who were treated as an "expert" of the issue in the article, commented the cases of pneumonia and skin complaint prevailing over American troops staying Iraq are strongly suspected as acute radiation injuries. These symptoms cannot be acute radiation effects, since even the contact skin dose from depleted uranium penetrator is as low as 2.3 mSv/hr or so (IAEA's estimation). It takes more than 2,000 hours for skin injury to appear with this dose rate.

Mass media should recognise that not all professors of physics are well acquainted with radiation physics and dosimetry, to say nothing of radiation biology and radiation protection. Desirable way of choosing commentator on scientific matter is to consult neutral public institutions or academic bodies, though their responses to inquiries are made usually not promptly.

Although mistakes in science in the news articles have decreased, expressions or context, which may lead misunderstanding or one-sided view about events related to radiation and radioactivity, is still frequently seen. It should be noted that such misleading would bring the readers miserable effects on some occasion.

For a typical example, mass media used a statement, "the dose limit for members of the public is 1 milli sievert per year" repeatedly in reporting the criticality accident at Tokaimura. Although the phrase "dose limit for members of the public" was introduced by ICRP with special meaning as the guideline of designing radiation facilities or planning procedures utilising radiation, mass media used it without proper explanation. Though it was not mass media but the government that has primary responsibility to provide the information, mass media should confirm it before writing or broadcasting news articles.

Being ignorant with ICRP terminology, most of the public would interpret the sentence literally. As the result, they misunderstood that dose more than 1 mSv is dangerous and actually harmful for the public.

Miserable consequences followed. Many inhabitants suffered from severe post-traumatic disease syndrome. Most of them were informed their estimated dose exceeding 1 milli sievert, but surprisingly, those informed the dose was less than 1 milli sievert were also included. Moreover, it is whispered that not a small numbers of medically unnecessary (but maybe psychologically necessary) abortion were executed. Official report on this subject does not exist, since abnormality in fetus is not legally allowable reason of abortion in Japan.

They say, "The pen is mightier than the sword." Indeed, mass media should remember that a pen (keyboard?) could hurt much more people than a fine blade.

Another issue observed in the output of mass media is the tendency of regarding danger of radiation is something special. To exaggerate hazardous effects of radiation in the articles is said the *sequela* of the propaganda during the cold war, when both the East and the West want to display the power of their own/enemy's nuclear weapons more terrifying. Such tendency would inundate articles in which effects of radiation are more or less exaggerated.

Inundation of media reports that attract vigilance of public to danger of radiation excessively would distort the balance in people's perception among various health risk factors. Because ionising radiation is *one* of the risk factors to human health.

Not necessary to refer *World Health Report* of WHO, our world is filled with various kinds of health risk factors; chemical pollutions, infectious diseases, drag addiction, *etc*. Governments are responsible for tackling these risk factors through their public health programs. Having limited social resources for the public health measures, *i.e.* financial, material and human resources, governments have to allocate them by the degree of imminence. The order of urgency among measures for various health risk sources varies country to country, as well as era to era.

If the public possesses excessive concern to the risk of radiation and radioactivity, governments could not take sufficient measures more urgent issues. Exaggeration of the danger of ionising radiation causes such an irrationality.

The article entitled "Risk of cancer from diagnostic X-rays: estimates for the UK and 14 other countries" published in *the Lancet* on 31st January of this year attracted strong concerns of mass media. *Yomiuri*, one of the major newspapers in Japan, respond ten days after the publication. It reported about the article with a banner headline, "Diagnostic x-ray exposure is responsible for 3.2 % of cancer," causing nation wide anxiety for medical exposure.

There were many inquiry to the website of Japan Association on Radiological Protection in Medicine and to other relating academic bodies'; whether the questioner itself or its relative should receive the recommended x-ray examination irrespective of the health condition, the amount of dose received from the examination and its foreseeable health effects, and various relating anxiety.

Of cause, *the Lancet* is the most responsible for the trouble, since it published such disputable article. However, had not used such sensational title in big type on the top page of a major newspaper, the news would not make so many patients and their families to worry about receiving indispensable x-ray examinations.

A senior journalist once told the author "News is an article of trade, too!" Another journalist complained, "Even we write manuscripts as accurate scientifically as possible, the desk may modify sentences later, which sometimes induce changes in impression of the story drastically."

If the statement "News is an article of trade" is true, market mechanisms act on mass media to *create* news values. Being unusual, dangerous or anxious raise news values, market mechanisms push mass media to emphasise these characters of the events. Unfortunately, we often encounter news articles that contain expressions or contexts emphasising *news values*.

For example, *Yomiuri On Line* on 12^{th} June 2004 reported the project of Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT), of investigating aircrew members' exposure to cosmic rays. It wrote a sentence which was not included in the article appeared on the newspaper: "For female aircrew members, who may continue her work without noticing pregnancy, influences to their fetus is a matter of anxiety." Insertion of this sentence, as rhetoric, may be very effective to attract readers' concern. However, the effect of the sentence to the public perception is nothing but a spray of unnecessary fear. Unfortunately, insertion of such decorative sentences is not very rare.

A public broadcasting in our country has an incomprehensible habit to connect leakage of radioactive material with troubles of radiation facility. The television was obsessive to leakage of radioactivity in the report of the criticality accident at Tokaimura, while other news media soon changed the report that there is only leakage of radiation. The obsession enhanced anxiety of nearby habitants. It also announced in the news of the steam pipe rupture accident in nuclear power plant on 9^{th} of this August that radioactive materials weren't contained in the steam that leaked out because the water in the steam turbines does not come into contact with water used as a coolant for the nuclear reactor, and added immediately that *however vigilance is necessary*.

We afraid such dramatisations in the news would drive the public into panic.

It is the mission of mass media to offer adequate information of the events or phenomena of interest happened or appeared in our society. The information consists of two parts; *correct description* of the fact and *proper explanation and/or comment*. Choice of materials and commentators are left to discretion of the desk, so depends on the desk's judgment of values. If the judgments were made only upon the value of merchandise, there would be danger that the mission of mass media be spoiled. The value of news as an article of trade is not necessarily proportional to the measure of academic accuracy.

The taskforce hopes to the mass media in publishing or broadcasting reports related to radiation and radioactivity as follows:

*A*ware the social responsibility and the danger of mass media's power of misleading the public,
*B*oost scientific quality to make reports on news, and
*C*onsult with neutral and reliable, real expert(s) of the field.

These are common requests for any reports of mass media and not restricted to those relating to radiation and radioactivity. However, special remarks are necessary for this category according to the observation of *status quo*, to say nothing of necessity to learn much more of radiation including variation in quality of effects with quantity.

6.6 Atomic Bomb Suffering and Chernobyl Accident Lessons learnt from International Medical Aid Programs

原爆被災とチェルノブイリ原発事故・国際ヒバクシャ医療協力からの教訓

Shunichi YAMASHITA*

山下俊一*

Department of Molecular Medicine, Atomic Bomb Disease Institute,

Nagasaki University Graduate School of Biomedical Sciences

長崎大学大学院医歯薬学総合研究科教授

1-12-4 Sakamoto, Nagasaki 852-8523, Japan

〒8528523 長崎市坂本 1－12－4、E-mail: shun@net.nagasaki-u.ac.jp

要旨

海外の放射能汚染地域における医療協力活動や学術共同研究を、原爆被災という負の遺産を背負う日本から推進すると、長崎・広島の地球全体から見た役割を痛感させられる。すでにチェルノブイリ周辺 3 ヶ国への医療協力は 14 年目に、そしてセミパラチンスク核実験周辺への支援活動も 10 年目に入った。両地域とも、急性障害ではなく、晩発性の放射線障害、とりわけ癌の発症リスクの増加への対応が問題となっている。

東西冷戦構造時代に起きたソ連における放射性降下物による内部被ばくの実態解明は、個人被ばく線量の推定が不可能なことなど困難な状況にある。乳幼児への甲状腺被ばくや、癌年齢に到達した成人から高齢者の放射線影響による健康問題の解決については、当事国はもとより国際機関を通じた国際協力が継続して必要である。しかし、現実として現場では大変厳しい社会経済問題を抱えて今なお混乱し、正しく放射線や放射能を理解することが困難であり、個別の対応が適切になされていない。そのような中にあり長崎・広島からの人的貢献や現場主義の協力関係構築は大いに評価され、わが国が目指す『非核平和外交』の屋台骨を支えている。その根幹をなす哲学は国内外での人間教育そのものである。

一方、国際ヒバクシャ医療協力のわが国に対する教訓は、人災に対する備えの重要性と同時に、日本があらゆる放射線事故に対する支援協力拠点として、国内外の事故に対応する必要性とその責務を教えている。ここでは、旧ソ連の放射線事故の実態と医療協力の現状を説明し、現在私たちが目指している『防人・海援隊プロジェクト』の一端を紹介する。

---

* Current position; Scientist at the Department of Radiation Program, Sustainable Development and Healthy Environment, WHO/HQ in Geneva, yamashitas@who.int

Abstract

The cooperative medical projects between Nagasaki University and countries of the former USSR have had being performed in mainly two regions: Chernobyl and Semipalatinsk since 1990 and 1995, respectively. The 21st Center of Excellence (COE) program of "International Consortium for Medical Care of Hibakusha and Radiation Life Science" recently established in Nagasaki University can now serve our knowledge and experience much more directly. Its activity can be further extended to the radiocontaminated areas around the world, and based on the lessons of the past, it can indeed contribute to the future planning of the Network of Excellence (NOE) for Radiation Education Program as well as Radiation Emergency Medical Preparedness and Assistance under the auspices of the WHO-REMPAN.

Within the frame of International Consortium of Radiation Research, a molecular epidemiology of thyroid diseases are now conducted in our departments in addition to international medical assistance. The clue of radiation-associated thyroid carcinogenesis may give us a new concept on experimental and epidemiological approaches to low dose radiation effects on human health, including those of internal radiation exposure. Concerning the role and responsibility of our work to the public, to avoid unnecessary radiophobia and to correctly understand radiation hazard and safety, we must build a bridge between basic research and widely open public education. Therefore, it is of high necessity to continuously work on clarification of the effects of ionizing radiation on human beings worldwide and to contribute the development of general guideline of radiation safety and radiation hazard, and to strive for the creation of substantiated radiation protection programs.

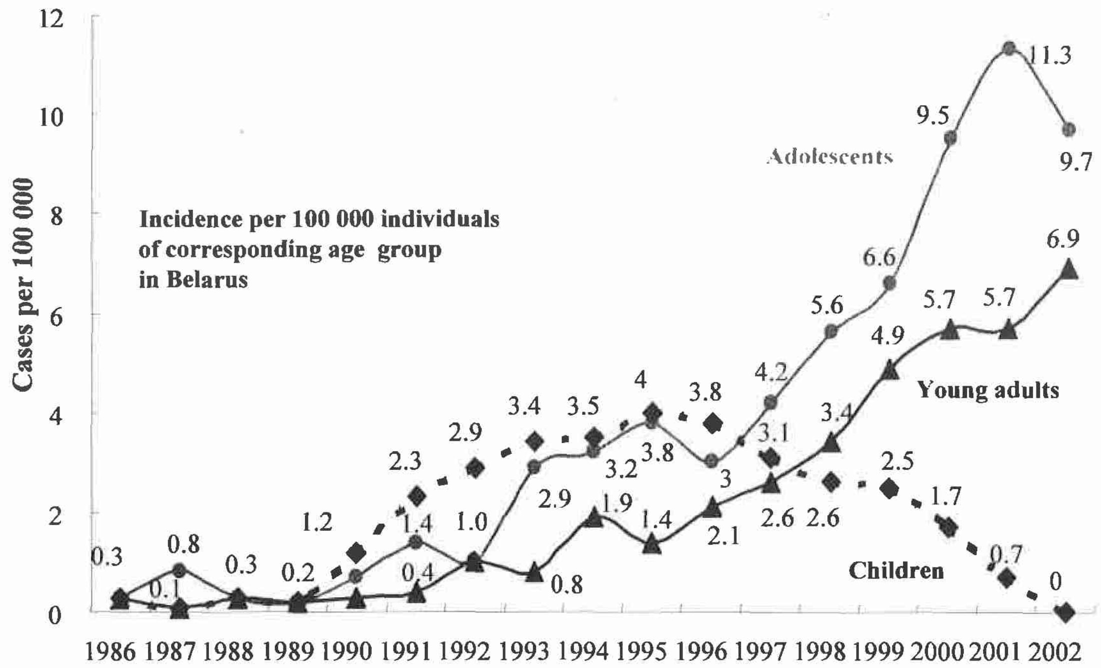
Introduction

Immediate acute manifestation of the atomic bomb diseases are well described in Hiroshima and Nagasaki victims and categorized into three entities; burns, external injuries and severe radiation-induced injuries. Late effects of the atomic bombings and those of emergency radiation medicine have been carefully analyzed and the risk of late-onset malignancies has been demonstrated in various organs (1). Such a tremendous amount of data (knowledge and experience) has been very useful for the treatment of radiation victims of Chernobyl and Semipalatinsk. However, the type and dose rate of radiation exposure are completely different between Nagasaki, Chernobyl and Semipalatinsk. Therefore, molecular epidemiology investigations are essentially needed to be established in the field of Radiation Life Sciences to clarify the real carcinogenic effect of ionizing radiation on various cells, tissues and organs (2). Such studies will undoubtedly contribute to establishment of correct diagnosis and appropriate therapy for radiation-associated diseases in humans in future.

During the past ten years, the counterparts of advanced medical institutes in the former USSR made mutual agreements for the exchange in the area of medical science and of specialists with our university. We have also been inviting visiting professors, medical researchers, and postgraduate students from these establishments every year to the Atomic Bomb Disease Institute at Nagasaki University School of Medicine. Such international cooperation at the level of doctors/scientists is expected to contribute on the radiation education program to the public.

Medical Cooperative Projects from Nagasaki to Chernobyl

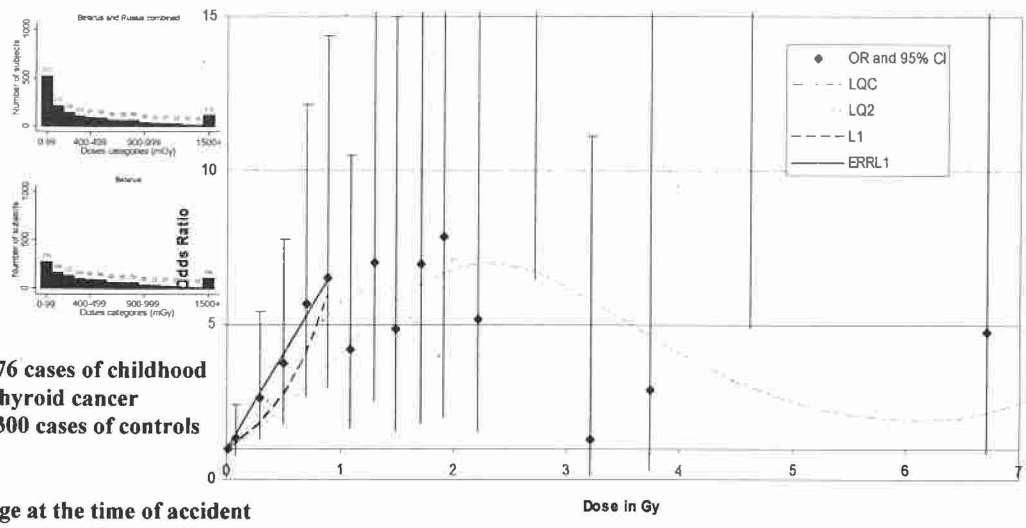
An overwhelming amount of various radionuclides has been released to the environment after the Chernobyl nuclear plant accident, which happened on April 26, 1986 in Ukraine. From Japan, different lines of medical assistance had been engaged, but specific medical aid based on a scientific approach was not started until 1991. One of the most comprehensive projects has been the Chernobyl Sasakawa Medical Cooperation Project. Direct linkages between Japan and Chernobyl ware established following the donation of modern equipment and various consumables from Sasakawa Memorial Health Foundation to the three affected countries making it possible to standardize our protocols of health screening that remained in effect even after USSR collapse. The first 5-year project launched in May 1991 had been completed in 1996 resulting in data collection on more than 120,000 children (3). Characteristic achievements of this project were the followings. Children at the highest risk to radiation health effects were identified (age at the time of accident from 0 to 10 year-old), and the screening mainly focused on elucidation of possible late effects of radiation was performed using common procedures of thyroid examination, hematological tests and whole body Cs-137 measurement in all the inhabitants to determine the current radiocontaminated levels and to relieve their anxiety.



(From Dr. Yu. Demidchik)

Figure 1. Incidence of Thyroid Cancers in Belarus after the Chernobyl Accident

Results of this large-scale screening demonstrated that nearly 3% of examined children had thyroid abnormalities other than goiter, for which we could perform an echo-guided fine needle aspiration biopsy and cytological diagnosis. Importantly among thyroid nodules exceeding 0.5 cm in size with abnormal echo findings, there were about 7% of malignancies suggestive of high incidence of thyroid cancer, especially papillary adenocarcinomas in children of Chernobyl areas. Further investigations revealed that more than 30% of such patients had local or distant metastases. According to the reports from Belarus, there has been specific timeline trends of operated thyroid cancers (i.e. thyroid cancer morbidity) sub-classified into three categories, (i) childhood (patients less than 15 year-old), (ii) adolescent (age 15 to 18 year-old), and (iii) young adult (19 to 30 year-old) cases. Figure 1 clearly demonstrates a rapid increase and declination of the incidence of childhood thyroid cancer in Belarus but the peak is now shifting from adolescence to young adults, indicative of high risk of thyroid cancer in individuals whose age at the time of accident did not exceed 15 year-old. It is very difficult to accurately evaluate radiation dose on the thyroid from ingested short-lived radioactive iodines, and several attempts employing different approaches were undertaken just after the accident within the framework of international cooperation. Recently, the joint international project involving a case-control study has been completed establishing a positive relationship between childhood thyroid cancer risk and thyroid radiation dose (Figure 2).



276 cases of childhood Thyroid cancer
1300 cases of controls

Age at the time of accident
Less than 15 year-old

(Cardis E et al; Risk of thyroid cancer following I-131 exposure in childhood, in press)

Figure 2. Risk of Childhood Thyroid Cancer around Chernobyl

Previously, we had also compared two groups of individuals born in the Chernobyl areas before and after the accidents and found that only in those children who had been born before the accident, especially whose age at the time of accident was 0 to 3 year-old, there has been high incidence of thyroid cancers (4). Thus, firstly the radio-sensitivity of neonates, infants and secondly a conclusion on the high probability of casual association between dramatic increase of childhood thyroid cancer and short-lived radionucletids (radiation fallout) from Chernobyl has been drawn.

Radiation doses due to direct residential external exposure after the accident were low and therefore there has been no evidence of childhood leukemia rate to increase. However, acute internal exposure might be high in children because of extensive incorporation of the fallout-derived short-lived radioactive nuclides into their thyroids through air and/or food chains. Also, chronic low dose rate exposure from the radiocontaminated soil and environment could not be neglected.

From May 1997 to April 2001, the second Chernobyl Sasakawa projects have been conducted in Belarus and Russia (5). Simultaneously, together with other international bodies such as EU, WHO and NCI, we have been participating in the international cooperative program of the Chernobyl Thyroid Tissue Bank project (http//www.chernobyltissuebank.com/). Nowadays, using this Chernobyl Tissue Bank, results of several studies have been published among which the genetic analysis of *BRAF* mutation revealed its low frequency in childhood papillary thyroid cancers compared to adult cases (6). In contrast, ret/PTC rearrangement rate is much more higher in childhood cases but this genetic alteration is not restricted to radiation-induced thyroid cancers and occurs in sporadic cancers as well. So far, there are no specific molecular genetic markers of radiation-induced or associated thyroid cancers despite of extensive efforts of a number of laboratories (7). Strongly desired is a follow-up study of the high-risk group of individuals who have already been diagnosed for thyroid diseases, especially nodules, and still live in the radiocontaminated areas around Chernobyl. Such long-term follow-up project along with well-designed epidemiological studies can contribute to the radiation education programs to the public as well as to improve welfare and direct medical care in the target population. Concerning the radiophobia, around Chernobyl, the mental and psychological care is essentially needed for the people who not only experienced the accident themselves but also for those still residing the radio-contaminated areas (8).

Conclusions

We are all "Hibakushsas", which means that during our life we are suffering not only from radiation but also from various kinds of environmental factors from the very birth. Understanding the impact of the environment on mental and physical health of a man gives us a chance to elucidate the importance of a cross-talk between the human body and multitude of environmental traits at the different levels and duration of exposure. In fact, radiation exposure problem is not a standalone entity in a line of other environmental factors although it is often regarded in the nuclear weapon, peace threatening and industrial context. Beside of health problems, socio-political aspects should be always taken into consideration, such as e.g. complicated compensation issues, when radiation effects on human health are being discussed. Clearly, these problems cannot expected to be solved at once and therefore we should continue our efforts from Nagasaki to contribute to International Hibakusha Medical Care through the international networks and education of young physicians and students, especially from the former USSR, to work together in serried ranks and adhering to the policy of global medical care standardization and universal radiation life sciences with wider perspectives. There may be a selection of opportunities from Nagasaki as shown in Table 1 to communicate within a frame of a proposed to be establishment of Network of Excellence (NOE). To overcome burden of limited epiphenomenal observations, such as uncertainty of radiation dose evaluation, we need to develop new methods that allow monitoring and determination of cause and effect relationship including molecular signature of radiation-induced/associated diseases. The transparency of research and understandability of research information to the public may improve radiation education programs performance and surmount obstacles of science scantiness and obscurity.

Table 1. Network of Excellence (NOE) on Education and Research for Radiation and Human Health from Nagasaki, Japan

1. **International Consortium for Radiation Life Science Research including Molecular Cancer Epidemiology (http://www.nagasaki-u.ac.jp/index_en.html)**
2. **Standardized Approaches and Common Protocol of Emergency Radiation Medicine within the WHO-REMPAN Framework (http://www.who.int/ionizing_radiation/a_e/rempan/en/)**
3. **NOE for Training and Education in Radiation Medicine in cooperation with NGOs, such as NASHIM (http://www.nashim.org/)**

References

1. Thompson DE, et al. Cancer incidence in atomic bomb survivors. Part II: Solid tumors 1958-1987. Radia Res 1994; 137: S17-S67.
2. Yamashita S, Shibata Y, Namba H, Takamura N, Saenko V. Molecular epidemiology of childhood thyroid cancer around Chernobyl. Radiation and Homeostasis. eds by Sugawara T, Nikaido O, Niwa O. Excerpta Medica 2002; ICS 1236; p201-p205.
3. Yamashita S, Shibata Y. (eds) Chernobyl; A Decade. Excerpta Medica 1997; ICS 1156; p613.
4. Shibata Y, Yamashita S, Masyakin V, Nagataki S. Fifteen years after the Chernobyl accident: novel evidence of post-Chernobyl thyroid cancer. Lancet 2001; 9297: 1965-1966.
5. Yamashita S, Shibata Y, Hoshi M, Fujimura K. (eds) Chernobyl; Message for the 21st Century. Excerpta Medica 2002; ICS 1234; p354.
6. Kumagai A, Namba H, Saenko VA, Ashizawa K, Ohtsuru A, Ito M, Ishikawa N, Sugino K, Ito K, Thomas GA, Bogdanova TI, Tronko MD, Nagayasu T, Shibata Y, Yamashita S. Low frequency of BRAF mutations in childhood thyroid carcinomas. J Clin Endocrinol Metab 2004; 89: 4280-4284.
7. Rognounovitch T, Saenko VA, Yamashita S. Mitochondrial DNA and human thyroid diseases. Endocrine J 2004; 51: 265-277.
8. Takamura N, Kryshenko N, Masyakin V, Tamashiro H, Yamashita S. Chernobyl-induced radiophobia and the incidence of tuberculosis. Lancet 2000; 356: 257.

6.7 Lessons from Nuclear Disasters

原子力災害から学んだもの

Itsuzo SHIGEMATSU
重松逸造

Radiation Effects Research Foundation
（財）放射線影響研究所
〒152-0023 東京都目黒区八雲 4-8-8 Tel/Fax:03-5729-1855

Abstract

The most severe and worst of all nuclear disasters is, needless to say, the explosion of an atomic bomb. The WHO committee on the effects of nuclear war, established in 1982, concluded that the only approach to the treatment of the health effects of nuclear warfare is primary prevention, that is, the prevention of nuclear war. Nuclear disasters have also occurred in nuclear power plants and nuclear facilities, causing various damage and acute anxiety among the workers and general public, but thus far the related health effects have not always been correctly evaluated. Such problems as exposed population, individual exposed dose and health risks which are associated with these evaluation efforts are discussed here.

1. はじめに

第２次世界大戦の末期、米国の原子爆弾（原爆）開発により原子力時代の幕が開かれることになったが、その後における冷戦時代の核軍拡競争は、膨大な量の核兵器によって人類を破滅寸前にまで追いつめるに至った。幸い冷戦構造は解消されたが、核兵器廃絶への道はなお遠く、1996 年に成立した包括的核実験禁止条約（CTBT）も、米国などの核大国がまだ批准していない有様である。

今日、多くの人が望む核兵器の廃絶と世界の恒久平和は、もともと広島と長崎における原爆被爆者の体験が原点となっており、それだけに被爆の実態や影響を科学的に明らかにすることは、被爆者の保健福祉に貢献するだけではなく、21 世紀に向けても多くの教訓を残すことになる。

原爆が最大、最悪の原子力災害をもたらすことはいうまでもないが、実際に使用された広島、長崎はもちろん、その後行われた多数回の実験（ビキニ環礁、ネバダ砂漠、セミパラチンスク、ムルロワ環礁など）によっても深刻な災害が発生した。1982 年に組織された世界保健機関（WHO）の“核戦争の影響”検討委員会は、広島、長崎の経験に基づいた検討を行い、「核爆発の健康に及ぼす影響に対処する唯一の方法は、核戦争の防止しかない」と結論した。

原子力災害は、原子力発電所（原発）（スリーマイル島、チェルノブイリなど）や核施設（南ウラル、ハンフォード、セラフィールドなど）などでも発生しており、種々の被害

や不安を関係者や周辺住民に与えている。しかし、健康面の影響だけについていえば、科学的に必ずしも正しく評価されていない点があり、ここでは評価に用いられる疫学調査上の問題点のいくつかについて述べることにしたい。

2. 原子力時代の歩みと原子力災害

Fig. 1 a, b, c に原子力時代の歩みの概要が示されているが、その幕開けは第二次世界大戦中､米国が人類最初の原爆製造を目指して極秘裡に発足させたマンハッタン計画である。

Fig.1a A Chronology of the Nuclear Age (1)

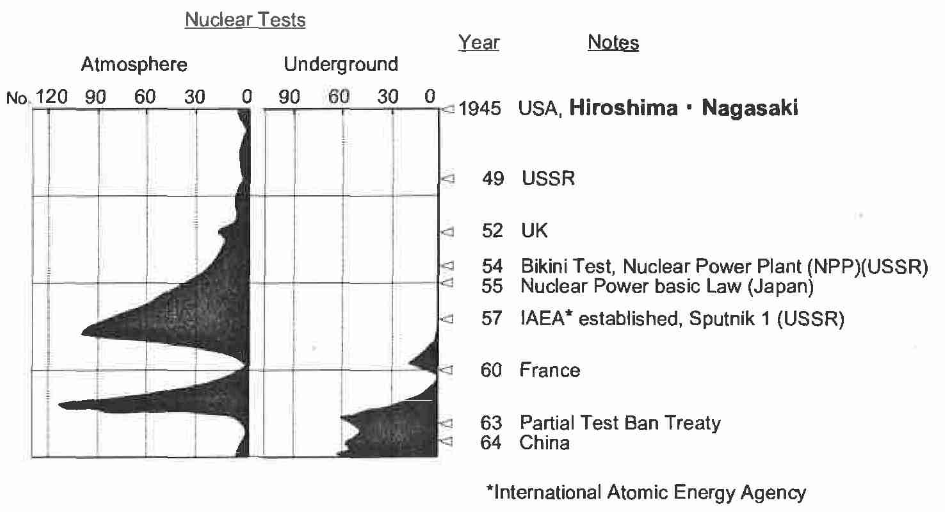


Fig.1b A Chronology of the Nuclear Age (2)

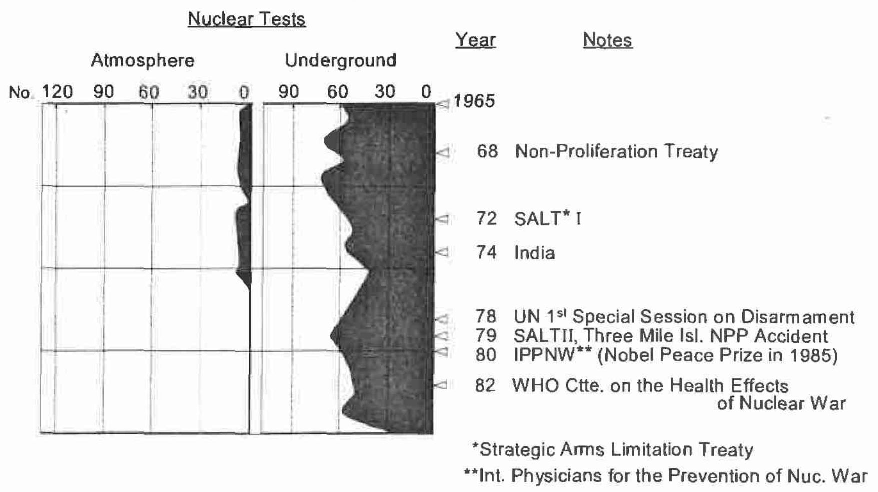
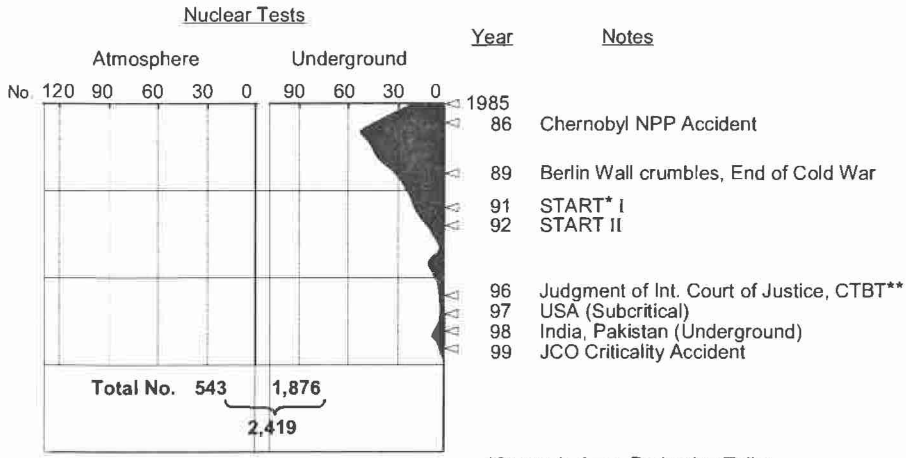


Fig.1c A Chronology of the Nuclear Age (3)



*Strategic Arms Reduction Talks
**Comprehensive Test-Ban Treaty

1945 年 7 月 16 日、ニューメキシコ州においてプルトニウム 239 原爆の爆発実験に成功するが、その 3 週間後の 8 月 6 日にはウラン 235 原爆を広島に、そして 8 月 9 日にはプルトニウム原爆を長崎に投下して未曾有の災害をもたらした。

米国の原爆独占は長続きせず、1949 年にはソ連、52 年には英国、60 年にはフランス、そして 64 年には中国がそれぞれ原爆実験を開始して、核軍拡競争に拍車をかけることになる。最近までに、核実験は大気圏内が 543 回、地下が 1,876 回の計 2,419 回にも達しており、核実験による地球環境の放射能汚染は、1963 年に世界平均で年間 0.15mSv と最高値を示した。

1954 年の米国によるビキニ水爆実験で、第五福竜丸乗組員 23 名全員が放射性降下物により被ばくしたが、同じ年にソ連は原子力発電の実用化をはじめており、翌 55 年には原子力の平和利用を目指すわが国で原子力基本法が制定されている。この法律を背景に、わが国では 1957 年より原子力発電を開始、現在稼動中の原発は、世界 31 か国の 425 基中、わが国が 52 基（12.2%）を占めている。

核軍拡競争の開始当初より、核兵器の禁止あるいは廃止を求める声はあったが、1963 年にはじめて部分的核実験禁止条約が、米国、ソ連、英国の 3 か国によって署名された。1968 年には核不拡散条約が成立し、1972 年には米国とソ連の間で第一次戦略核兵器制限条約（SALT Ⅰ）が締結された。この SALT Ⅰは、1979 年に SALT Ⅱへ発展するとともに、1991 年と 1993 年には両国間でそれぞれ第一次および第二次戦略核兵器削減条約（START Ⅰ, Ⅱ）が締結され、さらに 1996 年には CTBT が国連総会で採択されたことは、われわれに核兵器廃絶への希望を抱かせるものであった。世界の核弾頭数は、1986 年の約 7 万発より 1996 年には約 4 万発に減少したといわれている。

しかし、この CTBT は米国などの核大国がまだ批准をしていないため発効に至っていないし、加えて 1998 年にはインドとパキスタンが地下核実験を実施したことは、まさに

時代に逆行するものであった。そのため、核戦争による破局までの残り時間を示す米国科学誌の有名な“運命の日の時計（Doomsday Clock)”の針は5分進められ、地球の終末を意味する午前零時の9分前となった。

核兵器時代に対応する活動として特記すべきは、1980 年に誕生した核戦争防止国際医師会議（IPPNW）であろう。核戦争防止のための活発な国際活動により、1985 年のノーベル平和賞を受賞している。1996 年に国際司法裁判所は、“核兵器の脅威や使用は一般的に国際法に違反する”との判断を下しているが、これは WHO を通じて IPPNW が働きかけたことによる。また、WHO は 1978 年を第1回とする国連総会軍縮特別部会の一連の決議を受けて、1982 年より核戦争の健康影響に関する国際委員会を発足させたが、これについては次節で述べる。

Table 1　Examples of Nuclear Disasters

A-bomb

Hiroshima･Nagasaki; Marshall Islands (USA); Nevada (USA); Semipalatinsk (USSR); Mururoa Atoll (France) etc.

Nuclear Accidents

Southern Ural (USSR); Three Mile Island (USA); Chernobyl (USSR): Goiania (Brazil); Criticality Accidents with Fatalities (USSR 6, USA 4, Argentina 1, Yugoslavia 1, Japan 1) etc.

Table 1 は今日までに発生した主な原子力災害の例を示しているが、冒頭で述べたように最大、最悪の原子力災害をもたらすものは原爆であり、熱線、爆風、放射線による被害がいかに大きく、また長期間にわたり継続するものであるかは広島、長崎の例にみられる通りである。その他の例はいずれも原爆実験によるものであるが、実験従事者や周辺住民に主として放射線による被害を与えている。

核施設や原発あるいは放射性物質を取り扱う医療施設などにおいても事故による災害が発生している。ソ連の南ウラルにおける核兵器工場の爆発事故と放射性廃棄物による住民の被害やチェルノブイリ原発事故の災害は規模の大きさで有名である。臨界事故は核兵器の組み立てや解体作業、核分裂物質の化学処理、原子炉の暴走などの際に稀に発生するが、1999 年9月東海村で起こった臨界事故はわれわれの記憶に新しいところである。

3．核戦争の健康影響

前述したように、国連総会の決議を受けて 1981 年の第 34 回世界保健総会（WHA）は、WHO 事務局長に核戦争の健康影響に関する国際委員会の創設を勧告し、1982 年に委員会が発足した。正式には“WHA 決議を実行するための医科学、公衆衛生学専門家国際委員会”と呼ばれるが、その目的は健康と保健サービスに及ぼす核戦争の影響を検討することで、1984 年と 87 年に報告書を発表している。

これらの報告書の中では、核戦争が発生した場合の人的被害とその対策を7種類のシナリオについて検討しており、

Table 2a Scenario A1

1 Mt (Megaton) Bomb → A Large City (e.g. London)

	Dead	Injured
Low Altitude (580m)	1,800,000	1,700,000
High Altitude (2,500m)	1,600,000	1,600,000

Table 2b Scenario A2

"Limited" Nuclear War

Total 20 Mt Smaller Tactical Nuclear Weapons → Military Targets

Dead and Severely Injured: 9,000,000 *

Injured : 9,000,000 *

* More than 90% are Civilians

Table 2c Scenario A3

All-out Nuclear War

10,000 Mt Nuclear Bombs → All over the World

(Half of Total Nucl. Weapons)

- 90%: Europe, Asia, N. America
- 10%: Africa, Latin Am., Oceania

Dead: 1,150 Million

Injured: 1,100 Million

ここでは 1984 年報告書に掲載されているシナリオ３種類（A１－３）の要点を Table 2 a, b, c に示す。シナリオ A１では爆風、熱線、放射線の別に１メガトン（Mt）原爆の爆発高度別死傷者数が示されているが、ここでは一括した死傷者数を掲げた。シナリオ A2 は限定核戦争の場合、シナリオ A3 は全面核戦争の場合の死傷者数である。

1987 年の報告書では、４種類（B1－4）のシナリオについて検討しているが、要するにいずれのシナリオの場合も"直接の災害に加えて、環境に及ぼす長期影響があるため、飢餓や疾病などが拡がり、世界の社会、通信、経済体制も全面的に破壊される"としている。その結論は、"核爆発の健康に及ぼす影響に対処する唯一の方法は、そうした爆発の一次予防、すなわち核戦争の防止しかない"という簡明なものであった。

４．健康影響評価上の問題点

広島、長崎における原爆投下は、両市民に未曽有の惨禍をもたらすとともに、人類がはじめて経験する、老若男女を問わない多数の人々の放射線大量被ばくをひき起こした。この教訓より、放射線の長期的な健康影響がはじめて明らかとなってきたが、健康影響評価上の問題点もいくつか指摘されている。ここでは、そのうちの３点について述べることにする。

１） 放射線被ばく人口　　放射線の健康影響を知るためには、放射線に被ばくした

Fig. 2 Setting of ABCC-RERF Cohort

1945 — 1950 ——→ Estimating the risk of late effects

1950: First Census after the war

	Population		A-bomb Survivors		Cohort for LSS Survivors	Control	Total
Hiroshima	330,000	--→	159,000	→	66,000	20,000	86,000
Nagasaki	250,000	--→	125,000	→	27,000	7,000	34,000
Total	580,000	--→	284,000	→	93,000	27,000	120,000

集団（リスク人口 population at risk ともいう）を被ばく線量別に把握して、対照とする非被ばく集団とともに、これらの特定集団（コホートと呼ぶ）内に発生する疾病異常や死亡の状況を調べて比較する必要がある。Fig. 2 は原爆傷害調査委員会（ABCC）とその後身の放射線影響研究所（RERF）が寿命調査（Life Span Study: LSS）の目的で原爆被爆者コホートを設定した時期を示している。

要するに、このコホートには原爆放射線被ばく後の５年間に死亡などにより脱落した者は含まれておらず、もしこれらの脱落者が放射線に対する感受性が高い者であったとすれば、逆にこのコホートには放射線に対する抵抗力の高い者がより多く含まれることになるため、このコホート観察から得られる放射線の発癌リスクなどは低く見積もられているのではないかとの疑問がかねてより提出されてきた。

重要なことは、当初の５年間の脱落者が果して放射線感受性の高い者であったかどうかを実証することであるが、今日まで行われてきたこの点に関する多くの研究では、そのような事実を証明するには至っていない。広島、長崎の場合は、戦争末期とそれに続く戦後の混乱のため、コホートの設定が遅れてこのような問題を生じたが、コホートをできるだけ早期に設定することが望ましいことはいうまでもない。この点、例えばチェルノブイリ原発事故の場合は、分母となるべきコホートの設定に一層の遅れを生じ、一時は分子の健康異常者のみが強調されたことがある。

２） 個人被ばく放射線量　上述の放射線被ばく人口を把握する場合、被ばく者各人の個人被ばく線量の推定に全力が注がれねばならない。被ばくによる健康影響を評価するには、量・反応関係を知る必要があるからであるが、広島、長崎の場合は原爆放射線の被ばく線量推定が困難を極めた。原爆が最高機密兵器であったこと、熱線と爆風の影響が甚大であったこと、各人の被ばく条件（遮蔽の状況など）が大混乱の中で把握が困難であったことなどの理由によるが、ABCC-RERF が原爆被爆者について実施してきた個人被ばく線量把握のための努力の軌跡を Table 3 に示した。

これによると、当初は爆心地からの距離や急性放射線症状の発現状況から、各人の被ばく線量を推定していたが、1957 年にははじめて理論計算などから仮の線量体系（T57D）が提出され、これを契機にネバダ砂漠の核実験場で大がかりな遮蔽実験などが行われた結果、広島、長崎の被爆者の個人被ばく線量を推定するための暫定 1965 年線量（T65D）が誕生した。

Table 3　Individual Exposure Dose
Hiroshima・Nagasaki

Initial Stage: Distance from hypocenter/
Acute radiation symptoms
↓
1957 : T57D (Tentative 1957 Dose)
↓
1965 : T65D (Tentative 1965 Dose)
↓
1986 : DS86 (Dosimetry system 1986)
↓
2002 : DS02 (Dosimetry System 2002)

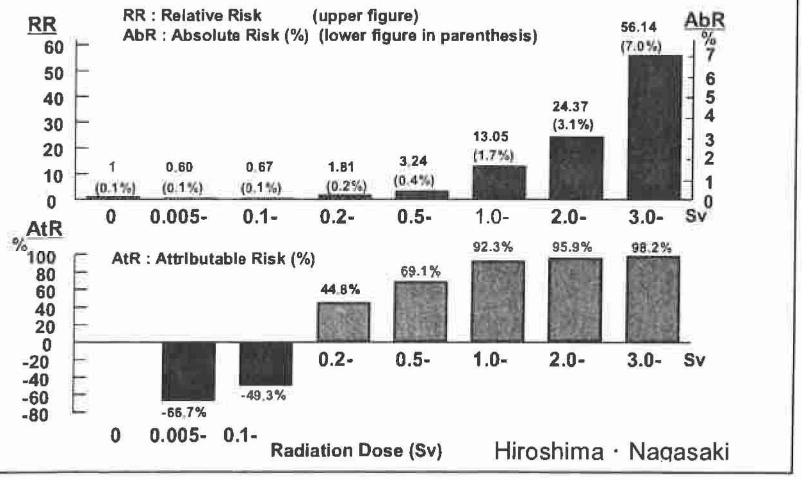
このT65Dに基づいた発がんなどのリスク値は、国際的にも広く使われてきたが、1970年代後半になってT65Dの問題点が明らかとなったため、日米合同の専門家委員会によって理論面と実測面の両面から再評価が行われた結果、1986年線量体系（DS86）が決定された。この新線量体系によって健康面のリスク値も補正されることになったが、DS86を決定する際に残されていた問題点についてはその後も日米共同で検討が続けられ、最終的に2002年線量体系（DS02）が導入されることになった。

DS02は、DS86に比べて線量が約10％増加し、逆に健康リスクは約10％減少することになるが、ここでは被ばく線量の推定にいかに多くの努力が払われてきたかの例として原爆被爆者の場合を紹介した。なお、上に述べたのは物理的な線量推定であって、このほかに生物学的な線量推定（染色体異常や歯の電子スピン共鳴法などによる方法）についても詳細な検討が行われていることをつけ加えておきたい。

3）　健康リスクの評価　放射線の健康リスクを定量的に把握するには、通常3種類のリスク値が用いられる。絶対リスク（ある因子にばく露した集団で、その因子に起因するであろうある事象発生の確率）、相対リスク（非ばく露群に対する、ばく露群の疾病罹患または死亡リスクの比）と寄与リスク（ばく露者中における、そのばく露に起因する疾病などの帰結の割合）であるが、相対リスクと寄与リスクは、疾病あるいは死亡とばく露との間の関連性の程度を表わし、絶対リスクはある要因に起因するであろう疾病や死亡が発生する程度を示す基本的な指標である。

Fig. 3は10歳未満で被爆した男女原爆被爆者の40年間における白血病死亡を、被ばく線量別のリスク3種類で示しているが、3 Sv（シーベルト）以上の被ばく者では相対リスクが56.14、寄与リスクが98.2%となって放射線と白血病死亡との間の関連性が強いことを示しているが、絶対リスクは

Fig. 3　RR, AbR (upper) and AtR (lower) of leukemia mortality by radiation dose, 1950-90 (both sexes and under 10 years)



7.0%と半数致死量に近い3Sv 以上の被ばくでも 93%の子供は白血病に抵抗性のあることを意味しており、分子疫学研究などを推進することによって、白血病発生機序解明への貢献が期待される。

おわりに

原子力による災害は多方面にわたっているが、ここでは健康面に関連する問題点のいくつかについて述べた。核兵器に関しては、廃絶が人々の健康を守る唯一の道であることは改めていうまでもないが、その他の核事故の場合も、予防対策の確立を最優先に、健康リスクを科学的により正しく評価する対応が求められる。

6.8 Probability of Cancer Risk in Medical Exposure

－Diagnostic X-rays－

医療被曝によるがん発生確率の問題

SHIMO Michikuni
下　道國
School of Health Sciences, Fujita Health University
藤田保健衛生大学

要旨

放射線をあびることよってがんが発生することはよく知られている。しかし、これはかなり多い量の放射線をあびたときであって、しかも必ず発生するわけではない。つまり、自然放射線レベルや医療における検査や診断で受ける量では、発生するかしないかわからないといえる。また、放射線によるがんの発生は確率現象であって、同じように多量の放射線をあびた人でも、がんが発症する人もいれば、発症しない人もいるのである。もちろん、あるレベル以上では、放射線をあびた量（線量）が増えれば増えるほど発生確率が上がることは認められている。

今年２月に新聞紙上に、海外の著名な専門誌からの記事として、わが国の医療被ばくが諸外国（15 ケ国）と比べて一番高く、欧米諸国の３倍程度であること、またわが国のがん発症の 3.2％ は医療被ばくに由来することが紹介され、話題となった。おそらく、多くの専門家でない一般の人々は、病院で放射線による検査を受けると１００人の内３人は癌になると理解したのではないだろうか。専門家の多くは、病院の検査で受ける程度では癌は発生しないだろうし、発生するとしても 3.2 ％にもなるとは考えていないだろう。

では、著名な専門誌に掲載された内容はいったいどういうことなのか。どちらかが嘘をついているか、あるいはどちらかが誤った解釈をしているのではないかと問われることになる。問題の論文について、(1) 議論の基となくデータはどのように集められたか、(2) がんの確率を計算するときのリスク（累積リスクと寄与リスク）の扱い方、(3) 広島・長崎の原爆被爆データを適用することの適否と、(4) がん発生は放射線が「どれほど低くてもあり」、しかもその発生確率は直線的であるという仮説（LNT 仮説）に準拠していること、などに関して考察し、論文を正しく理解する要点を紹介する。

It has already turned out that radiation has a certain influence on a human body immediately after discovering radiation by W. K. Roentgen in 1895. The medical treatment started just after discovery of radiation, and in the present time the medical treatment, diagnosis and inspection are greatly used and have become an indispensable means in the medical field. On the other hand, the injury has already appeared immediately after discovery of radiation and it has been reported that the doctor who treated X-rays died by the radiation injury at the beginning of 1900s. Thus, benefits and risks exist simultaneously as for use of radiation and it can be called the light and the shadow of radiation.

In this paper, probability of cancer by radiation in use is described in the use in diagnosis and inspection except medical treatment, attendance, and for the purpose of medicine research. First, it is shown in Table 1 that there is actually how much frequency exposed by diagnostic X-ray and inspection in Japan. Now, on 10 February 2004, two famous newspapers in Japan, The Yomiuri -shinbun and The Asahi-shinbun, reported about the probability of cancer risk in medical exposure by quoting a paper published in Lancet. The outline of presumption of cancer frequency was as follows. As the first step, exposure was calculated from statistics of inspection and diagnostic number of cases. First, the dose of each internal organs (internal organs besides the purpose) by a certain X ray inspection was presumed. Next, the frequency of the X-ray

Table 1 Medical Table 1 exposure in unit of mSv per examination in Japan (From "Atomic power" illustration 1997)

Site examined	Effective dose
Radiography	
Head	0.05
Chest	0.06
Stomach	2.7
Abdomen	3.0
Tomography	
Head	0.5
Chest	6.9
Upper Abdomen	Male 3.7 Female 3.8
Mass health screening	
Chest	0.05
Stomach	0.60
Lower Abdomen	Male 3.6 Female 7.1

inspection in a certain age was estimated, and the annual dose of the age was computed based on it. Furthermore, similarly, the dose of all X-ray inspection was investigated and those sums were taken. Finally, the total dose (virtual accumulation dose) of the whole life until it dies from 0 years old was calculated. As the second step, the accumulation cancer risk is called for using the "risk coefficient" obtained from the investigation of atomic bomb victims. It is assumed in that case that the cancer and the dose have the relation of direct proportion. Moreover, it was assumed that the influence by single exposure by A-bomb was equal to the influence by accumulation exposure by inspection whose quantity was far smaller than from the A-bomb. In the third step, the rate of the cancer considered to originate in radiation was calculated. The investigated country was 15 nations of the UK, Japan, the USA., European countries, Australia, Canada, and Kuwait. These countries had not had complete set of data of all, and the portion for which data was insufficient was presumed using the data of other country.

The result is shown in Table 2. In the analyzed 15 countries, the number of cases of annual X-ray inspection and diagnosis of Japan was almost 1500 times per 1000 persons. It was consequently evaluated that cancer based on diagnostic X-ray was equivalent to 3.2% of all cancers and the estimation was maximum among 15 countries. The countries with much number of cases to the next of Japan were Croatia and

Table 2 Frequency of diagnostic X-rays per 1000 populations and percentage of cumulative cancer risk to age 75 years attributable to diagnostic X-rays for 15 countries (From Berrington, A. and Darby, S)

Country	Annual X-rays	Attributable risk (%)	Country	Annual X-rays	Attributable risk (%)
Australia	565	1.3	Netherlands	600	0.7
Canada	892	1.1	Norway	708	1.2
Croatia	903	1.8	Poland	641	0.6
Czech Republic	883	1.1	Sweden	568	0.9
Finland	704	0.7	Switzerland	750	1.0
Germany	1254	1.5	UK	489	0.6
Japan	1477	3.2	USA	962	0.9
Kuwait	896	0.7			

Germany in the X-ray inspection and diagnosis. In Germany, the number of cases of annual X-ray inspection and diagnosis per 1000 persons was 1250 affairs, and in spite of being fewer than our country about 250 affairs, cancer occurrence probability was the half of Japan. The number of annual X-ray inspection and diagnosis of the UK per 1000 persons was 500 affairs and this was the lowest in 15 nations. Thus, the annual number of cases and annual cancer occurrence probability of X-ray inspection and diagnosis per 1000 persons do not necessarily become fair relation ship. It was thought that the complement (presumption) in the defect of the data of each country and calculation had influenced greatly as this reason.

The authors describe their opinions about the paper. First, it is necessary to notice that this paper about the collective cancer risk was presumed by probability theory based on the statistics data of X-ray inspection, and that an individual cancer risk was not presumed. Moreover, cancer cannot actually occur hardly with a quantity of this amount, and a cancer risk was not reasoned based on the survey of the cancer itself. In the process of reasoning, being calculated under assumption described in the 2nd step disregards the question over assumption that the linear-non-threshold (LNT) hypothesis, and the influence from accumulated dose being equal to that from extensive dose exposed at once. Then, that is not right if it says whether the paper is not only valuable but also useful. It can see as follows from the position of radiation management. That is, the circumstance of radiation risk by X-ray diagnosis became clear by using cancer risk as one hazardous index which was systematically compared between the exposed data obtained in each country. It can also be compared with other factors about the cancer risk. In the radiation protection, furthermore, the radiation management is performed from the position standing at a safe side in case where it does not understand well or in case it is doubtful. The figure is therefore able to use for a setting concrete target in order to reasonably mitigate exposure at diagnostic X-ray and inspection.

REFERENCES

1) Berrington,A. and Darby, S.: Risk of cancer from diagnostic X-rays: estimates for the UK and 14 other countries, Lancet, 306, 345-352, 2004.
2) 原子力文化財団編：「原子力」図面集、1997.
3) 保健物理学会ホームページ：最新の論文解説、http://wwwsoc.nii.ac.jp/jhps/paper/Lancet-Jan-2004.html
4) 酒井一夫：「日本でがんになる人の 3.2%は放射線診断による被ばくが原因か」？、教育フォーラムニュースレター, No.28, 3 月号, 2004.
5) 高橋希之：医療放射線被ばくの発がんのリスク評価、Isotope News, 7 月号,21-29, 2004.