THE IMPORTANCE OF MAKING RIGHT KNOWLEDGE ABOUT RADIATION POPULAR—ACTIVITY OF "RADIATION EDUCATION FORUM"

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I. INTRODUCTION

At present, radiation and radionuclides are not only indispensable in medical diagnoses and treatments, but are widely used in fundamental research and practical applications in various fields of science and technology, thus contributing much to us human being for elevating the quality of life. Nuclear power production is also playing an important role in saving the nonrenewable natural energy resources, without producing the potentially hazardous carbon dioxide.

However, a majority of people, including many intellectuals, have an excessive concern for the risk of radiation and radioactivity even for very minute quantities. This fact is without doubt the consequences of the following three reasons: (1) the first use of nuclear energy appeared as the disastrous weapon in 1945 and this has resulted a profound socio-psychological after-effect especially in Japan, (2) the major accidents of nuclear power plants which occurred in the 1980's have been repeatedly reported in mass media with undue sensationalism, and (3) the proposition, that every ray of ionizing radiation may destroy the human cell and is harmful for health such as by bringing carcinogenic or hereditary effects, has almost fixed as a suspicion-free common sense for general public. This proposition has its basis on the recommendation by ICRP, which adopts the "linear non-threshold" (LNT) model even for very low dose of radiation from the standpoint of radiation protection. We believe there are ample evidences that the LNT model is no longer scientifically correct for interpreting the radiation effect in low dose and low dose rate, as was reported before[1] and will be reported in this Congress by one of the present authors. At any rate, it is true that the majority of people show the syndrome of "radiophobia" by proliferation of the incorrect information about radiation.

In the present civilized society, the sound acceptance of science and technology by general public, based on full understanding and confidence, is needed to maintain the stability of the society and its sustainable development. Thus it is highly desirable that the level of both "SCIENCE LITERACY" and "RADIATION LITERACY" is elevated throughout the world. Otherwise, not only the proper use of radiation and the related nuclear disciplines in many scientific and technological areas will be obstructed by the shortage of working personnel, but also it is probable that the mankind may soon find difficulty in their existence in the event of a global crisis resulting from the exhaustion of fossil fuel. Especially, considering the fact that there are so many risks other than radiation in the present day civilization and that the severe regulation of radiation and the resulting radiophobia are producing various demerits in society, including vast economical loss, serious psychological stress for many radiation-exposed people, the above situation should be improved by attaining the "radiation literacy" of the public, i.e., by making the right knowledge about radiation and the related matters popular. This action should be done in worldwide scale.

As an approach to this aim, we established "Radiation Education Forum", a voluntary group,

comprised of scientists including distinguished physicists and expert radiologists, school teachers, conscientious journalists and citizens, in 1994 in Japan. We have continued various types of activities, focussing our energy mainly for improvement of radiation education in schools, because the social education has its basis on the school education. In order to extend this activity to an international scale, we hold "International Symposium on Radiation Education (ISRE 98)" on Dec. 11-14 in Kanagawa Prefecture, which was a fruitful event[2].

In this paper, reports will be made on the present status of general education about science and radiation at schools in Japan, problems in the description of currently used text-books at senior high schools, activities of the Radiation Education Forum, some of the useful information obtained at the international symposium, and future prospects of this activity.

II. PRESENT STATUS AND PROBLEMS ABOUT SCIENCE AND RADIATION EDUCATION IN JAPAN

A. General Educational Status and the Problems

There are several general features in the school education in Japan.

1. The first is the HIGH PERCENTAGE OF ATTENDING SCHOOLS at every stage in Japan. For example, the percentage of attending the obligatory schools (primary and junior high schools) in Japan is almost 100 percent, and that of entering senior high school, which is not obligatory, is as high as

more than 90 percent, and that for university is about 40 percent.

2. The second feature is the UNIFORMITY in the level of achievement of knowledge for all pupils for the lower education, i.e., at primary and junior high schools. This has been achieved by the governmental regulation called "Gakushu Shido Yoryo", an official teaching guideline prepared by Monbusho (Ministry of Education, Science, Sports, and Culture)[3]. According to this guideline, not only the teaching hours (and unit) for every subject in a week, as well as the distinction between obligatory subjects and selective ones, are strictly fixed, but also the contents and to how much depth the contents should be treated are determined in detail. The level of contents required is generally high. All new textbooks, within a whole limited pages, are reviewed by officials and approved before they are used in school, by scrutinizing whether or not they are in accordance with the items stated in the guideline. The guideline has been revised every ten years.
3. The third feature is the large INFLUENCE OF UNIVERSITY ENTRANCE EXAMINATION for lower stage education, especially in high schools. Although some amendments have been tentatively adopted for the entrance examination in limited number of universities recently, students and teachers have been eager in the usual question-answer type teaching method to obtain high marks in the examination, rather than the experiment- or discussion-type teaching method.
4. As for the PROBLEM OF SCIENCE STUDIES, recent tendency in the official guideline has been, very regretfully, in the direction of decreasing the teaching hours of this subject in schools, contrary to the continuous development of science and technology in society[4]. Furthermore, it is reported that recent students tend to dislike science studies, so to speak "Rika-banare", the science-shunning, although this tendency is said to be the worldwide one.
5. MERITS and DEMERITS of above circumstances are as follows: Owing to the equality of opportunity in learning, and to the uniformity as well as its relatively high level of the contents, Japan has boasted of the highest literacy in its literal sense (reading, writing, and arithmetic) in the world, and Japanese students have almost always won the first prizes in the international achievement test[5]. Prof. Akito Arima, ex-Minister of Monbusho, reported recently that the young children show much interest in science studies when they are at the age of primary schools, but they tend to lose their interest in learning science studies as they become junior and senior high school students[5]. He reported also that from an international comparison the marks obtained by Japanese students for the questions of science studies which were taught at schools are considerably high and in a narrow range of precision, but the marks for the questions which are of the kind of what have not been taught are very low[5,6]. This suggests that the emphasis of learning at school in Japan has been generally placed on memorizing of the topics which are written in text-books, not on the real understanding of the phenomena. At any rate, it is not a congratulatory fact that recent young people don't have the ambition of developing science and technology, while they are surrounded by various convenient products which are the outcome of recent development of these disciplines. Thus it has now been pointed out that the Japanese students are becoming weak in the ability of creativity in scientific thinking and of skillfulness in handwork. Moreover, after graduation, they generally tend to avoid to work classified in the type of so to speak "three K": "kitsui", i.e., hard, "kitanai", i.e., dirty, and "kiken", i.e., dangerous. Although the recent employment circumstances may somewhat improve this situation, many intellectuals fear the future of Japan. To improve the present educational status, amendment is keenly needed for the present educational systems of teacher-training course for up-bringing and encouraging of good teachers especially in science studies. For overall improvement of the educational circumstances, however, it seems that the importance of ethics of the whole society should be much stressed.

B. General Disadvantageous Circumstances around the Education of Nuclear-Related Matters

As for the degree of achievement in the basic knowledge of radiation and nuclear energy in schools, recent surveys comparing Japan and six European countries show that Japanese students learn about nuclear-related matters least at school among seven countries[7]. According to the report, Japanese students of 15～18 years old are learning these matters least from school, and yet they received the lowest score for the questions of nuclear energy or mechanisms of a power reactors. This fact suggests that, other than the situation described above, there are various causes which prevent the proper education of radiation and the related matters in Japan. In the following, these causes are described[8,9].

1. The educational contents and the teachers' own acquirement of knowledge

Nuclear-related matters are based on modern physics, so teachers themselves in general are not well-educated at the stage of a teacher-training course of a college. Therefore, when they become teachers, they cannot teach these matters correctly.

2. Treatment of nuclear matters in the curriculum

According to the usual methodology of following the order of scientific development, which begins with classical topics, nuclear matters usually appear at the end of textbook in physics. In addition, the recent tendency of shortening the total teaching hours for science studies frequently results in failing to cover nuclear matters.

3. Poor treatments of nuclear matters in the curricula other than physics

According to the present official guideline, it is determined that radiation and radioactivity are to be taught only in the curriculum of physics and in a small extent in geo-science among science studies So they are not treated in the curricula in chemistry, and biology, although radiation and radioactivity have important implications also in these subjects.

4. Students' choice of science subjects

Also by the current guideline, there is no obligatory curriculum in the subject of science, among the four, evenly treated subjects: physics, chemistry, biology, and geology. Clearly, physics is the most fundamental of science, which should be taken by every student, especially who wishes to become a scientist or an engineer in the future. Unfortunately, the fraction of students taking physics in high schools is reported to be small (ca 30 %) at present.

5. Inadequate description in textbooks

Inadequate descriptions on nuclear matters in textbooks can frequently be found[4]. "Inadequate" means lack of description about important topics, incorrectness of description in purely scientific facts, misuse of terminology, unfair presentation of facts (scientific and historical), or biased opinion on the significance of nuclear energy and the related matters. The examples will be shown in the next chapter.

6. Experimental inconvenience in teaching

Experimental apparatuses necessary for nuclear matters are often expensive, and therefore it is difficult to demonstrate even simple experiments in school for a large number of students. Recently, the classroom experiment in a school tends to be neglected, mainly due to the incentive for the preparation of entrance examination. (Quite recently however, a few convenient experimental apparatuses for radiation education, such as a simple portable radiation counter or a cloud chamber, have been developed.)

7. Legal regulation for handling radioactivity

There is strict legal regulation or recommendation for handling radioisotopes at schools even in small amount, and this makes the procurement of radioisotopes for educational use difficult, and teachers hesitate to handle it in a classroom.

8. Radiophobia for radiation and radioactivity

The widespread feeling of "radiophobia" or "nuclear allergy", which have been fostered by the majority of public, is one of the most important reasons that the teachers and students tend to avoid handling even a small amount of radioactivity into a classroom.

9. Attitude of teachers' union against the use of nuclear energy

It seems that a teacher who wishes to teach the right knowledge about radiation and nuclear energy to students have not been welcome by the organization of teachers, which hitherto has adopted ideologically an anti-nuclear stance, even for peaceful uses.

10. Attitude of Monbusho

It seems that Monbusho has been reluctant to introduce the controversial matters such as the nuclear-related matters into a classroom. This can be exemplified by the fact that "radioactivity" and even "isotope" do not appear in chemistry and biology curricula in the official guideline. (According to the most recent official guideline[10], the situation has been a little improved, such as an obligatory subject, "Rika-sogo", in which radiation and nuclear energy are included, has been installed in science studies.)

11. Correlation with the university entrance examination

Questions used in the university entranced examination are basically required to be the topics within the range of contents described in the official guideline. This fact, together with that the radiation-related matters are usually treated at the end of textbooks, has resulted that questions about these matters are rarely appearing in the entrance examination, thus the study on these topics is apt to be neglected at high school education.

III. INADEQUATE DESCRIPTIONS FOUND IN CURRENT TEXTBOOKS IN JAPAN4

The present authors surveyed the description of radiation and the related matters in (more than 250) textbooks of every subject currently used at senior high schools, since 1993. In the following, the report of the survey for the science studies ("Physics", "Chemistry", "Biology", and "Geo-science") and the non-science studies ("World history", "Geography", "Contemporary society", "Politics and economy", and "Health and

gymnasium").

A. Science Studies

Among about 180 books surveyed, about half is written by the old system of guideline, enacted in 1979. In the books of this category, the description for nuclear-related matters was in general very inappropriate, in that the number of pages spent for these topics are very meager except in "Physics" and "Rika-I", and that even in these books we could easily find various kinds of scientific mistakes. This situation has been considerably improved in the books prepared by the present guideline enacted in1989, i.e., in "Physics-IA" and "Physics-IB", etc. However, considering the wide application of radiation and radioisotopes, there is still a problem that only a few books contain the description of application of these discipline to medical uses.

As for other subjects than physics, i.e., chemistry and biology, the description is very poor even in recently published books. In chemistry, radiation is not usually touched, and radioactivity is touched but only to a small extent. In biology, every textbook describes the artificial mutation induced by UV and X-rays and by ionizing radiations, and this fact can be utilized for breeding of some agricultural products. However, strangely enough, there is no textbook of biology which describes the dose of radiation level in the environment and the radiation effect to human body. In geo-science, "nuclear energy", "natural radioactivity", and "age determination of rocks by radioisotopes" are considerably well-treated.

The followings are the examples of inadequate descriptions found in the currently used textbooks of "Physics-IA", "Physics-IB" and "Chemistry-IA", which were quite recently published (in 1998 and 1999). The authors can show examples of some amended sentences for each inadequate descriptions[4], but they are omitted here due to the limitation of space.

"Nuclear power generation has many stages in which abundant radiations are released."
"Isotopes have the same chemical property."
"The mass of proton and neutron is the same."
"It is said that the radiation exposure of more than 0.05 Sv per year id dangerous."
(As an opinion in the debate)*"Since the half-life of ^{137}Cs is 30 years, while that of ^{131}I is only 8 days, the former is more problematic."
"It is impossible to separate isotopes by chemical means."
"Proton and neutron easily combines."
"Becquerel thought that the unknown radioactivity was emitted from uranium."
"The nuclei which are produced either by nuclear fission or by absorption of neutron in a reactor have usually strong radioactivity, and they are extremely dangerous to human body. Therefore, safe design for the structure (of a building) and safe handling of radioactive waste should be sufficient, in order for such nucleus nor neutrons to leak out in such a case of earthquake."
"Since radioactivity sometimes remains in a spent fuel, sufficient care is needed for securing the safety and for nuclear power generation in a reactor."
"Nuclear power generation is now being utilized as a substituted energy for fossil fuels, without technological establishment for solving its safety and the problem of waste disposal."

B. Social Studies

Treatment of nuclear matters in textbooks of social studies is in general very problematic. While they acknowledge the contribution of nuclear energy to the supply of national energy supply, the manner of description is rather skeptical about the development of nuclear energy. The judgement is frequently done by unfair presentation of facts. For example, risks are frequently exaggerated for nuclear energy, while benefits are stressed for natural energy sources such as solar and wind. Thus, students may have much more expectation than scientific and economical truth. It is a problem that there is only a few textbook which describe the large merits of nuclear power supply, in that this is contributing greatly to Japan by minimizing the dependence of energy on the importation of oil. Most of textbook writers seem to have a firm belief that the safety of nuclear power station has not yet been established, that the technology of radioactive waste disposal has not been developed to ensure the safety, that radiation and radioactivity, as well as the contamination of radioactivity to body or to environment is extremely dangerous. The followings are the examples of problematic descriptions. Here also it is regrettable that the space does not allow the author to show the examples of corrected descriptions.

"Prospect for the sufficient safety of nuclear power station has not yet been established, in correlation with leak of radioactivity, disposal of radioactive waste including spent fuel, and decommissioning of a reactor."
"The impact caused by the Chernobyl accident on western countries is large, and several countries postponed new construction plan of power reactors. In Sweden, a law which aims the abandonment of all power stations was settled in the Parliament."

”The nuclear energy is released by artificial fission of nucleus, and the amount is enor4mously larger than other type of energy sources. The contamination by radioactive waste is dangerous.”
”The Chernobyl accident hit the world with horror for global radioactive contamination. It has been pointed out that the nuclear power generation is not economically advantageous considering the waste disposal and treatment, although it can afford the stable electric supply.”
”Radiation exposure to humans is inevitable, in the surroundings of a reactor, in a mine field or factories for the procedures of mining the ores, by enrichment and reprocessing of the fuel, and during the path of transportation. And thus the contamination of environment by radioactivity is inevitable. The accidents which may occur during reactor operation has a possibility of resulting very severe damage.”
”The safety of nuclear power generation is problematic, because its uses the nuclear energy of uranium, which produces a large amount of radioactivity, and it is dangerous for human body.”
”The TMI accident resulted in a great damage by radioactivity to the surrounding districts.”
”As shown in the accidents of TMI and Chernobyl, a reactor power station has a possibility a large disaster by a human error. Once an accident occurs the damage is severe and extensive, and questions have been raised by many people for the radioactive waste and safety of nuclear power stations.”
”In Japan also, the reactor accidents are consecutively occurring. There is firmly-established opposition and concern.”
”In 1991 in Japan, a large reactor accident occurred, where very much amount of primary cooling water leaked out, and ECCS (emergency core cooling system) worked”
”Even in a routine operation without any accidents, hazardous radioactive wastes are continuously accumulated, thus our offsprings are compelled to suffer the semi-permanent control and storage.”
”The radiation dose of workers f a nuclear power station is high, and an accident or thief might occur during transportation of nuclear fuel. When a nuclear facility has a military attack even by a usual weapon, damage due to radioactivity occurs just as in a nuclear war. The cost does not become advantageous against fossil fuel. The nuclear power generation has several difficult problems.”

IV. ACTIVITY OF “RADIATION EDUCATION FORUM”

The followings are various kind of activities we have done up to present or are now making efforts:
1. Since we have found several problems to be amended in the educational system about radiation, radioactivity, the nuclear energy in school we have submitted a document of appealing the improvement of the official guidelines to the Minister of Monbusho. (Some detail will be described in later chapter.)
2. We have organized several workshops for studying specific topics and preparing the summarized reports, which are useful for radiation education. The topics are (1) Effect of low level radiation, (2) Survey of description in textbooks and way of reporting in mass media, (3) Experimental methodology for radiation education in schools, (4) How should be the teaching curricula for radiation education at schools, (5) Risk education, and (6) Status of education about radiation at colleges and universities for medical students and nurses appropriate. It is aimed to prepare the summary reports, some of which shall be the standard text to be used in school.
3. We have held several meetings (2 times per year) and a symposium (once a year), where new information on radiation effects and on various topics useful for education are presented, and discussions were made on how to teach at schools the key topics such as are stated above.
4. For school teachers we have held several study meetings (two times per year), where educational experiences on radiation and general science studies in classroom, and novel experimental methodology are presented and discussed. The meetings were occasionally accompanied with the inspection of radiation or nuclear facilities.
5. We have published “Newsletter” 2 or 3 times per year (totally 15 numbers as of Nov. 1999) and a journal, “Radiation education” once a year (totally 2 volumes as of Nov. 1999). We are also publishing a list of reference which are useful for radiation education.
6. To extend our activity to an international scale, we have organized “International Symposium on Radiation Education (ISRE 98)” on December 11-14, 1998 in Kanagawa Prefecture in Japan. (Some information we have learned from this symposium will be described in later chapter.)

V. WHAT RADIATION EDUCATION FORUM APPEALED TO JAPANESE GOVERNMENT

A. Appeals to Monbusho

We have submitted two documents to Monbusho (Ministry of Education, Science, Sports, and Culture) to appeal for the improvement of education about radiation and the related matters in senior high

schools, by amending the official guideline. In the former, “Appeal for the improvement of radiation education in schools” (submitted on June 30, 1995), we have proposed several concrete plans of amending the official guideline for placing more weight on the radiation education in every subject. The main point is that these topics should be taught at schools as the obligatory curriculum in science studies, because radiation and nuclear energy belong to the most important scientific phenomena which have close implication to our human life.

In the latter, “how should be the education about radiation and radioactivity in correlation with the energy and environmental problems” (submitted on Nov. 19, 1996), we have explained in detail the reasons for making the former appeal. This document is composed of the following seven chapters:

1. The background for submitting this appeal,
2. A brief description of the fundamental nature and various applications of radiation and radioactivity,
3. How to understand and teach the effect of radiation on human body,
4. On the necessity of improving the education of energy and environmental problems in school,
5. The correlation between radiation education and nuclear power education,
6. On the education of risk which accompanies with the recent development of science and technology and modernization of social life, and
7. Other problems to be considered for establishing the educational policy.

It is our pleasure that this appeal seems to acted for the amended guideline to appear in 1999[10] .

B. Appeal to STA (science and technology agency)

Just after we submitted the second appeal to Monbusho, we have submitted to STA an appeal , “On the method of effective education of radiation and radioactivity in school and society”, on Dec. 18, 1996. The contents are the following:

1. Necessity of loosening of severe regulation for handling low level radiation source which is used for education at school
2. Necessity of special consideration of regulation for handling radioactive isotopes used at educational organizations for the purpose of activation of education and utilization for research
3. Necessity of careful adoption of ICRP recommendations into the direction of severer regulation than present, because this will make the general public feel more dangerous for radiation
4. Promotion of social education of science and technology

VI. SOME IMPORTANT INFORMATION OBTAINED BY ISRE 98

A. From the Panel Discussion on "The Status and Problems of Radiation Education in Various Countries

The common recognition and problems in every country are as described below:

"The majority of general public in every country believe that radiation and radioactivity are dangerous even in very small amount, so that the new information and the correct way of thinking on the radiation effect at low dose should be widely spread."

"The general public tends to have a negative image only to hear the words of "nuclear" , "radiation", or "radioactivity".

"Chernobyl accident has had a deep effect for the general feeling for nuclear problems."

"They believe the destructive power of atomic bomb only comes from radiation."

"There is a confusion between atomic bomb and the peaceful uses of nuclear energy."

"What makes the psychological situation worse, journalists and TV commentators are more interested in treating nuclear problem in sensational than explanatory presentation."

"Radiation education is very important, and it is effective to let the students learn about the existence of natural radioactivity and radiation."

"One obstacle for radiation education is the fact that the units of radiation is not easy for understanding and the numerous magnitude for the amount of radioactivity is usually very large."

B. From the Workshop (1. Experimental methodology, 2. School curriculum for radiation education, 3. Risk education)

From WS of school curriculum, an important summary was reported for the educational system in Japan. That is: before the correct scientific knowledge for radiation is given in the science studies in high schools (as an elective course) or university undergraduate course, somewhat deflected views on the use and the risk of radiation and nuclear energy are now being given to all students in the non-science studies as obligatory courses. This situation should be amended.

C. Some Exemplary cases

According to Esther Toth of Hungary, their experiences for decade show that nuclear literacy can be taught for the whole population of teenagers, by a compulsory part of the Hungarian high school curricula. There, basic concepts of nuclear energy and nuclear reactors are presented in a more transparent and picturesque way than e.g. resistance in circuits of alternating current. And the experimental experiences are now being offered to Hungarian youth by GM counter demonstrations and by measuring radioactivity concentrations in their homes by track detectors. The speaker reports that nuclear literacy increased even among those students who are interested in business or arts, due to the actual social relevance to the problems.

One unique presentation (by poster) which was admired by overseas participants was that presented by Dr.Yoshiko Harima and the coworkers: successful tentative lessons have been made in a classroom of a primary school in Tokyo. A simple digital survey meter, named "Hakaru-kun", was forwarded to each pupil of 11 years old, and children could quite naturally, with much curiosity, have leaned that (1) natural radiation exists everywhere, (2) the magnitude depends from place to place, and (3) the value fluctuates as a natural phenomena.

VII. FUTURE PROSPECTS

1. Effect of low dose radiation Radiation and radionuclides have existed around us since the birth of Earth, and we all human beings have continuously received some small amount of radiation doses. According to the recent studies, the LNT model is no longer valid, indeed, a small amount of radiation might possibly be indispensable for the existence of life in general, according to a school of thought. Thus we believe the concept of radiation education should be shifted to teaching not only its hazard at high level but also the possible existence of a threshold level below which the hazard is actually negligible, and to emphasizing its important benefits in various applications used in our civilization. This will mitigate radiophobia.
2. Radiation education at as young age as possible In methodological point of view, it is clearly effective for radiation education that the existence of natural radiation and radioactivity around our environment will be learned at as young age as possible. In this context, we have been much pleased to learn that radiation and the related matters will be treated as the topics to be studied in the newly prepared obligatory subject, “Rika-sogo”, according to the newest official guideline published in 1999[8].
3. Necessity of training the teachers It is urgently necessary to train as many competent teachers who can teach radiation and related matters as possible. It is advisable for the teachers to learn not only the experimental techniques about radiation but also the wide information covering the implications between science and society. And it is expected that he or she can accept the positive view on the use of science and technology to various applications to human society.
4. For education in society In radiation education for general public, the “teacher” may not always be a school teacher, but an expert of this field, who is enthusiastic enough to spare his or her time in talking with any people in general public. Of course the teacher may not always be a professional but be a voluntary citizen. It will be a requisite that he or she not only has a right knowledge about radiation but be a person of trust because he or she has to talk with a person who has a deflected view on radiation and nuclear energy.
5. Future direction Since this activity is very important, we are planning to construct a world wide network for promotion, and it is hoped to hold the second international symposium on radiation education in near future, somewhere in the world.

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