Invited Talk

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Radiation Education—the Importance of Proliferating the Correct Knowledge about Radiation, Radioactivity, and Nuclear-Related Matters

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Radiation Education Forum, 3-23-6, Nishi-Shimbashi, Minato-ku, Tokyo 105-0003, Japan

Abstract

The following topics will be reviewed: (1) why Japanese have the feeling of "Radiophobia", (2) what our "Radiation Education Forum" aims and have done for these 15 years, (3) the fundamental knowledge about radiation and radioactivity, (4) examples of incorrect expression about radiation and nuclear-related matters frequently found in textbooks and in mass media, and (5) the future prospects of radiation education.

Keywords: *radiation, radioactivity, radiophobia, atomic bombing, school curriculum,*

1. Introduction

The word, "Sustainable development," seems to have become a popular catch-word among several developed countries, as a synonym of subjugation of the "energy and the environmental problems." The practical effort for this goal is to save the fossil energy such as oil and coal, and to exploit the natural or new energy, such as solar, wind, biomass and so on, as well as the utilization of nuclear energy.

For obtaining the sustainable development, we have to rely much on the role of nuclear energy. In Japan, about 32% of the electricity is supplied at present by nuclear power. However, nuclear energy has great implications with radiation and radioactivity, and the feeling of the general public in Japan against radiation ("radiophobia") makes the social acceptance of nuclear energy considerably problematic.

In the hope of improving this situation, we have organized "Radiation Education Forum" in 1994, and are continuing our efforts in various ways. In this paper, our endeavor to propagate the in correct knowledge about radiation and nuclear-related matters to the public, especially to improve the educational circumstance in school, will briefly be reviewed. We propose here to extend this activity of educating general public along this line into global scale, because the future of the energy and environmental circumstances in the whole world will not be optimistic if all matters will be left according to the present competitive principle .

2. Why Japanese have the feeling of "radiophobia"

There are several reasons why Japanese general public have the feeling of radiophobia.

2.1. The after effect of atomic bombings of Hiroshima and Nagasaki

It was quite an unhappy event that the discovery of nuclear fission, which was purely an academic achievement, worthy of Nobel prize if this was not in a wartime, was immediately utilized as such a non-humanistic purpose as killing and injuring many innocent citizens and destroying the prosperous cities. The survived people, named HIBAKUSHA, have been told that their residual lives will be shortened due to the minor radiation dose received by the instantaneous flash of the bomb. Since then, all Japanese people have been told repeatedly about the risk of radiation by the mass media. It is true that there are not a few Japanese people who don't like even to hear the word "radioacitivity."

2.2. The attitude of mass media and school education

In the 1950's, a subsequent event occurred and reminded Japanese of the horror of nuclear weapon: in 1954 in Bukini. Following this, during the period of continuous development of the nuclear power production in Japan, two major nuclear accidents occurred in abroad, one in TMI in 1979 and then in Chernobyl in 1986, and these disasters were largely reported by mass media. The mass media has a tendency of reporting the demerit of radiation and nuclear-related matters frequently with much exaggeration. The usefulness of radiations such as in medical purpose should be much more advocated. In school education also, Japanese Monbusho (Ministry of Education, Science, Sports, and Culture) has been reluctant in the education for nuclear energy and radiation-radioactivity at the primary and secondary school age, contrary to the governmental policy of promoting the utilization of nuclear energy as the national policy. So the young students at the compulsory education have not the chance of studying the knowledge about these areas, and only a limited percentage of students have had this chance after entering into the senior high schools.

2.3. The fundamental principle of the radiation protection--LNT hypothesis

In the region of radiation protection, the "Linear Non-threshold Hypothesis" (LNT Hypothesis), which assumes that radiation may be risky even in a very small dose, is the basic principle. Although this is a conventional hypothesis, many people believe this is a scientific fact, and has surely become one of the reasons of becoming radiophobia.

It should be borne in mind that the recent radiological data (epidemiological and animal studies) in the low dose (and low dose rate) region show the existence of the threshold, and sometimes there are even health-promoting effect (radiation hormeses) such as used as a medical treatment (the radon therapy). We sincerely hope that this policy of ICRP will be amended in some near future. This author has a firm confidence that the LNT hypothesis is not correct, from the detailed examination of the data of atomic bomb-survivors, especially on the careful consideration of the additional dose received due to the residual radiations (Matsuura, 2002).

3. What our "Radiation Education Forum" has done to improve the present situation

Our "Radiation Education Forum (REF)", which was established in 1994 by us, to improve these situation, namely for filling the gap between the scientific facts and the perception of general public for the radiation and the nuclear-related matters. The members consist mainly of investigators (universities and institutes) in the fields of radiation and nuclear sciences, and teachers in schools. (The number of members is at present about 250.) The basic philosophy is to deliver the correct scientific facts, by excluding prejudices. We try to explain the data in an easily-understandable way when talking to non-experts. We are doing following various activities:

3.1. Holding of seminars and symposia.

*Seminars for members are held regularly three times in a year in Tokyo.

*The International Symposium on Radiation Education (ISRE) was organized three times: in 1998 in Kanagawa by REF, in 2002 in Debrecen, Hungary organized by late Prof. Marx, in 2004 in Nagasaki by REF, and the present symposium is the forth, organized by Taiwan group.

*"Seminar on Energy, Environment, and Radiation" for school teachers has been held since 2001 in various places throughout in Japan. This is for providing the recent information for school teachers to teach the radiation, radioactivity, and the related subjects in school. (The total number of participants in the seminar per year is about 500.)

3.2. Holding the expertise committees.

There are 6 committees at present in the REF to discuss various aspects of radiation education : "On the curriculum of radiation education in school", "On experimental materials for teaching for radiation in classroom", "On risk education", "On radiation effect at low level", "On the description in the text-book", and "On the account in newspaper and other mass media". The summaries of each committee are reported at the end of each Fiscal Year.

3.3. Publishing the periodicals

*"Newsletters" are published 3 times in a year, and totally 42 number of pamphlets (8～12 pages) has been issued up to Nov. 2008.

*Japanese journal "RADIATION EDUCATION" is published annually, and 11 volumes have already been published up to April 2008. In addition, since March 2000, it has now become a rule to publish as the extra version of this journal a summary report of the activity of the REF. Nine volumes have already been published, and these have become a suitable material for teaching radiation and nuclear-related problems in schools for the participants of the seminar.

3.4. Submitting Appeals to the Government

In order to improve the radiation education circumstances in schools, REF have submitted the appealing documents to the Monbu-Kagaku-Sho (Minister of Education, Science, Sports and Culture) several times during these 15 years. We have appealed the revision of official education guideline, which prescribes the detailed contents of curriculum of Science Studies in junior and senior high schools: in 1995, in 1996, in 2005, and in 2006. Our recent two appeals succeeded in revising the guidelines of the junior high schools, so that radiation and radioactivity should be taught in the Science Studies after the 30 years' blank period of excluding these items in the teaching curriculum at this stage.

3.5. Preparing the teachers' guide for teaching radiation, especially to meet the needs in junior high school

Responding the newly revised regulation for school curriculum, we have started to prepare the teachers' guide for teaching radiation and the related topics in the classroom in junior high schools.

4. The Items about Radiation to be Taught at the Stage of Junior or Senior High School

The followings are the items which we believe should be taught for relatively young students:

4.1. Existence of natural radiation and radioactivity

Radiation and radioactivity exist everywhere in our environment. (This fact must be demonstrated experimentally, using radiation measuring instrument)

Origin of natural radiation comes from various sources: ground, cosmic rays, human bodies, and radon in the air. The dose of radiation from the ground varies from place to place, depending on the geometric condition. There are several places in the world, where the level of natural radiation is extraordinarily high.

Natural radioactivity such as K-40 exists in a food which we daylily eat and so they exist also in a human body.

4.2. What is the nature of radiation and radioactivity?

Radiation is one type of energy. They should be taught in connection with the atomic and nuclear structures, nucleons (proton and neutron), isotopes, and the stability of nucleus, half life of radioisotopes.

What is the action of radiation with matter?

4.3. What is the nuclear energy?

What is the difference between nuclear power station and atomic bomb? What is the nuclear fission?

4.4. What kind of utilization does radiation have?

To what kind of nature of radiation does the utilization depend?

4.5. How is the radiation effect to the human body?

To what extent is the radiation can be regarded to be safe? According to the most recent data, we can say that it will be safe up to about 200 mSv. The effect of radiation for human body varies not only with the total dose, but also with the dose rate, i.e., the effect becomes less if the dose rate is small compared with the case when the same dose is given in a short time.

The effect is independent on whether the radioactive source is natural or artificial.

4.6. What is the common knowledge for protecting our body from the source?

There are the three principles: (a) to take a distance, (b) to place a shield, and (c) to minimize the working time.

4.7. There is a regulating law system to minimize the radiation exposure for working people.

It is recommended to use radiation according the principle of ARALA: (a) not to use when there is no merit of using radiation, (b) to use radiation under due caution, and (c) to obey the exposure limit, determined for the workers and for the general public.

5. Various Examples of Incorrect Statements about Radiation

The following are the examples of incorrect statements frequently found in textbook used at junior or senior high schools or in other publications:

(1) "Nuclear power produces radioactivity which is poisonous to human body in large amount."

(2) "Because radioactivity is highly poisonous, it is difficult to dispose it."

(3) "Radioactivity has an effect of threatening the existence of all living things."

(4) "Once nuclear accident occurs, a vast area is contaminated with radioactivity, and it brings an enormous bad affect for human body and ecological system for a long time."

(5) "As shown in the examples of accidents occurred in a large scale in abroad, the safety of nuclear power station is incomplete."

(6) "In Chernobyl accident, the radioactive contamination occurred in the scale of 500 times of that in the atomic bomb in Hiroshima."

(7) "In JCO accident, 700 residents were exposed with radiations."
(8) "New construction of nuclear power stations is rarely done in European countries and in America, considering the high cost and safety."

In general in the textbook of "social studies", we can frequently see the statements which favor the "natural energy" by almost neglecting their demerit and by exaggerating the demerit of nuclear energy.

6. Perspective for the Future of Radiation Education

The activity of making the correct knowledge widespread should be continued not only for school education, but also to the entire society. For the latter purpose, we think we experts should have much more contact with the mass media and those who may have great influence for changing the opinion of general public.

I believe this necessity is not restricted only to Japan, but also to all over the world, because many countries will probably have to meet the similar problem; namely, they will have to depend much on nuclear energy and to do with the various problems in some near future. Then, our experience and know-how to propagate the correct knowledge especially about the risk of radiation will surely be helpful for the decision- making of these countries. This kind of information will surely be welcomed as a valuable estate for the welfare-making of that country or district.

I feel, for that purpose, we experts should make our idea and opinion about the degree of risk of radiation more clear, and unite them into almost the same direction, such as for the basic criticism for the LNT hypothesis. Then, we hope we can be able to recommend ICRP to lead the revision of their recommendations.

Acknowledgements

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Radiation Education in School

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Abstract

The seminar has been for the teacher of junior and high school mainly to reflect energy, an environmental problem for school education definitely.

It is to train the fair judgments of the nature of the citizen for the issue of energy, environmental and atomic energy problems. It is important to perform substantially and upbringing of the school and in the society to find a future talented person in this field. The event is served the increase of the public interest. The seminar accords with mind which is both in the articles of association of NPO-*hojin* Radiation Education Forum. For a class of "Recommendation to Integrated Science and Education" for the school teachers, the time when the seminar has been keeping up with us in 2001 and aimed at spreading right knowledge to the pupils.

There are involving the seminar lectures, the experiment of radiation, a panel discussion, a free panel discussion, interchange society and visit to instrument party.

Keywords; energy, environment, radiation, right knowledge

Introduction

When the atomic energy experience seminar faculty of liberal arts course that intended for the staff of a school of the faculty of liberal arts was carried out mainly from 2001, NPO-*houjin* Radiation Education forum cooperated with Radiation Application Development Association (RADA). The Seminar was established "Energy, Environment, and Radiation seminar" as a new business which aims at right knowledge spreading to pupils through "Recommendation to Integrated Science and Education" starting in 2003 in high school from 2002

purpose of the NPO-*houjin* Radiation Education Forum "planned substantiality by deepening understanding for energy, environment, and radiation such as the by deepening understanding for energy, environment, and radiation such as the staff of a school. Realizing for the NPO-*houjin* Radiation Education Forum

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"planned substantially of the education of this field in a school and the society and the spread of right knowledge for energy environmental problem, radiation and training of fair judgments nature of the citizen for the issue of atomic energy and security of the future talented person in this field. It is to contribute to the increase of the public interest" as for this seminar.

2. The summary of the seminar

The seminar was held in ten national districts (Hokkaido District, Tohoku District, North Kanto District, South Kanto District, Shizuoka and Yamanashi District, Aichi, Gifu and Mie District, Toyama and Ishikawa and Fukui District, Kinki District, Chugoku and Shikoku District, Kyushu .and Okinawa District). Of these, established the held course had been done in each district on held course, a day and second days.

From 2001 to 2007, recruitments number and participant number was indicated in figure. Planning it by the contents which the member of the Radiation Education Forum played a key role as for the course contents, and staffs of faculty of liberal arts of a junior high school and the high school mainly intended for the education person concerned by the expert of each field, and

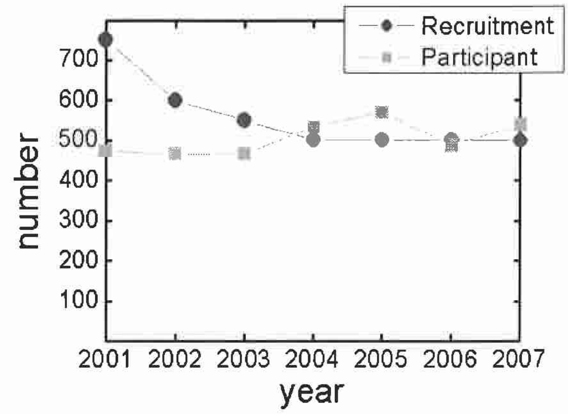

Fig. Recruitment and participant

helped a class in time for general learning

(1) An education system and energy and an environmental problem of educational issue (an idea and ideal method, an ideal method of the education of he 21st century and the directionality when it take up for a class of "Recommendation to Integrated Science and Education". international comparison of the scholastic ability of the Japanese junior and senior school pupil. technology and society. the positioning of radiation in the scientific as the basic knowledge.)

(2) Energy and an environmental problem of the 21st century, fossil energy (coal, oil, natural gas), an interest and the loss and gain of the natural energy (waterpower, the sun, the velocity of the wind, biomass, the ocean) nuclear energy, the world and Japanese energy circumstances and a future prospect. a global environment problem (carbon dioxide, acid rain, ozone, food and an artificial problem), a living of the 21st century. (basic knowledge about radiation and the radioactivity.) of radiation and the radioactivity. Natural radioactivity and

artificial radioactivity, radioactivity and everyday life. Application to each field that used radioactive rays, influence on human body. environmental endocrine disrupter).

(3) The fundamental and usage

(4) Panel discussion and topics (a report about an action and practice example of "Recommendation to Integrated Science Study" and how do place energy and an environmental education in an education system by discussing it each other cooperation with each subject?) Development of the educational program about energy and the environment: Development of the learning teaching materials for education about energy and the environment.

(5) Training and showing to observe radiations (The production of the Wilson's cloud chamber and hydraulic power generation by observation and the model of radiation and nuclear power generation)

(6) Visit society (The institution of a company about atomic energy institution, environment-related institution, energy and radiations)

(7) Interchange society (Reply to exchange of opinions with a lecturer and an observer and the student attending a lecture, the question of the school teacher.)

3 Discussions

Including a thing to be useful for very much in the contents of the program of the seminar whether it is the teaching materials helping the enforcement of the class of "Recommendation to Integrated Science and Education" directly. Let us fill up as the thing which is an inventive idea without deciding to make use of the characteristic of the seminar of each district (popular the theme of the medical application of radiation by 2007), and assuming the program of ten national districts uniform contents. It is referred to the questionnaire results that include not only the district organizer but also the local school staff of a school in this purpose on the occasion of the seminar plan of each district and examine needs information investigation and performed till now. There is made the program that did matching by the reporting from organizers as well as this as much as possible. In addition, it is put enough breaks and keep it in mind for the making of the program with a space in time generally.

About the lecture involves environmental energy, atomic energy, and radiations by a lecture name and the contents from the purpose of this seminar (with a thing concerned with atomic energy and radiation in the contents about the theme only for environment)

It is thought that the lectures such as a fundamental problem or the problem to extend over a faculty of liberal arts and the border domain with the physical science help it in "Recommendation to Integrated Science Study". However, actually it is the present conditions that just finish a seminar by difference in difference of the knowledge with knowledge and consciousness with a lecturer and the teacher, the teacher of the physical science and the teacher of the faculty of liberal arts or personal ability, lack in lecture time. It is to move an important point as a problem with concreteness by cooperation between subjects from an idea of the learning of the synthesis without remaining in content of general "Recommendation to Integrated Science ", and it is necessary to collect in an ideal method and an example of the practice in "time of the learning of the synthesis" in a mass.

It is popular at all with the teachers of the faculty of liberal arts, and, about the experiment, as for the training that natural radiation can observe with a handmade brief measuring instrument; a constant seller becomes it by the seminar of each district as well as the teacher of the physical science. In addition, a re-student attending a lecture is extremely small, but it is necessary to prepare for another experiment for such a teacher.

About interchange society or the exchange of opinions party, it is popular by the device of each district, but there are many people who do not like collective actions as a modern trend, and consideration that an organizer, a lecturer, an observer make the opportunity of the story for such a person positively is necessary. In addition, it is effective when dividing it into the small group when perform interchange party and carry it out.

Further more, it gathers up a seminar the document for one book, and distribution is thought about as a CD with distribution or a document of PowerPoint on carrying out a seminar.

Conclusions

The seminar has been enforced for eight years and achieved the results surely. It is important that this seminar performs by a steady effort steadily. It is necessary for the teacher of the school to tell the acquisition of right knowledge of radiation and the radioactivity to children by this seminar.

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Heavy particle beam therapy

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1. Introduction

As a medical discipline, radiology began immediately after the discoveries of X-rays (1895), radioactivity (1896) and radium (1998).There are three major fields of clinical radiology: diagnostic radiology, radiotherapy and nuclear medicine. Among these, radiotherapy deals nowadays almost exclusively with malignant tumors.

Approximately 300,000 people died of cancer every year in Japan. It its believed that twice as many new cancer patients are observed every year. The surgical operation is usually the first choice of treatment for localized cancers. Radiotherapy has been used as well for localized cancers. Its use has been increased of late because of its non–invasive nature. Technology of radiotherapy has remarkably progressed in recent years. In this presentation the heavy particle beam therapy using proton and carbon is to be described. In particular experiences with carbon beam therapy using HIMAC (Heavy Ion Medical Accelerator in Chiba) and its future aspects is presented.

2. Principles and classification of radiotherapy

High dose radiation exposures break DNA strands, which disables cell divisions and eventually cause cell death.

In principle ideal radiotherapy consists delivery of radiation high enough to kill all cancer cells without irradiating normal cells and tissues.

Varieties of techniques have been developed to deliver high radiation doses to cancer tissues sparing surrounding healthy tissue with exposure less than its tolerable dose which causes hazardous reactions. Those technology are classified as external beam irradiation (tele therapy), intra-cavity or intra-tissue irradiation (brachy therapy) and radiotherapy using unsealed radioisotopes. The heavy ion beam therapy is a cutting-edge technology of external irradiation.

3. Characteristics of proton and carbon beam therapy

Routinely used high energy X-rays from a Lineac or Gamma rays from Co-60, when irradiated, pass through the body gradually losing its kinetic energy. Therefore, it is unavoidable to deliver higher radiation doses and damage the tissues which lie along the path before reaching a deep-seated cancer in the body. On the other hand proton and heavy ion such as carbon lose large fraction of kinetic energy near the stopping point forming the so-called Brag peak. This Brag peak can be irradiated to the cancer tissue by manipulating the energy in accordance with the depth of the cancer. Thus the dose to the tissues which lie in the path before the target can be kept minimum. The tissues and organs which lie behind the target are not exposed to radiation.

In addition to the excellent dose distribution in cancer therapy the carbon ion has high relative biological effectiveness (RBE), which is estimated as 2-3 as compared with one for X-ray and 1-1.2 for proton.

4. Facilities of proton and carbon beam therapy in Japan

There are 4 facilities which treat cancer patients with proton therapy, one with both proton and carbon beam and one with carbon beam. Those facilities install large scale accelerators. Those facilities need a large fund for construction and operation as well as highly trained human resources. The construction costs have been less for proton accelerators than for carbon accelerators.

5. Carbon beam therapy using HIMAC

A large-scale medical purpose accelerator, the first of its kind in the world, was constructed in 1993 in National Institute of Radiological Sciences (NIRS) under a budget provided for the national "Ten-year Comprehensive Strategic Plan against Cancer". This accelerator was named as the Heavy Ion Medical Accelerator in Chiba (HIMAC). Clinical trials of cancer treatment using HIMAC started in June 1994 under the auspices of the NIRS. A large-scale multi-institutional clinical trial of heavy ion beam therapy for cancer was conducted under the "New Ten-year Strategic Plan for the Conquest of Cancer." A large number of specialists form outside the NIRS has been participating in clinical trials, which are of very high quality from both a scientific and an ethical point of view.

On the basis of the successful results of the clinical trials including more than 1,000 cancer patients the carbon beam therapy using HIMAC was approved by the Ministry of Health, Labour and Welfare as a highly advanced medical procedure as of October 2003.

By now more than 4,000 patients with various cancers have been treated at NIRS.

Very high local control ratios have been revealed in lung cancer, hepatoma, prostate cancer, malignant melanoma, osteosarcoma, etc. Representative cases will be demonstrated.

6. Future aspects

A research project on the development of a compact-size (1/3 of HIMAC) carbon beam accelerator to be applied in the medical community was vigorously conducted at NIRS in the year 2004 and 2005. The first accelerator based on the research is now under construction at Gunma University, which will be put into practical use within 2 years.

There has been lots of interest to install the same facilities as that in Gunma University. The increase in numbers of sites should facilitate the inclusion of particle beam radiotherapy in the national health insurance system.

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Evolution of the system of radiological protection

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Abstract

The current system of radiological protection based on the Linear No-Threshold (LNT) hypothesis has greatly contributed to the minimization of doses received by workers and members of the public. However, it has brought about "radiophobia" among people and waste of resources due to over-regulation, because the LNT implies that radiation is harmful no matter how small the dose is. The author reviewed the results of research on health effects of radiation including major epidemiological studies on radiation workers and found no clear evidence of deleterious health effects from radiation exposures below the current maximum dose limits (50 mSv/y for workers and 5 mSv/y for members of the public), which have been adopted worldwide in the second half of the 20th century. Now that the existence of bio-defensive mechanisms such as DNA repair, apoptosis and adaptive response are well recognized, the linearity assumption cannot be said to be "scientific". Evidences increasingly show that there are threshold effects in risk of radiation. A concept of "practical" thresholds or "virtually safe doses" will have to be introduced into the new system of radiological protection in order to resolve the low dose issues.

Keywords: radiation protection; low-level radiation; health effects; threshold

1. Introduction

How to secure necessary energy for the future is our big problem to be solved. Nuclear power does not emit attributable gases such as carbon dioxide and sulfur oxides, and now it is the only "safe, economic and practical" alternative to the dangerous methods of electricity generation by burning fossil fuels. Disposal of radioactive wastes will no longer be a problem difficult to be solved and medical uses of radiation will be fully enjoyed, if people don't have unnecessary fear of radiation after being familiar with the truth about the health effects of radiation in small quantities.

In this paper the author is going to make proposals for an evolved and simplified system of radiological protection in view of the current knowledge about low-level radiation health effects.

2. Current system of radiological protection

The ICRP revised its Recommendations in 2007 (ICRP 2007). The major features of the new Recommendations are:

1) Updating the radiation and tissue weighting factors and radiation detriment based on the latest available information of biology
2) Maintaining the three fundamental principles of radiological protection, namely justification, optimization, and application of dose limits
3) Evolving from the previous process-based protection approach using practices and interventions, by moving to a situation-based approach
4) Maintaining the individual dose limits for effective dose and equivalent dose
5) Re-enforcing the principle of optimization of protection
6) Including an approach for developing a framework to demonstrate radiological protection of the environment

Admitting that there are **recognized exceptions**, for the purpose of radiological protection the ICRP judges that the weight of evidence on fundamental cellular processes coupled with dose-response data supports the view that, in the low dose range, below about 100 mSv, it is **scientifically plausible** to assume that the incidence of cancer or heritable effects will rise in direct proportion to an increase in the

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equivalent dose in the relevant organs and tissues. This view (**LNT model**) accords with that given by UNSCEAR (2000), NCRP (2002) and NAS/NRC (2006) while a report from the French Academies (2005) argues in support of a **practical threshold** for radiation cancer risk.

Because of this uncertainty on health effects at low doses, ICRP judges that it is not appropriate, for the purposes of public health planning, to calculate the hypothetical number of cases of cancer or heritable disease that might be associated with very small radiation doses received by large numbers of people over very long periods of time.

The updated nominal risk coefficients to be applied to whole populations (not to individuals) remains unchanged at around 5% per Sv.

Recommended dose limits for workers and members of the public remain unchanged from those recommended in 1990 recommendations.

3. The LNT hypothesis

3.1. The advantages of LNT

Owing to the assumed additivity of radiation doses the LNT hypothesis simplifies exposure dose control and recording in radiation protection. Another merit of the hypothesis is that it can give people an incentive of exposure reduction.

3.2. The disadvantages of LNT

The assumption that radiation is harmful at all levels of dose has been regarded as a proven scientific fact by public opinion, mass media, regulatory agencies and many scientists, and has brought about "radiophobia" among people.

The criticality accident occurred at the JCO nuclear fuel processing plant in Tokai-mura, Japan on September 30, 1999 caused psychological uneasiness of people around the plant and a tremendous amount of economic damage due to rumors, although most of the nearby inhabitants received only such minute doses of radiation as less than 1 mSv. Fear of radiation has proved to be more harmful to public health than radiation itself.

Regulators are apt to misunderstand that the lower the dose limits, the more reassured people may feel. Lowering dose limits will rather increase anxiety about radiation.

4. Evidence of low dose radiation health effects

4.1. Hereditary effects

The 40-year follow-up studies on the genetic effects of atomic bomb radiation of Hiroshima-Nagasaki have demonstrated that there is **no statistically significant effect** of parental exposure to radiation of **0.4** to **0.6 Gy** on any of the genetic indicators studied (Kondo 1999).

4.2. Cancer-causing effects

(a) According to the report of the experts' group of OECD/NEA , **200 mSv** is the smallest dose for which a statistically significant radiogenic risk has been observed in the Life Span Study on Hiroshima- Nagasaki atomic bomb survivors (OECD/NEA 1998).

(b)Under acute irradiation conditions, **"non-tumor doses"**, *the highest doses at which no significant increase of tumors were observed above the control level*, were greater than 0.1 Gy for low-LET radiations and greater than 0.01 Gy for high-LET radiations. Under low dose-rate, chronic or partial body exposure conditions, "non-tumor doses" were much higher than the doses above (Tanooka 2001).

(c) Although there are **high radiation areas** exceeding 10 mSv/y in India, Brazil and Iran, there is no evidence that natural radiations are causing adverse health effects among the inhabitants (Krishnan Nair *et al* 1999).

(d) The second analysis of mortality of **Japanese** nuclear industry workers concludes that the results have not yielded any definite evidence as to whether exposure to occupational low-level radiation increases cancer mortality (Iwasaki *et al* 2003).

(e) The final report of the large study of **United States nuclear shipyard workers** funded by the US Department of Energy showed that there was significantly lower total mortality in the exposed groups (both the < 5 mSv and ≧5 mSv groups) than in the non-radiation workers who engaged in similar work (Matanoski 1991).

(f) The large combined study of nearly 96,000

United States, United Kingdom and Canadian nuclear workers showed **no excess (negative) risk** of total cancer mortality. (Cardis *et al* 1995) .

(g)The 100 years of observation on **British radiologists** revealed no statistically significant increase in cancer mortality among radiologists who first registered after 1920 compared to other male physicians in England. Their mortality was significantly lower than that of all male medical practitioners. Moreover, there was no evidence of an effect of radiation on diseases other than cancer even in the earliest radiologists whose average lifetime dose was estimated to be 20 Sv (Berrington *et al* 2001).

5. Proposal of an evolved system of radiological protection

5.1.The system shall be based on sound science

Now that the existence of bio-defensive mechanisms such as DNA repair, apoptosis, adaptive response and immune system are well recognized, the linearity assumption at all dose levels can be said "unscientific".

There are an abundance of data in low dose radiation health effects contradictory to the LNT hypothesis, including biologically beneficial "hormesis" (Luckey 1982). Evidences increasingly show that there are threshold effects in risk of radiation (Kondo 1999).

Calabrese and Baldwin commented on their belief that the most fundamental shape of the dose response is neither threshold nor linear, but **U-shaped (hormetic)**, and hence both current models, especially the linearity model, provide less reliable estimates of low-dose risk (Calabrese and Baldwin 2003).

The US Health Physics Society issued a position statement in 1996 (revised in 2004), in which the Society recommends against quantitative estimation of health risks below an individual dose of 5 rem (50 mSv) in one year or a lifetime dose of 10 rem (100 mSv) in addition to background radiation, because below 10 rem, risks of health effects are either too small to be observed or are non-existent (HPS 2004).

5.2. The system shall be coordinated with that of other "hazardous" substances

New systems can be coordinated with other health hazards such as ultra-violet rays and toxic chemicals, if we consider that ionizing radiations are no exception of the maxim of Paracelsus (1493-1541) below, which has been a principle in toxicology up to now.

"All substances are poisons, there is none which is not a poison. The right dose differentiates a poison from a remedy."

5.3. Implications of "practical" threshold

A "**practical**" threshold is a level of exposure below which induction of **detectable** radiogenic cancers or hereditary effects is not expected (Jaworowski 1999).

As far as exposures are maintained below "practical" thresholds there will be no need of "justification" and "optimization" (ALARA).

Accordingly the ethical issue of "justification" to allow benefit to society to offset radiation detriments to individuals can be resolved. And also the ethical issue of "optimization" to exchange health or safety for economical gain can be resolved. Introduction of the concept of "practical" thresholds can be said to be based on an individual-oriented philosophy and satisfies the egalitarian principle of ethics.

5.4. Proposed dose limits

The following dose limits are assumed to be below "practical" thresholds.

- *Worker : **50 mGy/y** (500 mGy/y for partial body or single organ exposure)*
- *Public : **5 mGy/y** (50 mGy/y for partial body or single organ exposure)*

In case of high LET-radiations such as alpha particles and neutrons, the above dose limits should be multiplied by **1 /10.*

6. Conclusion

ICRP emphasizes its view that ionizing radiation needs to be treated **with care rather than fear** and that its risks should be kept in perspective with other risks (ICRP 1991).

Radiation protection professionals do not need to convince scientists; they need to convince ordinary citizens who are afraid and worried, and who want to judge and decide for themselves.

We must not let radiation protection become a health hazard.

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Non-Ionizing Radiation

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Abstract: First, typical examples of non-ionizing radiations (NIRs) are shown and deductive definition of NIR is given. Secondly, taking electromagnetic fields produced in the vicinity of power lines and mobile phone receivers for example in focus, actions to human-body, possibly induced substantial health effects, reported results of studies on evidence hunting for adverse effects, examples of introduced or proposed controlling criteria for exposure are given. Thirdly, issues of radio-phobia to NIR are discussed. Finally, speaker's view and stance to the issue are presented.

Keywords: non-ionizing radiation; action to human body; adverse health effects; risk of carcinogenesis; electromagnetic fields; power lines, cellular phones; controlling criteria for exposure.

1. Introduction

Deductive definition of radiation is elementary particles in motion. Among various kinds, radiation called X-ray or gamma-ray is most familiar, whose constituents are photons. Usually, we cannot detect nor evaluate quantitatively the amount for the incidence of radiation to the body. Moreover, the actual target of exposure control is the suppression of the associated risk of carcinogenesis. In addition to these two facts, the knowledge of works of radiation as the power of the weapon, atomic bomb, make some people be afflicting with the so-called radio-phobia.

From view point of physics treating microscopic world, electromagnetic fields(EMF) are composed of photons. X-ray and gamma-ray are EMF composed of high energy photons. Radiations having capability of directly or indirectly ionizing matter are called ionizing radiations(IRs) and the other is non-ionizing radiations(NIRs).

Our living space is filled with various EMFs. Among them, those produced in the vicinity of transmitting power lines, mobile phone receivers, microwave ovens, draw people's attention concerning with their health effects. These are typical NIRs. The word radiation, remind people the harmful effects of IRs occasionally.

Before views and stance of the speaker to the issue is stated, physical substances and natures of NIRs, their actions to human body and possibly induced effects to health, studies of evidence hunting, introduced or proposed guidelines for exposure controls are given.

During the preparation, the speaker knew that the American Physical Society issued statements on the matter of Power Lines in 1995 and the statement was reaffirmed by its Council in 2005. Views and stance of the speaker on NRIs are exactly the same with these.

2. Substance and Nature of Non-Ionizing Radiation

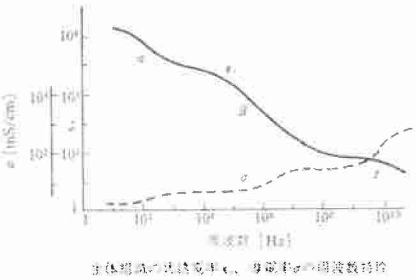

Fig.1 Permittivity and Permeability of living substance

Photons of energy less than 12.4 eV or wave longer than 100 nm are non-ionizing photon radiation. Static fields of electricity or magnetism, field of virtual photons from quantum physical view, and ultra-sound, similarly field of phonons, are included NIRs occasionally.

In general, the substance of radiation has nature of particle and wave, simultaneously. Ionizing photon radiations, such as gamma-rays from Co-60 or Cs-137, are "particle –like radiation" and Non-ionizing photon radiations such as EMFs of higher frequencies, like stray EMFs produced near cellular-phones or micro-wave ovens, are "wave-like radiation". EMFs produced in the vicinity of high-voltage and high-current transmitting power lines are not necessarily suitable to be called NIR and alias of "alternative electro-magnetic field" is preferable instead. In fact, electrical engineers treat these stray EMFs induced around power lines as quasi-static.

Comparison of energies of quanta and wave lengths of NIRs taken for examples are shown Table 1.

3. Actions to the Human-Body and Substantial Adverse Effects to Health

To magnetic fields, human-body is transparent, while to electric fields the body is "dielectric substance". Penetrated electric field is weaker inside the body and highest near the surface. Oscillating magnetic fields can induce electrical current in the body and the intensity of the induced current increases as the frequency increases. Thus, the EMFs except static magnetic field make induction current in the body, in general.

Substantial adverse effect for static or quasi-static electric field is "Electric Shock" (thunder stroke) through penetration and for EMFs of high frequencies are "Temperature-Rise" and "Physiological Disorder" through induced currents or through direct electromagnetic interaction. Risk of carcinogenesis, which is of major concern in case of IRs, is not for NIRs.

4. Recommended or Proposed Guidelines

Examples are shown in the right figure. It is clearly seen that effects depend strongly on wave lengths.

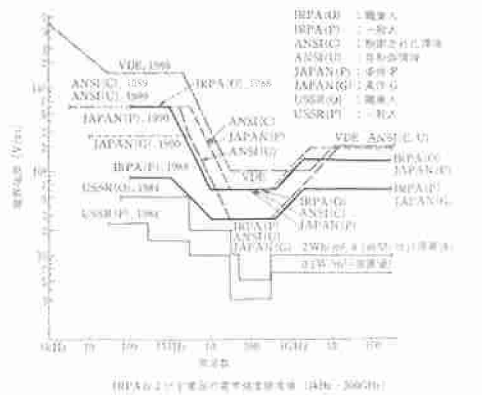

Fig.2 Examples of Guidelines

5. Claims of "Prudent Considerations" for NIRs

Studies in evidence-hunting have failed to the moment. Almost all results of studies on mechanism are negative and results of phenomenological, ie. epidemiological studies cannot bear quality checks. The tool of epidemiological study is not so powerful to find extremely low risk-coefficients, i.e., values of risk per unit amount of risk source.

Critical difference between IR and NIRs is in capability of ionization.

6. Speaker's View and Stance to the Issue

American Physical Society issued a policy statement "Power Line Fields and Public Health" on April 23, 1995. It was reaffirmed by its Council on April 15, 2005. The document (National Policy 95.2) can be seen on the web-site[1).

The views and stance of the speaker to the issue of health effects of NIRs are exactly the same with those expressed in this document. The following is the copy.

Physicists are frequently asked to comment on the potential dangers of cancer from electromagnetic fields that emanate from common power lines and electrical appliances. While recognizing that the connection between power line fields and cancer is an area of continuing study by research workers in many disciplines in the United States and abroad, we believe that it is possible to make several based on the scientific evidence at this time. We also believe that, in the interest of making the best use of the finite resources available for environmental research and mitigation, it is important for professional organizations to comment on this issue.

The scientific literature and the reports of reviews by other panels show no consistent, significant link between cancer and power line fields. This literature includes epidemiological studies, research on biological systems, and analyses of theoretical interaction mechanisms. No plausible biophysical mechanisms for the systematic initiation or promotion of cancer by these power line fields have been identified. Furthermore, the preponderance of the epidemiological and biophysical/biological research findings have failed to substantiate those studies which have reported specific adverse health effects from exposure to such fields. While it is impossible to prove that no deleterious health effects occur from exposure to any environmental factor, it is necessary to demonstrate a consistent, significant, and causal relationship before one can conclude that such effects do occur. From this standpoint, the conjectures relating cancer to power line fields have not been scientifically substantiated.

These unsubstantiated claims, however, have generated fears of power lines in some communities, leading to expensive mitigation efforts, and, in some cases, to lengthy and divisive court proceedings. The costs of mitigation and litigation relating to the power line cancer connection have risen into the billions of dollars and threaten to go much higher. The diversion of these resources to eliminate a threat which has no persuasive scientific basis is disturbing to us. More serious environmental problems are neglected for lack of funding and public attention, and the burden of cost placed on the American public is incommensurate with the risk, if any.

The document is with the power line issues and for American public, but the problems are common to all nations and the speaker believes that the document is applicable to any other EMF.

7. Conclusion

As exactly same to IRs, NIRs should be feared properly. Aspects of health effects of NIRs are quite different from those of IRs. Potentiality of carcinogenesis with NIRs is relatively very small, if any, and no specific measures for risk controls are necessary.

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Table 1. Physical Substance and Property of Selected NIRs

	Non-Ionizing Radiation		Ionizing Radiation
	Static and Quasi-Static Field of Electricity or Magnetism	HF-, VHF-, UHF-EMF	X-, γ-rays
Example	Power Lines	Mobile Phone	Co-60 γ
Physical Existence	Alternating EMF	Electromagnetic Waves	Elementary Particles
Frequency [Hz]	50(Tokyo) / 60(Hsinchu)	800M=8.0x10(+8)	2.9E=2.9x10(+20)
Wave Length	6.0km(Tokyo)/5.0km(Hsinchu)	37.5cm	100pm=1.0x10(-12)
Quantum Energy	0.2peV 3.3x10(-32)J	10 μ eV 5.3x10(-25)J	~1.2MeV 1.9x10(-13)J

Table 2. Action and Effects to Human Body

		Power Lines	Mobile Phone	Co-60 γ
Action	Ionization	X	X	○
	Thermal	○	○	○(fatal)
	Electromagnetic	○	○	X
	Chemical	X	X	○(thru ionization)
Physiol. Disorder		○ (in principle)	○ (in principle)	X (practically)
Denature of Protein		○	○	X (practically)
Damage to DNA		X (in principle)	X (in principle)	○
Indirect Damage to DNA		X (practically)	X (practically)	X (practically)

Table 3. Adverse Effects Needed Exposure Control

	Power Lines	Mobile Phone	Co-60 γ
Stochastic Effects	X	X	○ (accumulative)
Rise in Temp	○ (passing)	○ (passing)	X (practically)
Electrical Shock	○	○	X (practically)

Table4. Quantities Used for Protection

	Power Lines	Mobile Phone	Co-60 γ
Evaluation	SAR*	SAR*	Protection Doses
Hazard Index of Space	Intensity of EMF	Intensity of EMF	Spatial Dose Rates
Exposure Control	---	---	Accumulated Doses

*SAR = Specific Absorption Rate [W/kg] = Absobed Dose Rate [J/kg/s] in IR terminology

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Current Nuclear Medicine Related Research in National Tsing Hua University

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The unique nuclear facilities of College of Nuclear Sciences and Nuclear Science & Technology Development Center (NSTDC) at the National Tsing Hua University bestow the faculty the nuclear medicine related research. In recent 3 years, one neutron beam has been constructed together with a patient treatment room in the Tsing Hua Open-pool Reactor (THOR) specifically for boron neutron capture therapy (BNCT). I-131 is currently produced from the reactor and supplied to the major hospitals in Taiwan for diagnosis and treatment of thyroid diseases or cancers. Various radiolabeled compounds or pharmaceuticals for diagnoses and therapy for cancers are currently developed in the radiolabeling laboratory at the Department of Biomedical Engineering and Environmental Sciences (BMES).

Based on the three aspects of nuclear medicine technology as above mentioned, the undergoing key research works include the following topics:

- Development of boronated RGD peptide for BNCT for brain cancer (by Prof. Jem-Mau Lo, Department of BMES)
- Development of boronated nanoparticle drug for BNCT for liver cancer (by Prof. Feng-In Chou, Director of NSTDC)
- ^{99m}Tc (a γ-emitter) and ^{188}Re (or ^{131}I) (a β^--emitter) labeled monoclonal antibody (e.g., Herceptin) and peptide (e.g., octreotide) for diagnosis and treatment of cancers (e.g., breast cancer and pancreas cancer)(by Prof. Jem-Mau Lo)
- ^{99m}Tc labeled histidine tagged annexin V for apoptosis imaging (by Prof. Jem-Mau Lo)
- ^{123}I or ^{18}F labeled nucleosides as gene probes for gene therapy (by Profs.

Chung-Shan Yu and Chi-Shiun Chiang, Department of BMES)

Some of the works are being collaborated with the Radiopharmaceutical Production Center of the Institute of Nuclear Energy Research, Lungtan, Taiwan. Most of the developed drugs have undergone the in vitro and in vivo trials. The contents of these studies are briefly elucidated as below:

Boron neutron capture therapy (BNCT) is a binary therapy modality that is to give a suitable boronated drug being absorbed by tumor tissue and then to exert thermal neutron irradiation. By nuclear reaction of ^{10}B with thermal neutrons, high linear-energy-transfer (LET) α^{2+} and $^{7}Li^{+}$ are produced. If the boronated drug is able to concentrate on tumor tissue, the resulted high-LET radiations will kill tumor with sparing of the normal tissue. $\alpha_v\beta_3$ integrin is an important cell adhesion receptor involved in tumor-induced angiogenesis and tumor metastasis. The high binding specificity to $\alpha_v\beta_3$ integrins of the peptides containing Arg-Gly-Asp (RGD) residue suggests that the RGD peptides conjugated boronated compound may be developed as a potential BNCT agent. We have developed the boronated compound, 4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)benzoic acid (TDBA) and its conjugates with RGD for BNCT for treatment of brain tumor. In another study, synthesis of phenylboric acid-lipiodol nanoparticles combined with boric acid is developed for BNCT treatment of hepatoma in the campus.

Trastuzumab (Herceptin®), a humanized IgG1 monoclonal antibody directed against the extracellular domain of the HER2 protein, acts as an immunotherapeutic agent for HER2-overexpressing human breast cancers. Radiolabeled trastuzumab with β^- or α emitters can be used as radioimmunotherapeutic agent for the similar purpose but with additional radiation effect. In our study, trastuzumab is labeled with ^{188}Re for radioimmunotherapy of HER2/neu-positive breast cancer. ^{188}Re(I)-tricarbonyl ion, $[^{188}Re(OH_2)_3(CO)_3]^+$, is employed as a precursor for directly labeling the monoclonal antibody with ^{188}Re. The immunoreactivity of ^{188}Re(I)-trastuzumab is estimated by competition receptor-binding assay using HER2/neu-overwxpression BT-474 human breast cancer cells. The localization properties of ^{188}Re(I)-trastuzumab within both tumor and normal tissues of athymic mice bearing BT-474 human breast cancer xenografts (HER2/neu-overexpression) and similar mice bearing MCF-7 human breast cancer xenografts (HER2/neu-low expression) are investigated. ^{188}Re(I)-trastuzumab is shown to accumulate specifically in BT-474 tumor tissue in *in vivo* biodistribution studies. By microSPECT/CT, the image of ^{188}Re localized BT-474 tumor is clearly visualized within 24 h. In contrast, ^{188}Re(I)-trastuzumab uptake in HER2-low expressing MCF-7 tumor is minimal and the ^{188}Re image at the localization of the tumor is dim. These results reveal that ^{188}Re(I)-trastuzumab could be an appropriate radioimmunotherapeutic agent for the treatment of HER2/neu-overexpressing cancers.

Annexin V labeled with a γ emitter can be used for the imaging of apoptosis. ^{99m}Tc is very suitable for clinical imaging with its 140-keV γ ray, 6-h half life and economical availability from a ^{99}Mo-^{99m}Tc generator. In this study, we have constructed a form of annexin V with a N-terminal extension containing six histidine residues. The histidine-tagged annexin V (his-annexin V) can be directly labeled with ^{99m}Tc(I) tricarbonyl ion, $[^{99m}Tc(OH_2)_3(CO)_3]^+$. In labeling, $[^{99m}Tc(OH_2)_3(CO)_3]^+$ is freshly synthesized and incubated with his-annexin V at 37℃ for 1 h. The resultant ^{99m}Tc(I)-his-annexin V is assayed by high performance liquid chromatograph (HPLC) with size exclusion column. The labeled yield can be as high as ≧87%. ^{99m}Tc(I)-his-annexin V demonstrates good stability in PBS and serum. In the furthermore work, ^{99m}Tc(I)-his-annexin V will be applied for apoptosis imaging in a γ ray irradiated animal model.

The rat prostate cancer cell line Tramp-C1 is transduced with HSV1-sr39tk and IL-3 and uptakes of 5-^{123}I-iodo-arabino-uridine (abbreviated as [^{123}I] IaraU)] in the transduced Tramp-C1 referred as Tramp-C1/IL3-tk and in the parental Tramp-C1 as a control are investigated. The Tramp-C1/IL3-tk cells as well as the Tramp-C1 cells are inoculated subcutaneously into the left flank and the right flank of C57BL/6J mice separately to produce the prostate tumor xenografts. Biodistribution study in the tumor-implanted animals is carried out after intravenous injection of [^{123}I]IaraU at certain period of times, e.g., 6 h and 24 h. The animals are imaged after injection of [^{123}I]IaraU using microSPECT/CT at certain period of times, e.g., from 1, 3, 6 to 24 h.

New energy resources and nuclear power for a sustainable future

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Abstract

Climate change or global warming is increasingly recognized as one of the most serious threats to humankind. To attain a sustainable future, we are envisaged to reduce emissions of anthropogenic greenhouse gases (GHGs) to 50% or less of the present level by 2050. Reduction of CO_2 emissions from the combustion of fossil fuels (*i.e.* coal, oil and natural gas) is practically crucial, and extensive utilization of carbon-free resources of energy is highly appreciated. In fact, utilization of solar and wind energy of current interest is rapidly expanding worldwide. Here, we should be aware of significance of nuclear power, which provides not only large amounts of electricity without CO_2 emissions, but also "base-load" electricity that can compensate disadvantages of *intermittency* associated with both solar and wind power systems. The present paper deals further with advanced technologies of future interest such as ocean wave, enhanced geothermal systems, artificial photosynthesis and nuclear fusion reactors.

Keywords: new (renewable) energy; photovoltaic; wind power; nuclear power; nuclear fusion; sustainable future

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) has reported that warming of the climate system of our planet is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level [1]. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the increase in concentrations of anthropogenic greenhouse gases (GHGs) such as CO_2, CH_4 and N_2O. Global increases in atmospheric CO_2 concentrations from 280 to 387 ppm over the past 50 years are due primarily to fossil fuel use.

To attain a sustainable future, we will have to suppress the rise in global average temperatures within 2°C at the end of this century by reducing the anthropogenic GHG emissions to 50% or less of the present level (39.4 in 1990 and 49.0 $GtCO_2$-eq/y in 2004 [1]) by 2050. The stabilization can be achieved by deployment of a portfolio of technologies that are either currently available or expected to be commercialized in coming decades as summarized in Table 1 [1].

The present paper gives perspectives on new or renewable energy resources of current interest and deals further with advanced technologies of future interest, including ocean energy, enhanced geothermal systems (EGS), artificial photosynthesis, and nuclear fusion reactors (CRT) anticipated to be realized after 2050.

2. Electricity without CO_2 emissions

Global electricity generation provides 18 PWh of energy a year (around 40% of total energy use in our civilization), and emits more than 10 Gt of CO_2 every year [2], most of which are released from the combustion of fossil fuels. Of a wide range of

Table 1
Key mitigation technologies and practices for energy supply [1]

Currently commercially available	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of CCS (e.g. storage of removed CO_2 from natural gas)
Projected to be commercialized before 2030	Carbon Capture and Storage (CCS) for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and waves energy, concentrating solar, and solar photovoltaics (PV)

technologies that can generate

electricity without CO_2 emissions from fuel, the use of new or renewable energy — geothermal, hydroelectric, solar and wind power — ensures a possibility to reduce atmospheric CO_2 (Fig. 1). Renewable energy supplies 18% of the world's final energy consumption, including 13% of traditional biomass for cooking and heating [3]. With respect to electricity generation, the use of solar and wind resources is remarkable for its rapid expansion [4-6]. Particularly, capacity of wind power has risen by nearly 25% in each of the past 5 years and the world's installed capacity as of 2007 is 94 GW (Table 2), while the estimated solar-cell (photovoltaic) capacity is about 9 GW (one-tenth of wind) in 2008 [2].

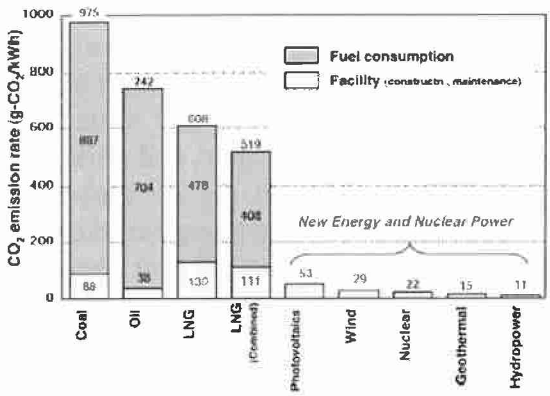

Fig. 1. CO_2 emission rate in power generation for a variety of energy sources. (Agency for National Resources and Energy, Japan)

Here, we should pay attention to nuclear power without CO_2 emissions from fuel. At present, 440 nuclear reactors in operation worldwide have an overall capacity as high as 370 GW (around 15% of the electricity generation), and 35 nuclear plants are under construction in 2007, almost all in Asia [2].

The use of nuclear power is highly appreciated, because not only of its negligible CO_2 emissions, but also of its important role in supplying "base-load" electricity that can compensate disadvantages of *intermittency* associated with both solar and wind power systems of current interest. The inherently quite low energy density of sunlight

(<kW/m^2) as well as wind (a few W/m^2) is another disadvantage that makes it hard to exploit new locations appropriate for extensive installations; *e.g.* the area necessary for a nuclear power station of 1 GW is 0.3 km^2, but areas as large as 60 km^2 for solar and 250 km^2 for wind are needed in order to generate the same amounts of electricity.

It is essential to compare costs of power generation. The light-water reactors, making up most of world's nuclear power capacity, produce electricity at ~\$0.03-0.07/kWh, whereas wind turbines produce at ~\$0.1/kWh. For solar power, photovoltaic (PV) cells produce electricity at around \$0.25-0.40/kWh, while the cost of concentrated solar thermal systems

Table 2
International rankings of wind, solar photovoltaic and nuclear power capacity (in GW)

Wind (2007)		Solar PV (2006)		Nuclear (2006)	
1. Germany	22.25	1. Germany	2.86	1. U.S.	104.75
2. U.S.	16.82	2. Japan	1.71	2. France	66.02
3. Spain	15.14	3. U.S.	0.62	3. Japan	49.58
4. India	7.85	4. Spain	0.12	4. Russia	23.19
5. China	5.91	5. Australia	0.07	5. Germany	21.37
...					
13. Japan	1.54				
World total	94.0	World total	5.1	World total	370

(using mirrors to focus the Sun's heat for heating up a working fluid that in turn drives a turbine) is estimated at about \$0.17/kWh [2].

3. Advanced renewal energy

In addition to conventional renewal energy sources currently used to reduce CO_2 emissions, R&D is extensively carried out in advanced fields of technologies, including ocean (tides and waves) energy, enhanced geothermal systems (EGS), concentrated solar systems as well as solar PV with high efficiency, and artificial photosynthesis.

Of these, ocean energy would be marginal on the global scale, although many researchers are trying to break into the renewable-energy market [7].

Geothermal systems use part of vast amounts of heat contained in earth's interior, but it is a hard resource to use for electricity generation except in a few specific places, such as those with hot springs. Only five countries – Costa Rica, El Salvador, Iceland, Kenya and the Philippines – generate more than 15% of their electricity this way. Recently, however, a DOE-sponsored study by a panel of the Massachusetts Institute of Technology (MIT) [8] suggested that enhanced geothermal systems (EGS) that inject water at depth from 3 to 10 km would make it possible

to set up 100 GW of geothermal electricity in the United States alone [9]. This idea leads to a global figure of a terawatt (TW) level of electricity generation, although there are uncertainties in the analysis and gaps in knowledge.

Earth receives about 100 PW of solar power at its surface; this is enough energy every hour to supply humanity's energy needs for a year. Taking account of the size of the resource, solar power would be the most promising carbon-free energy, but further technological development is required to overcome the ultimate limitation of *darkness*.

Solar cells do not generate electricity at night, and clouds decrease the power available. Some concentrated solar thermal systems get around this by storing up heat during the day for use at night (molten salt is one possible storage medium), which is one of the reasons they might be preferred over photovoltaic cells for large installations [2].

MIT researchers have reported a revolutionary leap that could overcome a major barrier to large-scale solar power: storing energy for use when the sun doesn't shine [10]. Inspired by the *photosynthesis* performed by plants, they have developed an unprecedented process that will allow the sun's energy to be used to split water into H_2 and O_2 gases. Later, the oxygen and hydrogen may be recombined inside a fuel cell, creating carbon-free electricity day or night. The key component in their process is a new catalyst that produces O_2 from water; another catalyst produces H_2. The new catalyst consists of cobalt metal, phosphate and an electrode, placed in neutral pH water, and works at room temperature.

4. Nuclear fusion, the ultimate energy source

Nuclear fusion research began early in the 1950's, with hopes of developing a fusion reactor or controlled thermonuclear reactor (CTR) that might give an ultimate solution to energy problems on the earth. During the first international conference on the peaceful use of atomic energy, held in Geneva in 1955, the chairman said that fusion technology would be developed within 20 years. It has passed more than 50 years since the conference, but the hope is not yet realized. Nobody understood the difficulty of confining high temperature plasmas, which would be the key to nuclear fusion to occur.

Based on the progress of plasma confinement technologies attained with large tokamak devices such as JET (EU), TFTR (US) and JT-60 (Japan) in the past decades, we are climbing now the stairs to realizing a CTR, called ITER (International Thermonuclear Experimental Reactor). ITER is designed to test the feasibility of fusion power. The machine will trap hydrogen isotopes − deuterium (D) and tritium (T) − in magnetic fields and heat them to above 100 million Celsius. At that temperature, the D and T nuclei will fuse to form ^4He, releasing 14-MeV neutrons and energy in the process. Although the natural abundance of deuterium (0.0153%) would ensure a sufficient supply of this isotope for the fueling of D-T fusion reactors, tritium with negligible abundance is to be artificially produced and a practical fusion reactor should breed at least as much tritium it consumes [11]. Despite the use of radioactive tritium as the fuel, a fusion reactor is envisaged to be a clean energy source, because it generate less amounts of long-lived radioactive waste compared with current fission reactors.

The ITER project was set up in 1988 jointly by US, EU, Japan and Russia as design work, and extended later to the construction project with 7 partners, including latecomers such as China, South Korea and India [12]. After an 18-month stalemate over whether Japan or France should host the ITER, the site was decided in Cadarache, France in June 2005. The construction of ITER machine was scheduled to start in 2007, but it will reportedly be delayed by as much as 3 years, because the experiment is set to cost up to 30% more than anticipated ($12 billion over 30 years) [13]. And the experiment, already delayed, will not be completed until anywhere from one to three years after its current 2016 due date. Operation of the first commercial fusion plant, anticipated in 2050, will also be delayed. Nevertheless, we do hope realization of nuclear fusion reactors that will solve the energy problem in its entirety.

5. Conclusion

There are a variety of carbon-free energy resources currently used or envisaged to become available in the future. To attain a sustainable future, we are expected to use different sorts of energy resources (not only renewable energy like solar and wind, but also nuclear power), taking account of their advantages and disadvantages. Nuclear fusion energy is an ultimate energy source, but we will have to wait until the second half of this century for its realization.

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Research Interest

Microdosimetry of BNCT, proton therapy, and Auger emitter
Optimization of diagnostic radiology (image quality versus radiation dose)
QA and radiation dosimetry of radiotherapy
Health physics

Publications (2007-2008)

1. C. M. Kwei, Y. H. Tu and C. J. Tung, Surface Excitation Parameter for Electrons Crossing the AlN Surface, Vacuum 82, 197-200, 2008 (SCI).
2. C. J. Tung, C. J. Lee, H. Y. Tsai, S. F. Tsai and I, J. Chen, Body Size Dependent Patient Effective Dose for Diagnostic Radiography, Radiation Measurements 43, 1008-1011, 2008 (SCI).
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Advancement of Medical Physics Education in Taiwan

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The history of medical physics education in Taiwan began at National Tsing Hua University (NTHU) more than 30 years ago. In 1975, the Graduate Institute of Nuclear Science of NTHU established its Health Physics Program for a Master degree (later for a Ph.D. degree), see Fig. 1. At that time, students were trained through a summer internship program at the Radiological Department of National Taiwan University Hospital. The "Graduate Institute of Nuclear Science" later became the "Department of Nuclear Science" which then became the "Department of Biomedical Engineering and Environmental Sciences" as we know it today. At the same time, the "Health Physics Program" has also been renamed as the "Medical Physics Program." Today, eleven M.S. and five Ph.D. students are enrolled in the Medical Physics Program each year. Approximately one third of them are working professionals, including physicians, medical physicists, medical technologists, government employees and etc. The Program offers fundamental courses such as Nuclear Science, Physics of Radiology, Health Physics, Radiation Biology, Radiation Dosimetry, and Radiation Detection and Measurement. Advanced courses in medical imaging (Biomedical Image Processing, Clinical Medical Physics Seminar: Diagnostic Radiology, Magnetic Resonance Imaging Principles and Applications, and Principles of Medical Ultrasonics), nuclear medicine (Diagnostic Nuclear Medicine, Molecular Imaging Pharmaceuticals, and Nuclear Medicine and Technology), and radiotherapy (Radiation Therapy Physics and Clinical Medical Physics Seminar: Radiation Therapy) are also available. Currently, a large number of clinical medical physicists working at hospitals in Taiwan as well as many renowned medical physicists in the United States are all graduates from this NTHU program.

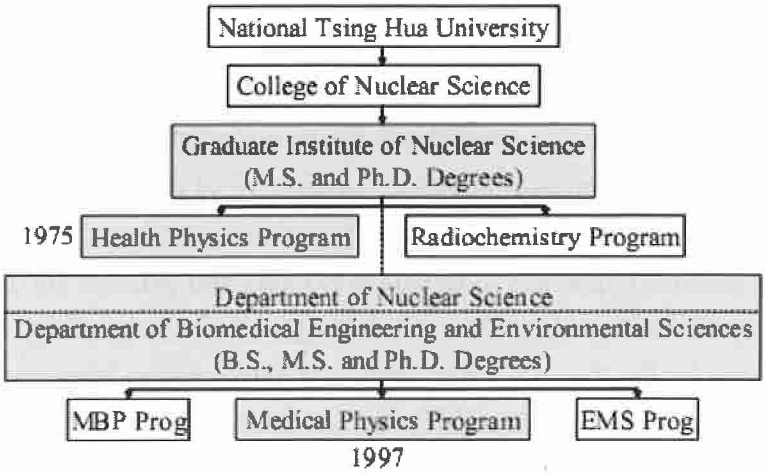

Fig. 1 The Development of Medical Physics Program at NTHU

Since NTHU does not have a medical school, students of its Medical Physics Program can only receive practical trainings from the off-site clinical facilities. Presently, through the 2-month summer internship program, trainings are provided to students at both local and oversea hospitals. Participants of such training programs include most major hospitals in Taiwan and a few cooperative hospitals in the U.S., see Fig. 2. In addition, to further promote the study of Medical Physics, a contract has also been signed between NTHU and Chang Gung Memorial Hospital where the two parties agreed to join efforts on a wide range of activities, including faculty exchange, research collaboration, and clinical training.

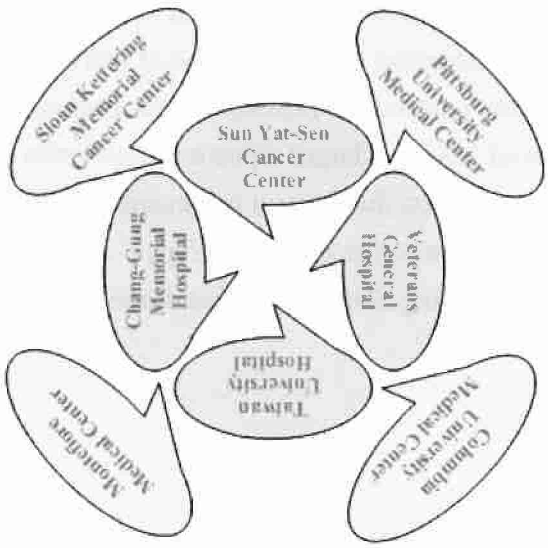

Fig. 2 Student Clinical Trainings through Cooperation with Local and Oversea Hospitals.

The release of Ionizing Radiation Protection Act in 2002 has had a profound impact on the medical physics profession in Taiwan. Before 2002, radiation protection standards applied only to radiation workers and members of the public. After the passage of the Act, protections are now extended to include patients who are subject to medical radiation exposures. Article 17 of the Act regulates all medical installations to perform QA on their facility and personnel. The purpose of QA is to assure that medical exposures to radiation workers and patients are as low as reasonably achievable (ALARA). Current QA standards generally follow those recommended by the American Association of Physicists in Medicine (AAPM) and the Mammography Quality Standards Act (MQSA). Presently, QA is mandatory only for mammography x-ray units, radiotherapy linear accelerators, Co-60 treatment units, brachytherapy sources, and CT simulators. QA for computed tomography and fluoroscopy will be required in the near future. The adoption of the Ionizing Radiation Protection Act has substantially increased the demand of medical physicists in the hospitals.

In Taiwan, important researches of new technologies in diagnosis and therapy involving medical physics are currently in progress. The NTHU has recently entered into an agreement with Taipei Veterans General Hospital to promote a study that led to a clinical trial of the boron neutron capture therapy (BNCT). This study includes interdisciplinary areas of boron compounds, nuclear engineering, radiation dosimetry/microdosimetry, and treatment planning. In addition, the Chang Gung Memorial Hospital has signed a contract with Sumitomo Heavy Industry, Japan to build a state-of-the-art proton therapy facility in Taiwan. Furthermore, the Evergreen Group is considering the importation of heavy ion therapy facility and promotion of heavy ion research in Taiwan. Both proton and heavy ion therapies have the advantages of having a larger value on the relative biological effectiveness (RBE) and a smaller value on the oxygen enhancement ratio (OER), see Fig. 3. Therefore, they are superior to the photon therapy. As the result of these ongoing researches, there is a growing demand of clinical medical physicists in Taiwan.

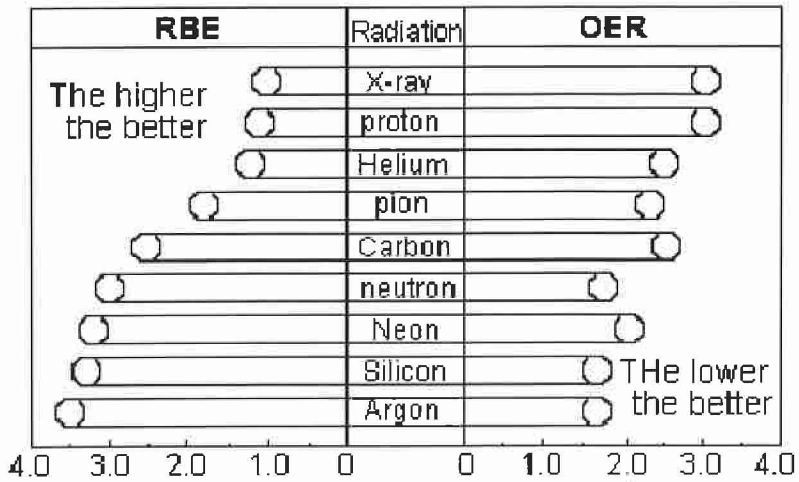

Fig. 3 Comparison of Different Particles on the RBE and OER for Radiotherapy.

Despite the steady progression and advancement of medical physics education in Taiwan, we continue to face many challenges. For one, pay compensation for clinical medical physicist in the hospitals are relatively low and should be increased. Another major issue is related to the establishment of QA regulations for medical exposures which certainly require further development and expansion.

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Introduction

The radiation and the radioactive substance exist everywhere on the earth. We always receive cosmic rays and the radiation from the radioactive substance of nature after the birth of the earth. Various radioactive sources exist in the environment that surrounds us. However, we live hardly considering the radiation because the radiation doesn't feel it in our senses.

History of the earth

The birth of the element and the formation of the celestial body are related to the natural existence of the radioactive material on the earth. Space exists from long-ago eternally, and it seems not to change forever. But, the star in space is born, grows up and grows old as well as the animal and the plant. In the beginning the hydrogen subject which is drifting in the space shrinks by its own weight and it begins to make the star. When these gases shrink, this gravity energy changes into heat and becomes a high temperature. The nuclear fusion reactions of the hydrogen combustion and the helium burning, etc. happen and a heavy element is made gradually when becoming a high temperature. These heavy elements gradually make a heavier element from a heavy ionic reaction further. This nuclear reaction continued for about six billion years. The dust generated after the nuclear reaction hardened over 200 million years later. Then the solar system was formed, and the earth was born. Though the earth is born and 4.6 billion years have already passed, the earth consists of the dust generated with various nuclear reactions like this. Therefore, many kinds of radioactive elements exist still in the earth. U and Th exist enormously since the time of the birth of the earth. Np etc. that are the short half-life elements have already disappeared. Therefore, radiation levels were far higher than now before three billion years the births of the life on the earth. Time until today is very little elapsed time compared with the history of the earth for two million years when the human race showed up on the earth. Therefore, it can be said that the level of the radioactivity doesn't have a big difference too much either. However, the living being including man has done evolution and development as it is surrounded by such a large amount of a radioactive material. The entire amount of the radioactive material contained in the earth's crust is presumed to exceed 10^{15}Ci. The decay energy of the radioactive material that exists in the soil is used to maintain the heat of the earth as a geothermal energy.

Cosmic rays

It is thought that the supernova explosion of the Galaxy and the sun will be the origin of cosmic rays. Cosmic rays are the mixture of not a single radiation but various radiations and there are primary and secondary cosmic rays in them. The primary cosmic ray that is the particle mainly composed of the proton is accelerated in the space and enters toward the earth. The secondary cosmic ray is generated with the nuclear reaction of the atom in atmosphere and the primary cosmic ray. A part of the cosmic ray that progresses toward the earth is captured in the magnetic field of earth which is in the height of over hundreds km from the ground level. And, the stratified space that is called a Van Allen belt with strong radiation intensity is made. Cosmic rays with large energy progress further to the earth, and the number of cosmic ray's particles that reach the earth becomes 1-2 pieces/$cm^2 \cdot s$ on the earth. Cosmic rays which came to atmosphere where the earth is surrounded reacts with the nucleus of the oxygen, nitrogen, argon, etc. and radioactive material, neutron, electron, etc. are generated. In addition, the neutron reacts with the nucleus of oxygen and nitrogen, and generates the radiocarbon. Strength of the cosmic ray is almost constant from the long-ago to the present age and strengthens while leaving the ground level high. The cosmic ray's strength rises rapidly which is one in the sea level, become to five at 4,500 meters high then become to 75 at 16,500 meters high.

Radiation from the earth

A lot of radioactive material such as U, Th exists in the earth's crust after the birth of the earth. The uranium and the thorium, start elements of the decay series, decay one by one and become the stable lead. There are three decay series of the uranium series, the thorium series, and the actinium series in nature. The element that belongs to three decay series, decay with radiation and changes into the other elements. Besides, in the earth's crust, there are many kind of the nuclide shown in Table 1. Therefore, we will receive the radiation from the earth from the outside of the body. The main radiation that we receive from the earth is a gamma ray. Strength of the gamma ray is different according to the chemical composition of the soil of the area.

Radioactive substance in water and food

Radioactive substances such as radon and ^{3}H exist in all natural water such as the surface seawater, the river water, the lakes and marshes water, rain water, and the hot spring water. Because Rn is a soil origin, it exists a lot in underground water than in the surface water. On the other hand, man's food also grows while taking water and the chemical composition from the earth. Therefore, in food there are various radioactive material especially ^{40}K. Food, plant and animal, takes K from water and the earth as a essential element of the living body. And there are various radioactive substances such as ^{14}C and ^{3}H and ^{210}Pb also excluding ^{40}K in food.

Table 1 Additional naturally occurring radioactive substances

Active Substance	Type of Disintegration	Half-Life (Years)	Isotopic Abundance (%)
^{40}K	β^-(89%),EC(11%)	1.26×10^{9}	0.0118
^{50}V	β^-(~30%),EC(~70%)	6×10^{15}	0.25
^{87}Rb	β^-	4.8×10^{10}	27.85
^{115}In	β^-	6×10^{14}	95.77
^{123}Te	EC	1.2×10^{18}	0.87
^{138}La	β^- (~30%),C(~70%)	1.12×10^{11}	0.089
^{142}Ce	α	$\sim 5 \times 10^{15}$	11.07
^{144}Nd	α	2.4×10^{15}	23.87
^{147}Sm	α	1.05×10^{11}	15.07
^{152}Gd	α	1.1×10^{14}	0.20
^{176}Lu	β^-	2.2×10^{10}	2.60
^{174}Hf	α	2.0×10^{15}	0.163
^{157}Re	β^-	4.3×10^{10}	62.93
^{170}Pt	α	6.9×10^{11}	0.0127

Radioactive substance in human body

There is a radioactive substance in the human body because the person depends on water and food with the radioactive substance. In the comparison, about 0.2% of the human body is essential element K. And, 0.012% of K is radioactive element, ^{40}K. The main radioactive elements that existed in the human body are summarized in Table 2.

Table 2 Radioactive material in human body and example of the concentration

Radioactive substance	Concentration (Bq/kg)	Radioactivity of whole body (Number of Bq of people of 60 kg)
^{40}K	67	4,100
^{14}C	41	2,600
^{87}Rb	8.5	520
^{210}Pb or ^{210}Po	0.074 ~ 1.5	19
^{238}U	—	1.1

The person is always receiving the radiation to the inside of the body with these radioactive elements. This says, "Internal exposure", and is distinguished from "External exposure" of the radiation received from outside of the body. The radioactive substance taken into the inside of the body is excreted without accumulating afterwards though is distributed in various internal organs and the organization according to the internal organs compatibility. Biological half life is time until the amount of the radioactive material in the inside of the body decreases to 1/2 with the excretion mechanism. The radioelement is properly excreted to outside of the body without accumulating by metabolizing. Therefore, radiation levels in the inside of the body do not go up. For instance, ^{137}Cs with a physical half-life about 30 years is actually excreted to outside of the body at the half-life of about 100 days.

That is, the amount of the radioactive substance taken into the inside of the body decreases by the synergy effect of the physical half-life and the biological half-life. Thus, radiation levels in the human body are kept constant almost through the life. And, the difference is not seen between ancient people and modern people as for radiation levels.

Conclusion

All men who live on earth have received the environmental natural radiation. Table 3 showed average value of the exposure dose of people in the world. However, this value is a mean value to the end, and it changes considerably greatly according to the region and the lifestyle where we live.

For instance, the radiation dose of the Kanto where Kanto-loam is made of the volcanic ash region is 0.2-0.3 mSv less than that of the Kansai area where are a lot of granite zones. In the world, there are some regions where the exposed dose is high in China, India, and Brazil. In these area, the height of the exposed dose are 5-20 mSv per year. However, there is no case who says that it died young by the natural radiation in such the provinces, and the Kerala area in India is known as a long life region.

Table 3 Exposure dose (average value in the world)

Origin of radiation	Exposure dose (mSv)
Cosmic Ray	0.39
Earth	0.48
Food	1.29
Rn in atmosphere	1.26
Total	~2.4

Human race's long history has progressed as mentioned above in the natural radiation that surrounds us. We cannot request the environment of radiation zero. Therefore, it is important to learn correct knowledge concerning the radiation and the atomic energy which increases more and more about the importance degree.

It is more important to be going to promote the radiation education in the future.

Biography of Dr. Chin Pan

Dr. Chin Pan is a professor of the Department of Engineering and System Science and the Dean of the College of Nuclear Science of the National Tsing Hua University (NTHU). Dr. Pan received his BS degree in nuclear engineering from National Tsing Hua University in 1979, MS and Ph.D degrees in nuclear engineering from University of Illinois at Urbana-Champaign (UIUC) in 1983 and 1985, respectively. After receiving his doctoral degree, Dr. Pan served as a visiting research assistant professor at UIUC before joining NTHU as an associate professor in 1986 and promoted to full professor in 1990. From August 1992 to August 1993, Dr. Pan conducted research and served as a Visiting Professor of the Department of Nuclear Engineering of UIUC with a fellowship from the National Science Council of Taiwan, ROC. In the summer of 1998, he conducted microchannel boiling studies in the Department of Engineering Science of the University of Oxford as an academic visitor with a visiting fellowship from Engineering and Physical Sciences Research Council, UK. In the next summer, he conducted researches on multidimensional modeling of two-phase flow in the Rensselaer Polytechnic Institutes as a visiting scholar with a fellowship from the National Science Council of Taiwan, ROC. He served as the Chairman of the Department of Engineering and System Science of NTHU from February, 2001 to January, 2004 and the director of the Center for Energy and Environmental Research from December 2003 to July 2008. Dr. Pan has been serving as the Dean of College of Nuclear Science since August, 2005.

Dr. Pan's research activities for the past twenty years have been in the areas of two-phase flow, boiling heat transfer and energy engineering with a special focus on transition boiling, nucleate boiling near CHF, nuclear reactor thermalhydaulics, two-phase flow instability with or without nuclear coupling, two-phase natural circulation loops, microchannel two-phase flow, microchannel boiling, microchannel heat sink, microchannel reactor, and thermal-fluid transport in fuel cell systems, especially micro direct methanol fuel cells. He published a book in Chinese entitled "Boiling Heat Transfer and Two-phase Flow" in 2001. He authored and co-authored about 60 SCI journal papers and 80 conference papers. He received a distinguished research award in 1998 and three excellent research awards earlier from the National Science Council of Taiwan, ROC. He also received an outstanding industry – academy collaboration award from the Ministry of Education of Taiwan, ROC in 2003. He served as the chairman of the academic committee for joint projects of Atomic Energy Council and National Science Council from 2001 to 2005. He is now serving as the chairman of the Advisory Committee of Nuclear Safety in the Atomic Energy Council.

Research and Education on Nuclear Science and Engineering at National Tsing Hua University

Chin Pan

College of Nuclear Science
National Tsing Hua University
Hsinchu, Taiwan

Abstract

Nuclear science and technology has been one of the major subjects of research and education in National Tsing Hua University (NTHU) since its establishment at Hsinchu in 1956. In fact, at that time, the Institute of Nuclear Science was the first and only educational unit in the University. The construction of Tsing Hua Open Pool research reactor was started in 1959 and it reached first criticality on April 19, 1961. The College of Nuclear Science was established in 1974 and now the College has been one of the largest educational units in the world on nuclear science and engineering offering comprehensive education and conducting integrated research. In this talk, the evolution of the College, some research activities and education on nuclear science and technology at NTHU, recent effort of the College on globalization, and contribution of NTHU nuclear science and technology education and research to the development of nuclear power and other civil applications will be addressed. It can be revealed that education provided and research conducted at NTHU has been the major driving force for the development of nuclear science and engineering in Taiwan

THMER

Tsing Hua
Mobile Educational Reactor

Curriculum vitae: Dr. Eszter Tóth

I was born in Budapest, Hungary in 1948.
Graduating Roland Eötvös University, Budapest as a teacher of mathematics, physics 1971.
PhD in 1976 „Teaching of Quantum-mechanics" at Roland Eötvös University, Budapest.

1971 – 1991 physics teacher in József Attila High School, Budapest.
1990 – 2003 physics teacher in Lauder Javne School, Budapest
1982 – 1992 and 2002 – co-worker at the Eötvös University, Atomic Physics Department

1992 – leader of the RAD Labor (RAD: Cancer Risk in Low Radioactive Doses)
2005 – chairwoman of Foundation Young Researchers, Science Center - Vác

1973 – 1983 member of the Education Committee of the Hungarian Academy of Sciences
1971 – member of the Roland Eötvös Physical Society (four years cycles serving twice as secretary general of the Educational Group)
1990 – member of the Hungarian Nuclear Association

1979 – member of GIREP (International Research Group for Physics Education),
1991 –1995 secretary general of GIREP

1985 – 1998 I taught in 10 Third Word countries sent by the UNESCO project: "Computers in Physics Education" of the Abdus Salam International Institute for Theoretical Physics, Trieste

Up till now I gave lectures at Conferences, Workshops and Symposiums on Physics Education (in 50 countries) and from 1992 on research in Indoor Radon Survey in Hungary.

I have published 70 papers in English on physics education, and 26 papers in English and 20 in Hungarian on indoor radon research. I wrote 6 books, among them 4 high school textbooks in Hungarian. The one written for 18 years old (contained atomic and nuclear physics) was translated to Chinese (published in Beijing in 2000), to Japanese (published in Tokyo in 1997, 1998, 1998), and the one written for 14 years old students was translated to Spanish (published in Venezuela in 1998) and to Chinese (published in Beijing in 1997).

Vác, Hungary, 11 december 2008

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Nuclear Literacy and Radiation Effects in Hungary

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Nuclear literacy is needed for all citizens to be free of fear from radioactivity and nuclear power or medicine. Hungary is a very special country concerning this task.

From geological point of view: two tectonic plates – The European-Asian and the African plates - collide just across under Hungary. It means that geology of our homeland is very complex. There are some regions where uranium-radium concentration of soil is high, the soil is relatively porous, and therefore the radon concentration in homes can be large. Indoor radon activity concentrations can be measured by nuclear track detectors easily. Local pupils can be involved in the distribution and collection of detectors. They also enthusiastic to collect information about the house structure, to draw conclusions on maps of their village, to find correlations between house structure parameters and radon level. And even they learn to feel responsibility for the village community; since they learn from the media that indoor radon in high concentrations can cause lung cancer.

But Hungary has another advantage from the point of view of the education on nuclear literacy. Leo Szilard, George de Hevesy, Eugen Wigner, John von Neumann, Edward Teller was born in Budapest, Hungary. They spent their youth in Hungarian schools; they loved the Hungarian poems, music, and the beautiful city Budapest. For the Hungarian students one can teach nuclear physics and medicine as a kind of Hungarian "business".

And the third "advantage" is that Hungary a small, flat country. We have no possibility for hydroelectric power, we have no good coal mines, we have a small amount of gas, and the number of sunny or windy days is not enough for using solar or wind powers in large scale. The only cheap and clean electric energy source is our nuclear power plant. About 40% of our electric consumption is given by our nuclear power plant.

Age 8 to 14

From 1992 there is a survey of indoor radon measurement in Hungary. This survey invited the teachers and their pupils in small villages into a common project with the RAD Laboratory, which also ran by teachers and high school students. The CR39 track detectors can be handling easily. The detectors were placed in bedrooms for three seasons (autumn, winter, and spring), and from the three results the yearly average of radon activity concentration were estimated.
The starting point of the common project was an "afternoon tea"; participants were the local pupils and the RAD Labor students. They were speaking about natural radioactivity, but which is more important they play with Geiger counters, they made some experiments. They realized that even human being is a source of radioactivity as well as the walls or tables or flowers in the school.

Experiment 1.

Take a balloon! Before you flow up to a big sphere measure how many clicks per minute are given by the Geiger counter. Flow it up! Rubbed it with your hair! (The balloon will be electrically charged.) Hang the balloon for a half an hour in the basement or the lowest level of the school building! Then let the air out of the balloon, measured it radioactivity again!
(If there is enough time you can measure the half life time of the balloon radioactivity. It is about 40 minutes, and it is a “semi” half life time, because of two daughters of the radon series – 214Bi and 214Pb.)

Experiment 2.
Take a vacuum cleaner; put 6 layers of medical gauze at the end of its tube. Sip the air for a half an hour. Measure the radioactivity of the gauze before and after the sipping. For the best results the sipping should be done in the lowest level of the building, in a closed room. Even if someone is smoking in the room, the result is fantastic! (And show the students that smoking is dangerous! ;-)

At the “afternoon tea” the local pupils learn also how to distribute the detectors, how to administrate it, how to fill the questionnaire of the house structure and living style of the family in the house. Because they meet the people of the measured homes, they are eager to learn “everything” about radon, about natural radioactivity, its possible health effects, and about the ways how to reduce radon level if it would be too high.

When the results arrive to the village from the RAD Laboratory the pupils post them to the families, they explain the meaning of the numbers, the can tell them what to do for reducing. They become important persons in their village via their nuclear knowledge!

Age 14 to 18

In traditional physics textbooks the nuclear chapter introduces the discovery of radioactivity with some sentences of history, pictures of men with beards, and with the well-known figure in which **α** goes left, **β** goes right, and **γ** goes straight forward. The poor students learning these things may very properly ask: *“How can I decide for or against nuclear power if all I know that* ***α*** *goes left or when Rutherford was born?”*

In 1984 a new physics curriculum was introduced in Hungary, in which the nuclear chapters are on the following topics:

- I. Experimental discovery of nuclei and the neutron (Rutherford’s, Chadwick’s and other experiments, shown by computer simulation).
- II. Droplet model for heavy nuclei (mapping the energy valley – i.e. plot of energy per nucleon versus the number of protons and the numbers of neutrons).
- III. Application of the droplet model (radioactive decay as ‘cooling’ of nuclei, fission, natural and artificial radiation, health effects, medical use of isotopes, reactors, power plants, bombs).

The textbook in this structure was written originally in Hungarian, but it is available in Chinese and Japanese as well. (For Chinese version contact professor Qin Kecheng qin@pku.edu.cn, for Japanese version: Maruzen Publisher.)

Experimentation in high schools uses one of the above mentioned experiments. There are also possibilities to observe the radioactivity of pieces of rocks, different mineral waters, or plants.

Some of the high schools were participated also in the Hungarian radon survey. Their students were eager to learn some mathematical statistics to evaluate the large number of the data.

In each year there is a student competition in nuclear physics in two age groups: from 12 to 16 and for 17-18 years old. Hundred problems of this competition are offered to the organizing committee of ISRE 2008, one can ask the pdf file from them. Surprisingly many of the students are able to solve these problems but the university professors...

Some examples:

1. The activities, the half-lives and the energies of the emitted particles are the same for two substances, which are called A and B. Substance A shows α-decay, substance B shows β-decay.
a) Is substance A or substance B more dangerous for us if they are at the same distance from us?
b) If substances A and B enter a human organism and remain there, which and why will cause more harm to the person's health?

2. Leo Szilard, when heard about the discovery of nuclear fission by German scientists, in 1939 thought that nuclear chain reaction can be realized in practice.
a) What made him think that nuclear chain reaction can be realized by nuclear fission?
b) What features are fissile nuclei supposed to have in order to be able to produce neutron chain reaction?
c) When and where was the first chain reaction initiated? Who were the Hungarian born scientists who participated at this event?

3. No spontaneous nuclear chain reaction could set off by itself on planet Earth now. However, traces of an „ancient reactor" were found in the vicinity of rich uranium sites in Mid-Africa (Oklo, Republic of Gabon) dating back to 2 billion years.
a) What evidence do you think the research workers found, which made them conclude that prehistoric reactors were active there, in which controlled neutron reactions went on?
b) What conditions could have existed 2 billion years ago that allowed the spontaneous regulation of the nuclear chain reaction? How could this nuclear chain reaction have been set off?

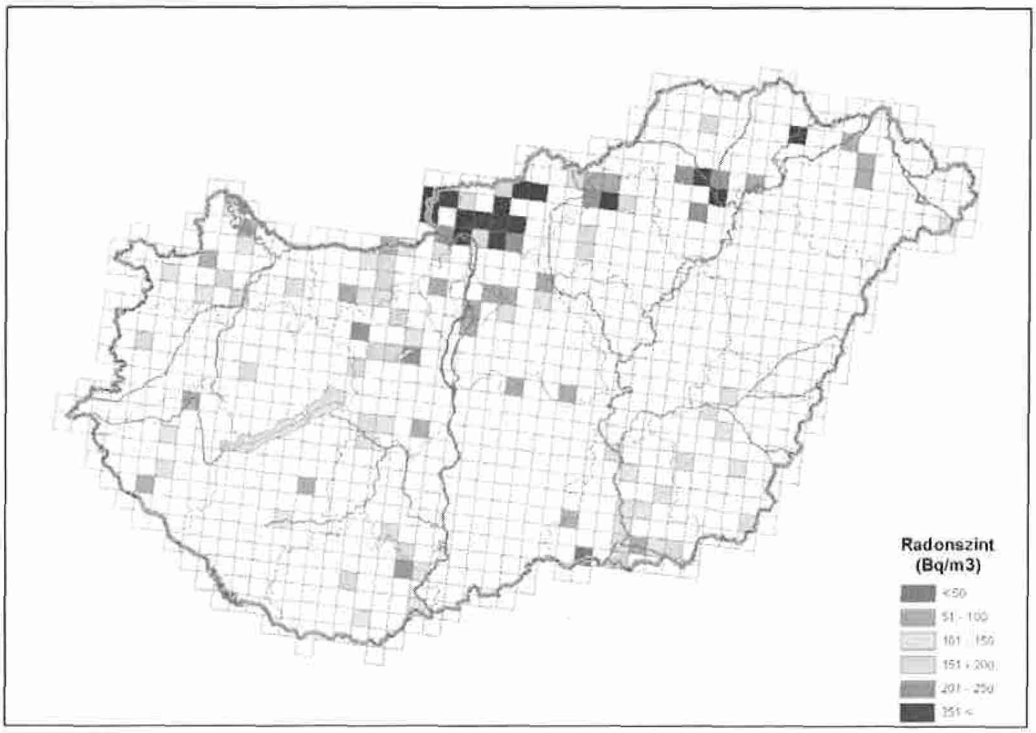
4. There are two stable helium isotopes occurring on the Earth, namely the rare ^{3}He and the more frequent ^{4}He. ^{3}He has much higher concentration in the air than in natural gas. How did this difference evolve?

The Hungarian Nuclear Association calls the high schools in each year for a competition. The participating schools have to create a series of events to introduce the topic of the year for the widest range of population taking the knowledge level of the audience into account. The presentations can be lectures, drama or music performances, experiments, posters, exhibition or any other interesting event. This year topic was *Edward Teller born 100 years ago*, the 2009 year will be dedicated *The First Artificial Nuclear Chain Reaction in Hungary, 1959*. This type of activity brings the non-science students closer to nuclear physics. For example Edward Teller was a brilliant pianist as well; he wrote some poems in Hungarian, so a group of my students played some Mozart's pieces, recite Teller's poems when they introduce nuclear power safety...

Some results by the students but not in a childish way

A mathematical statistical evaluation of house structures and radon levels showed that the one level, no-basement family houses built of sun-dried mud-bricks are the most effected by radon, if they located in North Hungary in the hills, or on a granite hill in Central Hungary.

Indoor radon map of Hungary for the European radon mapping (10x10 km^2 grid)



(*Radonszint* means annual average of radon activity concentration.)

One of the most radon affected village in Hungary is Mátraderecske. The population of Mátraderecske is 2500 people; they belong mostly to the Palotz ethnic group. The population of the village is rather steady. There is no air pollution. Men have worked in mines, factories, 60% of them is smoking. *Women,* however, stay at home and *don't smoke*. About 2000 people were studied concerning radon inhalation and cancer incidences. We can conclude with 98% confidence, that women of the age group 30-60 years do have a *smaller chance of getting cancer* if they live at medium high radon level (between 110 Bq/m^3 and 185 Bq/m^3), which is three to five times the country average. As if the little bit elevated radon level would save them from cancer.

Curriculum Vitae

Name: **Kazuo Sakai**

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Education

1977	B.S. in Biophysics and Biochemistry, University of Tokyo
1979	M.S. in Biophysics and Biochemistry, University of Tokyo
1982	Ph.D. in Biophysics and Biochemistry, University of Tokyo

Professional Career

1982-83	Research Associate, Department of Radiation Biophysics, Faculty of Medicine, University of Tokyo
1983-85	Research Fellow, Genetics Division, Children's Hospital, Harvard Medical School
1985-89	Research Associate, Department of Radiation Oncology, Faculty of Medicine, University of Tokyo
1989-99	Lecturer, Department of Radiation Oncology, Faculty of Medicine, University of Tokyo
1999-2000	Senior Research Scientist, Department of Bio-Science, Central Research Institute of Electric Power Industry
2000-2006	Senior Research Scientist, Low Dose Radiation Research Center, Central Research Institute of Electric Power Industry
2006 to date	Director, Research Center for Radiation Protection, National Institute of Radiological Sciences.

Membership

An Executive Committee Member of Japan Health Physics Society

A member of the Committee 5 of ICRP

Biological effects of low level radiation

Kazuo Sakai

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Abstract

Radiation is often said to be harmful no matter how low the dose is. This concept, called LNT model, is a basic concept for risk estimaion in the current radiation protection system. However, it is based only on extrapolation of data at high doses into low dose range, even to zero dose. Living organisms, on the other hand, posesse some protective functions; they are effective to reduce damage caused by radiation when its dose and/or dose-rate is low. In this sense the effects of radiation highly deped on its level. The detrimental effect of high level radiation should not be underestimated; however, one should not be too much scared of radiation.

Keywords: low dose; low dose-rate; adaptive response; LNT model

1. Introduction

It is sometimes said that radiation is detrimental no matter how low its dose is. It is true that high doses of radiation is damaging. However, situation is different when the level of radiation is low, as we will discuss below

2. Two types of biological effects

Biological effects of ionizing radiation has been grouped into two categories depending on the cause of effects.

One is called "deterministic effects" which are caused by the loss of the cells in tissues/organs. Radiation damage other than cancer and hereditary effects are classified into this category. The dose response of this type of effects has a threshold, below which no effect would be observed.

The other type of effects is termed "stochastic effect" which are thought to be caused by mutation of a cell. Cancer and hereditary diseases are classified in this category. Although extensive research has been carried out on the groups of people exposed to radiation, including A-bomb survivors in Hiroshima and Nagasaki, no increase in the hereditary effects has been detected. Therefore, the major concern is the induction of cancer.

Epidemiological data suggest cancer risk increases at the dose higher than 100 mSv. In the lower dose range, due to uncertainty associated with data, there is no significant increase in cancer risk (Pierce 1996, Preston 2003).

From the viewpoint of radiation protection, it has been assumed that the risk would increase linearly with the dose without threshold (ICRP 2007). This assumption is called "LNT hypothesis" or "LNT model". The LNT hypothesis relies on a simple model of carcinogenesis, which was proposed in earlier days (Fig. 1). Cancer is caused by a mutated cell. Mutation is caused by DNA damage; the amount of DNA damage is increased linearly to the dose; therefore, cancer is induced proportionally to the dose. From the viewpoint of the current biology, this is too simple.

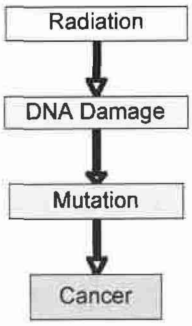

Fig. 1: A Simple Model as a Basis for LNT Hypothesis

3. Multiple steps in carcinogenesis and protective functions

Advances in cancer biology have revealed that the process of carcinogeneses is much more complexed than thoght earlier (Fig. 2). It begins with DNA damage caused by carcinogenic agents, including UV light, environmental carcinogens, and high doses of ionizing radiation. Thses agents damage DNA directly or indirectly through producing reactive oxygen species. DNA damage would cause mutation. When some types of mutation accumulate in a single cell, it will be transformed into a malignant cell which would keep growing without obeying to normal cell growth regulation to end up with a tumor. It was also revealed that against each step in carcinogenesis protective functions are equipped. (1) Antioxidative molecules to remove the reactive oxygen species; (2) DNA repair functions to remove the DNA damage; (3) a sophisticated system called "apoptosis" to remove those potentially malignant cells , in which mutation has been accumulated; and (4) the immune system to revomve malignantly transformed cells. With these protective functions taken into account, it would be reasonable to think the actural risk from low doses radiation would be less than predicted by the LNT model.

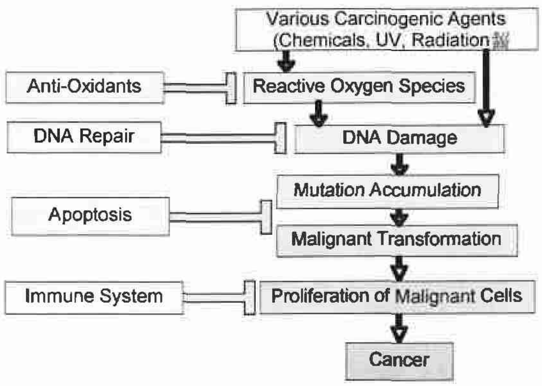

Fig. 2: Protective Functions and Carcinogenic Process

4. Dose-rate effects

Biological effects in general is smaller when a dose is given in fractionated manner. This effect is explained as follows (Fig. 3) . When the protective functions work to some extent, actual effect appears corresponding to those exceeding the protective capacities. For fractionated exposure, the the protective functions deal with the damage from each fractions to end up with less total effects. The same is true wihen a dose in a uniti of time (dose rate) is lower. The dose rate effects have been demonstrated in experimental systems (Ina et al. 2005) as well as in epidemiological studies (Tao 2000).

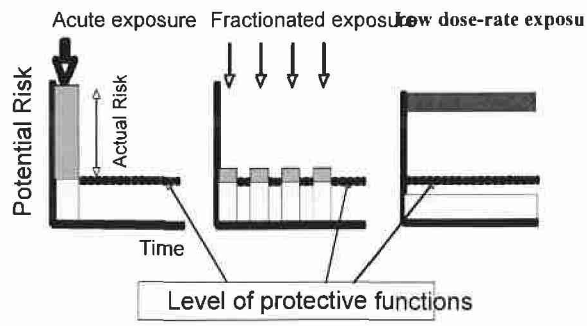

Fig. 3Effects of dose fractionation/dose-rate on risk frc

5. Adaptive Responses

Under certain condiions the protective functions are known to be stimulated by low level radiation (Kojima 1998 for antioxidants; Le 1998 for DNA repair; Chen 2004 for apoptosis; Ina and Sakai 2005, Ina et al. 2005, and Kojima et al. 2002) for immune functions). One may expect the increase in the protective function would results in the induction of resistance against radiation damage. In fact, aquired radioresistance after low level exposure has been reported. This phenomenon was termed radiation adaptive response. Originally the response was reported in human peripheral lymphocytes exposed to low level beta rays from tritiated thymidine followed by exposure to X-rays (Olivieri 1984). The endpoint was chromosome aberration (Ikushima 1989). The phenomena drew much attention of scientists and the many experiments have been done. Materials have been various types of cultured cells as well as human lymphocytes. Endpoints studied include chromosome aberration, micronuclei formation, mutation induction, and in vitro malignant transformation. The adaptive response is also observed in whole body system. C57 BL/6 mice pre-irradiated with small doses acquire resistance against lethal doses given several days later (Yonezawa 1996). Also, increased resistance against tumorigenesis has been reported for radiation-induced (Ina et al. 2005) and chemically induced skin tumors (Sakai et al. 2003)

6. Conclusions

Although for the purpose of radiation protection it is assumed that cancer risk increase linearly with dose. As we discussed above this does not necessarily reflect the actual effects of ionizing radiation. One should not ignore the harmful effects of high level radiation; however, one should not be too much scared of radiation when its level is low. To convey this message to younger generation through radiation education should be essential for our future with good use of inoizing radiation.

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BIO DATA

1. **Name:** Mrs. Pannee Pakkong

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3. **Age:** 58 year (date of birth : 22-07-1950)

4. **Professional area of specialization and interest:**
   - Radiochemistry as tracer technique
   - Environmental Radioactivity

5. **Education:**

Educational Institutions Attended	Location	Major fields of study	Degrees, Dip
South Dakota School of Mines and Technology	U.S.A.	Chemistry	M.S (1979)
Chulalongkorn University	THAILAN D	Nuclear Technology	M.En (1976)
Chulalongkorn University	THAILAN D	General Science	B.Sc (1972)

6. **Some publications:**

P. Pakkong, U. Kovitvadthi ,V.Ratanathongchai,P. Youngermjun, (2004). Elemental Analysis of Mollusk Shell using Neutron Activation .The 43 th Kasetsart University Conference Fishery Section,1-4 Feb 2004,P 59-65

Boonyarath Pratoomchat, Pichan Sawangwong,Pannee Pakkong,Jorge Machado. (2002).Organic and inorganic compound variations in haemolymph, epidermal tissue And cutical over the molt cycle in *Scylla serrata*(Decapoda), Comparative Biochemistry and Physiology PartA.131(2002) 243-255

Somboon Techapinyawat,Pannee Pakkong,Poonpilai Suwanarit and Pattarawadee Sumthong, 2002, Effect of Arbuscular Mycorrhiza and Fertilizer on Phosphorus Uptake of Vetiver Using Nuclear Technique,Kasetsart J.(Nat.Sci.)36:381.391.(2002) P381-391

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Kovitvadthi Uthaiwan,Pannee Pakkong,Napavarn Noparatnaraporn,Laura Vilarinho,Jorge Machado.(2002) Study of a suitable fish plasma for in vitro culture of glochidia *Hyriopsis myersiana*,Aquaculture 209 (2002) 197-208.

Kovitvadthi Uthaiwan,Pannee Pakkong,Napavarn Noparatnaraporn,Laura Vilarinho,Jorge Machado.(2003) Studies on the plasma composition of fish hosts of the freshwater mussel, *Hyriopsis myersiana* ,with implications for improvement of the medium for culture of glochidia. Invertebrate Reproduction and development 44(1) 53-61

Kiattipong Kamdee,Pannee Pakkong, Kanitha Srisuksawad, Nipon Tungtham, 2006.Development of Radioanalytical Thecnique for Lead-210 in sediment. 39th Scienctific Society Conference, October 2006,Bangkok, Thailand

7. Former research work: Use of radioisotope as a tracer in biology, Agriculture and environment

1. Gross Alpha-Beta in environmental samples .
2. Use of Ultra Low-Level Liquid Scintillation to determine alpha spectrum of radon in ground-water samples of some part of Thailand
3. Effective Use of Phosphorus from Sewage Sludge as fertilizer of Crop-plants by Using Nuclear Technique
4. Impact of Role of Nuclear Technique to assessment the Impact of ^{14}C-endosulfan on Apple Snail in Rice Paddy Ecosystem.

8. Current research work: Use of radioisotope as a tracer agriculture ecosystem and environment

1. Analysis of natural and manmade radioisotopes in soil and sediment as environmental terrestrial monitoring and for erosion and sedimentation in specific landused areas.
2. Use of nuclear methods in elemental analysis of food and environmental samples such as NAA XRF ICP-AES
3. Use of nuclear technique to study growth-promotion of Plant with de-polymerized chitin/chitosan by gamma irradiation

9. Training

1. IAEA/ RCA Regional TC Project (RAS/5/039, Part 2) Project Formulation Meeting, Philippines, 20-22 March 2005.
2. IAEA/ RCA Regional TC Project (RAS/5/039, Part 2) Measuring Soil Erosion/Sedimentation and Associated Pesticide Contamination by Using the Cs-137 Technique Beijing & Yanqing, China 9 – 20 May 2005

10. Academic activities in Kasetsart University:

Lecture Courses in undergraduate, graduate courses at Department of Applied Radiation and Isotopes and Doctor in Philosophy in Bioscience faculty of Science:

		Credit
421421	Isotope Tracer Techniques in Biology	3
421431	Environmental Radioactivity	3
421511	Nuclear Facilities and Utilization	3

421596	Selected Topics in Applied Radiation and Isotopes	3
421411	Radiation Health Protection	3
421412	Nuclear Method of Analysis	3
421591	Research Methods in Applied Radiation and Isotopes	3
421532	Radioecology	3
421597	Seminar	1

Chairman of the department committee to establish undergraduate and graduate programs in Nuclear Science for human resource development of Ministry of Education for NPP policy was put in the National Development Plan to the next 5 years from 2003.

Committee in Committee Board of Standard Regulation and License of Radiation Safety Officer (in OAP).

Present and Status of Radiation Education in Thailand
On
4^{th} International Symposium on Radiation Education

18-19 December, 2008

Pannee Pakkong

Abstract

Thailand had been established Office of Atomic Energy for Peace (OAEP) since 1961 ,OAEP was renamed as Office of Atomic for Peace (OAP) and established Thailand Institute of Nuclear Technology(TINT) in 2002.The main activities concern of nuclear knowledge management in Thailand as nuclear legislation , research and development including education and training are focus on non-power application. OAP and TINT had been supported national radiation education programs in the universities and institutes both research and international collaboration with member countries as students and staffs scientific exchange programs. Universities in Thailand established academic programs both in undergraduate, graduate and doctor of Philosophy in Science and Engineering in many universities. Kasetsart University established undergraduate program in BS, (Biology) of Applied Radiation and Isotopes and graduate program in MS.(Applied Radiation and Isotopes) in Department of Applied Radiation and Isotopes, Faculty of Science. Chulalongkorn University established graduate programs in MS and MEn. (Nuclear Technology) and PhD.(Nuclear Engineering) in Department of Nuclear Technology, Faculty of Engineering. There were graduate program in MS.(Physic) of Nuclear Physic in Chaingmai University, Suranaree Technology University and Kasetsart University. OAP and TINT provide research grants to graduate students and collaboration research works with the universities staffs in field of nuclear reactor and power plant, radiation safety, environmental radioactivity monitoring, radiation dosimetry, radioecology, nuclear materials, nuclear electronics and instrumentation, radiochemistry and radiation processing. etc. OAP and TINT and universities established national training programs in Radiation Protection at difference levels for worker who applied for radiation safety officer certificate. Education and training of medical and paramedical professionals are done mainly on the academic education. A specialist in Radiological Medicine is providing in Medical School. There is a number of Radiological Technology Programs providing in every Faculty of Associated Medicine. Training for nurses working in radiological department in hospital is also provided in major hospitals .OAP and TINT established specific training courses on reactor operation, non destructive testing and nuclear energy utilization. The other training programs on understanding nuclear energy and application promotion such as Nuclear Camp for students and science-teacher , Nuclear Knowledge Contest, OAP and TINT open-house, Nuclear Science Exhibition and National Conference mostly collaboration with the universities. The universities also established training programs in knowledge base of nuclear energy and specific field of nuclear energy application . Kasetsart University established Gamma Irradiation Service Center and Nuclear Technology with supported by IAEA had been set up gamma irradiated room for plants as acute and chronics irradiation for teaching and training program in nuclear energy application in agriculture as mutation breeding of ornamental plants

by using nuclear energy for teacher, researcher and farmer. The successful results were nuclear technology transfer through public for understanding and acceptance of nuclear energy applications. The researcher and farmer had been collected new varieties of economic ornamental plants from induce mutation using gamma irradiation technique

Recently Thailand government was put National Development Plan on NPP policy in the next 10 years from 2003.The current status were feasibility study for site selection (4 candidate sites were selected), EIA studies, establishment of Nuclear Regulatory Body and Nuclear Legislation preparation. In Human Resource Development, Ministry of Education plan to develop and establish academic programs to educate students and public groups of people for Understanding / Public Acceptance in high schools and universities. People must be educated about nuclear energy for benefit for life.

Introduction

Thailand had been participated in nuclear energy science 1954 by the government and was developed in series as:

1954 : Thai Atomic Energy Commission (Thai AEC) was initiated as policy making body for peaceful uses of nuclear energy.
1961 : Atomic Energy for Peace Act was enacted.
1961 : Office of Atomic Energy for Peace (OAEP) was established.
1966 : Nuclear Electricity Sub-committee was set up.
1976 : Cabinet approved NPP 600 MW.
(the project was opposed by public)
1984-88 : Economic aspect of NPP was studied with support from IAEA.
1992-96 : NPP policy was submitted in the National Development Plan.
1997 : Study for NPP in Thailand was re-initiated,
NPP are not suitable during economic crisis.
2002 : Restructuring into Office of Atoms for Peace (OAP)
2006 complete separation of OAP and TINT

The nuclear legislation in Thailand was composed of Nuclear Legislation and National Nuclear Program , national nuclear education system , National Nuclear Training System. The main responsibilities of OAP are cooperate for nuclear affairs and foreign relations, establish rules, regulations and measure for the control and regulation of the use of nuclear energy and waste management, research, development and promote the use of nuclear technology including the operation of national research reactor and technology transfer. Present situation of nuclear energy programs except nuclear legislation are research and development including education and training are focus on non-power application such as medical, industry, agriculture and environment . National education on nuclear related program was cooperative within the universities, OAP and TINT. In 1993 Nuclear Society of Thailand (NST)
was established and the members were group of Academies , Research Centers , Power Industries, Authorities, Nuclear Medicine, and etc. NST had been supported by

Ministry of Science and Technology , National Research Council , Council of Scientific and The Technological Associations of Thailand including Electricity Generating Authority of Thailand.

Radiation Education in Thailand

Thai Research Reactor-1 (TRR-1) was constructed in 1961 under responsibility of OAEP and radiation education of Thailand was implemented in OAEP and university was purposed elective courses in nuclear physic, radiochemistry and radiobiology including the application. OAEP was implemented training for teacher and researchers and cooperative of nuclear affairs and foreign relations under IAEA exchange programs of operation of national research reactor and technology transfer on the application.

Kasetsart University (KU) was implemented in radiation education on 1962 , Establishment of Atomic Energy Laboratory Unit with Gamma Greenhouse Irradiation Building and 100 Ci of Cs-137 was installed for plant mutation breeding research work and provided elective courses concerned nuclear application in agriculture in Department of Biology, Faculty of Science. Academic program in BS Biology (applied radiation and isotopes) was conducted on 1981 in Department of Applied Radiation and Isotopes, Faculty of Science with major course syllabi are as:

Radiation Life and Environment
Nuclear Science
Radiation Detection
Radiobiology
Radiation Health Protection
Radioisotopes tracer in Biology

The elective course syllabi are Principle of Nuclear Medicine, Environmental Radioactivity, Radiation Mutation, Radiation Imaging, Nuclear Method of Analysis,

In 2002 KU provided academic graduated program in MS. Applied Radiation and Isotopes with major course syllabi are as:

Nuclear Facility and Utilization
Radiation Dosimetry
Advance Radiobiology
Research Methodology

The elective course syllabi are Nuclear Instrument, Radioecology, Applied Radiation Technology, Radiological Monitoring and Assessment of the Environment, Induced Mutation Technology in Plant etc.

Faculty of Science provided resources for support radiation education in KU as Gamma facility of Gamma Room for Chronic Exposure and Self Shielded Gamma Irradiator, Nuclear measurement instruments(HPGe Gamma spectrometer, the student have to practice in research work for thesis which focus on radiation monitoring in environment, radiation safety, radiation processing for polymer modification and gem enhancement, effect of low-dose radiation and bio-dosimetry, radiation mutation and detection of irradiated food. KU have research collaboration and support grant with OAP and TINT for undergraduate , graduate and other research source of fund .

KU also have arrangement the international collaboration with many foreign organization and university on training and exchange programs such as IAEA, JAEA (FNCA and NSRA).

Chulalongkorn University (CU) was implemented radiation education program on M.En (Nuclear Technology) in Faculty of Engineering in 1972 for main responsibility of Nuclear Electricity sub-committee on NPP approval proposal and followed by M.S, and Doctor of Philosophy in Nuclear Engineering. Course syllabi and research in nuclear field at CU were focused on industrial application, nuclear reactor and power plant, nuclear materials, nuclear electronics and instrumentation, radiation measurements and applications, radiation chemistry and radiation processing, radioisotope production and utilization and radioactive waste management.

Technology transfer was one of important tool for radiation education in nuclear knowledge management. Establishment of Gamma Irradiation Service and Nuclear Technology Research Center (GISC) in KU were sponsored by the United Kingdom, IAEA and the Thai Government under the Technical Cooperation Program (TC-Project), which were composed of THA/5/037, THA/5/039and THA/5/045. From initiation until completion, the project took almost 8 years (1989 – 1997). The gamma room (composed of three Co-60 sources 200,400 and 200 Ci) was designed for chronic irradiation of *in vitro* culture as well as pot plants, under controlled light and temperature. The gamma irradiator Mark – I (Cs – 137, 4500 Ci) was used for acute irradiation of biological materials. These irradiator facilities provide gamma irradiation services to scientists, researchers and plant breeders, and act as the main irradiation Center in Thailand and the region , especially in Southeast Asia . The center carried out researches on induced mutation techniques for the improvement of plant varieties were successful in training program as technology transfer to farmer as collaboration research work for producing new varieties of plant

Conclusion

Nuclear energy and radiation education had been implemented in Thailand since 1961 until recently, OAP and TINT are main responsibilities organization for the control and regulation of the use of nuclear energy and cooperate for foreign organization relations including research, development and promote the use of nuclear technology including and technology transfer . The universities were implemented radiation education on academic program to serve the need of country policy on nuclear energy strategy . There are very close cooperation between the universities, OAP, TINT and private sector are fate through Nuclear Society of Thailand (NST) . Radiation education can provide not only serve for scientist but public are main responsibility for technology transfer and understanding.

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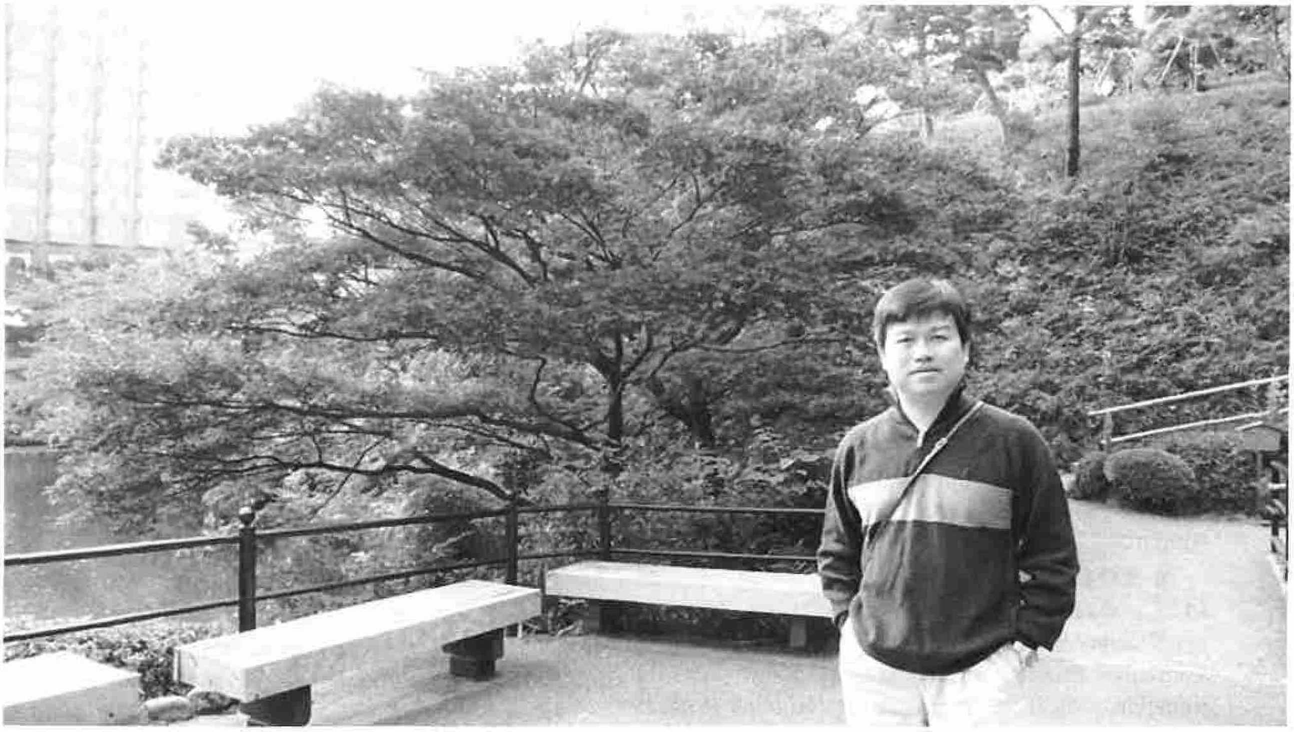

Training Programs for Radiation Protection Engineers, Technologists and Technicians

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Abstract

The concept of as low as reasonably achievable (ALARA) is becoming an important approach to reduce the worker's exposure to radiation with worldwide consensus. Based on the ALARA concept the training programs given by the Radiation Protection Association have been devised and conducted with continuing efforts to modify in order to meet the new requirements. In this presentation the management of training programs in Taiwan and the performing experiences by the Radiation Protection Association are fully elucidated. The benefits caused by training programs and the new International Commission on Radiological Protection (ICRP) recommendations incorporating into our training programs are also presented.

Keywords：ALARA；training program；ICRP

1. Introduction

In the past years from 2003 to 2007, the radiation workers in Republic of China (Taiwan) grew in quantity year by year. The number of radiation workers monitored increased from 31,683 (in the year 2003) to 43,447(in the year 2007)[1]. The increment reveals the fact that the use of radiation is getting widespread in Taiwan. The number of radiation workers in Taiwan is shown in Fig. 1. To choose the year 2003 as the reference is due to fact that the Ionizing Radiation Protection Act (Taiwan) was promulgated in 2003, and the recommendations of ICRP Publication 60 was also incorporated in the regulations in 2003.

In R.O.C. (Taiwan) the Atomic Energy Council (AEC) is the Competent Authority on radiation applications and protection, and the Ionizing Radiation Protection Act is the major law for radiation protection. To assist the radiation workers in learning the specific knowledge and technology in promoting radiation protection, the AEC stipulates that the personnel who are engaging in radiation practice shall receive special training specified by the AEC and obtain the radiation safety certificates or

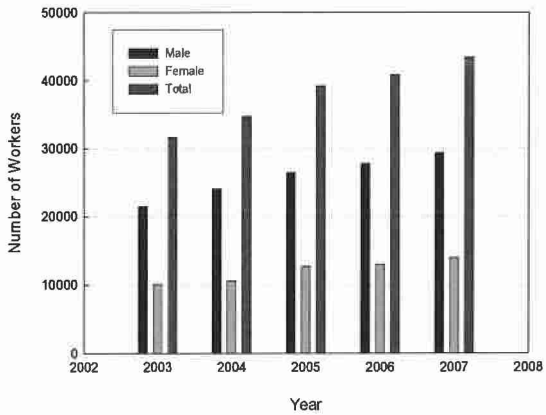

Fig 1. The number of radiation workers

licenses. The currently employed radiation workers are requested to participate in regular and periodical training program in accordance with the Ionizing Radiation Protection Act, particularly for certificate or license renewal.

The Radiation Protection Association (RPA) of the Republic of China established in 1990 is a non-profit organization aimed at assisting government to promote the radiation protection. With the assistance from AEC, National Tsing Hua University and other relevant organizations, the RPA has become the major training organization in R.O.C. During the past years the RPA has provided many training courses on radiation protection and assisted many radiation workers in applying for certificates or licenses. The training program provided by RPA also includes special seminars on new radiation protection knowledge and technology.

2. Classification of Training Program

In compliance with the Ionizing Radiation Protection Act (in the year 2003), the training course is divided into four categories as following, each training courses with different contents and lecturing hours was shown as table 1.

1. Radiation Protection Personnel: This is a comprehensive training course for the radiation protection personnel. The radiation protection personnel are required to have the responsibility and ability to design and manage radiation protection practice, even to serve as a lecturer for the training courses etc. The radiation protection personnel include radiation protection officer (RPO) and radiation protection expert (RPE). The training course for RPO is 144 hours, and that for RPE is 108 hours.
2. Radiation Safety Certificate (RSC): This is a training course for operators with a lecturing period of 36 hours.
3. Training in Lieu of Radiation Safety Certificate (TLRSC): This is a simplified training course for operators with a lecturing period of 18 hours.
4. Periodical Education and Training: This is a training program for currently employed radiation workers, since each workers should receive at least 3 hours of training per year as required by the regulations.

Table 1 The subjects and hours of each training course

<table>
<tr><th>Category / Subjects</th><th colspan="2">I</th><th>II</th><th>III</th></tr>
<tr><th></th><th>RPO(144 h)</th><th>RPE(108 h)</th><th>RSC(36 h)</th><th>TLRSC(18 h)</th></tr>
<tr><td>Basic Courses</td><td>18 h</td><td>18 h</td><td>6 h</td><td>4 h</td></tr>
<tr><td>Measurements</td><td>27 h</td><td>18 h</td><td rowspan="2">7 h</td><td rowspan="3">8 h</td></tr>
<tr><td>Dosimetry</td><td>24 h</td><td>18 h</td></tr>
<tr><td>Applications and Protection</td><td>36 h</td><td>26 h</td><td>14 h</td></tr>
<tr><td>Regulations</td><td>16 h</td><td>12 h</td><td>6 h</td><td>3 h</td></tr>
<tr><td>Exercises</td><td>23 h</td><td>16 h</td><td>3 h</td><td>3 h</td></tr>
</table>

The trainees for Categories I and II should participate in a government-sponsored examination, and can apply for a certificate after passing the examination. The average success rates for passing the examination are shown in Table 2.[2] The lowest success rates for RPO and RPE examination indicate the difficulty of passing the examination. A simple statistics shows the increase of radiation workers in Category I and II from the year 2003 to July 2008. The number of operators with radiation safety certificate increases from 6,899 to 12,284, the radiation protection officers from 485 to 759, and the radiation protection experts from 1,845 to 2,397.[3]

3. The Training Program of RPA

The trainees mostly come from the industrial sector. Most of them are engineers, technologists and technicians. For the training courses of radiation protection engineers, the RPA has provided many training courses for all Categories as listed above during the past years.

3.1. TLRSC(18 h)

The 3-day course provides basic knowledge of radiation protection to operators who operate the "registration" radiation sources. The lectures consist of the nature of radiation, measurement of radiation, biological effects of radiation and simple safe handling of radioisotope. The major exercise is radiation measurement. The laws and regulations are also introduced in this course.

3.2. RSC(36 h)

The 6-day course is designed for operators who operate the "permission" radiation sources. It provides broader and deeper radiation protection knowledge and technology than TLRSC course. Except the lectures given in the TLRSC, decontamination and radioactive waste management, utilization of radioisotopes and relevant laws are included this course. This course also helps participants to prepare for the government-sponsored examination for the license application.

3.3. RPE(108 h)

The 4-week course is designed for supervisor in radiation control. The lectures consist of the physics of radioisotopes, radiobiology, measurement of radiation, safety handling of radioisotope, internal and external radiation control, decontamination and radioactive waste management, utilization of radioisotopes, design of radiation facilities and studies of relevant laws and regulations. The exercises consist of radiation control, radiation measurement and decontamination. This course also helps participants to prepare for the government-sponsored examination for the license application.

3.4. RPO(108h + 36h)

The RPO course consists of RPE and a 5-day advanced course. The lectures of the advanced course consist of the radiation protection for neutron activation and accelerator, the specific radiation protection for high intensity radiation facilities containing highly radioactive source or high-energy equipment capable of producing ionizing radiation.

The lectures of the training courses will be revised with new radiation protection knowledge and technology. The lectures were revised recently according to the recommendations of the ICRP-60, the report NCRP-147 for x-ray shielding, and the new materials for dosimeter, such as radiophotoluminescence (RPL), optically stimulated luminescence (OSL), etc.

Since 2003 till 2007, there were 171 trainees attending radiation protection officer course and 70 of them passing the government-sponsored examination, 419 trainees attending radiation protection expert course and 228 of them passing the examination. There were 3,514 trainees attending Category II, 6,856 trainees attending Category III, and 8,360 trainees attending Category IV. The success rates for passing the examination by RPA trainees are shown in Table 2 comparing with the average passing rates of AEC statistics. The success rates of RPA trainees are higher than the average passing rate given by AEC statistics.

Table 2 The success rates for passing the examination of AEC (total average) and RPA (2003~2007)

	RPO	RPE	RSC
Statistics by AEC	21.2%	31.5%	71.1%
Trainees of RPA	40.1%	54.4%	---

4. Possible Effect of the Training Program

A good radiation protection practice needs a good training program. As a result of intensive training program, the possible effects can be seen from the personal dose statistics. In the period from 2003 to 2007, the number of radiation workers monitored increased from 31,681 to 43,447, the total collective dose decreased from 12.04 man·Sv in 2003 down to 9.83 man·Sv in 2007. The average annual dose for all radiation workers monitored was from 0.38 mSv in 2003 down to 0.23 mSv in 2007. [4] The downward trend of dose for radiation workers indicates the possible effects of intensive training to a certain extent.

5. Conclusions

Our experience shows the good coordination among teaching staff, trainees, administration support together with Ionizing Radiation Protection Act enforced by the Competent Authority would reach the goal of a good radiation protection practice yet without unduly limiting the beneficial actions giving rise to radiation exposure.

The ICRP proposed its new recommendations in 2007. According to Article 5 of the Ionizing Radiation Protection Act, "In order to limit the radiation exposure from radiation sources or practices, the Competent Authority shall refer to the latest standards of the ICRP to lay down the Safety Standards for Protection against Ionizing Radiation ..." This is another challenge for our training programs. The lecture notes should be revised accordingly, and the teaching staff should study the new ICRP recommendations.

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