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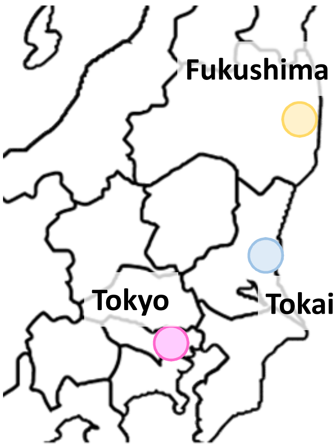


Yasuda Auditorium

LECTURE ABSTRACTS

Lecture 1

Overview of Nuclear Applications

Sunil SABHARWAL, International Atomic Energy Agency

Summary
Nuclear techniques are increasingly being used in industry and environmental management. The utilization of nuclear techniques in industry is based on the following advantages:

1. The ability of radiation to produce reactive chemical species in the irradiated material resulting in changes of chemical, physical and biological properties are effectively used in a number of processes for enhancing food and agriculture products availability, diagnosis and treatment of diseases, for the production of superior grade polymer products, sterilization of medical products or for treatment of effluents/wastewater from industry. **(RADIATION APPLICATIONS IN HEALTHCARE, FOOD & AGRICULTURE and INDUSTRY)**
2. Highly penetrating nature of gamma, X radiation and neutrons and dependence of their absorption on the nature and shape of the product forms the basis of non-destructive testing. (**RADIOISOTOPES AS SEALED SOURCES FOR NON-DESTRUCTIVE TESTING IN INDUSTRY).**
3. Ultra-high sensitivity and ease of detection at extremely low levels through non-physical contact with the material forms the basis of radiotracer application in industry. The continuous analysis and rapid response of nuclear techniques, many involving radioisotopes, mean that reliable flow and analytic data can be constantly available. This results in reduced costs with increased product quality. (**APPLICATIONS OF RADIOISOTOPES AS SEALED SOURCES, RADIOTRACERS IN INDUSTRY)**

1. Applications of Radiation and Radioisotopes in Food and Agriculture

1.1. Crop improvement through Plant mutation breeding

In the face of rapidly expanding population and the urgent need for more food, mankind can ill afford to ignore any means that would help to fulfil this need. Nuclear techniques have often proved to be effective, and sometimes, the only means, of providing appropriate solutions for a number of practical problems in agriculture. These include use of nuclear radiations as a tool to develop new strains of agricultural crops that are drought and disease resistant, are of higher quality, have shorter growing time and produce a higher yield.
High energy radiations are used to induce mutations and produce genetic variation of useful traits to develop desired mutant line that are resistant to disease, are of higher quality, allow earlier ripening, and produce a higher yield. It offers the possibility of inducing desired characters that either cannot be found in nature or have been lost during evolution. The technique depends on proper selection of mutant varieties having the desired characteristics which can lead to improved quality and productivity. During last two decades, radiation-

induced mutations have increasingly contributed to the improvement of crop plant varieties and it has become an established part of plant breeding methods. This technique of utilizing radiation energy for inducing mutation in plants has been widely used to obtain desired or improved characters in number of plant varieties all over the world.

1.2. Insect pest management through Sterile insect technique (SIT)

Insect pests are serious threat to agricultural productivity as they not only reduce crop yields but also transmit disease to cultivated crops. Radiation induced sterile insect technique has now emerged as an environmentally friendly alternative for pest control. The technique is based on application of ionizing radiation as a tool to sterilize male insects without affecting their ability to function in the field and successfully mate with wild female insects. This technique involves release of large numbers of sterile male insects of the target species in the field crop. Sterile male insects compete with the regular male population during sexual reproduction and the eggs produced from their mating are infertile so they produce no offspring. It is highly specific form of "birth control of insects" which reduces and eliminates the insect population after two or three generations. It has been effectively utilized in elimination of several insect pests of agricultural significance throughout the world.

1.3. Food Irradiation

Over 25-30% of the world's food produce are lost due to spoilage by microbes and pest and these losses are more in developing countries. This loss of food can be avoided by employing efficient food preservation methods. Radiation can be used to destroy microbes in food and control insect and parasite infestation in harvested food to prevent various kinds of wastage and spoilage. Extension of shelf life of certain foods of a few days by irradiation is enough to save them from spoiling. Irradiation of food has potential to produce safe foods with long shelf life. Irradiation does not heat the food material so food keeps its freshness in its physical state. The agents which cause spoilage (microbes, insects, etc.) are eliminated by irradiation from packaged food and packaging materials are impermeable to bacteria and insects so recontamination does not take place. Irradiation of food kills insects and parasites, inactivate bacterial spores and moulds, prevent reproduction of microbes and insects, inhibit the sprouting of root crops, delays ripening of fruits and improve technological properties of food. FDA has approved irradiation as a method to inhibit sprouting and to delay ripening in many fresh fruits and vegetables. Many countries have accorded clearance for gamma irradiation of food items.

2. Applications of Radioisotopes as Sealed Sources and Radiotracers in Industry

2.1. Established Applications

2.1.1. Sealed Sources

Some relatively simple portable measurement systems are widely used in petrochemical, chemical industries to assess the internal structures of chemical columns, the levels of fluids, etc.

Nucleonic control and measurement systems (NCMS) are relatively more complex systems which are used in industries for on-line quality control of products, for example: paper or metal sheets thickness, level of liquids in opaque containers, etc… These are generally produced by private companies for specific applications. The development of these technologies in developing MSs is limited by cost which is generally high and by the limited flexibility of these companies to develop new measurement systems fitting to the real needs at a low cost.

All these technologies have invaluable contribution in many industries as they can be operated without contact with the product, in harsh conditions.

2.1.2. Radiotracers

The concept of residence time distribution (RTD) has become an important tool for the analysis of industrial units and reactors. The RTD of fluid flow in process equipment determines their performance. Radiotracers are method of choice for obtaining the RTD in industrial processing vessels and wastewater treatment systems. Radiotracer RTD method has been extensively used in industry to optimize processes, solve problems, improve product quality, save energy and reduce pollution. The technical, economic and environmental benefits have been well demonstrated and recognized by the industrial and environmental sectors. Though the RTD technology is applicable across a broad industrial spectrum, the petroleum and petrochemical industries, mineral processing and wastewater treatment sectors are identified as the most appropriate target beneficiaries. These industries are widespread internationally, and are of considerable economic and environmental importance.

2.1.3. Non-Destructive Testing

Over the last forty years, non-destructive testing (NDT) techniques have become an essential part of quality assurance in the construction and manufacture of critical plants and equipment for key industries, and in many countries, quality assurance (QA) through non-destructive testing and examination is a mandatory requirement in ensuring the standard and useful life prediction of industrial specimen. NDT techniques are also widely used in regular maintenance procedures and to assess the reliability and safety of structures subjected to heavy loads, high pressure and corrosion. Conventional NDT is now firmly established in the everyday life of almost all countries, providing an important technological tool for the advancement of the industrialization in Member States.

2.2. Emerging Applications

In future, the focus is likely to be more on the following industrial sectors.

2.2.1. Applications in mineral industries

Radiation techniques are increasingly applied and continuously evolving for exploration and efficient tapping of natural resources, by the mining, metallurgy and mineral processing industries. Such industries are present in practically every country and often are the major contributors to the national economies.

Mineral industries will see the development of nuclear techniques and associated methodologies on the followings topics:

1. Radiotracers to derive data in a simple manner from a variety of complex and closed systems. Radiotracers provide vital information which can be gathered for optimal recovery of the desired mineral.
2. Geophysical radiation techniques as nuclear borehole logging systems for exploration purposes and new technologies will be introduced.
3. Nucleonic control systems for on-line measurements on processing lines for elemental analysis and for quality control and real-time process management

New radiotracers, miniature neutron generators and X-ray systems, user friendly software, new detectors and data acquisition systems are being developed and introduced in practice.

2.2.2. Applications in manufacturing industries

The development of new NCMS using miniature X-ray generators and new types of detectors with associated electronics will offer to manufacturing industries effective and innovative means for on-line quality control of the products directly on the production line. These new technologies will allow nuclear systems to compete with conventional techniques and also simplify regulatory aspects of nuclear technologies due to use of low activity radiation sources or X.Ray generators.

2.2.3. ***Applications for environmental protection***

With the increased public concern and regulatory impact on environmental protection against industrial activities, radioisotopes as tracers and sealed sources are often useful and irreplaceable tools. The climate change, together with human activities increasing pressure on coastal areas will definitely be a great opportunity for applications of nuclear technologies for sediment transport studies with the objective of coastal protection against erosion. Gamma scattering and transmission gauges are used for sediment monitoring. New innovative tools based on miniature X-Ray generators are being developed. Computational fluid dynamics (CFD) modelling is now an essential tool for the management of the natural systems and is increasingly used to study the fate and behaviour of particulates and contaminants.

3. Nuclear Techniques in Healthcare

3.1. Diagnostic Nuclear Medicine

Diagnostic techniques in nuclear medicine use radioactive tracers which emit gamma rays from within the body. These tracers are generally short-lived isotopes linked to chemical compounds which permit specific physiological processes to be scrutinised. They can be given by injection, inhalation or orally. It provides diagnostic information about the functioning of a person's specific organs which facilitates the doctors to make an accurate diagnosis of the patient's illness. Many organs such as thyroid, bones, brain, kidneys, heart and liver can be easily imaged, and disorders in their function revealed. Such diagnostic procedures are now routine. Sometimes radiation can also be used to treat diseased organs, or tumours. Over 10,000 hospitals worldwide use radioisotopes in medicine, and about 90% of the procedures are for diagnosis. The most common radioisotope used in diagnosis is technetium-99, with some 30 million per year worldwide, of which 6-7 million are in Europe, 15 million in North America, 6-8 million in Asia/Pacific (particularly Japan), and 0.5 million in other regions.

3.2. Radiotherapy

Rapidly dividing cells are particularly sensitive to damage by radiation. For this reason, some cancerous growths can be controlled or eliminated by irradiating the area containing the growth. Radiotherapy is the technique that is used to destroy particular targeted cancer cells. External irradiation (sometimes called teletherapy) can be carried out using a gamma beam from a radioactive cobalt-60 source, though in developed countries the much more versatile linear accelerators are now being utilised as a high-energy x-ray source (gamma and x-rays are much the same). An external radiation procedure is known as the gamma knife radiosurgery, and involves focusing gamma radiation from 201 sources of cobalt-60 sources on a precise area of the brain with a cancerous tumour.

4. Radiation Processing Application for Value Added Products and Cleaner Environment

Radiation technology uses ionizing radiations, mainly gamma-rays from 60Co and electrons from electron accelerators, as a source of energy in different industrial and environmental applications. The principal industrial applications of radiation are sterilization of health care products including pharmaceuticals, irradiation of food and agricultural products (disinfestation, shelf-life extension, sprout inhibition, pest control and sterilization), and material modification (crosslinking, curing). There are about 200 industrial gamma irradiators and 1400 high current EB units in commercial use providing billions of Euros of added value to numerous products. The applications can be briefly described as:

- Radiation sterilization using gamma-radiation or electron beam is applied to a number of disposable medical products like syringes, gloves, bandages, surgical blades, sutures, catheters, drapes, etc. in a large number of countries. Radiation technology has helped in the development of new biomaterials useful in medical applications.
- Radiation crosslinking technique is used for production of wires and cables insulated with polyvinylchloride and polyethylene. Such insulations have better

resistance to heat and chemical attack and increased resistance to mechanical damages.

- Some polymers with radiation induced cross linkage can be manipulated to shrink when heated. Such heat shrinkable products find extensive applications in different industries, such as packaging, electronic, power generating, gas or oil piping, etc.
- Radiation curing of surface coatings has great potential for use in a wide spectrum of industrial sectors such as printing, wood, plastic and metal coatings, and electronics.

With increasing experience and confidence in the technology, more facilities are being built with novel designs optimized for a specific application, or allowing multipurpose use. It is estimated, that about 85% of gamma irradiators are being used for sterilization of health-care products, while similar percentage of irradiators treat food and agriculture products. About 30% of facilities are being used to treat polymers, including wire and cable and tubing. The estimated use of EB facilities is shown on Figure 1.

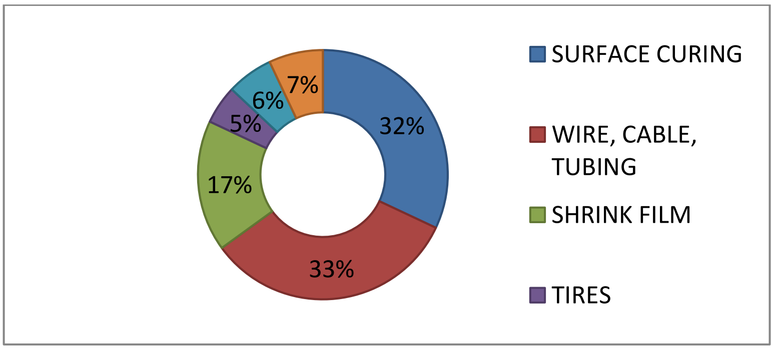

Fig.1. Typical industrial EB end-use markets - The bulk of the use is for cables, heat-shrinkable and surface treatment (over 80%), while applications for medical devices and food products are envisaged to increase in the future

5. Advances and Emerging Applications of Radiation Technology

In recent years, radiation technologists have been focusing on beneficially utilizing the potential for radiation technology for effectively treating pollutants from industries thereby reducing the environmental degradation to a great extent. Industrial effluents especially waste waters from textile dye industry discharged in the environment contain a number of refractory chemicals. Electron beam irradiation of these effluents breaks down these dyes into harmless substances or into substances that can be removed easily by using conventional techniques. The process has been successfully demonstrated in Republic of Korea where a large-scale electron beam facility was set to treat 10000 m^3 wastewater from textile dying complex in Daejon city.

Lecture 2

Basics of Nuclear Physics

Estiner KATINGEZA, The University of Tokyo

An atom consists of a positive nucleus with electrons orbiting around it. Within the nucleus are positively-charged protons and neutral neutrons. Some elements or their isotopes have unstable nuclei which undergo spontaneous decay (loss of energy) in order to attain stability. This spontaneous decay is referred to as radioactive decay. The strength of radioactive decay of a source is called radioactivity and has units of Becquerel (Bq). Each radionuclide has a distinctive half-life; the time it takes the radionuclide to decay to half its original mass. Radioactive decay is accompanied by the emission of ionizing radiation such as alpha particles, beta particles, and gamma rays. X-rays and neutrons are also ionising radiation which are produced in an X-ray tube and by nuclear reactions respectively. Radiations with more penetrating power, such as neutrons and gamma rays, tend to have low ionizing ability. When radiation interacts with matter, the energy it imparts per unit mass of material is called absorbed dose, given in units of gray (Gy). This physical quantity, absorbed dose, is used together with radiation-weighting and tissue weighting factors to give an indication of the biological effect of the radiation in units of sieverts (Sv).

Lecture 3

Radiation Biology

Hirofumi FUJII, National Cancer Centre

The radiation exposure induces some adverse effects on human health.

In this lecture, I talk about biological changes induced by radiation exposure including these adverse effects.

In the first half, I explain the effects of radiation exposure on living bodies.

The effects of radiation exposure on living bodies are induced mainly by the damage of DNAs in cells. This damage of DNAs depends on the type and dose of exposed rays. The damage induced by radiation exposure is independent of the kind of sources, namely, rays emitted from natural sources and those from artificial ones equally damage DNAs when the type and dose of exposed rays are same.

It is also important that most DNA damages can be correctly repaired and symptoms are temporal, if they would appear, when the dose is small enough.

The effects by external exposure and those by internal one is often confusing, too. However, when the radiation exposure dose is equal, the effects are same, whether external exposure or internal one.

In the latter half, I talk about the effects of radiation exposure on human health.

Various kinds of adverse effects appear when human bodies are irradiated. These adverse effects are categorized into some groups. An important classification is that of deterministic effects and stochastic ones. Acute high-dose exposure induces acute radiation syndrome, which is the most important deterministic effect. Oncogenesis is the most important stochastics effect and this adverse effect can be induced by any types of radiation exposure.

The effects of low-dose radiation exposure less than 100 mSv are controversial. Although some ideas are proposed, no conclusion has been reached in regard to this issue. The ICRP recommends the LNT model and most radiation protection authorities accept this model.

Radial rays are very useful in our daily life when they are properly used.

I would like to emphasize that we have to learn correct knowledge about radial rays and their effects on human bodies to minimize adverse effects induced by radiation exposure.

Lecture 4

Radiation Measurement and Dosimetry

Genichiro WAKABAYASHI, Atomic Energy Research Institute, Kindai University

Since we cannot see, smell or taste radiations, we need a radiation detector to know the existence of radiations. The detection principle of radiation detectors is based on the interactions of radiations with matter, especially for the ionization and excitation of atoms or molecules constituting a detector material. There are many kinds of radiation detectors, and each detector type has different characteristics. Therefore, we should choose a right detector for a physical quantity we want to know.

Gas detectors use the ionization of gas molecules filled in a detector. Applying a high voltage to two electrodes (anode and cathode) in the detector, electric charges produced in the gas by radiations are collected to the electrodes, and electric signals are produced. There are several kinds of gas detectors, which includes ionizing chamber and Geiger-Mueller (GM) tube. Ionization chambers are often used for measuring high levels of gamma-ray dose rate (μGy/h, μSv/h). GM tubes are widely used for various purposes because they are relatively cheap and have simple structure. But one should keep in mind that they can only measure the number of radiations entering the detector; count rate (cpm, cps).

Semiconductor detectors (solid state detector, SSD) work based on the same principle as ionization chambers, but they use electron-hole pairs produced in a semiconductor (usually silicon or germanium) by radiations as electric charge carriers. Semiconductor detectors have very good energy resolution. High purity Germanium (HPGe) detectors are used for the measurement of radioactivity (Bq) by measuring γ-rays from a sample and identifying the radioactive materials.

Scintillation detectors use the excitation of atoms in a special material called scintillator. When atoms in a scintillator are excited by a radiation, the scintillator emits light (photons) whose amount is proportional to the amount of radiation energy absorbed by the scintillator. These photons are measured with a very sensitive light sensor (usually photomultiplier). Scintillation detectors are used for the measurement of various physical quantities; radioactivity (Bq), radiation dose rate (μGy/h, μSv/h), count rate (cpm, cps). A variety of scintillator materials have been developed for various purposes. NaI scintillators are used for measuring γ-rays, ZnS scintillators are used for measuring alpha-rays, and plastic scintillators are used for measuring β and γ-rays.

Integrating dosimeters use special materials which can store the energy of radiations. One such detector is thermoluminescent dosimeters (TLD). A thermoluminescent material in a TLD stores the energy of radiations irradiated for a specified period of time, and it emits light (photons) when it is heated. The amount of the light is proportional to the amount of energy stored in the TLD, so we can know the total energy deposited in the TLD by radiations. TLDs are often used as personal dosimeters to know the radiation dose (Gy, Sv) of a radiation worker.

Lecture 5

Social Viewpoint on Nuclear Application: Economics and Social Acceptance

Ryuta TAKASHIMA, Tokyo University of Science

[Outline]

In this talk, we introduce social viewpoints on nuclear application by using three topics as cost and benefit analysis, low-dose extrapolation of radiation-related cancer risk, and public opinion for nuclear power. First, we explain the cost and benefit analysis using an example of radiation protection. An economics of polies and regulations have previously been evaluated by means of the cost and benefit analysis. In this talk, we introduce the ICRP model for the cost and benefit of radiation protection. In addition, an estimation of the benefit has been tired by many research groups. We explain an economic value as willingness-to-pay for deriving the benefit value, and show a numerical example. Next, we mention the model uncertainty of the function of the excess relative risk. Adopting the models for low-dose extrapolation of radiation-related cancer risk has been always discussed worldwide. Especially in Japan, recently growing attention about low-dose radiation risk has been occurred due to the Fukushima Daiichi Accident. In this work, we investigate a difference between the models for low-dose extrapolation of radiation-related cancer risk. We also show an implication of the difference by means of converting the risk to an economic value. Finally, we introduce an evaluation of a public opinion by means of the factor analysis. From viewpoints of public consciousness and knowledge dissemination, the Japan Atomic Energy Relations Organization has performed public opinion polls for nuclear power since 2006 in Japan. We analyze these polls results by using factor analysis in order to discover hidden factors included in the image of Japanese for nuclear power. We show what factors constitute the image for nuclear power. In addition, by observing the secular change of these factors, we confirm how the public awareness changes due to the impact of the Fukushima Daiichi Accident at the time of the Great East Japan Earthquake that occurred in 2011.

[Points for Education]

When policy makers evaluate an economics for policies and regulations, the cost and benefit analysis has previously been used. → What is the cost and benefit analysis? How is the analytical method used for policy decisions? The model uncertainty of the function of the excess relative risk is evaluated from a viewpoint of economic value as willingness-to-pay. → How can the risk be convert into the economic value? How is the model uncertainty discussed by using the economic value? The public opinion for nuclear power drastically changed before and after the Fukushima Daiichi Accident. → How does the Fukushima Daiichi Accident affect public opinion? Especially, which factor?

Lecture 6

Review of Radiation Basics

Takeshi IIMOTO, The University of Tokyo, Team JAPAN

[Outline]

α-particle, a Nuclei of Helium, emerges from unstable nucleus. β-ray, electron, also emerges from nucleus. γ-ray emerges as electromagnetic wave. X-ray emerges from the outside of a nucleus when an electron passes by near a big nucleus, apart from instability of nucleus. These are radiations.

Bq is the unit to show the level of radioactivity. Radioactivity gets weaker as time goes by. Physical half-life period is the time for the radioactivity to be reduced by half. Each radioactive substance has its own length of half-life period.

Sv is the unit of an indicator to show the possible effects of radiation on human body. We are always being exposed to radiation which comes out from atoms all over the place around our body. Japanese people are exposed to natural radiation about 2.1 mSv per year on average from four main natural sources; ground, eating foods, breathing air and cosmic space. UNSCEAR reports the annual representative world pubic dose as 2.4 mSv. Artificial radiation and radioactive materials are widely used, for example, in medical fields such as chest and stomach X-ray, CT scanning, and Interventional Radiology, etc. Having individual differences, some data shows that Japanese people are exposed to artificial radiation about 4mSv per year mainly for medical purposes on average. The epidemiological data of 120 thousand atomic bomb survivors of Hiroshima and Nagasaki to evaluate the radiation effects on human body. When our body is exposed to about 1,000mSv at one time, some people feel sick (nausea). In case of 4,000mSv, half of those who are exposed will die. Based on the epidemiological data, the risk to cause cancer seems to increase when our body is exposed to radiation over 100mSv at one time. Radiation protection system has been developed based on these data.

[Points for Education]

- ✓ Units of Bq and Sv are important to identify the level of radioactivity and exposure.
- ✓ Physical half-life is one of the major characteristics of radioactive materials.
- ✓ Knowledge on natural radiation would be a key for students to improve values on the level of radiation. UNSCEAR reports the annual natural dose in the world as 2.4 mSv, mainly from ground, eating foods, breathing air and cosmic space

Lecture 7

Radiation Protection Concept

Takeshi IIMOTO, The University of Tokyo, Team JAPAN

[Outline]

The aim of the recommendations of ICRP is to provide an appropriate standard of protection for people and the environment, without unduly limiting the beneficial actions giving rise to radiation exposure. The system of protection consists of types of exposure situations, types of exposure, identification of the exposed individuals, source-related and individual-related assessments, the three fundamental principles of protection, a description of levels of individual dose that require protective action, etc. Types of exposure situations are planned situations, emergency situations and existing situations. The three fundamental principles of protection are;

(1) The Principle of Justification is that any decision that alters the radiation exposure situation should do more good than harm.
(2) The Principle of Optimization of Protection is that the likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable (ALARA), taking into account economic and societal factors.
(3) The Principle of the Application of Dose Limits is that the total dose to any individual from regulated sources in planned exposure situations, other than medical exposure of patients, should not exceed the appropriate limits recommended by the Commission.

Under a planned exposure situation, as additional “dose limits,” 1 mSv per year is applied to the public exposure, and the annual average of 20mSv for five years is applied to the occupational exposure.

[Points for Education]

- ✓ The targets of the radiation protection are people and the environment.
- ✓ Types of exposure situations are planned situations, emergency situations and existing situations.
- ✓ The three fundamental principles of protection are; Justification, Optimization of Protection, and Application of Dose Limits.
- ✓ Dose criteria relating to radiation protection are dose limit, dose constraint and reference level.

Lecture 8

Radioactive Waste Management

Toshikatsu MAEDA, Japan Atomic Energy Agency

[Outline]

Core internals waste arouse from decommissioning of nuclear power plants contains relatively high concentration of not only short-lived nuclides but also long-lived nuclides having half-lives of longer than hundreds or thousands of years.

Therefore, it is necessary to protect the public and the environment from the influence of radiation caused by the waste over a long period of more than tens of thousands of years.

Nuclear Regulation Authority (NRA), Japan, has been discussing on new regulation for the intermediate depth disposal for core internals waste.

Fundamental measures for the safety after the end of the regulation period are isolation and containment. It is requested to select the site where is not expected to have volcanic activities and faults, and the facility is requested to be located at least 70m below the ground level for next 100,000 years. For long-term containment, optimized design using “Best Available Technique” is required for engineered barrier.

In addition, measures of institutional controls, as long as possible, will be implemented by the government including legal measures to prevent specific human actions (drilling, excavation, etc.).

[Points for Education]

- ✓ Fundamental measures for the safety over a long period of more than tens of thousands of years are isolation and containment.
- ✓ It is important that evaluation of volcanic activity, faults, uplift and erosion in next 100,000 years should be based on the history.
- ✓ No one can demonstrate nor predict accurately such a long-term future, it is important to improve robustness of disposal system and to reduce uncertainty of the evaluation.

Lecture 9

Nuclear Non-Proliferation and Nuclear Safeguards

Perpetua RODRIGUEZ, Invited Researcher, ISCN/JAEA

[Outline]

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is the centrepiece of global efforts to prevent the further spread of nuclear weapons. The NPT aims to prevent the spread of nuclear weapons and weapons technology, to foster the peaceful uses of nuclear energy, and to further the goal of disarmament. The Treaty establishes a safeguards system under the responsibility of the IAEA, which also plays a central role under the Treaty in areas of technology transfer for peaceful purposes. Under the Treaty's Article 3, each Non-Nuclear Weapon State is required to conclude a safeguards agreement with the IAEA. There are 3 different types of safeguards agreements which are based on the Model Safeguards Agreement, INFCIRC/153: Item-specific, Voluntary Offer and comprehensive safeguards. The corresponding verification activities performed by the IAEA are defined based on the relevant safeguards agreement signed by the State with the IAEA. These activities include the use of the non-destructive assay (NDA) and destructive assay (DA) techniques with containment and surveillance as complementary measures. The discovery of the clandestine nuclear weapon-related activities in Iraq in 1991 and the changing political framework in the period 1991-1995 brought the evolution of the safeguards system. In 1997, the adoption of the Protocol Additional, AP (INFCIRC/540) to the safeguards agreement gave the IAEA expanded authority for access to more information and to locations not involving nuclear material. The requirements of the AP bridged the gap/limitations identified under INFCIRC/153.

[Points of Education]

- ✓ Knowledge on the NPT and the IAEA safeguards system
- ✓ Familiarity with the IAEA nuclear-related verification activities
- ✓ Knowledge on the IAEA's scheme on drawing the safeguards conclusion

Lecture 11

Types of Accelerators and Their Applications

Mitsuru UESAKA, The University of Tokyo

[Outline]

Accelerators are devices to accelerate charged particles such as electron and ion to required energy for a diversity of applications, which are the most important in non-power application of nuclear technology. They are categorized into electrostatic type using DC voltage and RF (Radio-Frequency) type using AC voltage. Typical electrostatic accelerators are Cockcroft Wallton and Van de Graaff. RF accelerators consist of linear accelerator (hereafter linac), cyclotron and synchrotron. For electron, electrostatic type is chosen for below a few MeV, linac for a few ~ 100 MeV, and synchrotron for 100 MeV ~ GeV. In case of ion, electrostatic is for up to a few MeV, lineac for tens MeV, cyclotron and synchrotron for tens MeV ~ GeV. By hitting accelerated particles to solid/liquid/gas target, we can generate secondary particles such as X-ray, g-ray, neutron, positron, etc. Applications of accelerators are science, semiconductor production, medicine, agriculture, sterilization, material development, nondestructive evaluation, etc. Choice of accelerators depends on what kind of reaction to be induced, observed and utilized and target size. Bonding energies of nucleons, nucleus – electrons, molecules are in the ranges of MeV, keV and eV, respectively. Thus, if you want to induce nuclear, atomic and chemical reactions, we need particles of energies of more than MeV, keV and eV. Ion doping to semiconductor needs hundreds keV, and sterilization for smaller than 1 m^3 needs few MeV. 6 MeV electron linac X-ray source, 200 MeV proton cyclotron and 300 MeV carbon synchrotron are appropriate for cancer therapy. Moreover, advanced compact accelerator development and application are also introduced. Higher RF frequency technology, superconducting magnet, 2D/3D layout optimization and laser technology enable downsizing of accelerators from room-size to portable and table-top for a variety of applications recently. Since RF accelerating structure is a resonant cavity, X-band (9-12 GHz, l=30 mm) linac become robot-arm-type compared to gantry-type of conventional S-band (2-3 GHz, ~100 mm). X-band therapy linac can enter X-ray CT diagnostic machine so that both diagnosis and therapy are available by one machine. Superconducting magnets with shorter bending radius make cyclotron and synchrotron remarkably small. Even superconducting cyclotron becomes gantry-type to rotate around a patient for multiple direction irradiation. Superconducting magnet beam line gantry can also rotate around a patient. Portable X-band linac X-ray/neutron source is successfully applied to on-site inspection of bridges recently. Laser plasma ion source is expected to be adopted to superconducting carbon synchrotron for cancer therapy in future.

[Points for Education]

- ✓ Type of accelerators such as electrostatic accelerator, linac, cyclotron and synchrotron
- ✓ Applications and choice of particle and energy
- ✓ Electron linac X-ray source, proton cyclotron and carbon synchrotron for cancer therapy

Lecture 12

Extracurricular Activities of Nuclear S&T

Kayo MAKABE, Japan Atomic Energy Relations Organization

[Outline]

After the Fukushima Dai-ichi Nuclear Power Plant accident, Japan's energy policy changed from promotion of the necessity and the safety of nuclear power generation to considering the impact of Fukushima accident and public opinion, the need for nuclear energy weakened energy policy. As a result, the government projects for promotion were reviewed, many of which were abolished by the government ruling party at the time (Democratic Party of Japan). Along with that, the budget and few projects related to radiation and energy education have been greatly reduced, but the importance of energy education and radiation education remains unchanged in Japan.

In fact, the related organizations are aware of the necessity of education, and there are many teachers who need accurate information and knowledge. In such situation, we continue various activities for the secondary school.

I will introduce popular business in the trust project of the government and our voluntary business which we carried out for secondary school. Through JAERO's experience, we've consider that the important thing is sustainable activities for teachers.

We hope that our information will be helpful for participating countries, when they will plan new education curriculum and extracurricular activities in their country.

[Points for Education]

- ✓ Motivation of the student, teacher and school
- ✓ Continuity of cooperation by government and experts
- ✓ Sustainable frameworks

Lecture 14

Radiation Education Thinking from Fukushima

Katsuhiko YAMAGUCHI, Fukushima University

Since the accident at TEPCO Fukushima Daiichi Nuclear Power Plant (1F) that occurred in 2011, radiation education in various forms has been conducted in elementary and junior high school and high school in Fukushima prefecture. The radiation education includes not only science, but also wide-ranging contents rooted in life in Fukushima prefecture, including disaster education, food safety, rumor damage, moral education, and so on. In this lecture, through introducing these efforts, I would like you to understand the three principles of radiation protection and the recognition of natural radiation which are important as the basis.

In local government in Fukushima prefecture close to 1F, there are schools where evacuation still continues, and schools that have just returned. In such schools, comprehensive learning that learns about home is vigorous, for example, "Why did you have to evacuate?" "What are the points to keep in mind after returning?" “What kind of operations have been done for reconstruction? ", so on. With the developmental stage of students, it is the content to acquire the basis of radiation such as the principle of radiation protection and external radiation exposure, internal radiation exposure etc.

In the commercial and industrial zones in the prefecture, classes are being conducted for human resources development of decommissioning furnace and nuclear disaster prevention. It is expected that students will be interested in the technical field through learning the current situation of 1F and learning about advanced technologies such as robots to be introduced into the decommissioning furnace. In the class of nuclear disaster prevention, the municipal officials announced about the necessity of information to evacuate indoors and judge evacuation outside the prefecture according to the situation.

On the other hand, in areas far from 1 F, rumor damage and moral education etc. are focused. Fukushima Prefecture produces a lot of agricultural crops, but there was the fact that the shipment volume was greatly reduced due to rumor damage. Students learn that farmers have measured the radiation of products continuously to restore the shipment volume, but that such a steady effort is not yet known in foreign countries. And it is contents to think about what students can do in the future for the region.

The characteristic feature of radiation education in Fukushima prefecture is that subjects learning radiation are not limited to science, but are being implemented in mathematics, society, home economics, morality, disaster prevention education, career education and so on. I expect that you will be able to conduct radiation education with a broad perspective according to the current situation in your country.

Lecture S-3

Sustainability of HRD on Nuclear S&T and Its Motivation

Sunil Sabharwal, International Atomic Energy Agency

Summary

The significant industrial and economic growth in Asia and the Pacific involving nuclear science and technology (NST) requires an increase in the demand of human resource development in the nuclear sector. Despite the potential of nuclear science and technology to solve or mitigate regional challenges for development, the field remains largely unknown to the public, especially the youth. Furthermore, there has been a decline in the number of students who are taking up science and technology related courses in general, more so nuclear related courses.

A variety of factors limit the number of students who might ever consider a career in nuclear science and technology. Among others, the inappropriate and inaccurate treatment of nuclear topics in primary and secondary curricula, absence of regularly taught undergraduate courses in nuclear science and technologies at university level, constitute the major factor. For a student in the formative years at the school education level, the syllabus for nuclear science and technology is basic, inadequate and, in most Member States, even non-existent. The IAEA recognized this need for encouraging introduction and strengthening of nuclear science and technology education in secondary schools to support sustainability of peaceful applications of nuclear technology in Member States. Therefore, in 2012 a new TC programme RAS0065 that focused on addressing these factors by introducing nuclear science and technology in secondary schools in the Asia-Pacific region, by supporting the implementation of outreach activities to potential future nuclear scientists, engineers and technologists through specific extra-curricular activities and exercises. The Agency provided support to the project by enabling the transfer of knowledge and technologies through technical cooperation inputs such as regional meetings, regional training courses, scientific visits and fellowships, expert visits and national consultancies. The implementation the IAEA TC project RAS/0/065 during 2012-2016 provided valuable expertise in successfully introducing NST in secondary schools in the Asia-Pacific region in pilot countries to promote the nuclear science and technology to allow students to experience use of nuclear science in problem solving in everyday situations. The project led to development of information, education and communication materials and hands-on exercises, as well as co-curricular activities have made nuclear concepts more interesting to the younger generation. Countries that implemented the pilot activities demonstrated the success that can be achieved by the engagement of two sectors – the nuclear sector to provide the technical and scientific expertise and the educational sector to ensure the delivery of the topics in the classroom. Encouraged by the success achieved, a new IAEA TC project RAS/0/079 – "Educating Secondary Students and Science Teachers on Nuclear Science and Technology" has been initiated to now expand the project to all the Member States in the Asia-pacific region for the cycle 2018-2021 with a challenging task of reaching one million students. The specifics of the activities implemented under the RAS0079 so far, the way forward and expected action plans are detailed in this lecture.

Experiment 1a

Cloud Chamber Observation

Takehiro TODA & Rieko TAKAKI

[Outline]

A cloud chamber is a particle detecting device used for visualizing the passage of ionizing radiation. Cloud chamber significantly contributes to radiation education facilitating observations of particle tracks formed by nuclear decays, natural radiation or associated experiments.

Various experiments can be done by using cloud chambers.

1. Observation of tracks of natural radiations
   - Tracks of α-ray Thick clouds with a length of several centimeters
   - Tracks of β-ray Thinly crushed clouds like lint
   - Tracks of Cosmic-ray Long clouds of Muon from outer space
2. Compton scattering experiment
   - Compton scattering occurred a gamma ray inside the cloud chamber, and the tracks of emitted electrons are observed.
3. Tracks of α rays and βrays emitted from radioactive minerals
   - Place Euucenite and Radium ball inside the cloud chamber and observe various tracks
4. Observation of tracks of radiation coming from radioactive materials in the air
   - Using a dust sampler, adsorb the radioactive materials in the air to the filter paper, and place it in the cloud chamber.
5. Half-life experiment
   - Inject the Radon gas into the cloud chamber. Observe the track of α decay leading to 220 Rn → 216 Po → 212 Pb.
6. Observation of Compton scattering by X-ray
   - Using the Gisler tube (1 mmHg or more) and the Crux tube (0.1 mmHg or less) trace the history of radiation detection.
   - Place the X - ray tube on the cloud chamber and generate X - rays.

There are several types of cloud chambers. Each cloud chamber has its own characteristics and educational purpose.

Dry Ice cooling type, Peltier element cooling type, Liquid nitrogen cooling type, Compressor cooling type, High Temperature Diffusion Type, and High Temperature Diffusion Type.

[Points for Education]

- ✓ By conducting various experiments using cloud chambers, students can learn radiation visually.
- ✓ Depending on the situation and purpose, it is necessary to choose appropriate kind of cloud chamber.

Experiment 1b

Illustrating Radiation Properties Using a Hand-Made Air GM Counter

Team Tokyo, The University of Tokyo

A team of scientists from the Japan Science Museum developed a hand-made air GM counter as a teaching aid for radiation education. In this practical exercise, participants of the IAEA TTWS 2019 will have an opportunity to appreciate the role of simple and relatively low-cost innovations in enabling understanding of radiation concepts through practical illustrations. Participants will first assemble their own GM tube before completing the whole GM counter assembly. Then, they will use the assembled GM counter to conduct experiments that illustrate the inverse square law, the effect of shielding, and the exponential nature of radioactive decay. Other attributes that will be highlighted in this experiment are the statistical fluctuation of radiation and the ubiquity of radiation in the surrounding environment.

Experiment 2

KIND-pro experiments for environment survey, shielding and distance, calibration

Taichi KATO & Tomohisa KAKEFU, Japan Science Foundation

[Outline]

According to the report UNSCEAR reports 2008, the estimated value of worldwide average annual exposure to natural radiation sources is 2.4 mSv. External exposure is the total cosmic (including cosmogenic) radiation (0.39 mSv/y) and the total external terrestrial radiation (0.48 mSv/y). Internal exposure is the total inhalation exposure (1.26 mSv/y) and the total ingestion exposure (0.29 mSv/y).

KIND-pro can survey natural radiation of external exposure. KIND-pro senses Gamma-ray with CsI (Tl) Scintillator. KIND-pro provides 4 display mode so that teachers can choose modes for their educational target. KIND-pro also has data logger function to facilitate curriculums involving ICT and radiation education. Furthermore, 'Simple Calibration' enables comparison of the radiation dose between some survey meters.

In addition to environment survey, experiments using samples, simulation of screening, and experiments of distance and shielding, are also possible with KIND-pro. The variation of experiments enables providing Wow-factors for students.

With the progress of experiments, questions will arise, i.e. 'Why the radiation dose is different in locations?', 'What kind of radioactive isotope is contained in NORM (Naturally Occurring Radioactive Materials)?', or 'How can we save ourselves from external exposure?'. Discussing these questions might be helpful for understanding of radiation education.

[Points for Education]

- ✓ Radiations are emitted from radioactive materials. According to the reason of Natural emitted natural radiation, we can recognize the difference from each radiation dose.
- ✓ Clarifying targets and purposes of radiation education, we can design the curriculums through experiments.