RADIATION RE-EDUCATION MATERIALS THE UNIV. OF TOKYO DOC No.37 (2019)

1. Trends Concerning the Unit of Sievert (Sv) and Main Points

Sievert (Sv) is used for radiological protection as the universal unit of radiation. If physical quantities of radiation, i.e. fluence, kerma and absorbed dose, were used for radiological protection, the practice involving radiation regulation and management would get more complex. This is because the magnitude of radiation health effects is directly influenced by the types of radiation and exposure. Use of a single dose indicator would provide an easily understandable practice in radiological protection. Effective dose has emerged from the historical background on comparison between internal exposure of radon and external exposure. The magnitude of a radiation health effect indicates the risk of cancer and hereditary effects in low doses as expressed by probability that the diseases occur. Effective dose, E, is the sum of double weighted absorbed doses in all the organs and tissues. The intermediate quantity for calculating E is equivalent dose denoted by H.

$$E = \sum_T w_T \sum_R w_R \, D_{T,R}$$

$$H = \sum_R w_R \, D_{T,R}$$

The first weight is called as a radiation weighting factor (w_R) for radiation R, and can deal with all different radiations in a consistent way. The mean energy lost per unit distance in a material traversed is called Linear Energy Transfer (LET) and generally, radiation with a different LET provide a different biological effect leading to a different risk if the same absorbed dose is given. For instance, neutron and alpha radiations show higher biological effects than gamma and X-rays. Radiation weighting factors are defined as the relative values compared with gamma radiation, w_R=1. The second weight is called as tissue weighting factor (w_T), and shows the relative value of risk per Gy in an organ. The total of the tissue weighting factors is 1 for all the organs and tissues. For instance, E of a partial exposure in a body can be compared with of a whole-body exposure. In addition, E of internal exposure with different organ doses can be compared with of external exposure that is uniform over the whole body.

Average effective dose from natural radiation is estimated to be 2.4 mSv/y in the world. The doses can break into the external dose from terrestrial and cosmic radiations, and the internal doses from inhalation of radon and its progeny and from radioactive potassium in foods. The quantification of exposure can be easily expressed as a single number irrespective of different radiation and external/internal exposures.

Recently, some issues have been raised regarding effective doses. First, it is confusing that the unit of E is the same as of equivalent dose. It has been pointed out that use of equivalent doses is not appropriate for limitation of deterministic effects. Previously the equivalent doses to eyes and skin have been used for avoiding the tissue reactions because the dose multiplied by the Relative Biological Effectiveness (RBE) can be conservatively estimated. The latest International Commission on Radiological Protection (ICRP) reported that a new approach adopted will use absorbed doses in setting limits on organ/tissue doses to prevent tissue reactions. Equivalent doses should be considered as an intermediate quantity for calculating effective doses. Equivalent doses should not be used independently. Sieverts should be a unit of effective dose as a protection quantity to limit the stochastic effects. Effective doses focus on the risk of cancer and hereditary effects from exposure to low doses, and are applied in the range below 100 mSv, exceptionally, it can be used below about 1 Sv in an emergency exposure situation. It should be noted that the RBE of high LET radiations for tissue reactions are required for radiation protection while it is clear that absorbed doses will be used for limiting tissue reactions.

In the second issue, effective doses are sometimes used for risk projection. Primarily, effective doses are a tool for compliance by comparing some criteria and optimization, and thus should not be used for risk projection. In some practice, however, easy risk calculation has been used since effective doses are supposed to reflect radiation health

effects. The radiation-related health risk depends on sex, age at exposure and population that differs from cancer baseline rate. Tissue weighting factors are averaged over sex and age in a hypothetical population, and are unable to estimate a specific age risk. Effective doses have been built for a world-wide dose indicator for radiological protective decision.

In medicine, the doses such as entrance air kerma and Computed Tomography Dose Index (CTDI) are used for a specific patient. These doses are useful for some purposes but do not provide risk comparison among facilities, instruments or procedures. Effective doses are a useful tool for improving radiological protection of patients. When one compares the calculated risk of a medical examination based on the effective dose and nominal risk coefficient with the risk profile calculated by taking a specific age and sex into account, the effective dose could provide information to clinicians and patients for broadly distinguishing medical procedures for risk communication. However, effective doses are not an appropriate risk indicator for risk projection, although E has been built to quantify the approximate risk showing the magnitude of radiation effect for radiological protection.

Sieverts can provide radiation detriment based on the cancer risk averaged over composite populations of seven Westerns and Asian countries. In radiological protection, health risk is proportional to the dose even if low, below 100 mSv, and is also assumed to be the same even in acute or chronic exposure. The epidemiological studies of atomic-bomb survivors following high dose-rate exposure underlie current risk estimation. It would be important to clarify the uncertainty of the cancer risk at low dose and lose-dose rate. Furthermore, it is necessary to estimate the risk that can consider the modifying factors such as lifestyle, smoking and alcohol drinking, and population characteristics in addition to age and sex.

◆Reference

[1] Harrison, JD. et al. 2016. Use of effective dose. Ann. ICRP 45(1S), 221-228

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Re-education Theme : Topics

2. Bystander Effect and the Radiation Adaptive Response

Conventionally, the influence of radiation has long been thought that DNA in the nucleus of directly irradiated cells becomes a target, and that irradiated cells themselves are involved in mutation and cancerization.

However, since the 1990s, it has been confirmed in many laboratories around the world that there is an influence on surrounding unirradiated cells. Specifically, when irradiating a group of cells with a low dose of radiation, both directly irradiated cell and surrounding non-irradiated cells experience genetic instability, DNA damage, chromosomal abnormalities, cells.

A wide variety of radiation effects such as division / growth inhibition, apoptosis (cell suicide), induction of mutation and so on have been observed. Subsequently, this phenomenon was termed "bystander effect", suggesting that signaling between cells directly irradiated with radiation and non-irradiated cells plays an important role in the mechanism.

Currently, as a cause of the bystander effect, it is thought that gap bonding as an intercellular adhesion device, reactive oxygen (ROS) which is a signal molecule between cells, nitric oxide and cytokines are closely involved. It has also been reported that signaling via adenosine triphosphate (ATP), an energy donor, and ATP receptor (P2 receptor) expressed on the cell membrane, is involved. For example, in experiments using cultured cells (human normal cells), a drug that closes a small tunnel (gap junction) connecting adjacent cells in close proximity secreted active oxygen into the culture solution.

Results such as suppression of the bystander effect by adding a drug to capture and neutralize seeds are obtained. In classical ・traditional radiobiology:

1) There is no qualitative difference between irradiation of low dose and high dose.
2) There was a premise that it was thought that only hit cells were affected.

However, these premises are actually wrong, especially with low dose radiation, it is clear that:

1) The contribution of the biological response influences the irradiation effect.
2) It is not limited to the directly hit cells. It is getting on.

An example of the former is "radiation adaptive response", an example of the latter is "bystander effect".

The radiation adaptive response is a phenomenon that exhibits resistance to irradiation of a high dose after prior irradiating with a low dose of radiation. For example, if you irradiate a dose (0.5 Gy) that is not particularly affected two weeks before the mice are irradiated with a lethal dose (6.5 Gy), the survival rate after one month from the irradiation of lethal dose increases from 10% to 80% It is reported that it increased to 80%. In order to demonstrate such a life-saving effect, the timing and dose of preliminary irradiation are very important. Although details of the mechanism are unknown, induction of enzymes related to radio-resistance is considered to be one of the causes.

There is also a report that the effect transmitted by the bystander effect induces not only the injury effect of radiation but also defense action and resistance against radiation like radiation adaptive response, suggesting an aspect of working at the organization level defense. It is thought that the same work is probably occurring among normal individuals, and it is now expected that the complete mechanism of the molecular mechanism of the bystander effect is elucidated.

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3. Transfer of Radioactive Materials

When using radioactive isotope in other facilities, it should be properly managed according to laws and regulations. We will confirm necessary matters for delivery and transport from a radiation facility.

1 Delivery of radioactive material

When using radioactive isotope in other facilities, it should be confirmed that the facility is permitted to use. Confirm not only the nuclide of radioisotope but also radioactivity. The confirmation item for the sealed source is radioactivity matching and quantity of material does not exceed the upper limit, and for unsealed source is radioactivity does not exceed the storage capacity. If the same nuclide is already stored at the facility, it will be confirmed that the total activity will not exceed the storage capacity.

When delivery from the facility, we need "payment record". The date of departure from the facility, the name of the receiving facility, the nuclide of the radioactive isotope, and the radioactivity (in the case of a sealed source, also the quantity) are recorded.

When delivering, it is good to have and keep the receipt for proof that the recipient has received.

2 Transport of radioactive material

2.1 Laws and regulations of transport

To transport radioactive materials, it must comply with various laws and regulations. Depending on the transport mode or the type of radioactive material, the regulations will differ. All applicable laws and regulations must be observed and compiled with.

2.2 Package

The type of radioactive package is divided by the combination of the storage (radioactive material) and the transport container. Typical packages are Type L, Type A, Type B packages.

Type L packages: Package with very low radioactive isotope radioactivity contained in one package. It limits the radioactivity to be stored and makes the danger extremely small.

Type A package: The stored radioactivity is below the limit. The package has strength to withstand traffic accidents.

Type B packages: The stored radioactivity exceeds the limit value. Safety will be secured by using a strong transport container that can withstand serious accident.

Technical standards for type L packages are shown below.

Activity of radioactive materials are less than a limit (1/1000 of A1 value or 1/1000 of A2 value) specified for each nuclide.

Transport containers should be constructed that there is no fear of cracking or breakage during transportation and that it can be handled easily and safely. We keep a condition readable as "radioactive" in a position which is easy to see when the shipping container is opened. We should not put the document except necessary documents in a container. The dose rate on the surface of the package should be 5 μSv / h or less. It should be satisfying the conditions stipulated to ensure safety.

In the case of type A or B packages, the storage radioactivity becomes larger and restrictions of transport containers becomes severe. It is necessary to perform a drop test, penetration test and more because it is required that performance can be maintained in case of an accident. Further for Type B packages, it is necessary to Immersion test.

In addition to these requirements, in case of uranium hexafluoride or fissile nuclear fuel material, it is necessary that the material do not reach the critical state.

2.3 Transport vehicle

There are restrictions also on the truck carrying the package. Dangerous goods such as explosive substance and

high-pressure gas cannot be put on the truck together.It should be piled up so that the safety of the package to keep during transportation. And, confirm that the dose rate of the driver's seat, the surface of the vehicle and so on is lower than the limit level.

It is necessary to confirm, because restrictions change depending on the type of packages.

3 Emergency

We should act calmly, if accidents or disasters happen while transporting.

Firstly, secure own safety. If there are injured people, we will make an emergency call to the fire department and rescue and move the injured person. In case of fire, call to the fire department. we will try to extinguish the fire or to prevent the spread of the fire.

Next, we will check for the safety of radioactive packing on trucks. If you see abnormalities such as breakage, send the picture to the manager and ask directions. When handling abnormal packages, you should avoid handling with bare hands by using gloves or more. If you can contact your manager, you must follow the instructions and take actions such as restriction on entry.

When transporting, it is necessary to carry documents containing emergency contacts. If an accident happens, we will act according to the documents.

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4. Points of Attention about Revision of Radiation Hazards Prevention Program at The University of Tokyo

Introduction

As written in the last year's radiation re-education materials[1], amendment of the act and regulations concerning radiation has been done since last year. The new act (Act on the Regulations of Radioisotopes, etc.) and regulations will enforce in 1st September 2019. In accordance with the amendment of Article 21 of the NRA Ordinance, all authorized users shall revise their Radiation Hazards Prevention Program and notify the Nuclear Regulatory Authority, Japan before 30th August 2019. The NRA indicated items that must be included in Radiation Hazards Prevention Program as described in "Guide on Matters to be defined in Radiation Hazards Prevention Program (No. 17121320)"[in Japanese][2]. The table shows where the revision is required.

Table. A comparative table of the prior and amended article provisions shall be provided in Radiation Hazards Prevention Program

Article 21. of Ordinance after amendment	Before amendment
1 matters concerning the duties and organization of radiation protection supervisors and other persons engaged in safety management in handling of radioisotopes, etc. or radiation generating apparatuses (including the duties and organization of persons engaged in handling of radioisotopes, etc. or radiation generating apparatuses)	1 matters concerning the duties and organization of persons engaged in handling of radioisotopes, etc. or radiation generating apparatuses
	1-2 matters concerning the duties and organization of radiation protection supervisors and other persons engaged in safety management in handling of radioisotopes, etc. or radiation generating apparatuses
2 matters concerning of a deputy of a radiation protection supervisor	1-3 matters concerning appointment of a deputy of a radiation protection supervisor
3 matters concerning the maintenance and management of radiation facilities (including management of persons who enter an area not regarded as controlled area pursuant to the provision of Article 22-3 Paragraph 1) and the inspection of radiation facilities (controlled area in cases where a notification user uses sealed radioisotopes or manages wastes of sealed radioisotopes or objects contaminated with radioisotopes)	1-4 matters concerning the maintenance and management of radiation facilities (including management of persons who enter an area not regarded as controlled area pursuant to the provision of Article 22-3 Paragraph 1)
	1-5 matters concerning the inspection of radiation facilities (controlled area in cases where a notification user uses sealed radioisotopes or manages wastes of sealed radioisotopes or objects contaminated with radioisotopes)
13 matters concerning provision of information in cases where radiation hazards are likely to occur or have occurred	-
14 matters concerning required items to take measure emergency responses as described in Article 21 Paragraph 1 that those set forth in the following Items (limited to using radioisotopes or radiation generating apparatus provided for the NRA) a matters concerning the duties and organization of persons engaged measured to emergency responses b matters concerning maintenance of required facilities or equipment engaged measured to emergency responses c matters concerning procedure for implementation of emergency responses d matters concerning enforcement of training about emergency responses e matters concerning cooperation with prefectural police, fire services and medical institution or other related organs	-
15 matters concerning business improvement for prevent radiation hazards (limited to specified license user or license waste management operator)	-

Policies of amendment of Radiation Hazards Prevention Program at the university of Tokyo

Radiation Hazards Prevention Program should be established as local rules for each authorization user based on actual circumstances and revise as necessary. However, heath surveillance and education and training are carried out collectively at the university of Tokyo, and provision of information in case of accident will also be carried out collectively. Therefore, the Radiation Management Department of Division for Environment, Health and Safety decided to show common policies for some points. The examples are shown below.

1. Position of Radiation Hazards Prevention Program

   Radiation Hazards Prevention Program is regulations of each departments. Therefore, the organization representative (the final responsible person in radiation safety management at each authorized user) shall be Dean or Director.

2. Items that cannot be defined in the Radiation Hazards Prevention Program

   Such as the position of the Radiation Management Department of the Environmental Safety Division as the safety management organization of the university of Tokyo, items that cannot be defined by the regulations of

each department, that should refer to the upper rules and regulation and not describe in the Radiation Hazards Prevention Program. The upper rules and regulation that are follows.

(1) Management Rules for Prevention of Radiation Hazards at the University of Tokyo (rules and regulations at the University of Tokyo)

(2) Regulations on the Environment, Safety and Sanitation of the University of Tokyo Faculty and Staff (rules and regulations at the University of Tokyo)

(3) The University of Tokyo Environmental Philosophy - The University of Tokyo Environmental Basic Policy (President decision)

(4) Responsibility and authority of the University of Tokyo's environmental, health and safety management organization (President decision)

(5) The University of Tokyo Division for Environment, Health and Safety internal regulations (President decision)

(6) Policies concerning education of radiation at the University of Tokyo (Radiation Management Department) decision

(7) Policies concerning radiation heath surveillance at the University of Tokyo (Radiation Management Department decision)

(8) Policies concerning assessment prevention of radiation hazard process at the University of Tokyo (Radiation Management Department decision)

The contents of rules and regulations at the University of Tokyo and the President decision are published on the website (inside the campus only) [3, 4]. The details of Radiation Management Department decision are not published now, however will be published soon.

3. Education and Training Contents

Three items require to be described in Radiation Hazards Prevention Program; procedure for determining content of education and training, criteria for omission and revising or abolishing procedures, change and improvement of content or time. These items will be determined by the Radiation Management Department. Re-education and training will be done independently by each authorization user as of the current situation.

4. Standards concerning taking measures for disasters such as earthquakes

In accordance with a predetermined reporting system at the time of accident, inspection shall be conducted on the item specified separately by the person specified in advance, and the result shall be reported to the Dean or Director, facility director, radiation protection supervisor and environmental safety headquarters the head of Division for Environment, Health and Safety.

5. Provision of information (newly established)

In the case of radiation hazard or likelihood that require reporting of accidents, to provide for information with public or press inquiries, the facility director cooperates with the Division for Environment, Health and Safety to post on the website about the accident situation and extent of damage, etc. And a contact desk will be set up within the authorization user in order to respond to inquiries from outside.

6. Improvement of work at specified license user (newly established)

Specified license user is defined as “who stores the quantity 100,000 times of the lower bound quantity for each kind of unsealed radioisotopes” or “who uses over 10 TBq for a sealed radioisotope” or “who uses radiation generating apparatuses”. In the University of Tokyo, specified license user corresponds to Isotope Science Center, the Hospital, Graduate School of Frontier Sciences, Institute of Medical Science, IMSUT Hospital, Nuclear Professional School, Kamioka Observatory of Institute for Cosmic Ray Research, and Micro Analysis Laboratory Tandem Accelerator. For these specified license users, the Radiation Management Department plans to hold a meeting to report on the status of each facility and ask for opinions once a year.

Points of attention for a radiation user

All authorization user will enforce revised Radiation Hazards Prevention Program in this year. Most of the major revisions are concerning the roles and authorities of the managing system. However, at the time of this revision, each

authorization user should review the contents according to their actual situation. Even after revision of Radiation Hazards Prevention Program, the NRA requests an aggressive review in accordance with the actual situation of each authorization user. Because of necessary to notify the NRA within 30 days after revision of the Radiation Hazards Prevention Program, it is expected that many authorized users will create the lower regulations that do not need to be notified. In particular, please be sure to check the reporting system at the time of accident. Also, please check the other necessary items, including the lower regulations.

◆References

[1] Radiation re-education materials the Univ. of Tokyo No.36 (2018), https: //www.ric.u-tokyo.ac.jp/reeducation/reeducation36e.pdf

[2] Nuclear Regulatory Authority, "Guide on Matters to be defined in Radiation Hazards Prevention Program (No. 17121320)" [in Japanese], http://www.nsr.go.jp/data/000215736.pdf

[3] Rules and Regulations at the University of Tokyo (inside the campus only), https://www.u-tokyo.ac.jp/en/about/rules_main.html

[4] UTokyo Portal (inside the campus only) [in Japanese], https://www.ut-portal.u-tokyo.ac.jp/wiki/index.php/総長裁定

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5. Safety Control of X-ray Irradiators

The University of Tokyo has approximately 300 X-ray irradiators for researches. There are a wide variety of types, and various levels of safety functions to prevent exposure accidents. This document shows important issues when using or managing X-ray irradiators. For detailed information, please refer to the convenience book page* of Division for Environment, Health and Safety.

As a general premise, for an operator or an administrator of X-ray irradiator followings are required.

- ✓ When installing a new irradiator, do not forget predetermined procedures in advance through the safety manager of the faculty.
- ✓ Do not modify or release safety devices to prevent exposure accident of x-rays.
- ✓ During beam adjustment and maintenance, turn off the X-ray power and make sure that the safety beam shutter is closed.

Especially for an operator of X-ray irradiator followings are required.

- ✓ A person who operates X-CDE irradiator (whose exposure risk is assumed to exist outside of the devise) should wear a personal dosimeter at the specified position.
- ✓ Create and maintain operation records
- ✓ Open and close the safety beam shutter after checking for the irradiation status of X-rays
- ✓ If you notice any abnormalities, immediately turn off the X-ray and contact the equipment administrator
- ✓ When sharing one X-ray irradiator with multiple laboratories or researchers, display the operator's name during the time of use. In addition, check the status inside of the device before use, and return to the basic settings after use.

Especially for an administrator of X-ray irradiator followings are required.

- ✓ Shield it based on measurement results and usage conditions if necessary
- ✓ Display the emergency contact information, results of dosimetry, feature information on the equipment, and X-ray administrator's name
- ✓ Conduct periodical inspections once a year determined by The University of Tokyo for all devices, and for X-CDE irradiators, check the working environment as defined by laws and ordinances (every six months for use at a fixed point)

Recently, most of X-ray irradiators used for researches and educations has been designed with a consideration of safety. It is important to fully understand the structure and characteristics of the safety equipment in order to operate and control it.

※ Reference Portal-site Page: Access UTokyo Portal Manuals (https://www.ut-portal.u-tokyo.ac.jp/wiki/) and select as follows.
環境安全本部〉環境安全本部一覧〉エックス線装置・電子顕微鏡

◆References

[1] Eriko HAYASHI, Yuya KOIKE, Keiji KIMURA, Takeshi IIMOTO, Toshiso KOSAKO and Yuko NAKANISHI; Category Management for Safety Control of Various X-Ray Equipments Used for Researches , *Radioisotopes*, 58, 195-207 (2009) (in Japanese)

[2] Takeshi IIMOTO, Eriko HAYASHI, Keiji KIMURA, Takahiko SUZUKI, Asaya KOBASHI and Satoru TANAKA; Optimized Safety Management for X Ray Irradiators with Various Levels of Potential Exposure Risk Used for Researches; Radiation Emergency Medicine *Vol. 3, No. 1*, 45-49 (2014)

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