Development of Guidelines on Radiation Protection for the Lens of the Eye in Japan

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Abstract. In Japan, new regulations that revise the dose limit to the lens of the eye (the lens), operational quantities, and measurement positions for the dose of the lens will be enforced from April 2021. Based on the International and national guidelines, the results of the Radiation Safety Research Promotion Fund of the Nuclear Regulatory Authority (NRA), and other studies, the Working Group of Radiation Protection Standardization Committee, the Japan Health Physics Society (JHPS) developed the guideline on the radiation monitoring for the lens. In July 2020, the guideline was published by the JHPS. The guideline consists of five parts, a main text, explanations, references, three attachments and twenty-six questions. In the questions, the corresponding answers were prepared, and specific examples were given so that similar cases could be dealt with. In the Working Group, specifically time was spent discussing judgment of the criteria of non-uniform exposure and the management criteria set to not exceed the dose limit to the lens. With the development of the guidelines on the radiation monitoring of the lens, the radiation managers and workers will be able to smoothly comply with revised regulations and optimize radiation protection.

KEYWORDS: dose limit to the lens of the eye, guideline, radiation monitoring, operational quantities, management criteria, non-uniform exposure, Japan Health Physics Society

1 INTRODUCTION

From July 2017 to February 2018, the subcommittee of radiation protection of the lens of the eye (the lens) of the Radiation Council, Japan discussed implementation of the International Commission on Radiological Protection (ICRP) new dose limit to the lens [1] for Japanese regulations related to radiation protection for radiation workers and published the subcommittee report[2]. The Council judged that it is appropriate to revise current Japanese regulations, as recommended in the ICRP Statement on Tissue Reactions; equivalent dose limit of the lens should be 20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv[1]. The Council also recommended to revise the regulations so that the personal dose equivalent with 3 mm depth, $H_p(3)$, can be monitored to estimate the equivalent dose to the lens more accurately, but it is not mandatory to measure $H_p(3)$ if it was possible to estimate the equivalent dose of the lens by using 1 cm dose equivalent, $H_p(10)$, or 70 μm dose equivalent, $H_p(0.07)$, adequately. In addition, there are various exposure fields such as the medical sector, therefore, it was expected that related academies would prepare guidelines or some documents. The

Council recommended to take necessary measures for related regulations with reference to the subcommittee report.
In December 2018, the Ministry of Health, Labor and Welfare (MHLW), Japan, which has regulations related to occupational health, started to discuss implementation of the dose limit and the monitoring of the lens of the eye recommended by the Council[3]. All related regulations submitted by the relevant government agencies to the Council, and these were consulted by the Council until July 2020[4]. The Council reported that all revised regulations properly reflect their recommendation, however, they commented to a government agency on the thoroughness of dosimetry and reports of doses to decommissioning workers[5]. The all-related regulations will be hereby enforced in April 2021. The equivalent dose limit to the lens of the eye will be revised from 150 mSv/y to 100 mSv/5 ys and 50 mSv/y. The 3mm dose equivalent, $H_p(3)$, will be added to current operational quantities for the lens dose monitoring, the 1 cm dose equivalent, $H_p(10)$, and the 70 μm dose equivalent, $H_p(0.07)$. The measurement regions and operational quantities under the current regulations and after the revisions are shown in Figures 1 and 2, respectively.

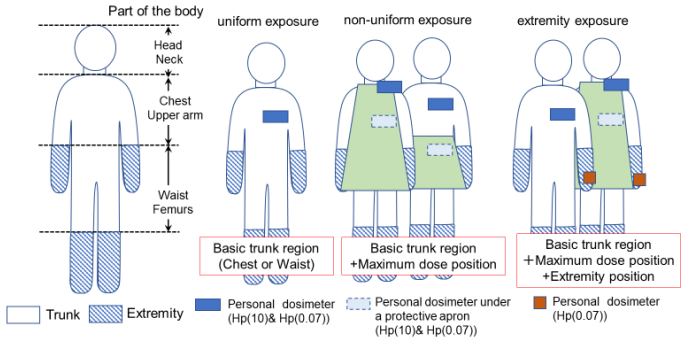

Figure 1: Dose measurement regions and operational quantities under the current regulations

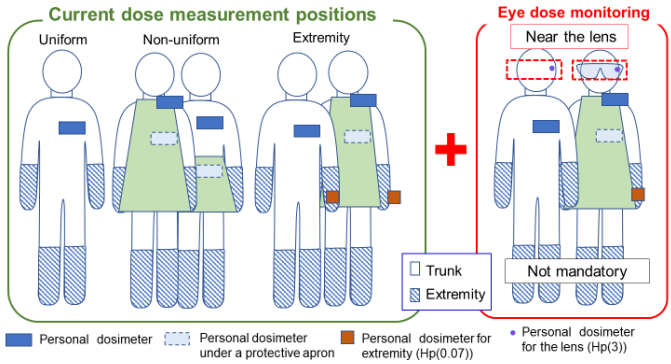

Figure 2: Dose measurement regions and operational quantities under the revised regulations

However, the lens dose limit for doctors with advanced skills whose dose to the lens cannot be reduced even if any dose reduction measures are taken will be maintained to be 50 mSv/y from April 2021 to March 2023[4]. After that, it will be 60 mSv/3ys and 50 mSv/y. Finally, it will be the same as the values for the other radiation workers.
The studies on development of application for the new dose limit to the lens of the eye had been supported by the Radiation Safety Research Promotion Fund of the Nuclear Regulatory Authority (NRA), Japan[6-8]. In 2019, we started to prepare guidelines on radiation monitoring for the lens related to all fields and radiation protection in medical sector in cooperation with related academic societies under the Radiation Safety Research Promotion Fund of the NRA[8].
At the same time, the Working Group of the Radiation Protection Standardization Committee, the Japan Health Physics Society (JHPS) started to discuss the guideline on the radiation monitoring for the lens while referring to the research products of the Radiation Safety Research Promotion Fund of the NRA. In July 2020, JHPS guideline was published[9].

2 BASIC CONCEPT

The Working Group of the JHPS Radiation Protection Standardization Committee consisted of nineteen members such as researchers of radiation protection and dosimetry in medical and nuclear fields, representatives of radiation managers from the nuclear power plants, technical experts of dose monitoring and ten observers such as radiation managers from nuclear power plants and technical experts of nuclear industries. The guideline was discussed by the Radiation Protection Standardization Committee and submitted to public consultation after discussion in the Working Group. Finally, the guideline was revised while reflecting the comments and published with approval of the JHPS board of directors.
The guideline consists of five parts, 1) Main Text, 2) Explanations, 3) References, 4) Attachments and 5) Questions. In three attachments, the trend of Japanese and international organizations of the reduction of equivalent dose limit of the lens, the IAEA proposal for monitoring the equivalent dose to the lens[10] and the conventional monitoring methods of the equivalent dose to the lens[11] are described.
In particular, the following are noted in developing the guidelines; 1) compliance with the revised regulations for the dose monitoring to the lens, 2) harmonization with the existing monitoring methods of measuring the effective dose and equivalent dose to the skin, 3) optimization of dose monitoring and radiation protection considering radiation workplaces and situations, and occupational safety and health, 4) supporting radiation managers by providing a simple and easy-to-understandable concept for radiation monitoring on the lens, including scientific evidence, and 5) advice on judgment of criteria of non-uniform exposure and dose management criteria for the lens to be decided by each radiation facilities.

3 MAIN TEXT

3.1 Scope of application

In Section 1 of the main text, it was shown that the guideline is applied to the monitoring of radiation workers' equivalent dose to the lens due to the photon, electron (700 keV or more), and neutron under planned exposure situations.
The reasons for applying these radiation types and situation were explained in Explanation (the section 5 (2) in the guideline), including the reasons why α particles electrons with lower than 700 keV were not applied.

3.2 Guidance on dose monitoring

In Section 2, judgment criteria for regions for the dose monitoring and the operational quantity for the lens of the eye were indicated. There are two steps to making decision for the dose monitoring regions and the quantities for the lens. In the first step, the monitoring methods for the lens are discriminated into two patterns, depending on uniform exposure or not. In the second step, these are decided by whether the dose to the lens is close to or exceed the management criteria for the lens for each type of exposure (uniform or non-uniform trunk exposures). The management criteria should be set to conservative values below the dose limits and decided by the employer or radiation dose manager in each facility.

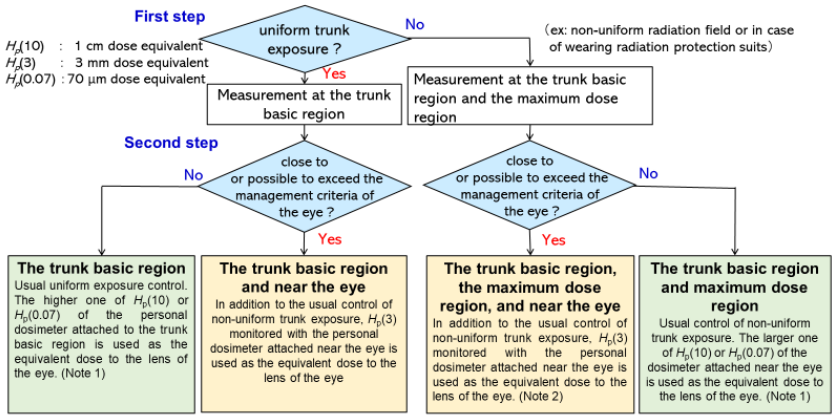

Figure 3: Flow diagram for lens dose monitoring

A diagram is attached to make it easier to understand the dose monitoring for the lens as shown in Figure 3.

4 EXPLANATION

4.1 Outline of EXPLANATION

The chapter of Explanation consists of five sections, 1. Objective, 2. Scope of application, 3. Related acts and regulations, 4. Glossary, and 5. The monitoring methods to estimate the dose equivalent of the lens.

4.2 Objective

In the section of Objective, it is shown as follows[9]:
The purpose of this guideline is to allow business proprietors to comply with the legislation and smoothly perform dose monitoring of the lens of the eye due to the amendment of the legislation of the equivalent dose limit of the lens of the eye. The guideline supplements the part of the dose monitoring of the eye lens of the "Measurement and Estimation Manual of the Exposed Dose".
(Partially omitted)
For the equivalent dose to the eye lens, it is required not only to comply with the law and regulations for the dose limit and other requirements of legislation, but also to consider optimizing the radiation protection of the eyes. To optimize the radiation protection, business proprietors must take the lead in establishing the working environment suitable to optimization of radiation protection, obtaining instructions from radiation protection professionals (radiation protection supervisor, etc.).
(Omitted below)
"Measurement and Estimation Manual of the Exposed Dose" is prepared when the related regulations were revised based on the ICRP 1990 Recommendation and often used for radiation monitoring for radiation workers and workplaces by the radiation managers and workers under the current regulations in Japan[11]. In the first paragraph, it was stated that the guidelines were limited to individual monitoring of the lens and were consistent with the dose estimation of the effective and the equivalent doses to the skin. In the second paragraph, it is shown that it is necessary of compliance with the related regulations and optimization of radiation protection including the other radiation monitoring and occupational safety and health.

4.3 Scope of application

In the section of Scope of application, it is shown that the guideline is applied to the individual dose monitoring of radiation workers under the planned exposure situation of workplaces described in ICRP Publ.103. In addition, radiation monitoring under the emergency and existing exposure situations are not included in the scope of application of the guideline. However, the basic concept of the dose measurement for the lens would be helpful under those exposure situations.

4.4 The monitoring method to estimate the dose equivalent of eye lens

4.4.1 Section structure

The section of “The monitoring method to estimate the dose equivalent of eye lens” consists of seven paragraphs as follows[9]:

(1) Basic concept
(2) Type of radiation to be applied (3) Desirable dose level of monitoring near the eye directly (management criteria)
(4) Recording level of the equivalent dose to the lens of the eye
(5) Monitoring regions to estimate equivalent dose to the lens of the eye
(6) Operational quantity used for estimation of the equivalent dose to the lens
(7) Methodology to judge that the equivalent dose to the lens of the eye is close to or may possibly exceed the management criteria.

In the Working Group, the judgment of the non-uniform exposure situation and the management criteria for the dose monitoring of the lens and the as shown in Paragraphs (3) and (5) were discussed.

4.4.2 Judgment of the non-uniform exposure situation

After the revised regulations, the judgment of the non-uniform exposure situation will be difficult, because a value of the equivalent dose limit to the lens is equal to that of the effective dose limit. The Japanese current dosimetry manual, "Measurement and Estimation Manual of the Exposed Dose" recommends wearing an additional dosimeter, when the maximum dose is more than three times of the dose measured in the basic trunk region, the chest or the waist[11]. This concept is based on the ratio of the dose limit to the lens to the effective dose limit (150mSv/50mSv). However, this ratio cannot be used under the revised regulations. Therefore, the ICRP Publication 75[12], the IAEA GSG-7[13], and the advice from the radiation protection experts when the Japanese previous regulations were discussed and revised based on the ICRP 1977 recommendation were referred to. The radiation experts recommended that multiple personal dosimeters probably must be attached when the dose ratio is only 2[14]. On the other hand, although indicators of non-uniform exposure situation have not been recommended in the ICRP publication 75[12] and the IAEA GSG-7[13], it was concluded that the range of the uncertainties of 1.5 to 2 in personal monitoring was helpful to consider this indicator. A specific description was also added to Question 1 in the chapter of Question.

4.4.3 Management criteria

The management criteria should be set to conservative values below the dose limits and decided by the employer or radiation dose manager in each facility as shown in Section 2.2. However, the guideline must provide the concept and reference examples for the criteria for the dose monitoring of the lens.
The concepts of individual monitoring were based on the ICRP publication 75[12]. In addition, the Manual for "Measurement and Evaluation of Exposed Dose"[11] supported discussion of the criteria.
The criteria are associated with measurement uncertainty and the criteria for non-uniform exposure. This answer was shown in Question 3 as a specific example. In this paragraph, it is shown that it may be better to wear a personal dosimeter near the lens when the dose equivalent, $H_p(10)$ or $H_p(0.07)$ measured by the personal dosimeter attached in the basic trunk or the maximum dose region exceeds the annual 13 mSv (= 20/1.5) considering the uncertainty of 1.5 of the personal dosimeter. In addition, an example was also shown that the criteria could be set to 17mSv/y (≈20 mSv/1.2) if the uncertainty can be estimated as 1.2. Besides these values, the applicable management criterion of the direct measurement near the lens indicated in the IAEA TECDOC No. 1731[10], the ISO 15382:2015[15], the IRPA Guideline[16], the Council Directive 2013/59/EURATOM[17], and our research supported by the Radiation Safety Research Promotion Fund[7] were proposed as references. These are shown in Table 1.

4.4.4 Region of eye-lens dose monitoring

For the dose monitoring of the lens, it was necessary to clarify " near the eye". Thus, the appropriate region for the dose monitoring of the lens was specified as "near the eye" referring to on the research report supported by the Radiation Safety Research Promotion Fund, NRA[7] in Subsection 4). Specifically, it means that part of the head and neck regions to monitor the radiation dose of the lens directly, where it can be judged that there is "no significant gradient" in radiation dose from the point where the radiation dose of both eyes is the highest.

5 QUESTIONS

Twenty-six related questions and their answers were set to respond to similar cases such as the judgement criteria for non-uniform exposure situation, the management criteria, optimization of the radiation protection for the lens, available personal dosimeters for the lens, calibration method for personal dosimeters, Japanese current status of radiation exposure for the lens in medical and nuclear fields, the international and national guidelines for dosimetry, dose estimation methods for electron, indirect estimation by calculation and so on. Table 2 shows a list of question titles.

The selection and development of these questions and answers were proceeded by listening to the opinions of the members of the Working Group, especially radiation managers who are familiar with the radiation and nuclear workplaces. The answers were prepared for experts in each field.
As mentioned in Subsection 4.4 in this article, it was shown that how the non-uniform exposure situation and the management criteria to direct measurement near the eye should be judged in Questions 1 and 3, respectively.
In Question 4, the possibility of dose estimation to the lens by monitoring with a personal dosimeter attached on the outside of the full-face mask and by the calculation using a shielding factor were replied referring to the report of the MHLW [4]. This report states that when personal protection equipment such as a full-face mask is worn, it is appropriate to measure by personal dosimeters inside the full-face mask. On the other hand, the paragraph 3 of Article 8 of the Regulation on Prevention of Ionizing Radiation Hazards[18] states that "when it is very difficult to measure the dose using a radiation measuring instrument, the dose can be estimated by calculation." However, "very difficult to measure the dose" means "the case when the radiation measuring instrument has not been developed yet". Therefore, it would be appropriate to measure by personal dosimeters inside the full-face mask directly in the above case.

Table1: Management criteria to judge the direct measurement near the eye as references.

Document of the recommendation	Management criteria of the equivalent dose to the lens
IAEA TECDOC 1731	5 mSv/y
Council Directive 2013/59/EURATOM	15 mSv/y
ISO 15382: 2015	6 mSv/y (when the exposure continues for multiple years) 15 mSv/y (when the exposure is only for a single year)
IRPA guideline protocol	1 - 6 mSv/y (0.2 - 0.5 mSv/month): recommendation 6 mSv/y (0.5 mSv/month): requirement
Reports of the Radiation Safety Research Promotion Fund	10-15mSv/y

6 CONCLUSION

In the JHPS, the guideline on radiation monitoring for the lens was developed by radiation protection experts. The guidelines were based on the international standards and guidelines, and new and old national regulations and research results. The issues regarding the operational quantities and the measurement points had been cleared. It is hoped that this guideline will be effectively used for compliance with the related regulations of the dose monitoring and optimisation of the radiation protection for the lens, including radiation monitoring. However, the guideline should be revised as necessary when new knowledge, technologies and methods for the monitoring come out in the future.

Table 2: List of question title.

No.	Question Contents
Q1.	How should the non-uniform exposure be judged?
Q2.	How should the uncertainty of the dose monitored with a personal dosimeter be estimated?
Q3.	What kind of value should be adopted as a management criterion?
Q4.	Is it possible to estimate the equivalent dose to the lens by monitoring with a personal dosimeter attached on the outside of the full-face mask and by the calculation of shielding attenuation factor by the full-face mask?
Q5.	Concerning the optimization of protection against the exposures of the lens, how should the result of dose monitoring be used?
Q6.	What kind of the lens dosimeters are available?
Q7.	What is the status of review of the international standards regarding the monitoring of 3 mm dose equivalent?
Q8.	What is the calibration method for the personal dosimeter dedicated to the lens?
Q9.	We would like to know the monitoring method of the lens in nuclear facilities.
Q10.	We would like to know the monitoring method of the lens at medical facilities.
Q11.	We would like to know the monitoring method of the lens of veterinary medical personnel.
Q12.	We would like to know the monitoring method of the lens for the X-rays from a Crookes tube.
Q13.	We would like to know the monitoring method of the lens for non-destructive inspections.
Q14.	We would like to know the monitoring method of the lens at nuclear fuel facilities.
Q15.	We would like to know the method to calculate the equivalent dose to the lens of radiation, including the bremsstrahlung X-rays generated when the electron rays (beta-rays) are incident on the personal protection equipment, such as protective goggles and masks.
Q16.	Is it possible to calculate the equivalent dose to the lens?
Q17.	Isn't it necessary to calculate the equivalent dose to the lens by measuring the 3 mm dose equivalent under the situation where beta-rays cannot be ignored?
Q18.	When the dose equivalent to the lens is high in a uniform trunk exposure situation, does it become a situation of dose control in non-uniform trunk exposure if shielding materials are used?
Q19.	Isn't it possible to judge the necessity of the dose monitoring with a personal dosimeter attached near the eye at the time of planning the work schedule?
Q20.	How should the dose of the lens be monitored if dose monitoring near the lens is needed from the middle of the month, or various work situations are mixed?
Q21.	If the measurement of the radiation dose near the eye is smaller than the radiation dose to the basic trunk region, which dose should be used for the estimation of the lens, the dose near the eye or that of the basic trunk region?
Q22.	When the dose monitoring of uniform trunk exposure is performed with an additional personal dosimeter attached near the eye, should the effective dose be estimated considering the measurement of the dose of head or neck region (near the eye)?
Q23.	If workers move to another facility before the formal dosimetry outcome at the previous facility is determined, how should the equivalent dose to the lens of the workers be estimated?
Q24.	Is it possible to apply to facilities in Japan the "idea of Bordy" proposed by the French Radiological Protection Society?
Q25.	What is the case for evaluation using the 3 mm dose equivalent except for “near the eye”?
Q26.	We would like to know the evaluation method of the validity of monitoring results of personal dosimeters dedicated to the lens.

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8 REFERENCES

[1] ICRP, 2012. ICRP Statement on Tissue Reactions / Early and Late Effects of Radiation in Normal Tissues and Organs -Threshold Doses for Tissue Reactions in a Radiation Protection Context. ICRP Publication 118. Ann. ICRP 41(1/2).

[2] Radiation Council, Japan, 2018, On a modality of the radiation protection for the lens of the eye; Nuclear Regulation Authority release/issue 18030211 (in Japanese).

[3] Ministry of Health, Labor and Welfare, 2019. A report on the study group meetings to review dose limits to the lens of the eyes (in Japanese).

[4] Ministry of Health, Labor and Welfare et al., 2019. Ministry of Health, Labor and Welfare, Health Policy Bureau release/issue 1223-1et al. (in Japanese).

[5] Radiation Council, Japan, 2020. Nuclear Regulation Authority release/issue 20012412 (in Japanese) .

[6] Fujita Health University, 2018. Standard equivalent dose monitoring, suitable management, and protection of the lens of the eye of nuclear power and health care professionals - Explore from the actual circumstances of the lens of the eye exposures -, FY2017 Report of the Radiation Safety Research Promotion Fund of Nuclear Regulatory Authority (in Japanese).

[7] Fujita Health University, 2019. Standard equivalent dose monitoring, suitable management, and protection of the lens of the eye of nuclear power and health care professionals - Explore from the actual circumstances of the lens of the eye exposures -, FY2018 Report of the Radiation Safety Research Promotion Fund of Nuclear Regulatory Authority (in Japanese).

[8] Fujita Health University, 2020. Design of the guideline on radiation protection of the lens of the eye for smooth regulatory operation, FY2019 Report of the Radiation Safety Research Promotion Fund of Nuclear Regulatory Authority (in Japanese).

[9] Japan Health Physics Society, 2020. Guideline on Dose Monitoring for the Lens of Eye (in Japanese).

[10] IAEA, 2013. Implications for Occupational Radiation Protection of the New Dose Limit for the Lens of the Eye, IAEA TECDOC No.1731. International Atomic Energy Agency, Vienna.

[11] Nuclear Safety Technology Center, 2000. “Measurement and estimation manual of the exposed Dose” (in Japanese).

[12] ICRP, 1997. General principles for the radiation protection of workers ICRP Publication 75

[13] IAEA, Occupational Radiation Protection, IAEA Safety Standards Series No. GSG-7. International Atomic Energy Agency, Vienna.

[14] Hamada T., et al., 1988. Introduction of 1977 Recommendations of the International Commission on Radiological Protection into the legislation (Answer to the question on the revision of legislation) (March 1988), Nuclear Safety Research Association, Tokyo, (in Japanese).

[15] ISO, 2015. Radiological protection - Procedures for monitoring the dose to the lens of the eye, the skin and the extremities, ISO15382:2015.

[16] IRPA, 2017. IRPA Guidance on Implementation of Eye Dose Monitoring and Eye Protection of Workers.

[17] European Union, 2013. Council Directive 2013/59/Euratom of 5 December 2013.

[18] Director of Labor standard in Ministry of Health, Labor and Welfare, 2000. Enforcement, etc. of the ministerial order which amends a part of Ordinance on Industrial Safety and Health and Regulation on Prevention of Ionizing Radiation Hazards a from the group - No. 253 (March 30, Heisei 13), (in Japanese).