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Monitoring the Eye Lens Dose

Recommendation of the German Commission
on Radiological Protection

Adopted at the 277th meeting of the German Commission on Radiological Protection on 2 and 3 July 2015

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Überwachung der Augenlinsen-Äquivalentdosis

Empfehlung der Strahlenschutzkommission

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1 Introduction

On 1 February 2008, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) commissioned the German Commission on Radiological Protection (SSK) to advise on questions pertaining to dosimetry of the eye lens. As a result of this advisory mandate, the SSK adopted a statement titled “Monitoring the Eye Lens Dose” (SSK 2010) at its 240th meeting held on 2 February 2010.

On 21 April 2011 the International Commission on Radiological Protection (ICRP) published a “Statement on Tissue Reactions” (ICRP 2012) in which it recommended for occupational exposure in planned exposure situations to reduce the equivalent dose limit for the lens of the eye from 150 mSv/year to 20 mSv/year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv.

The Council of the European Union adopted this recommendation in Article 9 (3) a) of its Directive 2013/59/Euratom dated 5 December 2013 (Euratom 2014) as follows:

> The limit on the equivalent dose for the lens of the eye shall be 20 mSv in a single year or 100 mSv in any five consecutive years subject to a maximum dose of 50 mSv in a single year, as specified in national legislation.

It can be assumed that this reduced limit on the equivalent dose for the lens of the eye will be incorporated into German radiation protection law when implementing Directive 2013/59/Euratom.

2 Advisory mandate

In its advisory mandate dated 24 May 2011, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) commissioned the German Commission on Radiological Protection (SSK) to present the consequences of the ICRP “Statement on Tissue Reaction” on the SSK statement “Monitoring the Eye Lens Dose” from 2010.

3 Recommendation

This recommendation[1] refers specifically to the SSK statement “Monitoring the Eye Lens Dose” from 2 February 2010. The statement contained 6 questions which were then answered based on the current state of scientific knowledge at that time. This recommendation represents an update to those answers now considering the Directive 2013/59/Euratom. All of the text used from the SSK’s 2010 statement are italicised.

Question 1:

> *Are any new findings available which go beyond the data presented in SSK Volume 43 (1998, 2nd edition 2006) on the eye lens dose, particularly with reference to Sections 3.2.1 and 5.4.3 of this Volume?*
>
> *The data published in SKK Volume 43 on the eye lens dose reflect the internationally recognised state of scientific knowledge in 2006. For electrons in particular, these data are based on calculations performed using a very approximate model of the human eye. Therefore, for beta radiation in particular, the conclusions drawn in Section 5.4.3 of this SSK Volume – that for persons occupationally exposed to radiation, monitoring of the skin dose with its limit value of 500 mSv per year also guarantees compliance with the limit value of 150 mSv in any one calendar year for the eye lens dose (provided that the dosimeter is positioned near the eye lens) – can no longer be upheld. This section of the SSK Volume must, therefore, be revised.*
>
> *For the eye lens dose, dose conversion factors should be used that are based on a more realistic simulation of the human eye and take account of the different sensitivities of areas within the lens to cataract formation following exposure.*
>
> *For photon radiation fields, Section 3.2.1 of SSK Volume 43 refers only to the relationship of the eye lens dose to the ambient dose equivalent. Given the exposure scenarios being investigated in radiology today, this is not adequate and must be reviewed.*

The statements made by the SSK in 2010 regarding question 1 remain unchanged and are even substantiated by the anticipated reduction of the limit on the eye lens dose.

Considerable progress has already been made in terms of revising SSK Volume 43 (SSK 2004).

Question 2:

> *What are appropriate operational quantities for a conservative estimate of the eye lens dose for penetrating radiation and radiation with low penetration depth?*
>
> *Regarding the question of the appropriate operational quantities for a conservative estimate of the eye lens dose for penetrating radiation and radiation with low penetration depth, the situation for photons (especially X-ray radiation) and beta radiation must be considered separately.*

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[1] For the purpose of this recommendation, the terms “eye lens dose”, “organ dose to the lens of the eye” and “equivalent dose to the lens of the eye” shall be used synonymously. The term “equivalent dose to the lens of the eye” is used in accordance with the standard DIN 6814-3 (2015).

In photon radiation fields, the operational quantity $H_p(0.07)$ adequately estimates the eye lens dose at energies of < 200 keV; the same applies to $H_p(10)$ at energies > 100 keV. For photon fields, there is, therefore, no need to introduce the additional personal dose equivalent $H_p(3)$ – and, therefore, possibly also the directional dose equivalent $H'(3,\Omega)$ – for the specific case of lens monitoring.

For the operational quantity $H_p(0.07)$, the personal dosimeter used must, however, be calibrated on an ISO water slab phantom (slab phantom), like a whole-body dosimeter, not on an ISO rod phantom as in the case of an extremity dosimeter.

This would entail a change in the practice customarily applied in Germany to date, whereby dosimeters for the personal dose equivalent $H_p(0.07)$ are not calibrated on a slab phantom, nor are design type tests for this type of dosimeter carried out neither are type approvals issued.

For radionuclides with beta radiation that are used in practical applications, the calculated value of the exposed eye lens dose largely depends on which area within the lens is used as the basis for calculating the eye lens dose (mean dose for the entire lens or mean dose in the area of that part of the lens that is sensitive to cataract formation).

It is recommended that efforts be made to achieve international clarification of the question of how the eye lens dose should be calculated – especially if the introduction of the personal dose equivalent $H_p(3)$ is considered in Germany.

In beta radiation fields and for the sensitive area of the eye lens, the personal dose equivalent $H_p(3)$ estimates the eye lens dose most accurately, although $H_p(0.07)$ also provides a conservative value for the eye lens dose for all radionuclides customarily used. However, for radionuclides with beta energies up to around 1 MeV, a substantial overestimation of the eye lens dose is possible, e. g. by a factor of as much as 280 for the radionuclide Re-186, as electrons with energies of < 0.7 MeV (low-energy electrons) no longer reach the lens of the eye but contribute to $H_p(0.07)$.

If the beta radiation source is positioned at some distance from the lens of the eye, the interaction of the beta radiation with the atmosphere can also lead to a substantial reduction of the eye lens dose. This applies especially to low-energy beta radiation.

The statements made by the SSK in 2010 regarding question 2 remain unchanged.

The statements made in response to question 3 provide information about how $H_p(0.07)$ dosimeters have been calibrated in Germany to date.

The SSK statement from 2010 recommended that efforts be made to achieve international clarification of the question of how the eye lens dose should be calculated. This recommendation has indeed been followed on an international level, with discussions taking place, e. g. in ICRP publication 116, annex F (ICRP 2010). The ICRP recommendations still provide an average for the entire eye lens. Irrespective of how the eye lens dose is calculated, the use of $H_p(0,07)$ for beta radiation may lead to considerable overestimation (cf. Section 3, Fig. 8 of the SSK statement from 2010).

Previous investigations have shown that when determining the eye lens dose in radiation fields with significant dose contributions due to beta radiation, only the operational quantity $H_p(3)$ is suitable in order to avoid overestimation of the eye lens dose – which may be up to a factor of 550 – that occurs when using the operational quantity $H_p(0.07)$ (Behrens and Dietze 2010).

A great deal of effort is being made on an international level to introduce the operational quantity $H_p(3)$ in individual monitoring. To achieve this, corresponding dosimeters are being developed (EURADOS 2012), intercomparison measurements of eye lens dosimeters are being performed (Clairand et al. 2015) and the international standardisation (IEC 62387, ISO 15382) is being updated. This shows that the operational quantity $H_p(3)$ has been accepted internationally.

The SSK notes that dosimeters can currently not be calibrated using the operational quantity $H'(3)$ as there are no conversion coefficients $H'(3)/K_a$ (K_a: air kerma) for photon radiation.

Modified $H_p(0.07)$ dosimeters could be used instead of the operational quantity $H_p(3)$ in order to avoid overestimating the eye lens dose in beta radiation fields. If an additional absorption layer of 2.93 mm tissue-equivalent material (e. g. 2.50 mm PMMA) is fitted in front of the detector on $H_p(0.07)$ dosimeters used for photon and beta radiation field measurements, this additional layer will give these dosimeters an effective measuring depth of 3 mm, which corresponds to the operational quantity $H_p(3)$. $H_p(0.07)$ dosimeters modified in this way can then be used to estimate the eye lens dose in beta radiation fields with sufficient accuracy and without considerable overestimation, thus permitting the initiation or evaluation of the effectiveness of appropriate radiation protection measures. These considerations also apply to the operational quantities $H'(0.07)$ and $H'(3)$.

Question 3:

> *Which operational quantity is particularly appropriate for a conservative estimate of the organ dose for the eye lens for low-energy photon radiation (< 100 keV)?*
>
> *In the specific case of exposure to X-rays for diagnostic purposes (e. g. in interventional cardiology) and exposure in scattered radiation fields, monitoring of the personal dose equivalent $H_p(0.07)$ is sufficient to determine the eye lens dose. Here, the personal dosimeter to be worn must either be calibrated on a slab phantom or, in the case of an extremity dosimeter calibrated on a rod phantom, it must be ensured that the dosimeter also accurately measures backscattered radiation from the phantom. Ascertaining which of the dosimeters currently used legally already fulfil this second requirement is recommended.*

The statements made by the SSK in 2010 regarding question 3 remain unchanged.

$H_p(3)$ is also conservative for photon radiation (Behrens 2012). The conservatism of the operational quantities $H'(0.07)$ and $H'(3)$ applies not only to photon radiation of up to 100 keV, but to the entire energy spectrum up to 10 MeV.

The recommendation given in the statement to investigate which of the previously approved dosimeters are also suitable for measuring close to the eye when calibrated on a rod phantom has been completed (Behrens et al. 2012). All of the ring dosimeters currently in official use in Germany are also suitable for determining the eye lens dose in photon radiation fields of up to 100 keV when calibrated on a rod phantom.

Question 4:

> *Are there any specific aspects of the dosimetric determination of the eye lens dose which must be considered?*
>
> *When determining the eye lens dose by monitoring the dose with a personal dosimeter, the dosimeter must be worn close to the eye or positioned on the body in such a way that it is exposed to approximately the same radiation field as the eye.*

It must be borne in mind, in this context, that shielding the eye, especially in beta radiation fields, will significantly influence the radiation field at the eye (resulting in a substantial reduction of the eye lens dose).

The statements made by the SSK in 2010 regarding question 4 remain unchanged.

Question 5:

Are there any policy recommendations concerning the need to introduce $H_p(3)$ and $H_p(0.07)$ (calibration on a slab phantom)?

Before utilising the operational quantities $H_p(0.07)$ for photon radiation with dosimeters calibrated on a slab phantom and $H_p(3)$ for electron radiation in order to determine the eye lens dose, it is recommended that workplace observations (analysis of existing workplace dosimetric data / monitoring of workplace the eye lens dose if no such data are available) be carried out in order to determine whether such introduction is appropriate.

The operational quantity $H'(0.07)$ can be used for area monitoring in photon radiation fields.

The measures that need to be taken to shield against beta radiation can be determined by simple radiation protection considerations. Should such radiation protection measures be subject to metrological verification, an $H'(0.07)$ dosimeter would significantly overestimate the eye lens dose of low-energy beta radiation (< 1 MeV, e. g. Re-186), which may give rise to extensive but unreasonable radiation protection measures.

For this reason it is recommended to use the operational quantity $H'(3)$ for area monitoring in workplaces with significant doses of beta radiation.

The operational quantities $H_p(3)$ and $H'(3)$ are suitable for individual and area monitoring, respectively, with respect to the eye lens dose. However, the operational quantities currently in use – $H_p(0.07)$ and $H'(0.07)$ – can only be used to a limited extent for beta radiation. Overestimates of the eye lens dose from beta radiation by up to two orders of magnitude are not appropriate given the limit of 20 mSv per annum. This is why the SSK recommends to implement the operational quantities $H_p(3)$ and $H'(3)$.

According to Section 41(3) of the German Radiation Protection Ordinance (StrlSchV), the eye lens dose must be measured if the eye lens dose is expected to exceed 45 mSv during a calendar year. It can be assumed that the change to the German radiation protection legislation due to the adoption of the new limit on the equivalent dose for the lens of the eye of 20 mSv (Euratom 2014) will lead to a major reduction of this value. A number of international investigations (e. g. EURADOS 2012) considering the eye lens dose in photon radiation fields in radiology are now available, but the amount of material related to nuclear medicine remains somewhat limited. The UFOPLAN proposal "Investigations into Radiation Exposure of the Eye Lens of Occupationally Exposed Workers" will also cover workplaces involving nuclear medicine, which will help to provide further insights.

Question 6:

Which protection measures are suitable for the eye lens?

Maintaining the maximum possible distance from the radiation source is the first step in keeping the eye lens dose as low as is practically achievable.

In the case of exposure to beta radiation from radionuclides (with a relatively low proportion of photon radiation), the use of protective eyewear can substantially reduce the eye lens dose.

In the case of exposure to scattered radiation fields in diagnostic radiology (photon energy < 150 keV), shielding with lead glass windows or lead glass protective eyewear is recommended, but is far less effective than in beta radiation fields (tenth-value thickness for 50 keV photon / 100 kV X-ray radiation: approx. 1 mm lead glass).

The statements made by the SSK in 2010 regarding question 6 remain unchanged.

4 Conclusion

The SSK concludes that the statement titled "Monitoring the Eye Lens Dose" (SSK 2010) is still valid.

Only the operational quantities $H_p(3)$ and $H'(3)$ are suitable for measuring the eye lens dose in beta radiation fields. $H_p(3)$ and $H'(3)$ are suitable for individual and area monitoring with respect to the eye lens dose in both, photon and beta radiation fields. The SSK, therefore, recommends the adoption of these two operational quantities.

The pending calculation of the conversion coefficients $H'(3)/K_a$ (K_a: air kerma) for photon radiation is still required in order to introduce these operational quantities into legislation.

The operational quantities $H_p(0.07)$ and $H'(0.07)$ can also be used in photon radiation fields that do not significantly contain beta radiation.

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