

## Impact of new operational dosimetric quantities on individual monitoring services

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### 1. Introduction

In 2017 the International Commission on Radiation Units and Measurements (ICRU) and the International Commission on Radiological Protection (ICRP) issued a draft for consultation containing a novel approach to external radiation exposure based on the introduction of new operational dosimetric quantities. These quantities include ambient dose  $H^*$  dose  $H_p$  for environmental and whole-body personal dosimetry, respectively. There are also new quantities for skin and eye lens dosimetry that are expressed in terms of absorbed dose instead of equivalent dose. The report based on the 2017 draft was published in late 2020 as ICRU Report 95 [1]. The main motivation was to tackle issues with the existing operational dosimetric quantities. In some irradiation situations, for instance in high-energy radiation fields, the operational quantities are not conservative with respect to the limit quantities such as effective dose. In other situations, such as low-energy photons in the energy range of tens of keV, the operational quantities are overly conservative. A detailed description of the proposed new framework has been provided by Otto et al [2]. Unlike the current operational quantity for whole-body personal dosimetry  $H_p(d)$ , the newly proposed quantity  $H_p$ , does not relate to a specific depth in tissue. It is instead based on effective dose and is calculated across the whole energy spectrum using an anthropomorphic computational phantom [3]. For calibration of dosimeters, the same conversion coefficients can be used on surrogates of the computational phantoms, such as the ISO water slab phantoms or the ISO PMMA (polymethyl methacrylate) rod phantom [4] [5], without important variations [1]. However, the proposed change to  $H_p$  implies a variation in a dosimeter's response because of the change in conversion coefficients. References [6–8] report theoretical studies of how a change to  $H_p$  would affect the responses of existing photon dosimeters. As expected, these studies show that the responses of the dosimeters are not suitable for the new quantity below an energy of 50 keV.

The new operational quantities will have a significant impact in terms of new procedures, education of personnel, adaption of calibration facilities, re-characterisation of dosimetry systems and modification of existing dosimeters. In this view, EURADOS [9] set up a task group that aimed to prepare a report on the consequence of the introduction of the new quantities on radiation protection practices. Within the framework of this effort, this paper focuses on an experimental comparison between  $H_p(10)$  and  $H_p$ , describing an inter-comparison exercise among individual monitoring services (IMSs) in terms of both quantities. In particular, two participants in the standard (i.e. referring to the existing quantities) inter-comparison exercise, agreed to characterise their dose evaluation algorithm in terms of  $H_p$ , based on the conversion coefficients reported in [8]. The results in terms of existing operational quantities and in terms of  $H_p$  have been processed according to the standard ISO 14 146 [10].

**1. Mark True or False. According to the author, as stated in the text (lines 1 – 7):**

- ( ) ICRU published in 2017 a final version of a report containing new dosimetric quantities.
- ( ) Ambient dose  $H^*$  dose  $H_p$  for environmental and whole-body personal dosimetry are well established operational quantities that ICRU proposed in 1995.
- ( ) The new quantities proposed by ICRU for skin and eye lens dosimetry have changed from absorbed dose to equivalent dose.
- ( ) Previous radiation quantities have issues (problems) that have led ICRU to update these quantities in the report 95.
- ( ) Quantities for the measurement of skin and eye lens are now addressed for the first time in ICRU 95 report.

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**2. The motivation for redefining operational quantities, according to the author (lines 7-14), is that:**

- I. In high-energy radiation fields, the old operational quantity underestimates the effective dose.
  - II. In low-energy photon fields the old operational quantity overestimates the effective dose.
  - III. In Report 95, a quantity  $H_p$  is proposed that more closely matches the effective dose than the older quantity  $H_p(d)$ .
- a) Only I is True.
  - b) Only I and II are True.
  - c) Only III is True.
  - d) All affirmatives are True.

**3. It is correct to say, according to the author (lines 15-21), that:**

- a) Dosimeters calibrated in  $H_p$  will have the same response as dosimeters calibrated in  $H_p(d)$ .
- b) At energies lower than 50 keV, it is expected that the dosimeter's responses are inadequate.
- c) The ISO water slab phantoms can be used without important variations.
- d)  $H_p$  and  $H_p(d)$  have similar conversion coefficients so no chance is expected.

**4. According to the author, the new operational quantities will have:**

- a) Require many changes in different areas, including modifications to existing dosimetric systems.
- b) Will have a significant impact only in the interpretation of the dose results.
- c) May require some modification of procedures, education of personnel, adaption of calibration facilities, re-characterisation of dosimetry systems and modification of existing dosimeters.
- d) Will not change existing dosimeters and procedures.

**5. What is the purpose of this paper?**

- a) To compare  $H_p(10)$  and  $H_p$  and propose a new dose algorithm.
- b) To describe the results of intercomparison exercises in both old and new quantities and propose measures to comply to exercises in  $H_p$ .
- c) To propose a new quantity  $H_p$  for radiation dosimetry, that complies to the standard ISO 14 146.
- d) To report conversion coefficients from  $H_p(d)$  to  $H_p$  to help individual monitoring services to comply to ISO 14 146.

## Text 2

**Title: A NEW DOSIMETRY DEVICE FOR QUANTIFICATION OF RADIATION****FIELD OF THE INVENTION**

[0001] The present application relates to a dosimetry device comprising a radiation sensitive composition, an optical means and a software means to quantify the dosage of radiation emitted from the radiation source. The present application further relates to use of said dosimetry device in various medical, food and industrial applications.

**BACKGROUND OF THE INVENTION**

[0002] Quantification of radiation emitted from various sources is an important function and finds several applications in medical, research, food storage, transportation of sensitive goods, and industrial operations. A dosimeter is one such device used to indicate or measure exposure to ionizing radiation. It is a solid object either available as a plate, or in any other shape that can be easily viewed and sometimes shows visual transformation of color without the use of a spectrophotometer. Several types of dosimeters such as Thermoluminescence Dosimeters (TLD), Optically Stimulated Luminescence (OSL), Radio Luminescence Glass (RLG), X-ray film, and Track Etch are currently available in the market. Typically, these are used for measuring and monitoring both medical and industrial radiations such as X-rays, gamma rays, high speed electrons etc.

[0003] Color changing / developing self-indicating Instant Radiation Alert Dosimeters (SIRAD) for monitoring low dose, e.g., are commercially marketed by JP Laboratories Inc., New Jersey under trademark SIRAD<sup>®</sup>. Dosimeter SIRAD<sup>®</sup> has a sensing strip made of polymeric material such as colorless solid monomers of diacetylenes. They usually form red or blue colored polymers / plastics when irradiated with high energy radiation such as X-ray, gamma ray, electrons, and neutrons. As exposure to radiation increases, the color of the sensing strip comprising diacetylenes intensifies proportional to the dose.

[0004] US Patent No. 8,242,464 [Assigned to Gordhanbhai N. Patel/JP Labs] discloses Identification Personal Dosimeter comprising self indicating radiation sensor, reader allowing the user to estimate the dose instantly.

[0005] US Patent No. 10,060,786 [Assigned to L'Oreal] discloses personal Ultra-Violet (UV) radiation measurement system comprising UV measuring device, terminal device to capture the UV radiation and receive the specific information about user's risk level of UV exposure.

[0006] RadSure<sup>®</sup> irradiation indicator is one kind of dosimetry device, marketed by Ashland Specialty Ingredients Inc. providing positive, visual verification of irradiation. When attached to blood products, RAD-SURE<sup>®</sup> indicators show whether the blood products have been irradiated or not. Before a blood product and its attached indicator are irradiated, the indicator reads "NOT IRRADIATED". After irradiation, the word NOT in the indicator window is obscured and the indicator reads "IRRADIATED". There are a few more commercially available indicators under the tradenames RADTAG<sup>®</sup> and ONPOINT<sup>®</sup> as shown in Figure 1.

[0007] Many modifications have been made to the indicators in means of identifying amount of irradiation, reducing contamination, safe-guarding temperature, and visual identification means to alert the user about risk of radiation. However, there is no accurate mechanism to measure actual amount of radiation emitted from the radiation source.

[0008] Therefore, there exists a need in the art for a dosimetry device which can quantify the actual radiation (X-rays or gamma rays) exposure at the location of the user and provide detailed information regarding the user.

[0009] Surprisingly, our dosimetry device quantifies the actual radiation emitted from the radiation source with high precision.

[0010] In one aspect, provided herein is a dosimetry device for quantifying the dosage of radiation emitted from a radiation source, the device comprising: (i) a radiation dose indicator comprising radiation sensitive composition to measure the radiation and visually represent the amount of radiation emitted as color change; (ii) an optical means to capture the color change of the dose indicator after exposure to radiation; and (iv) a software means to compare the optical density of the dose indicator as compared to a predetermined calibration curve developed using percentage optical density versus cumulative radiation dosage to quantify the dosage of radiation emitted from the radiation source.

57 [0011] In another aspect, provided herein is use of a dosimetry device comprising: (i) a radiation dose indicator  
58 comprising radiation sensitive composition to measure the radiation emitted from a radiation source and visually  
59 represent the amount of radiation emitted as color change; (ii) an optical means to capture the color change of the  
60 dose indicator after exposure to radiation; and (iii) a software means to compare the optical density of the dose  
61 indicator to a predetermined calibration curve developed using percentage optical density versus cumulative  
62 radiation dosage to quantify the dosage of radiation emitted from the radiation source; in sterilization of surfaces  
63 and solutions, medical imaging, medical or industrial equipment quality assurance testing, UV light measurement,  
64 food processing and storage, transportation of radiation sensitive materials, or blood storage.

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66 [0012] In yet another aspect, provided herein is a method of quantifying the dosage of radiation emitted from a  
67 radiation source, comprising the steps of: (i) exposing a dosimetry device to irradiation, said dosimetry device  
68 comprising radiation sensitive indicator which measures the radiation and visually represents the amount of  
69 radiation emitted as color change; (ii) capturing the color change of the dose indicator after exposure to radiation  
70 using an optical means; and; (iii) comparing the optical density of dose indicator to a predetermined calibration  
71 curve developed using percentage optical density versus cumulative radiation dosage to quantify the dosage of  
72 radiation emitted from the source.

**6. The present application is an invention that is different from previous inventions because:**

- a) It can measure the dose quantitatively by a visual color change in a material.
- b) Only this device identifies irradiation exposure, with a visual identification means to alert the user about risk of radiation.
- c) It gives the specific information about user's risk level of UV exposure.
- d) Only this material changes color upon receiving irradiation.

**7. RadSure®, RADTAG® and ONPOINT® irradiation indicators:**

- a) Measure precisely the amount of radiation a sample (eg. blood) will receive.
- b) Are not commercially available.
- c) Can only indicate if the material was irradiated or not.
- d) Are made of polymeric material such as colorless solid monomers of diacetylenes.

**8. The readout mechanism of the current invention is by:**

- a) An optical means used to capture a color change.
- b) Emission of light emitted when the material is heated.
- c) Electron paramagnetic resonance.
- d) Optically stimulated luminescence.

**9. Which of the following applications is not stated by the author as an application where this dosimetry device can be used in?**

- a) sterilization of surfaces and solutions or medical imaging
- b) radiotherapy and diagnostic imaging
- c) UV light measurement or food processing and storage
- d) transportation of radiation sensitive materials or blood storage

**10. To quantify the dosage of radiation emitted from the source, this system:**

- a) Compares optical density to a predetermined calibration curve using percentage optical density versus cumulative radiation dosage.
- b) Compares the intensity of the visible emission of light under UV exposure to a predetermined calibration curve.
- c) The system can only indicate that the material has been or not exposed to radiation.
- d) Compares the UV emission of light when exposed to visible high-intensity light.