Response of the alanine/ESR dosemeter determined for radiation from a ^{192}Ir brachytherapy emitter

The response of the alanine/ESR dosemeter as regards the absorbed dose to water D_w relative to ^{60}Co radiation has been determined for the radiation field of a ^{192}Ir source, as is often used in brachytherapy. Due to the lower photon energy of the ^{192}Ir radiation, the relative response varies along with the water depth: it ranges from 0.976 at a distance of 1 cm from the source to 0.956 at a distance of 5 cm. The standard measurement uncertainty (including the primary standard) amounts to approx. 2 %.

^{192}Ir emitters are used in radiotherapy to treat cancer. They are very small radiation sources that are placed inside or very close to the tumour by means of an afterloader system – both in interstitial brachytherapy and in intracavitary brachytherapy.

In the case of intracavitary brachytherapy, applicators are often used to protect radiation-sensitive, healthy tissue from radiation by means of a shield that is placed only on one side. These applicators influence the doses applied to the tumourous tissue, but have, to date, not been taken into account in the protocols of clinical dosimetry and in treatment planning. The influence of the applicators on the applied doses is to be investigated in the research project "Metrology for radiotherapy using complex fields" (EMRP-HLT09) within the scope of the European Metrology Research Programme, among other things using alanine/ESR. For this purpose, the response of alanine in the ^{192}Ir radiation field first had to be determined for the relevant water depths (1 cm – 5 cm) by means of a newly developed holder which can be placed in a water phantom.

^{192}Ir emitters are usually calibrated in terms of the Reference Air Kerma Rate (RAKR), the air kerma rate at a distance of 100 cm from the emitter. The actual measurand used in brachytherapy, the absorbed dose to water at a distance of 1 cm from the emitter, is obtained by multiplying the RAKR by the dose conversion coefficient Λ. In order to investigate the influence of the applicators, however, it has to be possible to measure in water and near the emitter.

Measuring the absorbed dose to water directly is a great metrological challenge where small uncertainties in the positioning of the emitter and of the probe as well as field disturbances caused by the probe have much greater impacts than in the measurement of the RAKR. This is where alanine exhibits an advantage: it has radiation transport properties similar to those of water and therefore only causes very small field disturbances. Also the dependence of the response on the radiation quality, which varies along with the water depth, is relatively low in the case of alanine.

The irradiations in the ^{192}Ir field were carried out in a water phantom with a source of the type Nucletron mHDR-v2. Four irradiation supports were arranged in a circle; in each of them, two alanine pellets were irradiated with approx. 15 Gy (Fig. 1). Hereby, one alanine pellet was located above the symmetry plane, and the other below. The irradiations were carried out at a distance of 1 cm, 2 cm, 3 cm and 5 cm from the emitter (see also Fig. 2). The absorbed dose to water applied was calculated with the aid of the calibration factor for the RAKR of the source and of the so-called "consensus data" available for this specific type of source [1-3]. The irradiations necessary for the calibration of the alanine dosemeter were carried out in PTB's ^{60}Co reference radiation field [4].

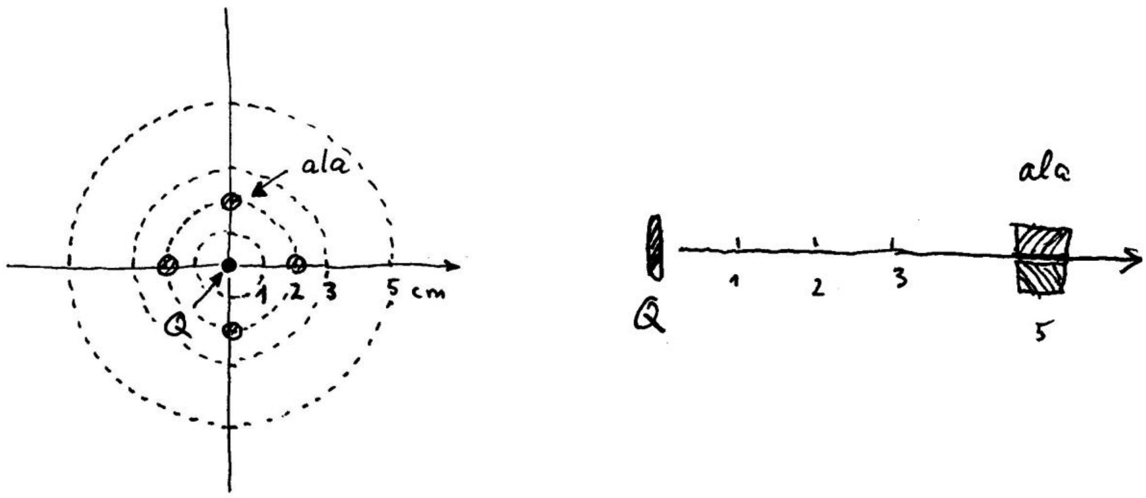

Fig. 1: Schematic drawing of the arrangement of the dosemeters during the irradiation. Left: top view, right: lateral view. The detector consists of two superposed alanine pellets (diameter: 4.8 mm, height: 3 mm for each pellet).

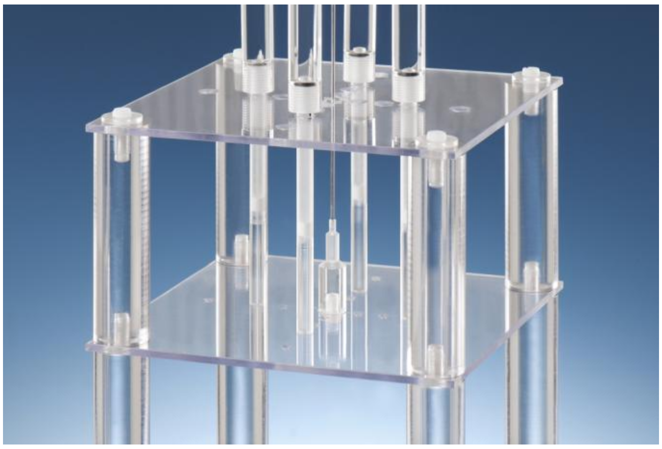

Fig. 2: Holder for the hollow needle in which the source is positioned (centre) and the four tubes for the detectors, arranged in a circle. During the measurement, the holder (made of Plexiglas® and of Makrolon®) is placed in a water phantom.

The circular arrangement of the irradiation supports serves the compensation of uncertainties due to the horizontal position of the emitter, since the emitter is inserted into a hollow needle (afterloader) to irradiate the alanine pellets and the exact (horizontal) position inside this hollow needle is not known. To compensate for geometry errors of the irradiation supports, the irradiations were repeated with the supports rotated by 180° and the results were averaged.

Since the alanine pellets were located very close to the emitter during the irradiation, some additional corrections have to be taken into account during the evaluation. In the near field of the source, the dose inside the alanine pellet no longer evolves in a linear way but follows a $1/r^2$ decrement instead, so that the spatially inhomogeneous sensitivity distribution inside the resonator of the ESR spectrometer has to be taken into account for the evaluation. The sensitivity distribution had previously been determined experimentally.

The response of alanine as regards the absorbed dose to water relative to ^{60}Co comes to between 0.976 (d =1 cm) and 0.958 (d =5 cm). The corresponding standard measurement uncertainties of the relative response vary between 2.15 % and 2.05 % (cf. Fig. 3). The greatest contributions to the uncertainty are caused by the air kerma rate S_k (RAKR) and the dose conversion coefficient Λ used to calculate the applied doses [1]. The uncertainty component caused by the alanine measurement is smaller than 1 %.

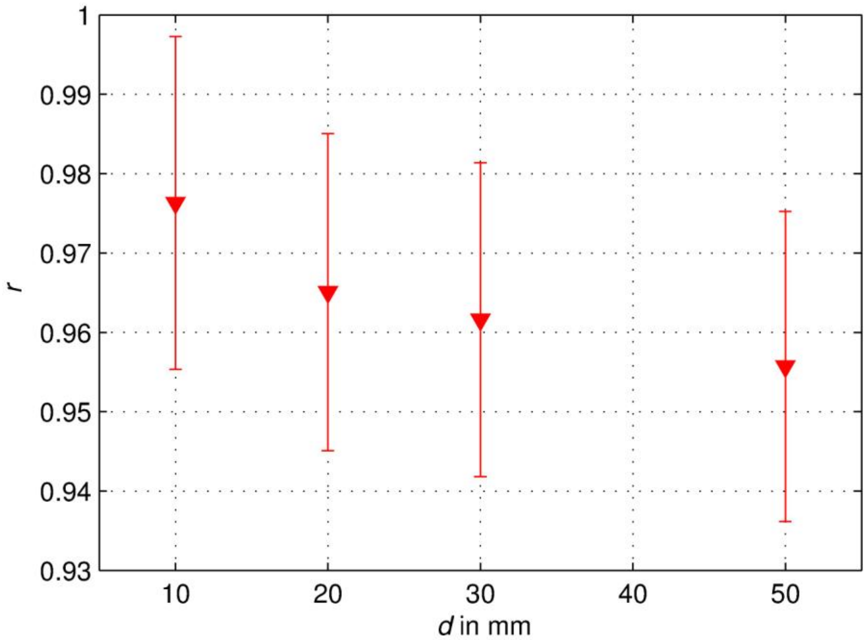

Fig. 3: Response ***r*** of the alanine dosemeter as regards the absorbed dose to water D_w for ^{192}Ir radiation, relative to ^{60}Co radiation, as a function of the distance *d* between the centre of the source and the centre of the detector. The error bars represent the standard measurement uncertainty.

Literature

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