GeVero Co.

2Day.QA®

2D dosimeter: item catalogue number: 2Day.QA−1, −2, −3, −4, −5, −6, and −7

User's Guide

2021

(manual v. 18.05.2021)

NOTICE

The GeVero Co**.** 2Day.QA® dosimeter must not be used for any purposes other than those described in this documentation.

GeVero Co. does not accept liability for injury to the users, personnel or patients that may result from the use and misuse of this dosimeter.

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I. About 2Day.QA®

This 2D dosimeter has been invented, designed and manufactured by GeVero Co. for 2D dosimetry of ionising radiation. Example applications of this dosimeter for radiotherapy can be as follows:

1. Daily checks of an accelerator beam geometry (testing coincidence of x-ray and light filed) – **main application**
2. Checks of a brachytherapy source position for an afterloader – **main application**
3. Verifications of planned dose distribution for a treatment planning system (TPS): likely

Some features of the dosimeter:

1. Very easy to use
2. For single use
3. Not for use in a water phantom; not water resistant
4. Can be delivered with some predefined scales or as a plain dosimeter without scales
5. Can be scanned with a flatbed scanner, Espon dedicated scanner for the like 2D dosimeters, and with a Vidar scanner. In case of scanning, make sure 2Day.QA® is not folded in order not to get "wavy images"
6. Original dosimeter sheets are designed with GeVero Co. logotype and 2Day.QA® trademark.

Dimensions:

The dosimeter is manufactured in A4 format.

II. Environmental requirements

1. 2Day.QA® should be protected from daylight. Store it in a light protecting packaging at room temperature. Occasional short exposure to room light during measurements is possible.
2. 2Day.QA® should not be exposed to solar radiation or artificial UV radiation.
3. Stability before irradiation, when stored at room temperature protected from daylight: more than 5 months.
4. Do not expose 2Day.QA® to elevated humidity. Store it in a dry place in a typical room/laboratory humidity.
5. Transportation temperature: ~10 – ~40 ^{o}C

III. Handling

2Day.QA® should not be touched with bare hands. Use gloves to handle it. Avoid touching the part to be irradiated and further processed with bare hands as it may leave finger prints on its surface affecting the quality of its readout. Wash hands with a soap in case of touching 2Day.QA® with bare hands.

IV. Setting up

2Day.QA® after manufacturing is packed for protection against daylight. Unpack a dosimeter sheet. Wear gloves, do not touch the dosimeter sheets with bare hands. Use it after unpacking for dosimetry purposes in radiotherapy. After irradiation store it in original packaging or another one protecting the dosimeter against daylight.

V. Using for experiment

Daily checks of an accelerator beam geometry – main application

Example use of 2Day.QA® dosimeter for checking a beam geometry is shown below (**Figure 1**). A dosimeter sheet was irradiated with a medical accelerator (SSD 100, X6, 600 MU/min, build-up: minimum 2 mm, dose range: apply doses of ~0.9–100 Gy). The fields of 10×10 cm^2 and 20×20 cm^2 were to be examined. They were set for irradiation of 2Day.QA®. After irradiation, white 2Day.QA® sheet converted to blue colour only in the regions confined to 10×10 cm^2 or 20×20 cm^2. The accelerator's beam geometry was verified for two fields.

In **Figure 1** a blue stripe on the right side of the dosimeter is an example for a gradiental irradiation. A square pattern of irradiation was used for calibration purposes of 2Day.QA® (**Figure 1**).

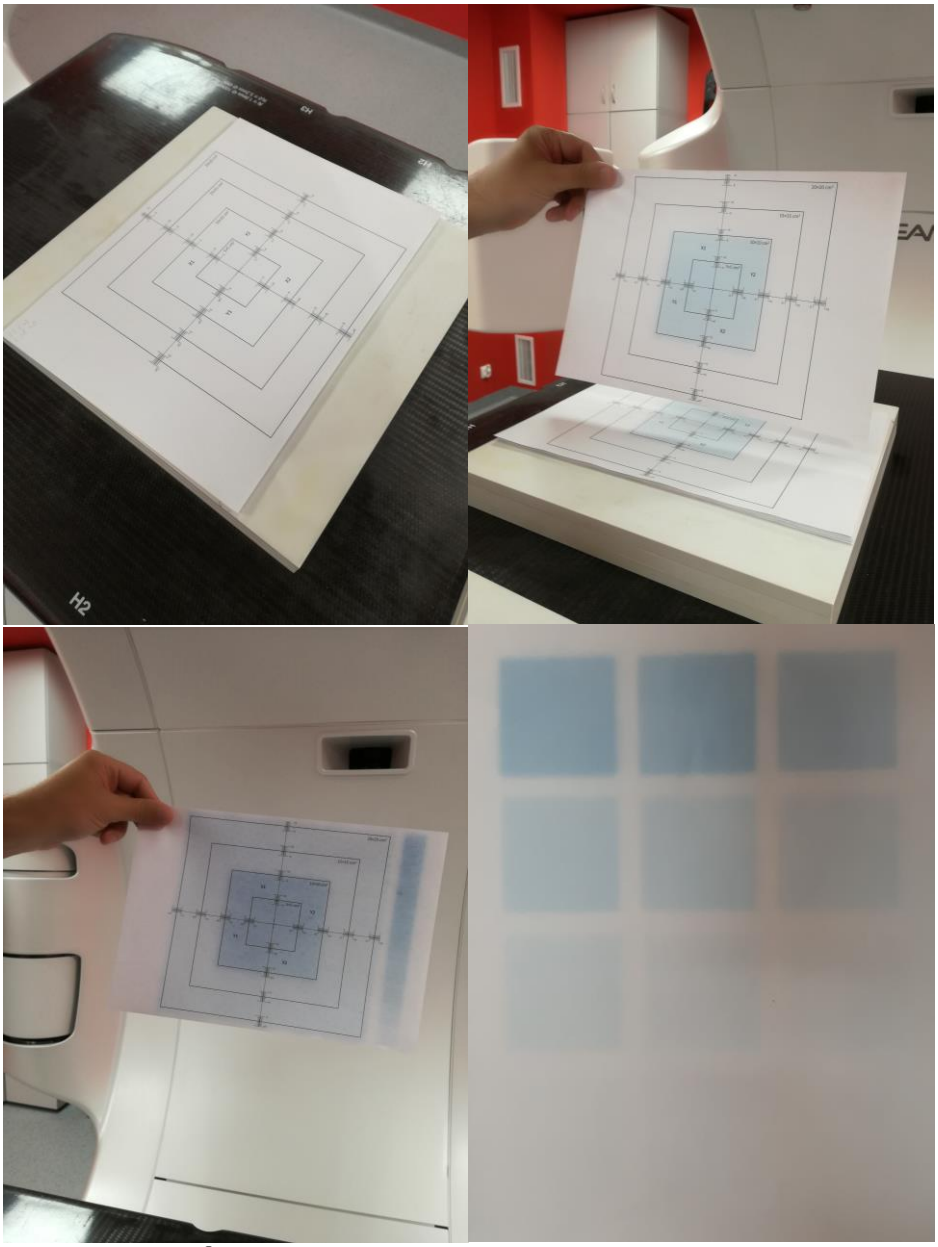
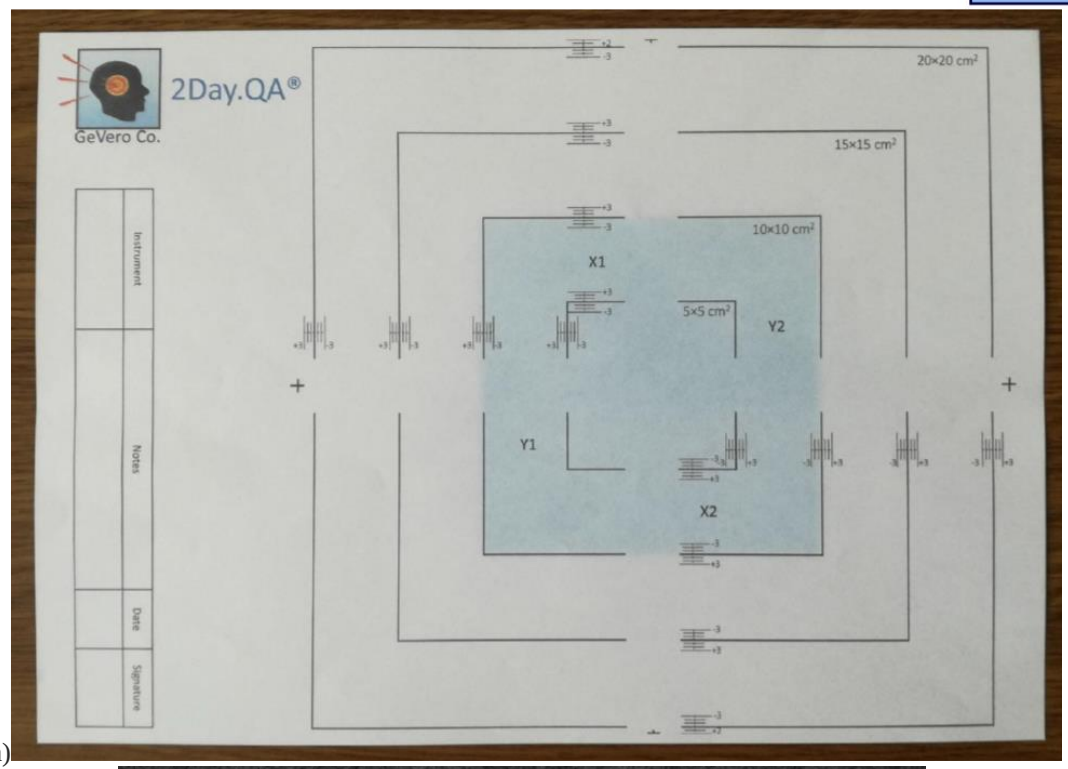


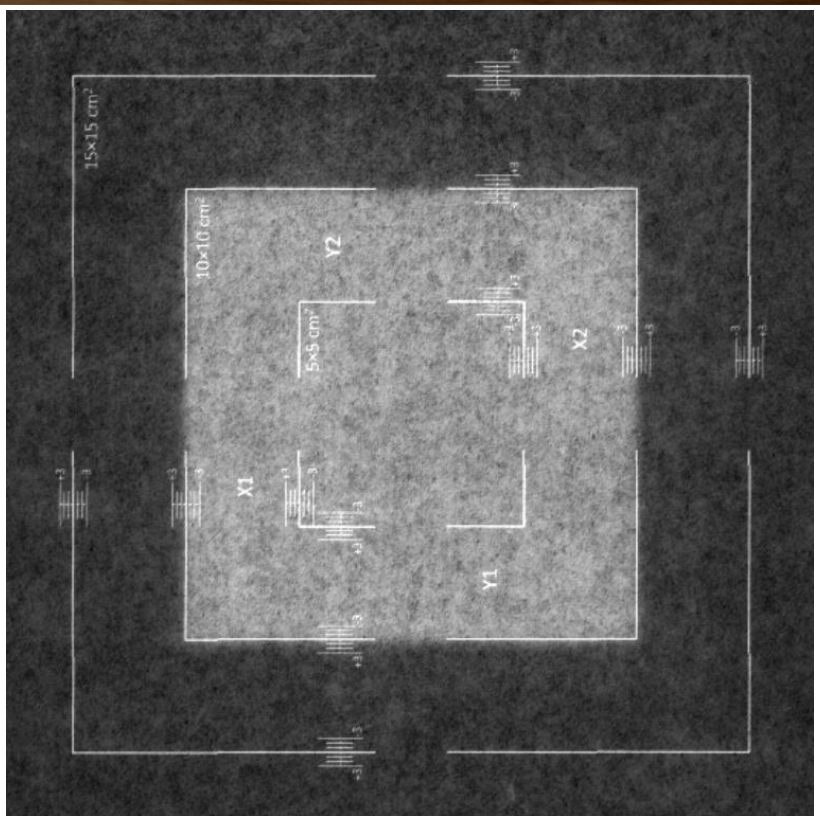
Figure 1. Top left – 2Day.QA® dosimeter sheet before irradiation; other photographs correspond to irradiated 2D dosimeter sheets with a medical accelerator, as follows: top right – a dosimeter sheet after irradiation with a photon beam of 10×10 cm^2 (25 Gy); bottom left photograph is for the 2D dosimeter sheet after irradiation with a photon beam of 10×10 cm^2 (25 Gy) and a photon beam of 20×20 cm^2 (25 Gy); a blue bar/stripe corresponds to a gradiental irradiation. Bottom right is for 2Day.QA® irradiated for calibration purposes to the doses in a range of 0.95–94.9 Gy (top left blue square region corresponds to 94.9 Gy, whereas bottom right corresponds to 0 Gy).

Note: 2Day.QA® converts to blue colour after irradiation. The dose effect for >9 Gy can be seen to the naked eye. However, the dose effect down to ~1 Gy may be seen after scanning 2Day.QA® with e.g. Vidar scanner (see below). For clear and easy observation of a dose effect with the naked eye apply a high dose of over 30 Gy. 2Day.QA® saturates at about 90 Gy.

In **Figure 2** an application of 2Day.QA® for beam geometry verification is presented for the second time. In this experiment a template "-6" (2Day.QA®-6) was used that allows to draw profiles across irradiated and non-irradiated regions due to specific pattern of this template.

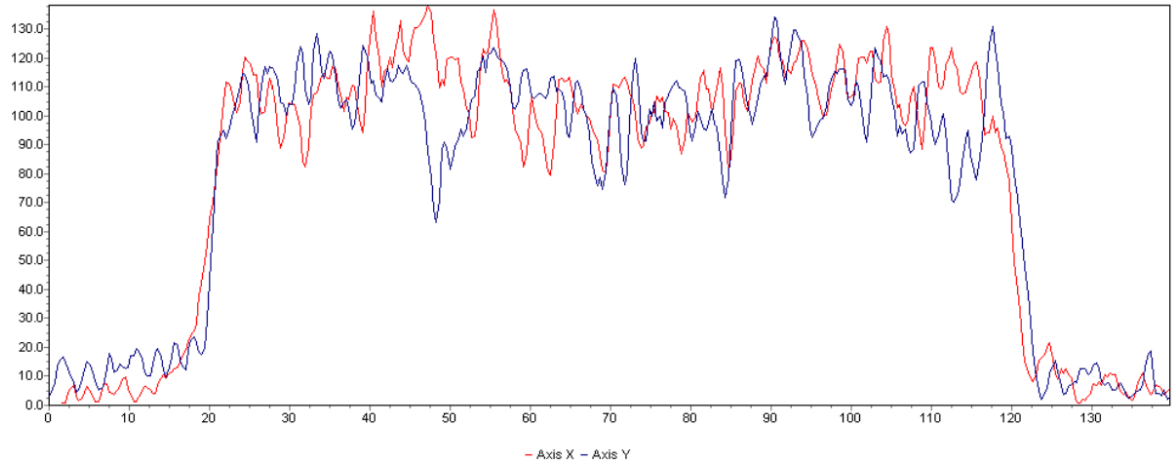


(a)



(b)

Figure 2. 2Day.QA®-6 applied for beam geometry verification and calculation of a beam width. Top photograph (a) is for the dosimeter as seen after irradiation (a photograph taken with a camera); blue zone is for the 10×10 cm^2 region irradiated with 6 MV photons at 2 mm build-up (5000 MU, SSD 100). (b) is an image as obtained after scanning with Vidar® Red LED Dosimetry Pro Advantage™ and data was processed with polyGeVero®-CT software package. (c) is for profiles in X and Y axes of the irradiated region shown in (b) (profiles not filtered).



(c)
Figure 2 (continued).

In **Figure 2(a)** the dosimeter is shown after irradiation of 10×10 cm^2 region. Blue colour denotes radiation-induced changes of the part that was exposed to radiation; other part of the dosimeter remains white in colour. The naked eye assessment of the blue region with respect to the 10×10 cm^2 pattern indicates that the beam geometry is preserved. For quantitative analysis of the dosimeter, it was scanned with Vidar® Red LED Dosimetry Pro Advantage™. In **Figure 2(b)** the result of the scanning is shown (2Day.QA®-6 image was cut to presnt only the region of interest). The image after scaning was processed with polyGeVero®-CT software package (GeVero Co.) to arrive at profiles as shown in **Figure 2(c)**.

The calculated width of the irradiated region in X and Y axes is equal to 100.97 and 101.46 mm, respectively. This is in agreement with a predefined beam geometry.

Tests of a brachytherapy source position for an afterloader

Details of a test:

1. 2Day.QA−5 A4 sheet. For this purpose one of the other templates can be used as well, for instance: 2Day.QA−2, 2Day.QA−3 and 2Day.QA−4.
2. ^{192}Ir GammaMed 12i (HDR); 370 GBq (planned), 216.374 GBq (scaled); total time 690 s; source to be exchanged in 64 days (source calibrated: 02.02.2021)
3. Seven positions of the source; length: 150 mm
4. Dwell times: 10, 20, 30, 60, 120, 150, 300 s
5. A photograph taken with a Huawei P7 light camera; a scan performed with Vidar® Red LED Dosimetry Pro Advantage™
6. polyGeVero®-CT software package (GeVero Co.) was used for processing a Vidar scan.

In **Figure 3** the results of irradiation of 2Day.QA® with ^{192}Ir are presented. Seven positions of the source during irradiation left effects in form of blue colour spots. The size of the spots increases with an increase in dwell time. The effects of the irradiation obtained indicate the application of 2Day.QA® for brachytherapy.

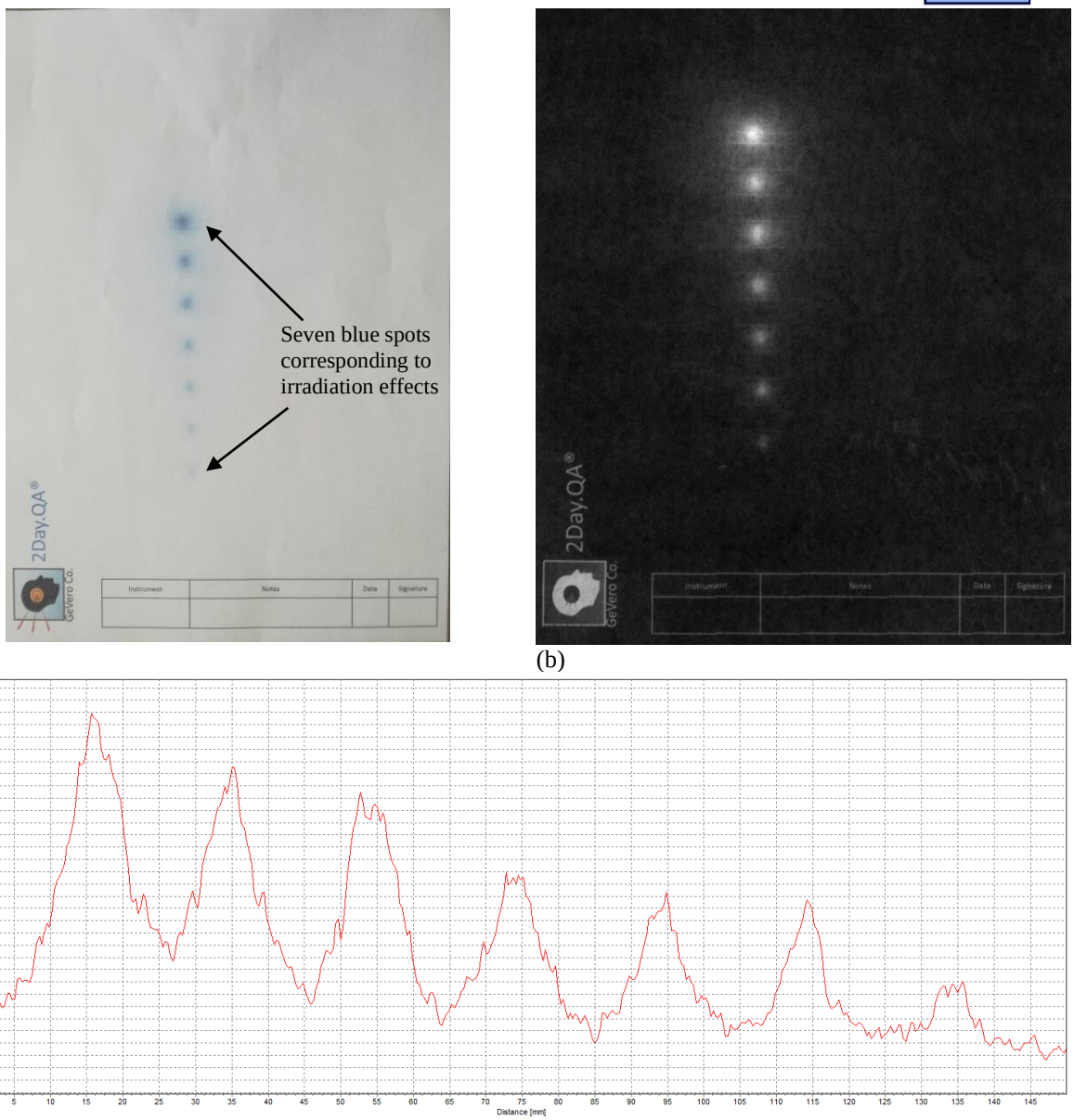


Figure 3. Example application of 2Day.QA® for testing position of ^{192}Ir source: (a) is for a photograph of 2Day.QA® taken after irradiation; (b) is for a scan as obtained with the aid of Vidar® Red LED Dosimetry Pro Advantage™ (75 dpi). The smallest spot corresponds to 10 s dwell time, the largest spot corresponds to 300 s dwell time (other dwell times: 20, 30, 60, 120, 150). In (c) a profile along the spots is shown (data without filtering; data obtained with the aid of polyGeVero®-CT software package).

Basic characteristic of 2Day.QA® dose response

Irradiation: a medical accelerator (TrueBeam™, VARIAN, USA, SSD 100, X6, 600 MU/min, build-up 15 mm, SP34 phantom RW3 (IBA), field size: 5×5 cm^2)
Scanning: HP Scanjet G3010 flatbed scanner and Vidar® scanners: Vidar® Red LED Dosimetry Pro Advantage™ and Vidar® VXR 12-plus™
Data processing: OmniPro™ IMRT (v. 1.7.0021) and polyGeVero-CT (v.1.0.1)

1. Calibration of 2Day.QA® – Vidar® scanners

The effect of 2Day.QA® irradiation and scanning with Vidar® Red LED Dosimetry Pro Advantage™ scanner is presented in **Figure 4**. Top left image corresponds to the dosimeter after scanning, whereas the top right is for the same image, however, after mean filtering.

A calibration of 2Day.QA® as a relation of optical density versus radiation dose is presented in **Figure 5** for both Vidar® Red LED Dosimetry Pro Advantage™ (red light) and Vidar® VXR 12-plus™ (white light) of 2Day.QA®. Since the red light scanning proved to be superior over the white light, further characteristics of the dosimeter are described for the results obtained from the red light Vidar® scanning.

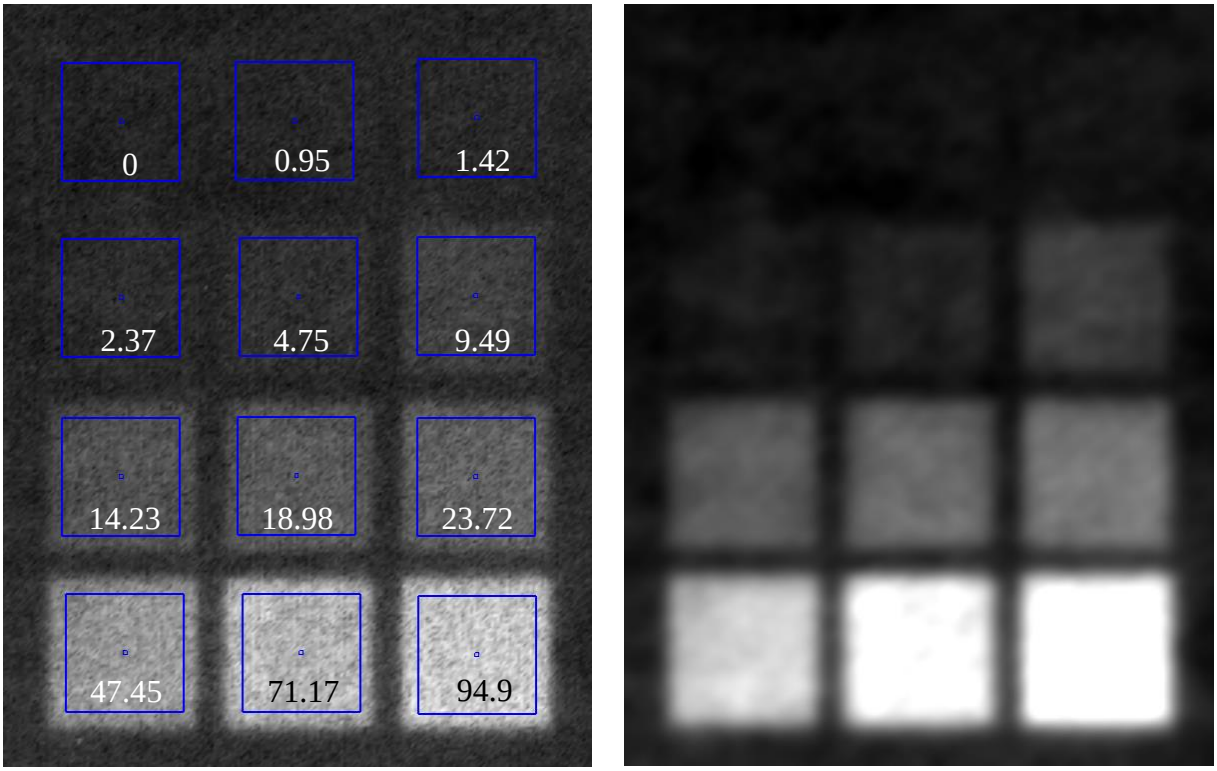


Figure 4. Top left: 2Day.QA® after scanning with Vidar® Red LED Dosimetry Pro Advantage™ (red light, 75 dpi). Square regions of different white colour intensities correspond to absorbed doses in the range of 0–94.9 Gy. Top right: the same image, however after filtration. Mean filtering (2 iterations, Kernel 5, Kernel unit: pixels) was applied (as one of many possible) with polyGeVero-CT software (GeVero Co.). Blue squares: ROIs from which mean pixel values were calculated for calibration purposes.

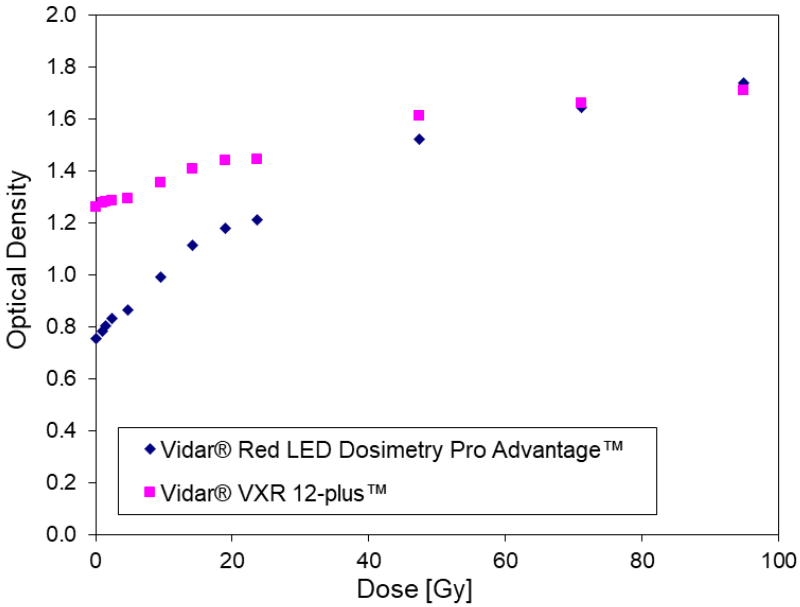


Figure 5. A comparison of scanning effects with Vidar® Red LED Dosimetry Pro Advantage™ (red light) and Vidar® VXR 12-plus™ (white light) of 2Day.QA® (no filtering of images was applied; measurements performed 16 days after irradiation).

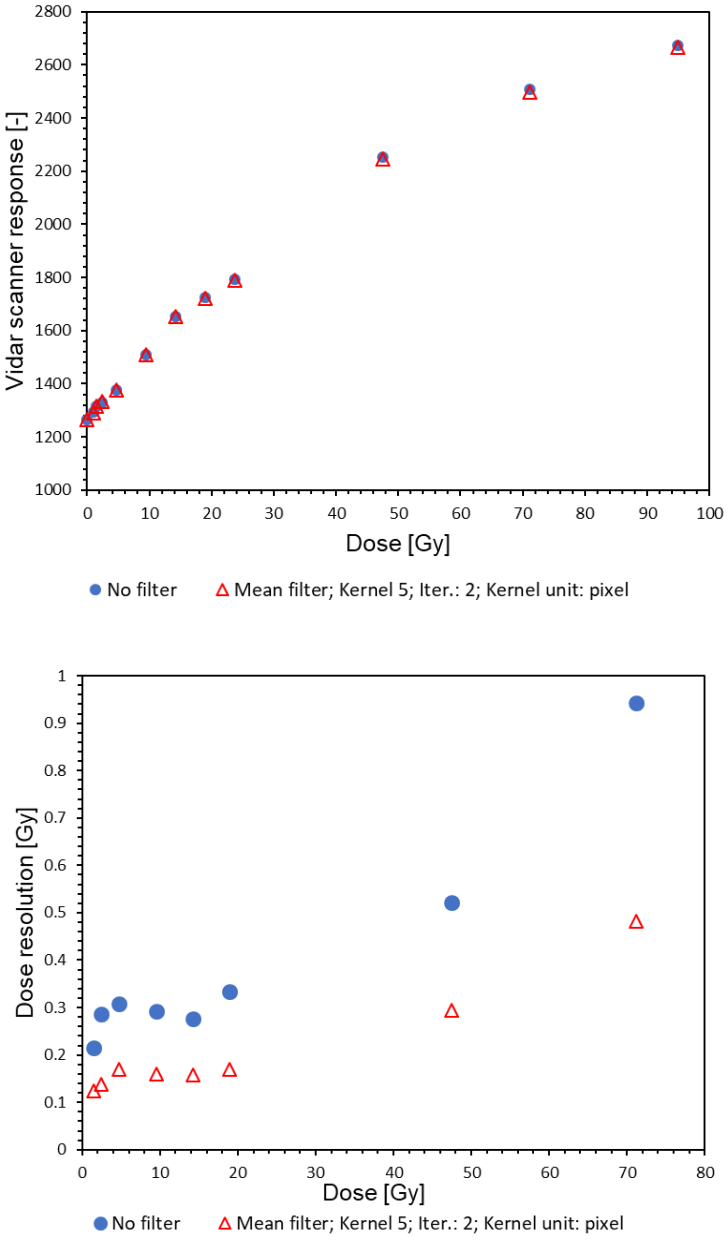


Figure 6. Calibration of 2Day.QA® versus absorbed dose (top graph) and dose resolution (bottom graph). The dosimeter measured with Vidar® Red LED Dosimetry Pro Advantage™ (red light) scanner immediately after irradiation. Data processed with polyGeVero-CT software package.

The impact of image filtration (Mean filtering: 2 iterations, Kernel 5, Kernel unit: pixels) on calibration and dose resolution of 2Day.QA® was examined (**Figure 6**). Mean pixel values were calculated from ROIs indicated in **Figure 4** in order to prepare the calibration graphs. Analysis of the calibration graphs (**Figure 5** and **6**) concluded with the following:

- 2Day.QA® responds to the lowest dose applied (0.95 Gy) and saturates at about 90 Gy
- Mean filtering has no significant impact on the calibration graph
- Mean filtering improves substantially the dose resolution of 2Day.QA®

2. Calibration of 2Day.QA® – HP Scanjet G3010 flatbed scanner

2Day.QA® after irradiation with an accelerator, scanned and resolved to red, green and blue channels of RGB colour scale is shown in **Figure 7**. The highest intensity of colour change after irradiation is observed for red channel.

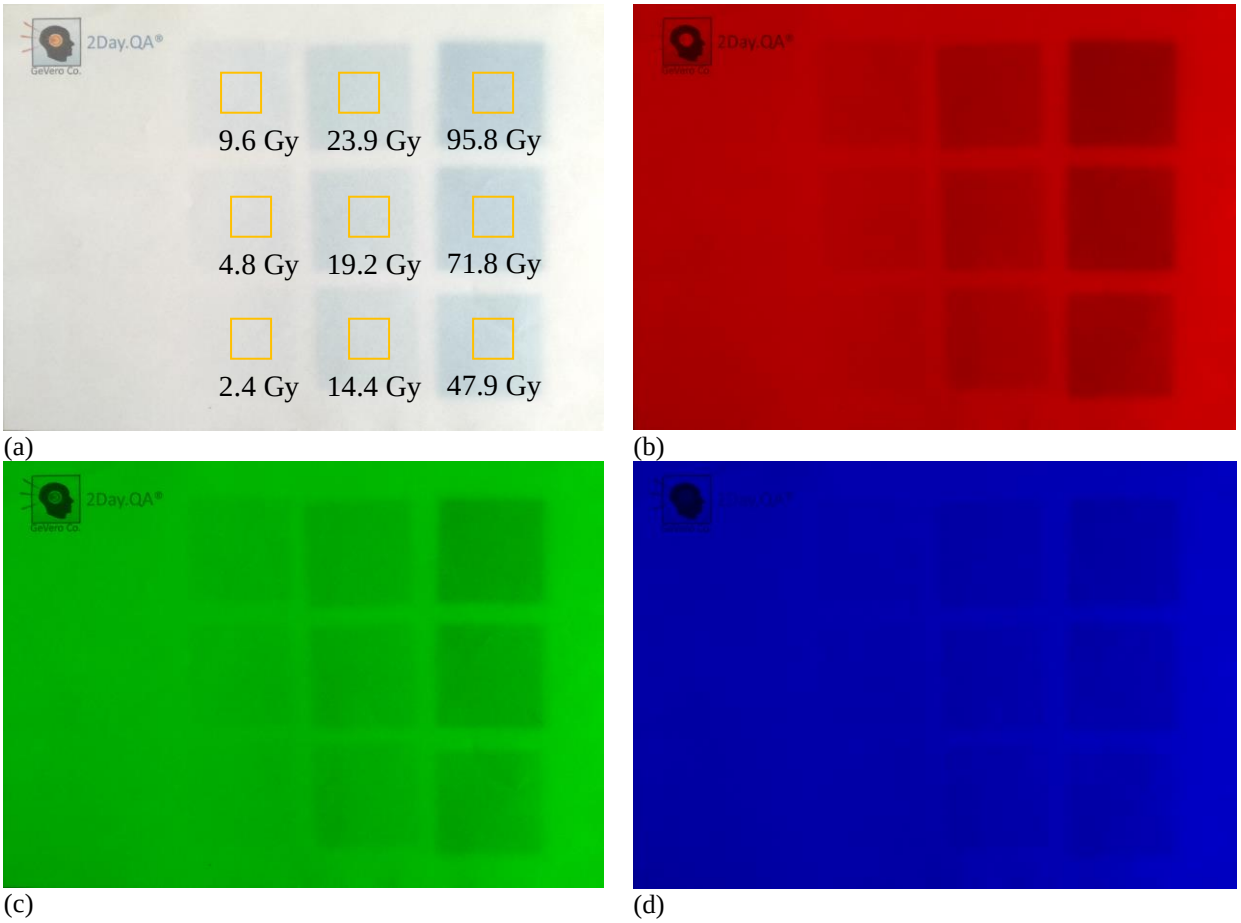


Figure 7. Example irradiation and processing after scanning with a HP Scanjet G3010 flatbed scanner of 2Day.QA® dosimeter: (a) corresponds to a sheet of 2Day.QA® after irradiation – blue square regions correspond to absorbed doses (dose range: 2.4–95.8 Gy); (b–d) corresponds to red, green and blue channels of RGB colour scale for 2Day.QA®. Red channel is the most vulnerable to irradiation (the highest sensitivity of colour change after irradiation). Orange squares in (a) indicate positions of ROIs from which mean values were calculated.

In **Figure 8** a calibration of red channel mean value (ROIs taken for calculations are indicated in **Figure 7**(a)) versus absorbed dose is shown.

Note that the quality of data obtained is related to the quality of scanning performed. We consider the quality of 2Day.QA® scanning with the HP Scanjet G3010 flatbed scanner used as medium. Nevertheless, the results show potential in scanning 2Day.QA® with a typical flatbed scanner.

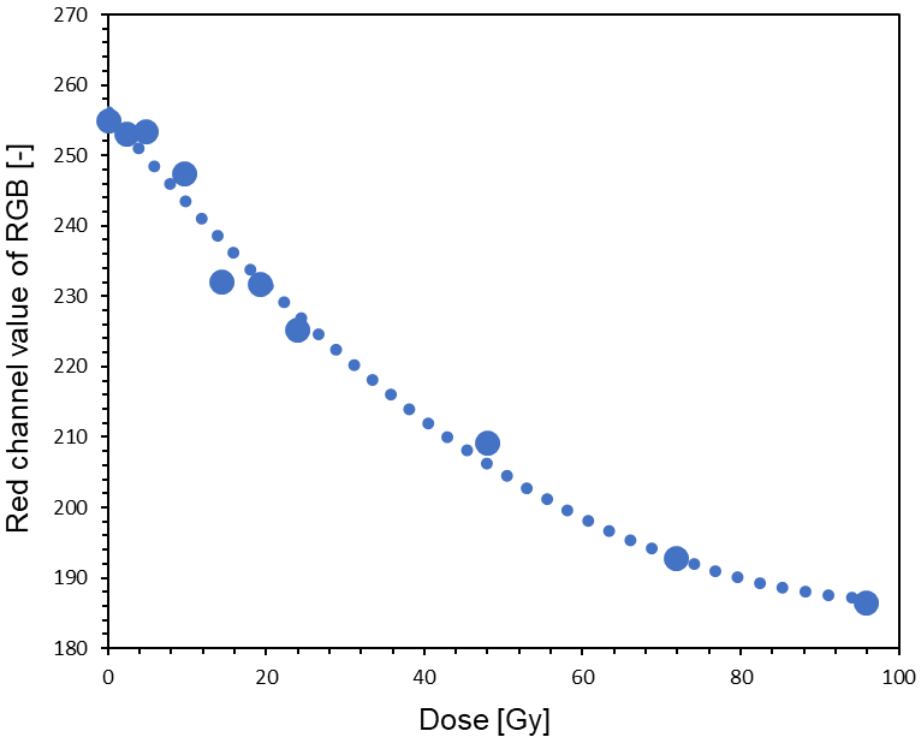


Figure 8. Calibration of 2Day.QA® versus absorbed dose. 2Day.QA® scanned with a HP Scanjet G3010 flatbed scanner and image was resolved into RGB colour scale. Red channel, as the most sensitive to radiation, was analysed.

3. Stability of 2Day.QA®

The stability of 2Day.QA was assessed both for non-irradiated and irradiated samples scanned with a HP Scanjet G3010 flatbed and Vidar® Red LED Dosimetry Pro Advantage™ scanners.

Before irradiation

In **Figure 9** stability of non-irradiated 2Day.QA® (0 Gy) is presented over the period of 80 days (samples scanned with a HP Scanjet G3010 flatbed scanner). No change of the dosimeter was observed that points to its stability for at least 80 days of storage in room temperature, protected from daylight (typical room/laboratory humidity).

After irradiation

In **Figure 10** stability of non-irradiated and irradiated 2Day.QA® is presented for samples measured with a HP Scanjet G3010 flatbed scanner. The measurements were performed for the period of 4–80 days after irradiation. Top graph: red channel mean signal versus time of storage; bottom graph: slope derived from the linear relations for the curves in top graph versus absorbed dose.

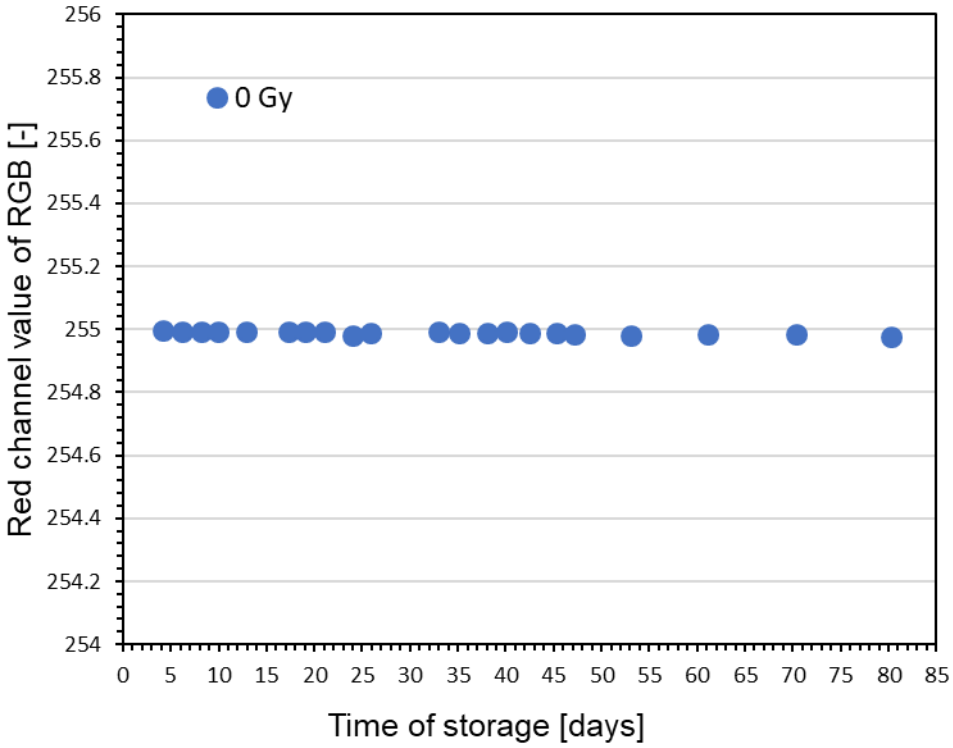
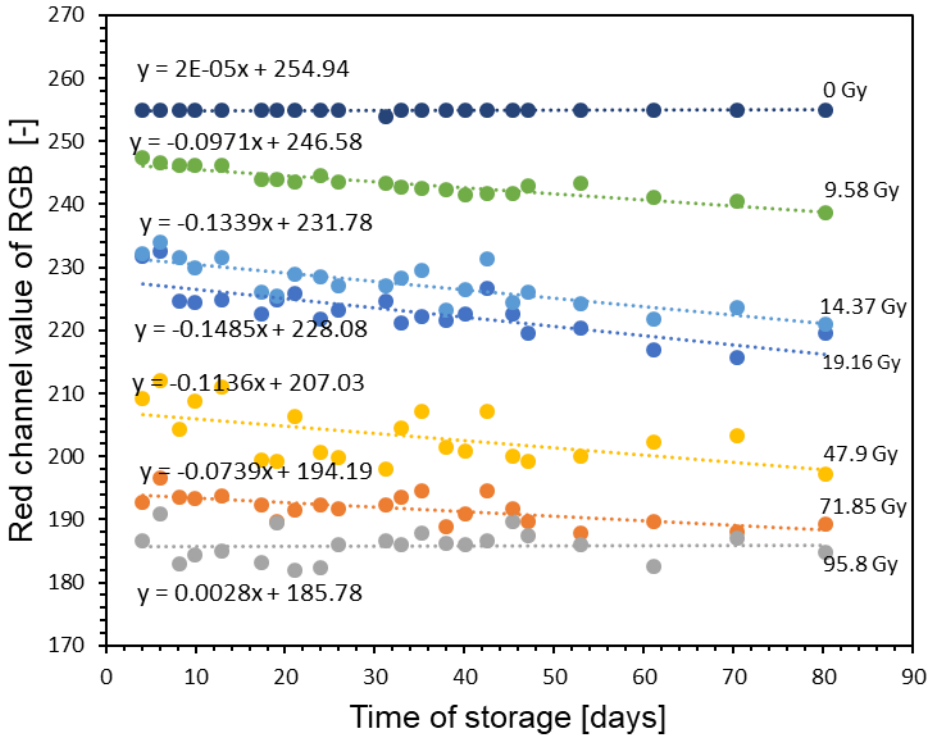
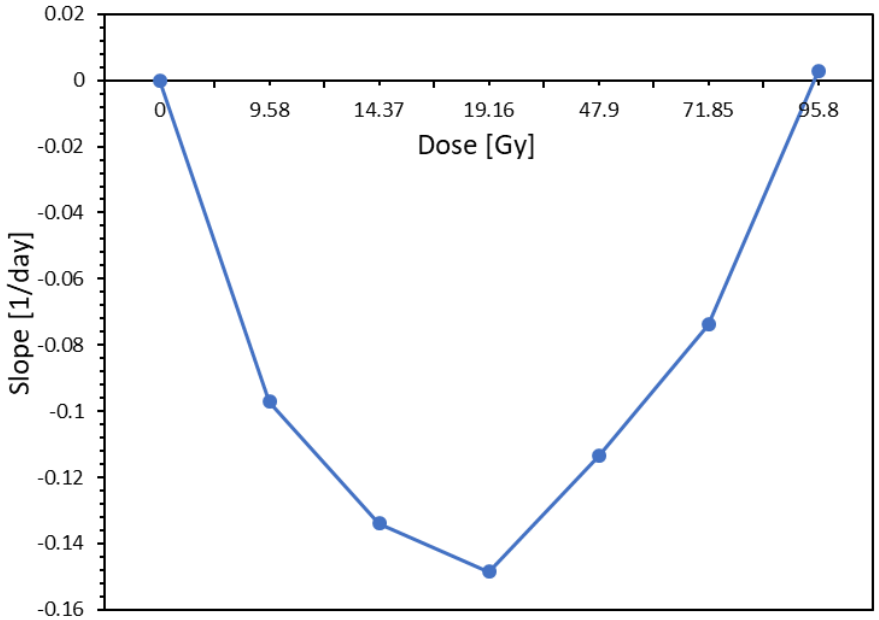


Figure 9. Stability of non-irradiated 2Day.QA® (0 Gy) over time of storage. Storage conditions: 2Day.QA® enveloped in a light protective foil; room temperature in a range of 20–23 ºC. 2Day.QA® scanned with a HP Scanjet G3010 flatbed scanner and images were resolved into RGB colour scale. Red channel, as the most sensitive to radiation, was analysed. Time period of measurements: 4–80 days.



(a)
Figure 10.



(b)

Figure 10 (continued). Stability of non-irradiated and irradiated 2Day.QA®. Storage conditions: 2Day.QA® enveloped in a light protective foil; room temperature in a range of 20–23 ºC. The measurements were performed for the period of 4–80 days after irradiation with a HP Scanjet G3010 flatbed scanner. Graph (a): red channel mean signal versus time of storage; graph (b): slope derived from the linear relations for the curves in the graph (a) versus absorbed dose.

The main conclusion drawn from **Figure 10 (a–b)** is that the irradiated 2Day.QA® slowly changes into darker blue (a slow drift), however, the maximal rate of this change is for the dose around 19 Gy and it drops down both for higher and lower dose applied. For 0 Gy region and the highest dose applied (95.8 Gy) it is close to 0, which means 2Day.QA® is very stable. Note that this slow drift for irradiated 2Day.QA® at a long period (**Figure 10 (a)**) is hardly observable to the naked eye.

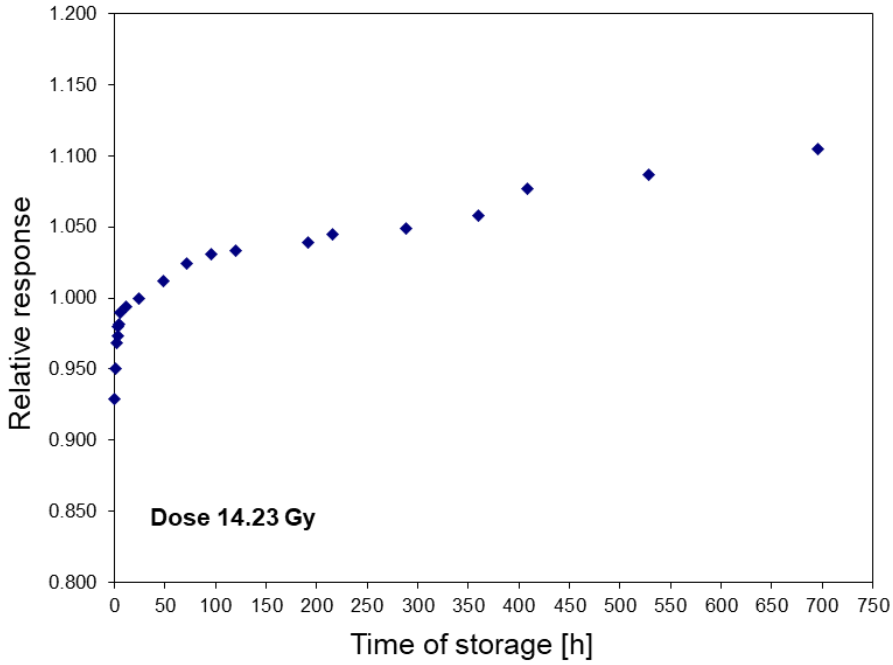


Figure 11. Stability of irradiated 2Day.QA® to the dose of 14.23 Gy over time of storage (30 days) as measured with Vidar® Red LED Dosimetry Pro Advantage™ (red light) scanner; normalised to data at 24 h after irradiation.

The stability of 2Day.QA® at a shorter (0–24 h) and longer (30 days) period after irradiation was assessed with the aid of Vidar® Red LED Dosimetry Pro Advantage™ (red light) scanner (**Figure 11**). Example results are shown for the region that absorbed 14.23 Gy (similar results were obtained for different doses applied). The Vidar® scanner results point to increasing the blue colour intensity after irradiation such that the most intensive changes occur during the first ~24 h after irradiation, which is followed by a slow drift at a longer period after irradiation. Note that this slow drift at a longer period is hardly observable to the naked eye.

VI. Recommendations for application of 2Day.QA®

1. For daily checks of an accelerator beam geometry (**main application**):

    a) apply a high dose to a sheet of 2Day.QA® with a template scale. Recommended dose: 30 Gy or higher to get a strong effect of blue colour appearance. Note that 2Day.QA® saturates at about 90 Gy. Apply a high dose rate to decrease the irradiation time for your convenience. Blue colour appears immediately. This allows for the naked eye assessment of alignment of applied light filed and dose field effect to the scale printed on 2Day.QA®. See below for example scales printed on 2Day.QA®.
    b) apply a lower dose to a sheet of 2Day.QA®, for example, in a range of 5–14 Gy. Use Vidar® Red LED Dosimetry Pro Advantage™ (red light) (75 dpi) for scanning irradiated sheet of 2Day.QA® and further assessment of alignment of applied light filed and dose field effect to the scale printed on 2Day.QA®.

2. For checks of a brachytherapy source position for an afterloader (**main application**):

    a) apply a high dose to a sheet of 2Day.QA® with a template scale. Recommended dose: 30 Gy or higher in the vicinity of 2Day.QA® to get a strong effect of blue colour appearance. Note that 2Day.QA® saturates at about 90 Gy. Blue colour appears immediately. This allows for the naked eye assessment of a source position with respect to a predefined position. See below for example scales printed on 2Day.QA®.
    b) apply a lower dose to a sheet of 2Day.QA® with respect to that in point 1. Use Vidar® Red LED Dosimetry Pro Advantage™ (red light) (75 dpi) for scanning irradiated sheet of 2Day.QA® and further assessment of the source position with respect to that predefined. Note that with Vidar® Red LED Dosimetry Pro Advantage™ (red light) one may observe changes of 2Day.QA® at lower doses.
    c) 2Day.QA® can be cut into stripes with scissors for your convenience.

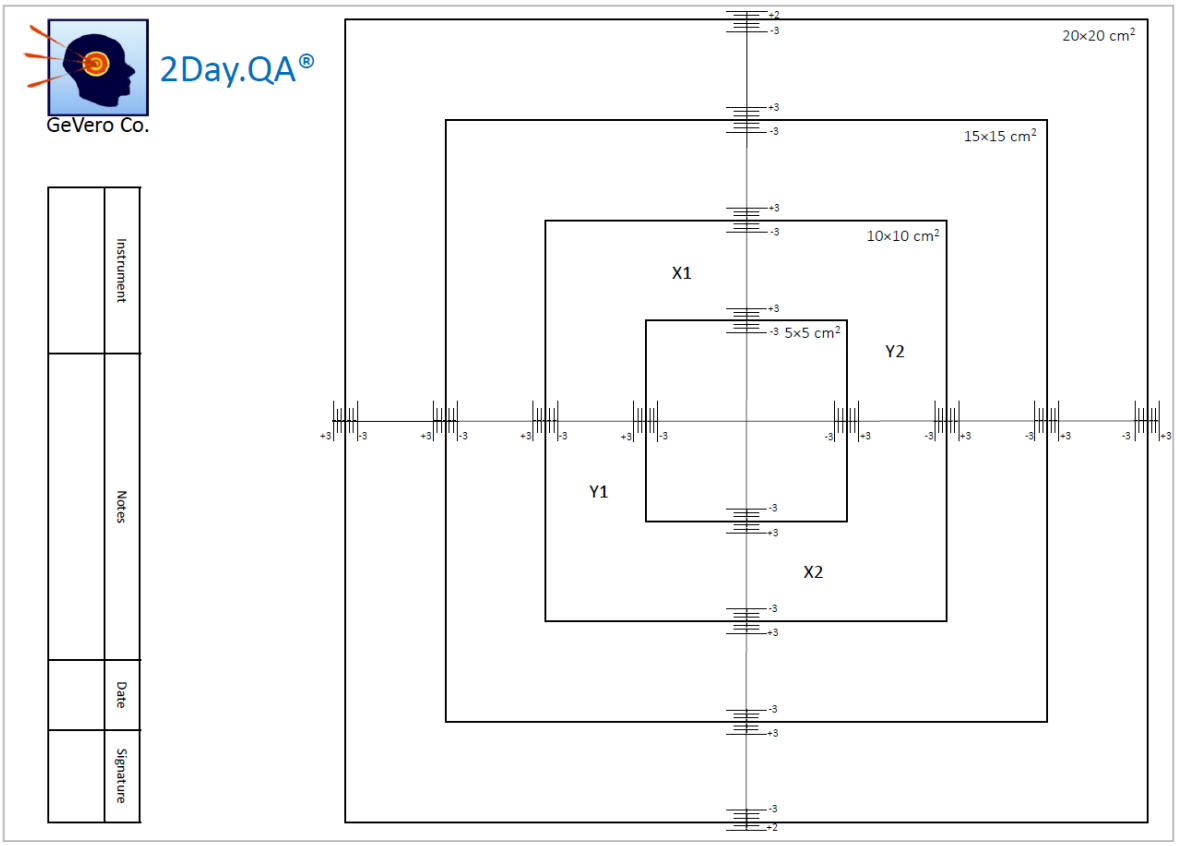
3. Verifications of planned dose distribution by a treatment planning system (TPS) (**likely application**):

    a) Use a part of 2Day.QA® sheet for calibration and a part of the same sheet for verification of a planned dose distribution
    b) Recommended application for verification of planned dose distribution in e.g. radiosurgery, for total high doses planned. Rather not recommended for verification of low fraction doses
    c) Use Vidar® Red LED Dosimetry Pro Advantage™ (red light) for scanning 2Day.QA®
    d) To boost dose resolution of 2Day.QA® apply filtering of scanned images
    e) Due to post-effect undergoing in 2Day.QA® after irradiation, pay attention to scanning the calibration and verification parts of the dosimeter at the same time after irradiation. Note that after 24 h after irradiation, the irradiated parts of 2Day.QA® will increase their intensity of blue colour at much lower rate than that during the first 24 h.
    f) Note that current state-of-the-art of 2Day.QA® dosimeter does not support and guarantee batch-to-batch and sheet-to-sheet repeatability to use separate sheets for calibration and verification purposes, since 2Day.QA® was designed mostly for the main application described in point 1 and 2.

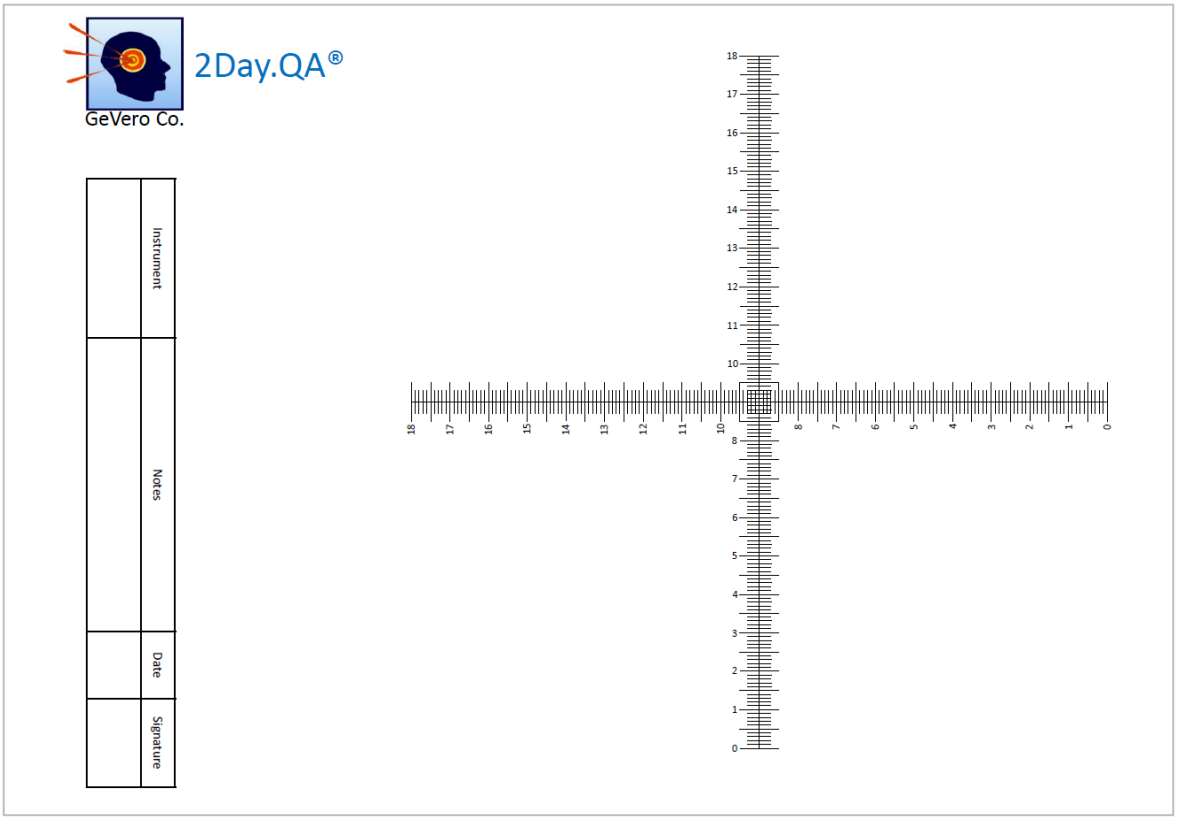
VII. Examples of templates on 2Day.QA® dosimeter

Note: *Any pattern can be prepared on 2Day.QA®.*

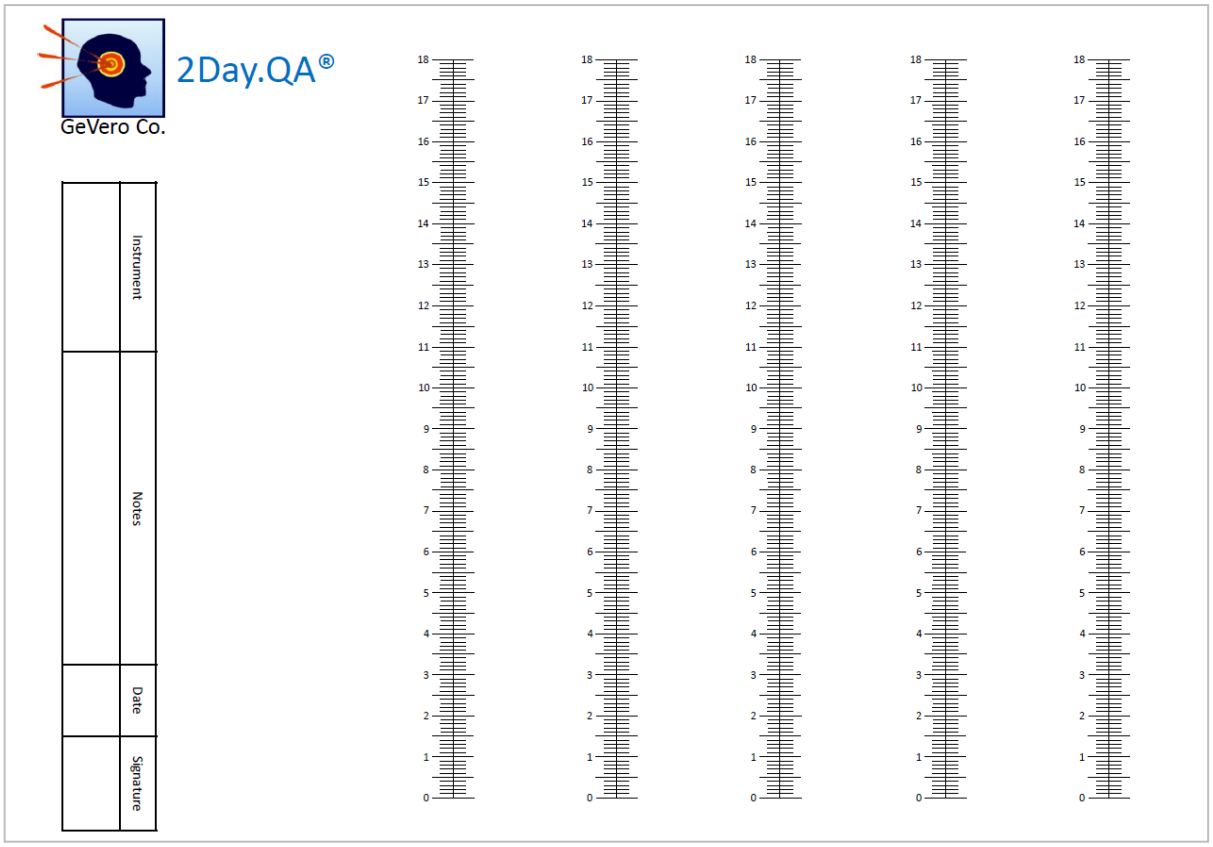
2Day.QA® for accelerator beam filed checking (catalogue no: **2Day.QA-1**):



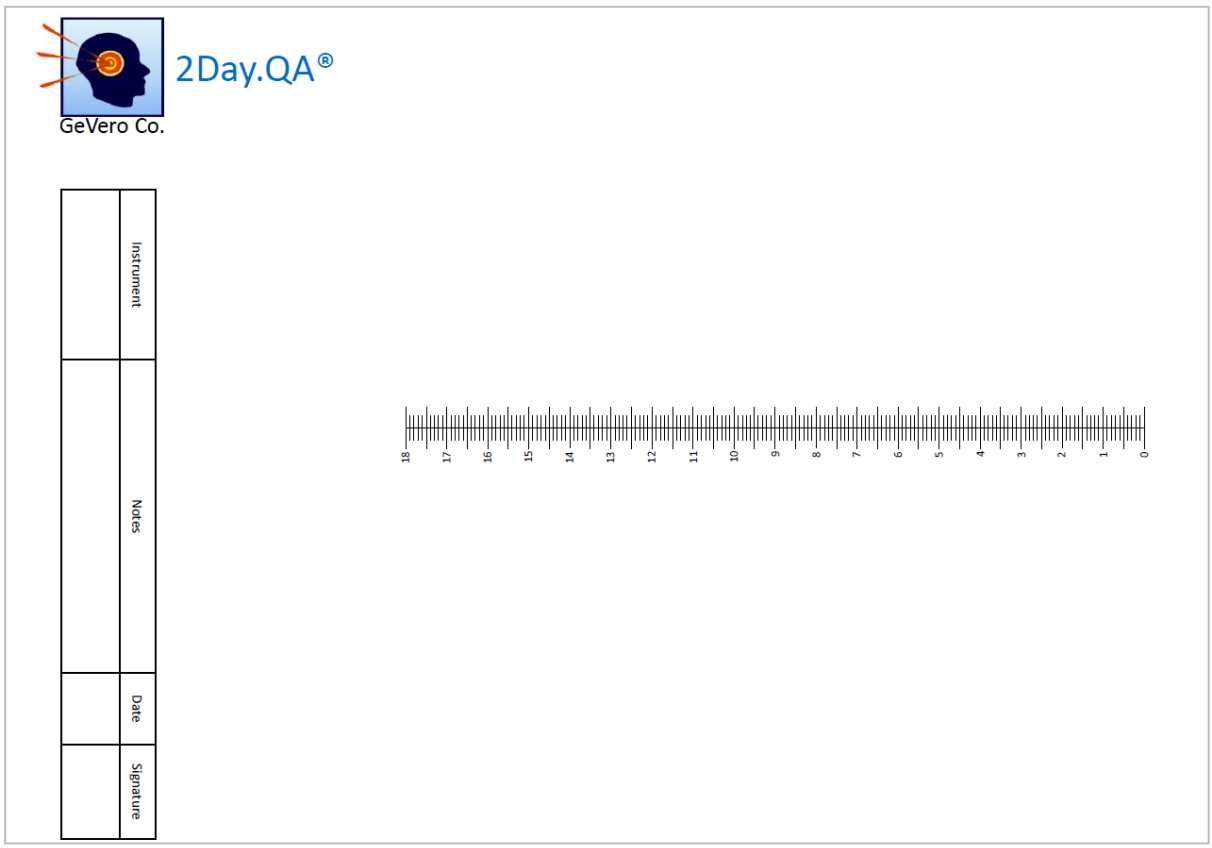
2Day.QA® for brachytherapy applications (catalogue no: **2Day.QA-2**):



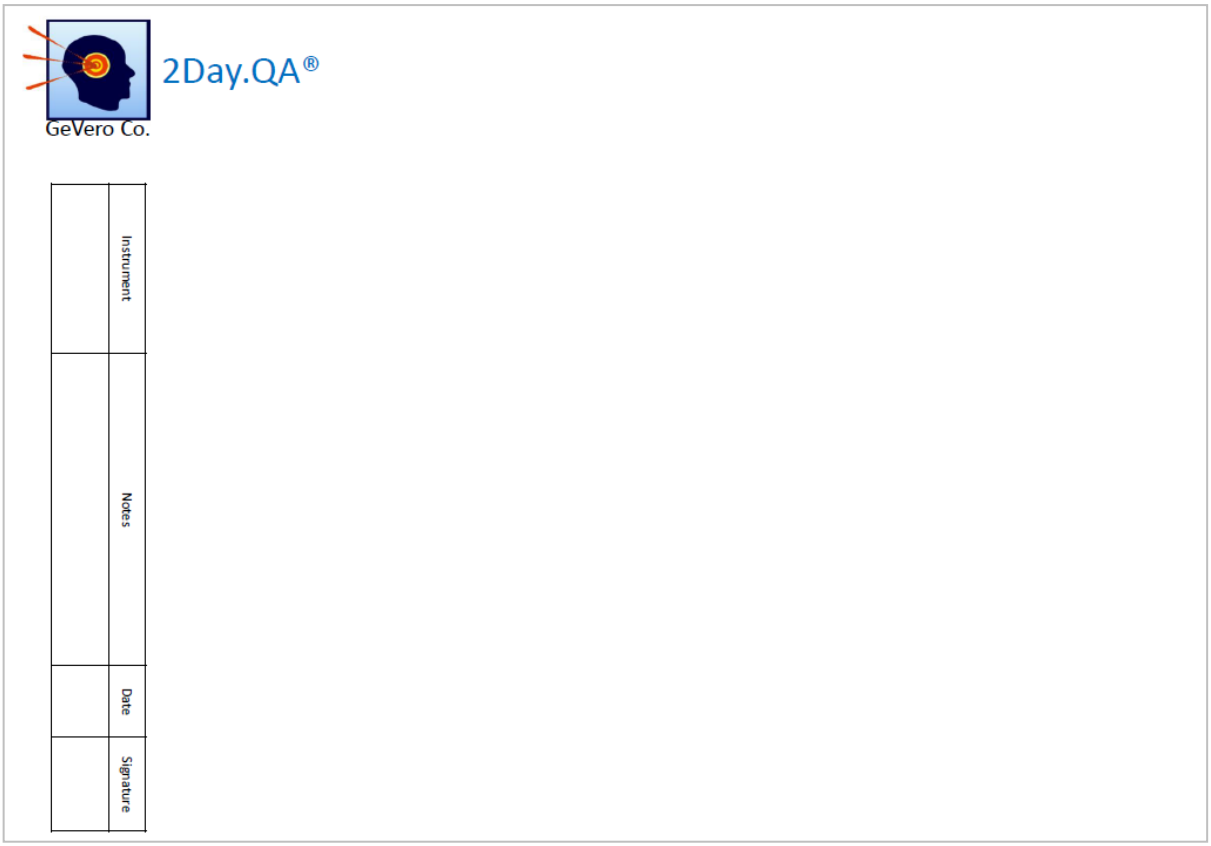
2Day.QA® for brachytherapy applications (catalogue no: **2Day.QA-3**):



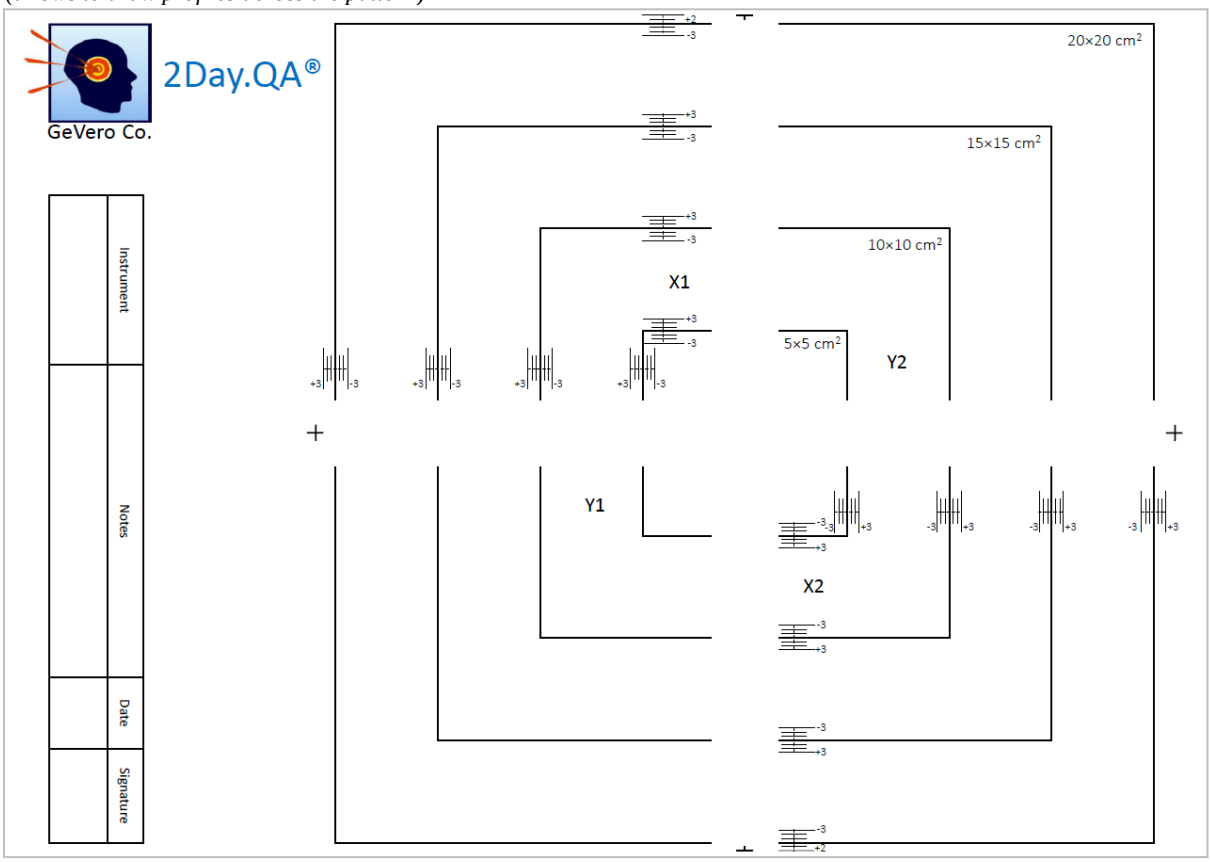
2Day.QA® for brachytherapy applications (catalogue no: **2Day.QA-4**):



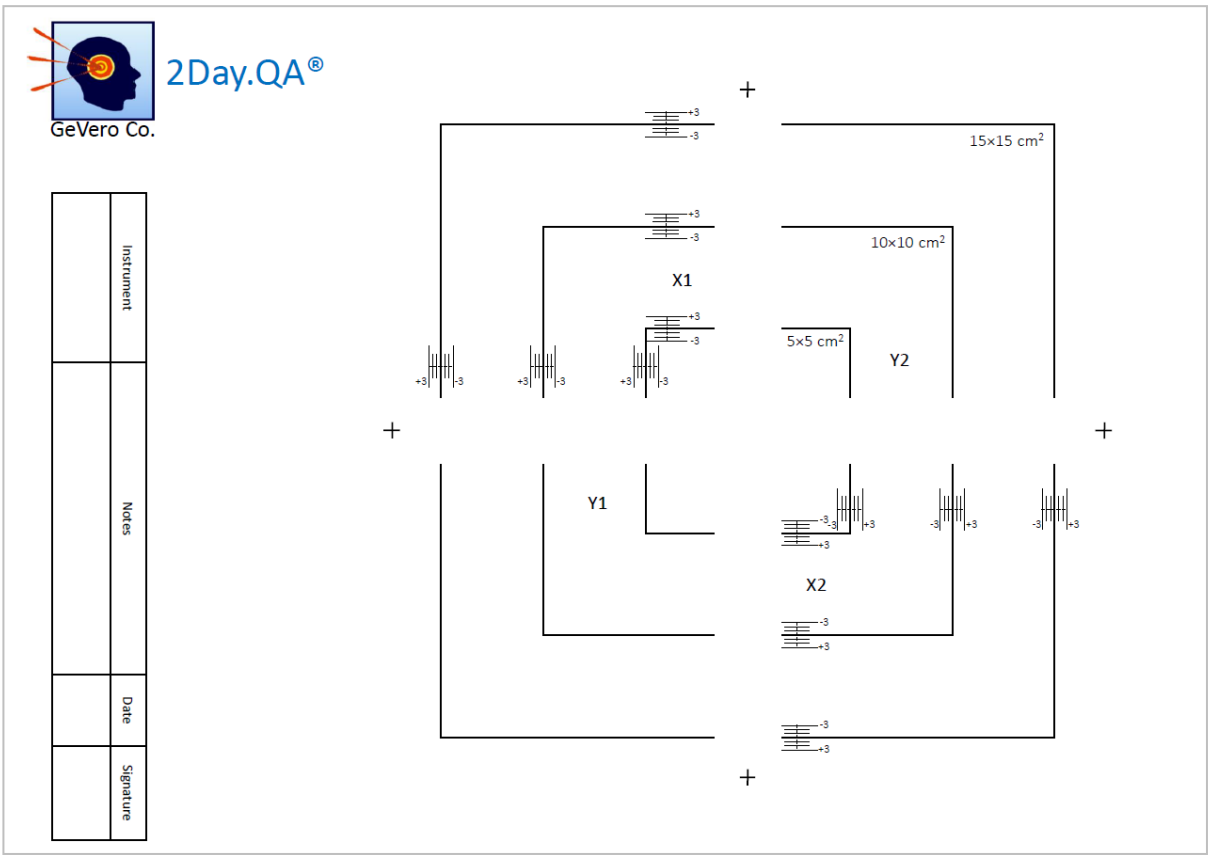
2Day.QA® for dose distribution measurements (blanc sheet) (catalogue no: **2Day.QA-5**):



2Day.QA® for accelerator beam filed checking (catalogue no: **2Day.QA-6**):
(allows to draw profiles across the pattern)



2Day.QA® for accelerator beam filed checking (catalogue no: **2Day.QA-7**):
(allows to draw profiles across the pattern)



VIII. Final remarks

The 2Day.QA® dosimeter is manufactured in Poland in line with generally applicable Polish law.

The dosimeter is almost entirely made of paper. The manufacturing process in eco-friendly. The dosimeter is degradable by the environment.

For proper disposal, act according to the local regulations related to the environment protection.

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