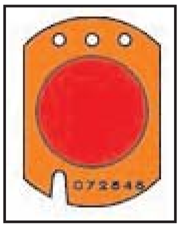
Kodalpha Radon-Dosimeter - specifications

I) Design and measuring principle of the Kodalpha Radon-Dosimeters

The Kodalpha Radon Dosimeter is a measuring method that belongs to the category of 'solid-state nuclear track detectors' (SSNTD). The result of the Radon measurement that is obtained with this kind of measuring device, represents the average Radon concentration over the entire measurement period. As this type of dosimeter requires no electric power for operation it is further categorized as a "passive" dosimeter.

Design:



The Kodalpha Radon Dosimeter is a small, black box consisting of dimensions 4.0 x 7.5 x 0.5 cm. The Radon-sensitive part, which is the actual dosimeter, is a small film badge which is housed on the inside section of the hinged lid of the dosimeter. These film badges are LR115 type nuclear track films produced by KODAK. The LR115 type films consist of a 100 µm thick polyester base that is coated with a 12 µm thin film of red coloured cellulose nitrate. These extremely high quality films are the result of more than 25 years experience within the KODAK company in SSNTD technology.

Measuring principle:

The LR115 type film is sensitive for α-particles such that when an α-particle hits the film it causes localised damage to the molecular structure of the cellulose nitrate layer. This damage can be visibly observed when the exposed film is etched in a bath of diluted sodium hydroxide solution amongst other specific conditions. After this processing small holes are visible under the microscope which is able to be quantitated. The holes exhibit diameters from 1 µm to 15 µm and show where the film was hit by α-particles.

Radon as well as its decay products (also called Radon progeny) Polonium-218 (Po-218) and Po-214 emit α-particles during their radioactive decay. When the LR115 SSNTD is exposed to a Radon containing atmosphere, the α-particles of both Radon and its decay products will thus leave tracks on the film that can be precisely identified and analysed. The number of tracks per square centimetre, taking into account the exposure time and the specific developing process, is indicative of the Radon concentration. When the dosimeters are used as so-called 'open' - type dosimeters (see section IV), the Radon decay products as well as Thoron and its decay products are detected by the LR115 film.

NOTE: The LR115 film is NOT sensitive to other types of radiation, like β- or γ-rays!

The detection of α-particles with LR115 films:

The distance that α-particles travel in air is dependent on their energy and usually range to only a few centimetres. Therefore these particles can only be detected if they have been emitted from the decaying source within a certain distance of the film's surface.

- The **maximum distance** for detection is approximately 35 mm for Radon (α-energy: 5.59 MeV) and about 60 mm for its most energetic decay product Po-214 (α-energy: 7.83 MeV).
- The **minimum distance** for Radon is about 5 mm and 30 mm for its most energetic decay product Po-214.

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Unique to this type of detection device α-particles which are generated too close to the film's surface cannot be detected by the LR115 film. In such cases their energies would be too high (> 4.5MeV) and they pass through the nitro cellulose layer without causing any interaction thus leaving no tracks. A minimum distance is therefore required between the film and the source of the α-particles for detection.

This particular feature of the LR115 films presents two major advantages:

• The LR115 Films are insensitive to the surface deposition of α-emitting Radon decay products, such as Po-218. Therefore our dosimeters are not influenced by the plateout effect (see below in Section II)!

• The LR115 SSNTD device is designed to keep the LR115 films Radon proof in order to avoid undesired exposure during storage which could result in erroneous results. The air volume between the film's surface and the container is less than the minimum distance necessary for the detection of the α-particles on the film. This is the reason why no background counts are observed with the Kodalpha dosimeters as long as the lid remains closed or is being kept in the plastic pouch supplied for return shipment.

Rn-proof pouch

II) A comparison of the LR115 films with other Nuclear Track Detectors

Nuclear track detectors, other than our LR115 detectors, that are used for the detection of Radon are made of polycarbonate. The most frequently used types are called 'CR39' or 'Makrofol'. In contrast to our LR115 detector, polycarbonate detectors consist of a thick detection film which differs in essential properties. These critical differences are discussed below.

Sensitivity, size of the nuclear tracks, saturation:
Although other detector materials may show greater sensitivity to α-radiation, they generally produce larger nuclear tracks on the film than our LR115 films. This fact of larger track size is disadvantageous regarding the saturation level of the detectors. The higher the saturation level the longer the dosimeters can be exposed even in high Radon concentration areas. The sensitivity of the LR115 films is about 1.5 - 2.4 nuclear tracks/cm^2, for a total Radon exposure of 1 kBq.h/m^3. The exact value is determined with each batch by the analytical laboratory through specific calibrations.

(The saturation level indicates the maximum density of nuclear tracks on the film at which the single tracks can still be distinguished. High densities of nuclear tracks are caused by high Radon concentrations and/or long exposure times. Oversaturation of the detectors leads to overlapping nuclear tracks and consequently leads to erroneous results.)

• The saturation level of the LR115 film is approximately 600 tracks/mm^2 (diameter of the tracks: 1 - 15 µm) compared to 50 - 400 tracks/mm^2 with other detector materials (diameter of the tracks: 5 - 80 µm).

• The maximum exposure (saturation level) of the LR115 film is 70 MBq.h/m^3 which is significantly better than for other dosimeter types.

• The minimum exposure, signifying the lower detection threshold, is only 2 kBq.h/m^3.

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The 'total exposure' is expressed in the unit 'kBq.h/m^3'. It is deduced from the number of nuclear tracks per mm^2 on the LR115 film, by means of specific calibrations. The average Radon concentration (in Bq/m^3) can finally be calculated via dividing the total exposure by the exposure time (in hours).

The values for the maximum exposure (70 MBq.h/m^3) and for the lower threshold (2 kBq.h/m^3) can be used to easily calculate for approximate maximum and minimum exposure time for the dosimeter. This only requires an estimate of the Radon level expected at a particular site:

Examples:

1) An extremly high Radon level of 30000 Bq/m^3 could be expected at a specific location where the dosimeter is to be situated for radon measurement.

The **maximum** theoretical exposure time is calculated as :
70•10^6 Bq.h/m^3 / 30000 Bq/m^3 = 2333 hours (~ 97 days!!!)

2) An average Radon level of 200 Bq/m^3 could be expected at a specific location where the dosimeter is to be situated for radon measurement.

The **minimum** theoretical exposure time is calculated as :
2000 Bq.h/m^3 / 200 Bq/m^3 = 10 hours.

Plateout-Effect:
The term 'plateout effect' describes the deposition of Radon decay products directly on the surface of the detector's sensitive film layer or inside the housing which encloses detectors of the 'closed' type (see below). The degree and the local distribution of the deposition of decay products depends on several factors, like the electrostatic behaviour and geometry of the dosimeter.

The plateout effect has an adverse influence on the precision of the Radon measurement as α-particles emitted from decay products will also be detected on the film. These decay products cannot be differentiated from Radon α-particles and thus falsely inflate the final result. It is primarily the dosimeters using 'CR39' or 'Makrofol' detectors that are affected by the plateout effect, whereas plateout effects only play a minor role in the dosimeters using LR115 film.

As already explained above, the reason for the insensitivity of the LR115 to deposited decay products is that α-particles that are generated too close to the film's surface can't be detected due to their high energies. Additionally, the LR115 film is usually applied in 'open' - type dosimeters.

Chemical treatment (etching) and analysis of the dosimeters:
Prior to analysis, the detector needs to undergo an etching process. This etching process makes the nuclear tracks visible using microscopy. The stability and control of the critical parameters (temperature and concentration of the etching bath, etching time…) is the basis for reliable and precise analytical results. Even small shifts of the bath's temperature may cause false results, but as the etching time of the LR115 film only requires approximately 1.5 hours (compared to up to 8 hours for other detectors) and the fact that our films are developed in large vessels which minimise temperature variation, the results of analysis are extremely reliable and reproducible.

Furthermore, the etching process of the LR 115 film leads to a slight but controlled depletion of the red coloured cellulose nitrate layer. This controlled loss is important as excess removal of this cellulose nitrate layer can lead to erroneous results. The thickness of the remaining cellulose nitrate layer is automatically determined by the laboratory by means of photo-optic techniques. This measurement of the remaining cellulose layer comprises part of the quality assurance protocol of the analytical laboratory.

For the analysis, nuclear track detectors are viewed under the microscope and transmitted light through the film is used to count tracks. When an exposed and processed LR115 film is viewed under these conditions each α-particle which has made a nuclear track will show as a brilliant point of light. This is different to other Radon detectors as nuclear tracks on other films absorb light and thus appear as dark spots. Therefore, the tracks on the LR115 film are more easily distinguishable from superficial defects in the sensitive layer, such as those caused by scratches. Also dust particles, which inevitably will deposit during the manipulation of the detectors in the laboratory will not be counted as nuclear tracks on the LR115 film. The deposition of dust particles on the surface of other detectors may lead to erroneous results.

III) Accuracy of measurements with LR115 films

On the table below, typical values for standard deviations (2*sigma) given as "%" and "Bq/m³" are correlated to different exposure times and Radon concentrations. The specific values depend on the production batch of the films and the temperature of the etching bath. These specific values are exactly known to the laboratory that is responsible for the analysis.

exposition (days)	+/–	+/–	+/–	+/–	+/–	+/–
90	8 - 11 17% - 21%	12 - 15 12% - 15%	24 - 30 6% - 8%	34 - 42 4% - 5%	38 - 47 4% - 5%	46 - 58 3% - 4%
75	9 - 12 18% - 23%	13 - 16 13% - 16%	26 - 33 6% - 8%	37 - 46 5% - 6%	41 - 52 4% - 5%	50 - 64 3% - 4%
60	10 - 13 21% - 26%	15 - 18 15% - 18%	29 - 37 7% - 9%	41 - 52 5% - 6%	46 - 58 5% - 6%	56 - 71 4% - 5%
45	12 - 15 24% - 30%	17 - 21 17% - 21%	34 - 42 8% - 11%	47 - 60 6% - 8%	53 - 67 5% - 7%	65 - 82 4% - 5%
30	15 - 18 29% - 37%	21 - 26 21% - 26%	41 - 52 10% - 13%	58 - 73 7% - 9%	65 - 82 6% - 8%	80 - 101 5% - 7%
15	21 - 26 41% - 52%	29 - 37 29% - 37%	58 - 73 15% - 18%	82 - 104 10% - 13%	92 - 116 9% - 12%	113 - 142 8% - 9%
7	30 - 38 60% - 76%	43 - 54 43% - 54%	85 - 108 21% - 27%	120 - 152 15% - 19%	134 - 170 13% - 17%	165 - 208 11% - 14%
	50 Bq/m³	**100 Bq/m³**	**400 Bq/m³**	**800 Bq/m³**	**1000 Bq/m³**	**1500 Bq/m³**

As far as Radon measuring devices are concerned, the accuracy of the measurements has to be better than ± 20 % according to guidelines published by the most renowned Radon Institutes (e.g. Federal Radiation Protection Office (BfS), Germany; National Radiation Protection Board (NRPB), Great Britain;).

Accreditation / Validation

The Kodalpha dosimeter has received full accreditation for more than 11 years and it is used by reputable organisations in many countries. By means of blind tests, this measuring device is validated every 6 months by the English NRPB, for more than 12 years. There are hardly any other dosimeters on the market (if any at all?) which can look back on a comparable history of successful validation tests!

In addition to this, The 'closed' - type Kodalpha dosimeters have been validated in 2003 and 2004 by the Federal Radiation Protection Office (BfS), Germany with **excellent results**!

IV) 'Closed' - type Radon dosimeters versus 'Open' - type dosimeters

Almost all Radon dosimeters available on the market are the so-called 'closed' - type. In these dosimeters the Radon sensitive part (like the LR115 film) is enclosed in a container of defined volume and shape which serves as the metering chamber. For the LR115 films, specially calibrated containers are available for this purpose.
Radon can penetrate through large openings which are covered by a filter, or through very small openings that allow the diffusion of Radon into the metering chamber. The essential property of the 'closed'- type dosimeters is that only Radon can enter the metering chamber but not its decay products, Thoron or Thoron progeny.

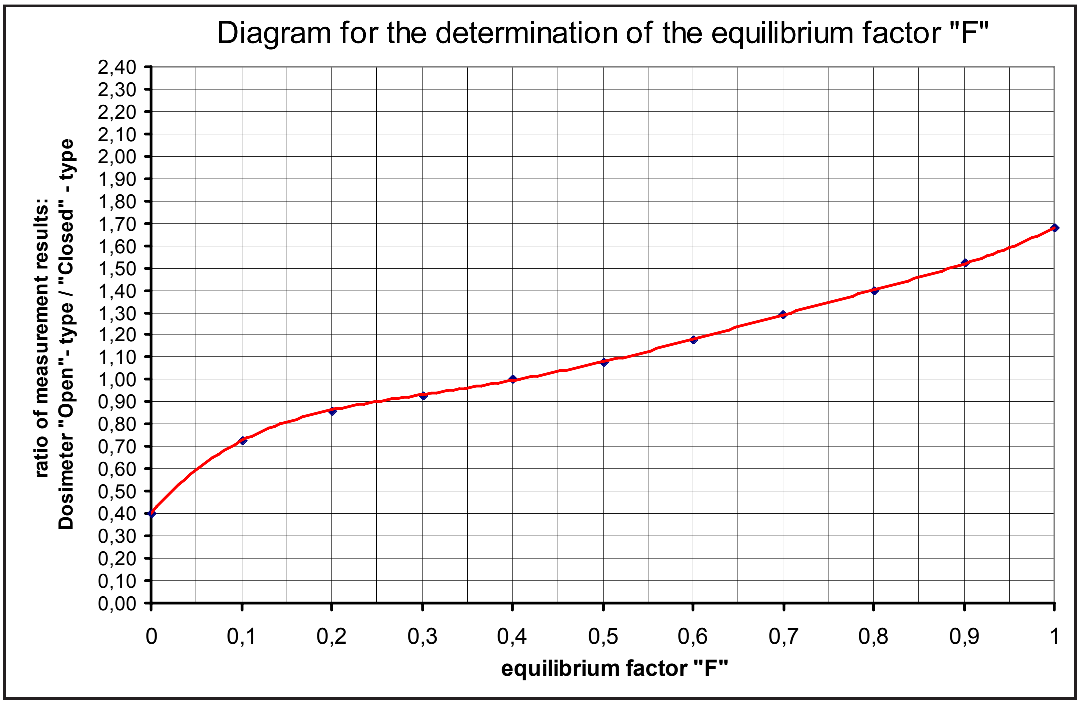
(Thoron is an isotope that is formed in the decay-chain of the element Thorium. Thorium, like Uranium is a naturally occurring radioactive element. It is found in small amounts in most rocks and soils, where it is about three times more abundant than uranium, and is about as common as lead. Compared to the "ordinary" Radon which has the isotopic number 222 and a half-life of 3,8 days, Thoron has the isotopic number 220 and a half-life of only 55.6 seconds. Although Thoron itself doesn't pose a health risk due to its short half-life, some of its decay products that have significantly longer half-lives may reach indoor concentrations that are significant.)

In contrast to the closed type dosimeter, the Radon sensitive film of the so-called 'open' dosimeter is not enclosed in a container, but directly exposed to the Radon containing atmosphere. The Kodalpha dosimeters are most frequently used as 'open' dosimeters. In this case, Radon and Thoron as well as their particularly dangerous decay products can be detected. In an ordinary indoor atmosphere the equilibrium factor 'F', which expresses the ratio of a certain parameter between Radon and its progeny, ranges from 0.3 to 0.6. In the analysis of the 'open' Kodalpha dosimeter an equilibrium factor of 0.4 is assumed and incorporated in the analysis of results. In some cases, like in rooms for balneotherapy or in mines the equilibrium factor can deviate significantly from 0.4.

The determination of the equilibrium factor 'F'

By means of simultaneous measurements of an 'open' and a 'closed' Kodalpha dosimeter the equilibrium factor 'F' can be assessed very easily on the graph represented below.
The procedure for the determination of the factor 'F' is as follows:
1) In order to find the value on the Y-axis, divide the analysis result of the 'open' dosimeter by the result of the 'closed' dosimeter.
2) Find the point on the graph which refers to the found Y-value
3)The corresponding value on the X-axis indicates the equilibrium factor 'F'.

Example:
The results of a simultaneous measurement of an 'open' and a 'closed' dosimeter gives 812 Bq/m³ for the 'open' and 576 Bq/m³ for the 'closed' dosimeter. The value on the Y-axis is calculated as: 812/576 = 1.4. The Y-value of 1.4 on the graph corresponds to the value of 0.8 on the X-axis. The equilibrium factor is thus 0.8!



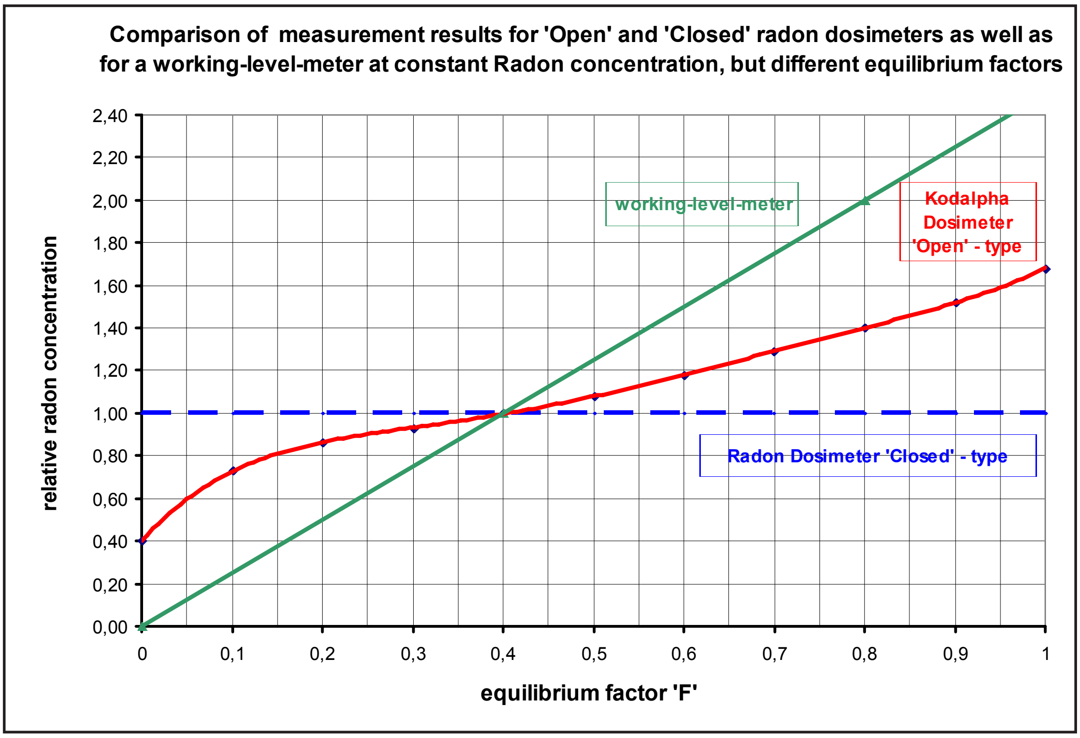
The assessment of the health risk

The Radon legislations for miners are expressed in WL (working level), which is a measure for the Radon decay products, while for the general population Radon legislation is generally expressed in terms of Radon gas. There is such a big difference between the legislation for miners and the legislation for the general population that in all probability, one legislation is more reasonable in terms of exposure concentration! It is our belief that the quantitation of Radon AND its decay products leads to a better assessment of exposure risk. Since it is the decay products that are responsible for the health risk, the legislation considering only the Radon gas must suppose two things:

1) There is no significant presence of Thoron and
2) The equilibrium Factor between progenies and radon is known, which allows to pass from the Radon gas concentration to the progenies' risk.

The KODALPHA, like any good 'open' detector, gives exactly the same Radon gas result as a good 'closed' detector, when the above hypothesis 1) and 2) are true. But, as soon as there is an unexpected Thoron concentration or a high 'F', the closed detectors under-estimate the health risk. That is why we still prefer the open detection, especially for screening tests when the aim is to estimate a general health risk by means of a cheap and single measurement.

The graph, printed below, shows the results of a 'closed' dosimeter, an 'open' dosimeter and a working level meter for a constant Radon level but at different equilibrium factors.



The 'closed' dosimeter can only indicate the same Radon level independent of the equilibrium factor. The working level meter indicates the presence of radon decay products, that rises proportionally to the equilibrium factor. The higher the working level, the higher the health risk.

When the equilibrium deviates from 0.4, the results of the 'open' dosimeter corresponds better to the results of the working level meter than the 'closed' dosimeter does. In the case of the 'closed' dosimeter, at an equilibrium factor of less than 0.4, this dosimeter will overestimate the health risk, and when the equilibrium factor is higher than 0.4, the health risk is underestimated!

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