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Comparative Alpha Tracks Counting Using an Optical Microscope and a Spark Counter

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Abstract

In the metrology of radon, an environmental lung carcinogen, the integrated measurements necessary for epidemiological studies are made very often using the tracks detector LR 115 type 2. For dosimetric analysis, the etched tracks from radon alpha particles on this detector are usually counted by means of an optical microscope or a spark counter. An optimal reading of the track densities which must be converted into radon concentrations, can't be done without a good mastery of the mode of operation and use of these devices. Furthermore, investigations to know as to whether or not each of those can be used to determine radon concentration are necessary. These are the objectives of the present work in which LR 115 samples exposed to radon for at least 3 months, were chemically developed under standard conditions and read. The track densities obtained with the microscope are very much higher than those of the counter for each sample. These results are consistent with those published by other authors. However, each of these devices can be used interchangeably for alpha tracks counting, as both provide radon concentrations with a very good linear correlation coefficient of 0.95 taking into account their respective calibration factors for the reading of this detector. In addition, the saturation phenomenon for the spark counter reading of LR 115 detector occurs beyond 11,000 tr/cm^2, a density never reached during our environmental radon measurements.

Keywords

LR 115 Detector, Optical Microscope, Spark Counter, Alpha Track Density, Calibration Factor, Radon Concentration

1. Introduction

There are numerous tools available to detect and measure environmental lung carcinogen radon gas [1] [2] [3]. Those are in general classified into active and passive techniques respectively for short and long-terms assessment.

We have to decide according to what we aim to do which technique to use on the basis of the feasibility and cost of the measurement as well as the accuracy and the applicability of the technique.

The risk of lung cancer from radon is related to the long-term exposure of people, so it is important that estimates of radon levels in homes and workplaces should be as close as possible to the long-term average [4]. For this reason, it is generally advised that short-term measurement should not be used as the basis of advice on whether or not a building has a radon problem. And this is why long-term measurement using passive methods should be appropriate. But continuous active measurements can be helpful in identifying the cause of the radon problem.

Among the different passive techniques, the Solids State Nuclear Tracks Detectors (SSNTD) and particularly the LR 115 detector, are the most widely used to do integrated measurements necessary for epidemiological studies [5] [6] [7]. We must therefore count the number of etched alpha tracks from radon on samples of this detector. Among the main instruments commonly used for this work, we have the optical microscope and the spark counter. Several authors used either one of these devices or the other separately for radon alpha tracks counting [8] [9]. But, our main concern in this study was to use both apparatuses alternatively to count tracks on a given sample. That allowed to compare the tracks densities obtained and also the corresponding radon concentrations. Thus, calibration process was performed to determine factors for the reading of LR 115 type 2 detector with both devices since those were needed to convert etched alpha track densities into radon concentrations [10] [11]. In addition, the saturation phenomenon for tracks counting on LR 115 samples by means of the spark counter, which could distort the results given by this apparatus, was carried out.

2. Materials and Methods

2.1. Detectors Exposure and Analysis

38 samples of LR-115 type 2 strippable films manufactured by DOSIRAD-France were taken. After their exposure to environmental radon gas for at least 3 months, those were chemically etched in the standard conditions [12] [13] *i.e.* in a 2.5 mol/L NaOH solution at a constant temperature of 60˚C. This operation was done during an optimum etching time of 120 min [14]. Then, the samples were rinsed off with tap water, put in distilled water and dried in dry air. For each sample, etched alpha tracks were counted first by means of the optical microscope. The sample was therefore set under the objective at a 10× magnification. By means of a linked camera, the image of the microscope field of view was

projected on the connected computer screen and was focused using the uploaded software. By changing of the focus, tracks can be seen and counted. The field of view was calibrated with the help of a stage micrometer glass slide to find out the scanned area. A meshing covering the whole area of the sample was done and counting was carried out on 50 fields of view. Afterwards, the sensitive layer of the sample was peeled off with a lancet and read using this time the spark counter. This technique was developed by Cross and Tommasino [15]. The spark counter system consists of two electrodes made of brass. The etched sensitive layer of the sample acting as an insulating material was placed between the electrodes forming a capacitor and was covered with an aluminized plastic foil. The aluminized side of the plastic foil was in contact with the thin detector. High voltage (1100 V) was applied which took place an electrical discharge through a track hole. The voltage pulse produced could thus easily be counted electronically. This first counting is called pre-sparking and is necessary for clearing and partially developed holes during the etching. When it stopped, the aluminized foil was removed and a fresh foil was placed on the sample without disturbing it. Now, the voltage across the electrodes was set to a lower operating voltage (500 V) and again the counting was started. At the end of this counting, the result obtained was noted down and the process was repeated twice again with fresh aluminized foil every time and the average of three reading was taken.

2.2. Detectors Calibration

10 LR 115 type 2 samples, not exposed to environmental radon gas, underwent the calibration process using an SRM 4973 source certified by NIST (National Institute of Standards and Technology) from the United States of America. This source had a radium-226 activity of (448.5 ± 6.2) Bq and a radon emanation level of (0.877 ± 0.014) at 21˚C [16]. The Ra-226 solution was contained in a polyethylene capsule placed in a glass bulb of known volume, hermetically sealed with valves. At the opening of the valves, a concentration gradient was created in the solution. The radon gas emitted then diffused through the polyethylene to occupy the volume of the bulb. It was then sucked without loss nor dilution, by the electronic pump, into the barrel where were exposed the LR 115 samples and the pre-calibrated AlphaGuard active detector whose measurements were transmitted on the computer screen, allowing a continuous monitoring of the radon concentration decrease (**Figure 1**) [17]. The samples were exposed to an average radon concentration of (1.99 ± 0.93) kBq/m^3 in the barrel for 261 h. After chemical development during 120 min under standard conditions, those were read both by means of the microscope and the spark counter.

The calibration factor and radon concentration were calculated using the following formula [18]:

$$k = \frac{\rho - \rho_0}{C \cdot t} \tag{1}$$

where

k is the calibration factor (tr/cm^2/kBq·m^{-3}·h);

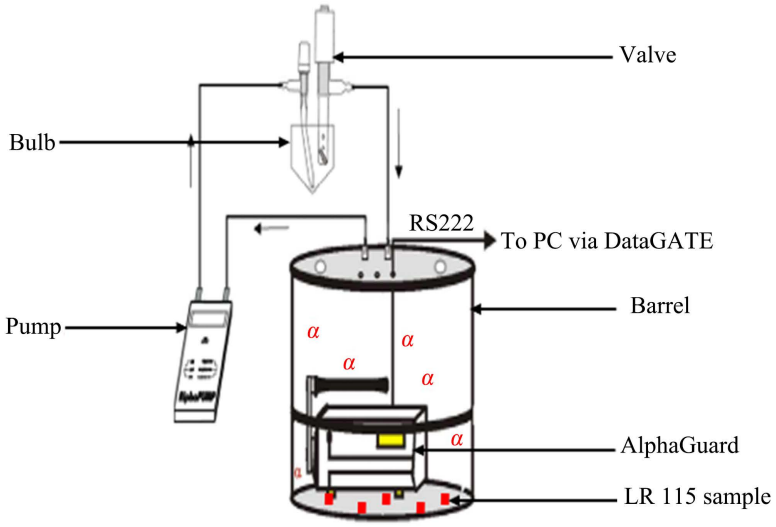

Figure 1. Shematic of calibration system.

ρ the tracks density read (tr/cm^2);
ρ_0 the background (tr/cm^2);
C the radon concentration (kBq/m^3);
and t the exposure time of LR 115 sample (h).

2.3. Study of the Saturation Phenomenon

08 identical size LR 115 samples, not exposed to environmental radon were irradiated with a Pu-239 radioactive source which α particle emission rate in 2π sr geometry is 3055 α/s, through a collimator of 21.79 mm height during respectively 5, 10, 15, 20, 25, 30, 35 and 40 minutes. Afterward, the samples were chemically etched in the standard conditions during 120 minutes and read by means of the spark counter.

3. Results and Discussion

The results obtained are reported in Tables 1-4 below.

Table 1 shows that tracks density read by the microscope is very much higher than the value given by the counter for each etched sample of LR 115 type 2. That agrees well with results we found in the literature [19]. In fact, with the microscope, all the visible etched tracks are read, even the smallest. But, for the counter, only tracks with a certain etching level to allow the voltage pulse to be produced are counted.

The average calibration factors found are in Table 2 [20]. We notice that their relative uncertainties are between 45% and 47%. That is due to the uncertainty on the concentration of radon into the barrel during the calibration process [(1.99 ± 0.93) kBq/m^3] which also gives a relative uncertainty of about 47%. This concentration which derives from the radon source used during this process was obtained in particular conditions we have to explain. We said previously that the radon source was a radium-226 solution contained in a polyethylene capsule.

Table 1. Average tracks densities read by the microscope and the spark counter for each sample.

Sample	Tracks density (tr/cm^2)	
	Microscope	Spark counter
S1	49,254	489
S2	21,679	235
S3	39,369	365
S4	33,299	254
S5	43,011	463
S6	65,036	682
S7	27,749	295
S8	24,280	257
S9	34,253	263
S10	40,756	355
S11	75,442	766
S12	48,561	572
S13	28,616	311
S14	27,749	286
S15	42,317	377
S16	61,568	690
S17	26,882	232
S18	103,625	1095
S19	41,883	355
S20	30,350	245
S21	26,015	225
S22	59,834	616
S23	47,693	408
S24	24,020	215
S25	27,749	226
S26	35,553	308
S27	41,883	455
S28	36,420	327
S29	21,679	243
S30	61,120	499
S31	57,083	383
S32	26,015	274

Continued

S33	35,553	305
S34	58,813	498
S35	41,450	355
S36	22,546	179
S37	39,629	426
S38	41,883	362

Table 2. Average calibration factors for the reading of LR 115 type 2 by means of the microscope and the spark counter.

Average calibration factor ($tr/cm^2/kBq \cdot m^{-3} \cdot h$)	
Microscope	Spark counter
119 ± 54	1.2 ± 0.56

Table 3. Exposure time and radon concentrations obtained with the microscope and the spark counter for each sample.

Sample	Radon concentration (Bq/m^3)		
	Exposure time (h)	Microscope	Spark counter
S1	2214	187 ± 84	184 ± 86
S2	2188	83 ± 37	90 ± 42
S3	2206	150 ± 68	130 ± 61
S4	2157	130 ± 59	98 ± 46
S5	2196	165 ± 74	176 ± 83
S6	2210	247 ± 111	257 ± 121
S7	2214	105 ± 47	111 ± 52
S8	2228	92 ± 41	96 ± 45
S9	2176	132 ± 59	101 ± 47
S10	2208	155 ± 70	134 ± 63
S11	2197	289 ± 130	291 ± 137
S12	2186	187 ± 84	218 ± 103
S13	2186	110 ± 50	119 ± 56
S14	2185	107 ± 48	109 ± 51
S15	2184	163 ± 73	144 ± 68
S16	2209	234 ± 105	260 ± 122
S17	2186	103 ± 46	88 ± 41
S18	2178	400 ± 180	419 ± 197
S19	2190	161 ± 72	135 ± 63

Continued

S20	2201	116 ± 52	93 ± 44
S21	2180	100 ± 45	86 ± 40
S22	2204	228 ± 103	233 ± 110
S23	2157	186 ± 84	158 ± 74
S24	2209	91 ± 41	81 ± 38
S25	2226	105 ± 47	85 ± 40
S26	2193	136 ± 61	117 ± 55
S27	2201	160 ± 72	172 ± 81
S28	2179	140 ± 63	125 ± 59
S29	2207	83 ± 37	92 ± 43
S30	2208	233 ± 105	188 ± 88
S31	2189	219 ± 99	146 ± 69
S32	2165	101 ± 45	105 ± 49
S33	2178	137 ± 62	117 ± 55
S34	2203	224 ± 101	188 ± 88
S35	2202	158 ± 71	134 ± 63
S36	2169	162 ± 73	139 ± 65
S37	2177	87 ± 39	69 ± 32
S38	2200	151 ± 68	161 ± 76

Table 4. Irradiation time and alpha tracks density read by the spark counter on the irradiated LR 115 samples.

Irradiation time (min)	Tracks density (tr/cm^2)
5	6050
10	7000
15	8900
20	9600
25	11,000
30	10,900
35	10,800
40	10,700

Unfortunately, when we were doing the calibration, we noticed that an important part of water in the capsule vaporized. And the consequence was that the diffusion process through the polyethylene was not done properly. So, we were even obliged a few days after the beginning of the process to inject again radon

from the source into the barrel. We can observe that on the graph of Figure 2. Finally, the LR 115 type 2 samples were exposed to radon into the barrel for 10 days instead of 15 days as we initially wanted to do. The values of calibration factors obtained were used for calculation of radon concentrations applying the Formula (1). And due to errors propagation, the concentrations of radon also have relative uncertainties between 45% and 47%. But the different results are acceptable first because in this domain of radon metrology, relative uncertainties vary a lot and also because these results allow to maximize the radiological risk.

Table 3 shows the different values of radon concentration obtained. Using these values, a statistic correlation particularly the linear correlation between radon concentrations obtained by means of the microscope and those given by the counter was studied.

Two regression lines were drawn on the graph of Figure 3 representing radon concentration obtained with the microscope as a function of radon concentration obtained with the counter and vice versa. These lines are intersecting, close to each other and almost merged. The linear correlation coefficient r is equal to 0.95.

All these mathematical characteristics regarding the two regression lines show a very good correlation between the two variables *i.e.* the results of radon concentration given by the microscope and those given by the spark counter. It is therefore reasonable to use the optical microscope as well as the spark counter for measurements of environmental radon concentrations and also for the monitoring of the radiological risk of this gas.

Table 4 gives alpha track densities read on LR 115 samples and the corresponding irradiation times. These results allowed to draw the graph of Figure 4.

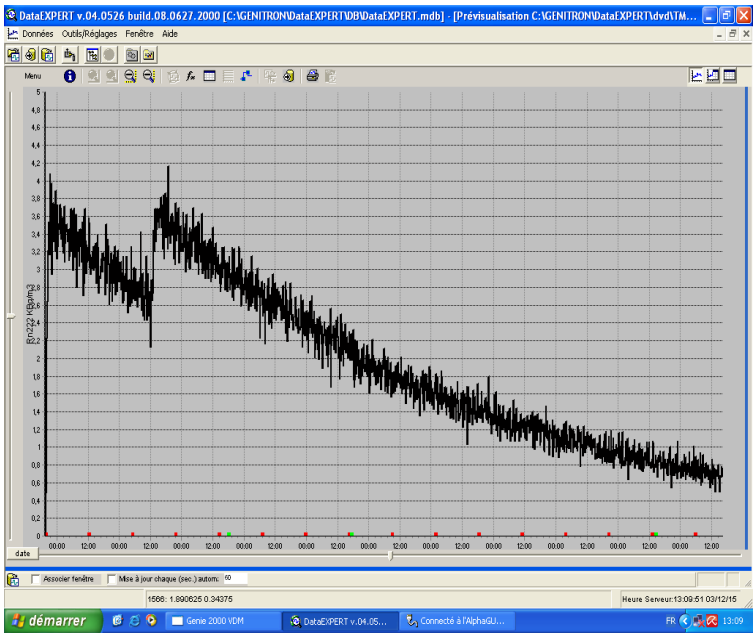

Figure 2. Graph of radon concentration into the barrel as a function of time on the visual display terminal.

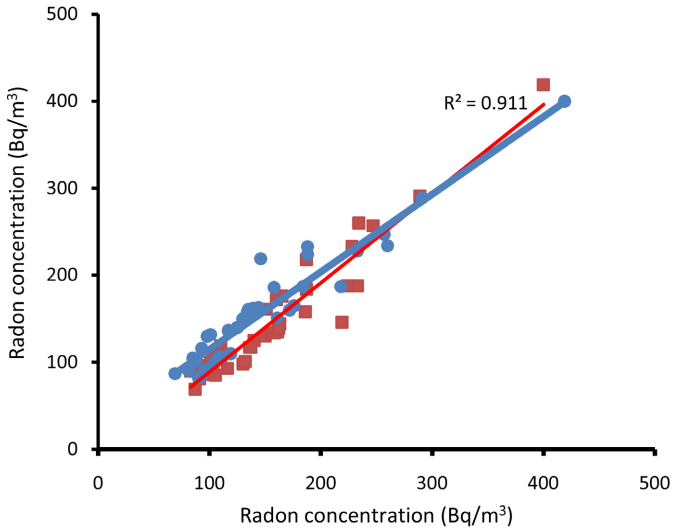

Figure 3. Radon concentration obtained with the microscope as a function of radon concentration obtained with the counter and vice versa.

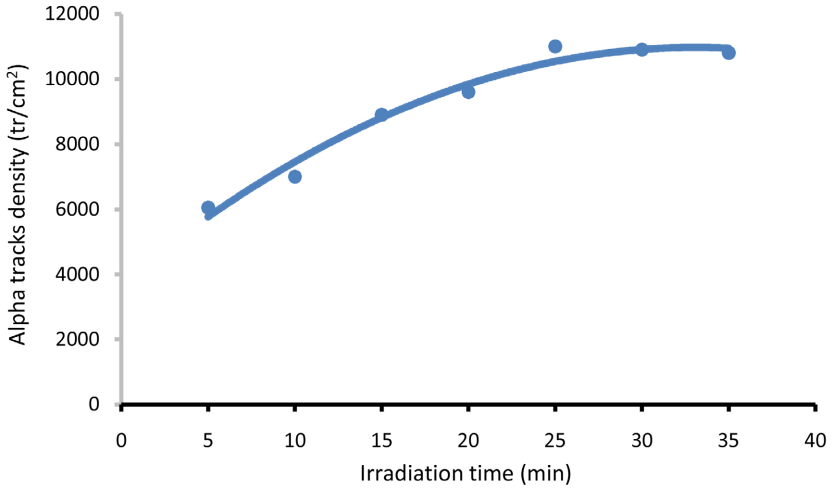

Figure 4. Alpha tracks density on the irradiated LR 115 samples as a function of irradiation time.

On this figure, we observe that track density increases with the irradiation time up to almost 11,000 tr/cm^2 and remains approximately constant beyond this value. 11,000 tr/cm^2 can reasonably be interpreted as the maximum value of track density that can be read by the spark counter. Beyond this value, we have the saturation phenomenon which distorts the results when it occurs. But it doesn't matter since this maximum track density is never reached as far as our environmental radon measurement is concerned. Therefore, the use of the spark counter is free for such a survey.

4. Conclusions

The investigations carried out in the present work show that care should be taken to the different steps in the handling of the optical microscope and the spark

counter for the determination of radon concentrations in order to obtain good results.

Otherwise, the densities of etched tracks from radon alpha particles on each sample of LR 115 type 2 detector counted by the optical microscope are always very much higher than those counted by the spark counter. But, taking into account the respective calibration factors of the two devices for the reading of the detector, corrections were made. Therefore, both apparatuses give radon concentrations with a very good linear correlation coefficient of 0.95. Moreover, the saturation phenomenon regarding the reading of LR 115 detector by means of the spark counter which can distort the results, occurs beyond 11,000 tr/cm^2 *i.e.* a density never reached as far as our environmental radon measurement is concerned. Thus, we can use the optical microscope as well as the spark counter to determine environmental radon concentrations as we did in Côte d'Ivoire. And in case of large scales measurements, the results obtained can be used for epidemiological studies related to the radiological risk of this gas.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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