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CALIBRATION OF RECYCLED CINEMA FILMS FOR USING AS SOLID STATE NUCLEAR TRACK DETECTOR

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ABSTRACT

The detection characteristics of recycled black and white cinema films have been determined and compared with the well-known solid state nuclear track detector (SSNTD) named Poly-Allyl Diglycol Carbonate (CR-39). The chemical composition of the used films has been identified as cellulose triacetate, also known simply as triacetate, TAc, by means of Infrared spectroscopy. The etching conditions have been optimized after irradiation of the cinema film with an artificial point source of Am-241 with activity 5.486 nCi, emitting alpha particle of energy 5.48 MeV. The calibration process has been performed, under the same conditions, with seven pairs of (1.0 cm × 1.5 cm) pieces of acetate films and CR-39 SSNTDs, using different radon gas concentrations ranging from 68.6 to 443.2, pCi/l. The deduced track density variation as a function of radon concentration is found to be linear in both cases with slopes 0.173 and 0.242 for cinema film and CR-39 respectively.

The two detectors (cinema film and CR-39) have been applied for measurements of α-track densities in 11 sedimentary rock samples, which were collected from Talat Seliem locality, Um Bogma area, southwestern Sinai, Egypt. They are found to range from 6.76 to 66.76 (track/mm^2/d) for cinema film and from 9.89 to 91.59 for CR-39. The deduced calculated radon concentrations are varying from 38.97 to 385.01 (pCi/l) for cinema film and from 40.76 to 377.45 (pCi/l) for CR-39, which are almost identical within error bars. Similar conclusion could be deduced from the calculation of the surface exhalation rates of the two detectors, which vary from 0.00207 to 0.01920 (Bqm^{-2}h^{-1}) for cinema film and 0.00198 to 0.01959 for CR-39. The emanation coefficient results in the two detectors are also comparable being slightly lower by a factor of 0.71 in cinema film.

Positron annihilation lifetime (PAL) is used to study the effect of α-particles irradiation on the nanostructure of free volumes (size and concentration) in CR-39 and the recycled cinema films. The size distributions of free volumes are well approximated by Gaussian-type function with maxima at 74 Å and 100 Å for the CR-39 and the films respectively. The shift of the free volume distribution in CR-39 to lower size compared to cinema films could be explained by the difference in chemical and physical properties of both.

INTRODUCTION

Radon (^{222}Rn) is a noble gas and radioactive in all of its isotopes. Despite of being hazardous, its possibility of transport makes it useful tracer for a variety of geophysical, geochemical, hydrological and atmospheric purposes. It enables exploration of uranium, hydrocarbons deposits, gas flow and fluid transport within the earth as well as seismic prediction thus mapping the faults and characterizing geothermal sources (Mansy et al., 2000). Radon and its daughters measuring methods in air, depend mainly on detection and quantitative measurement of particles that were emitted. The measuring operations are based either on production of ionizations in gas scintillation, in solid substances (active technique) or based on registration of the damage in some solid substances (passive technique) (Hassan, 2000). The sensitivity of detectors for radon radiation depends on: the used mode (bare, open cup, closed cup), measurement period, etching characteristics, filter type, calibration, etc. (Dawaikat et al., 2007). The allyl diglycol polycarbonate (CR-39) plastic, is one of the most popular types of SSNTDs with chemical formula $C_{12}H_{18}O_7$, formed by polymerization of oxide-2, 1-ethanedyl di-2 propenyl ester of carbonic acid (Cassou and Benton, 1978). El-Abnoudy (2008) used another type of films made of nitric fiber and deduced its calibration factor, which has been compared with the corresponding one found in CR-39. The author concluded that the sensitivity of the nitric fiber film was smaller by 50% compared to CR-39.

The objective of the present work is to identify the chemical structure and nanostructure of the recycled cinema films, with the aim to use them as a low-cost substitute detector to CR-39. The film optimum etching conditions that are required to produce a sensitive detector for α-particles are determined and compared with those of CR-39. On the other hand, the film detector and CR-39 are applied for the measurements of the radon concentrations at samples collected from Talat Seliem locality, southwestern Sinai, Egypt. In addition, exhalation and emanation rates have been calculated. The deduced results of both detectors are compared. In addition, an investigation of the radiation damage in used cinema film and CR-39 polymers is carried out after irradiation by different radon gas concentrations using positron annihilation lifetime. An attempt was made to find a correlation between the positron annihilation parameters of free volumes and the track density.

Many of the application-based macroscopic properties of polymers depend on the microstructure of the sub-nanometer local free-volume holes in these materials. PAL is an ideal tool to provide direct information about the size distribution of free-volume holes in polymers (Mogensen, 1995; Procházka, 2001; Dlubek et al., 2004). Besides, it is a useful probe in the study of physical and chemical properties of materials (Dlubek et al., 1998a, 2002; Marzocca et al., 2002; Igarashi et al., 2002; Ivanov and Mitroy, 2002). In molecular materials, such as polymers, Positrons that are injected into the polymer matrix may annihilate directly with electrons or may capture some electrons from the surrounding medium to form para-positronium state, p-Ps or ortho-positronium state, o-Ps (Mogensen, 1995). The positron of the o-Ps may annihilate with an electron other than its bound partner and of opposite spin resulting in a sharply reduced o-Ps lifetime pick-off annihilation, (Eldrup et al., 1981; Nakanishi et al., 1988). The o-Ps is preferentially formed and annihilated within the free-volume holes.

EXPERIMENTAL METHODOLOGY

Cinema Film Preparation

The cinema films are cleared by removing the old emulsions, such as AgBr, from its surface to produce a transparent film as shown on Figure (1). The clearing solution prepared is 4N of NaOH (160 gm NaOH are dissolved in one liter of distilled water), which is used only after being cooled to temperature lower than 40^0C.

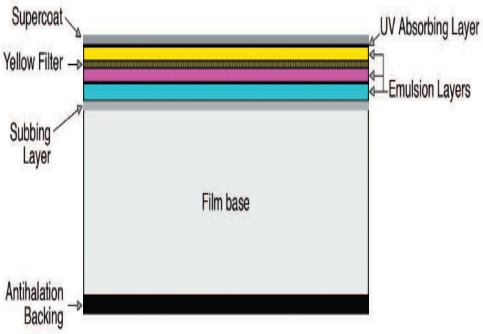

Fig. 1: Cinema film constituents (www.en.wikipedia.org/wiki)

Chemical Structure Determination

Infrared spectroscopy has been applied to provide information on the structure of Cinema film. Infrared vibrational absorption measurements are recorded in the range of (1400 to 400 cm^{-1}) using a JASCO FT/IR-4100 type A infrared spectrophotometer. The spectrum is shown on Figure (2).

It clearly illustrates the absorbance of Cellulose triacetate (CTA) in the IR region between 4000–400 cm^{-1}. Bands at 1219 and 1055 cm^{-1} are attributed to stretching modes of C-O single bond. CTA contains carbonyl group which absorbs in the region 1760-1665 cm^{-1} due to the stretching vibration of the C=O bond. This distinctive carbonyl band is particularly useful for diagnostic purposes because it has a characteristic high intensity.

Cellulose triacetate, is known simply as triacetate, CTA and TAc, with chemical formula $[C_{24}H_{32}O_{16}]_n$, as shown on Figure (3a) as compared with CR-39 (Fig.3b). It is a chemical compound manufactured from cellulose by acetylating cellulose with acetic acid and/

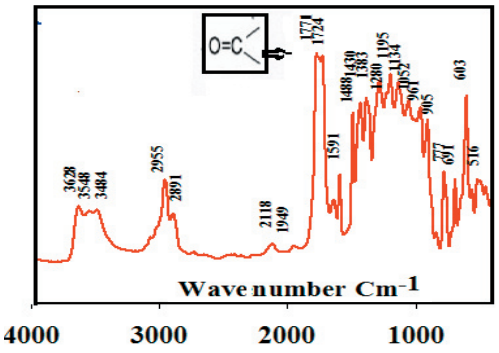

Fig. 2: IR spectrum of Cinema film

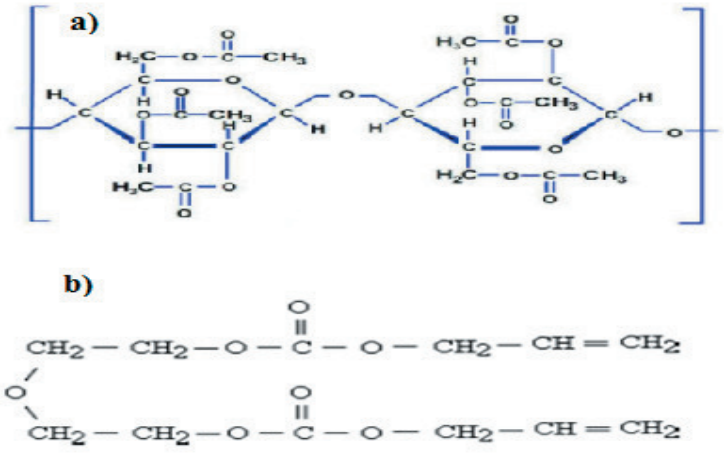

Fig. 3: Chemical structure of: a) Cinema film and b) CR-39

or acetic anhydride. Acetylation converts hydroxyl groups in cellulose to acetyl groups, which renders the cellulose polymer much more soluble in organic solvents.

Optimization of Etching Conditions

Sheets of cinema film (1.0×1.5) cm^2 are irradiated for 30 min with alpha particles of energy 5.48 MeV using a point source of Am-241 with activity 5.486 nCi. The irradiation was carried out in perpendicular geometry and in direct contact, that enables the particles to enter the detector surface directly and almost at right angles as shown on Figure (4).

The etching process is performed by taking the same values of normality (6.25 N) and temperature (70 °C) as used for CR-39 and the etching time was gradually increased from 15min to 45 min in order to get the etching time, that gives the best track density and the most clear image as shown on Figure (5).

From the above experiment, the deduced optimum conditions for etching process for cinema film is shown in Table (1) compared with the well-known etching conditions of CR-39.

It is worthwhile to note the large difference in etching time duration between cinema film and CR-39. This is due to the smaller thickness and low rigidity of the cinema film compared to CR-39.

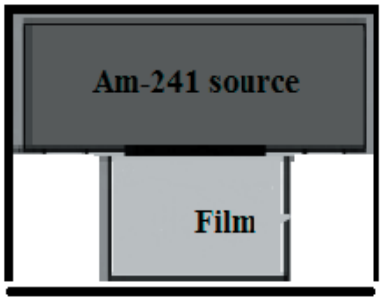

Fig. 4: Schematic diagram of experimental arrangement used to irradiate the Cinema film

Calibration Process

The calibration of the two detectors is performed by taking seven pairs of (1.0 cm × 1.5 cm) pieces of SSNTDs (Cinema film and CR-39), which were fixed in the bottom of plastic cups of 10 cm height and 5 cm diameter. Each of the two detectors were put in radon chamber for two days. The experiment was repeated using radon concentrations of 443.2, 305.7, 147.4, 131.2,80, and 68.6 pCi/l.

The calibration chamber of cubic shape is made of 5 mm thick sheet of transparent plexiglass poly methyl methacrylate (PMMA) with dimension 0.6 m and total volume 0.216 m^3. The chamber is connected by rubber tubes to a 0.025m^3 radon source that contains natural

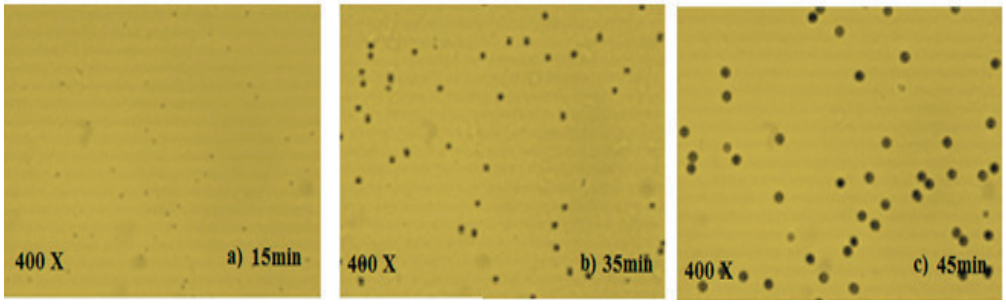

Fig. 5: Optical images of alpha particle's tracks on cinema film at different etching times: a) 15 min, b) 35 min, c) 45min.

Table 1 : Optimum etching conditions of detectors

Detector type	Solution normality	Temperature (^{o}C)	Etching time
Cinema film	**6.25N NaOH**	**70±1**	**45 (min)**
CR-39	**6.25N NaOH**	**70±1**	**6 (h)**

uranium ore and special type of gas valves to control the inlet and outlet flow of radon to the chamber through a fully controlled programmable pump, that is built in the Pylon AB-5 radon monitor (Al-Galal, 2016). At the end of each experiment, the radon concentration per liter is stored in the memory of AB-5 every hour.

At the end of exposure, the films were collected, then etched in 6.25N NaOH at 70 °C and etching time of 6 hours for CR-39 type and 45 min for cinema film type. The films are then counted under the optical microscope with magnification of 400X to get track density.

The track density (ρ_o) in the detectors is proportional to radon concentration (C_o) according to:

$$\rho_o = K\, C_o \qquad (1)$$

Where, K is a constant of proportionality, which is the calibration factor of the detector (Al-Galal, 2016).

Figure (6) shows the variation of the measured track density [(track/mm^2)/d] with radon gas concentration (pCi/l) for the two types of detectors. The calibration factors in this case (the slope of the curves) were 0.173 for cinema film and 0.242 for CR-39. The ratio between the two calibration factors was 0.71.

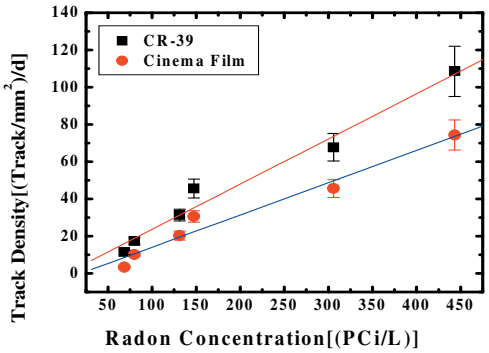

Fig. 6: Variation of measured track density as a function of radon concentration

Table 2: Summary of the main characteristics of the two studied detectors

SSNTD	Cinema film	CR-39 (Fleischer et al., 1975)
Composition	**$[C_{24}H_{32}O_{16}]_n$**	**$C_{12}H_{18}O_7$**
Density (gm/cm^3)	**1.31 (Lewin and Pearce, 1998)**	**1.30**
Foil thickness (µm)	**140**	**500**
Uniformity	**Poor**	**Good**
Surface view	**Smooth, moderate background**	**Smooth, moderate background**
Etching conditions: Normality:		
Temperature:	**6.25N NaOH**	**6.25N NaOH**
Time:	**70^{o}C**	**70^{o}C**
	45min	**6h**
Calibration factor (track.mm^{-2}.d^{-1}) / (pCi/l)	**0.173**	**0.242**

Positron Annihilation Lifetime Technique (PAL)

PAL was performed using a conventional fast–fast coincidence system. The lifetime of a positron is given by the time interval between the prompt γ-ray (1.28 MeV) that accompanies the emission of a positron from the ^{22}Na radioisotope and the positron annihilation γ-rays (0.511 MeV). A time resolution (full-width at half-maximum, FWHM) of 250 ps for the ^{60}Co γ-rays with a time calibration of 53ps/ch. is recorded. All the PAL measurements were conducted at room temperature (about 25 °C). The source absorption by the source holder (kapton foil) is about 10% and contributed to the short lifetime components. The sample (1.0 x 1.0 cm^2 of thickness 1 mm) with source–sample sandwich configuration, guaranteed that no positrons annihilates outside the sample-source system.

The analysis of the PAL spectra containing about 1.5 x 10^6 annihilation events were finite term analyzed, using LT 9.0 program (Kansy, 2002). Three lifetime components with average values τ_1, τ_2 and τ_3 and relative intensities I_1, I_2 and I_3 were found to give the best variance of fit and most reasonable standard deviations. It should be stated that, the short lifetime component (τ_1 = 0.125 ns) and its relative intensity I_1 were kept fixed during the analysis. They are attributed to the p-Ps self annihilation which has very weak interaction with the environment. The long lifetime of o-Ps (ortho-Ps, the triplet state) (τ_3) gives the lifetime of positrons in free volume holes and is a measure of their size according to the Tao–Eldrup semi-empirical equation (2), (Tao, 1972 and Eldrup et al., 1981).

$$\lambda_{o-p_s}=\frac{1}{\tau_o-p_s}=2ns^{-1}\left[1-\frac{r_h}{r_h+\delta r}+\frac{1}{2\pi}\sin\left(\frac{2\pi r_h}{r_h+\delta r}\right)\right]=1/\tau_3 \quad (2)$$

where the units of r_h ,the radius of free volume holes, and τ_3 are in nm and ns, respectively, δr = 1.656 Å is an empirical parameter and derived from fitting the observed o-Ps lifetimes in molecular solids with known hole sizes (Nakanishi et al., 1988).

The relative intensity (I_3) contains information related to the concentration of free volume holes because it is a measure of the o-Ps formation probability.

The free volume hole radius r_h obtained from equation (2), is used to estimate the mean free volume hole size, V_h; assuming a spherical form for the holes, by using a simple equation:

$$V_h=(4\pi r_h^3)/3 \quad (3)$$

Collecting Samples

Eleven samples were collected from Talat Seliem locality, Um Bogma area, Southwestern Sinai, Egypt. It is located between latitudes 29° 02` 45`` and 29° 03` N and longitude 33° 22` and 33° 22` 30`` E. Eleven rock samples were collected from the area under investigation (Fig.7). The lithologic description for these samples are shown in Table (3) after (Aita, 2015; Mira and Aita, 2012).

Exhalation Rate

Exhalation rate is defined as the number of radon isotopes atoms that left the surface of material per unit time. Two types of exhalation are known: *Surface Exhalation* rates (Bq m^{-2} h^{-1}) and *Mass Exhalation* rates (Bq kg^{-1} h^{-1}).

A closed sealed can is employed for detectors with dimension (1.0 cm x 1.5 cm), which are placed at the upper cover of the can at distance of 6 cm from the surface of the rock sample as shown on Figure (8). The whole equipment is sealed for 30 days to assure secular equilibrium between ^{226}Ra and ^{222}Rn. The detectors were then removed and etched for the measurement of track density.

The exhalation rate of radon is obtained for the two detectors from the following equation (Saad et al., 2013; Hassan et al., 2015):

$$E_x=\frac{C_{Rn}V\lambda}{A\left[T+1/\lambda\left(e^{-\lambda T}-1\right)\right]} \quad (4)$$

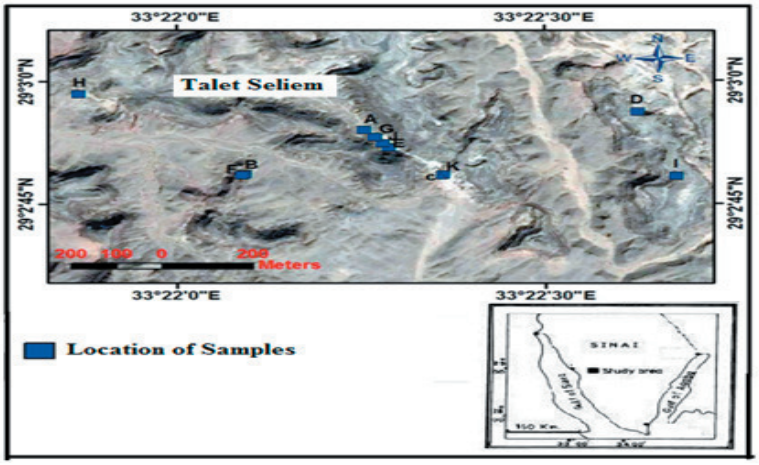

Fig. 7: Landsat image of Talet Seliem Locality showing location of collected samples

Table 3: Lithologic description of the collected samples

Sample No.	Lithologic description
A	Yellow ochres clay
B	Gray earthy soil material ± clay ± carbonate nodules
C	Kaolinite and White gibbsite
D	Gray to Violet, friable and soft mudstone ± Alunite nodules
E	Yellow marl
F	White to gray clay
G	Gray earthy soil material
H	Gray kaolinite ± earthy soil materials
I	Yellowish, friable and soft mudstone with marl
J	Gray earthy soil material with clay
K	Yellow siltstone

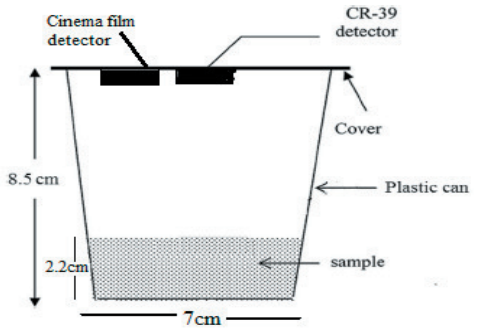

Fig. 8: Assembly for the measurement of radon concentration

Where E_x = surface radon exhalation rate (Bq m^{-2} h^{-1}); C_{Rn} = integrated radon exposure (Bq m^{-3}); V = effective volume of the can (m^3); λ= decay constant for radon (h^{-1}); A = area of the can (m^2) and T = exposure time (h).

Emanation Coefficient

The emanation coefficient is defined as the ratio between the effective radium content (calculated from the ^{222}Rn concentration) and the ^{226}Ra activity concentration measured by gamma spectroscopy (El-Aassy et al., 2016).

The ^{226}Ra gamma spectra for the rock sam-

ples are first measured by a high purity germanium (HPGe) detector. The specific activity of ^{226}Ra was measured using the 186.1 keV from its own gamma-ray (after the subtraction of the 185.7 keV of ^{235}U) (Abdel Gawad and Ibrahim, 2016).

The effective radium content is calculated using the following equation (Somogyi, 1990):

$$C_{Ra}(Bq/Kg) = \frac{\rho}{KT_e}\frac{h(m)A(m^2)}{M(Kg)} \quad (5)$$

where ρ is the background corrected track density (tracks.cm^{-2}), K=0.18 (tracks.cm^{-2}/(Bq/m^3.d) is the calibration factor of the cup (Abdel-Ghany, 2005). M, is the mass of the sample, A is area of the cup and h is the distance between the detector and the top of the sample. T_e is the effective exposure time and is calculated using equation (6):

$$T_e = \left(T' + \frac{(e^{-\lambda T'} - 1)}{\lambda}\right) \quad (6)$$

where λ is the decay constant of ^{222}Rn and T` is the exposure time in days.

RESULTS

Track Densities

Figure (9) shows a direct comparison of the measured track densities (track/mm^2/d) in the eleven samples under investigation for the two detectors , it ranges from (6.76 ± 1.17) to (66.76 ± 4.53) for cinema film and from (9.89 ± 0.94) to (91.59 ± 5.22) for CR-39. It is worthwhile to note that the track densities for all rocks detected by the CR-39 are slightly higher than the corresponding ones in the Cinema films. Their ratio values vary from o.69 to 0.73.

Radon Gas Concentrations

Figure (10) shows a histogram for the radon gas concentrations (pCi/l) calculated from equation (1) for the two detectors. These

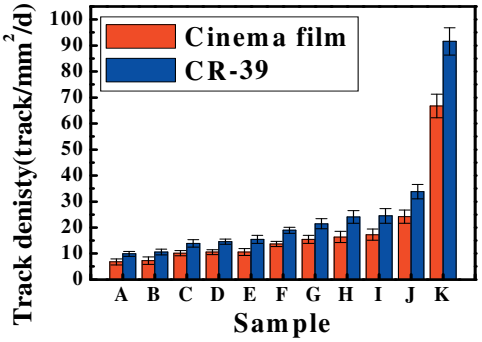

Fig. 9: The measured track densities for different samples by the two detectors

concentrations range from (38.97 ± 6.75) to (385.01 ± 26.13) for cinema film and from (40.76 ± 3.89) to (377.45 ± 21.51) for CR-39. It is noted that they nearly have the same range and also the same values of radon gas concentrations.

Exhalation Rates

Figure (11) shows the surface exhalation rates (Bqm^{-2}h^{-1}) of the two detectors as calculated from equation (4). They range from (0.00207) to (0.01920) for cinema film and from (0.00198) to (0.01959) for CR-39. These results are expected as exhalation rates are directly calculated from the measured radon gas concentrations.

The results of exhalation rates are within the range of sedimentary rocks in agreement with (El-Aassy et al., 2016).

Emanation Coefficient

Table (4) shows the results of emanation coefficients for the eleven rock samples calculated using equation (5). They are found to range from 0.0013 to 0.0049 for cinema films and from 0.0017 to 0.0072 for CR-39.

The emanation coefficient results in the two detectors are comparable being slightly lower by the factor of 0.715, as estimated from the ratio between the two calibration factors,

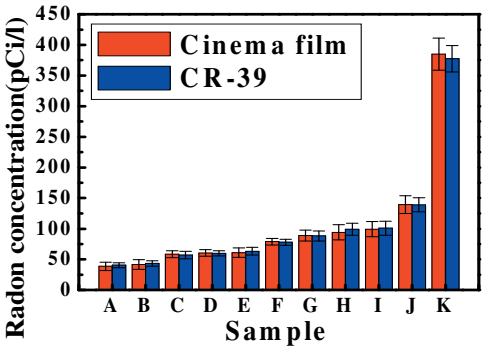

Fig. 10: The calculated radon gas concentrations for different samples by the two detectors

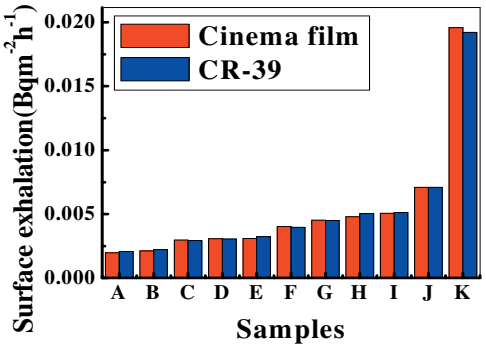

Fig. 11: The calculated surface exhalation rates for different samples by the two detectors

Table 4: Emanation coefficient results of both detectors

Sample No.	Ra (Bq/Kg) measured by HPGe	CRa (Bq/Kg) calculated		Emanation coefficient	
		Cinema film	CR-39	Cinema film	CR-39
A	1243.71	1.70	2.47	0.0014	0.0020
B	625.65	2.48	3.44	0.0040	0.0055
C	546.06	1.69	2.34	0.0031	0.0043
D	6144.26	10.71	14.70	0.0017	0.0024
E	1296.49	1.63	2.23	0.0013	0.0017
F	868.71	3.88	5.42	0.0045	0.0062
G	778.86	2.63	3.86	0.0034	0.0050
H	220.98	1.08	1.59	0.0049	0.0072
I	1117.28	2.20	3.04	0.0020	0.0027
J	621.45	2.77	3.93	0.0045	0.0063
K	253.66	1.16	1.69	0.0046	0.0067

in cinema film than in CR-39 for all rock samples. The emanation coefficients are found to be in agreement with the corresponding sedimentary rock values published by (El-Aassy et al., 2016 and Hassan et al., 2009).

Positron Annihilation Lifetime

The decay of positrons into the amorphous polymers, can be represented by three exponential decay terms $s(t) = \sum_i (I_i/\tau_i)\exp(-t/\tau_i)$ (i=1,2,3; $\lambda=1/\tau$) usually appear.

Where the positron stay in state i with lifetime τ_i and corresponding intensity I_i before annihilation. The spectra of the positron lifetime experiments were obtained for CR-39 polycarbonate and cinema film samples that have been irradiated by the field rock samples (Table 3) collected from Talat Seliem locality, Um Bogma area, Southwestern Sinai, in Egypt. These have been compared with blank samples of CR-39 and cinema film. The spectra consist of long lived lifetime components due to positron trapping in open-volume defects, besides exponential decay components.

The analyses of the lifetime spectra by Lifetime (LT 9.0) computer code led to lifetime and intensity of three components (τ_1, τ_2

and τ_3 with subsequent intensities I_1, I_2 and I_3). For the fitted spectra, the value of the variance χ^2, was gauged the goodness of the fit which should be near one ($\chi^2 \approx 1$).

A unique Gaussian component of 290 ps for the resolution function of the spectrometer was deconvoluted and one-component source correction equal to 382 ps corresponded to kapton foil annihilations in the fitting of lifetime spectra were considered.

The o-Ps lifetime (τ_3) is directly correlated to the free volume hole size which is very sensitive to structural changes in the polymer (Jean, 1990). The information about free volume hole concentration is obtained from the intensity of this component. The obtained results are presented on Fig.(12). As shown in the figure, the o-Ps parameters (τ_3 and I_3) are almost constant as a function of radon concentration in both detectors. This indicates that the radon concentration is too low to produce any variation in the size and concentration of free volumes.

For the o-Ps component the values of τ_3 (1.9 ± 0.5 ns) in CR-39 are constant and similar to the blank polymer detector. The values of τ_3 (2.2 ± 0.5 ns) in the film are higher than the CR-39 detector, which means that CR-39 contains smaller free volume holes. The difference in their chemical structure could be the reason. The variation of the intensities i.e. the concentration of free volumes has not been observed for CR-39 (I_3 = 18±5%) and for the Cinema film (I_3 = 15 ± 3%) with the radon concentration. The larger I_3 value in CR-39 compared to the film is positively correlated with the higher track density found in CR-39.

In order to determine the size distribution of free volumes in the two detectors the data have been analyzed using the LT 9.0 (Kansy, 2002). The program allows analysis of continuous lifetime distribution by introducing a dispersion σ, in the value of τ_3. The lifetime spectrum is expressed by the Laplace transformation of the functions $\alpha_i(\lambda)\lambda$, therefore the hole radius probability distribution, $n(r_h)=-\alpha_i(\lambda)d\lambda_i/dr_h$, can be calculated from (Liu et al., 1993 and Gregory, 1991)

$$n(r_h) = -3.32\left\{\cos\left[\frac{2\pi r_h}{(r_h+\delta r)^2}\right]-1\right\}\frac{\alpha_i(\lambda)}{(r_h+\delta r)^2} \qquad (7)$$

Where $n(r_h)dr_h$ gives the free volume holes with radii between r_h and $r_h + dr_h$. The hole volume distribution $g(v_h)$ follows from

$$g(v_h) = \frac{n(r_h)}{4\pi r_h^2} \qquad (8)$$

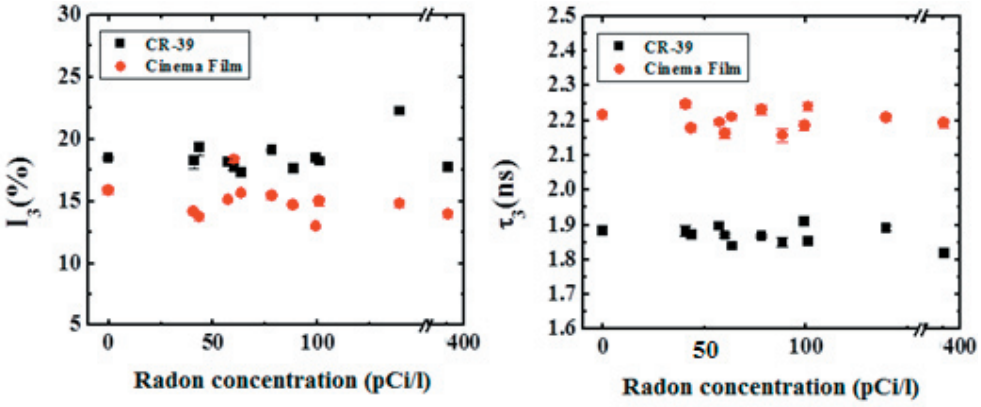

Fig. 12: Variation of o-Ps parameters (I_3, τ_3) with Radon gas concentration

Figure (13) shows the $r_h + dr_h$ distribution of free volume holes for blank and irradiated CR-39 and film samples by different radon gas concentrations.

The volume hole size, in which the o-Ps is trapped, as x-axis of this figure is calculated using equations (2) and (3).

The size distributions are well approximated by Gaussian-type function with maxima at 74 Å and 100 Å for the CR-39 and the films respectively. It is worthwhile to mention that, the distribution of free volumes in CR-39 detector is less broad (FWHM= 80 Å) compared to the corresponding one in the cinema film detector (FWHM = 110 Å). In addition, its probability density function is shifted to lower free volume size with no considerable variation with radon concentration.

CONCLUSIONS

The aim of the work is to produce a low cost solid state nuclear track detector (SSNTD) from recycled cinema films, to be used as alternative to the CR-39 detector. The size distributions of the free volumes in the two detectors have been probed using positron annihilation lifetime (PAL). The etching conditions of the cinema film have been optimized using the same etching conditions as CR-39. An optimum etching time of 45 minutes is obtained for cinema film which is much smaller than the 6 hours etching time in CR-39. The calibration of the two detectors has been performed by irradiation with known radon concentrations. The variation of the track density as a function of radon concentration is found to be linear with slope of 0.173 and 0.242 for the cinema film and CR-39 respectively, showing comparable sensitivity of the two detectors to radon concentration greater than 70 pCi/l. The two detectors have been tested in radioactivity field measurements at southwestern Sinai in Egypt. The ratios for the track densities of the eleven samples measured by the two detectors are ranging from 0.69 to 0.73. The calculated radon concentrations, exhalation and emanation rates deduced from the measurements of the two detectors are found to be comparable being slightly lower by a factor of 0.715 in cinema film.

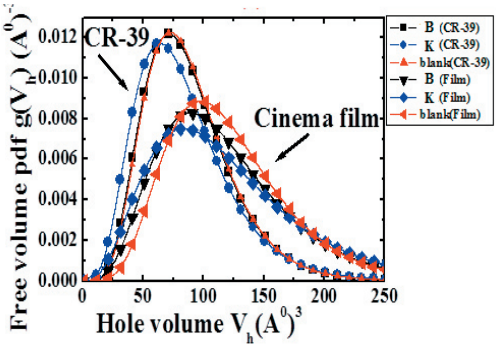

Fig. 13: Size distribution of free volume holes in CR-39 and cinema film for blank (non irradiated) and two different radon concentrations

No variation in the size and concentration of free volumes in CR-39 and cinema film has been detected by PAL in the concentration range 50 – 400 pCi/l. The size distribution of free volumes in CR-39 is found to be less broad and shifted to lower free volume size compared to cinema films. In addition, the larger concentration (I_3) of free volumes observed in CR-39 compared to the cinema film could be positively correlated with the higher track density observed in CR-39.

The optimized recycled cinema films can be competitively used as SSNTD for radon concentrations higher than 70 pCi/l. They can be considered as cost effective alternative detector to CR-39.

REFERENCES

Abdel Gawad, A.E., and Ibrahim, E.M., 2016. Activity ratios as a tool for studying uranium mobility at El Sela shear zone, southeastern Desert, Egypt. J. Radioanal Nucl. Chem., 308,129-142.

Abdel-Ghany, H.A., 2005. Variability of radon concentrations in different compartments of dwell-

ings in Egypt. Medical J. Islamic World Academy of Sciences, 15, 153-156.

Aita, S.K., 2015. Uranium mobilization by Quaternary karst processes in Um Bogma area, southwestern Sinai, Egypt. J. Sedimentology of Egypt, 22, 101-110.

Al-Galal, N.A.S., 2016. Study of the specific radioactivity for volcanic and rock samples using different nuclear techniques. M.Sc. Thesis, Fac. Educ., Ain Shams Univ., Egypt.

Cassou, R.M., and Benton, E.V., 1978. Properties and applications of CR39 polymeric nuclear track detector. Nucl. Track Detect., 2, 173-179.

Dlubek, G.; Stolp, M.; Nagel, Ch.; Fretwell, H.M.; Alam, M.A., and Radusch, H.J., 1998a. Effect of crystallization and of water uptake on the free volume hole size in polyamides 6 and 66. J. Phys.: Condens. Matter, 10, 10443-10450.

Dlubek, G.; Stejny, J.; Lupke, T.H.; Bamford, D.; Petters, K.; Hubner,C.H.; Alam, M.A., and Hill, M.J., 2002. Free volume variation in polyethylenes of different crystallinities: Positron lifetime, density and X-ray studies. J. Polym. Sci.: Part B: Polym. Phys., 40, 65-81.

Dlubek, G.; Fretwell, H.M., and Alam, M.A., 2004. Macromolecules. 33, 187p.

Dwaikat, N.; Safarini, G.; El-hasan, M., and Iida, T., 2007. CR-39 detector compared with Kodalpha film type (LR 115) in terms of radon concentration. J. Nuclear Instrument and Methods in Physics Research, Section A, 570, 289-291.

El-Aassy, I.E. ; Shaaban, D.H., and Ibrahim, E.M., 2016. Environmental impacts of waste produced from processing of different uraniferous rock samples. J. Radiation Research and Applied Sciences, 9, 303-309.

El-Abnoudy, A.A., 2008. Nuclear Materials Mining Activities Impacts on Aerial Environment, Case Study: Southwestern Sinai. M.Sc. Thesis; Fac. Sci., Cairo Univ., Egypt.

Eldrup, M.; Lightbody, D., and Sherwood, J.N., 1981. The temperature dependence of positron lifetimes in solid pivalic acid. Chem. Phys., 63, 51-58.

Fleischer, R.L.; Price, P.B., and Walker, R.M., 1975. Nuclear Tracks in Solids. University of California Press, Berkley.

Gregory R.B., 1991. Free-volume and pore size distributions determined by numerical Laplace inversion of positron annihilation lifetime data. J. Appl. Phys., 70 (9), 4665-4670.

Hassan, N.M.; Hosoda, M.; Ishikawa, T.; Sorimachi, A.; Sahoo, S.K.; Tokonami, S., and Fukushi, M., 2009. Radon migration process and its influence factors; Review. Japan. J. Health Phys., 44 (2), 218-223.

Hassan, S.F., 2000. Measurements of Radon Gas Concentrations and Radon Progeny in Uranium Exploration Galleries Allouga-Sinia, Egypt. M.Sc. Thesis, Fac. Sci., Cairo Univ., Egypt, 217p.

Hassan, S.F.; El Nagdy, M.S.; Shata, A., and Korany, K.A., 2015. Radiation Hazards Indices, Radon Exhalation Rates and Radon Diffusion Length for Some Soil Samples, Wadi Naseib Area, Sinai, Egypt. Series of Nuclear Materials Authority Publications.

Igarashi, A.; Kimura, M., and Shimamura, I., 2002. Unified treatment of positron annihilation and positronium formation. Phys. Rev. Lett., 89, 123201-1-123201-4.

Ivanov, I.A., and Mitroy, J., 2002. Pick-off annihilation in positronium scattering from alkali-metal ions. Phys. Rev., A 65, 034709-1-034709-4.

Jean, Y.C., 1990. Free volume hole properties of polymers probed by positron annihilation spectroscopy. 3rd Inter. Workshop on positron and positronium chemistry,1-29.

Kansy J., 2002. LT for Windows, Version 9.0, Inst. of Phys. Chem. Metals, Silesian University, Bankowa 12, PL-40-007 Katowice, Poland.

Lewin, M., and Pearce, E.M., 1998. Handbook of Fiber Chemistry. 2nd edition, Marcel Dekker, Inc.

Liu, J.; Deng, Q., and Jean, Y.C., 1993. Free volume distributions of polystyrene probed by positron annihilation: Comparison with free volume theories. Macromolecules, 26(26), 7149-7155.

Mansy, M.; El-Samman, H.; Hassan, M.A.; Mahfouz, E.; Eissa, H., and El-Fiki, M., 2000. Inter. Conf. Environmental Hazards, Cairo Univ., Egypt.

Marzocca, A.J.; Cerveny, S.; Salgueiro, W.; Somoza, A., and Gonzalez, L., 2002. Characterization of free volume during vulcanization of styrenebutadiene rubber by means of positron annihilation lifetime spectroscopy and dynamic mechanical test. Phys. Rev., E 65, 021801-1-021801-5.

Mira, H.I., and Aita, S.K., 2012. Remobilization of uranium and copper through Karstification processes; A case study in Abu Thor Locality, Um Bogma region, West Central Sinai, Egypt. Ann. Geol. Surv. Egypt, XXXI, 389-404.

Mogensen, O.E., 1995. Positron Annihilation in Chemistry. Springer-Verlag, Berlin, Heidelberg, New York.

Nakanishi, H.; Wang, S.J., and Jean, Y.C., 1988. In: Positron Annihilation Studies of Fluids (Sharama, S.C.,Ed.). World Scientific, Singapore. 292-298.

Prochazka, I., 2001. Positron annihilation spectroscopy. Mater. Structure, 2, 55-60.

Saad, A.F.; Abdallah, R.M., and Hussein, N.A., 2013. Radon exhalation from Libyan soil samples measured with the SSNTD technique. Applied Radiation and Isotopes, 72, 163-168.

Somogyi, G., 1990. The environmental behavior of radium. In Technical reports series, Inter. Atomic Energy Agency, Vienna, l, 229-256.

Tao, S.J., 1972. Positronium annihilation in molecular substances. J. Chem. Phys., 56 (11), 5499-5510.

معايرة أفلام السينما المستعملة لإستخدامها ككاشف نووي صلب

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تهدف الدراسة إلي إستكشاف مواصفات وخصائص أفلام السينما المعاد تدويرها ومقارنتها بكاشف الأثر النووي الصلب من نوع سي أر- ٣٩ الشائع إستخدامه. تم تعريف التركيب الكيميائي لأفلام السينما بإستخدام مطياف الأشعه الحمراء وتبين أنه عبارة عن سيليلوزثلاثي الأسيتيت.

تم إجراء التجارب المعملية لتعيين الظروف المناسبه لإظهار أثار جزيئات ألفا علي تلك الأفلام بعد تشعيعها بمصدر صناعي من الأماريسيوم-٢٤١ الذي يبعث جزيئات ألفا بطاقة ٥,٤٨ مليون إلكترون فولت وله نشاط إشعاعي يصل إلي ٥,٤٨٦ نانوكوري.

تم عمل المعايرة تحت نفس الظروف لكلا النوعين من الأفلام معا بإستخدام تركيزات مختلفة من غاز الرادون تتراوح بين ٦٨,٦ و ٤٤٣,٢ بيكوكوري لكل لتر. أظهرت نتيجة منحني المعايرة أنها خطية ومعامل المعايرة ٠,١٧٣ (تراك / ملي متر^{٢} / يوم) / (بيكوكوري / لتر) لأفلام السينما بينما كان ٠,٢٤٢ (تراك / ملي متر^{٢} / يوم) / (بيكوكوري / لتر) في حاله سي أر- ٣٩.

تم استخدام كلا النوعين من الأفلام لقياس تركيزات غاز الرادون المنبعث من عدد ١١ عينة صخرية رسوبية تم تجميعها من منطقه قلعة سليم في أم بجمه جنوب غرب سيناء مصر. وجد

أن تركيزات الرادون تتراوح بين ٣٨,٩٧ و ٣٨٥,٥١ بيكو كوري / لتر في حاله إستخدام أفلام السينما و تتراوح بين ٤٠,٦٧ و ٣٧٧,٤٥ بيكو كوري / لتر في حاله إستخدام سي أر- ٣٩ و هذه النتيجة تعتبر متطابقة عند أخذ مدي الخطأ في الإعتبار، نفس النتيجة ظهرت في حالة قياس معدل الإنبعاث السطحي (الفيض) الذي كان يتراوح بين ٠,٠٠٢٠٧ - ٠,٠١٩٢٠ بيكرل / م ٢/ ساعة لأفلام السينما و ٠,٠٠١٩٨ - ٠,٠١٩٥٩ بيكرل / م٢ / ساعه في حاله سي أر- ٣٩ . نتائج مكافئ الإنبعاث كانت ايضا متقاربة إلي حد ما " أقل بنسبه بسيطة ٠,٧١ في حاله أفلام السينما".

تم إستخدام خاصيه الفناء البوزيتروني لدراسة تأثير جزيئات ألفا علي التركيب الكيميائي لهذه الكواشف في حدود مقياس النانو من حيث أحجام الفراغات الناتجة وقد وجد أن توزيع احجام هذه الفراغات أحد أنواع داله جاوس وكانت القيمه العظمي لهذه الأحجام هي ٧٤ أنجستروم في حالة سي أر- ٣٩ بينما كانت ١٠٠ أنجستروم في حالة أفلام السينما ويرجع ذلك إلي إختلاف التركيب الكيميائي والخواص الفيزيائية لكلا النوعين من الكواشف.