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Determination of Alpha Rates Emitted from Animal Bones Using CN-85 Nuclear Track Detector

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Abstract: The aim of this study is to calculate the alpha rates emitted from some parts of animal which are not consumed (bones samples) and re-enter the human food chain as bone meal in various fodder products, or as fertilizers. This is performed by count the alpha tracks emitted from the natural radioactive nuclei (pb-210, po-210, Ra-226) of three common animals bones (beef, sheep, and chicken) by exposed the CN-85 detector to some grams of the samples filled in clear plastic cup (cup technique). The detectors were exposed to the samples for 60 days and then etched by water bath with 2.5N (NaOH) solution at 60°C. The results showed that the mean alpha emission rates of the samples were 50.85 $Bq.m^{-2}$, 58.24$Bq.m^{-2}$, and 67.99 $Bq.m^{-2}$ for sheep, beef and chicken respectively. The highest alpha emission rate observed in chicken samples and the lowest rate of alpha emitters observed in sheep samples, and the optimum etching time of CN-85 when its used to detect the natural alpha particles is 40 mints.

Keywords: Alpha Emission Rate, Bones, CN-85, SSNTDs, Radionuclides

1. Introduction

Operation of the solid-state nuclear track detector is based on the fact that a heavy charged particle will cause extensive ionization of the material when it passes through a medium [1]. Four decades have elapsed since the discovery of nuclear track detectors until now, there is no general agreement about the mechanism of track formation in these detectors [2], which is known to involve generally atomic displacement, ionization and excitation followed by chemical reaction. Particularly in polymers little is established about the inner structure of the latent tracks [3].

SSNTDs have the properties for registering charged ionizing particles, such as protons, alpha particles or fission fragments [4]. The widespread use of SSNTDs is due to their unique features, e.g. low cost, less weight, threshold nature [5]. One of the most common polymer based SSNTDs is the Cellulose nitrate (CN-85, Kodak) ($C_6H_{18}O_5N_2$) is one of the polymeric nuclear track detectors used widely for investigating both low and high energy ion (several MeV) registration [6].

U^{238} can be entered into the body via nutrition is 5 Bq, its specific concentration around bones is 0.15 Bq/Kg, and a soft tissue is 5×10^{-3} Bq/Kg. When considering the level of thorium-232, which is almost concentrated in the bones and can increase with age, activity concentration is around 4×10^{-2} Bq/kg in bones and 3×10^{-4} Bq/kg in soft tissues [7].

Through ingested, uranium might be concentrated within the bone; it increases the probability of bone cancer, or in the red bone marrow (leukemia) [8]. Bone marrow is a dynamic tissue compartment in the cavity of bones. In adults, hematopoietic cells are produced by the bone marrow cells in the large bones that account for 2– 5% of an adult's weight [9]. Alpha Particle emitting radionuclides such as Pb-210, Po-210 and Ra-226, accumulate in bone, which has proven to be a critical organ in the dosimetry of human and animal exposure to radionuclides. The fraction of the absorbed radionuclides within the skeleton differs widely between individuals [10]. And some 99% of Ra-226 body content is in human bones [11]. It is expected that Ra-226 would be present in bones because it tends to be moderately transferable in the physical environment [12].

Ra-226 and Ra-228 isotopes are considered as the most important natural radionuclides of the U-238 and Th-232 series, respectively. In the human body the radioisotopes behave chemically and physiologically like calcium and are inclined to concentrate in the bones [13]. Uranium may enter the body through the skin, lungs or gut. Once uranium enters the systemic circulation, it is distributed throughout the body. Ra-226 is a bone-seeking radionuclide that accumulates in calcareous tissues because of its chemical similarity to calcium [14]. The measurements of low level of long-lived α-emitting substances in different biological and environmental materials are important point of view [15].

The aim of this study is to calculate the optimum etching time of CN-85 when using to detect alpha emitted from biological natural samples, the mean alpha emission rates emanated from three common animals' bones have multiple uses.

2. Experimental Work

2.1. Samples Preparation

Fifteen bone samples are collected from animals that enter the human food chain. The samples are prepared by burning, grinding and sifting through a sieve with a net (650 microns), then weighing 20g of each sample and placed in a transparent plastic cup 12cm high and lower diameter 5cm and Upper diameter 7cm. The sample height in the mug is 1.5cm; the surface area of the sample is 19.625cm^2. The CN-85 detector (1cm^2) is placed touch on the sample. The mug was tightly closed and left for 60 days for reaching the radioactive balance. The following figure 1 is an illustration of the cup used to save samples with reagents.

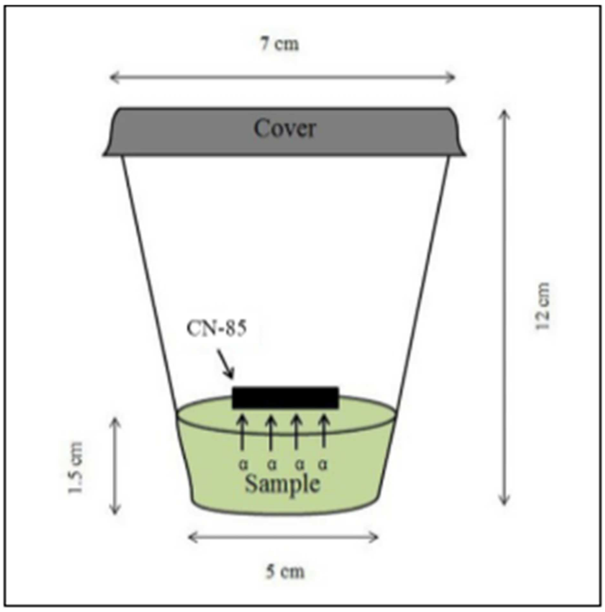

Figure 1. *Cup technique includes CN-85 detector exposed to some grams of bone sample.*

2.2. Etching Time

After two months, the detectors were plucking out from the cups. An arbitrary detector is chosen to etched with 2.5N (NaOH) at 60°C using water bath in order to investigate the optimum etching time (at which the largest alpha tracks were developed) for the detectors used in our experiment [1, 16]. This is done by etching the test detector for several times starting from 15minuts ending with 60 mints as shown in table 1, which includes the etching time, number of tracks, and the track density for each time. Figure 2 which includes some images of the etching steps clear that the largest number of tracks are appeared at 40 minutes.

Table 1. *Number of the tracks and track density versus etching time.*

Etching Time (minute)	No. of tracks	Track density (track.mm^{-2})
15	8.0	153.8
20	8.4	161.5
25	9.0	173
30	9.1	175
35	9.6	184.6
40	10.5	201.9
45	9.5	182.6
50	9.3	178.8
55	8.7	167.3
60	8.1	155.7

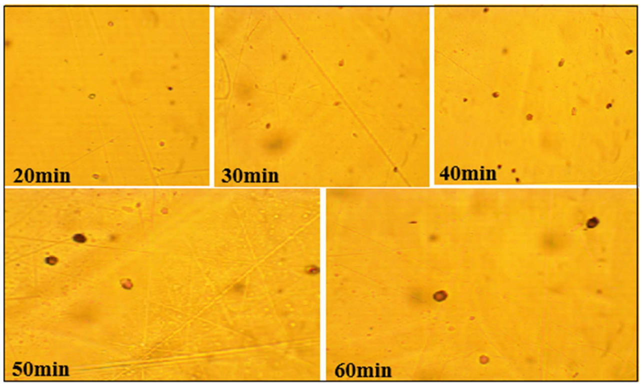

Figure 2. *Images of the registered tracks at each etching time.*

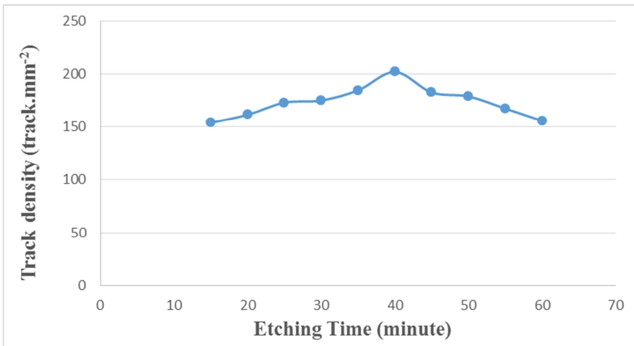

Figure 3. *Relationship between the track densities versus etching time.*

After the etching process, the tracks were computed by optical microscope of 400X magnification in order to calculate the track density in the detector using the following equation:

$$\rho = \frac{N_{Ave}}{a} \quad (1)$$

Where:

ρ: Track density.

N_{Ave}: Avarage number of total pits (tracks).

a: area of the field.

Figure 3 shows the relationship between the track densities and etching time; it's obvious that 40 minutes is the optimum time.

2.3. Calibration of Alpha Emission

The alpha particles emitters (Eα) emitted from bones samples were calibrated using alpha point source Am-241, by exposed a detector to Am-241 for different periods of time (2, 4, 6, 8, and 10 sec), the alpha flow from the source $E_{fsource}$ was calculated for each times of irradiation by the following equation [16]:

$$E_{\text{fsource}}\ (\text{Bq.sec/cm}^2) = \frac{A_{Am}\ t}{a} \quad (2)$$

Where

A_{Am}: the activity of Am-241 source (10μci).

a: the surface area of the detector exposed to Am-241 ($1cm^2$),

t: the exposure time per second.

Alpha tracks of Am-241 source recorded on the CN-85 detector used to calibrate the alpha emitters of the samples is shown in figure 4. The selected time used to expose the detector, the track density, and the $E_{fsource}$ are listed in table 2.

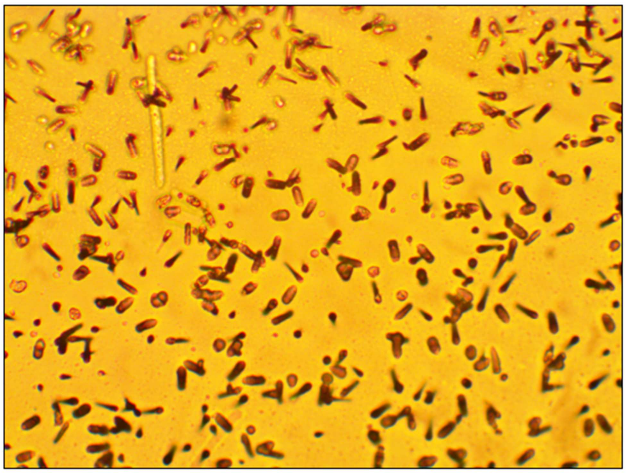

Figure 4. Tracks of Am-241 source on CN-85 detector.

Table 2. The exposure time, track density, and $E_{fsource}$.

Time exposure (sec)	Track density ($track.mm^{-2}$)	Alpha flow ($E_{fsource}$) ($Bq.sec.cm^{-2}$)
2	10000	688200
4	15000	1376400
6	17500	2664600
8	20000	2752800
10	25000	3441000

The relation between track density ρ_s and alpha flow $E_{fsource}$ can represent by kα (standard factor) which means the slope between them as shown in figure 5, and is calculated by:

$$K_\alpha = slope = \frac{\rho_s}{E_{\text{fsource}}}$$

$$= 0.0048\ (Track.\text{mm}^{-2}/Bq.sec.\text{cm}^{-2})$$

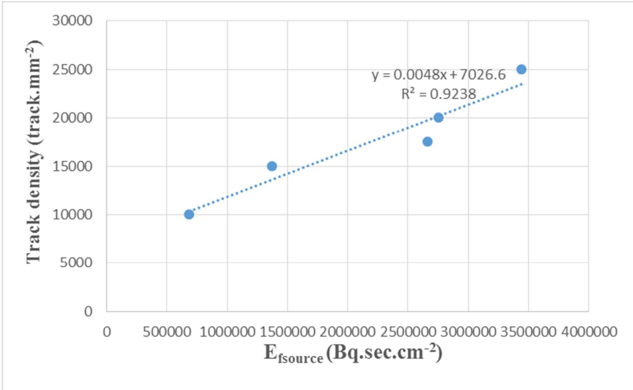

Figure 5. Calibration curve of alpha emitters when CN-85 detector.

2.4. Calculation of Alpha Emission Rate

Alpha emission rate Eα from the bones samples were computed by [16]:

$$E\alpha = \frac{\rho_\alpha}{(\rho_s/E_{\text{fsource}}) * t} \quad (3)$$

$$E\alpha = \frac{\rho_\alpha}{K_\alpha * t} = \frac{\rho_\alpha}{slope * t} \quad (4)$$

Where;

Eα: alpha emission rate from the samples.

ρ_α: track density of the samples.

E_{fsource}: The alpha fluence from the source Am-241.

ρ_s: track density of the source.

t: time of exposing the detectors to the bone samples (60 days).

3. Results and Discussion

Results shown that the optimum etching time is 40 mints, this is slightly different from reference [1] at which the researchers found that the optimum etching time about 30-35 mints when exposed CN-85 detector to an artificial alpha source. From this result one can conclude that each researcher must check the etching time in order to get the optimum one, because it may be different relative to the energy of alphas that the detector is exposed to it.

It's also shown that the mean alpha emission rate emitted from the chicken bone samples (67.99 $Bq.m^{-2}$) is higher than the mean value of alpha emission rate of beef bone samples (58.24 $Bq.m^{-2}$), which higher than lowest mean value which found in sheep bone samples (50.85 $Bq.m^{-2}$) as shown in table 3 and the diagram in figure 4 the slightly difference between these samples may be related to the subjective differences between the samples themselves or may be related to the type of feeding the animals.

Table 3. *Track density and alpha emission rate of the bone samples.*

No.	Types	Code sample	No. of tracks	Track density (track.mm^{-2})	Alpha Emission Rate Eα (Bq.m^{-2})
1		C1	10.5	201.9	81.13
2	Chicken	C2	7.6	146.1	58.71
3		C3	8.3	159.6	64.13
Mean					67.99
4		B1	5.8	111.5	44.8
5		B2	6.1	117.3	47.14
6	Beef	B3	6.11	177.5	71.33
7		B4	7.1	136.5	54.85
8		B5	7.6	146.1	58.71
9		B6	9.4	180.76	72.64
Mean					58.24
10		S1	7.7	148	59.47
11		S2	4.8	92.3	37.09
12	Sheep	S3	6.6	126.9	50.99
13		S4	6.5	125	50.23
14		S5	6	115.3	46.33
15		S6	7.9	151.9	61.04
Mean					50.85

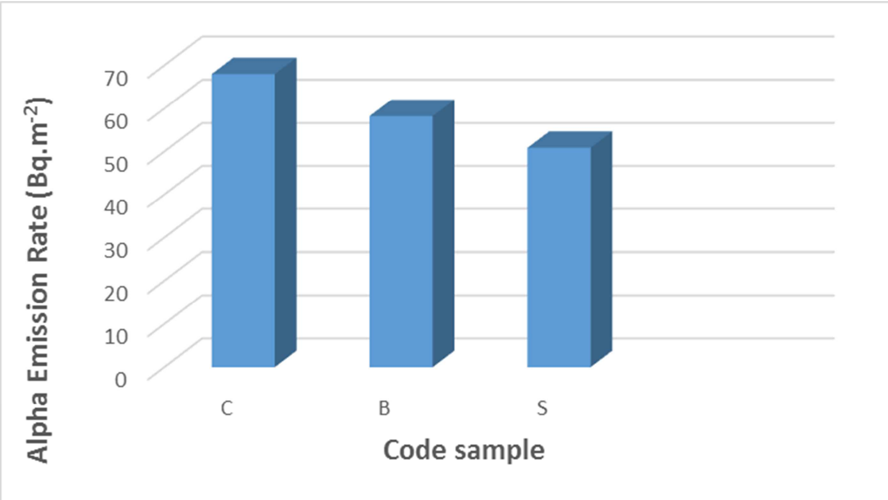

Figure 6. *Mean alpha emission rate of the bones samples using CN-85, B: beef, S: sheep, and C: chicken.*

4. Conclusions

The optimum etching time of CN-85 when using to detect alpha particles emitted from natural radioactive isotopes in the samples is 40 mints. The mean alpha emission rates of the studied bones are slightly different. The highest mean alpha emission rate is found in chicken samples. The lowest mean alpha emission rate is found in sheep samples. The diameters of the developed tracks were almost equal and have a cuneiform shape.

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