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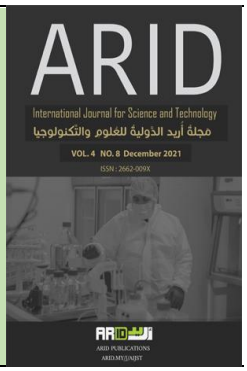

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Radon Monitoring by Alpha Track Detection Using Cn–85 Plastic Track

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مراقبة الرادون عن طريق كشف مسار ألفا باستخدام الكاشف البلاستيكي CN-85

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ABSTRACT

Radon sources can be found in external and internal radiation. Lead pencil (LP) is often used for drawing, sketching, etc. regardless of age nowadays. Paracetamol (PC) is commonly used around the world especially to treat fever, headache, menstrual pain, and common pain. Hence, the aim is to study the procedures for determining the radon gas comes out from different types of lead pencil and paracetamol.

Eight and five samples were collected from different companies of lead pencil and paracetamol, respectively. The samples were measured using the sealed technique in cylindrical plastic containers with CN–85 detectors. After irradiation, the detectors were chemically etched using 2 N sodium hydroxide (NaOH) solution at a temperature of 70 ºC for 62 min. The alpha track density on the surface of detectors was measured using an optical microscope at a magnification of 100×. Tracks on detectors were counted using Image software.

Radon concentration values including all samples in this study are within the limits of international which is 1000 Bq/m^3. The concentration of radium in LP and PC samples are lower than those reported in previous study. The result of the uranium concentration of both samples is quite low compared with the allowed limit which is 11.7 ppm. Annual effective dose levels are all below the dose limit which is 10 mSv/y. Lastly, there was a linear relationship between radium activity and radon exhalation rate. Therefore, using LP and eating PC cause no danger to humans. All results showed in this study are within internationally permissible limits, and therefore not a threat to human health.

Keywords: *lead pencil; Paracetamol; Radon; Track; alpha particles;detector*

الملخص:

يمكن العثور على مصادر الرادون من مصادر الإشعاع الخارجية والداخلية غالبا ما يستخدم قلم الرصاص للرسم والكتابة وما إلى ذلك بغض النظر عن عمر المستخدم، كما إن الباراسيتامول يستخدم بشكل شائع في جميع أنحاء العالم لعلاج الحمى والصداع وآلام الدورة الشهرية والآلام الشائعة الأخرى، لذلك كان الهدف من هذه الدراسة تحديد غاز الرادون الذي يخرج من أقلام الرصاص والباراسيتامول المصنعة من مختلف الشركات. جمعت ثمانية من الرصاص وخمس عينات من الباراسيتامول من شركات مختلفة. تم قياس العينات باستخدام تقنية محكمة الغلق في حاويات بلاستيكية أسطوانية مع كاشفات (سي ان -85). بعد التشعيع، تم حفر الكاشفات كيميائيًا باستخدام محلول 2 نيتروجين هيدروكسيد الصوديوم عند درجة حرارة 70 درجة مئوية لمدة 62 دقيقة. تم قياس مسار ألفا على سطح الكاشفات باستخدام مجهر ضوئي بتكبير 100 واستخدام برنامج خاص اسمه (امج-جي). وكانت قيم تركيز غاز الرادون بما في ذلك جميع العينات في هذه الدراسة هي ضمن الحدود الدولية وهي 1000 بيكريل / م 3. تركيز الراديوم في عينات أقلام الرصاص وحبوب الباراسيتامول أقل من تلك المذكورة في الدراسة السابقة. حيث كانت نتيجة تركيز اليورانيوم في كلتا العينتين منخفضة جدًا مقارنة بالحد المسموح به وهو 11.7 جزء في المليون. مستويات الجرعة الفعالة السنوية كلها أقل من حد الجرعة وهو 10 ملي سيفرت/ سنة. أخيرًا، كانت هناك علاقة خطية بين نشاط الراديوم ومعدل انبعاث الرادون. لذلك، اقلام الرصاص وحبوب الاراسيتامول لا يسبب خطورة للإنسان. جميع النتائج التي تظهر في هذه الدراسة ضمن الحدود المسموح بها دوليًا، وبالتالي لا تشكل تهديدًا لصحة الإنسان.

كلمات مفتاحيه: قلم رصاص – باراسيتامول- رادون- المسار - جسيمات الفا- كاشف

1. INTRODUCTION

In Solid State Nuclear Track Detection (SSNTDs) the track formation is correlated to the charged particles that produce damage permanently on the detector caused by the excess of the threshold unit. An ionizing particle that producing the intensity of ionization damage is directly proportional to the square of its charge and about inversely proportional to the square of its velocity. The most sensitive plastic is the type of organic polymers [1].

Compared to other materials the radiation damage path is more sensitive to chemical reactions. They will appear as black on the detectors when these canals reach a width similar to the wavelength of the visible light [4]. The most popular etching techniques using in laboratories are chemical etching because of its related parameters such as the concentration of the etchant solution, etching temperature, and duration of time are optimized and well established [8].

Polymer SSNTDs such as Columbia Resin No. 39 (CR–39) and Cellulose Nitrate 85 (CN–85) are most reactive to the energetic alpha particles. Alpha particles can cause severe damage trail as it passing through the detectors. SSNTDs have their own impressive characteristics which are insensitivity to visible (UV-, X-, β- and γ-rays) and non-fading of latent tracks [10].

Humans are continuously being exposed to background radiation. The source of background radiation is man-made and natural radiation. Other sources are terrestrial and cosmic radiations. Terrestrial sources come naturally from the soil, water and, air. While cosmic radiation is the radiation from outer space that mainly contain positively charged ions from the proton to larger nuclei.

Ionizing radiation can discard the electrons from the orbits to stabilize the atoms. Charged particles and atoms are called ions. Both natural and man-made radioactive materials

can emit ionizing radiation. Types of radiation are alpha radiation (α), beta radiation (β), photon radiation (gamma γ and x-ray), and neutron radiation (n). Their ability can discard one or more electrons away from the atoms in any material they pass through [7].

Radon (Rn) is a chemical element and the atomic number is 86. Radon half-life is 3.8 days. It is colorless, odorless, tasteless, naturally occurring, radioactive noble gas that is formed from the decay of radium. Radon is the heaviest gas that remains under normal conditions and is a health hazard [7].

From the previous studies, a study of radium in vegetables and foods become interesting. High radioactive chemical elements in radium consist in an assortment of foodstuffs. Under normal conditions of temperature and pressure, radium is a solid radioactive element [5].

Currently, black-core pencils contain graphite, not lead [2]. Pencil graphite core intercalated with clay particles (majorly silica and a few metal oxides) in conductive graphite [1].

Paracetamol or also known as acetaminophen commonly used around the world especially to treat fever, headache, menstrual pain, and common pain. The poisoning could lead to serious liver injury and even death [3].

Based on the previous study they are using drinking water, materials building, animal bones, vegetables, and biscuits to determine the radon gas. For our study, we are using different materials such as lead pencils and paracetamol. Most children prefer to use pencils during classes, especially in primary school. Another common thing humans always consume when they have a fever, headache, menstrual pain, and common pain which is paracetamol. Therefore, this study aims to determine the radon gas that comes out from lead pencil and paracetamol.

2. METHODOLOGY

Eight LP samples and five PC samples were collected from different companies in Malaysia. Each sample weight about 5 g (Table 1), in powder form by grinding using mortar and pestle.

Table (1): Weight sample and distance from surface of sample to the detector CN–85

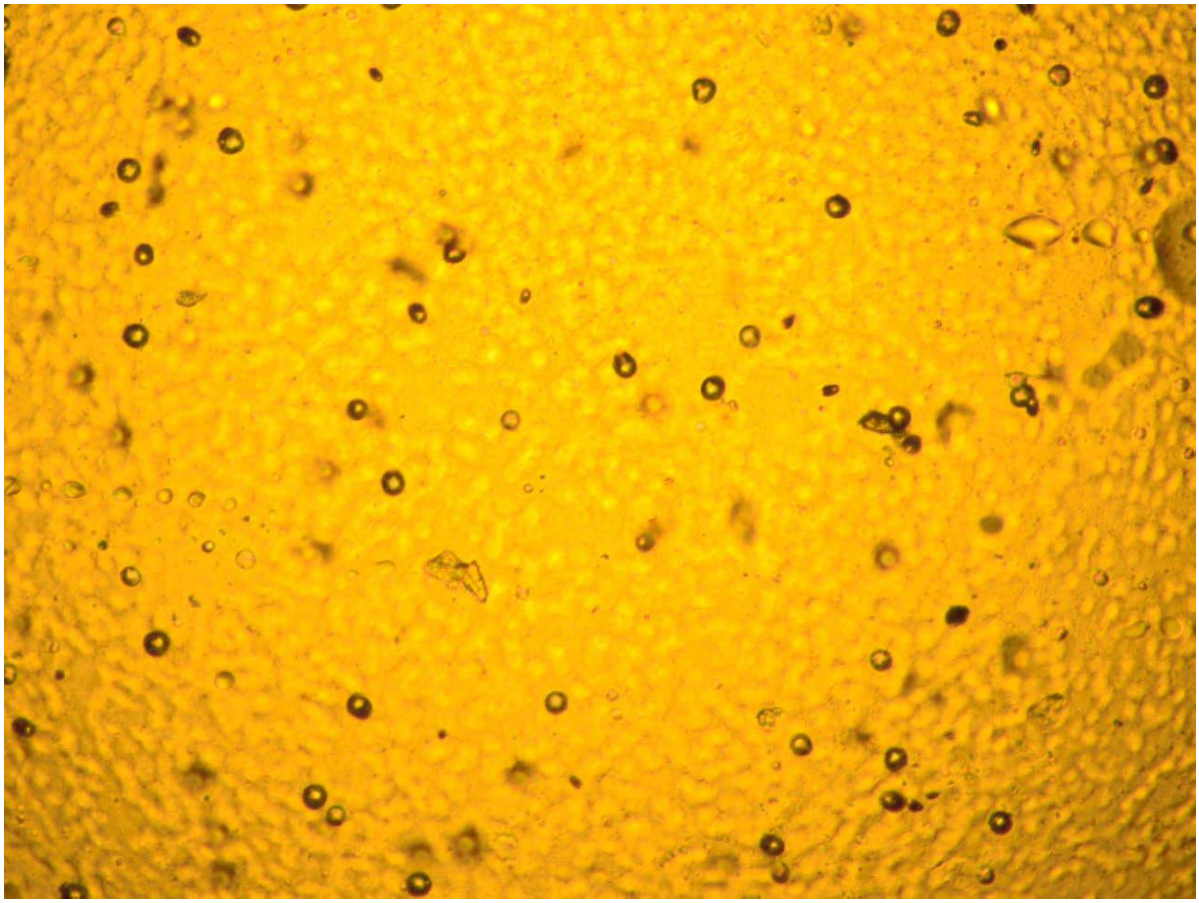
Code samples	Weight sample (g)	Distance from surface of sample to the detector CN–85 (cm)
LP1	5	3.0
LP2		2.6
LP3		3.9
LP4		2.6
LP5		4.0
LP6		2.8
LP7		3.0
LP8		3.0
PC1	5	2.2
PC2		2.0
PC3		2.0
PC4		2.6
PC5		2.6

Weighed samples were placed in cylindrical plastic containers of length 4.8 cm and diameter 2.1 cm. CN–85 in the form of sheets were cut into thirteen pieces, eight for LP samples while five for PC samples with dimensions 1×1 cm^2. One sheet of CN–85 was placed under the cap of the cylindrical plastic containers fixed by double-stick tape. From Table 1 the distance from the surface of each sample to the detector CN–85 is different. The cylindrical plastic containers were sealed to irradiate the detectors with alpha particles emitted from radon on 18th February 2020 and reopened on 22nd June 2020 for 126 days/4 months 5 days.

Put 20 g NaOH pellets in the beaker 500 mL. Pour 250 mL distilled water into the beaker. To ensure the solution mix well, the solution was stirred with the magnetic stirrer on the hot plate magnetic orientation.

After 126 days of irradiation, the detectors were pulled off from the double-stick tape. A Crocodile clip was wrapped around the stir rod. Then, the detectors were clipped by a crocodile clip and soaked in the NaOH solution. During the process, the detectors were etched by heater using 2 N NaOH solution at 70 °C for 62 minutes. Then the detectors let dry before being put in the plastic jar.

After the chemical etching process, the detectors from the plastic jar were put under an optical microscope with a digital camera on the microscope using a magnification of 100× and defined it on the computer. Twenty regions images were captured on each detector. After all images of detectors for each sample are captured, store these images (pixel unit) in the computer in the form (jpg) and name it. Then for alpha tracking image analysis, the images were inserted to program analysis ImageJ. ImageJ one of the designed program, and contain full options in processing and analysis. The number of tracks on the image appeared as a black round shape as in Figure 1. Each image contains the number of tracks was counted using ImageJ.



Figure(1): example image number of tracks for LP1 at region 1.

1. RESULTS AND DISCUSSIONS

After collecting data for a number of tracks, the average number of tracks were calculated and recorded as in Table 2.

Table(2): Average number of tracks for samples

Code samples / Reading		LP								PC				
		1	2	3	4	5	6	7	8	1	2	3	4	5
Number of tracks	1	42	23	66	37	53	35	31	68	21	18	54	37	30
	2	48	21	62	57	39	39	18	28	11	19	57	28	41
	3	45	32	36	42	41	64	17	39	19	24	58	46	43
	4	58	34	33	60	40	56	9	45	19	29	53	46	41
	5	63	36	22	32	26	61	11	54	11	26	52	38	42
	6	40	15	25	14	31	59	14	42	23	14	40	45	44
	7	34	16	28	19	29	62	13	19	8	13	55	58	54
	8	56	14	18	43	30	47	11	21	10	14	54	50	33
	9	55	15	34	56	20	56	23	17	19	16	63	30	46
	10	44	26	44	42	35	53	14	17	13	18	72	41	51
	11	53	20	42	23	43	65	16	38	20	14	48	52	39
	12	63	21	40	25	41	56	10	21	7	24	45	54	39
	13	58	34	55	28	25	55	11	25	19	25	57	48	46
	14	56	37	56	25	28	61	14	29	17	15	56	51	41
	15	45	92	28	32	48	53	18	61	13	17	52	39	49
	16	73	40	32	33	42	64	10	46	11	18	41	38	46
	17	57	21	23	46	40	56	14	55	12	15	49	54	33
	18	35	32	21	26	27	68	16	74	18	28	49	41	39
	19	41	43	20	45	32	64	13	44	13	10	62	53	42
	20	81	72	29	30	40	49	16	72	32	17	47	29	46
	Average	52.35	32.2	35.7	35.75	35.5	56.15	14.95	40.75	15.8	18.7	53.2	43.9	42.25

From this study, the results was analysed to determine the radon concentration in lead pencil and paracetamol. The measurements of track density (ρ), radon concentration (C_{Rn}), dissolved radon concentration of the sample (C_S), annual effective dose (AED), surface exhalation rate (SER), mass exhalation rate (MER), radium concentration (C_{Ra}), and uranium concentration (C_U) were recorded in Table 3.

Table (3): Track density (ρ), radon concentration (C_{Rn}), dissolved radon concentration of the sample (C_S), annual effective dose (AED), surface exhalation rate (SER), mass exhalation rate (MER), radium concentration (C_{Ra}), and uranium concentration (C_U) using CN-85 detectors for eight and five samples of LP and PC, respectively.

Parameters / Samples		No. of tracks (Track)	ρ (Track/cm^2)	C_{Rn} (Bq/m^3)	C_S (Bq/m^3)	AED (mSv/y)	SER (mBq/m^2.h)	MER (mBq/kg.h)	C_{Ra} (Bq/kg)	C_U (ppm)
LP	1	52.35	5235.000	227.214	6182.481	5.732	54.882	4.173	0.552	0.671
	2	32.2	3220.000	139.757	2696.521	3.526	29.257	2.224	0.294	0.358
	3	35.7	3570.000	154.948	10961.950	3.909	48.655	3.699	0.489	0.595
	4	35.75	3575.000	155.165	2993.808	3.915	32.482	2.469	0.327	0.397
	5	35.5	3550.000	154.080	12577.540	3.887	49.623	3.773	0.499	0.607
	6	56.15	5615.000	243.707	5570.256	6.148	54.942	4.177	0.553	0.672
	7	14.95	1495.000	64.887	1765.579	1.637	15.673	1.192	0.158	0.192
	8	40.75	4075.000	176.866	4812.533	4.462	42.721	3.248	0.430	0.522
PC	1	15.8	1580.000	68.576	947.335	1.730	12.147	0.924	0.122	0.148
	2	18.7	1870.000	81.163	946.479	2.048	13.070	0.994	0.131	0.160
	3	53.2	5320.000	230.903	2692.656	5.825	37.182	2.827	0.374	0.455
	4	43.9	4390.000	190.538	3676.313	4.807	39.887	3.032	0.401	0.488
	5	42.25	4225.000	183.377	3538.137	4.626	38.388	2.918	0.386	0.469

The range for track density values was between 1495–5615 (Track/cm^2) and 1580–5320 (Track/cm^2) for LP and PC samples, respectively. The track density values were corresponding to the radon concentrations values.

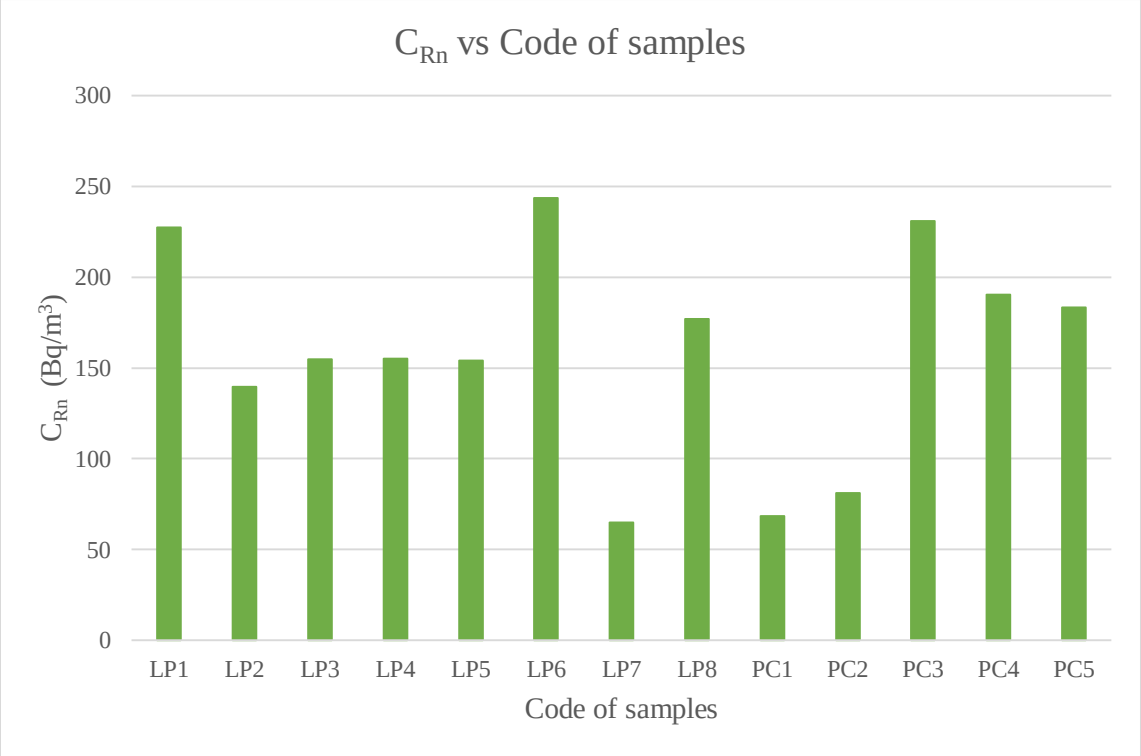
From Figure 3 the highest radon concentration was 243.707 Bq/m^3 found in ASTAR Rainforest 2B Pencil P1700 (LP6) while the lowest radon concentration was 64.887 Bq/m^3 found in Pencil HB Elite 161 (LP7).

The higher grade of pencil contains a higher graphite percentage. The highest radon concentration is 2B pencil which has a higher blackness, and the marks drawn are relatively black, while the lowest radon concentration is HB pencil which has a lower blackness, and the color of the marks drawn is relatively light, which is very different. There are obvious differences in the composition of the core between the two. The main component contains in 2B pencil lead is graphite, while the composition of HB pencil is in addition to half of the graphite. The usage of 2B pencil and HB pencil is not similar. 2B pencil is darker in color and lowers in hardness. It is suitable for drawing and painting. But HB pencil is not. It has high hardness and is not easy to break. It is suitable for writing, especially for children who have just learned to write. Besides, HB pencil is also suitable for marking on hard objects.

But for PC samples, the highest radon concentration was 230.903 Bq/m^3 found in Panadol Cold And Flu Day (PC3) while the lowest radon concentration was 68.576 Bq/m^3 found in Panadol 6 strip (PC1) based on Figure 4.1. PC3 caplets can be used for blocked and runny nose, headache and body ache, fever, sinus and pain relief. Active ingredients contained in each caplet are 500 mg of paracetamol, 25 mg of caffeine, 5 mg of phenylephrine hydrochloride. While PC1 is used for the fast effective temporary relief of pain and discomfort associated with headache, muscular aches, period pain, arthritis/osteoarthritis, toothache, migraine, colds and flu, tension headache, sinus pain/headache and backache. PC1 also reduces fever. It also acts in the brain to reduce fever. PC1 contain 500 mg of paracetamol as the active ingredient and they also contain

starch-pregelatinised maize, starch-maize, talc-purified, stearic acid, hypromellose, povidone, glycerol triacetate, potassium sorbate and carnauba wax.

Radon concentration values including all samples in this study are within the limits of international which is 1000 Bq/m^3 [6].



Figure(3): Bar chart showing radon concentration in LP and PC samples

Figure 4 shows the relation between uranium concentration with the radium concentrations in LP samples while Figure 5 shows the relation between uranium concentration with the radium concentrations in PC samples. A positive correlation has been observed between uranium concentration and radium concentration in both Figures 4 and 5.

ASTAR Rainforest 2B Pencil P1700 was characterized by the highest radium concentration was 0.553 Bq/kg and the lowest value radium concentration in LP samples was

found in Pencil HB Elite 161 0.158 Bq/kg. In addition to that, the average value of radium concentration in LP samples were 0.356 Bq/kg. While for PC samples, the highest radium concentrations was 0.401 Bq/kg found in Redamol by Royce Pharma Manufacturing Sdn. Bhd and the lowest radium concentrations was 0.122 Bq/kg found in Panadol 6 strip. The average value of radium concentration in LP samples was 0.262 Bq/kg. The concentration of radium in LP and PC samples are lower than those reported by [9] for a garden rocket, and are similar to the values typically found for cucumber, carrot, spinach, green beans, and green haricots.

The uranium concentrations are found to vary from 0.192–0.672 ppm with a mean value of 0.432 ppm for LP samples. While for PC samples the uranium concentrations are found to vary from 0.148–0.488 ppm with a mean value of 0.318 ppm. From Table 3, it has been observed that there are variations in the values of uranium and radium concentrations among both samples. This variation may be arisen due to the difference in the nature of the samples and nuclei content of these samples. The result of the uranium concentration of both samples is quite low compared with the allowed limit which is 11.7 ppm [11,12].

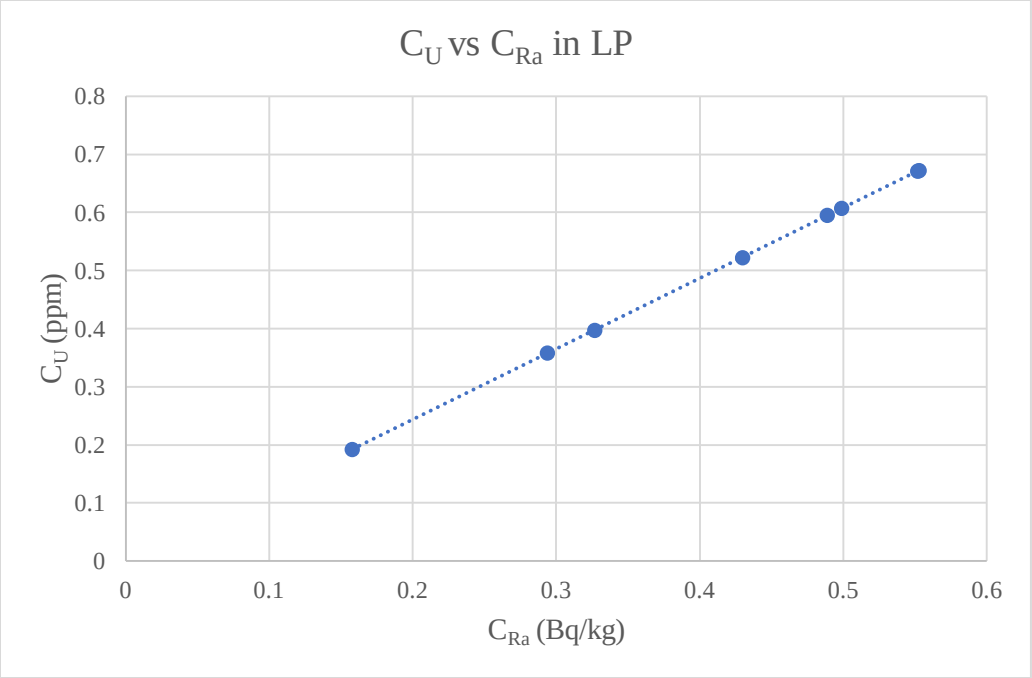
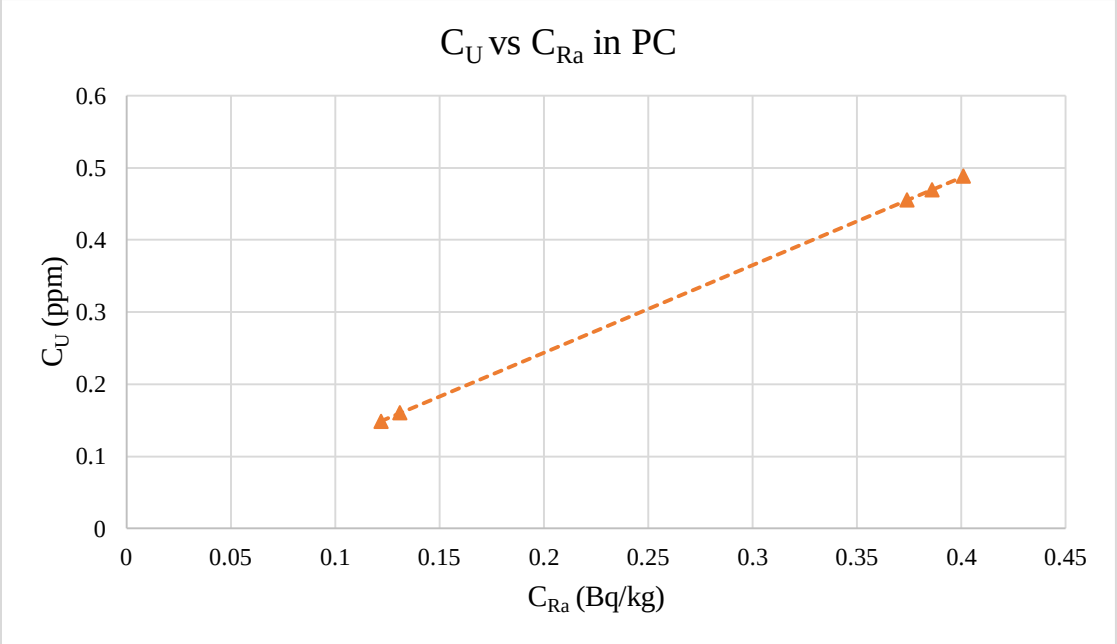
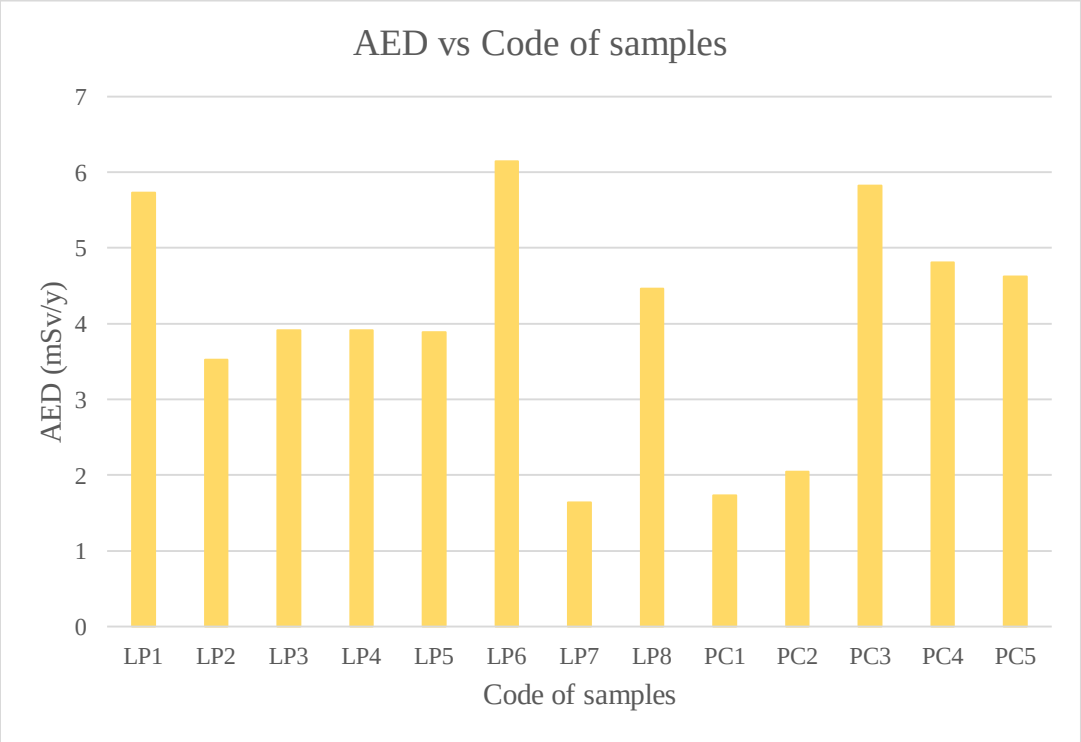


Figure (4): The correlation between radium and uranium concentrations in LP samples



Figure(5): The correlation between radium and uranium concentrations in PC samples

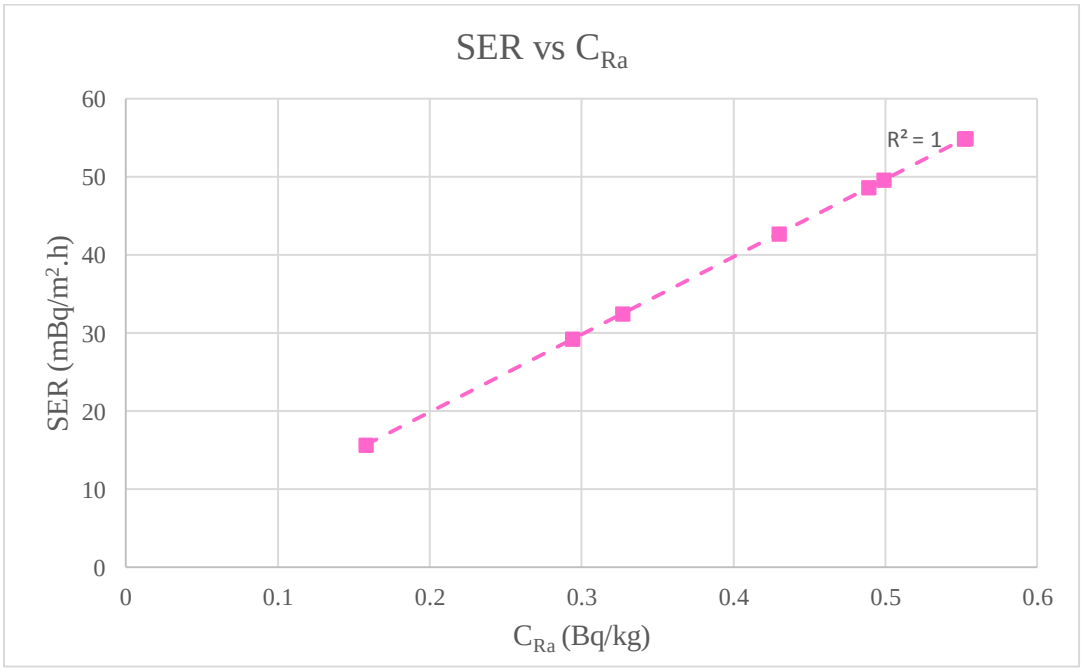
From Figure 6, the highest value of annual effective dose for LP samples is 6.148 mSv/y from (ASTAR Rainforest 2B Pencil P1700) and the lowest value of annual effective dose is 1.637 mSv/y (Pencil HB Elite 161). While for PC samples, the highest value of annual effective dose is 5.825 mSv/y (Panadol Cold And Flu Day) and the lowest value of annual effective dose is 1.730 mSv/y (Panadol 6 strip). Since the effective dose depends on the radon concentrations, the samples which recorded high concentrations also had high values of annual effective dose. These levels are all below the dose limit which is 10 mSv/y [6].



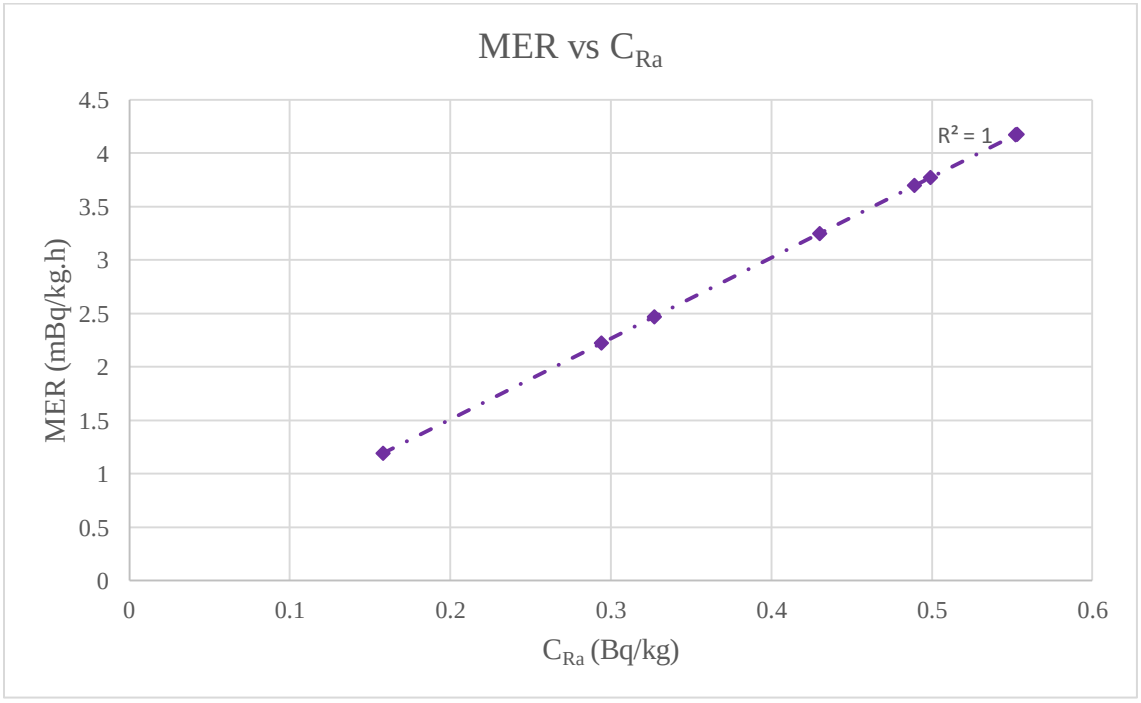
Figure(6): Bar chart showing annual effective dose in LP and PC samples

The surface exhalation rate values were in the range of 15.673–54.942 (mBq/m^2.h) and 12.147–39.887 (mBq/m^2.h) for LP and PC samples, respectively. While the mass exhalation rate was in the range of 1.192–4.177 (mBq/kg.h) and 0.924–3.032 (mBq/kg.h) for LP and PC samples, respectively. Figures 7 to 10 shows a direct relationship between radium activity and

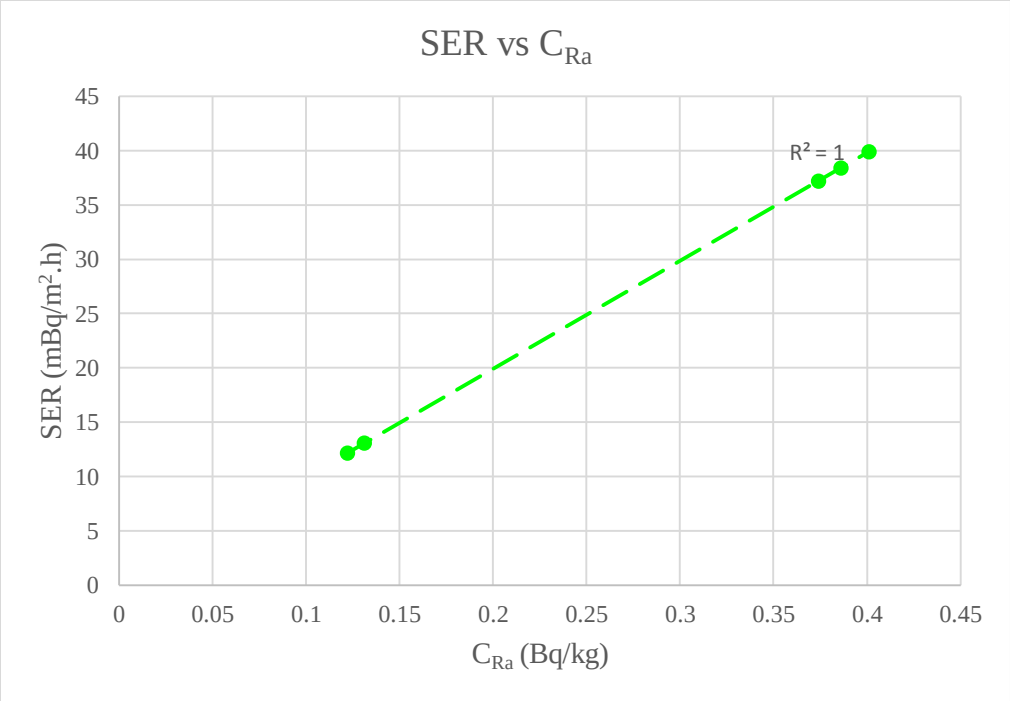
radon exhalation rate in LP and PC samples (R^2=1). Hence, there was a linear relationship between radium activity and radon exhalation rate.



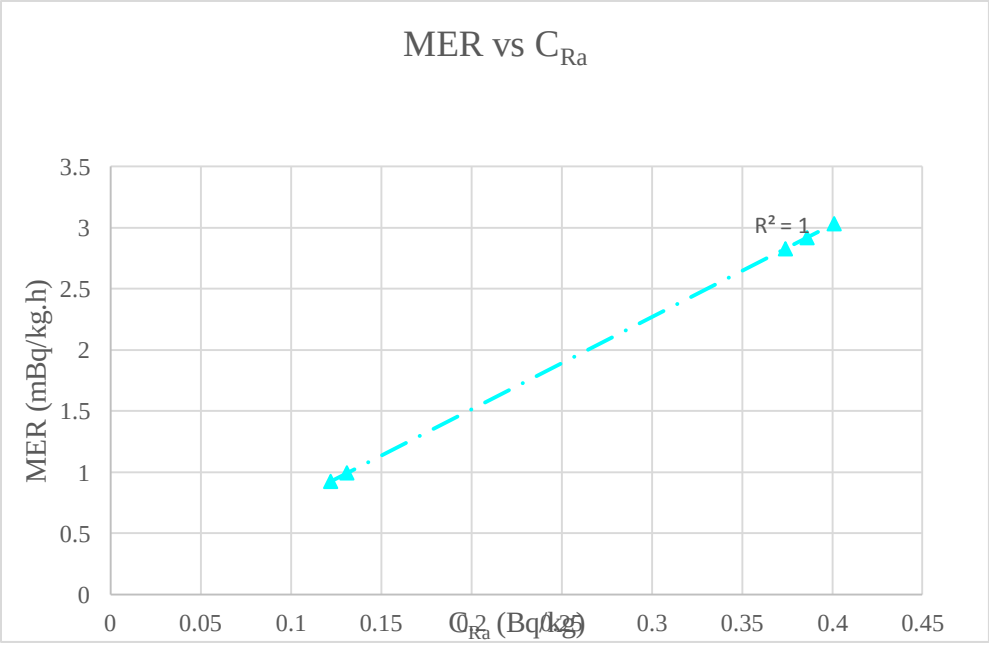
Figure(7): Correlation between radium concentration and surface exhalation rate for LP samples



Figure(8): Correlation between radium concentration and mass exhalation rate for LP samples



Figure(9): Correlation between radium concentration and surface exhalation rate for PC samples



Figure(10): Correlation between radium concentration and mass exhalation rate for PC samples

1. CONCLUSION

Radon concentration values including all samples in this study are within the limits of international which is 1000 Bq/m^3. The concentration a radium in LP and PC samples are lower than those reported by privious studeis. The result of the uranium concentration of both samples is quite low compared with the allowed limit which is 11.7 ppm . Annual effective dose levels are all below the dose limit which is 10 mSv/y. Lastly, there was a linear relationship between radium activity and radon exhalation rate. Therefore, using LP and eating PC cause no danger to humans. All results showed in this study are within internationally permissible limits, and therefore does not pose a threat to human health.

Acknowledgements

The authors appreciate the financial and technical support from School of Physics and RCMO (USM) via the research grant (304/PFIZIK/6315514).

List of Abbreviations

Bq	Becquerel
LP	Lead pencil
PC	Paracetamol
Rn	Radon
(SSNTD	Solid State Nuclear Track Detection

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[1] M. R. Akanda,. M. Sohail, , M. A. Aziz and Kawde, A. N.. Recent Advances in Nanomaterial-Modified Pencil Graphite Electrodes for Electroanalysis. *Electroanalysis*, *28*(3), (2016) 408–424. https://doi.org/10.1002/elan.201500374

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