Investigation of Annual Effective Dose of Radon in some Fertilizers and Cements

Khin Swe Oo[1], Myint Sein[2] and Thein Thein Win[3]

Abstract

Samples of fertilizer and cement have been analyzed for radon concentration for the measurements; alpha- sensitive CR-39 solid state nuclear track detectors (SSNTD) were used. In this research, to estimate the radon concentration in the fertilizer and cement samples, can technique was used. In the present investigation, the average annual effective doses due to radon from fertilizer samples range from 0.15±0.025147 $mSvyr^{-1}$ to 0.35 ±0.04361 $mSvyr^{-1}$ and the annual effective doses emanated from cement samples vary from 0.16 ± 0.0201 $mSvyr^{-1}$ to 0.97 ± 0.1094 $mSvyr^{-1}$ which are lower than 5 $mSvyr^{-1}$, the annual effective doses fixed for public (ICRP, 2007). It is seen from that the data, the low level of radon in samples typically do not occur health hazards to users as well as the people of that community.

Key words: Nuclear Physics

Introduction

Radium is a naturally occurring radioactive element present in trace amounts throughout the earth's crust. The decay of radium leads to radon in the environment (indoor and outdoor), soil, ground water, oil and gas deposits, which contributes the largest fraction of the natural radiation dose to populations. The interest in measurement of radium and radon concentration in water is due to associated health hazards and environmental pollution. There are three isotopes of radon-219Rn (actinon), 220Rn (thoron) and 222Rn (radon) and they belong to the decay chain of 235U, 232Th and 238U respectively. Radon (222Rn) is colourless, odourless and is an α-emitter that decays with a half-life of 3.82 days into a series of radon progeny.

Health hazard from radon is relatively smaller than what is expected from its progeny. Evidence on radon and lung cancer is now available from about 20 epidemiological studies of underground miners, including 11 studies that provided quantitative information on the exposure-response relationship between radon and lung cancer risk. The exposure of population to high concentrations of radon and its daughters for a long period lead to pathological effects like the respiratory functional changes and the occurrence of lung cancer.

Radon is a gas. It can move underground and can enter buildings through crack in foundations. Because radon is soluble in water, it can also enter ground water and be drawn into water-supply wells. Radon that enters homes in artisan well water can either be ingested directly in water used for drinking and food preparation, or released into the air at faucets and shower heads then inhaled.

The raw material used in production of some fertilizers is phosphate ore containing various amounts of natural radioactive elements. During phosphate ore processing, owing to chemical properties of Radium, practically all 226Ra gets incorporated into phosphogypsum and remains in disequilibrium status when compared to radioactivity levels contained in the raw material. Most of the phosphogypsum is considered waste and is stockpiled or discharged into the aquatic environment. Potential issues of concern resulting from phosphogpysum disposal are its environmental impact; possible increases in radio-nuclides in soils or in groundwater and consequential ingestion by humans through exposure routes such as drinking water and food chain.

Therefore, the measurements of radon concentration are needed for environmental purpose. The present work aims to find out the alpha track densities in fertilizer and cement samples. From the alpha track densities the radon concentrations and annual effective dose can be measured.

Radon

There are three isotopes of radon- 219 Rn (actinon), 220Rn (thoron) and 222Rn (radon) and they belong to the decay chain of 235U, 232Th and 238U respectively. 222Rn has the greatest emanation power among the three because it has the longest half life (3.82 days). This isotope is the main constituent of atmospheric radioactivity. Radioactive radon can migrate from soils and rocks and accumulates in surrounding enclosed areas such as homes and underground mines. It has been estimated that the radon, largely in homes constitutes, more than 50% of the dose equivalent received by general population from all sources of radiation, both naturally occurring and man-made.

On average, the constitution is as follows:

Rn 50%, Cosmic rays 8%, Terrestrial 8%, Internal 11%, medical X-ray and man-made 18%.

Radon (222Rn, 3.82 d) and thoron (220Rn, 55.6 s) are the messengers. Short-lived progeny (decay products) are the messages. Short-lived alpha-emitting heavy metals are:

238U $\longrightarrow$… 226Ra , 222Rn ,218 Po ,214 Pb ,214 Bi ,214Po

232Th $\longrightarrow$… 220Rn ,216 Po ,212Pb ,212 Bi ,212P

Experimental Procedure

Can Technique (For Fertilizer samples)

For the recording of the alpha tracks in SSNTD CR-39, the Can technique was used. Although there are many techniques to find out the alpha detection, the can technique is more convenient than other methods. In this technique, a known amount (60gm) of the fertilizer samples was placed in plastic cans. SSNTD CR-39 detectors about (1cm x 1cm) were fixed on the top of each can with tape such that, sensitive side of the detector faced the specimen. The can were tightly closed from the top and sealed. The geometrical parameters were plastic can with average diameter 7.18cm, height 6.7cm, volume 271.3cm3.The cups were left at room temperature for 50 days exposure time. During this time, α-particles from the decay of radon, thoron and their daughters bombard the CR-39 nuclear track detectors in the air volume of the cup.

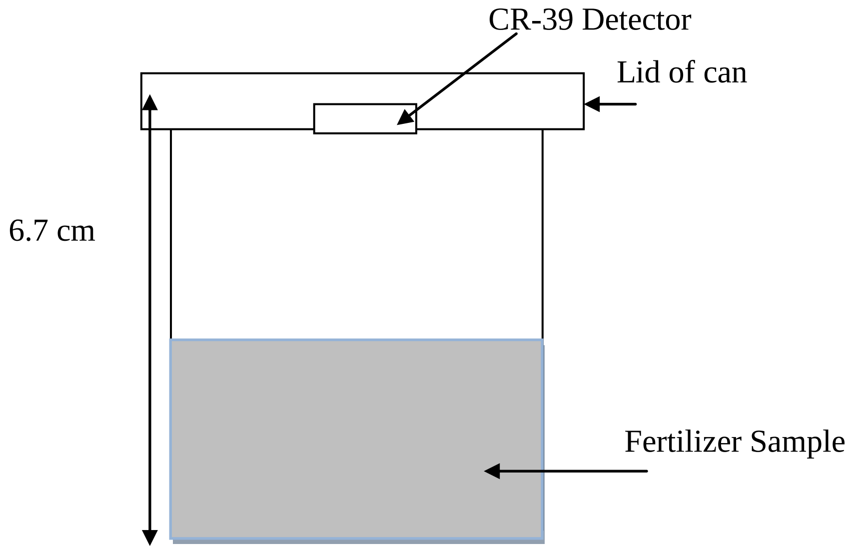
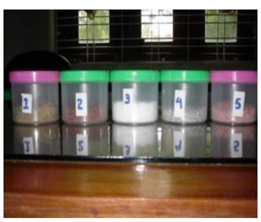


Figure 1. The schematic diagram of the Can Technique



Sample-1	The Sun Fertilizer
Sample-2	The Elephant Fertilizer
Sample-3	The Peal Fertilizer
Sample-4	Three Circles Fertilizer
Sample-5	Arrmo Fertilizer]

Figure 2. Five Fertilizer Samples

Can Technique(for cement)

To find out the radon concentration Solid State Nuclear Track Detectors (SSNTD) CR39 were used. SSNTDs are based on the created in a solid along the path of heavily ionizing particles such alpha particles and other ions. A known amount (0.08kg) of the cement samples and these samples were placed in a plastic can. SSNTD CR39 plastic detectors (1cm×1cm) were fixed on the top of the lid of each can with tape such that, sensitive side of the detector faced the specimen. The cans were tightly closed from the top and sealed.

The exposure times were 100days. At the end of the exposure time, detector was removed and etched in 6N NaOH solution at 70°C temperature for 6 hr 30mins. After it was etched, the detector was washed and dried and tracks produced by alpha particle were observed and counted under an optical microscope (400X).

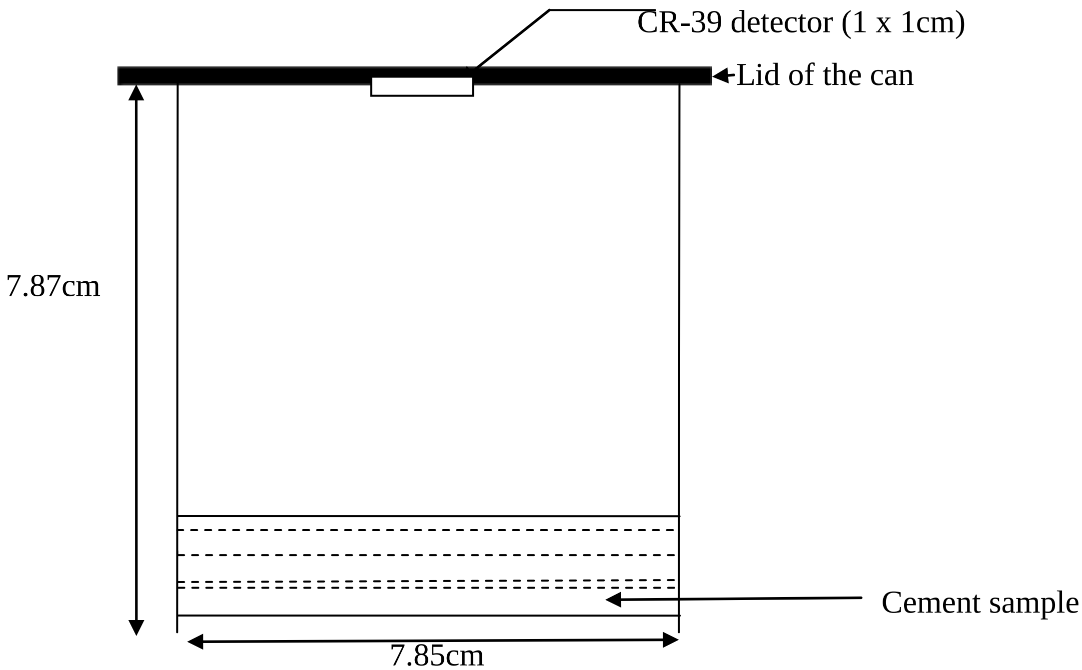


Figure 3. The schematic diagram of the Can Technique

Sample-1 Diamond Cement

Sample-2 Myanmar Elephant Cement

Sample-3 Lion Cement

Figure 4. Three Cement Samples

Photomicrograph of Alpha Tracks in CR-39 for Fertilizer

Photo1

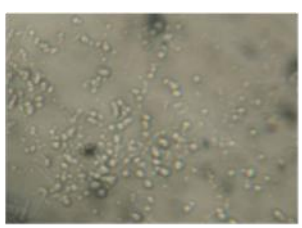


Photo2

Photo3

Photo1 - Photomicrograph of Alpha Tracks in CR-39 for Background

Photo2 - Photomicrograph of Alpha Tracks in CR-39 for sample(1) The Sun Seal Fertilizer

Photo3 - Photomicrograph of Alpha Tracks in CR-39 for sample(2) The Elephant Seal Fertilizer

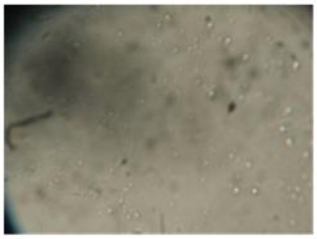


Photo4

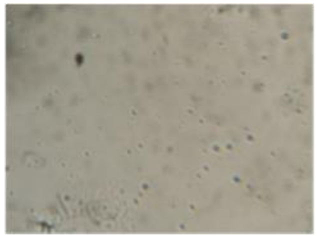


Photo5

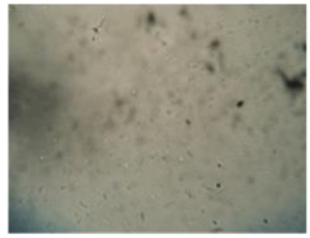


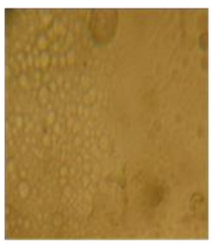
Photo6

Photo4 - Photomicrograph of Alpha Tracks in CR-39 for sample(4) The Peal Seal Fertilizer

Photo5 - Photomicrograph of Alpha Tracks in CR-39 for sample(5) The Circles Seal Fertilizer

Photo6 - Photomicrograph of Alpha Tracks in CR-39 for sample(6) The Arrmo Seal Fertilizer

Photo(1)



Photo(2)

Photo(3)

Photo(4)

Photo(1) Photomicrograph of Alpha Tracks in CR-39 for Background

Photo(2) Photomicrograph of Alpha Tracks in CR-39 for sample (1)

Photo(3) Photomicrograph of Alpha Tracks in CR-39 for sample (2)

Photo(4) Photomicrograph of Alpha Tracks in CR-39 for sample (3)

Determination of Radon concentration

. 222Rn concentration (C) is $C = \rho / K\eta t$

ρ = track density

K= attenuation factor of 222Rn

η = calibration coefficient ($cm^2 d^{-1} Bqm^{-3}$)

t = exposure time

The equations used for exhalation rates are:

$E_x = \frac{CV\lambda/M}{T + 1/\lambda e^{-\lambda T} - 1}$ ($Bq.kg^{-1}.\ h^{-1}$) for mass exhalation rate

$Ex = \frac{CV\lambda/A}{T+1/\lambda e^{-\lambda T} - 1}$ ($Bq.m^{-2}. h^{-1}$) for surface exhalation rate

where C = Integrated radon exposure ($Bqm^{-3}h$),

V = Volume of air above the samples in can (m^3)

T = Time of exposure (h)

λ = Decay constant for radon (h^{-1})

A = Area converted by the can or surface area of the sample (m^2)

Table 1. The Alpha track density, Radon Concentration and Annual Effective Dose of five fertilizer samples.

Sr. No	Sample Name	Alpha Track Density ($trackcm^{-2}day^{-1}$)	Radon Concentration (Bqm^{-3})	Annual Effective Dose($mSvY^{-1}$)
1	The Sun Fertilizer	0.99 ±0.189847	15 ±2.920728	0.26 ±0.050237
2	The Elephant Fertilizer	0.58 ±0.095032	9 ±1.462026	0.15 ±0.025147
3	The Peal Fertilizer	1.32 ±0.164807	20 ±2.535486	0.35 ±0.04361
4	Three Circles Fertilizer	1.17 ±0.14127	18 ±2.173387	0.31 ±0.037382
5	Arrmo Fertilizer	1.03 ±0.148053	16 ±2.277741	0.27 ±0.039177

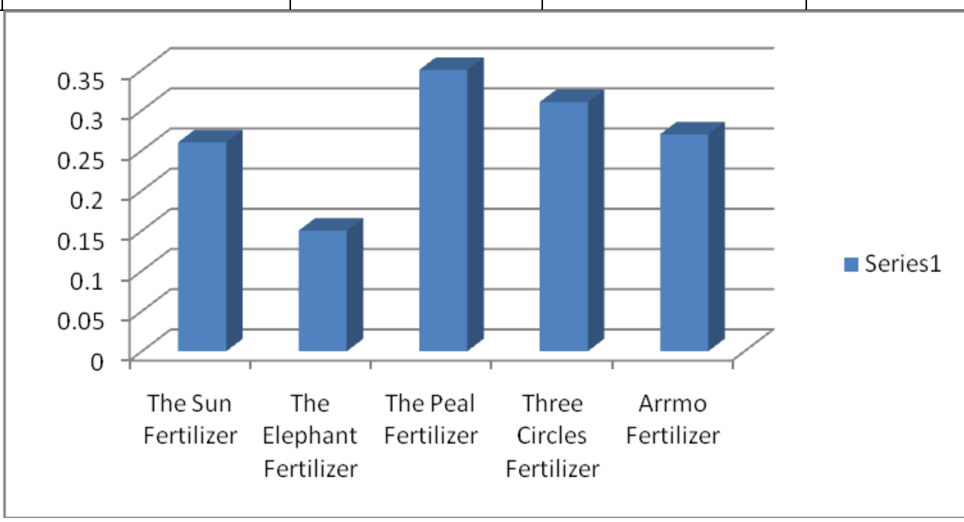


Figure 5. The comparison graph of Annual Effective Dose of the fertilizer samples

Table 2. Mass Exhalation Rate and Surface Exhalation Rate of Five Fertilizer samples

Sr. No	Sample Name	Mass Exhalation Rate ($mBqkg^{-1}hr^{-1}$)	Surface Exhalation Rate ($mBqm^{-2}hr^{-1}$)
1	The Sun Fertilizer	0.4188±0.0816	6.207±1.2085

2	The Elephant Fertilizer	0.262±0.042583	3.903±0.631
3	The Peal Fertilizer	0.5041±0.0639	7.47±0.947
4	The Three Circles Fertilizer	0.5352±0.06463	7.93±0.9577
5	Arrmo Fertilizer	0.4495±0.06399	6.661±0.9482

Table 3. The Alpha Track Density, Radon Concentration and Annual Effective Dose of three cement samples

Sr. No	Sample Name	Mass exhalation rate(mBq/kghr)	Surface exhalation rate(mBq/m^2hr)
1	Diamond Cement	1.51 ± 0.17	1.51 ± 0.17
2	Myanmar Elephant Cement	0.26 ± 0.03	0.26 ± 0.03
3	Lion Cement	0.28 ± 0.04	0.28 ± 0.04

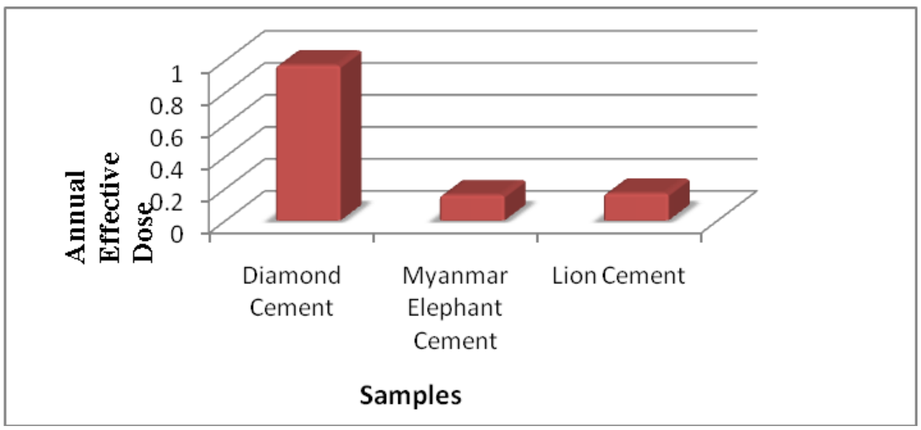


Figure 6. The comparison graph of Annual Effective Dose of the cement samples

Table 4. Mass Exhalation Rate and surface exhalation of three cement samples

Sr. No	Sample Name	Mass exhalation rate(mBq/kghr)	Surface exhalation rate(mBq/m^2hr)
1	Diamond Cement	1.51 ± 0.17	1.51 ± 0.17
2	Myanmar Elephant Cement	0.26 ± 0.03	0.26 ± 0.03
3	Lion Cement	0.28 ± 0.04	0.28 ± 0.04

Discussion and Conclusion

In the present study, the possible radon concentration due to the five fertilizer samples has been measured. Although the sample (3) The Peal fertilizer has the highest radon concentration compared with the other fertilizer samples, the annual effective dose in that sample (3) the Peal fertilizer is much lower than ICRP limited level. The value of annual effective dose recommended by International Commission of Radiological Protection Publication (ICRP) is 5mSv/yr. The low level of radon in five kinds of fertilizer samples typically does not cause health hazards to users. The tested radon level, mass exhalation rates and surface exhalation rates are low in fertilizer samples. The annual effective dose in the fertilizer is much lower than ICRP limited level.

According to international recommendations, the average exposure doses due to radon in cement vary from 0.16 ± 0.0201 mSv yr^{-1} to 0.97 ± 0.1094 mSv yr^{-1} which are lower than 5 mSv yr^{-1}, the annual effective dose also lies under in ICRP recommendation.

(ICRP – International Commission on Radiological Protection Publication)

Acknowledgements

We would like to express respectful gratitude to Dr. Aye Aye Myint (Rector, Yangon University of Education), and Dr. Pyone Pyone Aung (Pro-Rector, Yangon University of Education), who allowed us to write this paper.

References

G.Marovic and J.Sencar, ***226Ra and possible water contamination due to phosphate fertilizer production.*** J.Radioanal. Nucl. Chem., Letters., 200, 9-18, 1995.http://www.lenntech.com. http://www. vh.org.

International Atomic Energy Agency, ***Measurements of radio nuclides in food and the environment***, Vienna, IAEA; Technical Reports Series 295, 1989.

N.Ahmad, A.H.Matiulhah, A.J.Khatibeeh, ***Comparative studies of radon concentration levels in Jordan using CR-39 based bag and cup dosimeters***, Health Phys 75, 60-62, 1998.

S.Kumar, S.Cander, G.S.Yaday, A.P.Shama, ***Some environmental effect studies on the response of CR-39 plastic track detector***, Nuclear Tracks 12, 129-132, 1986.

T.P.Laich, ***A radiological evalution of phosphogysum***. Health Phys., 60-691-693, 1991.

United Nations Scientific Committee on the Effects of Atomic Radiation.

UNSCAR 2000 report to the general assembly, with scientific annexes.

Sources and effects of ionizing radiation. United Nations, New York, 2000.