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Research Article

Case Study of Air Kerma Standardization Comparison for Cs-137 For Radiation Protection Level

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ABSTRACT

In this work, ^{137}Cs radioactive source was measured at the Gamma irradiation lab, Radiation Safety & Health Division, Malaysian Nuclear Agency. The experiment was developed to ensure the standard of the calibration annual processes. Different thicknesses of lead sheets were used for beam attenuation to measure the ^{137}Cs dose range. Five sets of charges per minute were measured using an ionization chamber at a 1.0 m source-detector distance (SDDs). The temperature pressure correction factor, K_{TP} was calculated from the average pressure and temperature of each set. The beam charge of the unattenuated and the lead attenuated beam was measured. The air kerma, K of each set, has been calculated and compared with the 2016 data set. The deviation of the measured doses was calculated and is within below 2%. The close agreement of the year 2016 and 2023 results ensures the uniformity of the measurements has been complied with.

Keywords: Air Kerma, Cesium 137, Chamber, Gamma Rays, Radiation Protection

1. INTRODUCTION

Radiation is involved in various health-related occupations and industries all over the world. Recently, there were concerns about radiation exposure among healthcare workers regarding their genetic damage, where the results read a positive correlation between radiation exposure and genomic anomalies (Allam et al., 2024; Cobanoglu & Cayir, 2024). Before the 1950s, it was reported that the workers who were exposed to low-dose ionizing radiation (IR) were involved with an increased risk of many types of cancers (Sari-Minodier et al., 2007; Adliene et al., 2020). Hence, it is crucial to identify the radiation doses from the related devices by calibrating them periodically. The Malaysian Nuclear Agency (ANM) is a government agency under MOSTI, an organization of research and development focusing on nuclear

science and technology in Malaysia. The Radiation Safety & Health Division, the Malaysian Nuclear Agency is the department that takes responsibility for measuring the standard dose of radiation samples and servicing them for calibration purposes. Based on the rules and circulars set by the Atomic Energy Licensing Board (AELB), the related agencies such as companies or hospitals are required to calibrate their instruments annually to determine their accuracies. The radiation detection equipments for industrial or company devices such as survey meters and area dosimeters, medical radiation therapy devices, and industrial gauges, must be regularly checked to ensure that they remain in proper working order.

In this work, Cesium-137 (^{137}Cs) is being used as the source. The main objective is to ensure that the value of air kerma and the absorbed dose of ^{137}Cs comply with the standards. The ^{137}Cs Gamma ray source charges per minute were measured with different lead sheets using an ionization chamber with a distance of 1.0 meters. From the data obtained, we calculate the temperature pressure correction factor, K_{TP} and Air Kerma, K value of ^{137}Cs source. Finally, these data sets of air kerma, K values, and deviation were compared to the previous data sets in the experiment done in 2016 in the same lab using the same instruments. The comparison of these two sets of data (years 2016 and 2023) ensures the accuracy of the dose determined to secure the calibration capabilities of the ionization chamber calibrations for radiation protection. In the meantime, this may identify potential issues and ensure adherence to The International Atomic Energy Agency (IAEA) standards.

2. MATERIALS AND METHODS

The work has taken place at SSDL Calibration laboratory irradiation lab no. 191010, Radiation Safety & Health Division (BKS), Malaysian Nuclear Agency, which uses gamma emission as the source. The radioactive that has been used in this experiment is ^{137}Cs, which decay via beta and gamma emission (Alexander, 2016). ^{137}Cs are commonly used in medical and nuclear reactors. Table 1 shows the details of ^{137}Cs.

Table 1. Radioisotope details of ^{137}Cs (Allam et al., 2024)

Half-life	30.17 years or 11019 days
Mode of radiation decay	Beta and Gamma
Produce by	Nuclear fission
Advantages	Small/ controlled amounts are used for calibrations in industries
Disadvantages	Extensive amount exposure causes burns, risk for cancer, death

Figure 1 illustrates the technical setup of the outer part of the Gamma irradiation lab, which consists of a control panel OB 85 and electrometer PTW-UNIDOS 10001 which display the values detected, respectively. At the control panel OB 85 display, there are two radioactive sources, ^{60}Co and ^{137}Cs, which indicates there are two primary radioactive sources used in this lab. The setting began by choosing the radioactive source at the OB 85 control panel. Next is the setup of the PTW-UNIDOS, which is the operation procedure for reset and interval, as in this case every 60 seconds repetitively for 10 sets. The instruments are required to be set up for 2 hours before the experiment begins.

Figure 2 shows the inner lab setup of the Gamma irradiation lab, consisting of (a) ionization chambers, (b) Gamma Irradiator OB 85, (c) collimator and (d) and (e) filters. The length between the source in the Gamma Irradiator OB 85 and the ionization chamber is set up at a specific distance of 1.0 m. A vented spherical ionization chamber (PTW M32002 sn: 096) of nominal volume 1000 cm^3 was used as a reference standard for ^{137}Cs sources. The reference point of the ionization chamber was marked at the cavity volume centre. At the same time, it was positioned perpendicular to the beam with the distance from the source to chamber of 1.0

m. The filters are both made of lead and the thickness of OB 85-10-02 and OB-10-03 filters are 2.42 cm and 2.00 cm, respectively.

Figure 1. Outer setup at Gamma irradiation lab, Radiation Safety & Health Division (BKS), Malaysian Nuclear Agency

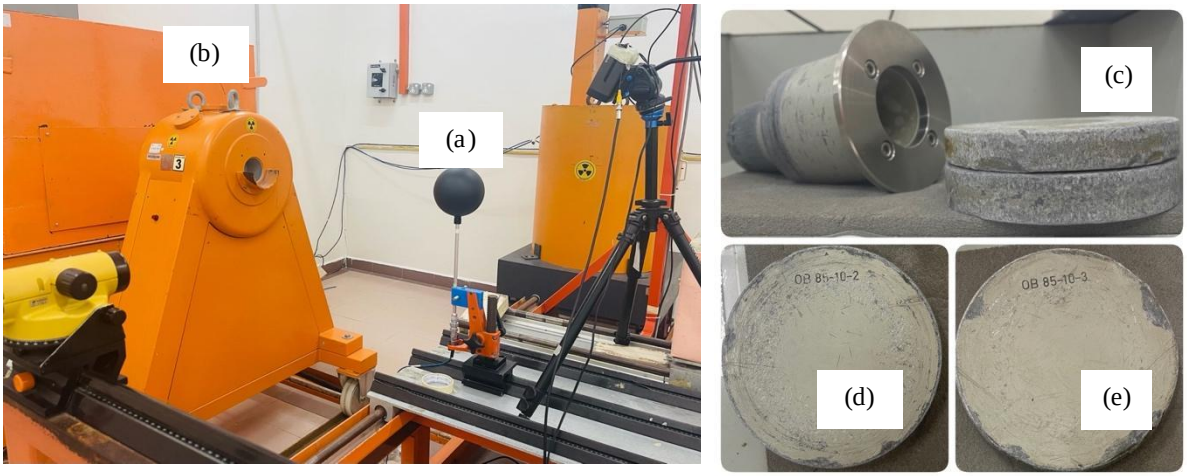

Figure 2. Inner setup at Gamma irradiation lab, where; (a) ionization chambers, (b) gamma irradiation ray, (c) collimator, (d) Filter OB 85-10-02 and (e) Filter OB 85-10-03

Several technical adjustments must be made before the experiment begins. Temperatures, humidity (%) and air pressure (mbarr) must be collected each time of the interval for the environmental effect correction (Safety Report Series 16, 2000). In this work, five (5) sets of charges per minute (nC/min) data have been recorded, with every set has different parameters. These collected data were then analyzed and labelled as Set A. Another previous set of the same experiments was made on 30th June 2016 and was labeled as Set B as in Table 2, using the same radioactive source in the same lab. The days between Set A and Set B (Δt) were computed to be 2694 days or 7.3 years.

Table 2. Details of sets A and B

Set	Experiment Dates	Exp.	Collimator	Filter OB 85-10-02 2.42 cm	Filter OB 85-10-03 2.00 cm
A	14th November 2023	1	-	-	-
		2	/	-	-
		3	/	/	-
		4	/	/	/
		5	/	-	/
B	30th June 2016	1	-	-	-
		2	/	-	-
		3	/	/	-
		4	/	/	/
		5	/	-	/

In each experiment, the collimator and filters were installed accordingly as in Table 2 and Figure 3 which indicates the details of each set A and set B, where both sets consist of 5 experiments. In experiment 1 (Exp. 1), no collimator and filters were installed at the Gamma Irradiator OB 85. In experiment 2 (Exp. 2), only a collimator was installed at the Gamma Irradiator OB 85. For Exp. 3, collimator and filter OB 85-10-02 was set up. The subsequent experiments, Exp. 4 consist of collimator and both filters. Lastly, for Exp. 5, collimator and OB 85-10-03 filter was installed at the Gamma Irradiator OB 85. For every experiment, for example, Exp. 1 includes 10 data values (average) of 60 sec intervals.

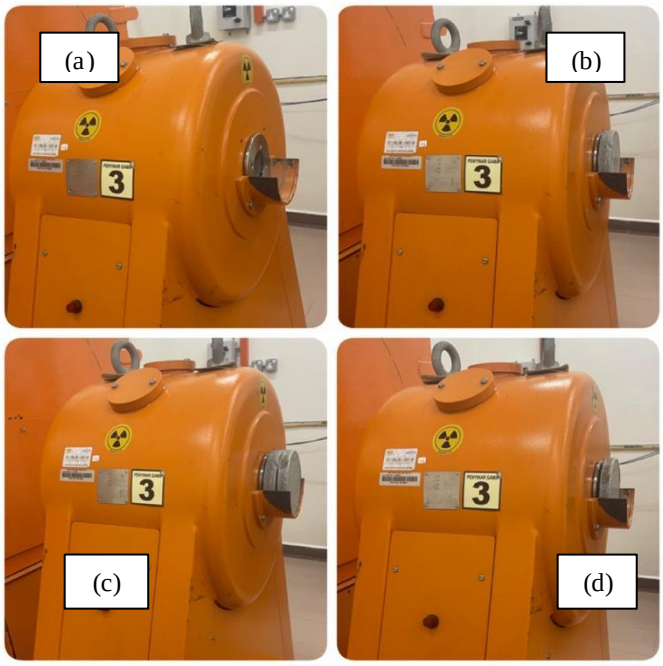

Figure 3. The measurement of five Exp. data excluding Exp. 1 (not in the diagram). (a) Exp. 2: only collimator, (b) Exp. 3: collimator and filter OB 85-10-02, (c) Exp. 4: collimator and both filters and (d) Exp. 5: collimator and filter OB 85-10-03

3. RESULTS AND DISCUSSION

The two sets of data Set A and Set B were analysed and compared. The correction factor for temperature, T and pressure, P (K_{Tp}) were determined using eq. 1 as below.

Correction factor, K_{TP}

$$K_{TP} = \frac{P_0}{\underline{P}} \times \frac{(273.15 + T)}{273.15 + T_0} \quad (1)$$

where T is the temperature in measuring volume in ºC, and P is the air pressure at measuring point in hPa. The reference environmental conditions where T_0 is the reference temperature 20ºC or 22ºC and P_0 is the reference air pressure 1013.25 hPa (mbar). Data of average temperature, average humidity, average pressure were then computed using eq. 1 to obtain the K_{TP}. Table 3 displays the data comparison of Set A and Set B. The two sets show subtle differences as the data obtained depends on the condition of that specific day (weather).

Table 3. Data obtained on Set A and Set B for experimental conditions during calibration measurements: average temperature, average pressure and K_{TP}

Exp.	Average Temperature (°C)		Pressure (mBar)		Correction factor, K_{TP}		Average Charge per minute, $\underline{B}$(nC/min)	
	Set A	Set B	Set A	Set B	Set A	Set B	Set A	Set B
1	22.4	21.8	1002	1002	1.0198	1.01698	24.32	29.28
2	21.1	21.2	1001	999	1.0158	1.01811	23.08	27.62
3	21.1	21.2	1001	999	1.0159	1.01826	1.695	3.273
4	21.1	21.1	1001	999	1.0158	1.01824	0.226	2.034
5	21.1	21.1	1001	999	1.0158	1.01827	2.689	2.632

The air kerma rate, *K* was performed where the temperature and pressure were corrected.

$$K = \underline{B} \times K_{TP} \times N_K \quad (2)$$

$$K = K_o e^{-\frac{ln2\Delta t}{t^{1/2}}} \quad (3)$$

where $\underline{B}$ is the average charge per minute in nC/min, and N_k is the chamber value for ^{137}Cs gamma ray referring to the IAEA Calibration certificate no. MLY/2023/5. The number of days between the two dates, Δt (days) was calculated 2694 days.

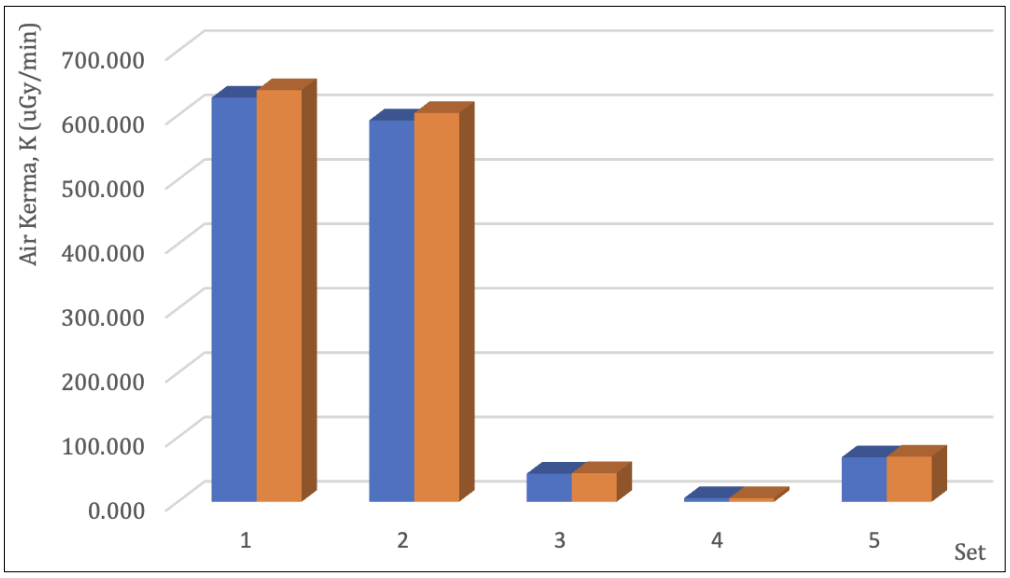

Figure 4. The comparison of five data sets

Table 4 shows two air kerma rates measured on 14 Nov 2023 and 30 June 2016. The air kerma rate dated 30 June 2016 was recalculated using formula (3) to take into account the decay factor of radioactive materials. The air kerma value obtained from formula (3) was compared with the air kerma value on 14 Nov 2023. The comparison results found that all experiments conducted on 14 Nov 2023 were within the percentage deviation range of 0.87% to 1.90%. The percentage deviation value was found to meet the reproducibility requirements for ionization chambers, which is within the range of ±2% [7]. Figure 4 shows a comparison of the air kerma rates for both dates in the form of a bar chart.

Table 4. Comparison of Air Kerma Data, *K* obtained of Set A & Set B

Exp.	Detail		Set A 14th Nov 2023	Set B 30th June 2016	Deviation (%)
			Air Kerma (uGy/min)	Air Kerma (uGy/min)	
1	Collimator	-	627.392	639.165	1.84
	Filter OB 85-10-02	-			
	Filter OB 85-10-03	-			
2	Collimator	/	592.072	603.543	1.90
	Filter OB 85-10-02	-			
	Filter OB 85-10-03	-			
3	Collimator	/	43.569	44.443	1.97
	Filter OB 85-10-02	/			
	Filter OB 85-10-03	-			
4	Collimator	/	5.802	5.752	0.87
	Filter OB 85-10-02	/			
	Filter OB 85-10-03	/			
5	Collimator	/	69.122	70.264	1.63
	Filter OB 85-10-02	-			
	Filter OB 85-10-03	/			

4. CONCLUSION

A vented spherical graphite ionization chamber of nominal volume 1000 cm^3 was used as a reference standard for ^{137}Cs sources. This work has successfully computed the ^{137}Cs Gamma ray source charge per minute with different lead sheets and calculated the temperature pressure correction factor, K_{TP} and Air Kerma, K value of ^{137}Cs source. Comparison of the air kerma, K values and the deviation of the 2 sets of data have been compared and are within below 2%. The air kerma, K of this ionization chamber for ^{137}Cs source was determined by analytical calculations and by using a reference ^{137}Cs source. The K values of this chamber were determined to be in excellent agreement. Thus, it is anticipated that the findings of this study will be referred in the next standard calibration in the future.

Conflict of Interest
The authors declare that there is no conflict of interest.

Author Contribution Statement
Faridah Lisa Supian: Conceptualization, Investigation, Methodology, Writing Original Draft. Mohd Taufik Dolah: Writing-Review & Editing. Mohd Syahriman Mohd Azmi: Resources & Supervision. Chee Fah Wong: Writing-Reviewing and Editing. Abdullah Faisal Al Naim: Writing-Reviewing and Editing.

Data Availability Statement
The authors confirm that the data supporting the findings of this study are available within the article.

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