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Stability of Calibration Factors of Survey Meters: A Five-Year Comparative Study

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ABSTRACT

Introduction: Analysis of historical calibration data can reveal a lot about survey meters. The study aims to analyse a five-year historical calibration data of selected survey meters for the stability of indication or otherwise.

Material and Methods: A 1000-cc Physikalisch-Technische-Werkstaetten (PTW) spherical ionisation chamber coupled to a PTW UNIDOS Electrometer was used as the reference dosimeter to determine ambient dose equivalent in a ^{137}Cs radiation beam. Ten survey meters were calibrated every year by the substitution method for five continuous years. The yearly calibration results were analysed. These survey meters are used in border and port control, extractive mining industry, non-destructive testing industry, and health care delivery.

Results: Analysis revealed that there are deviations in the calibration factors (CFs) from their initial year 2019 values for all devices. The percentage deviations in the CFs in the year 2020 and beyond from year 2019 values ranged from -34% to 24%. Averagely, each device overestimated its indication of ambient dose equivalent by 0.075 ± 0.009 mSv/h within the five years and underestimated the ambient dose equivalent by an average of 0.163 ± 0.019 mSv/h.

Conclusion: The stability of calibration factors of the survey meters degraded with time and usage. Survey meters that are out of calibration produce inaccurate measurements. To help detect the instability early, it is suggested that users of survey meters resort to counting statistics on their measured data at regular intervals.

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Introduction

Measurements generate important data that is relied upon to make decisions and to formulate policies. Measurements that are made with radiation survey meters have the aim to determine the status of an area regarding the radiation dose that a person within that area is likely to receive [1-4]. To ensure the safety and security of practices employing nuclear materials and radiation sources, measured data must be accurate. To obtain a high degree of data reliability, calibration of radiation protection measurement equipment plays a vital role. Calibration certificates give the assurance that an instrument is functioning properly, and suitable for its intended purpose [5, 6]. Calibration provides the needed traceability route to the international system of measurement through a secondary standard. Another way to achieve the traceability of a secondary or reference standard to a primary standard is to participate in interlaboratory intercomparison programs with other international laboratories [7, 8]. According to the International Atomic Energy Agency (IAEA) Safety Report [5] which provides guidance on the establishment and operation of calibration facilities for radiation monitoring instruments, licensees are encouraged to calibrate their equipment regularly (yearly, quarterly, etc) and retain their certificates of calibration for a period determined by national regulatory authorities. The need to calibrate a survey meter can also arise out of the internal requirements of a practice's quality management system. It is a good practice to record the reason for any calibration. Calibration is always performed according to a specified documented calibration procedure and measurement conditions.

Radiation detecting and measuring equipment can be calibrated in radiation fields that have well characterized fields. The limitation of these radiation

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fields is that a large amount of scattered radiation will result in the unreliability of the specified radiation field. Therefore, most secondary standard dosimetry laboratories (SSDL) use the substitution method [5]. This method involves obtaining the air kerma rate of a radiation beam of a chosen quality. The air kerma rate is established with the SSDL reference standard. This standard is calibrated at a primary standard dosimetry laboratory (PSDL) at the same beam quality. The device meant for calibration is then positioned at the same point in the beam as the SSDL reference standard. The calibration factor or coefficient of the instrument is calculated as the ratio of the indication of the SSDL reference standard to the mean indication of the instrument. To most users of field equipment, the essence of keeping calibration results for an extended period is to satisfy regulatory requirements. However, there are many more benefits to derive from keeping calibration records and subsequently reviewing them. One advantage of keeping calibration records over a defined period is that the users can examine the performance of their devices over time and determine when to discontinue the usage of devices based on the instability of the calibration factors. At what point to discard a survey meter is always a difficult decision to make once it continues to produce readouts. Examining the performance of calibration factors over a period for stability can help make that decision less difficult

The continuous stability of the calibration coefficient or factor is not guaranteed after calibration ends. It is only valid at the time of calibration. There are some research works that have examined calibration factors of survey meters over time. Chida et al [9] examined 24 survey meters and 28 pocket dosemeters for stability and found various degrees of instability. They recommended frequent checks and recalibration to sustain the performance of the survey meters and pocket dosemeters. However, they did not state the exact checks that will ensure the continuous stability of the devices examined. In Akerele et al's [10] work, they retrospectively assessed survey meters' calibration durability, behaviour, and fault trends. The research covered 160 survey meters of 10 different models. The study report both variability and reliability in the devices' calibration factors. In conclusion, the study reports that when survey meters are calibrated regularly, handled properly, and users trained, the accuracy of the instruments will be maintained and the radiation detector last longer. The study did not suggest how stability can be checked in between consecutive calibration due dates.

Calibration laboratory is a unique place to collect data on various models of radiation survey meters that are used in various industries and give advice and recommendations on the selection of the survey meters for various tasks [11]. Ionization chambers, geiger-müller (GM) counters, and scintillation counters are the common types that are used for personal and environmental radiation monitoring [12]. Understanding the performance and reliability of radiation survey meters are vital for radiation safety, emergency response, and regulatory compliance [10]. Stability studies will result in adequate data on the faulty trends and calibration behaviour of radiation detectors over a period. In this work, the researchers calibrated ten survey meters every yearly between 2019 and 2023 at a ^{137}Cs radiation quality. The calibrations were done by the substitution method [5]. The calibration records were reviewed and analysed in 2024. The focus of the analyses is to evaluate the status of the equipment, in terms of the stability of the calibration factors, over the five-year period, and point out the need to have a backup method of evaluating the stability of the indication of survey meters in between calibration due dates.

Materials and Methods

The following materials were used in this study; a ^{137}Cs irradiator, a 1000-cc PTW spherical ionisation chamber with a PTW UNIDOS electrometer as the secondary standard or reference dosimeter, two calibration benches, digital barometer, laser alignment systems, thermometers, a close circuit television (CCTV) camera, and ten survey meters. The survey meters are used in border and port control, extractive mining industry, non-destructive testing industry, and health care delivery. The secondary standard was calibrated by a primary standard laboratory, Physikalisch-Technische Bundesanstalt (PTB), in Germany. The secondary standard can also be traced to the IAEA Dosimetry Laboratory in Austria through interlaboratory comparison exercises [2, 4]. The ionization chamber chosen for this study is gas-filled. The calibration dosimetry reported in this work was done in terms of air kerma (free in air (N_K)) as well as ambient dose equivalent, $H^*(10)$ and was recommended by published reports [13 - 16].

Pre calibration checks

Functional tests were conducted on the survey meters as a prerequisite to the calibration. The instruments' response to radiation was checked using calibrated standard reference sources. The survey meters were exposed to high dose rates at very short source-to-detector distances (SDD) until the survey meters indicated that the dose rates were beyond their ranges. The irradiator system is equally taken through pre-calibration checks. A series of ten counts of background radiations were recorded at each SDD for both the secondary standard and the equipment to be calibrated. The ionization chamber's background radiation readings were recorded as leakage current.

Calibration process

The device under test was positioned at an SDD of 1 m along the axis of the calibration beam with the help of the laser alignment system. The mark on the device's surface indicating the entrance to the sensitive volume was placed such that it is in a plane perpendicular to the central axis of the calibration beam. This was done to reduce bias due to non-uniformity and directional dependence of the calibration beam distribution across and though the device's sensitive volume. The device under test was left in this position in the calibration bunker for 30 minutes to attain equilibrium with the ambient temperature, humidity, and pressure. These environmental conditions were monitored and recorded throughout the calibration process. The device was pre-irradiated for 15 minutes to condition it for calibration. Background radiation levels were read off the device using the CCTV camera focused onto the device screen. The device was irradiated, and a series of ten readouts were recorded at a regular interval of 10 seconds. The procedure was repeated at SDD of 1.5 m, 2.0 m, 2.5 m, 3.0 m, 3.5 m, 4.0 m, 4.5 m, and 5.0 m. The ambient temperature, pressure, and humidity were recorded at an interval of 60 seconds.

The reference dose rates were determined from air kerma rates according to methods published in [2]. In this study, the ionization chamber's reference point, where the calibration factors or coefficients apply, is taken to be in chamber's collecting volume geometrical centre as defined by its external walls. The calibrations were done by the substitution method. The calibration factor, CF, was determine using Equation 1 [5]

$$CF = \frac{H^*(10)}{M_I} \quad (1)$$

where M_I is the average of the corrected survey meter indications normalised to standard environmental conditions and $H^*(10)$ is the ambient dose equivalent of the survey meter at the time of calibration.

Propagation of uncertainty

The uncertainties associated with each measurement is a combination of several factors. These factors include errors in the secondary standard and its placement in the irradiator beam, the stability of the secondary standard used, the random nature of the radioactive phenomenon, and the randomness with which the incident radiation produces ion pairs within the sensitive volume of the detectors. In this study the uncertainties due to the decay of the source were not considered and treated. Their contribution to the air kerma rates and H*(10) are negligible as ^{137}Cs has a half-life beyond 30 years [2]. The components of the uncertainties associated with the calibration process arise from the determination of air kerma rate (conventional true value), instrument resolution, instrument reading repeatability, temperature and pressure correction factor, and positioning of the instrument on the calibration jig. The uncertainty regarding the measurements results in this study was estimated using recommended methods by the IAEA, National Physical Laboratory and International Standard Organization (ISO) [6, 17, 18]. The uncertainties were estimated by employing type A and type B uncertainty methods according to ISO designation [17]. For $\boldsymbol{n}$ measurements taken with observed values, $\boldsymbol{x_i}$, the arithmetic mean, $\boldsymbol{\bar{x}}$ of the data set is given mathematically by Equation 2

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (2)$$

The fluctuations of other observed values $\boldsymbol{x_i}$ of the data sample of $\boldsymbol{n}$ measurements around the mean value $\boldsymbol{\bar{x}}$ in equation 2, is given by the standard deviation, $S(x_i)$, [4]. This is expressed mathematically in Equation 3 as

$$S(x_i) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad (3)$$

For a series of mean values generated from repeated measurements, there exists a small random variation among these mean values. The standard deviation of this mean, $S(\bar{x})$, is estimated using Equation 4

$$S(\bar{x}) = \frac{1}{\sqrt{n}}S(x_i) \quad (4)$$

The left-hand side expression in Equation 4 provides the measure of the width of the expected distribution of the mean values [6]. The measurements of air pressure and temperature were done to determine the air density correction, K_{TP}, for the reference ionization chamber. Assuming that the air in the sensitive volume of the ionization chamber obeys the ideal gas law, K_{TP}, is evaluated by Equation 5

$$K_{TP} = \left(\frac{273.15+T}{293.15}\right)\left(\frac{101.325}{P}\right) \quad (5)$$

where P is the pressure (in kPa) and T is the temperature (in kelvin) at the time charges were collected. Air density correction was evaluated in standard uncertainties terms of pressure and temperature [6] using Equation 6

$$\frac{U_{K_{TP}}}{K_{TP}} = \sqrt{\frac{U_P^2}{P^2} + \frac{T^2}{(273.15+T)^2} x \frac{U_T^2}{T^2}} \quad (6)$$

where $U_{K_{TP}}$ is the temperature–pressure correction factor's uncertainty component; U_P denotes the pressure component's uncertainty (which includes barometer's mean readings, resolution, and calibration uncertainty); U_T is the temperature's uncertainty component (includes thermometer's mean readings, resolution, and calibration)

The ambient dose equivalent's uncertainty was determined by Equation 7

$$\frac{U_{H^*(10)}}{H^*(10)} = \sqrt{\left(\frac{U_Q}{Q}\right)^2 + \left(\frac{U_{KTP}}{K_{TP}}\right)^2 + \left(\frac{U_{N_K}}{N_K}\right)^2 + \left(\frac{U_h}{h}\right)^2} \quad (7)$$

where $U_{H^*(10)}$ is the ambient dose equivalent's uncertainty; U_Q is the ionisation chamber mean reading uncertainty component; U_h is the dose conversion coefficient uncertainty (with a recommended value of 2%); and U_{NK} is the standard ionisation chamber calibration uncertainty component (extracted from the calibration certificate). Sensitivity coefficients, c_i, were derived for each influence quantity. In equation 6, the sensitivity coefficient of temperature is expressed in Equation 8 as

$$c(T) = \frac{T}{(273.15+T)} \quad (8)$$

as the sensitivity coefficient of temperature. The uncertainty contributed by each influence quantity is determined as $c_i u_i$, and summed in quadrature to give the combined uncertainty, u, as expressed in Equation 9

$$u^2 = \sum_i (c_i u_i)^2 \quad (9)$$

The combined standard uncertainty inherent in the CF of any survey meter, U_{CF}, is determined by Equation 10 as

$$U_{CF} = \frac{H^*(10)}{M_I} \, x \sqrt{\left(\frac{U_{H^*(10)}}{H^*(10)}\right)^2 + \left(\frac{U_{M_I}}{M_I}\right)^2 + \left(\frac{U_{K_{TP}}}{K_{TP}}\right)^2} \quad (10)$$

An overall expanded uncertainty in the calibration of a survey meter for 95% confidence probability is expressed as a product of the standard uncertainty and a coverage factor of k = 1.96 [17]. In expressing the final measurement result, the value and its uncertainty were rounded off to the same precision.

Results

The survey meters' readout directly indicated ambient dose equivalent. In the case of the reference standard, H*(10) was estimated from air kerma rates. The H*(10) values from the reference standard and the ten coded devices for 5 years are shown in Table 1. The regulatory requirement for the calibration frequency of these survey meters is annually [2]. Table 2 compares the calibration factors of the ten equipment over the five-year period. Collectively, the devices have been calibrated 50 times within the five-year review period. Seven devices overestimated H*(10) values for 12 times by varying margins. All 10 devices made underestimations for 38 times. The underestimated margins, Var, can be seen in Table 1 with a negative (-) sign before the values. They are in the range 0.0002 mSv/h ≤ |Var| ≤ 0.3946 mSv/h. The overestimates fall within the range of 0.0171 mSv/h ≤ Var ≤ 0.2237 mSv/h. Averagely, each device overestimated its indication by 0.075 ± 0.009 mSv/h within the five-year period. In terms of underestimation, the average variation is 0.163 ± 0.019 mSv/h. The researchers had no knowledge of the calibration factors of the devices prior to year 2019. As a result, the 2019 values were set as the reference point for the analysis. The trend of the calibration factors over the period is shown in Figure 1. In Figure 2, a comparison of deviations in CFs from 2019 reference values is made. The stability or otherwise of the calibration factors are displayed in Figure 3.

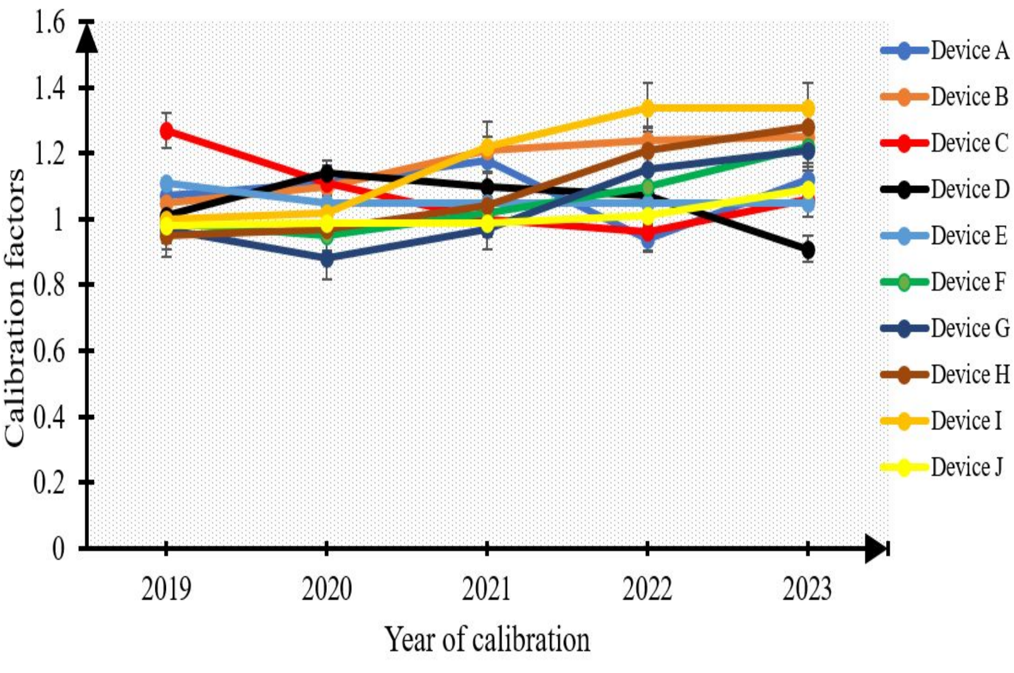

Figure 1. Calibration factor trends over the five-year period

Table 1. Average ambient dose equivalence in mSv/h estimated by reference standard and devices during calibration

Device code	2019			2020			2021			2022			2023		
	$H^*(10)$	M_I	*Var	$H^*(10)$	M_I	*Var	$H^*(10)$	M_I	*Var	$H^*(10)$	M_I	*Var	$H^*(10)$	M_I	*Var
A	1.6897	1.5792	-0.1105	1.6570	1.4928	-0.1642	1.6042	1.2798	-0.3244	1.5755	1.6688	0.0933	1.5366	1.3720	-0.1646
B	1.6987	1.6178	-0.0809	1.6550	1.5045	-0.1505	1.6223	1.3407	-0.2816	1.5645	1.2617	-0.3028	1.5480	1.2384	-0.3096
C	1.6915	1.3335	-0.3580	1.6536	1.4897	-0.1639	1.6097	1.6095	-0.0002	1.5711	1.6423	0.0712	1.5328	1.4455	-0.0873
D	1.6987	1.6819	-0.0168	1.6398	1.4384	-0.2014	1.6020	1.4563	-0.1457	1.5643	1.4620	-0.1023	1.5465	1.6995	0.1530
E	1.6942	1.5197	-0.1745	1.6612	1.5866	-0.0746	1.5976	1.5259	-0.0717	1.5836	1.5082	-0.0754	1.5517	1.4715	-0.0802
F	1.6968	1.7139	0.0171	1.6465	1.7278	0.0813	1.6023	1.5709	-0.0314	1.5722	1.4293	-0.1429	1.5387	1.2618	-0.2769
G	1.6968	1.7547	0.0579	1.6550	1.8787	0.2237	1.6124	1.6623	0.0499	1.5789	1.3730	-0.2059	1.5391	1.2728	-0.2663
H	1.6987	1.7881	0.0894	1.6536	1.7565	0.1029	1.6218	1.5636	-0.0582	1.5853	1.3077	-0.2776	1.5353	1.1994	-0.3359
I	1.6875	1.6873	-0.0012	1.6536	1.6925	0.0389	1.6205	1.3225	-0.2980	1.5829	1.5829	-0.0018	1.5466	1.1520	-0.3946
J	1.6839	1.7120	0.0281	1.6313	1.6543	0.0230	1.5957	1.6196	0.0239	1.5726	1.5570	-0.0156	1.5381	1.4111	-0.1270

Note. *Var indicates variation between reference dose profile and instrument reading

Table 2. Detector types and their calibration factors

Device code	Detector type	Area of application	Calibration Factors					
			2019	2020	2021	2022	2023	5-year average
A	Proportional counter	Border and port control	1.07 ± 0.13	1.11 ± 0.13	1.18 ± 0.14	0.94 ± 0.11	1.12 ± 0.13	1.08 ± 0.13
B	Geiger Muller counter	Border and port control	1.05 ± 0.13	1.10 ± 0.13	1.21 ± 0.14	1.24 ± 0.15	1.25 ± 0.15	1.17 ± 0.14
C	Proportional counter	Extractive mining	1.27 ± 0.15	1.11 ± 0.13	1.00 ± 0.12	0.96 ± 0.11	1.06 ± 0.13	1.08 ± 0.13
D	Geiger Muller counter	Extractive mining	1.01 ± 0.12	1.14 ± 0.14	1.10 ± 0.13	1.07 ± 0.13	0.91 ± 0.11	1.05 ± 0.13
E	Proportional counter	Healthcare	1.11 ± 0.13	1.05 ± 0.13	1.05 ± 0.13	1.05 ± 0.13	1.05 ± 0.13	1.06 ± 0.13
F	Geiger Muller counter	Non-destructive testing	0.99 ± 0.12	0.95 ± 0.11	1.02 ± 0.12	1.10 ± 0.13	1.22 ± 0.15	1.06 ± 0.13
G	Geiger Muller counter	Non-destructive testing	0.97 ± 0.12	0.88 ± 0.11	0.97 ± 0.12	1.15 ± 0.14	1.21 ± 0.14	1.04 ± 0.12
H	Proportional counter	Non-destructive testing	0.95 ± 0.11	0.97 ± 0.12	1.04 ± 0.12	1.21 ± 0.14	1.28 ± 0.15	1.09 ± 0.13
I	Pressurized ionization chamber	Healthcare	1.00 ± 0.12	1.02 ± 0.12	1.22 ± 0.15	1.34 ± 0.16	1.34 ± 0.16	1.18 ± 0.14
J	Proportional counter	Extractive mining	0.98 ± 0.11	0.99 ± 0.12	0.99 ± 0.12	1.01 ± 0.12	1.09 ± 0.13	1.01 ± 0.12

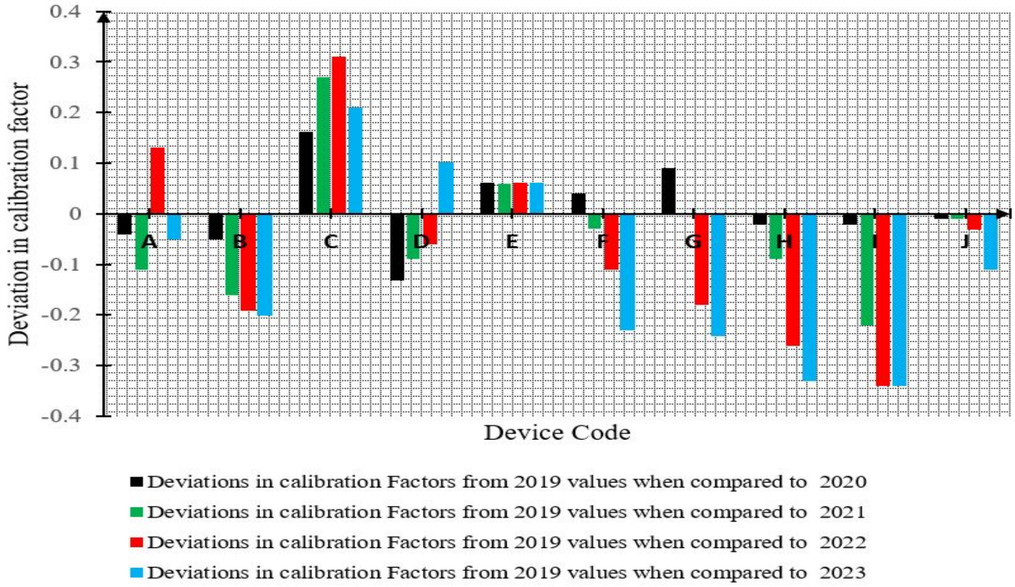

Figure 2. A comparison of deviations in CFs from 2019 reference values

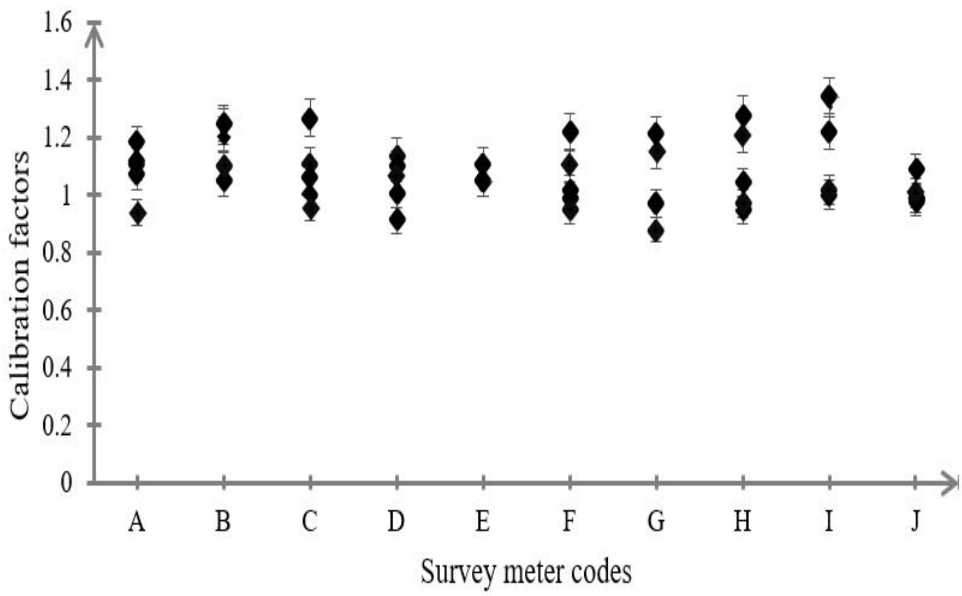

Figure 3. CFs of the ten survey meters calibrated from 2019 to 2023.

Discussion

Between the years 2020 and 2023, there are deviations in the CFs from their initial year 2019 values for all equipment as seen in Figure 2. Additionally, for all the years, there were deviations in the measured values compared to the true (reference) values for all the devices as shown in Table 1. Generally, these deviations increase with usage and time. In Figure 1, it can be inferred that the deviations are least in 2019 with the CF for Device C being an outlier. The standard deviation of the CFs was the least in 2019 with a value of 0.05(excluding outlier CF of Device C) and increased steadily to a maximum of 0.13 in 2023. The small standard deviation of 0.05 indicates that the CFs of most of the devices are tightly clustered around the 2019 mean CF of 1.04. The 2023 standard deviation of 0.13 shows a higher extent of the spread of the CFs around the 2023 mean CF of 1.15. Collectively, the devices generally gave their best indication in 2019. The extent of the individual deviations is tabulated as a percentage of the 2019 values in Table 3.

Table 3. Percentage deviations in calibration factors from 2019 initial values

Instrument	Deviation in calibration Factors from 2019 values (%)			
	2020	2021	2022	2023
Device A	-3.74	-10.28	12.15	-4.67
Device B	-4.76	-15.24	-18.10	-19.05
Device C	12.60	21.26	24.41	16.54
Device D	-12.87	-8.91	-5.94	9.90
Device E	5.41	5.41	5.41	5.41
Device F	4.04	-3.03	-11.11	-23.23
Device G	9.28	0.00	-18.56	-24.74
Device H	-2.11	-9.47	-27.37	-34.74
Device I	-2.00	-22.00	-34.00	-34.00
Device J	-1.02	-1.02	-3.06	-3.06

Table 4. Descriptive statistics for 5-year calibration factors of the ten devices

Parameters	Calibration factor
Standard deviation	0.11
Sample mean	1.08
Standard deviation of the mean	0.04
Variance	0.01
Minimum	0.88
Maximum	1.34
First quartile	0.99
Third quartile	1.16
Kurtosis	-0.42
Skewness	0.56

Device H produced the highest deviation in 2023 with Device G indicating the least deviation in 2021.

The most consistent deviation was recorded by Device E and this is shown in the plot of CFs of the ten devices in Figure 3. Device E, a proportional counter, produced the most stable CFs over the period. It's CF dropped from 1.11 ± 0.13 in year 2019 to 1.05 ± 0.13 in 2020. It remained at this value for the remaining period. The second-best stable CFs was produced by device J. The mean value of the CFs for Device E is 1.06 with a standard deviation of 0.03. Device J has a mean CF of 1.01 with a standard deviation of 0.04. The largest value of standard deviation was recorded for Device I at 0.17. The percentage deviations in the CFs in 2020 and beyond from the 2019 values ranged from -34% to 24%. In a study conducted by Azhar et al [9], five survey meters calibrated at Caesium-137 quality have calibration factors between 0.9139 and 1.5396. The calibration factors were much lower when calibrated at energy quality of 250 kV and lower. Szewczak et al [19] presented results for five dose rate meters which showed that their calibration factors fluctuated by 50% in a one-year period for a particular instrument and by than 100% for two devices of the same type.

The statistical analysis of the CFs in Table 4 agrees strongly with the results of some other studies conducted by Azah et al [2] and Adjei et al [4]. The reported mean CF in this work is 1.08 ± 0.13. Azah et al reported a mean CF of 1.18 whilst Adjei et al reported a mean CF of 1.102 ± 0.130 (2 standard deviations). For H*(10), the coefficient of variation is 11.31% and that for CFs is 10.32%. This implies that, relative to the mean, the H*(10) values of the devices, are much more variable than the CFs. With a skewness value of 0.56 obtained in this work, the distribution of the CFs is skewed toward the right. A kurtosis value of -0.42 in Table 4 indicates that the distribution of the CFs is flatter than a bell-shaped distribution as opposed to a positive value indicating a distribution with a sharper peak than a bell-shaped distribution. The uncertainty budget for the calibrations is stated in Table 5. The overall uncertainty in the CFs of the survey meters is a sum of the uncertainties in the primary standard, the calibration of the secondary standard at the PSDL, the secondary standard and the calibration of the survey meters at the SSDL. The study is limited to devices that detect and measure photons, specifically, gamma radiations. These devices are of three types: pressurized ionization chamber, proportional, geiger muller counters.

Table 5. Estimated relative standard uncertainty

Influence quantity	Distribution	Type	Relative standard uncertainty, u (%)	Sensitivity coefficient, c	Uncertainty component, c x u (%)
Reference standard					
Calibration from PSDL	Gaussian	B	2.50	1	2.50
Long term stability of the secondary standard	Gaussian	A	0.17	1	0.17
Change in source position	Gaussian	B	0.1	1.41	0.07
Temperature change	Rectangular	B	0.02	1	0.02
Pressure change	Rectangular	B	0.1	1	0.10
Reference air kerma measurements - repeatability	Gaussian	A	0.05	1	0.05
Reference air kerma measurements - resolution	Rectangular	B	0.1	0.32	0.31
Device under test					
Temperature change	Rectangular	B	0.02	1	0.02
Pressure change	Rectangular	B	0.1	1	0.10
Device reading - repeatability	Gaussian	A	2.00	1	2.00
Device reading - resolution and other effects	Rectangular	B	0.2	0.32	0.62
Device positioning	Rectangular	B	0.05	2	0.01
Overall relative uncertainty					5.97
Relative expanded uncertainty (k = 2)					11.94

Conclusion

Survey meters that are out of calibration produce inaccurate measurements. This is evident in the outcome of this study. Three types of detectors were studied in this work. The most stable indication of ambient dose equivalent was produced by two proportional counters used in healthcare delivery and extractive mining industry. The sensitivity of survey meters changed with usage and time. This resulted in an increase or decrease in the values of the calibration factors. The change in sensitivity could be due to many factors including handling, maintenance culture, and frequency of usage. The results of this study reveal that proportional counters produce stable results over time. Analysis of calibration factors and other results for a defined period can reveal the degree of instability of the indications of survey meters. While it is wise to follow the calibration interval indicated in the operating manual of survey meters, it is recommended here that users can either extend or shorten the calibration interval by examining the deviation and stability of the calibration data over a defined period. The degree of instability in calibration factors can help users characterise their equipment and aid them in deciding which device to use to undertake very important and sensitive surveys as well as to determine when to decommission them or get them repaired. Although the findings in this work improve our understanding of the possible applications of calibration factors and results, they do not exhaust the maximum benefits that can be derived from the evaluation of these records. This study can be expanded to include devices that detect and measure neutrons, beta and alpha particles to reveal other insights. This study does not provide any insight into the exact time, after calibration, that the CFs begins to become unstable. To help detect the instability early [20], it is suggested that users of survey meters resort to counting statistics on their measured data at regular intervals.

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