Calibration of Survey Meters at the Secondary Standards Dosimetry Laboratory at the Radiation Protection Institute of Ghana Tomic Energy Commission

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Abstract: ***Some digital and analogue radiation surveys meter have been calibrated at the Secondary Standard Dosimetry Laboratory at Radiation Protection Institute of Ghana Atomic Energy Commission using Cs-137 radiation source. All the survey meters were a total of ten having the ratio of 2:8 indicating 20% were analogue whereas 80% were digital survey meters. Calibration of radiation survey meter instruments is a process which may be conducted with varying degrees of accuracy and precision. Both are a function of the facilities and equipment, time, personnel and financial resources available to perform the calibration. Proper care of radiation detecting and measuring equipment, as with all equipment, is the primary mechanism for ensuring its proper functioning. Radiation measuring devices need to process calibration, which might lose their sensitivity and extent of the response and the amount of stability under a changing condition from time to time in which this period depends on the nature and the use of radiation field in which the device is used. For all the selected radiation survey meters brought to Secondary Standards Dosimetry Laboratory, the radiation survey meter from the company S5 had the highest response whereas the survey meter from S8, had the lowest response hence the highest calibration factor.***

Keywords: Calibration, Dose rate, Radiation, Response and Instrument

1. Introduction

In the year 1896, Henri Becquerel found that Uranium salts emitted nuclear radiation which was traced to be from natural radioactivity by the element Uranium. This radiation can be in the form of particles like alpha and beta particles or electromagnetic radiation either gamma rays or both. Nuclear radiations have many and several applications in our life, so we need instruments to detect these radiations. But these detectors must be calibrated just before their first use and then they should be recalibrated periodically either annually or bi-annually [1,2].

The protection of occupational exposed workers from the hazards of ionizing radiations has been a major concern of the Radiation Protection Institute of Ghana. Therefore periodic calibration and standardization of radiation survey instruments are done to ensure accurate and correct radiation readings in these various radiation fields where the survey meters are used. Radionuclides such as Radium -226, Caesium-137 and Cobalt-60 have often been used as sources of gamma-rays for calibration[3 ,4].

The main aim of the calibration is to ensure that an instrument is working properly and to determine, under a controlled set of standard conditions, the indication of an instrument as a function of the measured value. Also to adjust the instrument so that the overall measurement accuracy of the instrument is highly optimized.

2. The Calibration Facility

The Secondary Standard Dosimetry Laboratory in Ghana was established in 1988 under the International Atomic Energy Agency, Technical Co-operation project number GHA/1/007 as part of the network of the World Health Organization and IAEA SSDLs distributed worldwide. The Radiation Protection Institute(RPI) maintains and operates the SSDL which is available to provide periodic calibration, standardization of radiation monitoring and protection of survey instruments that are used by occupationally exposed workers. The SSDL also provides radiological hazards and performance evaluation surveys of Radiotherapy facilities and Nuclear Medicine Centres in the country[5, 6]. For the calibration of survey instruments, standard sources of Co-60 and Cs-137 are used. Survey Instruments needing calibration should be taken to RPI by the RSO of the user facility. Usually the turn-around time is approximately a week. After an instrument is calibrated, it is picked up from RPI and returned to the user group by the Radiation Safety Officer. The main source of radiation used in this facility is Cs-137 gamma irradiator[7-11]. In Ghana, many types of ionizing radiation sources are employed in a variety of useful applications. These applications include non-destructive testing, medicine, well logging, density and level gauging in industries, teaching and research. The measuring instruments used in the various institutions include radiation survey meters, contamination monitors, proportional counters and sometimes thermoluminescent dosimeter (TLDs).

Determination of Calibration Factor

The instrument with various theoretical dose rate values and the exposure distances are computed using the inverse square law as used in equation **(1).**

For X and gamma radiations, the inverse square law is as shown in equation(1)

$$I = \frac{K}{d^2} \quad (1)$$

Where *I* is the intensity of radiation, *d* is the distance and *K* is the proportionality constant. Similarly the inverse square law may be further written as

$I_1 d_2^2 = I_2 d_1^2$ **(1a)**

Relating equation (1) in terms of dose rate $\dot{D}$, then it becomes

$$\frac{\dot{D}_1}{\dot{D}_2} = \frac{d^2_2}{d^2_1} \quad (2)$$

The survey meter is then exposed at computed distances and actual exposure dose rate readings are recorded, using the source to detector distance method.

From the readings taken, the calibration factor (C.F) can be computed using the relation in equation (3)

$$C.F = \frac{Theoretical\ Reading}{Observed value} \quad (3)$$

The calibration factor, *CF*, is defined as the conventional true value of the quantity the instrument is intended to measure H, divided by the indication measurement *M*, given by the instrument, i. e.

$$CF = \frac{H}{M} \quad (3a)$$

The *C.F* is dimensionless quantity because the indicated value and the measured value have the same units. A perfectly accurate instrument should have a calibration factor of unity,(*C.F=1).*

Correction for the reference instrument

In order to obtain the conventional true value of the quantity to be measured, it is necessary to correct the reading of the reference instrument by various factors which arise from differences between the standard test conditions and reference conditions as well as from other conditions as prescribed for using the reference instrument.

The necessary corrections that needs to be done

The following necessary corrections are to be done, these are

(i) Background radiation:
The background reading of the measuring instrument in absence of any reference sources should be recorded and corrected for the calibration of high sensitivity.

(ii) Pressure:
For an unsealed ionization chamber, the deviation of the actual air pressure P from the reference pressure (P_0 =101.3 kPa) is corrected by:

$$kP = P_0/P \quad (4)$$

(iii) Temperature:
For an unsealed ionization chamber, the deviation of the actual air temperature T from the reference temperature (T_0=293.15 K) has to be corrected by:

$$kT = T/T_0 \quad (5)$$

By combining equations (4) and (5) the combined correction for both temperature and pressure is written as follows in equation **(6)**

$$C_{TP} = \left(\frac{T}{T_0}\right) * \left(\frac{P_0}{P}\right) \quad (6)$$

Where T is the temperature at any time, T_0 is the room temperature, P_0 is the normal atmospheric pressure and P is at any pressure. The environmental conditions needed for calibration are T_o=20°C, P_o=101.324kPa and Relative Humidity=50%.

NB: if the difference of the relative humidity is less than 1% the relative humidity may be neglected hence there would be no need for correction of relative humidity.

The diagram in Fig. 1; is a typical universal survey meter that was brought to the SSDL for calibration.

Fig .1: A typical universal survey meter(Rados-120)

Table 1: Characteristics of some radionuclides mostly used for calibration for gamma equipment

Radionuclide	Half-life/($T_{1/2}$)/years	γ -ray energy/MeV
Cobalt-60	5.26	1.25
Caesium -137	30	0.662
Radium- 226	1622	0.83

3. Materials and Methods

In the laboratory, the source to detector distance variable dose rate or exposure rate method is usually used. The materials used in this research of study are PTW UNIDOS Electrometer, Cs-137 source, digital barometer, thermometers, calibration bench with telescopic and laser beam alignment systems.

The radiation survey meters are the most important resource that, an occupationally exposed worker needs to determine the presence and intensity of radiation. The proper calibration of these survey meters assures that they are functioning properly. The radiation survey meters of the various Companies are periodically sent to the SSDL at RPI either for recalibration or when they acquire new survey meters. For a calibration to be done, the survey meter undergoes a lot of functional tests such as battery check, radiation response, and zero checks.

Calibration procedure's using Cs-137 gamma source

The following are the steps normally used at the Secondary Standard Dosimetry Laboratory during calibration of the radiation survey meter;

1) Set the survey meter at an appropriate exposure rate or dose rate range,
2) Carefully place the survey meter in the calibrated source beam at an appropriate distance from the source making sure that the survey meter is right in the middle of the beam,
3) Expose the survey meter with the radiation source;
4) Record the meter reading displayed on the survey meter at least five times within a regular interval of time example ten(10) seconds;
5) Calculate the average reading value and determine the standard deviation;
6) Repeat steps 1-5 for other distances and exposure rates or dose rate ranges
7) Finally calculate the calibration factor and the response.

The diagram in **Fig. 2**: shows the set-up of the standard procedure that is used at the laboratory for the calibration of a survey meter.

Figure 2: Set up for the calibration of a survey meter at the Secondary Standard Dosimetry Laboratory.

4. Results

The SSDL at RPI permits almost all the companies in the country to bring their radiation survey meters for calibration annually or bi-annually. Using the source to detector distance method, the survey meters are calibrated for re-use on the radiation fields. Some selected companies have been designated as S1-S10 as shown in the appendix.

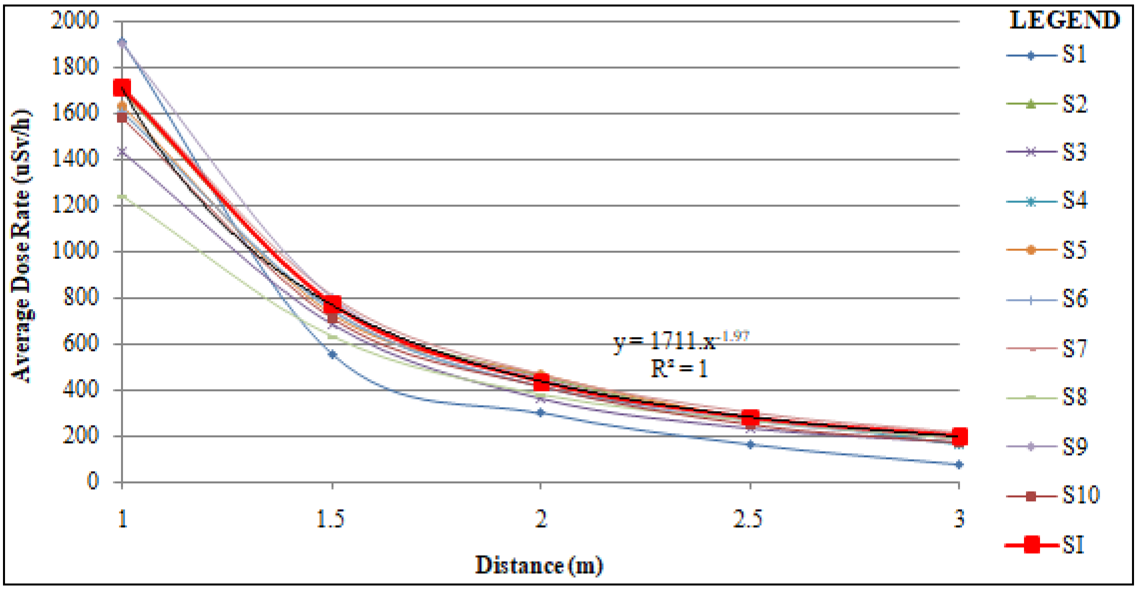

Figure 3: The variation of average dose rate with distance for different survey meters of some selected companies.

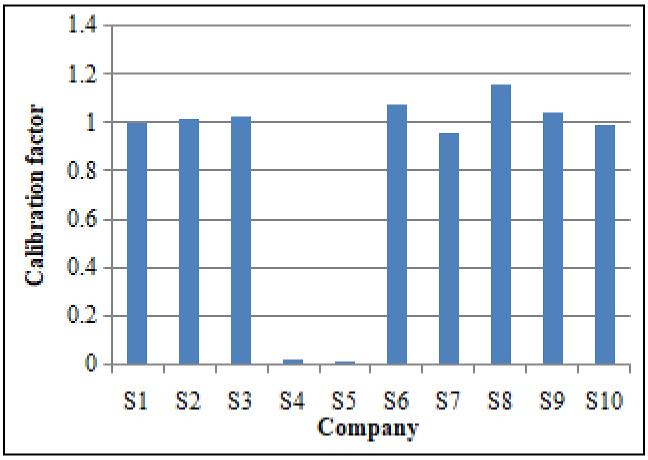

Figure 4: A graph of calibration factor verses company

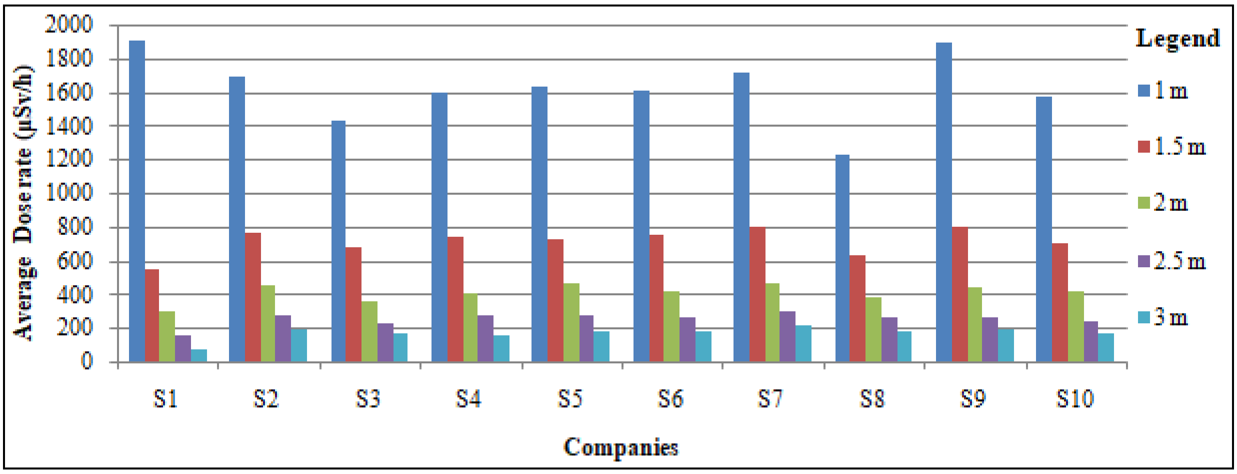

Figure 5: Distribution of average dose rate with various Companies

5. Discussion

The variation of the average dose rates with the corresponding distances are plotted in Fig 3. The ideal standard average dose rate (SI) was plotted in red having the power equation of $y=1711.2e^{-1.97}$ with the regression coefficient of $R^2=1.00$. All the graphs follow the inverse square law. About four of the companies fell below standard average dose rate value at a distance of one(1) meter. Only two companies also had their average dose rate below the standard dose rate value at a distance of three(3) meters hence indicating that the survey meters from these companies need to be fine tuned. From the graph in Fig 3, the company S1 recorded the highest average dose rate at a lower distance of one meter. At a distance of three meters the company S1 recorded the lowest average dose rate. The company S8 recorded the highest calibration factor indicating the lowest response. Also it was observed that, S5 had the lowest calibrating factor hence the highest response. It was also observed that, the companies designated S1, S2, S3 and S10 had their survey meters a calibration factor of approximately equal to 1.00 indicating that they were performing very well and therefore no need for fine tuning. The companies designated as S4, S5 and S7 had very low values which are less than 1.00 of the calibration factor and therefore their survey meters need to be fine-tuned before in-use. Only two companies had very high values which higher than 1.00 of calibration factors which also need to be fine-tuned.

6. Conclusion

All the selected survey meters both digital and analogue have been calibrated with great accuracy and precision.. Only four companies had their calibrating factors almost equal to 1.00 which does not need fine tuning but the rest of the companies should have their survey meters to be fine-tuned before reuse at their facilities.

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References

[1] IAEA, Calibration of radiation protection instruments. International Atomic Energy Commission Safety Report series No. 16. IAEA(2000)

[2] McDonald, J. C. Calibration measurements and standardization for Radiation Protection Dosimetry. Radiat. Prot. Dosim, 109(4) 317-321(2008)

[3] Lwis, V. E, Woods, M. J. Burgess, P. Green, S. Simpson, J and Wardle, J. Measurement Good Practice Guide; No. 49: the assessment of uncertainty in radiological calibrations and testing. ISSN: 1368-6550(2005)

[4] Hospital Physicists' Association Revised Code of Practice for the Dosimetry of 2 to 35MV X-ray, Cs-137, Co-60 Gamma ray beams. Phys.Med.Biol. 28, 1097-1104.(1983).

[5] International Atomic Energy Agency, The Safe Use of Radiation Sources, Training Course Series No. 6. IAEA, Vienna-Austria,(1995).

[6] International organization for standardization, X and Gamma Reference Radiation for calibrating Dose Meters and Dose Rate Meters for Determining their Response as a function of Photon Energy Characteristics of the Radiations and their Methods of Production, ISO Standard 4037-1, Geneva(1995).

[7] Bohm, J; Griffith, R; Ouvard, R and Thompson, I; Calibration of Radiation Protection Monitoring Instruments, IAEA, Austria, (2000)

[8] Gaillard –Lecanu-L.D.E; European Radiation Protection Course, Physical Dosimetry (2001)

[9] Khan, F,M; The Physics of Radiation Therapy, William and Wilkins, (1984)

[10] Frank, H; Attix and Willium, C;Roesch; Radiation Dosimetryvol 1, 2nd edition, Academic Press, New York; (1968).

[11] Haward, L; Andrews and Ralph, E;Nuclear Radiation Physics, 3rd Edition, Prentice-Hall, Inc, Englewood Cliffs, N.J. USA; (1964)

Appendix

Table 1: The variation of distance with dose rates for different Companies designated as S1-S10.

Distances (m)	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
1	1908	1688	1434	1603	1633	1605.5	1718.3	1235.3	1900.6	1578
1.5	555.25	769.72	684.5	741	729.3	748	803.7	630.6	798.131	711
2	299.28	452.66	361.6	413	465.8	417.6	468.9	381.7	448.24	415.1
2.5	164.46	277.14	234.3	283.8	275.7	261.2	300.4	261.8	271.038	244.3
3	77.907	200.02	169	161.3	187.3	188.4	214.8	186.16	194.66	173.9

S1 = Digital survey meter
S2 = Analogue survey meter
S3 = Digital survey meter
S4 = Digital survey meter
S5 = Digital survey meter
S6 = Digital survey meter
S7 = Digital survey meter
S8 = Digital survey meter
S9 = Analogue survey meter
S10 =Digital survey meter

Table 2: The various companies with their calibration factors and responses of the survey meters

Company Identification	Calibration factor(C.F)	RESPONSE(R) R=1/CF
S1	1.003	0.997
S2	1.015	0.985
S3	1.024	0.977
S4	0.026	38.462
S5	0.016	62.500
S6	1.073	0.932
S7	0.961	1.041
S8	1.162	0.861
S9	1.041	0.961
S10	0.99	1.010