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Standardisation of Radiation Measuring Devices Using Ambient Dose Equivalent for Radiation Protection in Bangladesh

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For the purpose of human life, radiation is used, however unselective application of it may serve as a hazard to life. One of the preventive actions is the proper use of calibrated dose as well as dosimeters in order to monitor the harmful impact on healthy cells. The dosemetry of ^{137}Cs, ^{60}Co sources from gamma calibrator GC-60, G-10 and X-ray narrow series qualities (N-40, N-60, N-80, N-100, N-120, N-150, N-200) was performed in SSDL, Bangladesh with standard ionisation chambers of model NE-2575#386 (600cc) and PTW32002 (1000cc) according to the recommended protocol of IAEA SRS 16 and ISO 4037. In this study, it is found that larger volumes have less uncertainty than smaller volumes for the low dose ionisation sources. For Cs-137 20 mCi activity both of our chambers measure very close ambient dose equivalent H*(10) rather than other. The ambient dose equivalent H*(10) can be used for the implementation of new ICRU operational unit as a radiation safety.

Keywords: Ambient dose equivalent; Radiation protection; Safety Report Series (SRS) 16; International Organization for Standardization (ISO) 4037; International Code of Radiological Unit

I. INTRODUCTION

The science of protecting the radiation workers and patients from unnecessary radiation exposure is commonly familiar as radiation protection. Radiation protection has advanced from such a concern that is connected with diverse factors. One such factor is associated with collection and evaluation of the latest data and information pertinent to the problems of radiation measurement and dosemetry. Next recommendation is to be made on the most acceptable values and techniques for its exposure. To achieve the maximum benefit from the use of ionising radiation, it is essential that the photon beam should be standardised to reduce radiation hazards (IAEA-TECDOC-1599, 2007). International Atomic Energy Agency (IAEA) recommended the Basic Safety Standard (Safety Series-ll5-1) (IAEA, 2000; S.R. Wagner *et al.*, 1985) for dose limit. To achieve the goal of radiation protection, the radiation monitoring devices such as survey meter, area monitor, pocket dosemeter, contamination monitor and personnel dosemeter is not only used in daily manners but also calibrated for standardisations. Periodical calibration of these types of instruments is one of the quality control programs and plays an important role in radiation protection (A. Allisy, 1998; ICRU Report-47, 1992). S. Sajib (2017) had been studied the X-ray calibrator that was reflected with standard procedure recommended by IAEA, SRS-16 and ISO-4037 in terms of ambient dose and personal dose equivalent. He measured the characterisation of half value layer, homogeneity coefficient, effective energy and conversion coefficient. S. Saha (2017) analysed some radiation device performances by finding their response at different Gamma-ray and X-ray beam radiator. He used GM tube, Si diode, and Ionisation chamber to calculate ambient dose equivalent H*(10) and their accuracy at different

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radiation level. He found that GM tube pocket dosemeters are more accurate at relatively high energy field of ^{137}Cs source where it showed low performance at ^{60}Co source; and Ion Chamber is good for X-ray radiation.

The problem associated with the use of radiation measuring instruments has recently been the subject of international interest because of the over exposure can produce undesirable biological damage to the exposed persons. Inadequate calibration facilities will cause a large error to estimate dose received by the radiation worker and population (R. Casanovas, 2016). For this reason the radiation measuring instruments should be calibrated properly with the different radiation quality fields following international recommendation such as ICRU, IAEA. The main objective of this study is to protect not only the patients but also the occupational worker from excessive radiation by monitoring the standard devices.

II. METHODOLOGY

In this recent work, different equipment of the Secondary Standard Dosemetry Laboratory (SSDL) was used such as GC-60 and G-10 Gamma irradiator system; and X-ray 225 kv beam irradiator system (BAEC, 2006), dose-1 electrometer, barometer, thermometer, survey meter, linear positioning system, power stabiliser system, two ionising chambers (Spherical PMMA ionisation chamber with volume 1000 cc (iba dosimetry, 2019), NE-2575#386 reference standard ionisation chamber with volume 600 cc (iba dosimetry, 2019).

Figure 1. Operational set-up of X-ray beam irradiator in Bangladesh Atomic Energy Commission Savar, Dhaka.

A protection level standard Ionisation Chamber of 600cc had been used as the reference instrument. This reference instrument was used to estimate the H*(10) to calibrate the radiation survey meter. At the first step, air kerma K_a was determined and then standard ambient dose equivalent H*(10) was determined for the Gamma ray with Cs-137 source [2, 20, and 200 mCi; 20 Ci], Co-60 [10 mCi and 1 Ci] and X-ray for different beam qualities. Dose-1 (iba dosimetry, 2019) electrometer provided the outputs of exposure of Cs-137 and Co-60 gamma radiation and X-ray photons. Outputs were obtained in nano-coulombs per minute. This electrometer reading should be corrected by temperature and pressure in the laboratory. The corrected factor in terms of temperature and pressure is denoted by K_{TP}.

During exposure, kinetic energy released per unit mass per hour in air rate (air kerma rate, K_a) was obtained by,

$$K_a = CR\ (nC/min) \times CF\ (\mu Gy/nC) \times 60\ min \tag{1}$$

Where, CF denotes the calibration factor of the irradiator which contains the source.

For conversion of air kerma to ambient dose equivalent H*(10), conversion coefficient was to be multiplied with the air kerma rate.

$$H^*(10) = K_a \times Conversion\ coefficient \tag{2}$$

True Conversion coefficient for each effective energy were given by the ISO. Conversion coefficients were calculated by interpolating from the standard ISO conversion coefficient vs effective energy curve. The narrow beam spectrum series conversion factors were provided in the ISO-4037-1 and also in the IAEA safety report series 16 (IAEA, 2000). The ambient dose equivalent was calculated by multiplying the air kerma and the conversion coefficient.

III. RESULTS

A. Dosemetry of Calibrator Gc-60 and G-10

Dosemetry was carried out by using the standard gamma ray sources with the beam quality ^{137}Cs and ^{60}Co of different activities and X-ray of different beam qualities. The dose rate at the calibration field should be measured by using standard measuring instrument. Dose rate at different distances were measured using a secondary standard ionisation chamber [NE2575#386] and health physics ionisation chambers [PTW32002] those were coupled with an electrometer [Dose-1] and traceable to IAEA dosemetry laboratory. Difference in the measured ambient dose equivalent using equation 2 at 100 cm SSD was determined by two different chambers is listed Table 1.

Table 1. Comparison between two ionisation chambers at 100 cm SSD according to the variation of response to the ambient dose equivalent at various activities

Calibrator: GC-60			
Source	**Activity**	**Ambient dose equivalent H*(10) [mSv] PTW32002**	**Ambient dose equivalent H*(10) [mSv] NE2575#386**
^{137}Cs	2 mCi	0.019 ± 0.001	0.007 ± 0.003
^{137}Cs	20 mCi	0.071 ± 0.002	0.069 ± 0.002
^{137}Cs	200 mCi	0.676 ± 0.023	0.649 ± 0.019
^{60}Co	10 mCi	0.051 ± 0.002	0.042 ± 0.001
Calibrator: GC-10			
Source	**Activity**	**Ambient dose equivalent H*(10) [mSv] PTW32002**	**Ambient dose equivalent H*(10) [mSv] NE2575#386**
^{137}Cs	20 Ci	57.575 ± 1.920	57.576 ± 1.650
^{60}Co	1 Ci	3.325 ± 0.109	5.043 ± 0.143

B. Dosemetry of Narrow Series Radiation Qualities (N-40, N-60, N-80, N-100, N-120, N-150, N-200 and N-250)

Using equation 2 at 100 cm source to surface distance (SSD) the ambient dose for different X-ray is listed in Table 2.

For the same activity sources different ambient dose equivalent was measured by two different ionisation chambers is shown in Table 3. The ambient dose equivalent H*(10) was decreased with the increasing SSD for all the sources. The total uncertainty of measurement measured between 2.7% and 9.28% for k=1.

Table 2. For PTW32002 and NE2575#386 chambers at 100 cm SSD difference in ambient dose equivalent in different X-ray beam irradiator

Beam quality	**Tube potential [kV]**	**Ambient dose equivalent H*(10) [mSv] in PTW32002**	**Ambient dose equivalent H*(10) [mSv] in NE2575#386**
N-40	40	60.166 ± 2.010	36.931 ± 1.049
N-60	60	180.555 ± 5.940	100.608 ± 2.908
N-80	80	99.589 ± 3.376	54.533 ± 1.478
N-100	100	48.896 ± 1.648	27.275 ± 0.739
N-120	120	49.763 ± 1.672	27.945 ± 0.779
N-150	150	375.332 ± 12.761	201.278 ± 5.616
N-200	200	133.203 ± 4.382	70.881 ± 1.956

Table 3. Difference in ambient dose equivalent between two ion chambers (PTW32002 & NE2575#386) at the same SSD and for the same activity of sources

Activity	**SSD [cm]**	**Ambient dose equivalent H*(10) [mSv]**	
		PTW32002	**NE2575#386**
2mCi ^{137}Cs	80	0.019 ± 0.001	0.0110 ± 0.0004
	100	0.016 ± 0.001	0.0070 ± 0.0003
	120	0.0132 ± 0.001	0.0040 ± 0.0004
	150	0.0118 ± 0.0004	0.0030 ± 0.0002
	200	0.0107 ± 0.0004	0.0020 ± 0.0001
10mCi ^{60}Co	80	0.066 ± 0.002	0.066 ± 0.002
	100	0.051 ± 0.002	0.042 ± 0.001
	120	0.030 ± 0.001	0.028 ± 0.001
	150	0.027 ± 0.001	0.017 ± 0.001
	200	0.019 ± 0.001	0.0100 ± 0.0003
X-ray			
Beam quality N-40	80	94.391 ± 3.200	54.797 ± 1.501
	100	60.166 ± 2.010	36.931 ± 1.049
	150	25.405 ± 0.851	15.828 ± 0.434
	200	14.729 ± 0.520	7.669 ± 0.226
	250	9.342 ± 0.317	4.976 ± 0.145
	300	6.146 ± 0.221	3.605 ± 0.200

Ambient dose equivalent for different SSD was measured by two different ionisation chambers in (2 mCi) ^{137}Cs and (10 mCi) ^{60}Co is shown in Figure 2 and Figure 3, respectively, where ■ represents the uncertainty bar associated with the PTW32002 chamber and ▲ the uncertainty of NE-2575#386.

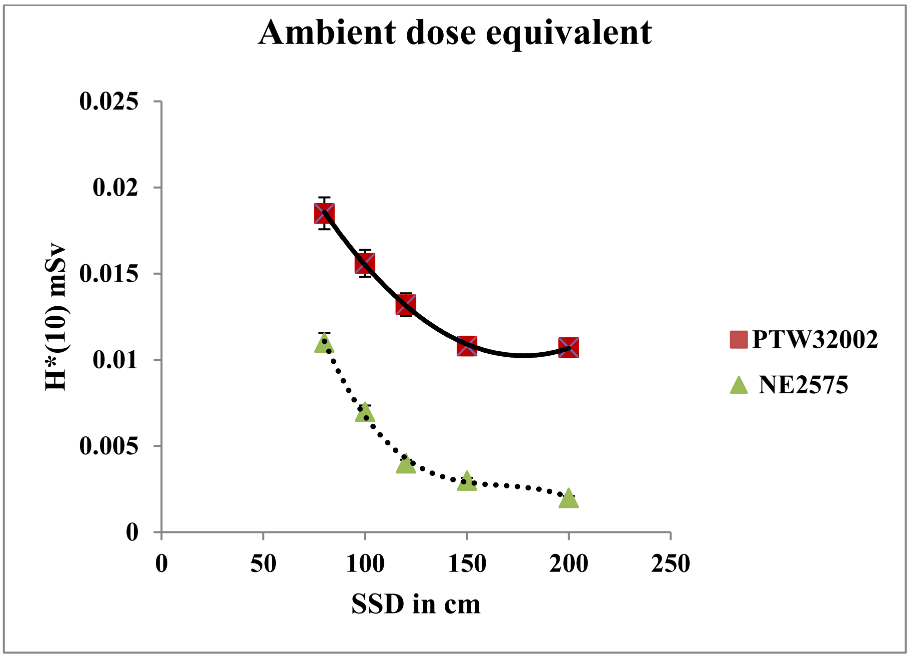

Figure 2. Graphical representation of ambient dose equivalent H*(10) [mSv] of two ionisation chambers of different volume using low activity (2 mCi) ^{137}Cs gamma source

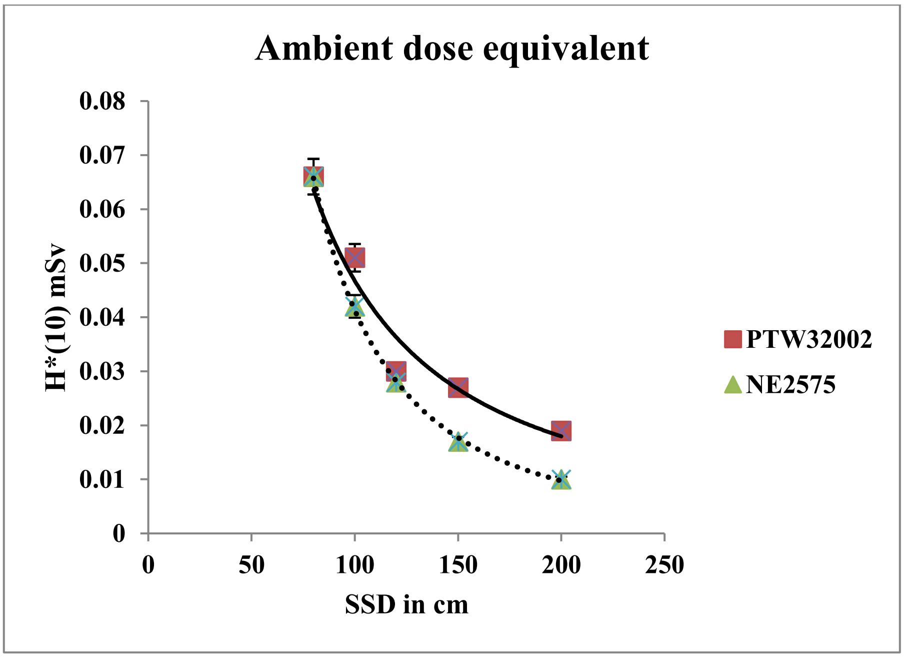

Figure 3. Graphical representation of ambient dose equivalent H*(10) [mSv] of two ionisation chambers of different volume using low activity (10 mCi) ^{60}Co gamma source

For different X-ray tube voltages measured ambient dose equivalent using two ionisation chambers is shown with uncertainty (■ represents the uncertainty bar for the PTW32002 and ▲ for NE-2575#386) in Figure 4.

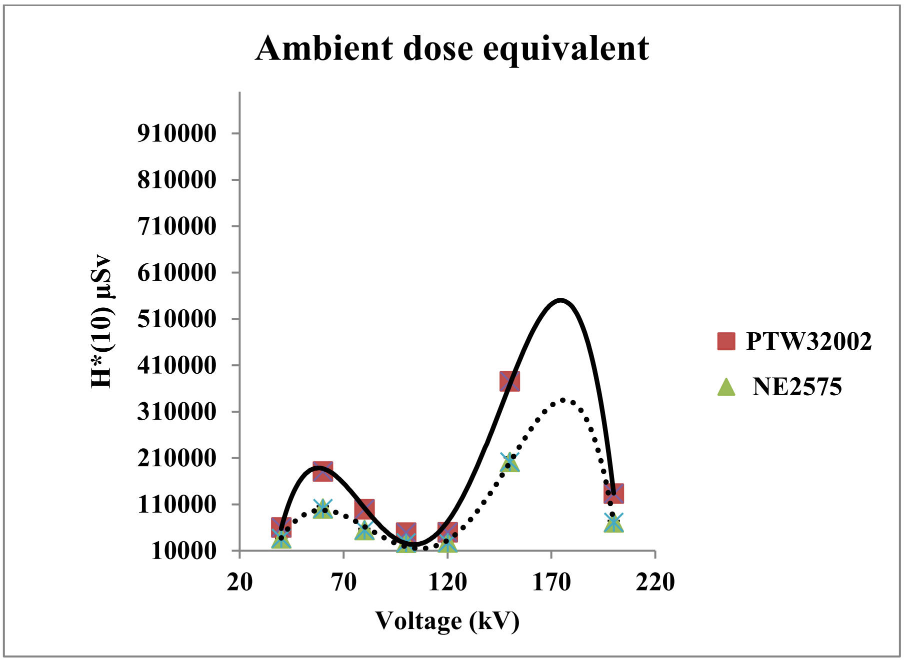

Figure 4. Graphical representation of ambient dose equivalent of two ionisation chambers of different volume using different X-ray beam qualities

Response linearity test of ion chamber type survey meter (VICTOREEN 451B-RYR) suggested that the scale of the survey meter was linearly marked (A. Khrutchinsky, 2012; Q. Li, 2021). Investigation of an Ion type survey meter that was calibrated in the SSDL laboratory shows in Table 4 the calibration factors are good in agreement with the recommendation. The uncertainty of the survey meter was found less than 1.43%.

Table 4. Measurement of the calibration factor and energy response of an Ion type survey meter for different X-ray beam qualities

Beam quality	**Energy [keV]**	**SSD [cm]**	**Range of Survey Meter per hour [µSv]**	**Standard Dose per hour [µSv]**	**Meter Reading**	**Calibration factor**	**Response**	**Uncertainty k=1**
N-40	33	100	10000-100000	36931.43	29000	0.785	1.273	1.31
N-60	48		10000-100000	100607.89	74000	0.736	1.359	1.28

N-80	65		10000-100000	54533.26	37000	0.678	1.474	1.25
N-100	83		10000-100000	27274.58	20000	0.733	1.364	1.28
N-120	100		10000-100000	27945.39	23000	0.823	1.215	1.33
N-150	118		10000-100000	201278.43	177000	0.879	1.137	1.37
N-200	164		10000-100000	70881.09	71000	1.002	0.998	1.45

IV. DISCUSSION

Excessive radiation is dangerous to both humans and the environment. Therefore, to at least mitigate this effect, calibration is required to prevent radiation hazards. The ambient dose equivalent of H*(10) is one of the main issues in calculating the right dose of irradiation (K. Saito, 2014; K. Yoshimura, 2020). The ambient dose equivalent was calculated here on standard equipment in compliance with the IAEA guideline. For larger volume ionisation chamber PTW32002, ambient dose equivalent H*(10) suggests higher values rather than the smaller volume ionisation chamber NE2575#386 due to Brag Gray cavity theory at different SSDs. When electrometer is connected to the chamber it provides the measurement in charge or current unit due to ionisation of air inside the chamber. This charge rate is then multiplied by pressure and temperature correction factor k_{tp} to convert the charge rate into corrected charge rate. For low-activity sources, absorbed doses display a little discrepancy, but for high-activity sources, this is actually negligible. To calibrate the ion style survey meter, the measured values of the ambient doses were used. Finally, in this process, the calibration factor measured was found to show good results with recommended uncertainty.

V. CONCLUSION

On account of both gamma and X-beam radiation, the standardised ionisation chamber PTW32002 shows more vagueness than NE-2575#386. Good response to the IAEA was found in our deliberate energy-based Particle type survey meter. The consequence of this investigation would help the radiation specialist and the climate to be shielded from the sudden openness of silly radiation just as to be shielded from the high likelihood of being influenced by the deadly malignant growth.

Compliance with Ethical Standards:

This article does not contain any studies with human participants performed by any of the authors.

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Conflict of Interest: All authors declare that they have no conflict of interest.

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