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Original Research Article

Comparison of Room Scatter Factors Using Diodes and an Ion Chamber by Multiple Distance Method and Air Kerma Rate Determination

Jumaa Dachi K.[1] and Koleleni Yusuf I. A.[2*]

[1]Ocean Road Cancer Research Institute (ORCI), P. O. Box 3592, Dar es Salaam, Tanzania.

[2]Physics Department, University of Dare s Salaam, P. O. Box 35063, Dar es Salaam, Tanzania.

***Corresponding Author's Email: ykoleleni@gmail.com**

Abstract

At ORCI, the Co-60 source with two gamma rays having energies of 1.17 MeV and 1.33 MeV which are is used for treatment of cancer of gynaecological malignancies in the HDR brachytherapy unit. The Room Scatter Factor, $K_{scatter}$ suitable to a treatment room must be known before determination of reference air Kerma rate. This is because $K_{scatter}$ depend on the geometry set up of the source to chamber and immediate environment (IAEA, TECDOC1274, Faiz 2010). The ^{60}Co source with an activity of about 2.0 Ci was installed in the treatment unit at the ORCI. The room scatter factor need to be known in order to determine reference Air Kerma Strength, K_R. The objective of this study was to determine room scatter factor suitable for Ocean Road Cancer Institute (ORCI) High Dose Rate (HDR) Brachytherapy room and is reported in this paper.

Keywords: Cancer treatment, Cobalt-60, Kerma, ORCI, UDSM

INTRODUCTION

Cobalt-60,is a synthetic radioactive isotope of cobalt with a half-life of 5.27 years. It is produced artificially by neutron activation of the isotope ^{59}Co. The ^{60}Co undergoes a beta decay to the stable isotope nickel-60. The activated nickel nucleus emits two gamma rays with energies of 1.17 and 1.33 MeV, hence the overall nuclear equation of the reaction is:

$$Co_{27}^{59} + n \rightarrow Co_{27}^{60} \rightarrow Ni_{28}^{60} + \bar{e} + \gamma \text{ rays}$$

(Faiz, 2010).

Cobalt-60 has two qualities which are valuable to physicists and doctors developing new programs of radiation treatment for cancer. First, it is a stable, predictable isotope with an unvarying half-life of 5.258 years. Knowing an element's half-life – the period during which it loses half of its radioactivity – allows a medical physicist to make precise calculations of the exposure time necessary to produce any total radiation dosage. As radioactivity decreases, exposure time must correspondingly increase to achieve the same dosage.

High dose rate (HDR) brachytherapy using ^{60}Co source with an activity of about 2.0Ci is a treatment unit available at the Ocean Road Cancer Institute (ORCI) in Dar es Salaam, Tanzania. Independent verification of the source strength provided by the manufacturer is needed before starting clinical use. The Reference Air Kerma Rate is defined as the Kerma rate to air, in air, at a reference distance of 1 m corrected for air attenuation and scattering as reported in ICRU reports (1977,1985,2001). It is expressed in mGy/h at 1 m or µGy/sec at 1 m is the recommended quantity for the specification of Gamma ray brachytherapy sources. For in-air measurement with cylindrical ion chamber a source to chamber distance (SCD) of between 10 cm and 40 cm is recommended by the IAEA TECDOC 1274. To minimize scatter from the holder, a calibration JIG of low density plastic are recommended to be used. The difference between measured and manufacturer's

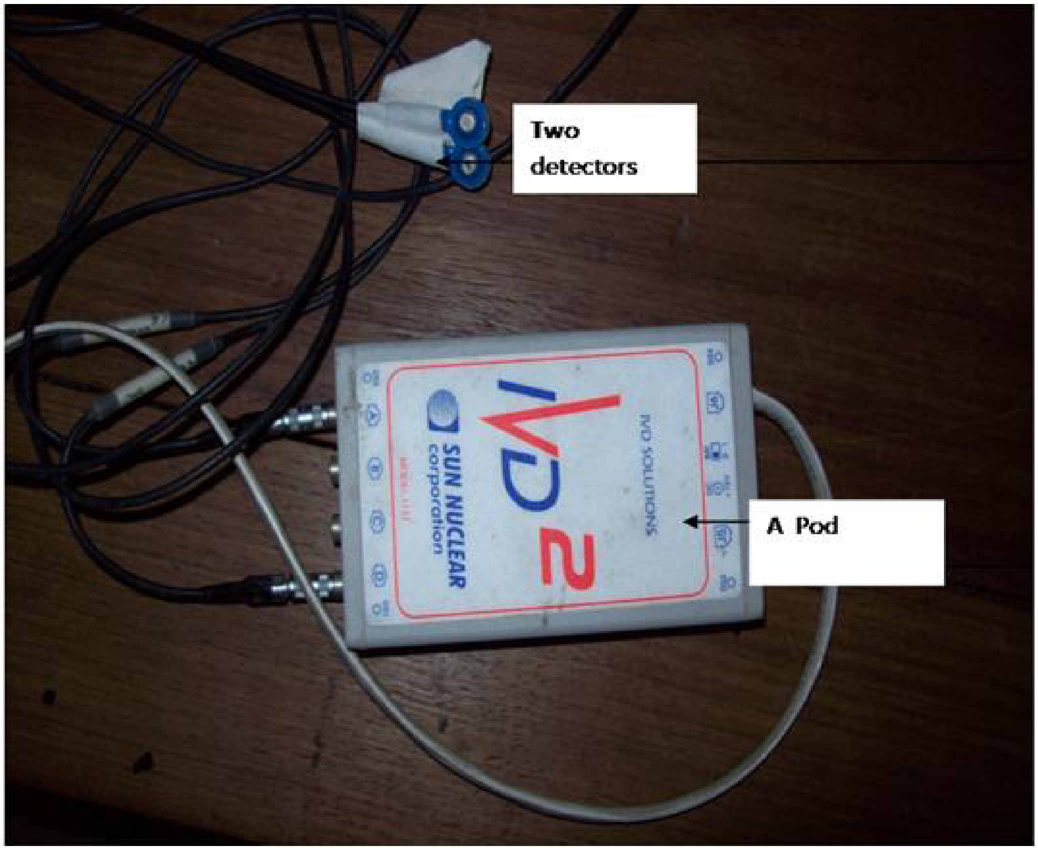

Figure 1. A Pod with detector connected

certificate value of Air Kerma Rate is required to be not more than 2% is acceptable, according to ORCI internal rules. The diodes were also used to determine the room scatter factor. Finally the comparison between room scatter factor s using Diodes and an Ion chamber were made.

The room scatter correction factor is needed during determination of air Kerma rate. The problem faced is the lack of room scatter correction factor ($K_{scatter}$) which suits the High Dose rate Brachytherapy room of Ocean Road Cancer Institute .$K_{scatter}$ is correction for scattered radiation from the walls, floor, measurement set-up, air etc. The reason is that, $K_{scatter}$ values published in the IAEA TECDOC 1274 were determined in the specific conditions like, Specific Size of the room, Specific ionization chamber and Ir -192 source were used and Shadow shield method was used. Quoting from report of Task Group 40 (TG 40) of the American Association of Physicist in Medicine (AAPM) “Each institution planning to provide brachytherapy should have the ability to independent verify the source strength provided by manufacture” as reported by Kutcher et al. 1988.Taking into account Size of the HDR room, Ionization Chamber and Type of source used in ORCI are different from the above mentioned, the effect of ignoring $K_{scatter}$ in the determination of Reference Air KermaRate were assessed. Multiple distance method was used instead of shadow shield method.

Therefore the objective of this paper was to determine room scatter factor hence calculating air Kerma rate which is the source strength. Finally the air Kerma rate was compared to that of manufacture, taking into account both room scatter and without room scatter. The comparison between the room scatter factor obtained by using diodes and ionization chamber are also reported.

MATERIAL AND METHODS

PTW 30001 Farmer chamber (Figure 5) of 0.6 cc was used for calibration of HDR ^{60}Co brachytherapy source in air. UNIDOS® Electrometer (Figure 3), Thermometer, Digital Barometer, A locally constructed JIG (Figure 5), a set of Diodes (Figure 1) and (Figure 2)

The experiment is composed of the following set up. A pod connected to two detectors (Figure 1). A control panel and display screen of the diodes (Figure 2). A UNIDOS® Electrometer (Figure 3). A display screen (Figure 4) where a treatment planning system display the isodose. A set of a Jig, an ion chamber and transfer tube (Figure 5) from the after loader system.

Figure 2. Control Panel and display screen of the diodes.

Figure 3. Electrometer

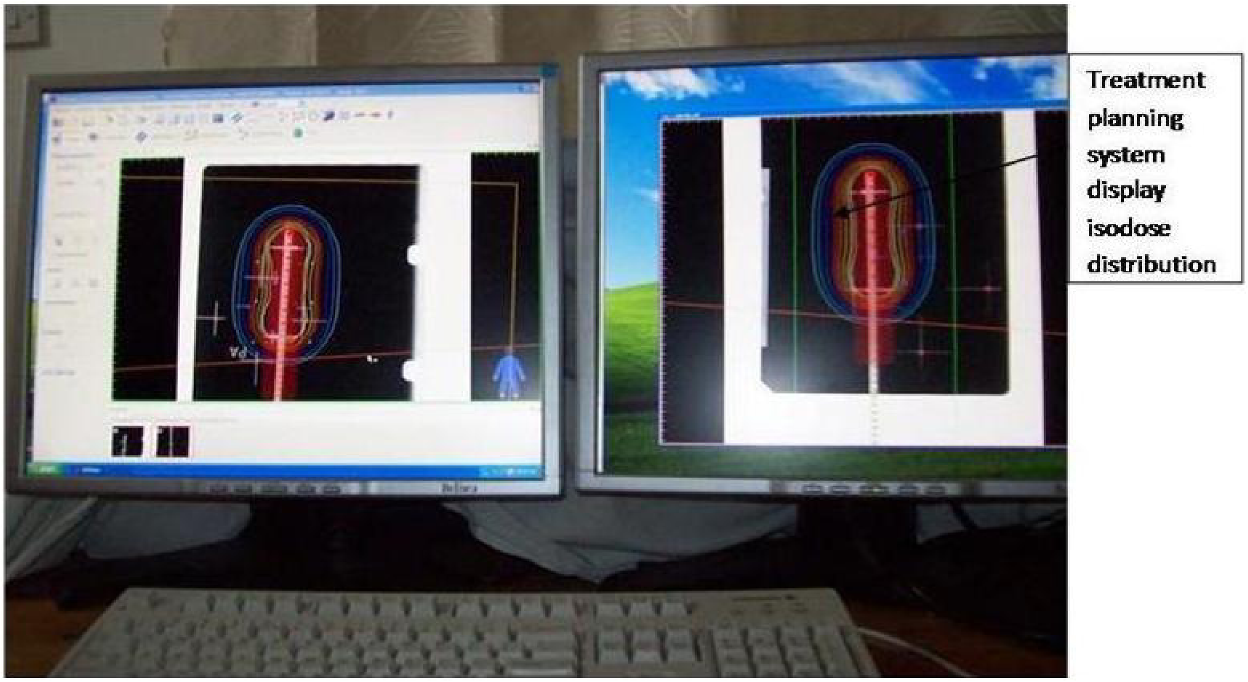

Figure 4. Displaying screen

Figure 5. Set up of a jig, an ion chamber and transfer tube from the afterloader system.

Treatment planning system display the isodose of executed treatment plan (Figure 4) used in the measurement of Room Scatter and Air Karma Rate.

Calibration in air

The locally constructed jig (Figure 5) was used to hold the ionization chamber and the source during calibration in air. The measurement was made using the farmer chamber with a build up cap. Using the HDR basic 2.6 a Treatment Planning System software, the plan was developed. In the plan, a single dwell position at the tip of applicator was activated. The dwell position was given enough dwell time to collect the charges in one minute from different source to chamber distances and source to diode distances. The tip of applicator is aligned parallel with the point of sensitive volume of a chamber and

Table 1. The charges collected at different distances from the ion chamber as shown in the table below.

	Charges in (p C)				
Distance from ion chamber to the source (cm)	**1**	**2**	**3**	**4**	**Average**
10	607.0	607.5	607.5	607.5	607.5
15	276.5	276.5	276.5	276.5	276.5
20	156.5	154.5	154.0	155	155
25	99.5	99.5	99.5	99.5	99.5

Table 2. The table below shows distance between source to diodes and their respective charges were collected.

	Charge in (p C)		
Distance (cm) from the diodes to the source.	**Diode A**	**Diode D**	**Average**
5	20.1	19.8	19.95
10	6.9	6.4	6.65
15	3.1	3.0	3.05
20	1.8	1.7	1.75

diodes. The charges were collected when source to chamber distances are 5cm, 10 cm, 15 cm, 20 cm and 25cm (Table 1-2)

Temperature and pressure correction factor K_{TP}

Temperature and Pressure at the beginning of Data collection were T_1 =26 ^{0}C and
P_1 =101.21KPaat the end of data collection were T_2 = 25 ^{0}C and P_2=101.18KPa
Average: T = 25.5 ^{0}C P = 101.195KPa

Using $K_{TP}=\left(\frac{273.2+\ T}{273.2+T_o}\right)\frac{P_o}{p}$ ____________________ (1)

K_{TP} = 1.020067

Ion recombination correction P_{ion}

The charges were collected at 30 cm distance from the Chamber with High Voltage V_H and Low Voltage V_L

V_H = 400V M^H_{raw}= 63.5 pc and V_L= 200V M^L_{raw}= 62.5 pc

For continuous radiation beam P_{ion} (V_H) = $\frac{1-\left(\frac{V_H}{V_L}\right)^2}{\frac{M^H_{raw}}{M^L_{raw}}-\left(\frac{V_H}{V_L}\right)^2}$ ______ (2)

Plugging the above values gives 1.0054

The non-uniformity correction factor K_n

The correction is needed because, the photon beam from the source is not collimated which yield variation in the photon flux in the air cavity of the chamber (IAEA-TECDOC-1274). This factor depends on: Shape and dimensions of the ionization chamber (Spherical, cylindrical, internal radius and length). Measurement distance and the source geometry ("point source" line source, etc) Material in the inner wall of the chamber, and Energy of the photons emitted from the source, IAEA-TECDOC_1274. The PTW ion chamber, used in this study. Its engineering diagram indicates; The length of Chamber = 23 mm, Half -Length of Chamber L_C =11.5 mm, The Radius of Chamber R_C = 3.05 mm, Shape factor $\sigma = \frac{R_C}{L_C}$

σ = 0.2652

Distance factor $\alpha = \frac{R_C}{d}$ where d is the distance from source to chamber. From this equation the α values were interpolated to provide results given in table 3.

Material and photon energy dependent factors, ω

The wall material is the material in the inner wall of the ionization chamber. The Chamber used has GRAPHITE material.The value ω is 0.992 as given in table 4 (IAEA-TECDOC_1274).

$A'_{pn}(d)$ Determination:

Using table 4. (IAEA-TECDOC-1274). The values of the above term were derived by interpolation method as shown in the table 4.

A^{KR}_{pn} (d) Determnation

Using table 5. IAEA-TECDOC_1274, the values of the

Table 3. The distance factor obtained by varying distances from the source to the Chamber

Distance (c m)	Distance Factor (α)
10	0.0305
15	0.0200
20	0.0154
25	0.0122

Table 4. Variation of $A'_{pn}(d)$ with distance

Distance d (cm)	$A'_{pn}(d)$
10	-3.7236×10^{-3}
15	-1.5944×10^{-4}
20	-1.2132×10^{-3}
25	-5.3003×10^{-4}

Table 5. Variations of A^{KR}_{pn} (d) with distancesIAEA-TECDOC_1274

Distance d (cm)	$A^{KR}_{pn}(d)$
10	0.9938
15	0.9968
20	0.9980
25	0.9991

Table 6. IAEA-TECDOC_1274.Variation of A_{pn}(d) with distance by interpolation method

Distance d (cm)	$A_{pn}(d)$
10	0.9901
15	0.9966
20	0.9968
25	0.9986

Table 7. Variations of K_n with distances

Distance d	K_n
10 cm	1.0099
15	1.0034
20	1.0032
25	1.0024

above term was derived by interpolation method as shown in table 5

Using A_{pn} (d) $= A^{KR}_{pn}(d) + \omega A'_{pn}$ _____________ (3)

$A_{pn}(d)$ Evaluation

$A_{pn}(d)$ was evaluated by substituting the values of table 4 for $A'_{pn}(d)$ and values of $A^{KR}_{pn}(d)$ from table 5 in equation 3 while the value of ω = 0.992. From these the A_{pn} (d) evaluation is given in table 6.

Using $K_n = \frac{1}{A_{pn}(d)}$ ____________________ (4)

The values of K_n given in table 6 wa obtained by making substitution in equation 4 with values of $A_{pn}(d)$ from table 7

Determination of $K_{Scatter}$ by multiple distance method

In this method, the readings taken at different distances reflect the inverse square law and an assumed constant amount of scatter. The source to chamber distance of

Table 8. The table below shows the distance between source to ionization chamber and their respective room scatter factors.

Distance (d) in cm	$K_{scatter}$
10	1.021
15	0.997
20	1.000
25	0.997

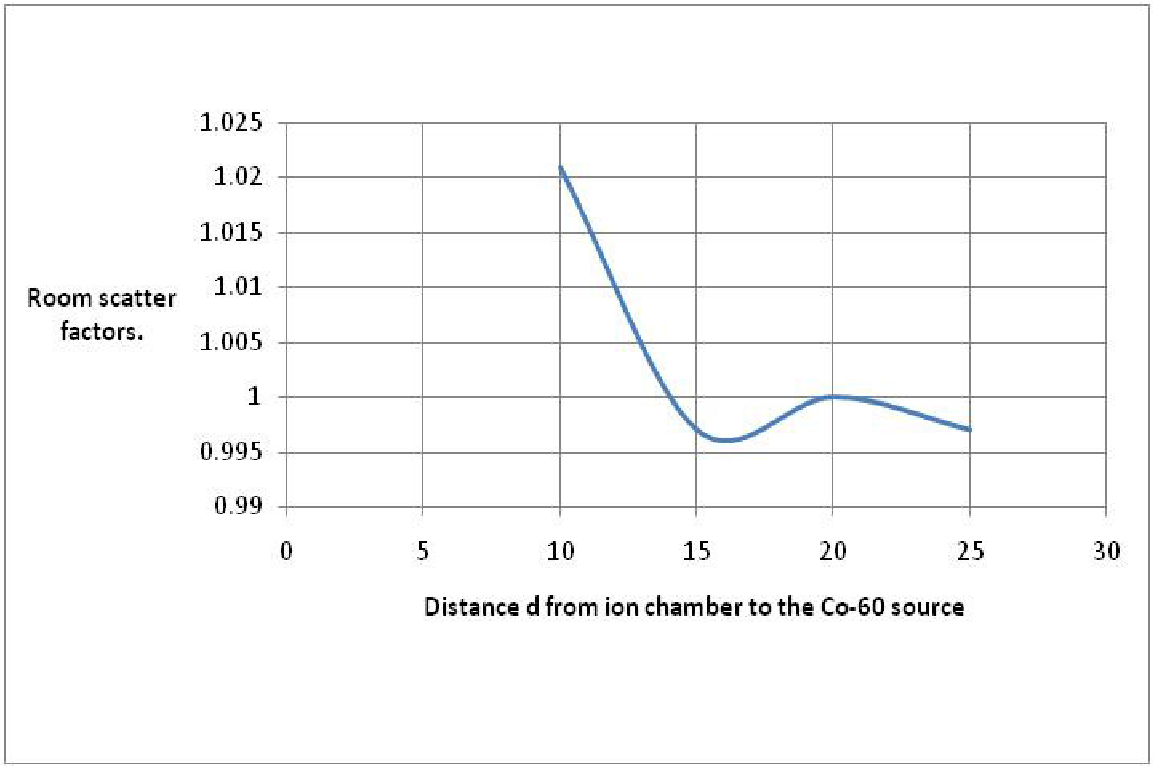

Figure 6. Scatter factors Vs Distance from ion chamber

Table 9. The table below shows the distance between source to diodes and their respective room scatter factors.

Distance (d) in cm	$K_{scatter}$
5	1.404
10	1.053
15	1.020
20	1.000

20cm is selected as reference distance in the determination of $K_{scatter}$ (Ezzel 1988) (Table 8)

$K_p (d) = K_o \left(\frac{d_o}{d}\right)^2 + K_s$ ________________________ (5)

$K_{Scatter} = \frac{K_{p\,(d)} - K_S}{K_{p\,(d)}}$ (ICRU 2001)______________ (6)

The graph (Figure 6) shows the variation of the room scatter factors with the distance from the ion chamber the maximum scatter factor was 1.02 and the minimum values was 0.997 when the ion chamber wa used. (Table 9)

Average $K_{scatter}$ for the measurement conducted using ionisation chamber at distances 10,15, 20 and 25 cm.

$K_{scatter,average}$ for ion chamber $= \frac{1.021+0.997+1.000+0.997}{4} =$ 1.00375≅1.004

The graph Figure 7 shows diodes detected the maximum scatter factor of 1.4 and minimum scatter factor

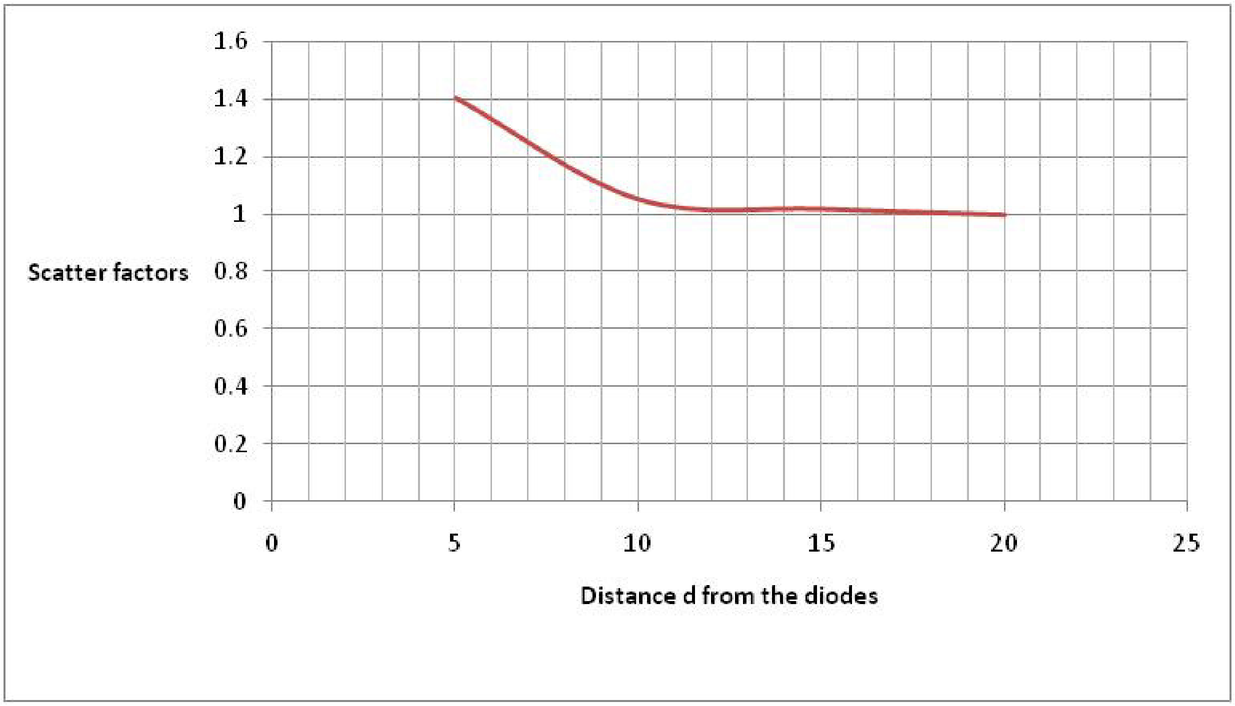

Figure 7. catter factors Vs Distance from the diodes

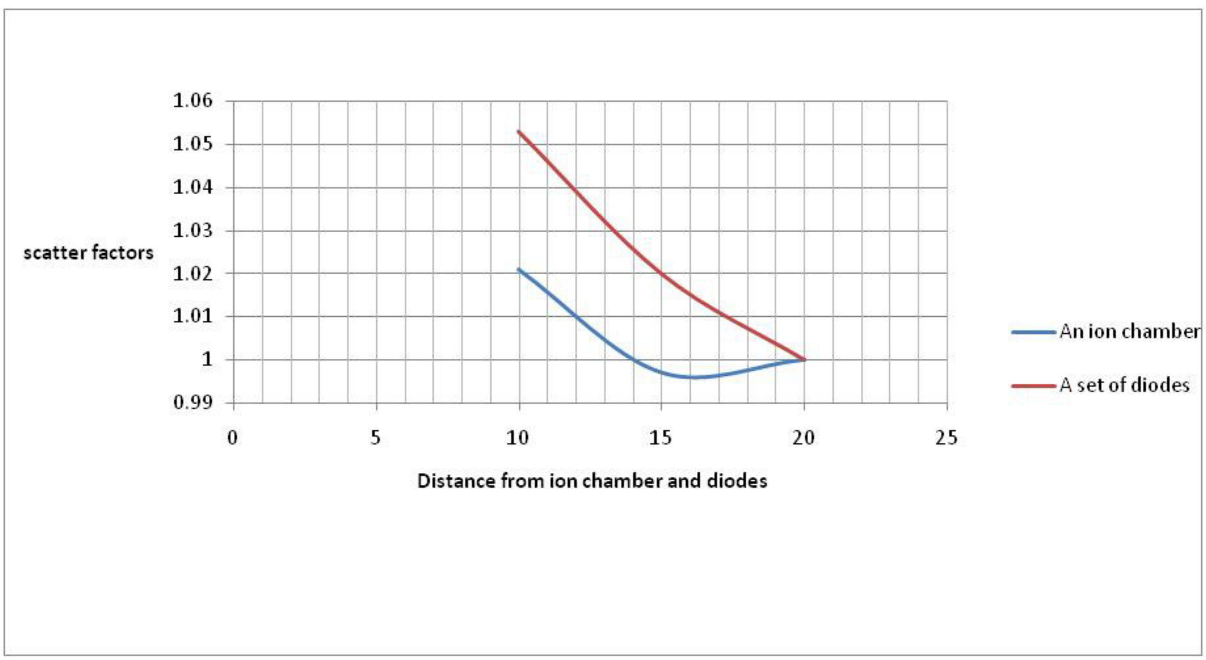

Figure 8. Scatter factors Vs Distances from ion chamber and diodes

was 1.0 The average $K_{scatter}$ for the measurement conducted using the diodes at distances 5, 10, 15 and 20cm.

$$K_{scatter,average\ for\ diodes.} = \frac{1.404+1.053+1.020+1.000}{4} = 1.11925 \cong 1.119$$

Figure 8 shows both diodes and ion chamber compared in measuring room scatter factors.The reference air Kerma rate(ICRU 2001).

K_R at 1 m was determined by using IAEA report.$K_R = N_K (M_u/t) K_{air} K_{scatt} K_n (d/d_{ref})$_____(7)

Table 10. Variations of K_R($mGyhr^{-1}m^2$) with distances

Distance d (c m)	K_R ($mGyhr^{-1}m^2$)
10	18.42
15	18.29
20	18.29
25	18.26

Average K_R = 18. 32 $mGyhr^{-1}$ m^2

Table 11. Percentage difference between measured $k_{scatter}$ and $k_{scatter}$ = 1 using ionization chamber

Distance in cm	Measured $K_{scatter}$	% Deviation
10	1.021	2.1
15	0.997	-0.3
20	1.000	0.0
25	0.997	-0.3

Table 12. Percentage difference between measured $k_{scatter}$ and $k_{scatter}$ = 1using diodes.

Distance in c m	Measured $K_{scatter}$	% Deviation
5	1.404	40.4
10	1.053	5.3
15	1.020	2
20	1.000	0.0

Whereby, K_R is reference Air Kerma Rate defined by ICRU [1977, 1985, and 2001] as the Kerma rate to air, in air, at a reference distance of one meter, corrected for air attenuation and scattering. N_K is the air Kerma calibration factor of the ionization chamber at the actual photon energy. M_u is the measured charge collected during time t and corrected for ambient temperature pressure and recombination losses and transit effect in case of afterloading system. K_{air} is the correction for attenuation in air of the primary photons between source and the chamber.K_{scatt} is the correction for scattered radiation from the wall, floor measurement set-up, air etc. K_n is the non- uniformity correction factor, accounting for non - uniform electron flux within the air cavity. d is the measurement distance, i.e. the distance between the centre of the source and the centre of ionization chamber. d_{ref} is the reference distance of 1 m. The equation (Ezzel G. 1988) above gives the Air Kerma Rate of a day of measurement. In the case of another day the correction for decay is required. (Table 10-12)

DICUSSIONS

The reference distance between source to both Diodes and an Ion chamber was 20 cm. The charges were not collected at 5 cm using ion chamber because was not recommended in the protocol, given in IAEA report. The diodes were not recommended in determination of reference Air Kerma Rate. Therefore it was not used for determination of the air Kerma rate in this paper. The Diodes were just used to compare between the room scatter factors.

The difference of 2.1% higher was obtained when $K_{scatter}$ was measured and taken into account determination of air Kerma rate. The $K_{scatter}$ depends on the geometry set up of the source to chamber and immediate environment. In the Treatment Planning system (HDR basic 2.6) the Air Kerma Rate displayed in the day of Calibration was 18.6028 $mGyhr^{-1}$ m^2. Therefore, the value of Air Kerma rate from the TPS is higher by 1.52% compared with Measured Air Kerma Rate.

The Air Kerma Rate obtained using decay formula from the day source was commissioned was 18.60 $mGyhr^{-1}m^2$ it has an agreement with the one displayed in the Treatment Planning System within 0.015 % . Also the decayed Air Kerma rate higher than measured air Kerma Rate by 1.51 %. The treatment Planning System (HDR basic 2.6) is working correct since it has acceptable percentage difference with both measured Air Kerma Rate and Calculated air Kerma Rate from manufacturer. The K_{scater} if were not taken into account i.e$K_{scatter}$ = 1the discrepancy would rise to 1.91% higher than measured.

The values of $K_{scatter}$ obtained using Diodes at distances 10 cm, and 15 cm are higher than Ion chamber by 3.2% and 2.3 % respectively.

CONCLUSION

Physicists should determine the room scatter for their HDR room because the values published at the IAEA TECDOC 1274 depend on the local condition. $K_{scatter} = 1$ is discouraged because presence of scatter radiation. During in air calibration the JIG should be kept at the centre of the room to minimize scatter.

The collected readings must be corrected to the non uniformity (non-collimated geometry) factor. The ion chambers of different engineering diagram have different K_n values. Therefore medical Physicist must derive those factors and use them accordingly as indicated in IAEA report. The diodes are discouraged to be used in determination of room scatter because of poor sensitivity in the primary radiation. The ion chamber shows good sensitivity in the primary radiation.

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