THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Determination of Diagnostic X-Ray Quality Control Parameters in Some Selected Hospitals in Benue State-Nigeria

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Abstract:
This research work is aimed at determining the Quality Control and Status of diagnostic X-ray machines and to also ensure that a high Quality diagnostic image is produced with minimum radiation dose administered to the patients in all the X-ray units. The Quality Control Assessment of the diagnostic X-ray Machines were successfully carried out using Radiologic/Fluoroscopic kit, model Gammex 184D, in Some Radiological Departments in Benue State. Five X-ray machines in the radiology departments were monitored and the Hospitals were abbreviated as Hospitals H-1, H-2, H-5. Four Quality Control Test Tools were employed in this research work, and they include; Tube Potential (kVp) Accuracy, Tube output consistency, Tube Filtration (Half Value Layer) and Focal Spot Size. Tube output consistency test carried out on the five X-ray machines shows that only two X-ray machines are within the set gradient coefficient standard of 2.5 as recommended by National Centre for Devices and Radiological Health (NCDHR), tube potential(kVp) accuracy test indicates that most of the X-ray machines have values well beyond and below the recommended standard of ±5.0%as recommended by International Commission on Radiological Protection (ICRP). The measured tube filtration (half value layer) on the various machines are in good agreement with the recommended minimum value of 2.3mmAl at 80kVp except one of the machine which has a measured value of 0.82mmAl, and this could lead to overexposure of low level radiation to a patient. Finally, the focal spot sizes of the X-ray machines were within a range of 0.8mm to 1.5mm with magnification not more than 1.33 as recommended by FDA. This quality control tests are to ensure that exposure to radiation from X-ray machines is justified and optimized in keeping with the ALARA principle.

Keywords: *X-ray machines, dose optimization, diagnostic imaging, quality control.*

1. Introduction

In Nigeria, X-ray is the most frequently used ionizing radiation in medicine despite advances in magnetic resonance imaging and ultrasound techniques. It has maintained a key role in diagnosis of diseases, injury and in X-ray therapy. In effect it is the largest man-made source of ionizing radiation to the world population (UNSCEAR, 1993; Muhogora and Nyanda, 2001). X-ray is the major contributor to the effective dose of both the patient and the personnel. Because of the radiological risks involved, it is usually recommended that dose to patient from X-ray be kept as low as reasonable achievable (ALARA) with adequate image quality (IAEA, 1996). In addition, programmes for diagnostic imaging departments, regardless of the size should at least contain the following components: equipment quality control, administrative responsibilities, risk management and radiation safety programme. Equipment quality control unit carries out evaluation of equipment performance to ensure proper image quality, as well as patient and operator safety (Papp, 2002). Moreover, radiation safety unit is to ensure that patient exposure is kept as low as reasonably achievable and that departmental personnel, medical staff and members of the general public are protected from overexposure to ionizing radiation (Oluwafisoye*et al.*, 2010).

To reduce differences in the provision of radiographic imaging services around the world, the World Health Organization (WHO) since the 1970s has established a standard reference criteria for ascertaining equipment quality to provide basic radiography (IAEA, 2011).Since the 1950s the Pan American Health Organization (PAHO) has addressed the problem of effectiveness and safety in radiology departments in the Americans by performing national and regional surveys and by implementing quality assurance and quality control programs(Jimenez and Borrás,2006).

The establishment of a Quality Control Program (QCP) implies the implementation of a set of procedures for the regular and periodic testing of medical equipment and the evaluation of imaging quality to ensure the radio-diagnostic imaging process is in conformity with regulations (Gray*et al.*, 2008).

Without appropriate Quality Control (QC) measures for X-ray machines in place, the benefits of reduced dose to the patient and early diagnosis will not be realized. Quality control also makes it possible to unify X-ray-imaging practices in the country using international image quality guidelines. The impetus for this work resulted from the concern that with the current number of X-ray machines in Benue state that are not under any form of regulation, coupled with limited technical support to maintain and operate them, increased radiation risk to patients and lower diagnostic accuracy are very high. The aim of this work is to report on the current status of diagnostic X-ray machines in Benue state in order to produce the data needed to formulate QC policies and strategies. These policies and strategies are needed to ensure that patients receive the lowest possible radiation risk and maximum health benefits from X-ray examinations.

1.1. Study Area: Benue State

Benue State is located within the North Central Nigeria. Benue State lies between latitude $6^{0}25^{1}$N and $8^{0}8^{1}$N and longitudes $7^{0}47^{1}$E and 10^{0}E. It is surrounded by five (5) States, namely; Nasarawa to the North, Taraba to the Northeast, Cross River to the South, Ebonyi and Enugu to the Southeast and Kogi to the Southwest. The people of the State are predominantly farmers with a total population of over 6 million.

2. Materials and Method

The radiographic/fluoroscopic measurements were performed on five X-ray machines in five hospitals. The machines have three phase and single phase generators.

PTW Diavolt Universal kV meter was used to measure the "practical peak voltage" as well as kVp, radiation dose and irradiation time. Diavolt is a test device for quality control and acceptance testing in diagnostic radiology. It is used for non-invasive measurement of tube voltage of X-ray systems in the range 22kV to 150kV. It is also a diagnostic dosimeter for measurements of RQR qualities according to IEC 61674. Other materials used include Half Value Layer Attenuation set and Focal Spot Test Tool.

The measurement procedures for this study are explained below step by step.

In each of the measurements, a lead apron was placed on top of a radiographic table top with the centre in the approximate center of the table top. A dosimeter was used to avoid back-scatter radiation which can reduce the accuracy of the readings obtained. The X-ray beam was collimated when the central ray of the beam was centered to the dosimeter using an SID distance of 1m and a field size of 9×15.5cm.

2.1. Measurement Procedure for Tube Potential (kVp) Accuracy

This was performed between 40-102kVp keeping the mA constant, the dosimeter was reset to zero (cleared) after each exposure and five readings recorded which were used to determine the percentage error for the tube potential accuracy (kVp).

2.2. Measurement Procedure for Half Value Layer (HVL)

The Tube Filtration Half Value Layer (HVL) test was carried out by setting the aluminium filters (with purity of greater than 99%) with thickness range of 0.1 to 5.5mmAl. The mA and time for the initial measurement was chosen in order to obtain a full scale reading on the Diavolt meter with no aluminium attenuator in the beam. Additional measurements were taken with the same mA and time but with increasing thickness of aluminium attenuating sheets, positioned between the X-ray source and the Diavolt meter until the meter was reduced to halve of its value.

2.3. Measurement Procedure for Tube Output Consistency

The X-ray tube output was determined as the ratio of dose reading to the mAs setting (X-ray tube output). The values of X-ray tube output were plotted against kVp^2.

2.4. Measurement Procedure for Focal Spot Size

To obtain the focal spot size, the distance between the bar pattern and the tube focal spot was set at 46cm (18inches) for 4/3 magnification. The base tool was placed directly on the intensifying screen cassette and the tool positioned such that the printing and arrows on the label aligned with the long axis of the tube. By setting the Focal Film Distance (FFD) at 61cm (24inches) an exposure of approximately 10mAs and 80kVp was taken.

3. Results

3.1. Tube Potential (kVp) Accuracy for H-1 Stationary X-ray Machine

For H-1 this was performed between 50 to 102kVp with minimum percentage error of 1.4 at 90kVp and maximum percentage error of 4.9 at 102kVp as shown in Table 1. This implies that it is within the acceptable limit of ±5% recommended by ICRP, 2007.

3.1.1. kVp or Tube Potential Accuracy for H-2 Stationary X-ray Machine

The kVp accuracy was performed on 60, 65, 74 and 80 kVp for chest/elbow, skull, cervical/femur and pelvic exposures. The minimum percentage error was 10.6% at 80 kVp for pelvic exposure and the maximum percentage error was 16.5% at 60 kVp for chest/elbow exposure as shown in Table 2. This implies that it is highly above the acceptable limit of ±5% recommended by ICRP, 2007.

3.1.2. kVp or Tube Potential Accuracy for H-3 X-ray Machine

The kVp accuracy was performed on 44, 47, 50, 60 and 65 kVp for Leg, Chest (Lateral), Skull/Abdomen exposures. The minimum percentage error was 6.2% at 65 kVp for Skull/Abdomen exposure and the maximum percentage error was 13% at 44 kVp for Leg exposure as shown in Table 3. This implies that it is highly above the acceptable limit of ±5% recommended by ICRP, 2007.

3.1.3. kVp or Tube Potential Accuracy for H-4 X-ray Machine

The kVp accuracy was performed between 50 to 85 kVp for Chest, Pelvic and Skull exposures. The minimum percentage error was 1.3% at 60, 70 and 80 kVp for Chest/Pelvic and Skull exposures and the maximum percentage error was 5.3% at 85 kVp for Skull exposure as shown in Table 4. This implies that it is slightly above the acceptable limit of ±5% recommended by ICRP, 2007.

3.1.4. kVp or Tube Potential Accuracy for H-5 X-ray Machine

The kVp accuracy was performed between 50 to 85 kVp for Chest, Pelvic and Skull exposures. The minimum percentage error was -1.7% at 60 kVp for Skull exposure and the maximum percentage error was 16.0% at 50 kVp for Chest exposure as shown in Table 5. This implies that it is highly above the acceptable limit of ±5% recommended by ICRP, 2007.

3.2. Tube Output Consistency with kVp for H-1

This test was carried out at 50 to 102 kVp settings. Table 1 summarizes the results of this test. The plot of the Dose per unit mAs versus kVp^2 as shown in Figure1 was found to be linear (from origin) with a gradient of 0.0103 and R^2 = 0.9986. The plot of the log Dose per unit mAs versus log kVp as shown in figure (4.3) was found to be almost linear (but not from the origin) with the gradient of 2.0678 and R^2 = 0.9977, which are within the acceptable limit of 2 to 2.5 according to FDA (Food and Drug Administration).

3.2.1. Tube Output Consistency with kVp for H-2

This test was carried out by varying them as value between 8 to 32. This was performed between 44 to 65 kVp settings. Table 2 summarizes the results of this test. The plot of the Dose per unit mAs versus kVp^2 is as shown in Figure2 was found to be linear (from origin) with a gradient of 0.5249 and R^2 = 0.0288. The plot of the log Dose per unit mAs versus log kVp as shown in Figure.3 was found to be almost linear (but not from the origin) with the gradient of -0.4955 and R^2 = 0.0182, which are within the acceptable limit of 2 to 2.5

kVp	kVp^2	Log kVp	Dose (µGy)	Dose /mAs	Log Dose/mAs	
44	1936	1.64	171.0	10.69	1.03	
47	2209	1.67	240.2	12.01	1.08	
50	2500	1.70	101.0	4.04	0.61	
60	3600	1.78	149.2	4.66	0.67	
65	4225	1.81	149.2	4.66	0.67	
65	4225	1.81	149.2	18.65	1.27	

Table 1: Results of Tube output consistency with kVp

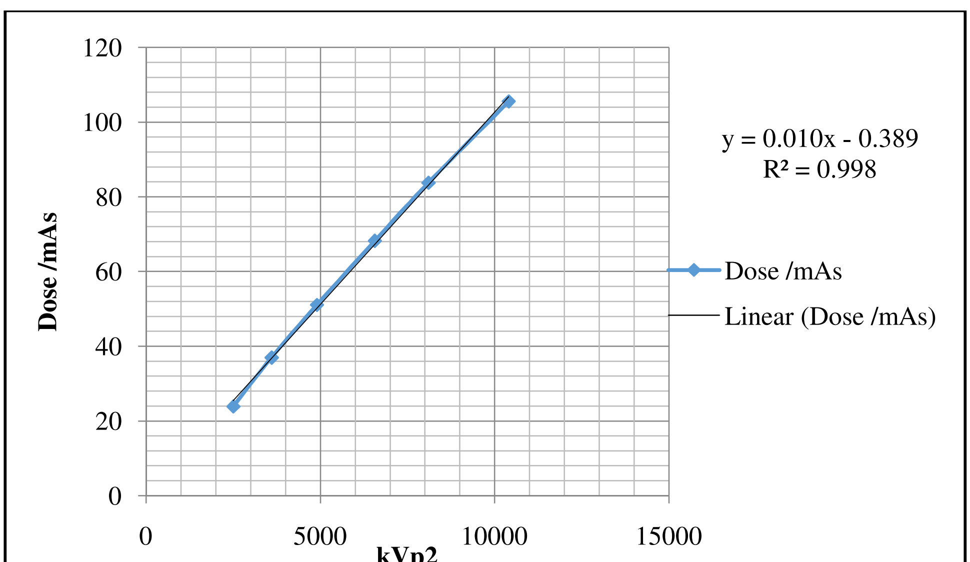

Figure 1: The relationship between kVp^2 and Dose per unit mAs

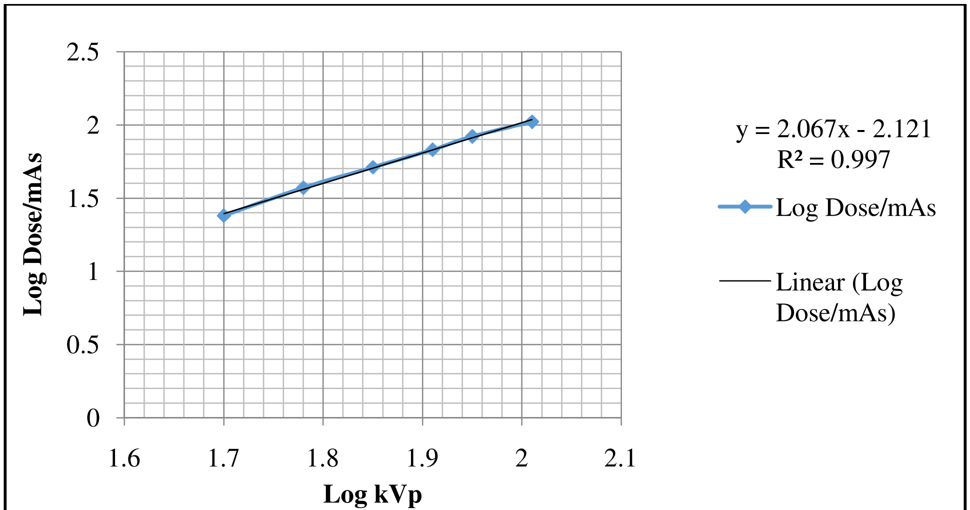

Figure 2: The relationship between log kVp^2 and log Dose per unit mAs

3.2.2. Tube Output Consistency with kVp for H-3

This was obtained by varying the mAs value of 4 to 20. This was performed between 50 to 85 kVp settings. Table 2 summarizes the results of this test. The plot of the Dose per unit mAs versus kVp^2 is as shown in Figure5 was found to be linear (from origin) with a gradient of 0.0007 and R^2 =0.6043. The plot of the log Dose per unit mAs versus log kVp as shown in Figure 6 was found to be almost linear (but not from the origin) with the gradient of 2.1424 and R^2 =0.5442 which are within the acceptable limit of 2 to 2.5

kVp	kVp^2	Log kVp	Dose (µGy)	Dose /mAs	Log Dose/mAs
50	2500	1.70	4.4	1.10	0.04
60	3600	1.78	11.0	1.83	0.26
70	4900	1.85	16.9	1.69	0.23
75	5625	1.88	23.0	1.77	0.25
80	6400	1.90	39.8	2.49	0.40
85	7225	1.9	106.4	5.32	0.73

Table 2: Results of Tube output consistency with kVp

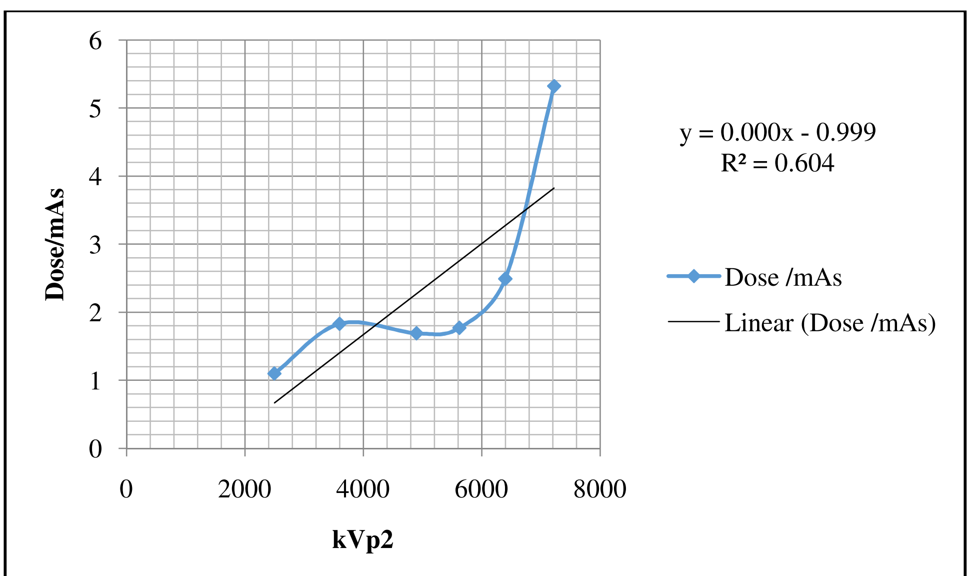

Figure 3: The relationship between kVp^2 and Dose per unit mAs

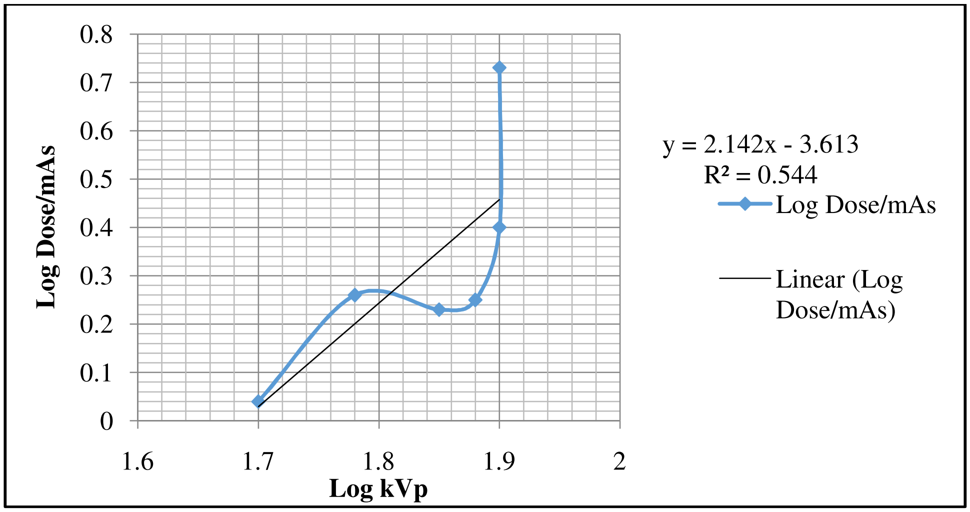

Figure 4: the relationship between log Dose/mAs and log kVp

3.2.3. Tube Output Consistency with kVp for H-4

This test was carried out by varying mAs value of 30 to 800, a field size of 9 × 15.5cm and a large focal spot. This was performed between 60 to 80 kVp settings. Table 4 summarizes the results of this test. The plot of the Dose per unit mAs versus kVp^2 is as shown in Figure7 was found to be linear (from origin) with a gradient of - 0.0013 and R^2 = 0.5404. The plot of the log Dose per unit mAs versus log kVp as shown in Figure8 was found to be almost linear with the gradient of -6.5667 and R^2 = 0.5169, which are within the acceptable limit of 2 to 2.5

kVp	kVp^2	Log kVp	Dose (µGy)	Dose /mAs	Log Dose/mAs
60	3600	1.78	457.0	3.80	0.58
65	4225	1.81	669.1	5.58	0.75
74	5476	1.87	991.5	4.13	0.62
80	6400	1.90	366.4	0.46	-0.34

Table 3: results of Tube output consistency with kVp

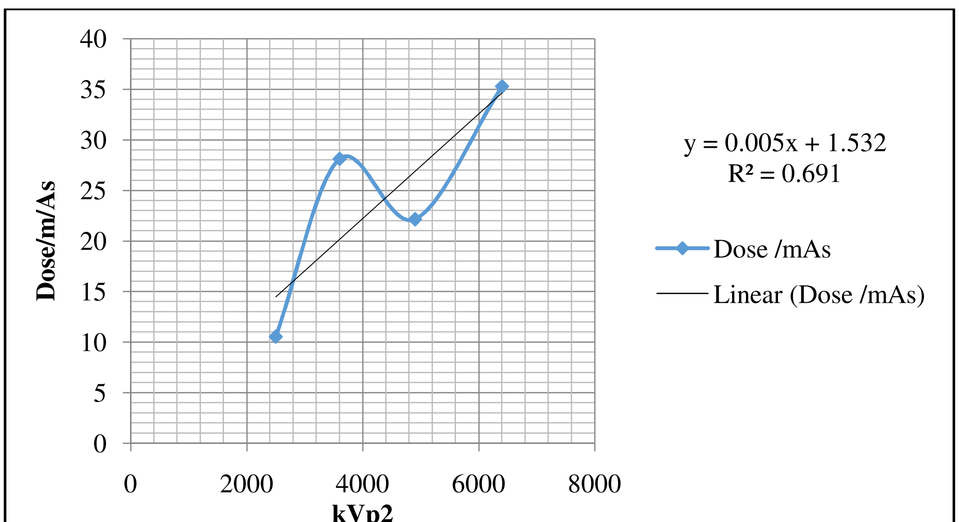

Figure 5: the relationship between Dose/mAs and kVp^2

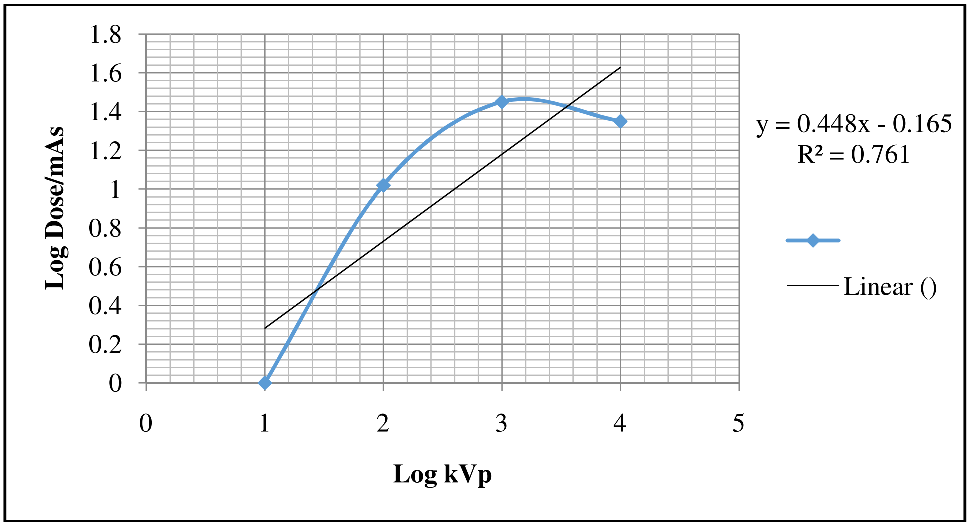

Figure 6: the relationship between log Dose/mAs and log kVp

3.2.4. Tube Output Consistency with kVp for H-5

This test was carried out by varying the mAs value of 4 to 20. This was performed between 50 to 85 kVp settings. Table 4 summarizes the results of this test. The plot of the Dose per unit mAs versus kVp^2 is as shown in Figure 9 was found to be linear (from origin) with a gradient of -0.0007 and R^2 = 0.0414. The plot of the log Dose per unit mAs versus log kVp as shown in Figure 10 was found to be almost linear with the gradient of -19.129 and R^2 = 0.08704 which are within the acceptable limit of 2 to 2.5

kVp	kVp^2	Log kVp	Dose (µGy)	Dose /mAs	Log Dose/mAs
50	2500	1.70	73.5	18.38	4.60
55	3025	1.74	120.5	24.10	4.82
60	3600	1.78	178.5	29.75	4.96
65	4225	1.81	207.8	25.98	3.25
70	4900	1.85	300.0	30.00	3.00
70	4900	1.85	251.4	25.14	2.51
75	5625	1.88	257.2	21.43	1.79
80	6400	1.90	490.4	30.65	1.92
75	5625	1.88	291.9	24.33	2.03
80	6400	1.90	273.4	17.09	1.07
85	7225	1.9	323.3	16.17	1.21

Table 4: Results of Tube output consistency with kVp

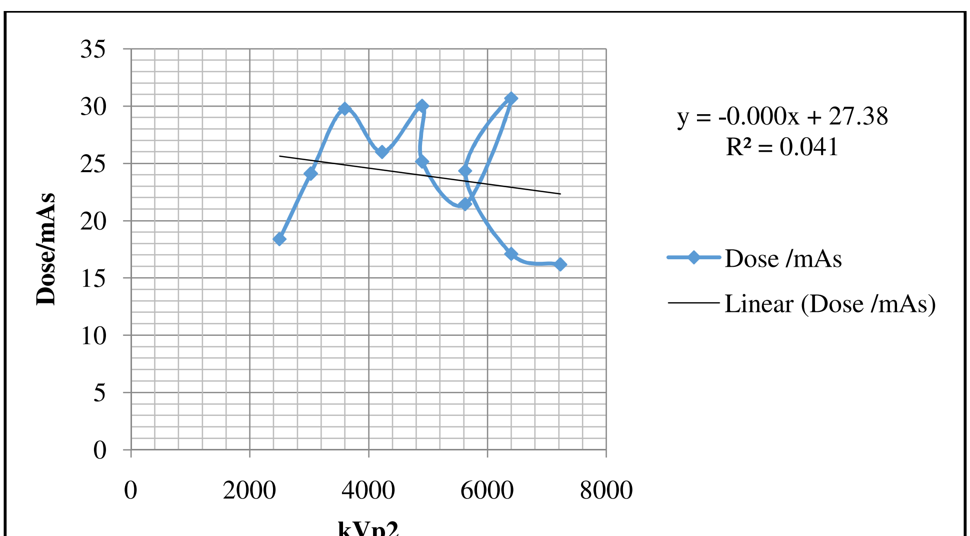

Figure 7: The relationship between kVp^2 and Dose per unit mAs

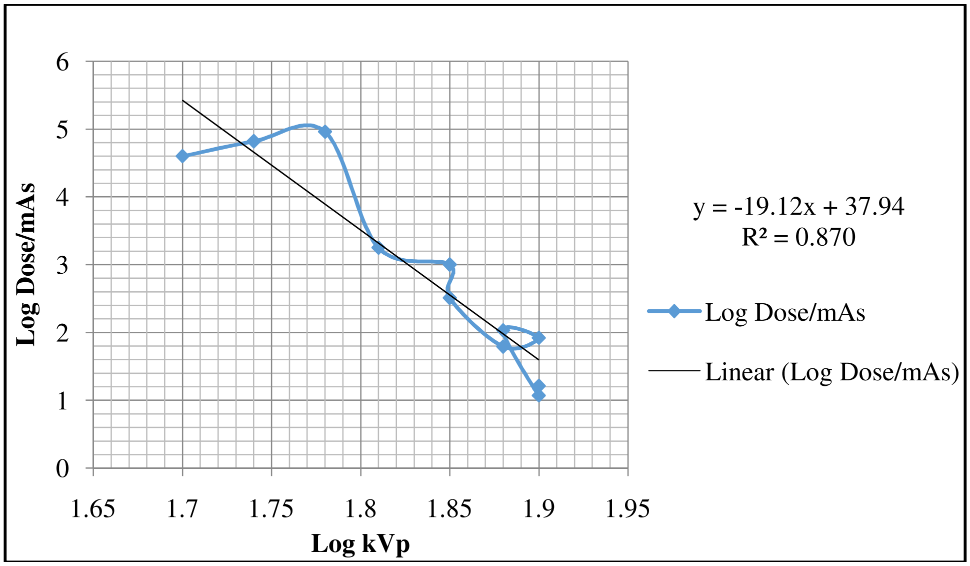

Figure 8: the relationship between log Dose/mAs and log kVp

3.3. Determination of tube filtration Using 80kVp and 20mAs (Half Value layer) at H-1

This test was carried out on a three-phase machine at 80kVp, 20mAs and a field size of 9 × 15.5cm, the parameters as shown in Table 5 were used to determine the Half Value Layer which was found graphically from Figure1 to be 4.7mmAl

S/N	Filter thickness (mmAl)	Input (ms)	Peak (kVp)	Maximum (kVp)	Mean (kVp)	Output (ms)	Dose (µGy)
1	0.00	32.4	88.3	89.2	89.2	33.2	405.6
2	1.00	32.4	89.1	90.3	90.3	32.9	334.3
3	2.00	32.4	90.0	91.1	91.2	33.2	297.3
4	3.00	32.4	85.5	86.1	86.1	32.9	262.2
5	4.00	32.4	85.9	87.0	87.0	32.6	228.1
6	5.00	32.4	86.2	86.6	86.7	33.2	200.8
7	5.50	32.4	86.4	86.8	86.9	32.6	188.2

Table 5: Determination of tube filtration using half value layer (HVL)

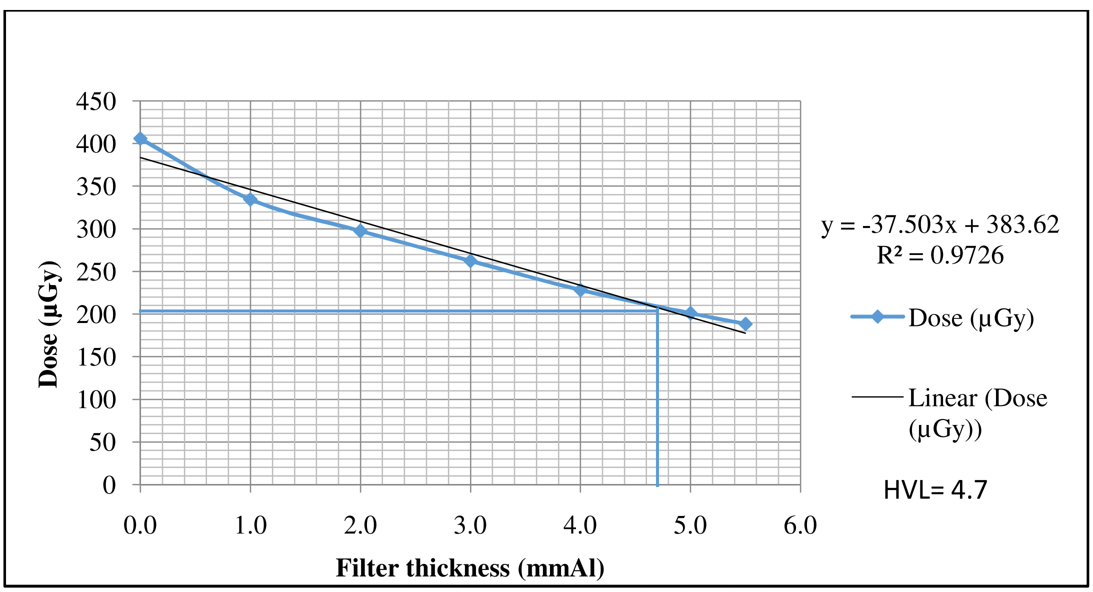

Figure 9: Relationship between Dose and Filter thickness at H-1

3.3.1. Determination of tube filtration using 80kVp and 50mAs (Half Value layer) at H-2

This test was carried out on a three-phase machine at 80kVp, 50mAs. The parameters as shown in Table 6 were used to determine the Half Value Layer which was found graphically from Fig 9 to be 2.9mmAl. The Half Value Layer which was found graphically from Fig. 10 to be 0.82mmAl

S/N	Filter thickness (mmAl)	Peak kVp	Maximum kVp	Mean kVp	Output ms	Dose (µGy)
1	0.0	84.2	89.0	88.6	997.5	188.8
2	1.0	84.7	88.3	88.1	994.4	87.9
3	1.5	84.7	89.2	89.3	999.3	130.3
4	2.0	84.0	88.8	88.3	994.1	147.1
5	2.5	84.2	88.8	88.6	994.7	138.4
6	3.0	84.3	89.2	88.6	1005.0	121.6
7	3.5	84.6	89.2	88.9	994.4	113.8
8	4.0	85.0	89.8	89.4	994.7	101.2
9	4.5	85.2	90.0	89.6	1005.0	93.2
10	5.0	87.9	93.3	92.8	994.7	96.0

Table 6: Determination of tube filtration using half value layer (HVL)

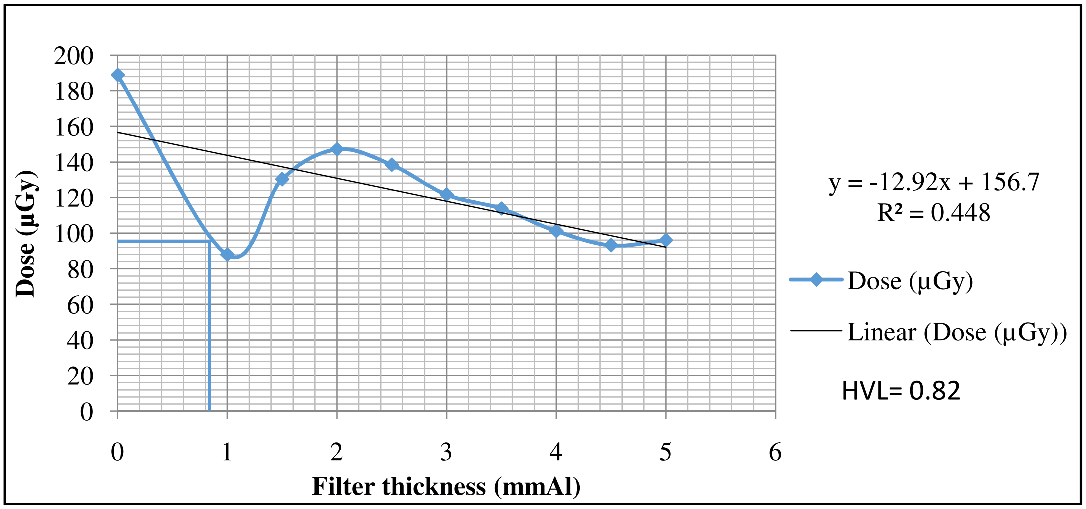

Figure 10: Relationship between Dose and Filter thickness at H-2

3.3.2. Determination of tube filtration using 80kVp and 50mAs (Half Value layer) at H-3

This test was carried out on a three-phase machine at80kVp, 20mAs as shown in Table 7 were used to determine the Half Value Layer which was found graphically from Fig 11

S/N	Filter thickness (mmAl)	Peak kVp	Maximum kVp	Mean kVp	Output ms	Dose (µGy)
1	0.0	81.5	85.1	84.2	708.1	3464
2	1.0	82.5	86.0	85.1	709.0	2603
3	1.5	82.9	86.9	85.6	711.5	2314
4	2.0	83.4	87.1	86.1	712.4	2075
5	2.5	83.9	87.8	86.6	713.4	1873
6	3.0	84.3	88.3	87.0	709.0	1739
7	3.5	84.7	88.9	87.6	713.0	1582
8	4.0	85.1	89.2	87.9	716.4	1445
9	4.5	85.6	89.9	88.6	716.7	1326
10	5.0	86.0	90.5	89.0	718.8	1220
11	5.5	86.5	90.8	89.5	703.4	1130

Table 7: Determination of tube filtration using ha) to be 3.7mmAl

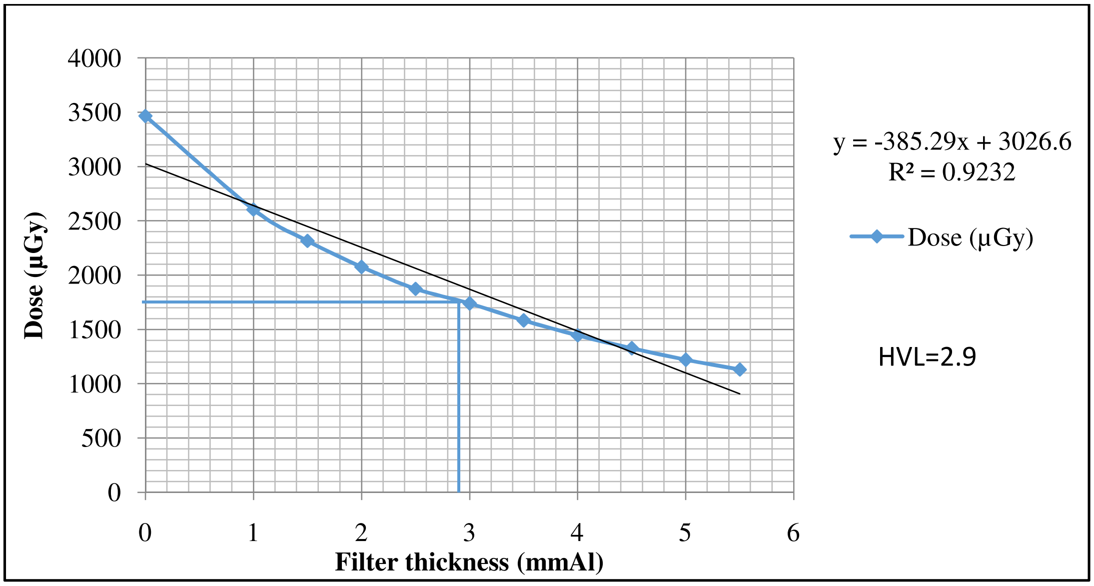

Figure 11: Relationship between Dose and Filter thickness at H-3

3.3.3. Determination of tube Filtration using 80kVp and 50mAs (Half Value layer) at H-4

This test was carried out on a three-phase machine at 80kVp, 50mAs as shown in Table 8 were used to determine the Half Value Layer which was found graphically from Fig.12 to be 0.82mmAl

S/N	Filter thickness (mmAl)	Peak kVp	Maximum kVp	Mean kVp	Output ms	Dose (µGy)
1	0.0	81.6	84.9	82.8	1343	2717
2	1.0	82.3	84.9	83.8	1342	2141
3	1.5	82.5	84.9	83.9	1341	1923
4	2.0	82.9	85.6	84.4	1342	1743
5	2.5	83.4	86.0	85.0	1340	1588
6	3.0	83.8	87.7	85.3	1339	1488
7	3.5	84.2	87.2	85.8	1339	1365
8	4.0	84.5	87.4	86.2	1345	1257
9	4.5	85.0	88.0	86.7	1335	1154
10	5.0	85.4	88.3	87.2	1337	1070
11	5.5	85.8	89.0	87.7	1334	993

Table 8: Determination of tube filtration using half value layer (HVL)

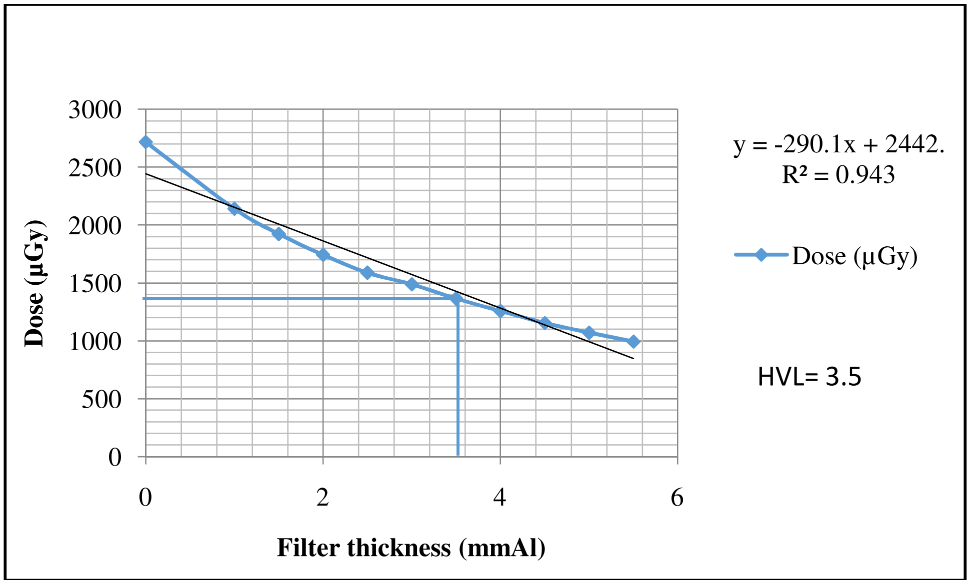

Figure 12: Relationship between Dose and Filter thickness at H-4 and 50mAs.

3.3.4. Determination of tube filtration using 80kVp at H-5

This test was carried out on a three-phase machine at 80kVp and 50mAs parameters as shown in Table 9 were used to determine the Half Value Layer which was found graphically from fig. 3.3.5 to be 3.5mmAl

S/N	Filter thickness (mmAl)	Peak kVp	MaxkVp	Mean kVp	mAs	Output ms	Dose (µGy)
1	0.0	82.5	86.3	88.3	346.2		64.8
2	1.0	82.2	87.8	87.9	343.4		53.6
3	2.0	85.5	91.7	91.7	335.8		45.9
4	3.0	83.0	89.9	89.9	347.8		82.7
5	4.0	83.2	90.7	90.7	306.3		9.5
6	5.0	76.3	82.4	82.5	214.1		15.4

Table 9: Determination of tube filtration using half value layer (HVL)

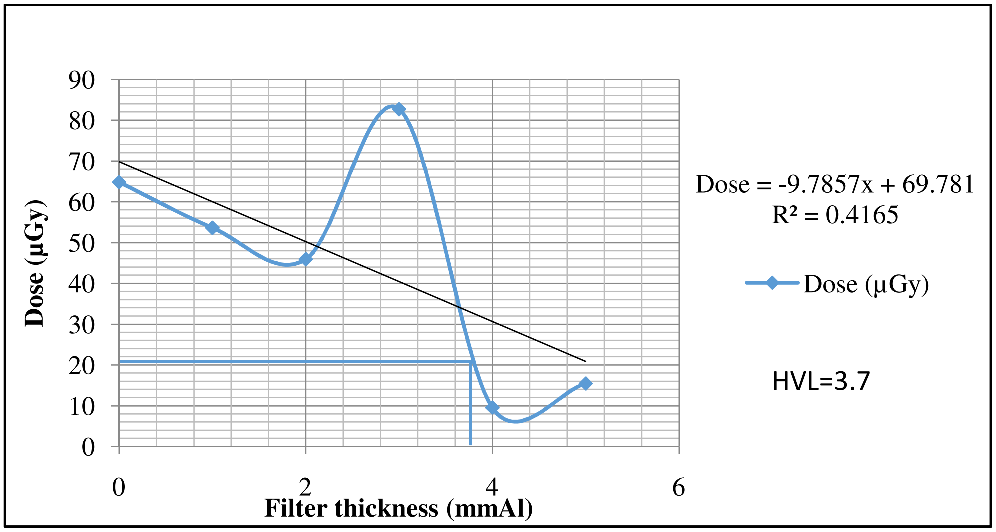

Figure 13: Relationship between Dose and filter thickness at H-5.

3.4. Focal Spot Test for H-1

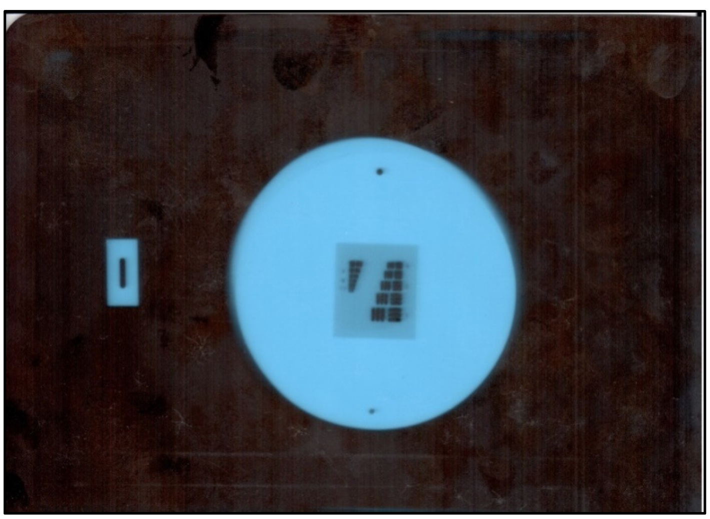

Figure 14

$$f_s = \frac{M}{M-1.0} \cdot \frac{1}{(lp/mm)} \quad \ldots\ldots (3.1)$$

Where; f_s = focal spot

M = magnification

lp = line pair

mm = millimeter

$$M = \frac{imagedistance}{objectdistance} = \frac{S}{D}$$

$$M = \frac{77}{60} = 1.28$$

Where; FFD = Film Focal Distance

D = distance between the holes on test tool = 6cm = 60mm

S = distance between the centers of pixels of the two holes on the film = 7.7cm = 77mm

The smallest group resolved using the focal spot test tool 112B which consist of a metal target with 12 bar pattern was 12 bars from the exposed film at radiographic parameters of 80kVp, 10mAs, 61 FFD and a field size of 10 × 12inches. The measured line pairs/mm ranges from 0.85 to 5.70mm with a calculated dimension of the effective focal spot of 5.4 to 0.8mm. The magnification of the X-ray machine was found to be 1.28.

Group resolved	Line pair/mm of group	Dimension of effective focal spot size (mm)
1	0.85	5.4
2	0.90	5.1
3	1.00	4.6
4	1.50	3.1
5	1.85	2.5
6	1.95	2.4
7	2.00	2.3
8	2.50	1.8
9	3.50	1.3
10	3.59	1.3
11	4.00	1.2
12	5.70	0.8

Table 10: Determination of focal spot sizes at H-1

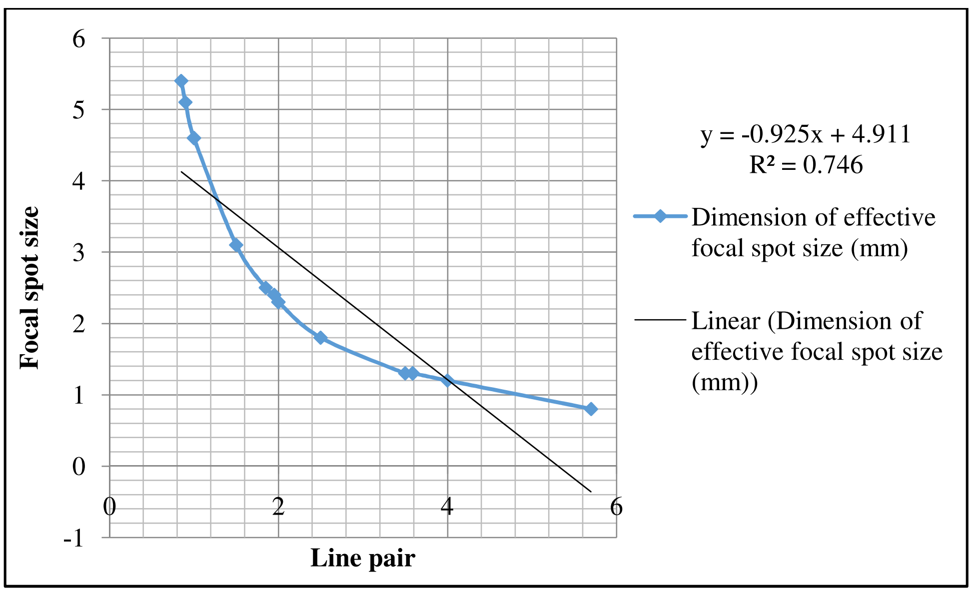

Figure 15: Focal spot size against line pair

Focal spot Test at H-2

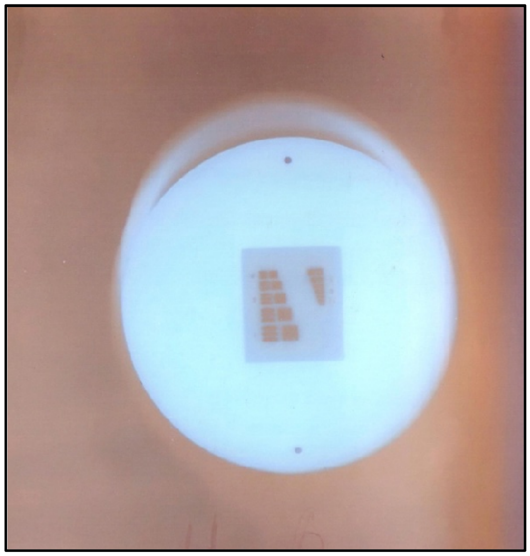

Figure 16: Focal Spot Test film at H-2

$$M = \frac{72}{60} = 1.2$$

S = 7.2cm = 72mm

The measured line pairs/mm ranges from 0.40 to 3.90mm with a calculated dimension of the effective focal spot of 15.0 to 1.5mm. The magnification of the X-ray machine was found to be 1.2

Group resolved	Line pair/mm of group	Dimension of effective focal spot size (mm)
1	0.40	15.0
2	0.50	12.0
3	0.70	8.6
4	0.90	6.7
5	1.00	6.0
6	1.20	5.0
7	1.50	4.0
8	1.90	3.2
9	2.00	3.0
10	2.90	2.1
11	3.10	1.9
12	3.90	1.5

Table 11: Determination of focal spot sizes at H-4 X-ray machine

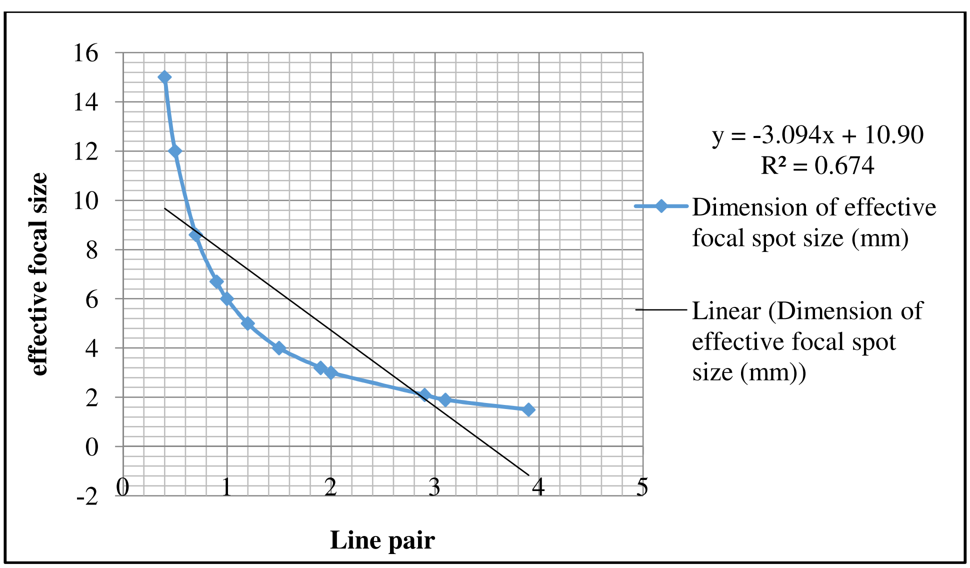

Figure 17: Effective focal spot size against line pair

Focal Spot Test at H-3

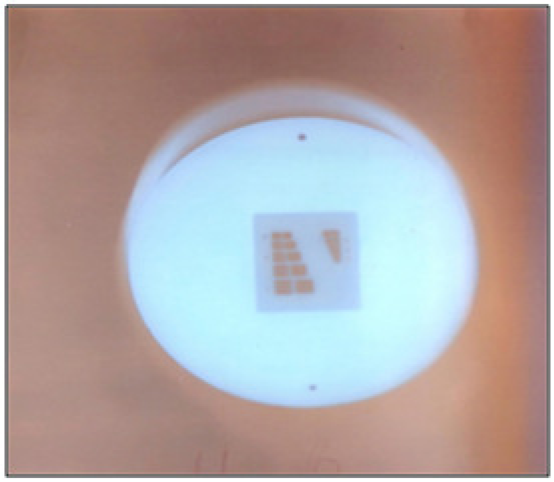

Figure 18: Focal Spot Test film at H-3

$$M = \frac{72}{60} = 1.2$$

S = 7.2cm = 72mm. The measured line pairs/mm ranges from 0.40 to 3.90mm with a calculated dimension of the effective focal spot of 15.0 to 1.5mm. The magnification of the X-ray machine was found to be 1.2

Group resolved	Line pair/mm of group	Dimension of effective focal spot size (mm)
1	0.40	15.0
2	0.50	12.0
3	0.70	8.6
4	0.90	6.7
5	1.00	6.0
6	1.20	5.0
7	1.50	4.0
8	1.90	3.2
9	2.00	3.0
10	2.90	2.1
11	3.10	1.9
12	3.90	1.5

Table 12: Determination of focal spot sizes at H-3 X-ray machine

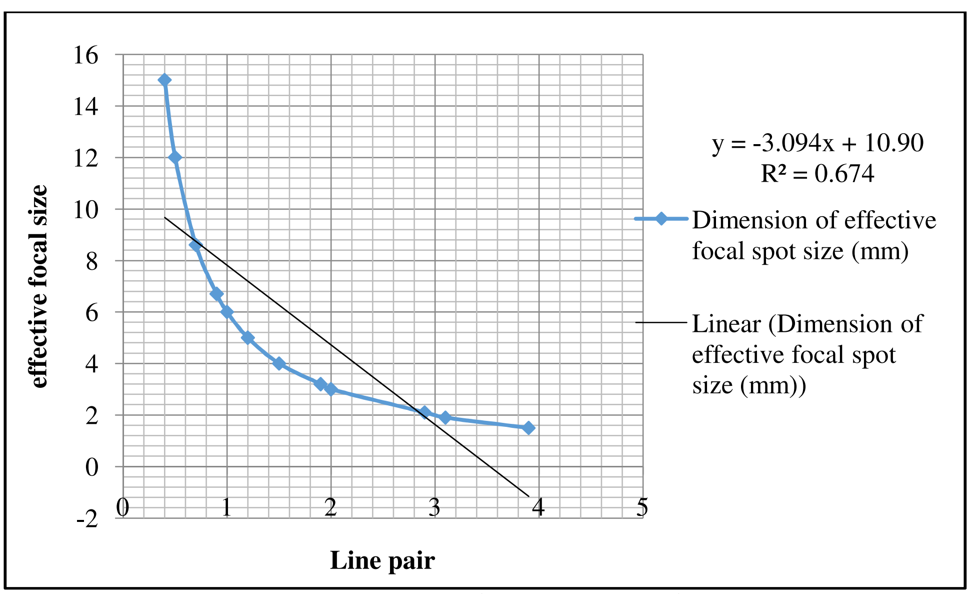

Figure 19: Effective focal spot size against line pair

Focal Spot Test at H-4

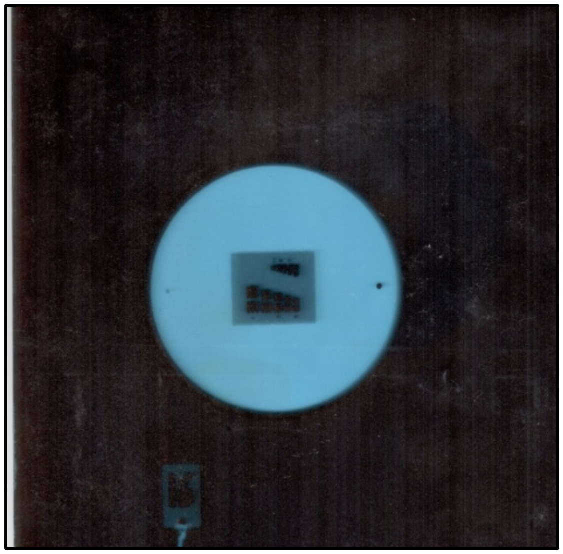

Figure 20: Focal Spot Test film

The measured magnification, M, was

$$M = \frac{75}{60} = 1.25$$

Where S at H-3 was measured to be 7.5cm = 75mm

The measured line pairs/mm ranges from 0.50 to 4.30mm with a calculated dimension of the effective focal spot of 10.0 to 1.2mm. The magnification of the x-ray machine was found to be 1.25. The measured line pairs/mm ranges from 0.50 to 4.00mm with a calculated dimension of the effective focal spot of 12 to 1.5mm. The magnification of the X-ray machine was found to be 1.2

Group resolved	Line pair/mm of group	Dimension of effective focal spot size (mm)
1	0.50	12
2	0.70	8.6
3	0.90	6.7
4	1.00	6.0
5	1.10	5.5
6	1.50	4.0
7	1.90	3.2
8	2.00	3.0
9	2.10	2.9
10	3.00	2.0
11	3.10	1.9
12	4.00	1.5

Table 13: Determination of focal spot sizes at H-7 X-ray machine

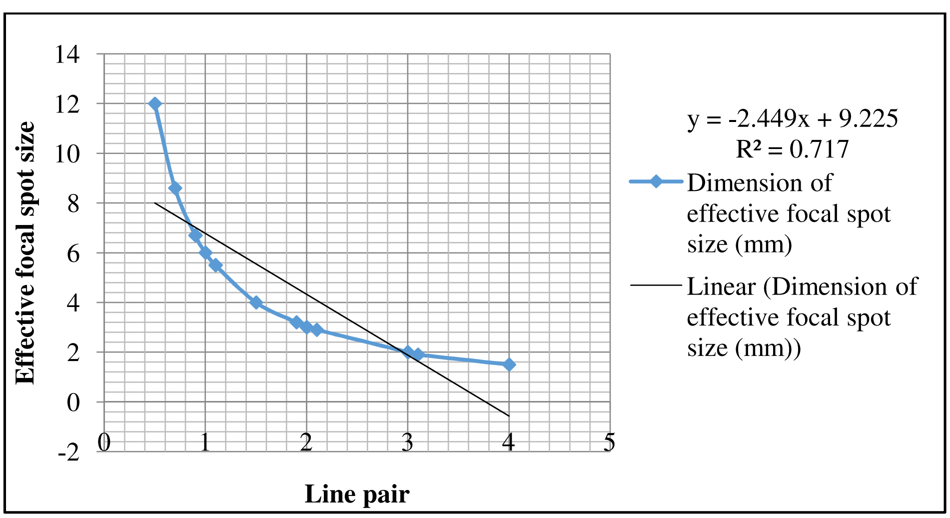

Figure 21: Effective focal spot size against line pair

Focal Spot Test at H-5

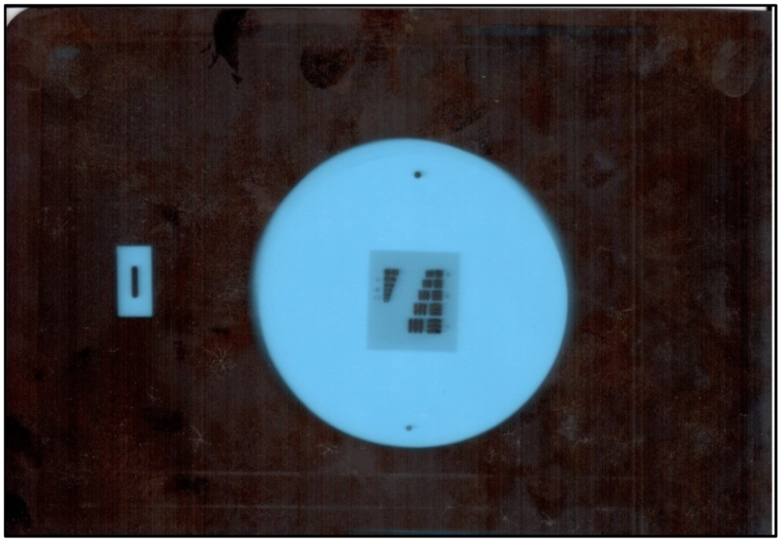

Figure 22: Focal Spot Test film

The measured magnification, M, was

$$M = \frac{75}{60} = 1.25$$

Where S at H-4 was measured to be 7.2cm = 72mm

The measured line pairs/mm ranges from 0.50 to 4.30mm with a calculated dimension of the effective focal spot of 10.0 to 1.2mm. The magnification of the x-ray machine was found to be 1.25

Group resolved	Line pair/mm of group	Dimension of effective focal spot size (mm)
1	0.50	10.0
2	0.70	7.1
3	0.90	5.6
4	1.10	4.5
5	1.18	4.2
6	2.00	2.5
7	2.60	1.9
8	2.80	1.8
9	3.00	1.7
10	3.60	1.4
11	4.30	1.2

Table 14: Determination of focal spot sizes at H-6 X-ray machine

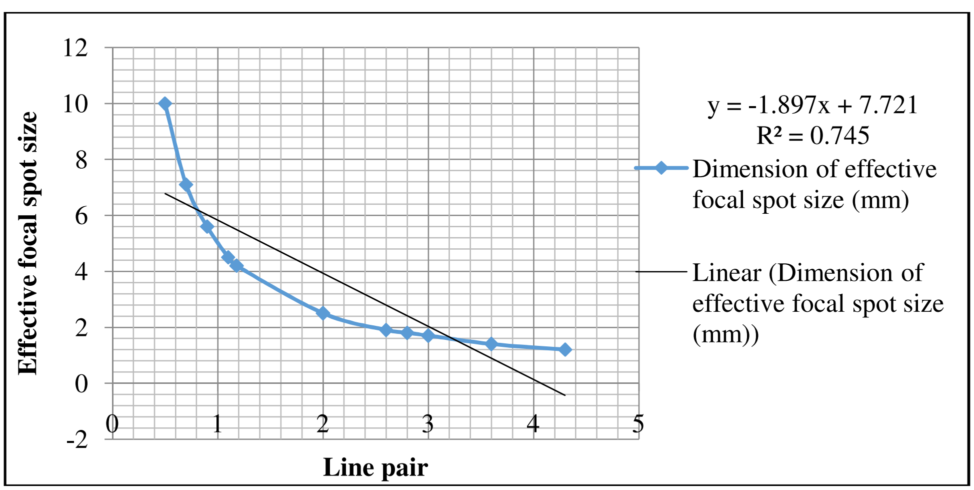

Figure 23: Effective Focal Spot size against line pair

3.5. Discussion

The result of this research work shows that the X-ray Machine Tube potential accuracy at H-1 has a minimum value of 1.4% at 90kVp and a maximum value of 4.9% at 102kVp which is within the ±5% ICRP (2007) recommendation for the safe exposure of patients. For H-2 the tube potential accuracy test gives a minimum value of 10.6% at 80kVp and a maximum value of 16.5% at 60kVp and this result fall outside the safety limit of ±5% and could pose as hazard to patients by adding to photon absorption. At H-3 the tube potential accuracy has a minimum value of 6.2% at 65kVp and a maximum of 13% at 44kVp and can also be seen to add to patient photon absorption. At H-4 the tube potential accuracy is within the acceptable safety standard with a minimum value of 1.3% at 80kVp and maximum value of 5.3% at 85kVp. For H-5 the machine tube potential accuracy has a minimum value of 1.7% at 60kVp and maximum value of 16.0% at 50kVp which also fall outside the acceptable safety standard.

Tube consistency test on the various values shows that H-1 has a gradient coefficient of 2.0678, H-2 with -0.0013, H-3 with -0.4955, H-4 with -19.125, thus only H-1 has a measured coefficient consistency within the safety limit of 2 to 2.5 and coefficient outside this limit could lead to poor image of the X-ray film.

The measured Half-value layer for H-1 was 4.7mmAl which shows that the machine is in good form since this value is more than the minimum half value standard of 2.3mmAl as recommended by FDA and NCRP. For H-2 the machine half value layer was 0.82mmAl which means that most of the soft x-rays will pass through the filters and contribute to patient dose and also affect the image quality. The half value layers at H-3, H-4 and H-5 are 2.9mmAl, 3.5mmAl and 3.7mmAl respectively which are all in good agreement with the safety standard.

The image focal spot at H-1 was 0.8mm with image magnification of 1.28, at H-2 it was 1.3mm with magnification of 1.25, at H-3 it was 1.9 with magnification of 1.2 and finally at H-5 it has a value of 1.5mm with magnification of 1.2, thus all the machines has magnifications not exceeding the upper limit of 1.33 as recommended by Radiological Medical Imaging (RMI). Since magnification beyond this could lead to increase in focal spot blurring and thus altered the image geometry.

4. Conclusion

This work has shown that none of the diagnostic X-ray machines passed the four quality control test, although H-1 had the best result out of all the machines monitored. It can thus be said that most of this machines could contribute to increased photon absorption by patients and also produce X-ray films with poor image quality. This situation may lead to wrong diagnosis of ailment or disease condition ad have wrong treatment could be advanced.

5. References

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