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# Comparative Study of Radiation dose measurement around $^{192}Ir$ Source with manual calculation

Dissertation submitted in partial fulfillment for Degree of Bachelor of Health Science in Medical Radiation

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2004

# CERTIFICATE

This is to certify that the dissertation entitled

"Radiation dose measurement with manual calculation, LiF Thermoluminescence and Gafchromic film around a $^{192}Ir$ brachytherapy source, using vaginal cylinder-applicator"

Is the bonafide record of research work done by Nazifah binti Abdullah

During the period from to December to March

Under my supervision.

Signature of Supervisor:

Assoct Prof. Dr Ahmad Zakaria

School of Health Sciences

University Science Malaysia

Date: 29/4/04

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# ABSTRACT

The purpose this study is to measure dose around an HDR $^{192}Ir$ source in a vaginal-applicator. The dosimeters used were gafchromic film, and LiF Thermoluminescent dosimeter (TLD 100 chip). The manual calculation was carried out to compare the results with measurement.

Gafchromic film was calibrating using 6MV photon beam, to obtain the relationship between absorbed dose and film response. In this study gafchromic film and LiF Thermoluminescent was setup in three different configurations. The remote after loading machines was programmed to send the source ($^{192}Ir$) move through a cylinder to the programmed position and dwell time.

The results showed that the manual calculation was higher than TLD and film dosimeter.

# INTRODUCTION

Radiation dosimeter is a process whereby a reading is recorded through interactions of the incident radiation with matter causing a measurable change in its properties. Radiation dosimeters for industrial and medical purposes have steadily evolved over the last few decades with the introduction of various new detectors. Many different detectors have their niche areas of applications depending on the qualities for radiation dosimeters they exhibit. For brachytherapy intracavitary treatment, dosimeter radiation source can be measured with LiF Thermoluminescent dosimeter and gafchromic film.

The most commonly used thermoluminescent material is lithium – fluoride. Lithium fluoride is suitable for measurement in nuclear medicine because of its capability to absorb radiation in the same way as tissue. For this reason it is called tissue equivalent (1). Thermoluminescent is available in reusable rods, chips, and maybe used in vivo and in anthropomorphic phantom studies (2). Thermoluminescent dosimeter is widely used in daily clinical practice.

Thermoluminescent (TL) dosimeters are also of interest because of their following advantages (3): i) wide useful dose range, ii) small physical size, iii) does not require high voltage or cables,

***Thermoluminescent*** (TL) is a phenomenon by which certain crystals are able to store energy transmitted to them by radiation and then emit energy in the form of visible light when heated. In 1953 it was proposed that thermoluminescent can be used as a radiation detector. As a dosimeter, a TL material must have relatively strong light output and able to retain trapped electrons for reasonable periods of time at temperature encountered in environment.

Some thermoluminescent material does not require the addition of an activator but rely instead upon inherent impurities and defects in the natural crystal. A simple model (see figure 1) can be used to explain the thermoluminescent process.

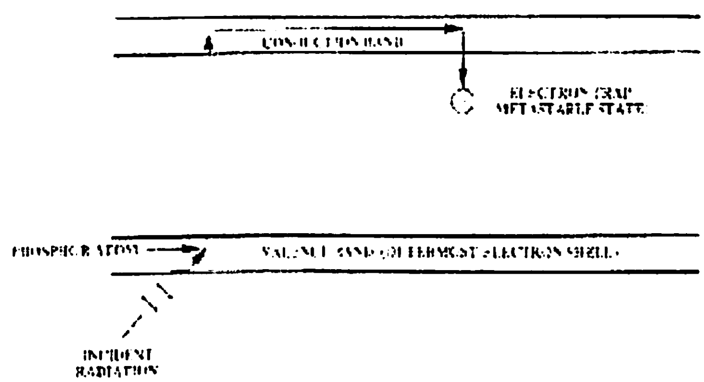


Figure a. When a crystal is exposed to ionizing radiation, electrons are excited from the valence band into conduction band.

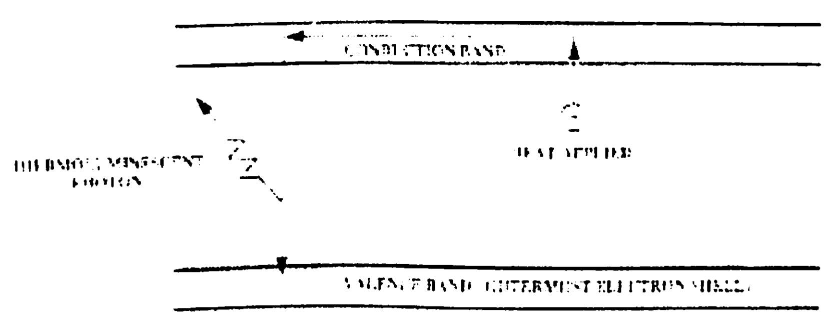


Figure b. In most materials, this energy is given up as heat in the surrounding material, however, in some materials a portion of energy is emitted as light photons.

Figure 1 (a-b). Thermoluminescent process

The highest filled band is called the valence band and is separated by several electron volts from the lowest unfilled band called the conduction band. When a crystal is exposed to ionizing radiation electrons are excited from the valence band into the conduction band, leaving a vacancy in the valence band called a hole. The electron and hole are free to wander independently throughout their respective bands. The presence of lattice defects or impurities gives rise to discrete local energy levels within the forbidden region between the valence and conduction bands. These discrete energy levels trap electrons which on subsequent heating and recombination causes thermoluminescent.

The energy gap between the valence and conduction bands determines the temperature required to release the electron and produce the thermoluminescent and is characteristic of the material used. Usually, many trapped electrons and holes are produced. As the temperature of the crystal is increased, the probability of releasing an electron from a trap is increased, so the emitted light will be weak at low temperatures, pass through one or more maxima at higher temperatures, and decrease again to zero as no more electron-filled traps remain.

Gafchromic film has been established as accurate detecting system for measuring the dose around brachytherapy source. Gafchromic film has good spatial resolution, and high sensitivity radiochromic film has been found to be useful (4, 5), gafchromic film effect involves the direct colouration of a material by the absorption of energetic radiation, without requiring latent chemical, optical or thermal development or amplification (6). Radiochromic reactions were first observed and recorded by Niepce in 1826. This observation involved an unsaturated hydrocarbon polymeric mixture based on bitumen that cross-linked upon irradiation, which left a light scattering pattern (7).

When gafchromic film is exposed to ionizing radiation, colouration occurs. This colouration is due to an attenuation of some of the visible light coming through the developed film, resulting in a 'greying' of its appearance. The reduction in light passing through the film is a measure of its 'blackness' or 'optical density' (OD). A pivotal assumption in film dosimeter is that the dose to the film is reflected in the resulting optical density of that film. This relationship can be expressed as follows:

$$\text{Optical density} = \log_{10} [I_0 / I]$$

Where $I_0$ is the light intensity with no film present and I is the light intensity after passing through the film. Note that since $I_0/I$ have an exponential relationship to the dose, the optical density is appropriately linear with dose.

Gafchromic film based on polydiacetylene has been introduced for medical applications (see figure 2). The film consists of a thin microcrystalline monomeric dispersion coated on flexible polyester film base. The film is clearing (translucent) before it is irradiated. It turns progressively blue upon exposure to radiation.

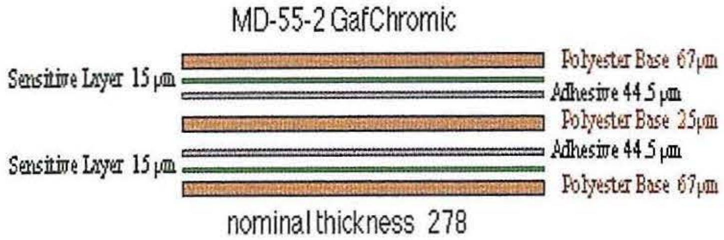



Figure 2.MD-55-2 Gafchromic Film™ is composed of a highly uniform transparent coating, sensitive to ionizing radiation. The two thin radiosensitive layers are made of colourless organic microcrystals of a radiation-sensitive monomer uniformly dispersed in a gelatin binder on a polyester base.

# OBJECTIVE OF THE STUDY

4.1 To measure the dose around an HDR $^{192}$ Ir source in a vaginal-applicator using LiF Thermoluminescent and gafchromic film.

4.2 To compare the data from measurement with the calculated value.

# MATERIALS

4.1 Radioactive source

The source used in this study was $^{192}Ir$. The cylinder active $^{192}Ir$ has a length 3.5mm and 0.6mm in diameter. It is encapsulated in AISI 316L stainless steel sheath with an outer length of 5.0mm, and 1.1 mm in diameter (see figure 3).

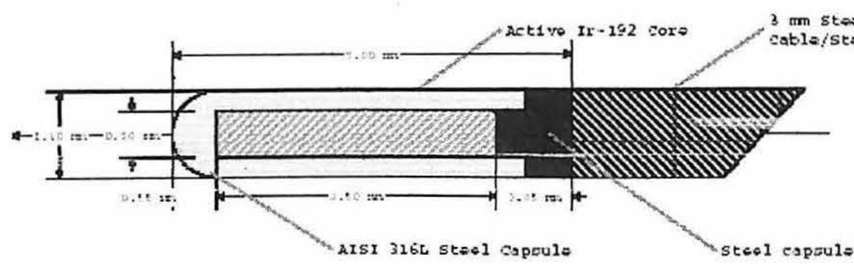



Figure 3 .Schematic diagram of the radioactive source.

4.2 Vaginal cylinder

The length vaginal cylinder was 10 cm, and diameter was 1.0 cm (see figure 4).

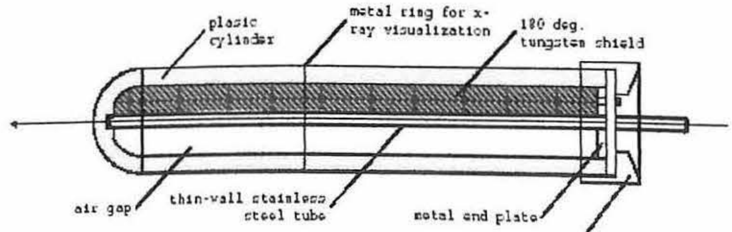



Figure 4. Schematic diagram of the vaginal cylinder

4.3 LiF Thermoluminescent dosimeter

Size of TLD-100 chip is 3.1mm x 3.1mm x 0.89mm (see figure 5)


Figure 5. LiF Thermoluminescent dosimeter

4.4 Gafchromic film

Type of gafchromic film used in this study was MD-55 II, model number 37-041, Lat # 970116 (see figure 6).


Figure 6. Model gafchromic film

4.5 Formula manual calculation

Using the traditional formalism, the dose rate at point with coordinate (r,ɵ), $D_r$ (r,ɵ) can be expressed as:

**$Dr(r,ɵ) = S_k .t. (\mu/p)_{tissue,air} . F(r,ɵ). T(r)$**

**$S_k$**

Air kerma Strength ($cGyh^{-1}$ $cm^2$) is a measure of brachytherapy source strength which is specified in terms of air kerma rate at the point along the transverse axis of the source in free space.

**t**

Time of exposure

**$(\mu/p)_{tissue, air}$**

Ratio of the mass energy absorption coefficient of tissue to that of air, where

$(\mu/p)_{tissue,air} = (\mu/p)_{tissue} / (\mu/p)_{air}$

**F(r,ɵ)**

The angular anisotropy function accounts for the anisotropy of the dose distribution around the source including the effects of the absorption and scatter in the medium. Value depend of angle (see table I at appendix), and the function value on the transverse axis, F ($r,90^0$), is define as 1 for all r values.

**T(r)**

Tissue attenuation function, accounts absorption and scatter in tissue along the transverse axis. For medium or low energy isotope, T(r) also depends on the filtering of the radiation through the source encapsulation (see table 2 at appendix).

# METHODS

5.1 Calibration film

The gafchromic film was cut to small pieces, 1.8 cm square (see figure 7). The film were placed 1.5 cm from the surface (at $d_{max}$) uses solid water phantom, which was large enough to create full scatter condition. The solid water phantom size is 30 x 30 x 1cm and was clamped together. Films was calibrated using 6MV photon were made at 100 SSD, field size 10cm x 10cm (see figure 8).

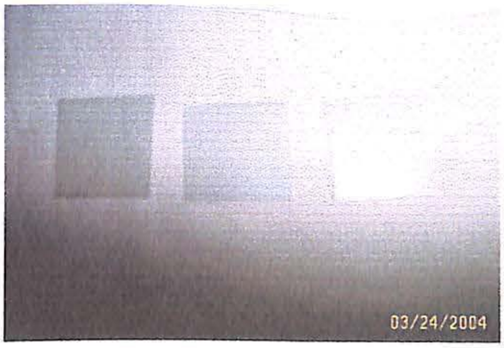
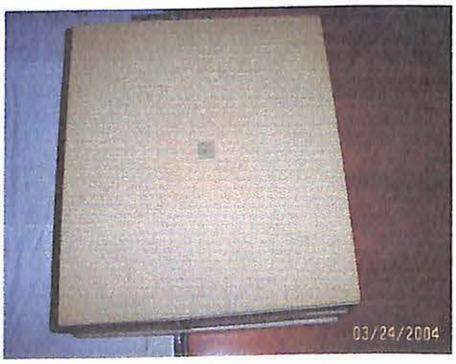



Figure 7. Small pieces of gafchromic film



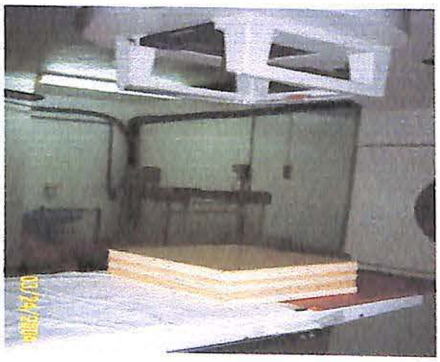



Figure a. Gafchromic film at middle Solid water phantom

Figure b. Calibrate at100 SSD, field size 10cm x 10cm

Figure 8 (a-b).Set up gafchromic film for calibration film

Film was irradiated to a photon dose in range 1Gy – 35Gy. Before the film was irradiated, the reading OD for every film was taken, it is important to determine fog value for every film before its expose to radiation. When gafchromic film is exposed to ionizing radiation, colourations occurs (8), this colourations is due to an attenuation of some visible light coming through develop film, resulting in a graying of its appearance (see figure 9)

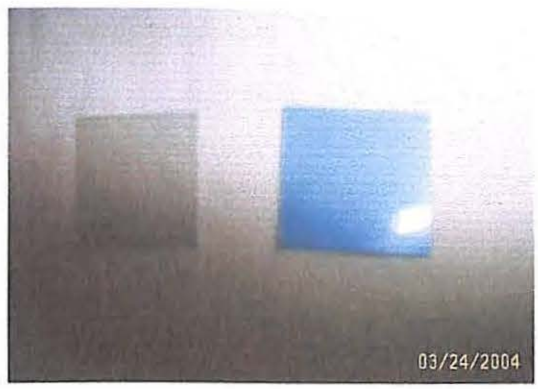



Figure 9.Coloration occurs when gafchromic film exposed to radiation.

After irradiate film, optical density (OD) of the film was measured uses densitometer. This instrument (densitometer) consists of light source, a tiny aperture through which the light is directed and a light detector (photocell) to measure the light intensity transmitted through the film. After get complete result (see table 3), graph optical density (OD) versus dose of photon was plotted (see graph 1 and 2) and lastly get equation for relationship between optical densities with dose of photon.

5.2 Experimental set up gafchromic film and TLD at cylinder

The film strip and TLD were placed 1 cm to either side of the catheter, different type of condition were performed to measure dose at point A, B and C. In setup 1($90^0$ from source), small pieces of film, 1.8 cm square and TLD were placed at point A between catheter.

The source was placed in 8 positions (at point A) with step size of 5.0mm, source placed $90^0$ under the gafchromic film and TLD (see figure 10), and exposed to radiation of $^{192}Ir$ for a prescribed amount of time.

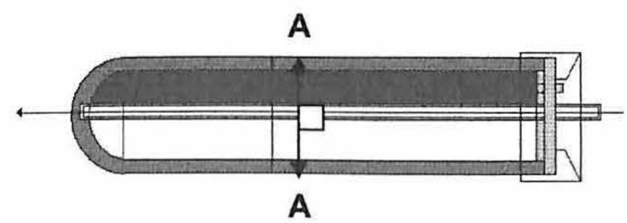



Figure 10. Set up 1, gafchromic film and TLD $90^0$ from source

In set up 2, gafchromic film and TLD were placed at 3 point (point A, B, C). The source was placed in 12 positions with step size 5.0mm, (see figure 11), gafchromic film and TLD, exposed to radiation of $^{192}Ir$ for a prescribed amount of time.

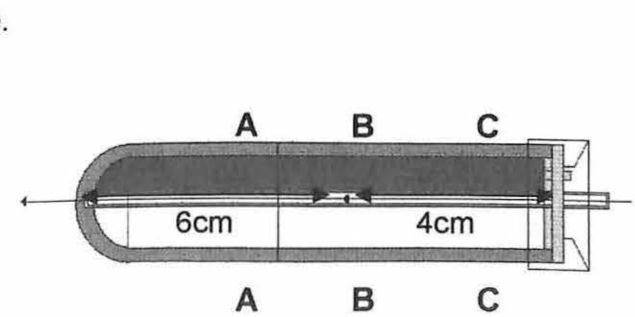



Figure 11.Set up 2, gafchromic film and TLD have certain angle from source

In set up 3, gafchromic film and TLD were still placed at 3 point (see figure 12), and exposed for a prescribed amount of time, but source move at 3 positions at different time (position 8, 12, 18).

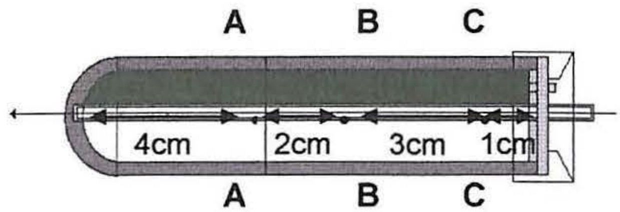



Figure 12.Set up 3, gafchromic film and TLD have certain angle from source

After experimental set up gafchromic film and TLD, the applicator will then be inserted and connected to the treatment machine (see figure 13), and machine will send the radiation source through the tube and into the applicator. The radiation source ($^{192}$Ir) passed through the tube and into the applicator by a computer-controlled machine. The treatment detail will be printed out on paper containing date of treatment, treatment identification and source activity in applicator.


Figure 13. Applicator connected to treatment machine

# RESULTS

Table 3. Result for calibration gafchromic film

| $X_1$ | $Y_1$ | $(x_1-x)$ | $(y_1-y)$ | $(x_1-x)$ | $(x_1-x)(y_1-y)$ |
|---|---|---|---|---|---|
| 100 | 0.05 | -1250 | -0.57 | 1562500 | 712.5 |
| 200 | 0.10 | -1150 | -0.52 | 1322500 | 1598 |
| 300 | 0.15 | -1050 | -0.47 | 110.2500 | 493.5 |
| 400 | 0.18 | -950 | -0.44 | 902500 | 418 |
| 600 | 0.27 | -750 | -0.35 | 562500 | 262.5 |
| 800 | 0.38 | -550 | -0.24 | 302500 | 132 |
| 1000 | 0.47 | -350 | -0.15 | 122500 | 52.5 |
| 1250 | 0.62 | -100 | 0 | 10000 | 0 |
| 1500 | 0.71 | 150 | 0.09 | 22500 | 13.5 |
| 1750 | 0.81 | 400 | 0.19 | 160000 | 76 |
| 2000 | 0.90 | 650 | 0.28 | 422500 | 182 |
| 2500 | 1.12 | 1150 | 0.5 | 1322500 | 575 |
| 3000 | 1.34 | 1650 | 0.72 | 2722500 | 118 |
| 3500 | 1.55 | 2150 | 0.93 | 4622500 | 1999.5 |
| 18900 | 8.65 | 0 | 0 | 15160000 | 6703 |

The table 3 shows results of calibration gafchromic film with 6MV photon beam. $X_1$ denote for energy and $Y_1$ denote for optical density (OD).

Table 4. Result for set up 1

| Time exposure(s) | Manual calculation(cGy) | TLD(cGy) | Film(cGy) |
|---|---|---|---|
| 645.99 | 2839.00 | 2222.82 (21.7%) | 1712.0 (39.7%) |
| 904.40 | 3974.70 | 3530.12 (11.2%) | 2413.30 (39.3%) |

* The detail of manual calculation a shown in appendix

Table 5. Result for set up 2

| Time exposure(s) | Point | Manual calculation(cGy) | TLD(cGy) | Film(cGy) |
|---|---|---|---|---|
| 245.70 | A | 173.64 | 116.21 (33.1%) | 105.66 (39.1%) |
| | B | 1074.70 | 600.65 (44.1%) | 648.64 (39.6%) |
| | C | 118.30 | 67.80 (42.7%) | 83.03 (29.8%) |
| 491.40 | A | 346.94 | 243.14 (29.9%) | 196.15 (43.5%) |
| | B | 1979.54 | 1246.08 (37.0%) | 1282.13 (35.2%) |
| | C | 243.66 | 155.87 (36.0%) | 105.66 (56.6%) |
| 860.00 | A | 607.17 | 406.80 (33.0%) | 512.90 (15.5%) |
| | B | 3464.40 | 2558.15 (26.2%) | 2322.85 (33.0%) |
| | C | 410.68 | 284.22 (30.8%) | 286.65 (30.2%) |

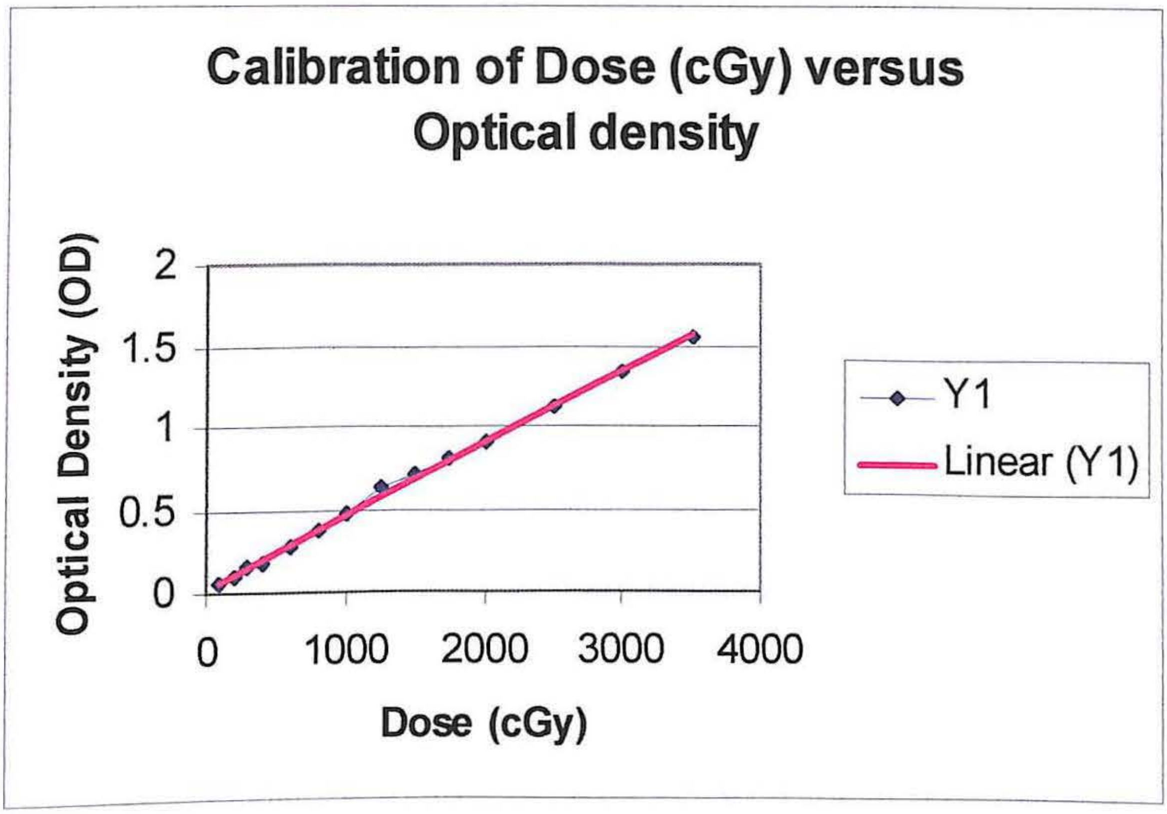
* The detail of manual calculation a shown in appendix

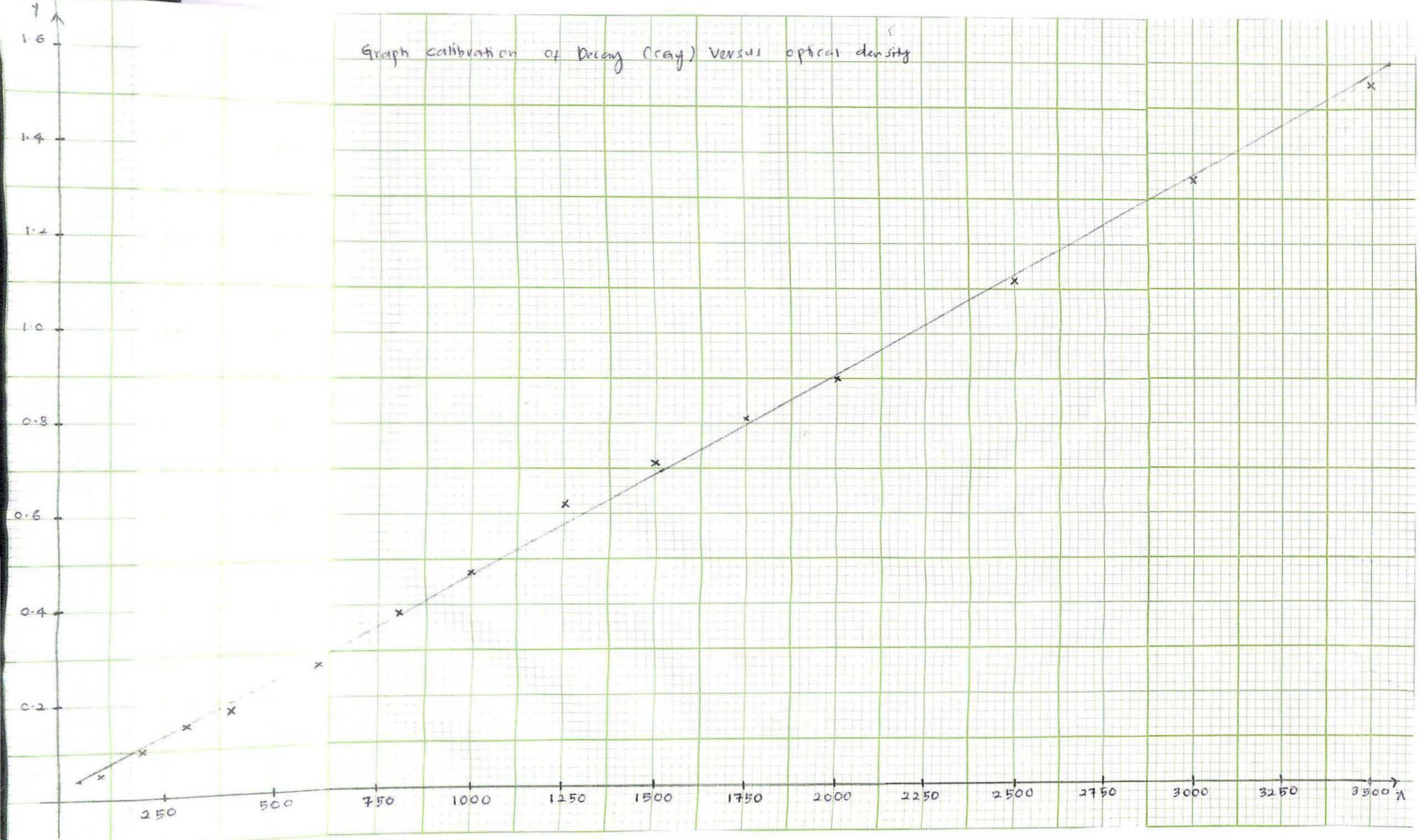
Table 6. Result For set up 3

| Time exposure (s) | Point | Manual Calculation (cGy) | TLD (cGy) | Film(cGy) |
|---|---|---|---|---|
| 1111.2 | A | 878.69 | 499.16 (43.2%) | 671.27 (23.6%) |
| | B | 1993.33 | 1278.53 (35.9%) | 1327.38 (33.4%) |
| | C | 2883.29 | 2117.83 (26.5%) | 1847.74 (35.9%) |

* The detail of manual calculation a shown in appendix

Graph 1. Graph calibration dose versus optical density




Graph calibration of Decay (cag) versus optical density
Y
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
X

# DISCUSSION

8.1 Data analysis

Graph 1 and 2 showed calibrations of gafchromic film with 6MV photon beam. Based on the results, optical density increased linearly with dose (cGy). According to table 1( set up 1) measured dose by TLD was higher compare to gafchromic film , but table 2 ( set up 2) showed not all LiF Thermoluminescent dosimeter (TLD) were higher than gafchromic film. Result for table 3 (set up 3) showed similar condition with table 2. However all result manual condition showed higher dose compare to LiF Thermoluminescent dosimetry (TLD) and gafchromic film. The reason is that, manual calculation is calculated expose dose $^{192}Ir$ source, but LiF Thermoluminescent dosimetry (TLD) and gafchromic film measured absorbed dose for $^{192}Ir$ source. Therefore, the exposure dose might reduce, because of the spread of $^{192}Ir$ and absorption by cylinder. As a results, the absorbed by LiF Thermoluminescent dosimeter and gafchromic film is less than the dose which is exposed from the source $^{192}Ir$.

In overall, the results were not really acceptable, theoretically measured dose by LiF Thermoluminescent dosimeter (TLD) and gafchromic film should be the same as result with manual calculation. But it was difficult practically to get because of limitation, so measured dose by TLD was expected to be closer with manual calculation, compare measure dose by gafchromic film. The reason is that because TLD have a good sensitivity (10) and film depend to angle of the source or beam (11).

## 8.2 Limitations

There are several limitations in this study, for example misallocation is the major problem happened when the experimental setup for LiF Thermoluminescent dosimeter (TLD) and gafchromic film at vaginal cylinder applicator. This condition caused both of dosimeter wrongly measured the dose exposed by $^{192}$Ir.

## 8.3 Suggestions

There are several suggestions can be practice. When handling gafchromic film, soft gloves or tweezers must be used to avoid finger prints and other contaminants which may affect the measurement. By attaching a paper or plastic tab onto the side of the film with adhesive tape, it can also be easily handled without touching the film. Gafchromic film is tending prone to scratch which can affect the optical density readout, therefore care should be taken not to slide the film on surfaces with any force (7). When set up LiF Thermoluminescent dosimeter (TLD) at vaginal cylinder, exit LiF Thermoluminescent dosimeter (TLD) from plastic Teflon, because hard to guess appropriate location. In order to calibrate gafchromic films, $^{192}$Ir can be used for this purpose rather than photon beam (9).