DESIGNING SOFTWARE TO CALCULATE DOSE RATE AND SIMULATE EQUIDOSE LINE OF CONDENSED CYLINDER GAMMA SOURCES

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Abstract: In this work, we establish analytical expressions and design the software based on MATLAB software to evaluate dose rate at an interested point, which is caused by the condensed cylinder gamma sources such as ${}_{27}Co^{60}$, ${}_{53}I^{131}$, ${}_{55}Cs^{137}$, ${}_{77}Ir^{192}$, ${}_{18}Ar^{41}$, ${}_{19}K^{40}$, ${}_{29}Cu^{64}$, ${}_{30}Zn^{65}$… From this programe, dose rate without and with shielding especially concerning self-absorption correction in the source will be determined. Furthermore, the program allows us to simulate the equidose line – 2D and the equidose surface – 3D and to know dose rate at a certain position on graphic by clicking mouse at the interested point. Also, it is able to estimate the thickness of shielding material (concrete, ion, lead, etc…).

Keywords: *dose rate, condensed cylinder gamma sources, self –absorption, equidose line*

I. INTRODUCTION

Nowadays, ionizing radiation sources, gamma sources, are very helpful and useful for human life [8, 9]. They have being applied for many fields such as radiation detection instruments, material analysis, and medical physics... Hence, it is necessary to compute dose rate, to evaluate the thickness of shielding material, and to simulate equidose line of gamma sources quickly. For these reasons, our paper is created.

In this article, we have been establishing analytical expressions and designing a software based on MATLAB software and basing on radiation safety standards, we design a software has some functions as calculating dose rate at the interested point, simulating the equidose line in plane and the equidose surface in three – dimentional space with interested dose rate and to evaluate the thickness of shielding material (concrete, aluminum, iron, stannum, and lead). Besides, this program can be carried out with one of gamma sources such as ${}_{27}Co^{60}$, ${}_{53}I^{131}$, ${}_{55}Cs^{137}$, ${}_{77}Ir^{192}$, ${}_{18}Ar^{41}$, ${}_{19}K^{40}$, ${}_{29}Cu^{64}$, ${}_{30}Zn^{65}$.

There are several softwares to help calculation quickly like Matlab, Maple, and Mathemmatica. Here, we choose Matlab software [1, 3] to design calculating and simulating our program because it has calculation and graphic dominance helping us solve these problems quickly and effectively.

II. THEORY

2.1. Unshielded and shielded source

In Cartesian coordinate system (Oxyz), a condensed cylinder gamma source is placed along the Oz axis and its center lies at origin of the coordinate axis as Fig.1. Assume that radioactivity of gamma source is C [Ci]. Then, we estimate dose rate at P (a, b, h) [4, 5]

$$P = \frac{CK_\gamma}{\pi r_0^2 H}\int_{-H/2}^{H/2}\int_0^{r_0}\int_0^{2\pi}\frac{r\,dr\,dz\,d\varphi}{a^2+b^2+r^2-2r\left(b\sin\varphi+a\cos\varphi\right)+\left(h-z\right)^2} \qquad (1)$$

In the case of the gamma source is shielded by a material with its width is d as Fig.2. The build-up factor also becomes important when shielding material presents between the source and the interested point. When gamma radiation is incident on a thickness of material, it can cause some probability ionizing radiations will interact in the material and be scattered. This process may produce secondary radiations entering detector. Thus, the extent to which such secondary gammas add to dose at the interested point is usually described through the use of an appropriate buildup factor. Hence, the dose rate at P (a, b, h) is estimated as the following [4, 5]:

$$P = \frac{CK_\gamma \delta}{\pi r_0^2 H} \sum_{i=1}^{2} A_i W\left(a, b, h, H, r_0, \mu_i d\right) \qquad (2)$$

$$W\left(a, b, h, H, r_0, \mu_i d\right) = \int_{-H/2}^{H/2} \int_0^{r_0} \int_0^{2\pi} \frac{e^{\frac{-\mu_i d\sqrt{a^2+b^2+r^2-2r\left(b\sin\varphi + a\cos\varphi\right) + \left(h-z\right)^2}}{b - r\sin\varphi}}\, r\,dr\,dz\,d\varphi}{a^2+b^2+r^2-2r\left(b\sin\varphi + a\cos\varphi\right)+\left(h-z\right)^2} \qquad (3)$$

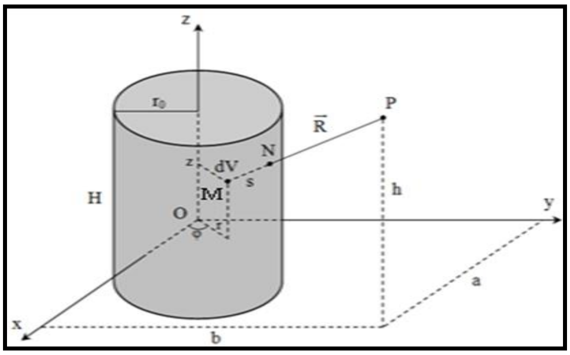

Fig.1. Unshielded condensed cylinder gamma source

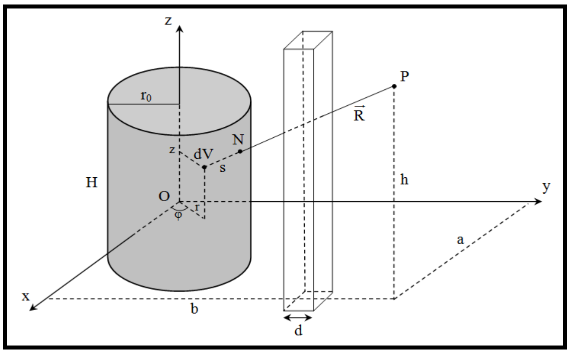

Fig.2. Shielded condensed cylinder gamma source

2.2. Unshielded and shielded source concerning self-absorption effect

Besides the build-up factor, another effect what influent on the exact result of dose rate is exponential absorption inside a volume source, especially condensed cylinder source. Hence, the dose rate at interested point P as Fig.1 was given as:

$$P = \frac{CK_\gamma}{\pi r_0^2 H} \int_{-H/2}^{H/2} \int_0^{r_0} \int_0^{2\pi} \frac{e^{-\mu' s} r\,dr\,dz\,d\varphi}{a^2+b^2+r^2-2r\left(b\sin\varphi + a\cos\varphi\right)+\left(h-z\right)^2} \qquad (4)$$

- Case 1: [$(a\text{-}r\cos\varphi)^2 + (b\text{-}r\sin\varphi)^2$] # 0

*Δ =0: $MN = s = t\sqrt{(a - r\cos\varphi)^2 + (b - r\sin\varphi)^2 + (h - z)^2}$ (5)

*Δ =0: $MN = s = t_1\sqrt{(a - r\cos\varphi)^2 + (b - r\sin\varphi)^2 + (h - z)^2}$ (6)

- Case 2: [$(a\text{-}r\cos\varphi)^2 + (b\text{-}r\sin\varphi)^2$] =0 and $2r(a\cos\varphi + b\sin\varphi - r)$ # 0

$$MN = s = t_3\sqrt{(a - r\cos\varphi)^2 + (b - r\sin\varphi)^2 + (h - z)^2} \qquad (7)$$

In case source is shielded by shielding material as Fig.2 the dose rate concerning self-absorption correction at any point P was given as [4, 5, 7]:

$$P = \frac{CK_{\gamma}\delta}{\pi r_0^2 H}\sum_{i=1}^{2} A_i W\left(a, b, h, H, r_0, \mu_i d\right) \qquad (8)$$

$W(a, b, h, H, r_0, \mu_i d)$ is the same (3)

III. PROGRAM

3.1. Form main and simulation equidose line form

The main screen as Fig.3 contains all the primary headings which lead to important functions of the program. Moreover, the interface of form main shows option buttons with different purposes. In specific, "Calculate dose rate" button, "Calculate thickness" button, "Simulate equidose line" button are respectively used to access to the interface of evaluating dose rate at an interested point, to the interface of determining thickness of shielding material to launch to the interface of simulating equidose line of source without and with shielding (concrete, iron, lead,ect) especially including self-absorption effect within the source. Besides, "Exit" button has the function of escaping from current program.

The main function of form as Fig.4 is to simulate equidose line – 2D and equidose surface – 3D in different cases. To appear equidose line, firstly, we choose one of sources, one of options of time and then input necessary parameters (C, H, r_o, P). Secondly, we choose "Simulate equidose line – 2D" button or "Simulate equidose surface – 3D" button to simulate. If we click to the former, the equidose line with points which have the same dose rate will show and if we select the latter, the simulation of equidose surface in three – dimentional space will appear. Moreover, the equidose line getting color depends on the amount of following dose rate. If $P \geq 10$ (mR/h), $10 < P \leq 5$ (mR/h), $5 < P \leq 1$ (mR/h), $1 < P \leq 0.5$ (mR/h), $P \leq 0.23$ (mR/h) are red , pink, yellow, green, blue respectively.

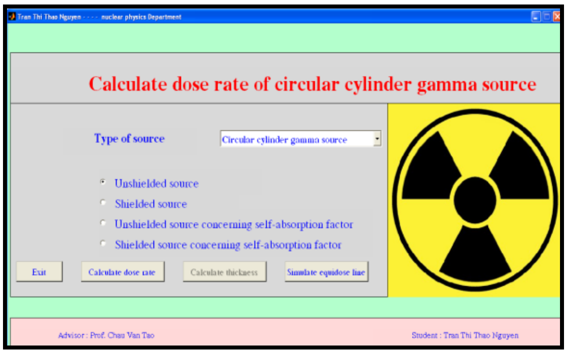

Fig.3. Interface of form main

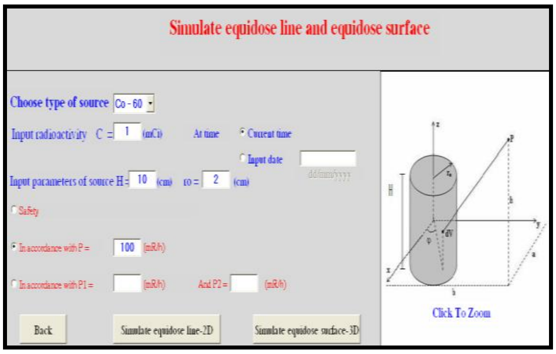

Fig.4. Interface of simulation form

3.3. Forms of calculation of dose rate in cases

The main function of calculation form as Fig.5a, Fig.5b is to evaluate dose rate in cases especially concerning self-absorption effect at the interested point. To estimate dose rate, we have to choose one of sources, including $_{27}Co^{60}$, $_{53}I^{131}$, $_{55}Cs^{137}$, $_{77}Ir^{192}$, $_{18}Ar^{41}$, $_{19}K^{40}$, $_{29}Cu^{64}$, $_{30}Zn^{65}$, choose one of options of time, current time or another date. In the case of choosing "input date", we have to input the default information with format as "dd/mm/yyyy". Then, we input necessary parameters – the interested point (a, b, h), parameters of source (H, r_o), radioactivity C. Finally, we choose “Calculate dose rate” button to calculate dose rate and to output result. Still, “Back” button helps program come back “form main”.

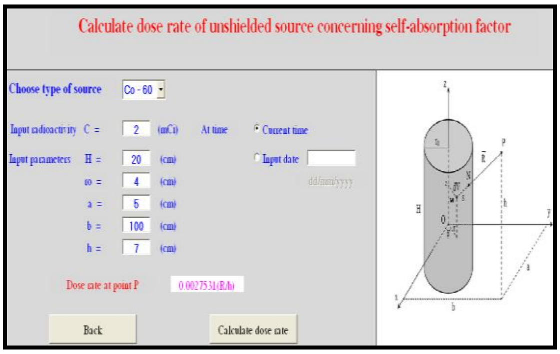

Fig.5a. Dose rate for unshielded source with self-absorption correction

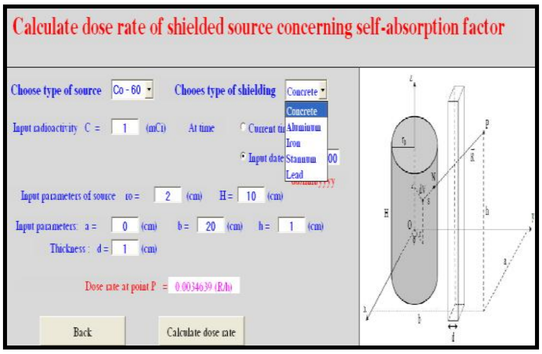

Fig.5b. Dose rate for shielded source with self-absorption correction

3.4. Form of calculation of the thickness of shielding material

The main function of forms as Fig.6a, Fig.6b is to evaluate thickness of shielding material. We carry out some steps which are similar to steps of calculating dose rate. However, there are some different steps as inputting necessary parameters – the interested point (a, b, h), parameters of source (H, r_o), radioactivity C, and dose rate. Eventually, we choose “Calculate thickness” button to evaluate thickness of shielding material and to output result.

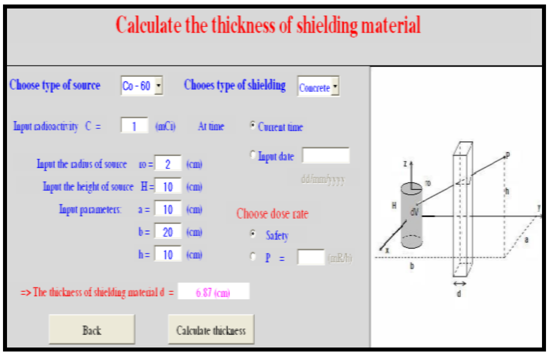

Fig.6a. Thickness of shielding material without self-absorption correction

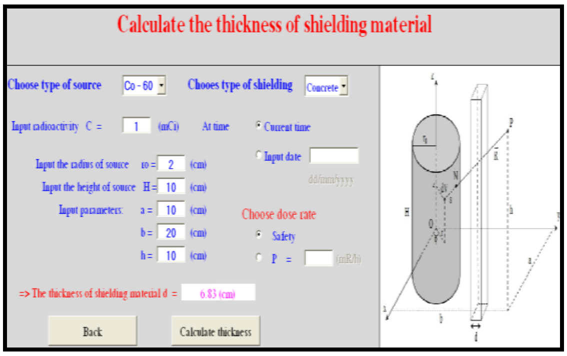

Fig.6b. Thickness of shielding material with self-absorption correction

IV. RESULTS AND DISCUSSION

In calculation dose rate, we evaluate dose rate P_1 of Co – 60 source and dose rate P_2 of Cs – 137 source with radioactivity of these sources, C, are 1[Ci]. The distance from interested point to center of source, R, is 2 [cm]. The shielding is lead and its width is 1[cm]. Parameters of source, radius and height, is respectively 2 [cm] and 10 [cm].We survey dose rate of source in different distances: 5, 10, 25, 50, 100, 150 and 200. As a result, we obtain Table 1 and Table 2 from my software in case unshielded and shielded gamma source concerning self-absorption correction.

In these tables, we can see the dose rate will decrease when increasing the distance. In addition, concerning self-absorption, we can get the results of dose rate is more exact.

Table 1. Unshielded condensed gamma source regarding self-absorption effect

R (cm)	5	10	25	50	100	150	200
Dose rate P_1 (R/h)	319.975	91.852	15.551	3.931	0.987	0.4390	0.2471
Dose rate P_2 (R/h)	153.466	44.057	7.457	1.885	0.473	0.2103	0.118

Table 2. Shielded condensed cylinder gamma source regarding self-absorption effect

R (cm)	5	10	25	50	100	150	200
Dose rate P_1 (R/h)	191.333	56.426	9.629	2.437	0.612	0.2723	0.1532
Dose rate P_2 (R/h)	67.851	20.649	3.557	0.902	0.226	0.0968	0.0575

In simulation equidose line, we simulate equidose line 2D, equidose surface 3D, and two equidose line in the same graphic in different cases as unshielded and shielded source without and with self-absorptions correction. Here, we just illustrate some figures to demonstrate cases above. In specific, Fig.7a illustrates equidose line with dose rate P = 100 (mR/h). Fig.7b illustrates equidose line with dose rate P_1 = 50 (mR/h), P_2 = 100 (mR/h) in the same graphic in the case of unshielded source regarding self-absorption effect. Fig.7c illustrates equidose surface – 3D with dose rate P = 50 (mR/h). Fig.7d illustrates equidose line with dose rate P = 1 (mR/h) and condensed cylinder source is placed along Ox axis.

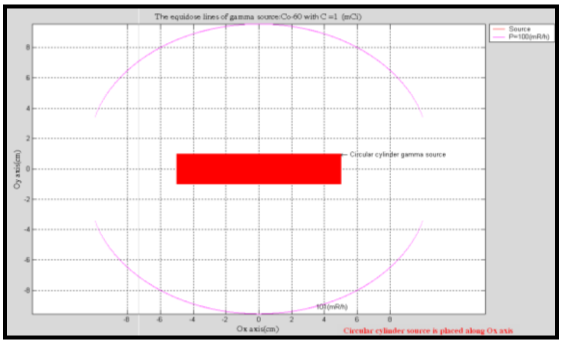

Fig.7a. Equidose line of unshielded source regarding self-absorption effect

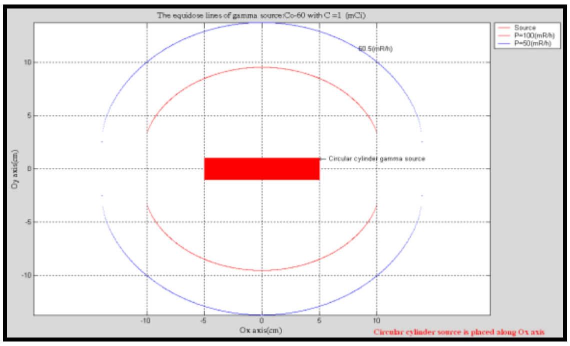

Fig.7b. The equidose line with dose rate P_1 and P_2

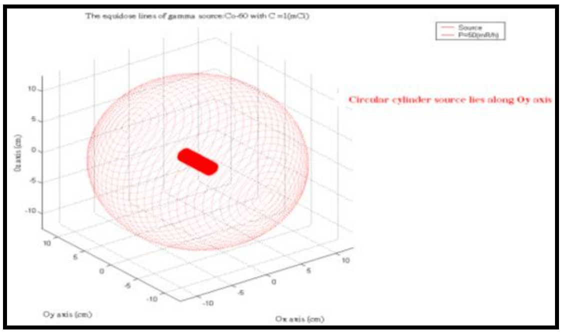

Fig.7c. Equidose surface of unshielded source regarding self-absorption effect

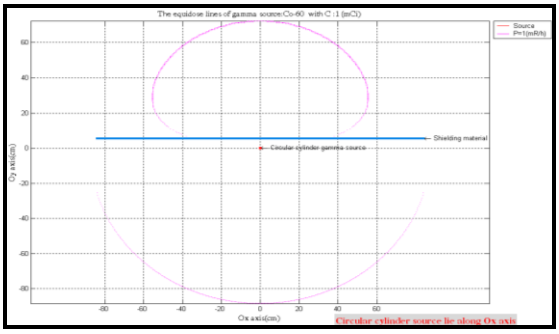

Fig.7d. Equidose line of shielded source regarding self-absorption effect

V. CONCLUSION

The present thesis obtains some following results as follow:

Firstly, we find out analytical expressions to evaluate dose rate at an interested point, which is caused by condensed cylinder gamma source with and without shielding (such as concrete, ion, lead, etc…) especially concerning self-absorption effect in condensed cylinder gamma source, which are usually used in radiation detection instruments, material analysis, and medical physics such as ${}_{27}Co^{60}$, ${}_{53}I^{131}$, ${}_{55}Cs^{137}$, ${}_{77}Ir^{192}$, ${}_{18}Ar^{41}$, ${}_{19}K^{40}$, ${}_{29}Cu^{64}$, ${}_{30}Zn^{65}$.

Secondly, we build up the program of calculation and simulation for these different cases. In particularly, this program has some following functions: The first function is to calculate dose rate at interested point in some cases including unshielded and shielded source, those regarding self-absorption effect. The second function is to calculate the thickness of shielding material (concrete, aluminum, iron, stannum, and lead). Final one is to simulate the equidose line – 2D and the equidose surface – 3D.

However, this program is only applicable to one layer of shielding material. We need to build up the program which can use many layers of shielding material to evaluate dose rate and to simulate equidose line.

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THIẾT KẾ CHƯƠNG TRÌNH TÍNH SUẤT LIỀU CHIẾU VÀ MÔ PHỎNG ĐƯỜNG ĐẲNG LIỀU CHO NHỮNG NGUỒN GAMMA HÌNH TRỤ ĐẶC

Tóm tắt: Trong bài báo này, chúng tôi thiết lập công thức và thiết kế chương trình dựa vào phần mềm MATLAB để tính suất liều tại một điểm bất kỳ được gây ra bởi nguồn trụ đặc như ${}_{27}Co^{60}$, ${}_{53}I^{131}$, ${}_{55}Cs^{137}$, ${}_{77}Ir^{192}$, ${}_{18}Ar^{41}$, ${}_{19}K^{40}$, ${}_{29}Cu^{64}$, ${}_{30}Zn^{65}$…. Từ chương trình, suất liều được tính trong trường hợp không sử dụng và có sử dụng che chắn, đặc biệt có tính đến sự tự hấp thụ của nguồn. Thêm vào đó, chương trình cũng cho phép chúng ta mô phỏng đường đẳng liều và mặt đẳng liều và cung cấp thông tin suất liều tại một điểm nào

đó trên hình vẽ bằng cách đưa con trỏ vào điểm đó. Chương trình còn cho ta tính được bề dày bề dày của vật liệu che chắn (bê tông, sắt, chì…).