CALCULATION OF DOSE DISTRIBUTION AND DOSE RATE AT EACH DWELL POSITION IN ^{60}CO IRRADIATOR SVST-CO-60/B IN VIETNAM

Tran Van Hung

Research and Development Center for Radiation Technology

202A, 11 Str., Linh Xuan, Thu Duc, HoChiMinh City, Vietnam

---***---

Abstract - *The dose distribution in irradiation room and the dose rate at each dwell position of ^{60}Co irradiator SVST-Co-60/B have been calculated using MCNP code. The calculated results are useful information to estimate radiation safety and design irradiator, as well as to design the staying irradiation positions and process optimization.*

Key Words: *Monte Carlo, MCNP code, Dose distribution, Dose rate*

1. INTRODUCTION

Today, Monte Carlo technique has been successfully used to simulate for the industrial facility. A number of studies have been reported in this field. These studies provide good information for irradiation planning (Oliveira et al., 2000a) and for dose distribution and dose mapping, as well as dose prediction and process optimization at the gamma irradiation facility (Pinna-Villalpado and Sloan, 1995, 1998; Raisali et al., 1990, Douglas E. Weiss and Ronald J. Stangeland, 2003).

Several reports have recently appeared for the application of MCNP code (Oliveira et al., 2000a, 2000b, 2002, Sohrabpour et al., 2002, Hung T. V. and An T. K., 2010). Monte Carlo simulation could be also used to predict the dose rate at each dwell position in the irradiator. It is significance for optimal design of the product transport system and the source configuration. For this calculation, Bailley et al (2009) used EGSnrc Monte Carlo code. The results obtained from the modelling showed very close agreement with experimental data using the radiation resistant electronic dosimetry system (RTD) and alanine dosimeters.

The evaluation of the dose distribution in iradiation room and mazing of the irradiation facility is of great concern from the viewpoint of radiation safety, especially, in accident case of source jam.

This paper describes the use of Monte Carlo MCNP code to calculate the dose rate at each dwell position and dose distribution in the irradiation room of SVST-Co-60/B irradiator. The calculated are compared with measurements made with Ethanol Chlroro benzene (ECB) dosimeters. In addition, the applications from the MCNP simulation are also presented and discussed.

2. FACILITY DESCRIPTION AND MONTE CARLO MODELING

Irradiator SVST-Co-60/B is tote-box and wet storage type, which was described in detail in paper of Hung T. V. and An T. K. (2010). The irradiator is product-source overlapping configuration type. The irradiator has three source racks with four modules for each and was surrounded by a source-pass mechanism that contained 68 totes. A water pool with 3 m long, 2 m wide and 6 m deep, which is covered with re-enforced stainless steel plates, shields the personnel in the irradiation room when the source at storage position. The biological shielding design is made of ordinary concrete of density 2,3 g/cm^3.The irradiator is designed with two mazes: a product maze and a personnel maze. The product and personnel doors are lead lined and encased with iron frame.

The product transport system consists of two levels. Each level has four rows; two rows are on both sides of the source. Each tote box with the dimension of 50 cm long x 50 cm wide x 90 cm high are move step by step on each row through 68 positions of the product transport system by cylinder before exiting. A schematic diagram of the product transport system and the moving mechanism of tote box in it are presented in fig. 1.

In this study, MCNP code version 4C (Briesmeister, 2000) has been used to simulate the configuration of irradiator SVST-Co-60/B. The modeling is similar to those of paper of Hung T. V. and An T. K. (2010).

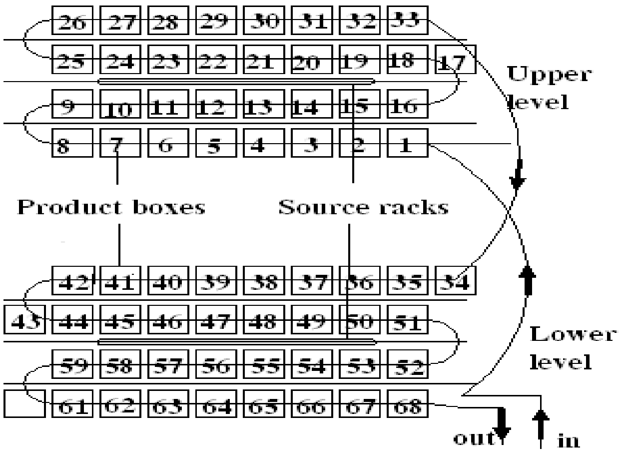

Fig.1 The moving mechanism of tote box in the irradiator SVST-Co-60/B

3. RESULTS AND DISCUSSION

3.1 The dose for each of the dwell position in the path through the irradiator

This calculation, the tote filled rice-huck (as dummy) with density of 0.2 g/cm³. The product path involves four passes of the source on each of the two levels. This is shown in Fig. 1, where the dwell positions have been referred by sequential numbers to present easily later. The totes are made of aluminum and are 48x48x90 cm³ in size. The source strength at the time was 280 kCi and the dwell time was 180 s. There were 68 locations in this mechanism.

In paper of Bailley et al (2009), the dose rate distribution at each dwell posision is measured using a radiation resistant electronic system. This system has been developed P. H. G. Sharpe et al (2000). However, in this report, the intergral dose of all dwell points in the modelling is compared with that obtained from ECB dosimeters.

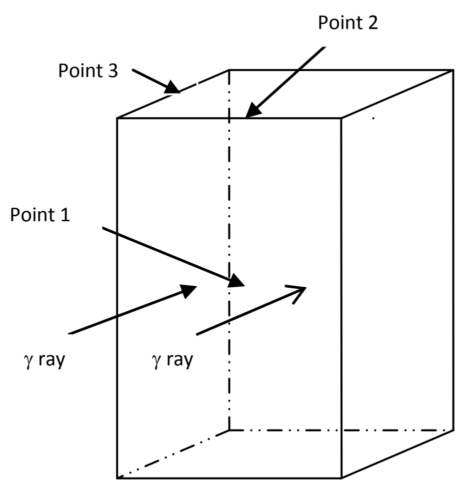

Fig.2 Locations of dose simulation in tote box

The modeling and measurement were carried out three positions in the tote: the centre of tote face (point 1), the middle of the top edge of the tote face (point 2) and the middle of top edge of the side (point 3), see Fig. 2. From paper of Hung T. V. and An T. K. (2010), point 2 and point 3 are maximum and minimum dose locations in the tote, respectively.

The dose rate at each dwell position is shown in Fig.3. The variation of intergral dose with dwell points is presented in Fig.4 and the intergral dose in modelling and measurment is given in Table 1. The calculated values have the relative error of 3% and the experimental values have the error of 5%. FromTable1, the simulation and experimental values are in good agreement with each other. The dose rate and integral dose at each dwell position are useful for a lot of reasons and applications. It helps in designing the irradiator source rack configuration and the structure of the product transport system.

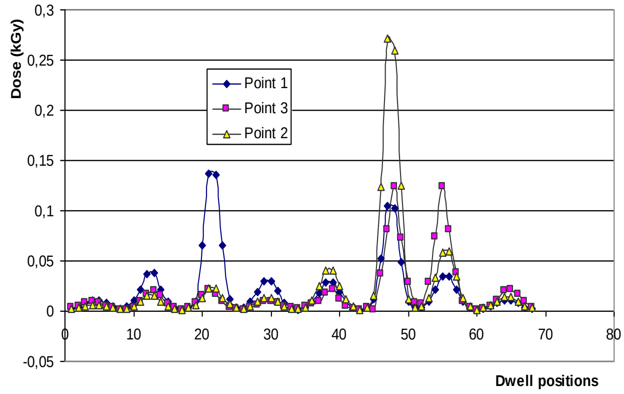

Fig.3 The dose rate at each dwell position

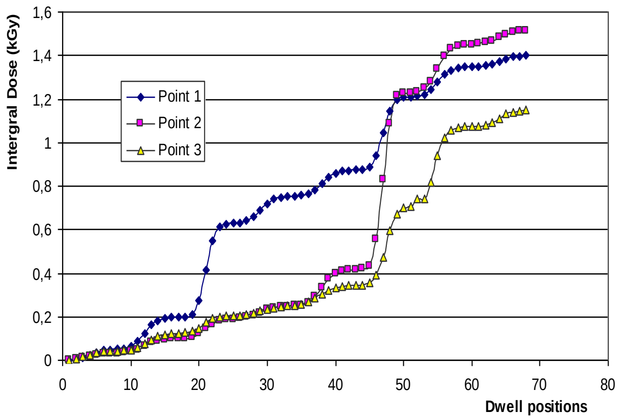

Fig.4 The intergral dose at dwell positions

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 02 Issue: 02 | May-2015 www.irjet.net p-ISSN: 2395-0072

Table 1 Integral dose in simulation and experiment

(Source strength 100 kCi and the dwell time 180 s)

Position	Simulation(kGy)	Experiment (kGy)
1	1.40 ± 0.04	1.46 ± 0.07
2	1.51 ± 0.04	1.53 ± 0.08
3	1.14 ± 0.03	1.19 ± 0.06

Clearly, from Fig.3, shape of the distribution in the dwell positions reflects exactly the physical phenomenon. That is correlation between the the modeling positions, material and source. These results provide useful information for process control chart and the innovation as well as facility designs

The results of the integral doses obtained from modeling very close agreement with data from the ECB dosimeters. It demonstrates the applicability of the MCNP code to the prediction of the dose in the irradiator. It will be again discussed below.

3.2 Calculation of dose distribution in irradiation room

The irradiator is designed with an irradiation room and two mazes: a product maze and a personnel maze. Fig.5 presents the calculation points in the irradiation room and the mazes of the irradiator SVST-Co-60/B.

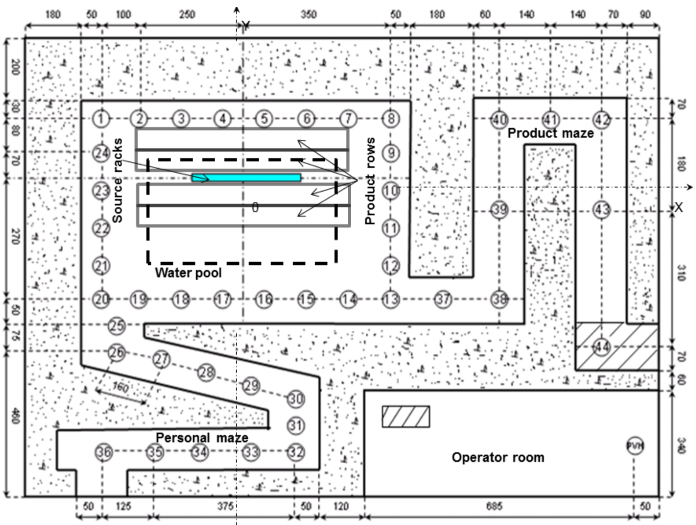

Fig.5 The dose calculation points in the irradiation room

All calculation points in this work are at height of 1m over the floor. The calculated data in the irradiation room, the personnel and the product mazes with the product density of 0.2 g/cm³ are given in Table 2. The dose distribution in similar positions with the product densities of 0.4 and 0.6 g/cm³ also calculated. The calculated data show that dose values of certain positions in the density cases of 0.4 and 0.6 g/cm³ respectively are about two and three times lower than one in the density of 0.2 g/cm³.

Table 2 Simulation results of dose in the irradiation room, the personnel and the product mazes with the product density of 0.2 g/cm³ (hight of 1m over the floor,)

Pos.	Dose (Sv/h)	Rel. error	Pos.	Dose (mSv/h)	Rel. Error
1	8.11E+04	0.01	23	9.86E+04	0.01
2	1.68E+05	0.01	24	1.35E+05	0.01
3	4.42E+05	0.01	25	7.85E+04	0.01
4	9.15E+05	0.01	26	1.24E+04	0.01
5	8.76E+05	0.01	27	2.61E+03	0.01
6	4.05E+05	0.01	28	9.07E+02	0.02
7	1.52E+05	0.01	29	4.32E+02	0.02
8	7.71E+04	0.01	30	1.54E+02	0.03
9	1.27E+05	0.01	31)	1.43E+02	0.02
10	9.33E+04	0.01	32	1.80E+01	0.03
11	7.74E+04	0.01	33	4.32E+00	0.06
12)	7.01E+04	0.01	34	2.35E+00	0.16
13	7.61E+04	0.01	35	4.70E-01	0.07
14	1.33E+05	0.01	36	2.31E-01	0.06
15	2.21E+05	0.01	37	3.70E+04	0.01
16	3.03E+05	0.01	38	5.73E+03	0.01
17	3.08E+05	0.01	39	8.08E+02	0.01
18	2.30E+05	0.01	40	1.46E+02	0.01
19	1.40E+05	0.01	41	1.09E+02	0.01
20	7.97E+04	0.01	42	3.62E+00	0.03
21	7.54E+04	0.01	43	2.17E-01	0.17
22	8.05E+04	0.01	44	2.93E-02	0.15

From the calculation results show that the dose rate inside the irradiation room, the personnel and the product mazes are very high in comparison with the occupational dose limits. The dose rates at points located near the source are with the uncertainties of 1%. The dose rates calculated at points 35, 36 (on the personal maze), 43 and 44 (on the product maze) are low with the uncertainties of more than 10%. However, a survey instrument for measuring the dose rate inside the personnel maze with a Geiger counter located near the position P10 showed that the dose rate at the measuring point is about 0.2 to 0.25 mSv/h. It is good agreement with the calculated result.

These results showed the distribution of dose rate inside irradiation room during the working of the facility. They are very important for the making recommendations and response plans to radiological acident and mitigation of consequences, when the source racks are jammed, could not return to the storage position.

3.3 Some of other application calculation

MCNP code were used very successful for the irradiator SVST-Co-60/B. Apart from the results to this report and paper of Hung T. V. and An T. K. (2010), MCNP code has been applied to evaluate the ability of the improvement on the product transport system and the moving mechanism of tote-boxes and study on improvement of the SVST-Co-60/B irradiator for increasing the irradiation throughput (Tuan L. M. et al., 2013). MCNP code has been also used to calculate the design of the staying irradiation positions for low and high doses.

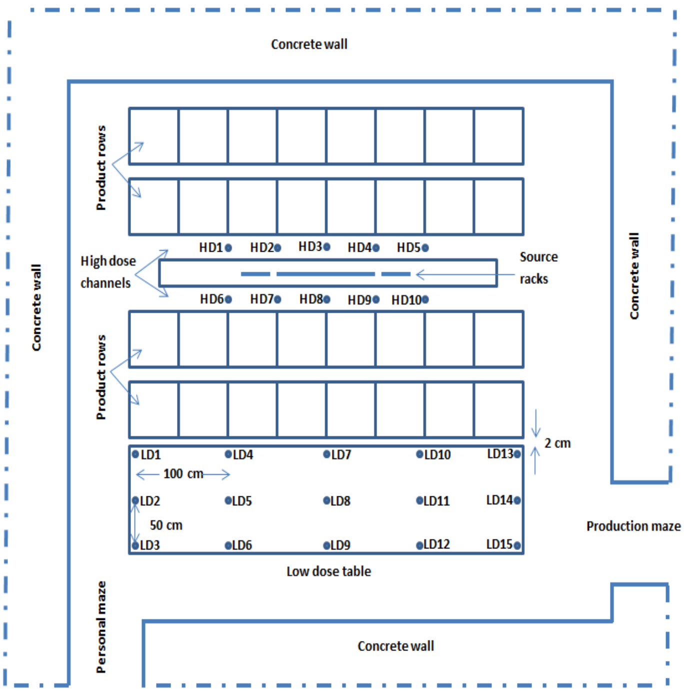

Fig.6 Calculation positions for low and high doses

Base on the structure of the iradiation room as well as the structure between the production transport system and the source racks, the staying irradiation posisions for low and high doses had been chosen as presented in Fig. 6.

In the irradiator SVST-Co-60/B, a shield made of Aluminium to avoid the knock on the source racks. The distance between Al-shield and the inner rows is about 3 cm enough to design a space for some applications of high dose. The calculated results for dose rates in the positions were presnted in Table 3 with the relative error of 0.01 in the high and about 0.02 in the low dose areas.

Table 3 Dose rates in low and high dose area

High Dose Area		Low Dose Area	
Position	Dose (Gy/100 kCi)	Position	Dose (Gy/100 kCi)
HD1	2.117E+02	LD1	4.37E+01
HD2	1.52E+04	LD2	1.95E+02
HD3	1.59E+02	LD3	3.23E+02
HD4	1.92E+02	LD4	1.82E+02
HD5	1.51E+04	LD5	4.40E+01
HD6	1.92E+02	LD6	4.74E+01
		LD7	1.20E+02
		LD8	2.03E+02
		L Đ	1.33E+02
		LD10	5.01E+01
		LD11	4.87E+01
		LD12	9.20E+01
		LD13	1.10E+02
		LD14	8.30E+01
		LD15	4.85E+01

From Table 3, in the high dose area, the dose distribution is 1.810^2 to 1.610^4 Gy/(100kCi.h). However, in the region of the positions H2, H3, H4 and H7, H8 and H9, the dose distribution is relatively uniform and a change of dose is about 6%. It is designed to irradiate gem-stones such as topaz, quartz or aquamarin. The colorless topaz stones, or aquamarin contaned in Al-boxes of 30x4.5x4cm are irradiated with the integral dose about 10^4 or 10^2 kGy, respectively, and after that the stones are heat-treated to eliminate undesirable or extraneous shades of color and to lighten the color back to the most marketable tone. In the case of the colorless topaz performed this way, it will give a sky blue and quartz give a yellow color

For the low dose areas, it was designed a table, on which is presented a grid board for the dose identification. It was used to irradiate fruits to study of the effects by low dose to quantity, the shelf life of fruits (The D. T. et al., 2012). The fact is that, the dose in all experiments using ECB or alanine dosimeters were good agreement with those in calculation using MCNP code. The difference of the dose was about 10%.

4. CONCLUSIONS

MCNP code was used to simulate the irradiator SVST-Co-60/B. The calculated results used this code provided good information for the irradiator design, the estimation of radiation safety, irradiation planning and many other applications. In fact, the results obtained from MCNP code were good agreement with those of experiments. It demonstrates the applicability of the MCNP code used as a predictive tool for dose measurements in the irradiator and in many cases, it helps us to overcome experimental difficulty.

REFERENCES

[1] Bailley M., Sephton J. P, Sharpe P. H. G, 2009. Monte Carlo modelling and real-time dosimeter measurements of dose rate distribution at ^{60}Co industrial irradiation plant. Radiat. Phys. Chem. 78, 453-456.

[2] Briesmeister, J. (Ed.), 2000, MCNP™ - A General Monte Carlo N-Particle Transport Code, LA 1265-M, Version 4C, Los Alamos Laboratory, USA.

[3] Douglas E. Weiss and Ronald J. Stangeland, 2003. Dose prediction and process optimization in a gamma sterrilization facility using 3-D Monte Carlo code. Radiat. Phys. Chem. 68, 947-958.

[4] Oliveira, C., Salgado, J., Botelho, M. L., Ferreira, L. M., (2000a) Dose determination by Monte Carlo – a useful tool in gamma radiation process. Radiat. Phys. Chem. 57 (2000), 667-670.

[5] Oliveira, C., Salgado and A. F Carvalho, 2000b. Dose rate determinations in the Portuguese gamma irradiation facility: Monte Carlo simulations and measurements. Radiat. Phys. Chem. 58 (2000), 279-285.

[6] Oliveira, C., M. L., Ferreira, L. M., I. F. Goncalves and J. Salgado, 2002. Monte Carlo optimization of the irradiator geometry of the portuguese gamma irradiation facility. Radiat. Phys. Chem. 65, 293-295.

[7] Pina-Villalpando, G., Sloan, D. P., 1995. Use of computer code for dose distribution studies in a ^{60}Co industrial irradiator. Radiat. Phys. Chem. 46, 1385-1389.

[8] Pina-Villalpando, G., Sloan, D. P., 1998. Dose distribution studies of a gamma industrial irradiator using a PC code. Radiat. Phys. Chem. 52, 563-567.

[9] Raisali, G. R., Sohrabpour, M., Hadjinia, A., 1990. A computer code for dose rate mapping of gamma irradiators. Radiat. Phys. Chem. 35 (4-6), 831-835.

[10] Sharpe P. H. G., Sephton J. P., Chu R. D., 2000. Real time dosimetry measurements at an industrial irradiation plant. Radiat. Phys. Chem. 57, 687-690

[11] Sohrabpour, M., Hassanzadeh, M., Shahriari, M., Sharizadeh, M., 2002. Dose distribution of the IR-136 irradiator using a Monte Carlo code and comparison with dosimetry. Radiat. Phys. Chem. 63, 769-772.

[12] Hung T. V. and An T. K., 2010. Dose mapping using MCNP code and experiment for SVST-Co-60/B irradiator in Vietnam. Appl. Radiat. Isot. 68, 1104-1107.

[13] The D. T., Lang V. T., Chung C. V., An T. T. T., Thi N. H. H., 2012. Effects of gamma irradiation on different stages of mealubug Dysmicoccus neobrevipes (Hemiptera: Pseudococidate). Radiat. Phys. Chem., 81, 97-100

[14] Tuan L. M. Hung T. V., An T. K., 2013, Reaseach and experimental design of a product transport mechnism of the Cobalt-60 inductrial irradiator, VINAGAMMA document file.

