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ARTICLE

Application of MCNP to Study the shielding Effect of Zinc Bromide Solution

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As a possible option, zinc bromide solution viewing window can be used in the mobile hot cell. In China, there are few successful cases for zinc bromide solution to be used as viewing window, and the shielding characteristic data is not available. MCNP, one of the shielding calculation methods, is applied to simulate the shielding against 1000Ci ^{60}Co γ ray with different concentration of zinc bromide solution and zinc bromide solution of non-uniform concentration. It is shown that the dose rate is reduced to 45μSv·h^{-1} by 1500 mm thickness of zinc bromide solution which concentration is 57.2% or above.

KEYWORDS: MCNP, shielding calculation methods, does rate, zinc bromide solution

I. Introduction

There are tens of thousands of disused sealed radioactive sources stored in user's premises in China. The storage conditions of some are not acceptable. Some of them are stored at the place where they were last used. They are either left where they were last used or moved to an adjacent room. The records in some cases do not exist. Almost all of these are stored in their working shield which was not intended for long term storage. And the activity of some of them are higher than thousands Curies. As a result, the accident could happen and it could result in serious injuries[1)]. For improving the safety and security of public, China had carried out the program for studying disused sealed radioactive sources conditioning, especially for disused high activity sealed radioactive sources mobile conditioning.

It is a high risk for mobile conditioning the disused high activity sealed radioactive sources, because it's high ionizing radiation with high dose rate around it. So it is hard to carry out the conditioning with near distance unless has a good shielding mobile hot cell with manipulators and viewing system. The main viewing system in mobile hot cell in China was a type of liquid filled viewing window which was filled with zinc bromide solution.

The shielding data is less to accurate calculation the dose rates of the disused high activity sealed radioactive sources, especially for shielding characteristic of zinc bromide solution, Mont-Carlo shielding method MCNP-4C code has been introduced to radiation shielding calculation.

II. Viewing Window

1. Viewing Window Introduction

Base on the type of filled material, transparent viewing windows can be divided into two classes.

(1) The solid type and,

(2) The liquid filled tank.

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(1) Solid Type

Early research involved investigation into phosphate and lead glasses, but the field seems to have now narrowed to lead glasses only. In a density range from 3.27g·cm^{-3} to 6.2 g·cm^{-3} with the most popular and largest sizes at 4.3 g·cm^{-3}.The most troublesome aspect of lead glasses is the discoloration due to irradiation.

If ordinary concrete is used in the shield construction it is advisable to use a glass of comparable density. Ordinary glasses can be used and these are referred to as commercial lime (2.52), water white lime (2.52) and protected silicate (2.68). The most troublesome aspect of glasses also is the discoloration due to irradiation

(2) Liquid Filled

The main reason for liquid filling appear to be the increase in light transmission due to the elimination or reflecting surfaces in the laminated glass boxes, initial cheapness and the ease of recovery after radiation exposure by retreatment.

Water is the cheapest available filling, but this is often not convenient due to its low specific gravity. Some effort was made overseas to find a high density liquid. Some success was experienced with lead acetate, acetylene tetrabromid, zinc chloride, methylene bromide. cadmium borotung state, thallium formate-mallonate and others, but these were not finally chosen for various reasons.

The best choice liquid filled material was zinc bromide solution. At high radiation, the intensities decomposition will take place unless hydroxylamine hydrochloride stabilizer is added. This is completely effective and operates as below.

$$\gamma + 2HBr \rightarrow H_2 + Br_2 \quad (1)$$

$$Br_2 + 2H_2NOH \rightarrow H_2O + N_2O + 4HBr \quad (2)$$

A more effective stabilizer for zinc bromide solution has been found to be hydrazine hydro-bromide which does not release Hydrochloric acid during breakdown. And the best type of containing tank seems to be a glass-fiber construction[2)].

2. Viewing Window of Mobile Hot Cell in China

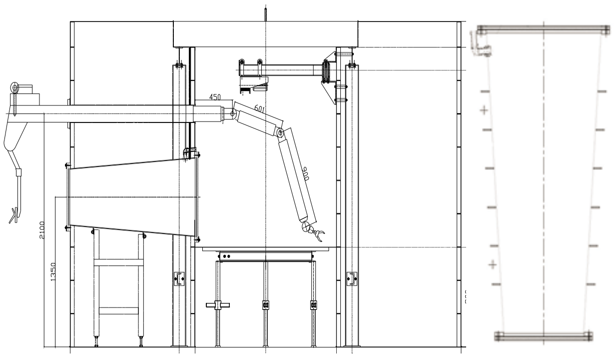

Fig. 1 Mobile hot cell assembly and viewing window

The liquid filled with zinc bromide solution was the best type as the viewing window with its light transmission, non oxide, ease of recovery after radiation exposure by retreatment and cheaper than lead glass. **Fig. 1** shows the assembly of mobile hot cell in China and viewing window which filled with zinc bromide solution.

III. Simulation and Result

1. Shielding Effect in Different Concentration

Shielding effort depends on the density but the shielding date of the solid can not be used directly by the solution. The shielding effect of zinc bromide solution with six groups of concentration has been studied. The relation ship between concentration and density which was gotten from zinc bromide solution density experiment was showed in **Fig. 2**. The concentration is linear with the density.

Six groups of zinc bromide solution with different concentration were chosen for shield characteristic simulating according to the density of the zinc bromide solution experiment. The concentration of six groups of zinc bromide solution for simulating was showed in **Table 1**. The MCNP-4C code was used for shielding calculation.

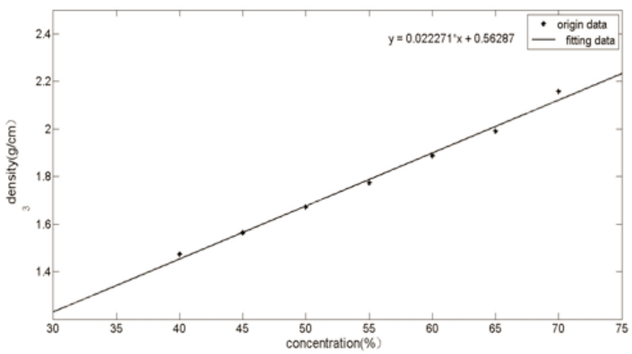

Fig. 2 Relation ship between concentration and density of zinc bromide

The largest number of disused high activity sealed radioactive sources in China is ^{60}Co. The mobile hot cell in China can protect operators, the public and environment from an

Table 1 Zinc bromide solution characteristic which was simulated by MCNP

Case	Concentration(%)
1	44.8
2	51.0
3	55.5
4	60.9
5	65.0
6	70.0

equivalent of a 1000Ci ^{60}Co γ source ionizing radiation. The does rate outside of the wall for operator is 45uSv•h^{-1}. The thickness of shielding material which was chosen is 1500mm in conditioning work, because of the limit of space. The dose rate measurement is 1500mm far away with the ^{60}Co γ sources. **Fig. 3** shows the shielding concept module which simulated by MCNP code.

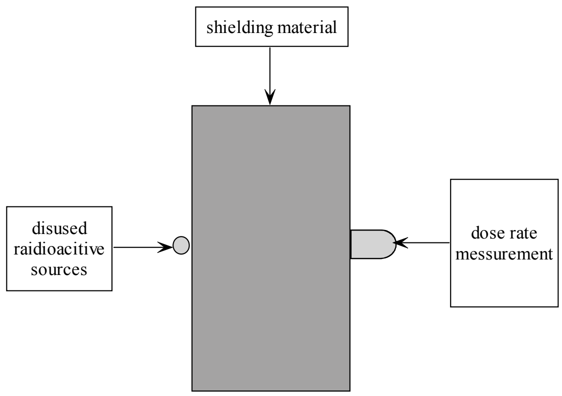

Fig. 3 MCNP simulating concept module

Fig. 4 shows the simulation result. The dose rate is 1500mm from the 1000Ci ^{60}Co γ source and shielded by 1500mm thick bromide solution. Zinc Bromide solution with a density higher than 1.8g·cm^{-3} and lower than 1.9g·cm^{-3} is needed. But it wasn't the accurate concentration for application. Then the density between 1.8g·cm^{-3} and 1.9 g·cm^{-3} of the zinc bromide solution was chosen for more detail simulation. The concentration which was simulated in detail by MCNP-4C code was shown in **Table 2**. **Fig. 5** shows the result which was simulated by MCNP-4C code in detail. And the dose rate point is 1500mm from 1000Ci ^{60}Co γ source and shielded by 1500mm thick bromide solution the same.

Fig. 5 shows that zinc bromide solution with concentration of 57.2% can shield against 1000Ci ^{60}Co γ source with the thickness of 1500mm, the dose rate which is 1500mm from the 1000Ci ^{60}Co γ source can reduce to 45 uSv•h^{-1}.

2. Influence of Non-Uniform Concentration on Shielding Effect

Some bubble will be formed and radiation intensities

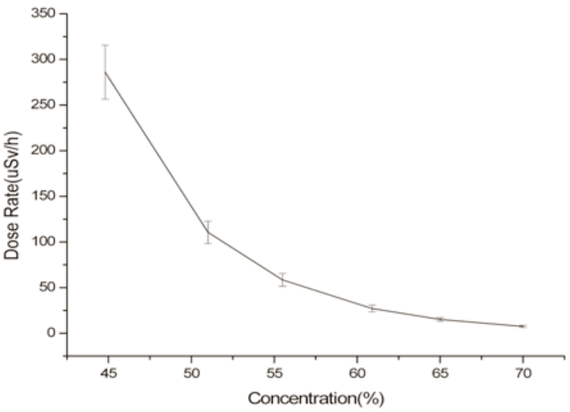

Fig. 4 Dose rate of 1000Ci ^{60}Co which was shielded by zinc bromide solution with differences concentration at the thickness of 1500mm (Errors which was showed in figure 4 was 10 times of original error.)

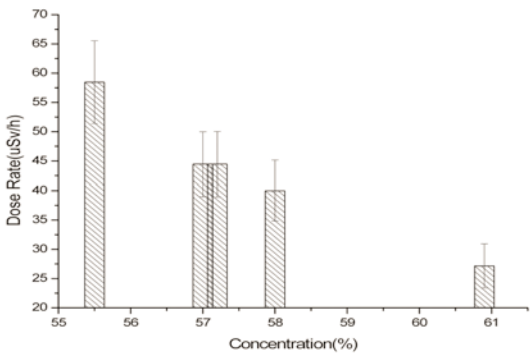

Fig. 5 Detail simulation result of the Dose rate of 1000Ci ^{60}Co which was shielded by zinc bromide solution with difference concentration at the thickness of 1500mm (Errors which showed in figure 5 was 10 times of original error.)

decomposition will take place for zinc bromide solution at high radiation environment. These will decrease the density of zinc bromide and its concentration, and will form non-uniform zinc bromide solution. In order to protect operator and public, the influence of zinc bromide solution of non-uniform on shielding was estimated.

Non-uniform concentration liquid is a complex system, in order to simulate, we had made an assumption according to the strength of radiation. This assumption is that the concentration of the nearest of the radioactive sources has lowest concentration, the furthest one has highest concentration. Highest concentration's density of the zinc bromide solution subtract the lowest one, then divide the highest concentration's density is 1.58%, 4.73%, 9.46%. And highest concentration is 57.2% with the density of 1.8386 g·cm^{-3}.Detail configuration of three type of non-uniform concentration of zinc bromide solution was shown in **Fig. 6**. Detail MCNP module was shown in **Fig. 7**.

Table 2 Zinc bromide solution characteristic which was simulated by MCNP-4C in detail

Case	Concentration(%)
1	55.5
2	57
3	57.2
4	58
5	60.9

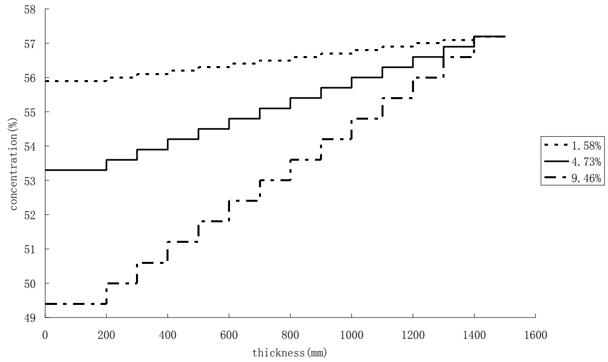

Fig. 6 Three type of zinc bromide solution of non-uniform concentration on shielding configuration

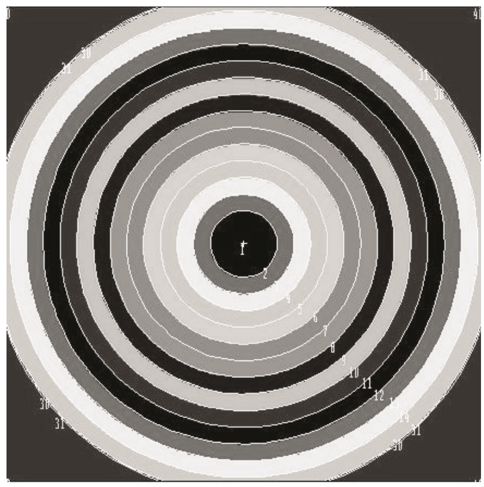

Fig. 7 The non-uniform simulated by MCNP

Except thickness of zinc bromide solution, 0mm also means the concentration of the solution is the nearest concentration with the radioactive sources which place against the sources. The simulation results of three type of non-uniform concentration of zinc bromide solution and uniform solution with concentration of 57.2% were shown in **Table 3**. X means limited dose rate, it is 45uSv•h^{-1}. The relative departure of the dose rate of $45uSv \cdot h^{-1}$ less than 10% is 1.58% non-uniform case.

Table 3 The simulated result of zinc bromide solution of non-uniform concentration

Case	Description	Dose rate ($uSv \cdot h^{-1}$)	$(x_i-X)/X$
1	uniform solution with concentration of 57.2%	44.4600 (±0.5558)	-0.012
2	1.58% non-uniform case	49.4964 (±0.4752)	0.0992
3	4.73% non-uniform case	61.2896 (±0.6006)	0. 3620
4	9.46% non-uniform case	82.0440 (±0.7712)	0.8232

Ⅳ. Discussion and Conclusion

The zinc bromide solution with concentration of 57.2% can shield against equivalent 1000Ci ^{60}Co γ sealed radioactive sources without thinking about non-uniform of zinc bromide. If think about the case of non-uniform with zinc bromide solution added the hydroxylamine hydrochloride stabilizer, the non-uniform is better than 1.58% non-uniform case, using zinc bromide solution of 57.2% concentration can be safety for shielding against 1000Ci ^{60}Co γ for dose rate of $45uSv \cdot h^{-1}$.But if other non-uniform cases which will get the non-uniform worse than 1.58% non-uniform case, they must change their shielding design and increase the concentration of the zinc bromide solution much higher than the concentration of 57.2% in order to protect operator and public.

Acknowledgment

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