Analysis of The Utilization of Depleted Uranium as Shielding Material for the Storage Container of Disused Teletherapy Source

Rinaldi Hadisaputra, Kusnanto, Anung Muharini, Sita Gandes Pinasti

Department of Nuclear Engineering and Engineering Physics, Universitas Gadjah Mada
Jl. Grafika 2, Yogyakarta 55281, Indonesia
rinaldi.hadisaputra@mail.ugm.ac.id

1. Background and Goal

The need for storage containers for radioactive waste is increasing along with the increasing use of radioactive sources in various industrial and medical fields. Shielding material is needed to keep the radiation exposure as small as possible not to harm living things. There are several choices of materials as radiation shields for storage containers, one of them is depleted uranium.

This research aims to analyze the relationship between the rate of exposure on the surface of the package to the thickness of the radiation shield of the radioactive waste storage container of the teletherapy source. The reference material used as a radiation shield is depleted uranium with Carbon Steel and 304L Stainless Steel as cladding. This analysis was performed using MCNPX software version 2.7.E. This research is expected to be a basis for consideration in the selection of safe and economical materials if, in the future, this research is continued to the manufacturing process stage.

2. Depleted Uranium Thickness Calculation

The thickness of depleted uranium was calculated by performing numerical calculations. Calculation of the thickness of the inner shield is obtained using the equation: $X_t = X_0 \cdot B e^{\mu x}$ with the value of the build-up factor calculated using the GP Fitting method and extrapolating method using secondary data (Kiyani, et al., 2013).

The initial exposure rate for cobalt-60 teletherapy source with an activity of 6,000 Ci (3 sources @2,000 Ci), with one-meter distance from the source, is 76,032 mSv/h. When the activity becomes 12,000 Ci (6 sources @2,000 Ci), with the same measurement length, the initial exposure rate for cobalt-60 teletherapy source with an activity of 12,000 Ci is 152,064 mSv/h.

The initial thickness value for each activity is obtained by dividing the μx value by the attenuation coefficient of depleted uranium. That thickness value is used for determining growth factors using the GP factor method. The thickness of depleted uranium for the GP fitting method and extrapolated method are shown in the table below:

Total Activity (Ci)	Xo	Depleted Uranium Thickness (cm)	
		Extrapolated	GP fitting
6,000	76,032	10.51156	9.962929
12,000	152,064	11.13816	10.57744

3. Cladding Thickness Calculation

There are two materials used as cladding in this research: carbon steel and stainless steel 304L; the simulated container's geometry is a cube and a cylinder, with sizes according to the thickness of the depleted uranium for each method and the dose limit value. The choice of cube geometry is intended as a variation of the commonly used container design. The thickness of cladding for every BUF method and every cladding material are shown in the table below:

Total Activity (Ci)	Xo	Dose Limit (mSv)	Cladding Thickness (cm)			
			CS (cm)		SS-304L (cm)	
			Extrapolated	GP fitting	Extrapolated	GP fitting
6,000	76,032	2	0.01	0.01	0.01	0.01
12,000	152,064		0.02	0.01	0.01	0.01

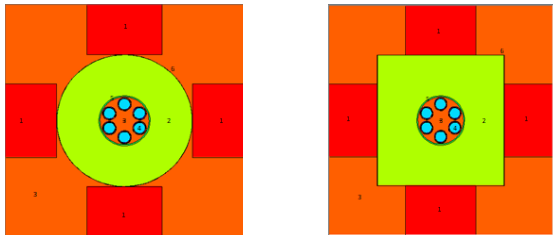
Based on the result from the table above, it is known that there is no significant difference in value between the use of carbon steel or 304L stainless steel as the outer material of the container. Hence, the choice of cladding material can be considered according to other factors such as economic considerations, considerations of material availability, and so on.

4. Analytical Calculation of Radiation Exposure Rate

Number of Sources (pcs)	Total Activity (Ci)	Analytical Exposure rate (mSv/h)			
		Surface (CS)		Surface (SS-304L)	
		Extrapolation	GP Fitting	Extrapolation	GP Fitting
3	6000	1.9948	1.9935	1.9949	1.9936
6	12000	1.9944	1.9948	1.9945	1.9949

Based on the results of analytical calculations, it is known that the rate of exposure that escapes the surface of the container has met the requirements proposed by BAPETEN (*Nuclear Energy Regulatory Agency of Indonesia*), which is below two millisieverts on the surface of the container. However, the dose rate values obtained in the table above need to be validated by direct measurements or by conducting simulations to establish whether the analytically calculated thickness value can withstand radiation exposure that escapes the container.

5. MCNP Simulation Result



MCNP modeling for simulation with a different geometry: cylindrical (left) and cube (right)

Total Activity (Ci)	Geometry	BUF Method	Cladding	Exposure Rate (mSv/hour)
6,000	Cube	Extrapolation	CS	1.9
			SS	1.9
		GP Fitting	CS	6.73
			SS	6.73
	Cylinder	Extrapolation	CS	9.24
			SS	7.42
		GP Fitting	CS	35.8
			SS	35.8
12,000	Cube	Extrapolation	CS	1.32
			SS	1.32
		GP Fitting	CS	4.61
			SS	4.61
	Cylinder	Extrapolation	CS	6.29
			SS	6.29
		GP Fitting	CS	21.5
			SS	21.5

6. Conclusions and Acknowledgements

The dose rates outcome in this simulation, with the extrapolation BUF method and cube geometry, have met the requirements set by BAPETEN, which is below two millisieverts per hour on the surface of the container. On the other hand, the simulation result shows no significant difference between the carbon steel and 304L stainless steel used as cladding. Hence, the choice of cladding material can be considered according to other factors such as economic considerations, considerations of material availability, and so on.