Conceptual Design of Transportation Container for Radioactive Waste Fission Product Molybdenum Capsule

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1. Introduction

In Indonesia, PT INUKI has started producing 99Mo since 1983, but almost all the resulting radioactive waste from the production process are not immediately sent to the radioactive waste treatment facility in belonging to the Directorate of Nuclear Facility Management (DPFK) so that it only accumulates in the hot cell. For this reason, DPFK is conducting revitalization of Temporary Waste Storage Facilities High Activity (PSLAT) as preparation for the management of PT INUKI waste which has high radioactivity. To improve capabilities For PSLAT facilities, a transport container sub-system is needed for transport certain types of high activity waste from waste generation facilities. With the availability of adequate transport containers, it is hoped that improve safety and security in the management of radioactive waste from 99Mo production process activities. In this way, the design and construction activities can be revived directly and support increased production of radioisotopes and domestically made radiopharmaceuticals (especially 99Mo).

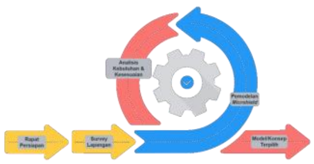
2. Experimental Method

2.1. Material and tools

This design activity uses MicroShield 7.02 software. MicroShield is a product of Grove Software, Inc. the first version began to be built in 1990. This software is used to perform deterministic modeling and calculation of radiation shielding which is limited to certain geometric shapes.

2.2. Working Procedure

This design process is illustrated through agile modeling, which is a practice-based process for modeling and documenting a system/sub-system effectively. In agile modeling, goals are defined before creating a model. In addition, several models were created where each model represents a different aspect of the other models. Agile modeling has 3 (three) objectives, namely, to determine and show how to combine principles and practices for effective and easy modeling, overcome modeling problems with an easy approach, and to improve modeling activities which also support the development of the software used.



agile modelling in design transport container

The design and build activities began with a survey preparation meeting which also became a media for discussion with the owner of radioactive waste, namely PT INUKI on February 10, 2020. Then a field survey of PT INUKI's radioactive waste was carried out, especially the SS/FPM capsule, on February 18, 2020. The results of this field survey were carried out by modelling transport containers for several designs using MicroShield 7.02 software. From the designs that have been modelled, they are then analyzed to see which transport container design has the optimal radiation shielding capability and is the easiest to transport, both during the loading process at PT INUKI's facilities and during unloading at PRTLR's PSLAT Facility. From the results of a field survey conducted on February 18, 2020, the level was obtained radiation from a sample of 3 (three) SS/FPM capsules, as follows:

No.	Capsule Type	Dose Rate (*mSv*/hour) at Distance	
		Contact	100 cm
1.	Stainless Steel Capsule	893	3.67
2.	Stainless Steel Capsule	890	3.96
3.	Stainless Steel Capsule	153	1.78

With the high radiation levels of the FPM capsule (on the order of hundreds of mSv/hours to Sv/hour), to send the radioactive waste to the PRTLR's PSLAT Facility a transport container must be used that can withstand radiation of less than or equal to 2 *mSv*/hour.

The first step in modelling shipping containers is to estimate the activity of each capsule. From the results of field surveys and history/documentation of 99Mo production, the estimated activity of the FPM capsule with 60Co as the dominant gamma-emitting radionuclide was detected. Assuming that the radiation level on the surface of the FPM capsule is 1 Sv/hour, the estimated activity for each capsule is 2 Ci. Calculation of the estimated activity of this capsule uses the MicroShield 7.02 software by conducting a trial & error backcount to obtain surface radiation exposure close to 1 Sv/hour for known capsule materials and dimensions.

The design of the container which also acts as a radiation shield (shielding) will be made with respect to radionuclide and type the radiation. Where containers become a barrier that can absorb radiant energy/radiation exposure. So, it is expected that most of the incoming energy can be absorbed by the container. Mathematically, the initial radiation intensity (**I0**) passing through the radiation shield will be the final radiation intensity (**I**) according to the equation:

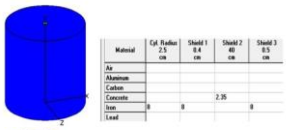
$$I = I_0 . e^{-\mu x}$$

where **μ** is the linear attenuation coefficient of the material as a radiation shield for gamma and X-ray radiation in units of cm-1 and **x** is the thickness of the radiation shielding material used.

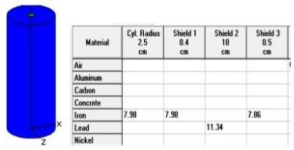
In choosing the type of radiation shielding material, it is necessary to consider the availability, effectiveness, economic considerations, and constraints in applying it. In design which will be made using 2 (two) types of materials that are relatively inexpensive and easy to obtain. The first is lead (Pb), in which this material is most often used as a radiation shield because it has a high atomic number, density high cost, relatively inexpensive, and of course effective in blocking gamma radiation. The second material used in this design is concrete, where concrete is an effective and economical material to be used as a shield radiation as applied to nuclear reactor buildings, accelerators, and laboratories research using radioactivity with relatively high activity. This is due to the compressive strength and durability of the old concrete material.

By using the software MicroShield 7.02, Modeling was carried out with 2 (two) types of alternative materials above as radiation shield:

a. Container design 1: cylinder shape made of SS – concrete – SS material with each thickness 0.4 cm: 40 cm: 0.5 cm.



b. Container design 2: cylinder shape made of iron – lead – iron material with each thickness of 0.4 cm: 10 cm: 0.5cm.



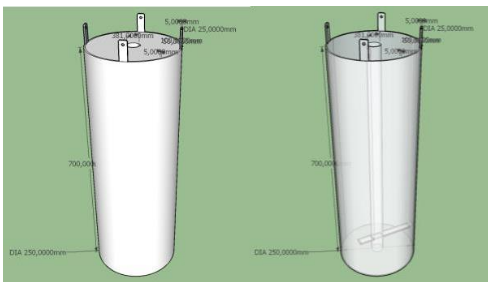
3. Results and discussion

Using Microshield 7.02 modelling for the calculation of the FPM capsule radiation shield, the value of the radiation level on the surface of the capsule using cylinder surface modelling for the first container design is 1.33 mSv/hour and for the second container design is 0.53 mSv/hour. Thus, the transport container design used is the second container design. To optimize the performance of the radiation shield thickness (lead/Pb) against decreasing radiation levels, a variation of the Pb thickness was carried out as follows:

Thick Pb(cm)	Contact Exposure (*mSv/hour*)
8	2.22
9	1.08
10	0.53

From the results above, it can be decided that the design to be used is the second container design with a radiation shield in the form of Pb with a minimum thickness of 9 cm. In addition to the ability to withstand better radiation, with a smaller thickness it will make it easier to lift and transport even though you still need tools. With the availability of Pb material owned by PRTLR, the cost of making transport containers with the second container design is estimated to be not much different from the first container design made of concrete.

After obtaining the type of material and the thickness of the radiation shield, which is adequate, the next step is to design a prototype of the container to be made by reviewing the ease of lifting and loading and unloading. Tubular containers that have been designed using MicroShield then. added parts that will be used to facilitate its later use for transporting FPM capsule waste.



transport container prototype design FPM capsule

4. Conclusions and Acknowledgements

- To transport FPM capsule radioactive waste from the PT INUKI facility to PRTLR's PSLAT Facility, a transport container is required that meets the requirements set out in Government Regulation Number 58 of 2015 concerning Radiation Safety and Security in the Transport of Radioactive Substances. From the conceptual design activities carried out, it was found that the transport container design used was a transport container that used Pb material with a minimum thickness of 9 cm.
- Acknowledgements are given to DPFK management in general, and especially to colleagues in the High Activity Radiaoctive Waste Management Technology Development Team who have assisted in this design activity.