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Comparative Evaluation of Atmospheric Dispersion Models for Beyond Design Basis Accidents at the GA. Siwabessy Multi-Purpose Reactor in Indonesia

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1. Introduction

Gerrit Agustinus Siwabessy Multi-Purpose Reactor (RSG-GAS) is the biggest nuclear reactor in Indonesia. Located in Serpong Nuclear Area, South Tangerang, the reactor was built in 1983. It reached the nominal power of 30 MW in March 1992. RSG-GAS is a pool type reactor. This reactor was designed as medium power research reactor (30 MW). The site is located at 6º 21' 40'' south and 106º 39' 57'' east and about 60 meters above the sea level with the height of the reactor building is about 25 meters. The reactor is surrounded by research facility of National Research and Innovation Agency of Indonesia (BRIN) [1]. RSG-GAS fuel is a plate type with low enriched uranium. The number of fuel elements is 40 fuel elements (FEs) and 8 control elements (CEs). Coolant and the moderator are light water (H_2O) with a Beryllium reflector. This reactor is used mainly for nuclear reactor research group and also for production of radioisotopes and silicon doping [2]. Previous studies show the emergency management of the reactor when the reactor is faced with Beyond Design Based Accident (BDBA). Simulated accident was trigged by blockage of the coolant flow in the fuel that caused the fuel element to melt [1]. The simulation shows released radionuclide into the atmosphere and could cause effective dose to the surrounding of the reactor. In this study, the same radionuclide that generated by the previous study is used to be the sample. Difference in the model will be added in this study. Comparative assessment of the model can be used for the reactor emergency preparedness and response manual. In this study, RASCAL and HOTSPOT were used as model to compare the effective dose and thyroid equivalent dose.

2. Method and Result

2.1 Method

In this study, comparison of three atmospheric dispersion models of HOTSPOT, RASCAL and PC-COSYMA were conducted. HOTSPOT was developed by Lawrence Livermore National Laboratory's National Atmospheric Release Advisory Center (NARAC) and response time of calculation was immediate [3]. For RASCAL which was developed by United States Nuclear Regulatory Commission, more complex weather data, two-dimensional atmospheric transport and real response time was possible [4]. PC-COSYMA was developed by National Radiological Protection Board of European Union. This model used probabilistic and deterministic dispersion model and the response time was based on post-incident analysis [5].

Event that happens in this calculation was five melted fuels. Each fuel element and control element consist of 21 and 15 U_3Si_2-Al fuel plates with a 19.75% uranium enrichment. This event is considered as a Beyond Design Basis Accident. This event then calculated with ORIGEN-2.1 for the source term. From the previous research, the result has shown the number of radionuclide and source term that is generated [1]. Source term refers to the quantity and composition of each radionuclide that release to the atmosphere [6].

Table 1. Information on Source Term [1]

Nuclide	Bq	Nuclide	Bq
Kr-85	8.38E+12	Sr-89	1.67E+10
Kr-85m	6.31E+14	Sr-90	3.33E+08
Kr-87	8.64E+14	Ba-139	1.87E+10
Kr-88	1.63E+15	Ba-140	1.81E+10
Xe-133	3.89E+15	Ru-105	3.22E+09
Xe-135	6.27E+14	Ru-106	5.82E+08
I-131	4.11E+11	Rh-103m	1.00E+10
I-132	6.20E+11	Rh-105	2.68E+09
I-133	9.79E+11	La-140	1.84E+10
I-134	1.10E+12	Y-90	3.57E+08
I-135	9.15E+11	Y-91	2.02E+10
Cs-134	9.08E+07	Nb-95	2.15E+10
Cs-137	3.45E+08	Pr-143	1.69E+10
Rb-88	1.05E+10	Nd-147	6.56E+09
Te-132	1.23E+10	Ce-141	2.01E+10
Sb-125	4.00E+08	Ce-143	1.71E+10
Sb-127	4.00E+08	Ce-144	9.06E+09

ORIGEN-2.1 simulation resulted in the source term of Table 1, then was applied into the RASCAL and HOTSPOT simulation. RASCAL input for the event is assumed to occur in 1 hour and the location of the event is set into the location of RSG-GAS. Calculation distance for the environmental impact assessment is set to be 0.8 km, 1.6 km, 2.4 km, 3.2 km, 4.0 km, 4.8 km, 5.6 km, 6.4 km, 7.2 km, 8.0 km, 8.8 km, 9.6 km, 10.4 km, 11.2 km, 12.0 km, 12.8 km, 13.6 km, 14.4 km, 15.2 km and 16.0 km. This distance was also used as an input data for the HOTSPOT. Metrological data that used in this study was shown in the previous study [1], with the wind speed between 2.4 and 3.8 m/s with the mean wind speed is 3.1 m/s. Stabilities that used is stability class D (neutral atmospheric conditions) with no rain. Wind rose is dominant to blows too south.

2.2 Result

Calculation with the dispersion model software has resulted in the various number of effective doses. The result shows different number with HOTSPOT shows higher number than other 2 model. HOTSPOT was design to give an early estimation and fast response for an accident. It is a conservative model with no calculation of atmospheric dispersion. Simulation of the effective dose that have done is shown in Fig. 1, Fig. 2, and Fig. 3 below. With the distance near the location of the accident, the effective dose has higher number. But with the increase number of distance, the effective dose decrease.

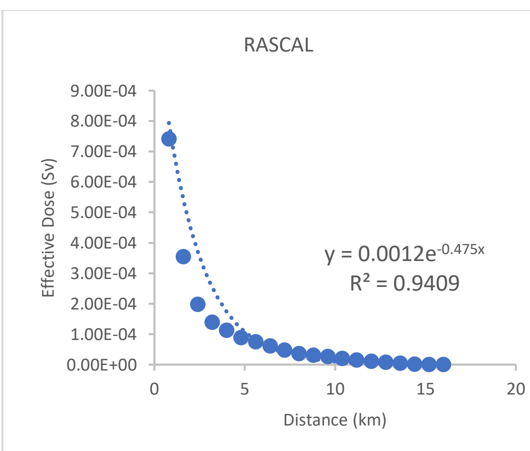

Fig. 1 RASCAL Simulation for Effective Dose

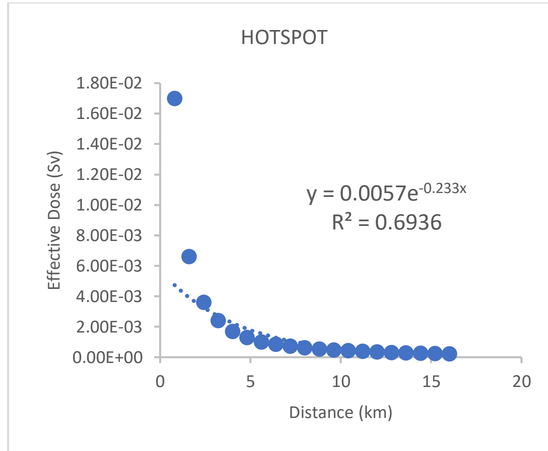

Fig. 2 HOTSPOT Simulation for Effective Dose

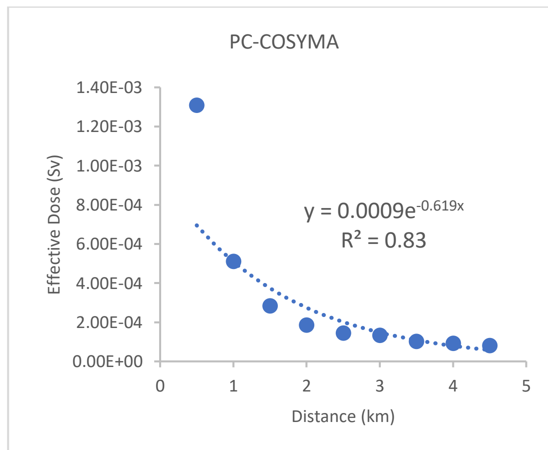

Fig. 3 PC-COSYMA Simulation for Effective Dose

Simulation done by all dispersion atmospheric model showed that HOTSPOT simulation simulate higher effective dose compare to other model. HOTSPOT uses a simple Gaussian model without any complex variation in weather or topographic. This effective dose graph shows an exponential trend. Graph above shows equation of each model which are, RASCAL ($y=0.0012e^{-0.475x}$), HOTSPOT ($y=0.0057e^{-0.223x}$) and PC-COSYMA ($y=0.0009e^{-0.619x}$). From the equation, shows that:

- HOTSPOT effective dose decreases lower than other model, as shown with lower decay constant (RASCAL=0.475, HOTSPOT=0.223, PC-COSYMA=0.619)
- HOTSPOT initial dose is higher, as shown in initial dose (RASCAL=0.0012, HOTSPOT=0.0057, PC-COSYMA=0.0009)

In the event of nuclear emergency, thyroid is one of the most vulnerable organs that can be affected by effective dose. Therefore, measurement of thyroid equivalent dose is important so that emergency workers can prepare countermeasure to prevent any severe damage to the thyroid organ.

With the RASCAL and HOTSPOT, calculation of thyroid equivalent dose is calculated and compare. The result shows the same trend with effective dose. HOTSPOT always shows higher number of equivalent doses. The assumption for both calculation is the same, that's why the equivalent dose from HOTSPOT has higher number. From Fig. 4, Fig. 5, and Fig. 6 below, shows the relation of equivalent dose with distance from the source. All three model show the same trend. Although with different number, all graphic trend shows the decrease of each equivalent dose.

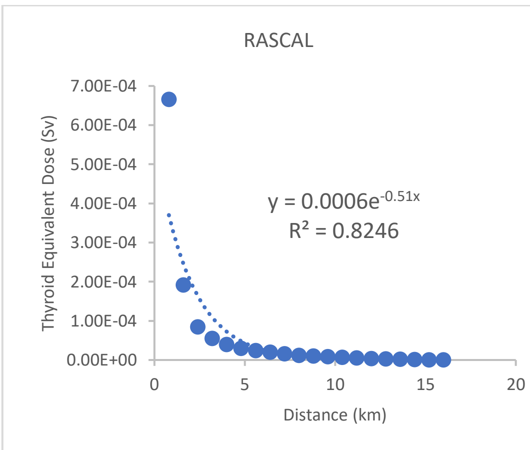

Fig. 4 RASCAL Simulation for Thyroid Equivalent Dose

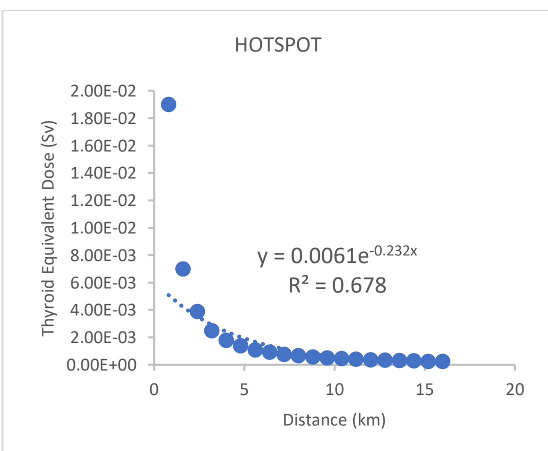

Fig. 5 HOTSPOT Simulation for Thyroid Equivalent Dose

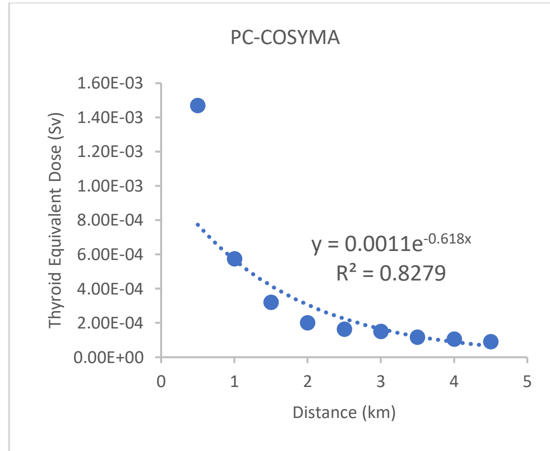

Fig. 6 PC-COSYMA Simulation for Thyroid Equivalent Dose

Equation from all graph also shown the same trend with effective dose, which are:

- HOTSPOT equivalent dose has initial dose higher than all model (HOTSPOT=0.0061, RASCAL=0.0006, PC-COSYMA=0.0011)
- HOTSPOT have lower decay constant, which means that equivalent dose decreases lower than another model (HOTSPOT=0.232, RASCAL=0.51, PC-COSYMA=0.618)

In case of emergency preparedness and response calculation, HOTSPOT is better to be used as a model that provides quick estimation for emergency planning. Equation shown that HOTSPOT has higher initial dose and lower decay constant, making it better as a simple model for the first responder.

3. Conclusion

In this study, the comparative study of RSG-GAS BDBA event was calculated by three different computer model. It was found that, generally HOTSPOT model estimates higher values compared to the rest model. HOTSPOT model uses conservative (estimated radiation dose always bigger) estimation of the radiation effect associated with the atmospheric release of the radioactive materials.

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