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Radiological Safety Assessment for Triga Puspati Reactor in Malaysia

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1. Introduction

Assessment and simulation of potential risks from radioactive release to the atmosphere in event of an accident is very important for nuclear facilities [1]. Dose assessment of research reactors throughout both regular operation and accident conditions is necessary for public security and safety [2]. Triga Puspati Reactor (RTP) is the one and only nuclear research reactor in Malaysia with 1 MW thermal power and it has been in operation since 1982 for advanced neutron and gamma radiation studies. RTP has been utilized for neutron activation analysis (NAA), delayed neutron activation analysis (DNA), neutron radiography, small angle neutron scattering (SANS) and radioisotope production for agricultural, industrial and also medical studies. Like other research reactor, RTP has a good self-reliant ventilation system to regulate and reduce release of radioactive to the atmosphere as well as protecting working personnel from unnecessary exposure of radiation [2]. Gas and particles of radionuclides might be released to the outside atmosphere by ventilation system of reactors through stacks and dispersion of radionuclides depends on several factors such as wind speed and atmospheric stability.

Meteorologists differentiate a few conditions of atmospheric surface layer with classes A-F from the most unstable to neutral condition and to the most stable atmospheric condition. Simulation of this accident scenario influenced by several vital parameters discussed in the following section. In addition, assumption of total malfunction or breakdown of the main operational system ventilation were made to simulate dispersion of radioactive nuclides to the environment from reactor stacks. Total effective dose equivalent (TEDE) assessment was conducted in favor of radiation protection and environmental safety to avoid risks and hazards coming from released radionuclides to the public using HOTSPOT health physics code. Theoretical research of accidental released of radioactive nuclides from the 1 MW thermal power of RTP was calculated. Initially, in order to provide health physics reactors personnel with a fast, field–portable calculation tool for assessing accidents related to radioactive materials, Lawrence Livermore National Laboratory (LLNL) developed the HOTSPOT 3.1 code. The code can be used to assess and analyze gaussian plume model (GPM) of the air concentration and TEDE from radioactive nuclides releases to the public and environment [3].

2. Methods and Results

Several important parameters were set up to simulate the assessment of accidental release of radioactive nuclides to the environment due to system failure of reactor main ventilation.

2.1 Source term release

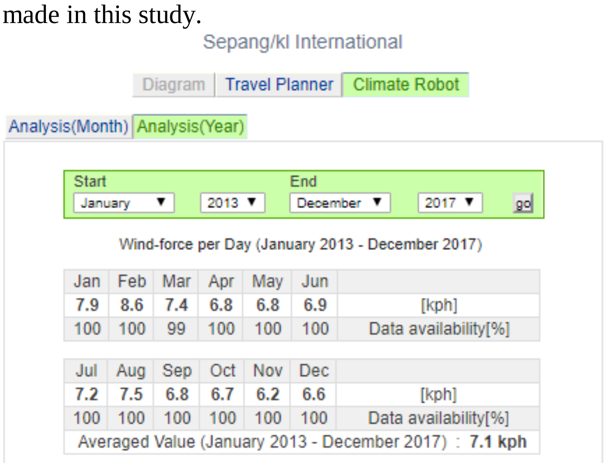
The source term release of RTP is assumed based on a specific study of 5 MWth Tehran research reactor (TRR) of Iran and the ratio analysis has been calculated for RTP's 1 MWth reactor [2]. From the assessment study, a few group of radioactive nuclides (noble gas, halogens and alkali metal) were chosen in which considered as volatile to be released to the environment. Radioactive nuclides released from RTP is shown in Table I according to group of nuclides and these source term releases have been obtained from ORIGEN 2.1 code [1].

Table I: Radioactive nuclides released from RTP

Nuclides	Activity in core (Bq)	Release fraction	Activity to environment (Bq)
Kr-83m	3.50E+13	1	3.50E+13
Kr-85m	5.64E+13	1	5.64E+13
Kr-87	8.22E+13	1	8.22E+13
Kr-88	1.54E+14	1	1.54E+14
Kr-89	1.57E+14	1	1.57E+14
Xe-131m	1.52E+12	1	1.52E+12
Xe-133	6.52E+13	1	6.52E+13
Xe-135m	1.39E+14	1	1.39E+14
Xe-135	1.14E+11	1	1.14E+11
Xe-137	7.12E+14	1	7.12E+14
Xe-138	6.36E+14	1	6.36E+14
I-131	2.72E+14	0.3	1.09E+14
I-132	6.40E+14	0.3	2.56E+14
I-133	7.58E+14	0.3	3.03E+14
I-134	8.68E+14	0.3	3.47E+14
I-135	7.46E+14	0.3	2.98E+14
Cs-137	6.40E+11	0.3	1.92E+11
Total	5.32E+15		3.35E+15

2.2 Speed of wind

According to data provided in [4] from January 2013 until December 2017, the average predominant wind around RTP is from North East (NE) with an average wind speed value of 1.97 m/s (7.1 kph), as shown in Fig. 1. For comparison purpose, maximum wind speed of 6 m/s from South South-West (SSW) assumption was also made in this study.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Start: January 2013 — End: December 2017

Wind-force per Day (January 2013 - December 2017)

Jan	Feb	Mar	Apr	May	Jun	
7.9	8.6	7.4	6.8	6.8	6.9	[kph]
100	100	99	100	100	100	Data availability[%]

Jul	Aug	Sep	Oct	Nov	Dec	
7.2	7.5	6.8	6.7	6.2	6.6	[kph]
100	100	100	100	100	100	Data availability[%]

Averaged Value (January 2013 - December 2017) : **7.1 kph**

Fig. 1. Average predominant wind around RTP

2.3 Height release

The stack height of RTP is approximately 20 meters and the results of plume contour plot of TEDE for class A stability at 1.97 m/s and 6.00 m/s wind speeds are shown in Fig. 2 and Fig. 3 respectively. For wind speed of 1.97 m/s, the affected area of outer plume dispersion is around 2.4 km and for wind speed of 6.00 m/s, the outer plume dispersion is around 1.42 km.

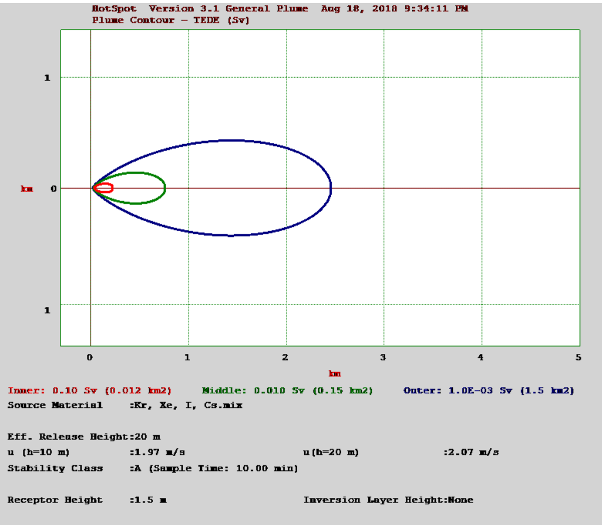

Fig. 2. Plume contour plot of TEDE for class A stability at 1.97 m/s of wind speed

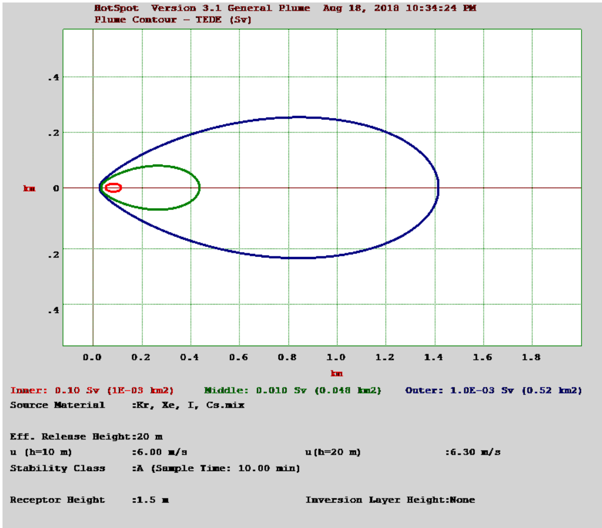

Fig. 3. Plume contour plot of TEDE for class A stability at 6.00 m/s of wind speed

2.4 Condition of atmospheric stability and receptor height

Stability of atmospheric condition around Triga Puspati Reactor (RTP) were investigated for all classes from A-F (unstable to stable condition). For calculating TEDE from HOTSPOT code, receptor height of 1.5 m is used as default value due to average height of a normal person in public [3]. In Fig. 4 and Fig. 5, plume centerline graphs of TEDE for atmospheric stability classes A-F at 1.97 m/s and 6.00 m/s wind speeds are shown.

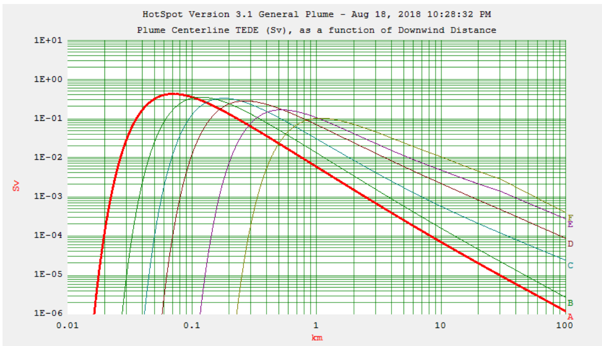

Fig. 4. Plume centerline graphs of TEDE for atmospheric stability classes A-F at 1.97 m/s of wind speed

Based on the result shown in Fig. 4, the maximum value of exposure is 400 mSv at distance of 70 from RTP for class A stability at 1.97 m/s of wind speed. For wind speed of 6.00 m/s, the maximum value of exposure is 150 mSv at same distance of 70 meters and also same class stability as shown in Fig. 5. Based on information of both situations, for safety purpose and reducing the risk of stochastic effects, immediate sheltering and evacuation is needed for working personnel around RTP compound since it exceeds the value of 100 mSv according to general safety requirements part 7 of IAEA report, for generic criteria for protective actions and other response actions in an emergency to reduce the risk of stochastic effects [5].

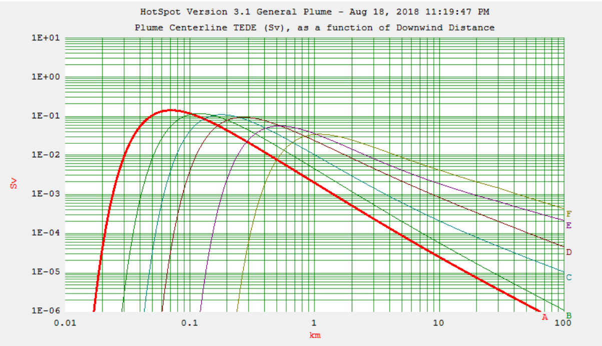

Fig. 5. Plume centerline graphs of TEDE for atmospheric stability classes A-F at 6.00 m/s of wind speed

2.5 Affected population

Population of the whole city of Kajang, Malaysia is around 428,131. As shown in Fig. 6, for wind speed of 1.97 m/s (NE) class A stability, the nearest building compound (Institute of Visual Informatics, Universiti Kebangsaan Malaysia) affected inside the contour plume is around 900 meters from RTP and population of the whole Universiti Kebangsaan Malaysia is around 29,000 people. From this information, for distance of 900 meters, the value of exposure is 8 mSv as shown in Fig. 4. And for wind speed of 6.00 m/s (SSW) class A stability, the nearest neighborhood (Savanna Boulevard Shops at Southville City with population around 69,000 people) affected inside the contour plume is around 650 meters from RTP as shown in Fig. 7. From this data, for distance of 650 meters, the value of exposure is 4 mSv as shown in Fig. 5. According to the results of TEDE calculation, the values of exposure dispersion for both situations are considered low compared to value of exposure around RTP compound. In case of emergency situation, the neighborhood of Savanna Southville City and compound of Institute of Visual Informatics, Universiti Kebangsaan Malaysia shall be informed about safety precaution of this hypothetical accident.

Fig. 6. Output from Google Earth for wind speed of 1.97 m/s (NE direction) and class A stability

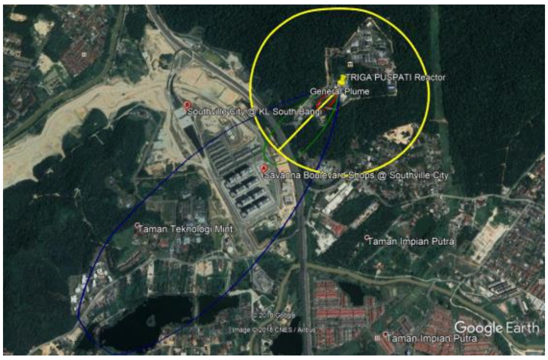

Fig. 7. Output from Google Earth for wind speed of 6.00 m/s (SSW direction) and class A stability

3. Conclusions

In this study, it is found that several factors such as wind speed and atmospheric stability can affect the value of TEDE exposure to the environment. The higher the wind speed around RTP, the lower the value of maximum TEDE. The most unstable atmospheric condition of class A has greater value of maximum TEDE. Radiological dose analysis using atmospheric dispersion model is essential in the safety assessment of radioactive accident scenario of RTP in Malaysia.

ACKNOWLEDGEMENT

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