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The Study of Radiological Environmental Impact Assessments for G. A. Siwabessy Nuclear Research Reactor in Indonesia

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Abstract

In order to protect the public and the environment from radiation exposure, the National Nuclear Energy Agency (BATAN) in Indonesia is responsible for using the Radiological Environmental Impact Assessment to periodically assess radioactive gaseous and liquid effluents released from the G. A. Siwabessy Nuclear Research Reactor (RSG-GAS) 30 MWt. The radioactive gaseous and liquid effluents are released into the environment, but the effluents discharge has to meet environmental release levels permit. This study provides an extensive general review of the radioactive effluents release from RSG-GAS reactor and the effect of that release on the annual effective dose to the public. The environmental impact assessment was performed using computer code INDAC 2.1 (Integrated Dose Assessment Code Package) created by Korea Institute of Nuclear Safety (KINS) to be used for licensing process in the normal operation of nuclear power plants or nuclear research reactors. The average radioactive doses to the public were approximate in the range order between 10^{-2} to 10^{-3} mSv. Although RSG-GAS reactor discharges some radioactive substances into the environment, gaseous and liquid effluents were inside the regulatory of safety limits permit and the resulting effective doses were much less than effective dose limits. The annual effective doses to the public under normal operating conditions are taken into account insignificant when compared to the dose limit permit or even the radiation dose of natural background while the public doses have been practically kept at greatly low levels.

Keywords: radiological impact, dose estimation, gaseous effluent, liquid effluent, nuclear research reactor.

1. Introduction

Indonesia has 3 nuclear research reactors which are currently in operation. The number of nuclear reactors in Indonesia is continually increasing, with the construction of an additional Experimental Power Reactor (RDE) planned in the near future. The concerns from the public and the Nuclear Energy Regulatory Agency (BAPETEN) for radioactive substances released from reactors into the environment have augmented speedily because of the increase in the number of commissioning research reactors [1]. Outstandingly, thorough periodic monitoring and management of safety for radioactive substances are organized to ensure radiation protection for the public living members around nuclear research reactors, considering the reactor process on a single site [2]. Principally, the radioactive materials generated during RSG-GAS reactor operation are classified as gaseous, liquid, and solid waste. The solid radioactive waste is mostly sent to the Center for Radioactive Waste Technology-BATAN. In this paper, only gaseous and liquid effluents were analyzed. Regardless of their concentration on radioactivity, all these substances are classified into radioactive waste as defined by BAPETEN regulations of radiation protection and safety in nuclear energy utilization. The monitoring of gaseous and liquid effluent is done both before and after they are discharged into the environment.

This paper presents radiological environmental impact assessment done by periodically evaluating radioactive gaseous and liquid effluents released from G. A. Siwabessy Nuclear Research Reactor (RSG-GAS) 30 MWt in the Serpong Nuclear Complex. This assessment is done in order to protect the public and the environment from radiation exposure using computer code INDAC 2.1 (Integrated Dose Assessment Code Package). INDAC 2.1 provides many output data but the focus in this paper is on the individual effective dose by age group to meet the annual dose limit. The purpose of this study is to comprehend the radioactive effluents present status of RSG-GAS reactor release. In order to achieve this purpose, these quantities of radioactive effluents released into the environment and the total of effective doses to the public members living around RSG-GAS reactor were analyzed for the year 2016-2017. The results of the study analysis can also be used for comparing the changes of the release of the radioactive substances and the effective dose to the public.

2. Materials and Methods

The radiological environmental impact assessment was performed using computer code INDAC 2.1 with the data input:

- RSG-GAS reactor stack and liquid discharge rate specification [3],

- Radioactive gaseous effluent source term released from RSG-GAS reactor [3],
- Meteorological data around RSG-GAS reactor [4],
- Atmospheric food rate intake of plants and animals [4],
- Radioactive liquid effluent source term released from RSG-GAS reactor [4],
- Aquatic food and shoreline rate intake [4].

The radiological environmental impact assessment procedure as shown in Fig. 1.

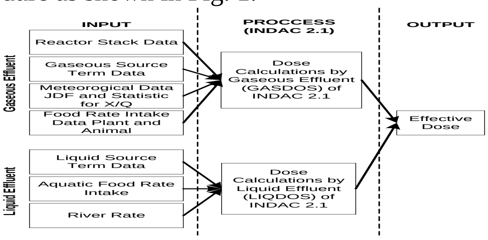


Fig.1. The radiological environmental impact assessment procedure using INDAC 2.1[5]

2.1 The RSG-GAS nuclear research reactor

The RSG-GAS reactor in Indonesia has reactor stack design and liquid discharge specification as shown in Table I [3]:

Table I: RSG-GAS reactor stack and liquid discharge rate

Stack	Specification
Stack Height	60 m
Stack Diameter	1 m
Stack Speed	20000 m^3/s
Distance to nearest residence village	500 m
Liquid effluent discharge rate	5.84×10^{-5} ft^3/sec

2.2 RSG-GAS reactor radioactive effluents released

The radioactive effluents concentration must be much less than the limits permit control of effluent at the offsite boundary area. The amount of the limits permit control of effluent are equivalent into the radionuclide concentrations, which if ingested, inhaled and absorbed continually over the course of a year would generate the annual dose limit of 1 mSv/yr for the public [1,2]. The effective dose from radioactive effluents to the public members living around nuclear reactors must not exceed the annual effective dose standards, which are design goals for the facilities to maintain levels of radioactive gaseous and liquid effluents to offsite areas As Low As Reasonably Achievable (ALARA) throughout the normal operation of nuclear reactors.

In particular, dose standards for the public are based on the design objectives of US-NRC on Regulatory Guide 1.109 regulations pertaining to radioactive effluents [6]. These regulations are based on a generic concept that effective dose estimation for the public members come from the release of radioactive substances from nuclear reactors. The data used in this study was from annual summary reports of RSG-GAS reactor in Indonesia [3,4]. The radioactive gaseous and liquid effluent source term released as shown in Table II and III. The RSG-GAS reactor and its nuclear-related facilities like Radiometallurgy Installation (IRM), Radioisotope and Radiopharmaceutical Production Unit (INUKI), Radioisotope and Radiopharmaceutical Installation (IRR) potentially release of radioactive gaseous effluent in the Serpong Nuclear Complex.

Table II: Radioactive gaseous effluent source term released

Radionuclide	Amount [Bq/yr]	Contribution From
Ag-110m	7.85E+03	RSG-GAS, RMI
Am-241	3.98E+02	RMI
Am-243	5.38E+01	RMI
Ba-137m	1.84E+05	RMI
Ba-140	2.76E+05	RSG-GAS
Br-82	4.40E+04	RSG-GAS
Br-83	5.99E+05	RSG-GAS
Ce-141	8.21E+03	RSG-GAS
Ce-144	1.50E+06	RSG-GAS, RMI
Cm-242	6.93E+04	RMI
Cm-243	5.88E+01	RMI
Cm-244	7.98E+03	RMI
Cs-134	3.19E+05	RMI
Cs-137	3.02E+05	RSG-GAS, RMI
I-125	1.16E+05	RRI
Eu-154	2.31E+04	RMI
Eu-155	1.47E+04	RMI
H-3	7.00E+09	RMI
I-131	1.23E+12	RSG-GAS, INUKI, RRI, RMI
I-132	2.79E+12	RSG-GAS, INUKI
I-133	4.31E+12	RSG-GAS, INUKI
I-134	1.31E+06	RSG-GAS
I-135	2.55E+12	INUKI
Kr-83m	5.99E+11	RSG-GAS
Kr-85	1.21E+13	RSG-GAS, INUKI, RMI
Kr-85m	7.65E+13	RSG-GAS, INUKI
Kr-88	1.29E+14	RSG-GAS, INUKI
La-140	1.26E+05	RSG-GAS
Nb-95	1.37E+06	RSG-GAS, RMI
Nd-147	8.07E+03	RSG-GAS
Pr-144	1.49E+06	RSG-GAS, RMI
Pu-238	5.75E+03	RMI
Pu-239	5.59E+02	RMI
Pu-240	8.82E+02	RMI
Pu-242	4.41E+00	RMI
Rh-103m	3.21E+04	RSG-GAS
Rh-106	9.19E+05	GAS, RMI
Ru-103	2.25E+05	RSG-GAS
Ru-106	9.16E+05	RSG-GAS, RMI
Sb-125	2.63E+04	RSG-GAS, RMI
Sm-151	5.70E-01	RSG-GAS
Sn-125	5.48E+01	RSG-GAS
Sr-89	5.96E+03	RSG-GAS, RMI
Sr-90	9.47E+10	RSG-GAS, INUKI, RMI
Te-125m	6.17E+03	RMI
Te-127	1.31E+04	RMI
Te-127m	1.43E+04	RSG-GAS, RMI
Te-129	5.07E+04	RSG-GAS, RMI
Te-131m	1.01E+05	RSG-GAS, RMI
Te-132	4.70E+04	RSG-GAS, RMI
U-238	4.91E-01	RMI
Xe-131m	6.29E+11	RSG-GAS, RMI
Xe-133	6.55E+14	RSG-GAS, INUKI
Xe-133m	3.39E+13	RSG-GAS, INUKI
Xe-135	2.64E+14	RSG-GAS, INUKI

Xe-135m	7.70E+13	RSG-GAS, INUKI
Xe-138	1.54E+07	RSG-GAS
Y-90	2.44E+05	RSG-GAS, RMI
Y-91	6.40E+03	RSG-GAS
Zr-95	7.96E+05	RSG-GAS, INUKI

- RSG-GAS (G. A Siwabessy Nuclear Research Reactor)
- INUKI (Radioisotope and Radiopharmaceutical Production Unit)
- RRI (Radioisotope and Radiopharmaceutical Installation)
- RMI (Radiometallurgy Installation)

Table III: Radioactive liquid effluent source term released

Radionuclide	Amount [Bq/yr]	Radionuclide Dominant or Non Dominant
Co-60	8.69E+07	Dominant
Zn-65	7.53E+07	Dominant
Na-24	8.24E+06	Dominant
I-125, I-13, Gd-153, Ho-166, Au-198, Re-188, Hg-203, Lu-177, Tc-99m, Ir-192, P-32, Sm-153, Pd-103, Br-82, F-18 Yb-169, Re-186, Sr-90, Y-90, W-188, Mo-99, Cu-64, Co-58	-	Non Dominant

2.3 The meteorological data around RSG-GAS reactor

Radioactive substances such as small quantity of gaseous effluents are released from the nuclear facility through its stack into the air. In order to monitor radiological environmental impact, the meteorology tower is installed in one station for meteorological parameters monitoring such as wind speed and direction, air pressure and temperature, relative humidity, rainfall, and solar radiation. The meteorological data is used to estimate the spread of radioactive substances which is released into the air taken continuously during normal operation and in case of a radiation accident. The tower is installed with several sensors which are positioned in level 2m, 10m, and 60m. The meteorological data average of periods 2016-2017 that are measured at each level are shown in Table IV [3,5]:

Table IV: The average of meteorological data around RSG-GAS reactor in periods 2016-2017

Meteorological Level	2016	2017	Average
Level 2m (ground)			
• Temperature [°c]	26.76	26.8	26.78
• Humidity [%]	85.07	75.57	79.95
• Precipitation [mm]	0.37	4.08	2.37
Level 10m			
• Wind Direction [°]	166.47	177.42	172.39
• Wind Speed [m/s]	1.02	1.02	1.02
• Temperature [°c]	26.6	26.78	26.70
Level 60m			
• Wind Direction [°]	190.2	191.95	190.99
• Wind Speed [m/s]	2.80	2.73	2.77
• Temperature [°c]	26.76	26.53	26.65

2.3 The Annual food consumption rate intake

The annual food consumption rate intake for atmospheric such as plant and animal are shown in Table V and VI, also aquatic food and shoreline rate intake is shown in Table VII [3].

Table V: Atmospheric food rate intake of plant [kg/year]

Age Groups	Crop	Fruit	Root Veg.	Green Veg.	Inhalation [m^3/yr]
3 Months	0.36	0.84	0.00	0.00	1100
1 Years	0.92	1.04	0.85	0.00	1900
5 Years	3.62	2.07	5.53	1.92	3200
10 Years	6.42	3.17	10.35	4.22	5600
15 Years	8.56	4.07	14.02	6.18	7400
Adult	10.06	4.77	16.54	7.78	8100

Table VI: Atmospheric food rate intake of animal [kg/year]

Age Groups	Beef	Lamb	Chicken	Milk	Powder Milk
3 Months	0.00	0.00	0.00	0.27	1.35
1 Years	0.00	0.00	0.00	0.27	1.23
5 Years	0.03	0.06	0.08	0.22	0.65
10 Years	0.07	0.13	0.18	0.17	0.00
15 Years	0.11	0.20	0.28	0.11	0.00
Adult	0.15	0.27	0.38	0.06	0.00

Table VII: Aquatic food and shoreline rate intake

Age Groups	Fish [kg/hr]	Shore-line [hr/yr]	Crop, Fruit, Root Veg. [kg/yr]	Leaf Veg. [kg/yr]	Milk [l/yr]	Meat [kg/yr]
3 Month	0.63	0.00	1.20	0.00	0.27	0.00
1 Years	1.08	0.00	2.81	0.00	0.27	0.00
5 Years	3.34	194.6	11.23	1.92	0.22	0.17
10 Years	5.80	475.5	19.95	4.22	0.17	0.38
15 Years	7.86	692.3	26.67	6.18	0.11	0.59
Adult	9.52	844.9	31.39	7.78	0.06	0.80

2.4 Dose estimation using INDAC 2.1 for members of the public around RSG-GAS reactor

The computer code, INDAC is presently used to perform dose estimations and calculations for the public members living around nuclear power plants or nuclear research reactors in Korea and it was used for this study. INDAC is a program for assessing the exposure dose of the population residing in the vicinity of the site in the licensing process and normal operation of nuclear power plants or research reactor. INDAC 1.0 is originally released by Korea Institute of Nuclear Safety (KINS) in 1999, and the upgraded version, INDAC 2.1 is developed in 2014. INDAC 2.1 consist of the following 2 codes: GASDOS for dose estimations and calculations in consequence of the gaseous effluents, LIQDOS for dose estimations and calculations in consequence of the liquid effluents [5].

3. Results and Discussion

3.1 Analysis of radioactive effluents released from RSG-GAS reactor

The general overview of the assessment approach and parameter is needed for assessing the gaseous and liquid effluents released from RSG-GAS reactor as shown in Fig.2.

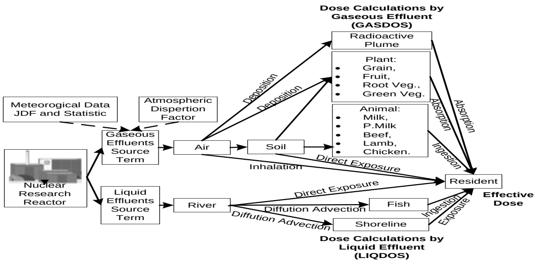
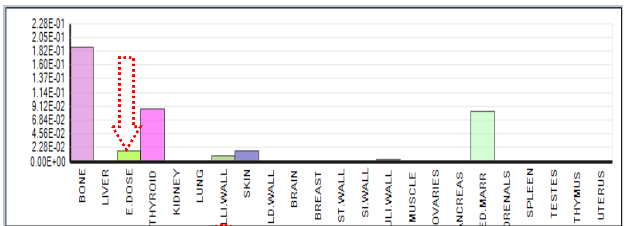


Fig.2. The pathway of radioactive effluent release

This is the initial step to analyze characteristic and amount of gaseous and liquid effluents released into the environment. The pathways of exposure from gaseous and liquid effluents are established on US-NRC RG 1.109 and consist of some site specific deliberations [6]. The other specific parameters including meteorological data, effluent release activity, and food intake rate around RSG-GAS reactor are taken from the annual reports on updated of environmental data of Nuclear Serpong Complex in Indonesia [3,4].

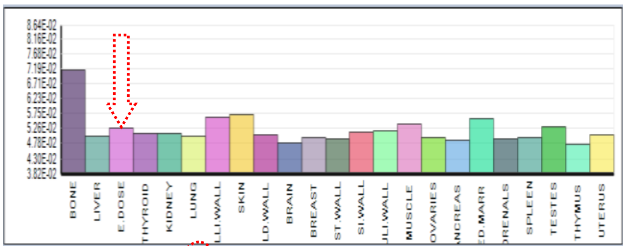
3.2 Results of the effective doses in consequence of radioactive effluents released from RSG-GAS reactor

The averages of the effective dose in consequence of gaseous and liquid effluent by age group to the public members living around RGS-GAS reactor in 2016-2017 were approximately in the range order between of 10^{-2} to 10^{-3} mSv as shown in Fig.3 and Fig.4.



Age Group	BONE	LIVER	E.DOSE	THYROID	KIDNEY	LUNG	LLI.WALL	SKIN	BLD.WALL
ADULT	1.90E-01	1.22E-03	1.86E-02	8.72E-02	1.23E-03	2.65E-03	1.11E-02	1.77E-02	2.09E-03
15 YR	6.93E-01	1.34E-03	3.81E-02	1.22E-01	1.35E-03	2.77E-03	1.06E-02	1.78E-02	2.54E-03
10 YR	2.81E-01	1.43E-03	2.50E-02	1.37E-01	1.43E-03	2.80E-03	1.33E-02	1.79E-02	2.44E-03
5 YR	9.54E-02	1.36E-03	1.61E-02	1.61E-01	1.36E-03	2.50E-03	1.23E-02	1.78E-02	2.00E-03
1 YR	2.15E-02	1.07E-03	9.49E-03	1.25E-01	1.08E-03	2.16E-03	5.11E-03	1.75E-02	1.31E-03
3 MON	2.38E-02	1.04E-03	7.22E-03	7.58E-02	1.04E-03	1.80E-03	2.86E-03	1.75E-02	1.20E-03

Fig.3. The effective dose in consequence of gaseous effluent by age group



Age Group	BONE	LIVER	E.DOSE	THYROID	KIDNEY	LUNG	LLI.WALL	SKIN	BLD.WALL	BRAIN	BREA
Adult	7.20E-02	5.04E-02	5.32E-02	5.11E-02	5.13E-02	5.06E-02	5.64E-02	5.73E-02	5.08E-02	4.83E-02	4.98E
15Years	6.10E-02	4.34E-02	4.53E-02	4.35E-02	4.40E-02	4.34E-02	4.74E-02	4.81E-02	4.18E-02	4.10E-02	4.22E
10Years	4.72E-02	3.36E-02	3.48E-02	3.37E-02	3.41E-02	3.29E-02	3.82E-02	3.52E-02	3.18E-02	3.17E-02	3.10E
5Years	2.56E-02	1.86E-02	1.92E-02	1.87E-02	1.88E-02	1.76E-02	2.26E-02	1.75E-02	1.83E-02	1.74E-02	1.57E
1Year	6.96E-03	5.01E-03	5.17E-03	5.11E-03	5.13E-03	4.48E-03	7.04E-03	3.20E-03	4.19E-03	4.46E-03	3.20E
3Months	8.96E-03	6.70E-03	6.31E-03	6.63E-03	6.81E-03	5.76E-03	7.15E-03	4.36E-03	5.43E-03	5.91E-03	4.20E

Fig.4. The effective dose in consequence of liquid effluent by age group

The effective dose to the public members living around the nuclear reactor should be lower than the annual dose limits as shown in Table VIII [3,4].

Table VIII: Annual dose limit [mSv/yr]

Effluents	Category	Annual Dose Limit
Gaseous	Atmospheric Dispersion	1×10^{-1}
Liquid	Aquatic Dispersion	1×10^{-1}
Others	Reserves: Experimental Power Reactor (RDE)	1×10^{-1}
	Total Amount	3×10^{-1}

The effective doses to the public members in consequence of radioactive effluents released from RSG-GAS reactor met both the effective dose limit permit and the BAPETEN on the regulation of standard effective dose.

4. Conclusions

The averages of the effective doses to the public members living around RSG-GAS reactor in 2016-2017 were approximately on the range order between 10^{-2} to 10^{-3} mSv and the resulting effective doses were much less than dose limits on the order 10^{-1} mSv.

The annual effective doses to the public members from radioactive effluents released from RSG-GAS reactor under normal operating conditions are taken into account insignificant when compared to the dose limit permit or even the radiation dose of natural background while the public doses have been practically kept at greatly low levels.

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