

Present Status of Marine Radioecology in Jakarta Bay

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ABSTRACT

Operation of nuclear facilities such as research reactor and its supporting installation in Serpong Nuclear Area may release controlled radionuclides to Cisadane River and then it would flow to Jakarta Bay. There are limited marine radioecology studies or radionuclides monitoring at Jakarta Bay. Therefore monitoring of ^{239/240}Pu and ¹³⁷Cs was carried out from Tanjung Pasir to Tanjung Kerawang. The ERICA Assessment Tool was used to evaluate radiological risk in the marine environment of Jakarta Bay area. The ¹³⁷Cs concentration in sea water and sea sediments were in range of 0.17 – 1.17 Bq.m⁻³ and 0.34 – 1.21 Bq.kg⁻¹, respectively. Moreover, result of ^{239/240}Pu measurement showed that concentration at sea water and sea sediment were range from < MDA – 0.53 mBq.m⁻³ and 2.64 – 55.70 mBq.kg⁻¹ respectively. The results of risk analysis were indicated that all the total dose rates per organism were millions time lower than the screening rate (10 mGy.h⁻¹).

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INTRODUCTION

Jakarta Bay is located in the capes of Tanjung Pasir (west) and Tanjung Karawang (east). Land based activities mostly influences the Jakarta Bay that pollutants were transported by 13 rivers, i.e., Ciliwung, Cisadane and Angke [1,2]. The pollutants such as heavy metals, POPs, radionuclides in sea water and sea sediments have potential to be bioaccumulated and then become biomagnified at higher trophic levels. Operation of nuclear facilities such as research reactor and its supporting installation in Serpong Nuclear Area may be release controlled radionuclides to Cisadane River and then flow to Jakarta Bay. In the future, Jakarta Bay will receive more radionuclides due to the planning of contraction of Experimental Nuclear Power Plant (NPP) with its capacity of 10 MW.

Mostly focus of pollutants study in Jakarta Bay were chemical and biological contaminants

[1,3,4]. On other hand marine radioecology studies or radionuclides monitoring in Jakarta Bay is still limited. These studies only limited marine monitoring and concerned to the distribution of natural radionuclides and ¹³⁷Cs on Jakarta Bay [5]. Furthermore, another study was concerned to the accumulation rate in Jakarta Bay that used ²¹⁰Pb dating. These previous studies only measured the radionuclides concentration and for geochronological purpose. On other hand updating status of marine radioecology is needed to record the present level of radionuclides before the operation of experimental nuclear power plant in Serpong. The most valuable marine radioecological study for NPP siting is to find and understand about radionuclides concentration before the operation of nuclear power plants [6].

Risk assessment is also required to obtain information about the impact of the existing nuclear research reactor in Serpong to Jakarta Bay. The quantification of environmental risk regarding to radioactivity release can be estimated by using ERICA Tool, whereby a measurement of exposure

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was provided from data on dosimetry and environmental transfer [7]. ERICA Assessment Tool was used to evaluate radiological risk in the marine environment of Jakarta Bay area. ERICA (Environmental Risk from Ionizing Contaminants: Assessment and Management) provides an integrated approach to the scientific, managerial and societal issues surrounding the environmental effects of contaminants emitting ionizing radiation, with an emphasis on biota and ecosystem [7]

In this paper we report result of radionuclides monitoring and risk assessment in Jakarta Bay.

EXPERIMENTAL METHODS

The methods consist monitoring of in area Jakarta Bay from Tanjung Pasir to Tanjung Kerawang (Fig. 1) and calculation of risk assessment was done by using ERICA Tool. Sampling were carried out at 3-5 April 2016. Seawater sampling was carried out at 11 locations of Jakarta Bay (Fig. 1). Approximately up to 150 L of surface sea water samples were taken from each location. About 10 g of copper (II) and 10 g of potassium hexacyanoferrates (II) trihydrate nitrate salt were added to water samples and then were stirred until homogenous. After precipitate was allowed to settle for 24 h, then it was separated from the marine water sample using paper filter. This water preparation method was conducted according to the standard procedures with minor modifications [8].

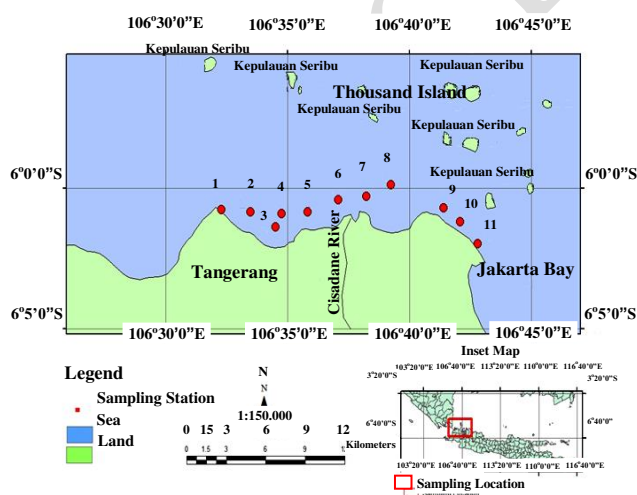


Fig. 1. Sampling locations.

The high-purity germanium (HPGe) detectors (efficiencies of 20-25 % and a fullwidth half maximum (FWHM) of 1.8 keV for a peak of 1332 keV of ⁶⁰Co Canberra GX2018, Canberra GC2020, and Ortec GMX 25P4-76) were used to

measure radioactivities. Approximately 500 g sediment samples and 1 kg of dry biota were measured by direct counting method. The measurement method included detector calibration, the detector counting efficiency, the cumulative counts of the samples and background at regular intervals, smoothing of the photopeak and linear regression.

Sample preparation of plutonium isotope was used preconcentration MnO₂ co-precipitate methods [9]. After radiochemical separation and electrodeposition, alpha spectrometer (Alpha analyst, Canberra) was used for ^{239/240}Pu analysis. Erica tool software was used to accomplished the assessment risk to the environment following a given release of radioactivity [8].

RESULTS AND DISCUSSION

The ¹³⁷Cs concentration in sea water of Jakarta Bay and sea sediments were in range of 0.17-1.17 Bq.m⁻³ and 0.34-1.21 Bq.kg⁻¹, respectively (Table 1). This value was comparable with that in other area of Indonesia coasts. Previous study reported that ¹³⁷Cs in seawater from eastern and western coasts area of Indonesia were 0.12-0.32 Bq m⁻³ [10]. In addition in off shore of Indonesia marine water, the concentration were <MDA to 0.38 Bq.m⁻³ [11].

Table 1. Activity Concentration of ¹³⁷Cs in sea water and Sediments in several locations of Jakarta Bay

Location	¹³⁷ Cs	
	Sea water (Bq.m ⁻³)	Sea sediments (Bq.kg ⁻¹)
106° 32' 17.6" E, 06° 00' 47.3" S	1.17 ± 0.19	1.07 ± 0.11
106° 33' 29.8" E, 06° 00' 51.0" S	1.16 ± 0.20	0.54 ± 0.06
106° 34' 32.6" E, 06° 01' 24.2" S	1.22 ± 0.12	0.60 ± 0.06
106° 34' 45.6" E, 06° 00' 55.2" S	1.12 ± 0.16	0.42 ± 0.04
106° 35' 48.3" E, 06° 00' 51.6" S	0.27 ± 0.03	0.52 ± 0.05
106° 37' 6.443" E, 06° 00' 26.6" S	0.17 ± 0.03	0.34 ± 0.05
106° 38' 11.6" E, 06° 00' 17.3" S	0.21 ± 0.03	0.42 ± 0.03
106° 39' 14.7" E, 05° 59' 54.9" S	0.82 ± 0.10	1.21 ± 0.09
106° 41' 25.5" E, 06° 00' 42.8" S	0.21 ± 0.03	0.73 ± 0.09
106° 42' 05.2" E, 06° 01' 12.6" S	0.17 ± 0.04	0.31 ± 0.05
106° 42' 47.4" E, 06° 01' 58.8" S	0.27 ± 0.05	0.56 ± 0.07

On other hand, its concentration in sea sediments was range 0.19-1.64 Bq kg⁻¹. ¹³⁴Cs radioisotopes were not detected in all samples taken from Jakarta

Bay. This is a typical of the background level in Jakarta Bay due to global fallout. In contrast, even ¹³⁷Cs were present in very low concentration, fishes and other marine biotas have ability to accumulate from seawater [12]. The ¹³⁷Cs concentration in biotas from Jakarta Bay were ranged 12.40-148.40 mBq.kg⁻¹ (Table 2). The result comparable with biota from other Indonesia coasts [13].

Table 2. Activity Concentration of ¹³⁷Cs in several marine biotas of Jakarta Bay

Biota	Concentration (mBq.Kg ⁻¹)
Starry triggerfish (<i>Abalistes stellaris</i>)	12.4 ± 1.2
Crimson snapper (<i>Lutianus erythropterus</i>)	148.4 ± 15.5
Squid (<i>Mastigoteuthis flammea</i>)	110.4 ± 12.1
Mantis shrimp (<i>Odontodactylus scyllarus</i>)	20.6 ± 2.2
Local crab (<i>Portunus sanguinolentus</i>)	22.2 ± 2.5

Anthropogenic radionuclides could be present in Jakarta Bay because there are nuclear research activities in Serpong such as operation of nuclear research reactor, nuclear fuel installation, radioactive waste installation, radiopharmaceutical installation, etc. These research activities have potential to release amount liquid radioactive. These radionuclides are carried to Jakarta Bay coastal by Cisadane river. ¹³⁷Cs (t_{1/2} 30 years) radioisotope is fission product, usually present as simple cations and have high solubility and mobility in marine environments [9]. Furthermore, coastal sediments accumulate ¹³⁷Cs because contain clay mineral such as vermiculite and illite and suspended sediment irreversibly adsorb ¹³⁷Cs from seawater [14]. In contrast only less than 10 % of ¹³⁷Cs transport to ocean bottom sediment [14].

The isotopes of plutonium have becomes much public and scientific concern because they have characters such as: radio and chemical toxicity and long half-live [15,16]. Plutonium is normally produced in reactor fuel as a mixture of isotopes. The predominant isotope, ²³⁹Pu, is produced by neutron capture in ²³⁸U [17]. The result of measurement showed that concentration of ^{239/240}Pu in sea water and sea sediment were range from < MDA-0.53 mBq.m⁻³ and 2.84-55.70 mBq.kg⁻¹, respectively (Table 3). Our result of analysis indicated these concentrations of ^{239/240}Pu is very low compared with Pacific Ocean [18]. The extensive testing of nuclear weapon that

carried out by US weapon testing program are input of plutonium to the Pacific Ocean [18,19].

Table 3. Activity Concentration of ^{239/240}Pu in Jakarta Bay at several locations

Location	^{239/240} Pu	
	Sea water (mBq.m ⁻³)	Sea sediments (mBq.kg ⁻¹)
106° 32' 17.6" E, 06° 00' 47.3" S	0.24 ± 0.04	9.90 ± 1.00
106° 33' 29.8" E, 06° 00' 51.0" S	< MDA	2.64 ± 0.4
106° 32' 17.6" E, 06° 00' 47.3" S	0.53 ± 0.06	55.70 ± 5.80
106° 33' 29.8" E, 06° 00' 51.0" S	< MDA	34.20 ± 3.90
106° 34' 32.6" E, 06° 01' 24.2" S	< MDA	4.12 ± 0.50
106° 34' 45.6" E, 06° 00' 55.2" S	0.23 ± 0.04	2.84 ± 0.30

MDA < 0.1 mBq.m⁻³, 0.5 mBq.kg⁻¹

Isotopes of ¹³⁷Cs, ²³⁹Pu (represent of ^{239/240}Pu) were selected in the assessment and 10 µGy.h⁻¹ was set as a dose screening value. The highest activity concentrations of ¹³⁷Cs and ²³⁹Pu in the seawater and sediments were input into the assessment. Assessment were performed by completing of the Tier 2. The default value in ERICA was set for radionuclides concentration in environment, distribution coefficient (Kd), concentration ratio (CR), dose conversion coefficients, uncertainty factor and occupancy factors. Moreover, value of weighting factors for low beta, beta/gamma and alpha were set to 3, 1 and 20, respectively. The results of risk analysis are listed in Table 4. These indicated that all the total dose rates per organism were lower than the screening rate (10 µGy.h⁻¹).

Table 4. ERICA tool Tier 2 assessment for Total dose rate in several marine biotas of Jakarta Bay

Biota	Total Dose rate		Screening Value (µGy h ⁻¹)
	¹³⁷ Cs (µGy h ⁻¹)	²³⁹ Pu (µGy h ⁻¹)	
Benthic fish	1.79E-4	5.57E-5	1.00E1
Benthic mollusc	1.83E-4	1.75E-5	1.00E1
Crustacean	1.64E-4	2.54E-6	1.00E1
Macroalgae	2.01E-4	6.52E-5	1.00E1
Pelagic fish	1.92E-5	5.57E-5	1.00E1
Phytoplankton	5.74E-7	1.91E-3	1.00E1
Polychaete worm	3.84E-4	2.39E-5	1.00E1
Zooplankton	1.65E-5	1.24E-4	1.00E1

Although the strong environment issue related to Jakarta Bay such as land base source of pollution from industrial activities, the possible impact of

RSG GAS 30 MW located at Serpong did not appear on the surface at public domains. In addition, regulations that concern to protective impact from radionuclides in marine environment is still very limited. Some regulations were presented in Table 5. In fact, RSG GAS 30 MW were operates for 104 days. There isn't potential release liquid waste since no waste dilution policy. Due to limited number nuclear activity on research and development or nuclear application in Indonesia, the potential release of anthropogenic radionuclides to environment only in small quantity. Radioactive waste were managed in installation of radioactive waste management.

Table 5. Nuclear regulations related to the presence of radioactive substance in environment

Regulations	With reference to	Description
Regulation of Indonesia Nuclear Board Licence No. 7/2013	Maximum radioactivity in environment	¹³⁷ Cs content, air : 3.1 x 10 ¹ Bq.m ⁻³ water : 2.5 x 10 ² Bq.m ⁻³ ¹³⁴ Cs content, air : 2.0 x 10 ¹ Bq.m ⁻³ water : 1.7 x 10 ³ Bq.m ⁻³ ²³⁹ Pu content, air : 2.2 Bq.m ⁻³ water : 2.7 x 10 ³ Bq.m ⁻³ ²⁴⁰ Pu content, air : 2.2 Bq.m ⁻³ water : 2.7 x 10 ³ Bq.m ⁻³
Health Ministerial Regulation 416/1990	The requirements and Water Quality Monitoring	The water quality must meet the health requirements which include the requirements in microbiology, physics, chemistry, and radioactive Total gross alpha 0.1 Bq.l ⁻¹ Total gross beta 1 Bq.l ⁻¹
Government Regulation no 82/2001	Management of water quality and water pollution control	Local government should have recommendation from Nuclear Energy Regulation Agency regarding to waste water released that contain radioactive substances
Environment ministerial regulation 51/2004	Standard Quality of marine water	Unknown radionuclides 4 Bq.l ⁻¹

Some researches of environmental radionuclides monitoring have been performed near RSG GAS 30 MW site. The amount of 2,91 x 10⁻⁶ Ci.year⁻¹ were estimated to be released from reactor stack that calculated from source term [20]. Furthermore, another study reported that quantity of ¹³⁷Cs released from reactor does not exceed to source term [20]. In contrast, according to

the Safety Analysis Report (SAR) of RSG GAS 30 MW in Serpong have potential to release about 1.07 X 10⁵ Bq.y⁻¹ [20]. The potential release of ¹³⁷Cs (source term) from reactor stack and result of measurement were presented in Table 6. Radiocesium will be released from reactor stack to the atmosphere and then it was dispersed by the wind until deposited around nuclear area through the dry and wet deposition processes. Radiocesium will be run off from soil to Cisadane river and finally entered to Jakarta Bay. Based on Source Term, Safety Analysis Report (SAR) and monitoring data, the estimation of ¹³⁷Cs entering to Jakarta Bay was maximum 1.07 X 10⁵ Bq per year. The radiocesium released will dilute in river water and sea water in Jakarta Bay.

Table 6. Potential radioactivity released from Serpong Nuclear Research Center

Realease radioactive	Radionuclides	References
Measurement	¹³⁷ Cs release from Stack of Nuclear Research Reactor: below 2.91X 10 ⁻⁶ Ci.year ⁻¹	20
Estimation	Release from reactor stack were estimated from source term 2.91X 10 ⁻⁶ Ci.year ⁻¹	20
	Potential release according to Safety Analysis Report (SAR) of RSG GAS 30 MW 1.07 X 10 ⁵ Bq.y ⁻¹	20

Due to analysis by gamma spectrometer did not detect the ¹³⁴Cs it means the presences of ¹³⁷Cs in Jakarta Bay did not originated from RSG GAS. It is can be explained that finger print of radionuclides in surface water and sediment from global fall out were the concentration ratio of Pu/Cs. The ratio in surface water and sedimen were below 0.002 and 0.02-0.5 respectively [17]. We found the ratio concentration of Pu/Cs in sea water and surface sediment were below 0.002 and 0.03 so that is was known that the radionuclides in Jakarta Bay were originated from global fall out.

CONCLUSION

The baseline level of ¹³⁷Cs in sea water and sea sediments were range 0.17-1.17 Bq.m⁻³ and 0.34-1.21 Bq.kg⁻¹ respectively. Result of ^{239/240}Pu measurement show that concentration at sea water and sea sediment were range from < MDA-0.53 mBq.m⁻³ and 2.64-55.70 mBq.kg⁻¹,

respectively. The results of risk analysis were indicated that all the total dose rates per organism were millions time lower than the screening rate (10 mGy.h^{-1}). Anthropogenic radionuclides such as ^{137}Cs and $^{239/240}\text{Pu}$ in Jakarta Bay were originated from global fall out.

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