Condition of ^{137}Cs Activity in Karimunjawa Waters and its Distribution When an NPP Jepara is Operated

Muslim*[1], Heny Suseno[2], and Siti Saodah[1]

[1]*Oceanography Study Program, Diponegoro University,*
Jl. Prof. H. Soedarto, S.H, Tembalang, Semarang, Jawa Tengah, 50275, Indonesia
[2]*Marine Radioecology Group, Center for Radiation Safety Technology*
and Metrology National Nuclear Energy Agency
Jl. Lebak Bulus Raya No. 49, Kotak Pos 7043 JKSKL Jakarta Selatan 12070 Indonesia
Email: muslim.ir@undip.ac.id

Abstract

Karimunjawa islands are located in the middle of the Java Sea, approximately 83 km northwest of Jepara city. These islands have become an Indonesian marine tourism destination and since 2001 had been designated as a national park. The Indonesian government has chosen Muria peninsula in the district of Jepara, Indonesia as a site for a potential nuclear power plant (NPP). The purpose of this study was to determine the current level of radiocesium (^{137}Cs) activity and forecast its spread if an NPP is operated at Jepara. To determine the distribution of ^{137}Cs in Karimunjawa waters, a sampling of water was done in six stations. Simulation modeling was used to map the distribution of ^{137}Cs should an NPP be constructed in Jepara. The results showed that ^{137}Cs activity in Karimunjawa waters ranges from 0.12 to 0.39 $mBq.L^{-1}$ with an average of 0.24 $mBq.L^{-1}$. This value is slightly higher than previous studies in the coastal waters of Gresik, which had an average activity of 0.200 $mBq.L^{-1}$ because the waters around Karimunjawa have a lower dilution rate than the coastal waters of Gresik. However, these values were considerably lower than those in the waters of Northeast Japan before the Fukushima nuclear power plant accident which registered ^{137}Cs activity at 2-3 $mBq.L^{-1}$.This indicates that ^{137}Cs in Karimunjawa is not entirely from Fukushima rather from the global fallout. The ^{137}Cs distribution model suggests that after 15 days, a leakage in the Muria Peninsula nuclear plant will not contaminate Karimunjawa waters because the current in the Java Sea is relatively weak and dominant in the westward direction. Thus, when an NPP leak only runs for 15 days, Karimunjawa waters remain safe.

Keyword: *^{137}Cs, Karimunjawa, NPP, modeling, Muria Peninsula*

Introduction

The electrical energy needs of Indonesia increases every year. The level of electrical energy consumption per capita is still relatively low, even when compared to other ASEAN countries (Ardisasmita, 2006), but people still fear to build an NPP (Nuclear Power Plants), especially after NPP Chernobyl accident in April 26, 1986, which claimed many victims, despite the benefits of NPP as a cheap, clean and safe source of electrical energy.

Indonesian's government already had the idea to build and operate nuclear power plants since 1956 (Utomo, 2011). A feasibility study on the construction of nuclear power plants have been conducted in 1976. Setiabudi, (2010) revealed that there are two best locations for proposed nuclear power plant site are Ujung Watu, Keling in Muria Peninsula (Jepara) and Sluke in Lasem (Suntoko, 2010).

Forty-five miles (83 km) north of Jepara is the Karimunjawa Islands, which is a national marine park and has become a tourism destination for both Indonesian and foreign tourists (Rahman and Sugianti, 2011). The relatively short distance between Karimunjawa Islands and Jepara may allow waste radionuclides released from the proposed Jepara Muria Peninsula nuclear power plant (NPP) site to be carried by sea currents into Karimunjawa's waters. Some study of marine radioecological has been a performance at Jepara NPP candidate site (Suseno and Umbara, 2003; Umbara *et al*., 2006; Suseno and Umbara, 2006; Suseno, 2013; Suseno and Wisnubroto, 2014). These studies reported the status concentration of anthropogenic and natural radionuclides that showed in background level of global fallout.

It is necessary to study the activity of the radionuclides present post-Fukushima Daichi nuclear power accident in Karimunjawa waters and

*) Corresponding author

ijms.undip.ac.id
DOI: 10.14710/ik.ijms.21.3.143-150
Received : 21-06-2016
Accepted : 23-08-2016

to model the ^{137}Cs distribution when the Muria Peninsula nuclear power plant is operational. Radioactive material released from nuclear installations operating under normal circumstances is not harmful to people and the environment, as it can be kept below the exposure limit (Yuliastuti and Nurlaila, 2007). It is evident that the radionuclide activity in coastal areas near nuclear power plants is lower than the activity offshore from global fallout (Muslim, 2007). However, in the event of an accident; nuclear installations will release fission radionuclides, which are very dangerous. According to Tsumune *et al*., (2012); Windriani *et al.,* (2014); and Zhao *et al*., (2015), one of the radioactive products of fission nuclear reactors fueled by Uranium and Plutonium is the radionuclide cesium-137 (^{137}Cs). This element is radioactive, emitting gamma and beta rays and has a relatively long half-life (30.17 years). ^{137}Cs radiotoxicity level is quite high (Nareh and Warsona, 1999) and can increase the risk of cancer (Windriani *et al*., 2014), so it is often used as an indicator for the presence of radionuclides in the environment from fallout fission.

The Fukushima Daichi nuclear power plant accident in Japan on March 11, 2011, has shocked the world, including in Indonesia. In Japan itself is causing a nuclear crisis (Qiao *et al*., 2011). This incident was a result of the largest documented earthquake (mega-earthquake) in Japan and was unanticipated by experts in Japan (Matsuzawa and Iio, 2012). Tsunami waves swept the east coast of Japan and distributed radionuclides including large quantities of ^{137}Cs to the Pacific Ocean; the greatest nuclear accident leaking radionuclides into the ocean (Buesseler *et al*., 2011). Radionuclides released into the sea rapidly contaminate fish including the Pacific Bluefin tuna and *Thunnus oriental* (Madigan *et al*., 2012). The release and distribution of radionuclides from Fukushima has created a model to study the long-term horizontal and vertical transport of ^{137}Cs in the ocean (Zhao *et al*., 2015). The simulation results showed that the distribution of ^{137}Cs to the east in accordance with the direction of flow of the Kuroshio current and its extension. After 4 to 5 years, the ^{137}Cs has spread up the west coast of North America with a concentration of 2 $mBq.L^{-1}$. The ^{137}Cs that enters the Indian Ocean and the South Pacific through the branches of ocean currents is only found in very low concentrations. After the Fukushima Daichi incident in Japan, some studies of the leakage distribution from the nuclear power plants have been conducted on a relatively short timescale (Qiao *et al*., 2011; Dietze and Kriest, 2012; Tsumune *et al*., 2012, 2013; Miyazawa *et al*., 2013) using forecasting models of climate and ocean circulation in a short time with a few assumptions. Furthermore, Nakano and Povinec (2012) added support for modeling the distribution of radionuclides climatology. Therefore, the purpose of this study to make a simulation of the distribution of ^{137}Cs within 15 days after the NPP's leak in Muria Peninsula, Jepara. Some study of the possible impact of Fukushima accident in Indonesia marine water have been conducted (Suseno, 2012; Suseno and Prihatiningsih, 2014; Suseno *et al*., 2015; Muslim *et al*., 2015). The result of these study was not possible to impact of Fukushima in areas of investigation. The on another hand, still limited data in Indonesia marine water.

Materials and Methods

Primary and secondary data used in this study. Primary data includes data of radionuclide (^{137}Cs) activity and ocean currents in Jepara measured when sampling. Secondary data used are the bathymetric map of Jepara regency in 2004 obtained from DISHIDROS (Indonesian Hydro-Oceanography Office) Navy, data of Jepara's tidal waters in 2014 which were obtained from the harbormaster in the Kartini Port, Jepara, a stream flow of the Balong River which was obtained from the Jepara district office and the average temperature of the sea water in situ.

Seawater sampling for analysis of ^{137}Cs was carried out on August 31 and September 1, 2014. Sixty-five liters of seawater was collected from surface and poured into an 80-liter PVC container. Ten grams of $K_4[Fe(CN)_6]$ and 10 grams of $CuSO_4$ were added to each container to bind ^{137}Cs in the water, stirred for 30 minutes, then let stand until the precipitate formed. The clear water above the precipitate was removed using a plastic tube and the precipitate was transferred to 1.5 L plastic bottle and stored for further processing in the marine radioecology laboratory.

The research location is shown in Figure 1. The six research station locations, both coordinates, and depth of each station, is shown in Table 1. Stations 1, 2, 4 and 6 are located in the eastern, southern, northern and western part of Karimunjawa Island, respectively. Station 3 is located in the sheltered island and station 5 is located between Parang Island and Nyamuk Island.

Analysis of ^{137}Cs activity in the Laboratory

Water samples (stored in the 1.5 L bottle) were filtered to separate water that remains from the precipitate. ^{137}Cs deposited on the filter paper was dried in an oven at 100 °C for approximately 3

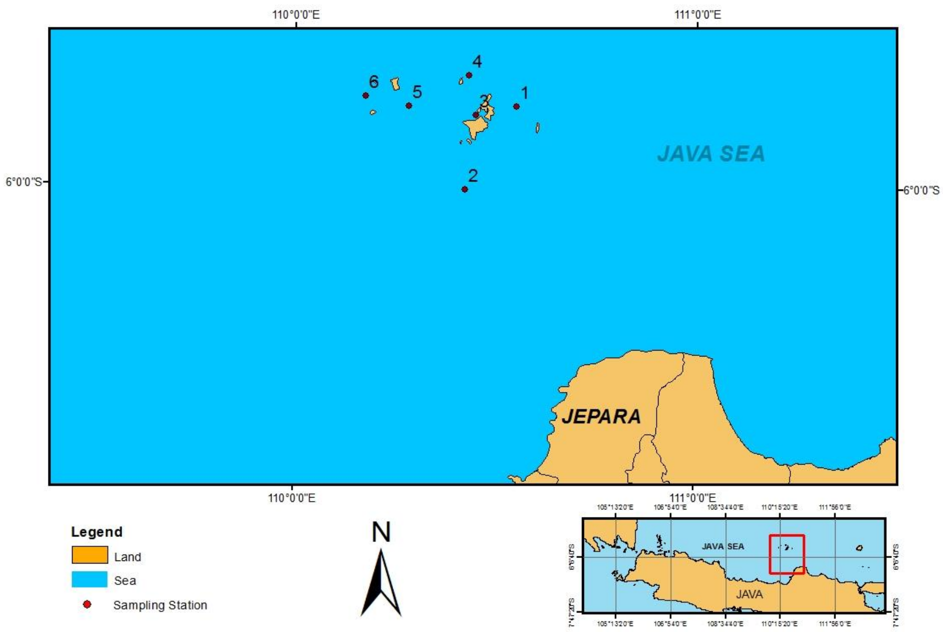


Figure 1. Research Location

days. The dried samples were transferred to a Marinelli beaker and ^{137}Cs activity was counted using a Gamma Spectrometer with Genie-2000 software. The data was recorded for 3 days to determine the activity of ^{137}Cs in the samples.

Current measurement and verification

Current speed was measured in the field and modeled using RMA2 module (Resource Management Associate-2) in the SMS software (Surface Water Modeling System). Current data model and current data from the field were then verified by finding the MRE (Mean Relative Error) using the formula:

$$RE = \frac{|x - c|}{x} \times 100\%$$

$$MRE = \sum_{1}^{n} \frac{RE}{n}$$

Note :
RE = Relative error;
x = Field data;
MRE = Mean Relative Error;
c = Simulation results data;
n = Amount of data

Software modeling with SMS is acceptable if the calculation verification of the model states MRE value is within the limit of 40%.

Table 1. Station site location

Station	Coordinate		Depth (meter)
	Longitude	Latitude	
1	5° 48' 6.41"	110° 33' 0.34"	39.8
2	6° 00' 33.7"	110° 25' 23.4"	51.0
3	5° 49' 20.5"	110° 26' 58.2"	20.8
4	5° 43' 23.6"	110° 25' 55.3"	41.0
5	5° 48' 08.2"	110° 16' 58.2"	43.0
6	5° 46' 40.3"	110° 10' 23.8"	39.3

^{137}Cs Distribution Model

The ^{137}Cs distribution model was created using the Software Surface Water Modeling System (SMS) module RMA4 (Resource Management Associate - 4). ^{137}Cs distribution can be analyzed if the current pattern is known. In addition to the speed and direction of currents, radionuclide release is also used to process RMA4. In this study, the radionuclide ^{137}Cs detached from the prospective nuclear power plant site in Muria peninsula that enters the coastal water in the simulated scenario is 0.729 mBq/L, with a decay value of 0.0000633 mBq/L (IAEA, 2001; Lambers and Williams, 2008). Those values are average daily detachment and decay of ^{137}Cs of AP1000 types of nuclear installations that common using in many countries.

Result and Discussion

Temperature and ^{137}Cs activity in Sea Water

The average seawater temperature in Karimunjawa during the study was 26.6 ^{o}C (Table 2). This value is used as a secondary data in addition to the tidal current, the water flow of the river and bathymetry.

The results of the ^{137}Cs activity analysis in the waters of Karimunjawa Islands ranged from 0.12 to 0.39 mBq.L^{-1} with an average of 0.24 mBq.L^{-1}. The highest concentration was 0.39 mBq.L^{-1}, which occurred at station 5 and the lowest, was 0.12 mBq.L^{-1} at station 4. This value is slightly higher than previous research in the area of coastal waters Gresik, where the average activity was 0.200 mBq.L^{-1} (Muslim *et al*., 2015), therefore the dilution rate in Karimunjawa is still less than that in coastal Gresik.

Table 2. Temperature and ^{137}Cs activity in each station

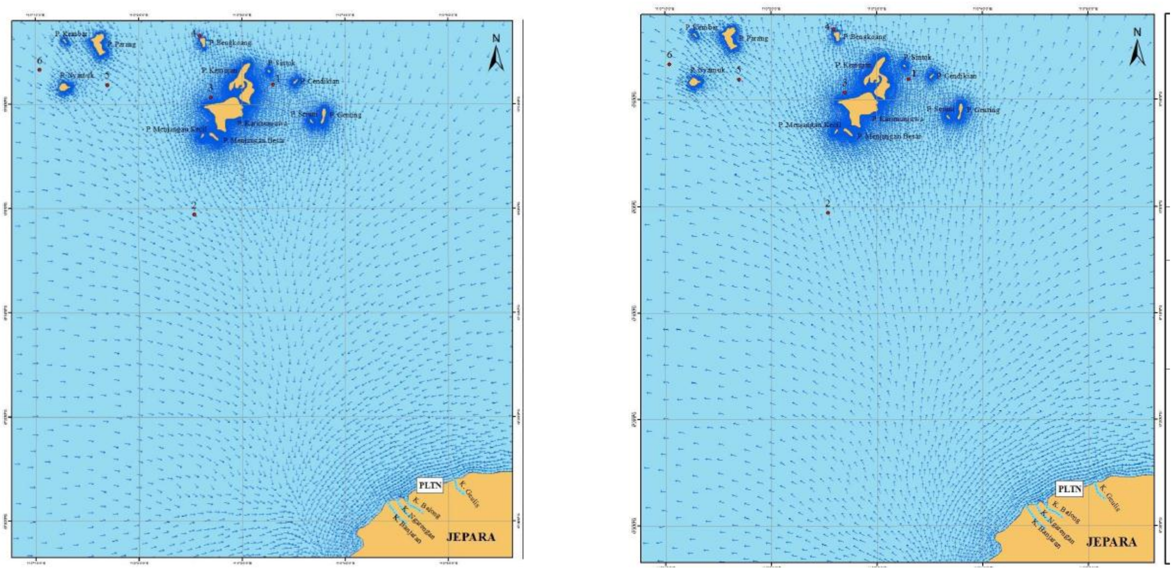
Station	Temperature (^{o}C)	^{137}Cs Activity (mBq.L^{-1})
1	25.1	0.283 ±0.03
2	28.2	0.166 ±0.02
3	28.3	0.295 ±0.03
4	25.2	0.120 ±0.01
5	25.0	0.397 ±0.04
6	28.1	0.180 ±0.02
Mean	26.6	0.24

This value is still much lower than ^{137}Cs activity in the waters of Northeast Japan even before the Fukushima nuclear power plant accident, where ^{137}Cs activity was measured at 2-3 mBq.L^{-1} (Inoue *et al*., 2012). This indicates that ^{137}Cs contained in Karimunjawa is not from Fukushima but from global fallout and it due to Indonesia's lack of nuclear reactor that released ^{137}Cs.

^{137}Cs activity values and seawater temperature at each station is presented in Table 2. The average value also is still much lower than the average value in the South China Sea, East China Sea and the Yellow Sea where ^{137}Cs was measured at 1.12 ± 0.08 mBq.L^{-1} from April to June 2011 (Wu *et al*., 2013). According to Tsumune *et al*., (2012), although ^{137}Cs is a radionuclide of which the highest quantity discharged from the Fukushima plant accident, its distribution is not very wide, and only spread to the North Pacific from March 26 until the end of May 2011. This range is still lower than past global fallout, even that which reached the bottom of the ocean (ocean basin) because its value is very small as a result of the diffusion and advection in the ocean.

Surface current simulation and its verification

Modeling the current pattern is shown under two conditions, at high tide (Figure 2a) and at low tide (Figure 2b). The MRE (Mean Relative Error) of the data was 31.99 %, and current speed direction was 28.53 %. The verification results are presented in Table 3.



(a) (b)

Figure 2. Current pattern: a. High tide b. Low tide in the Java Sea between Jepara and Karimunjawa Islands

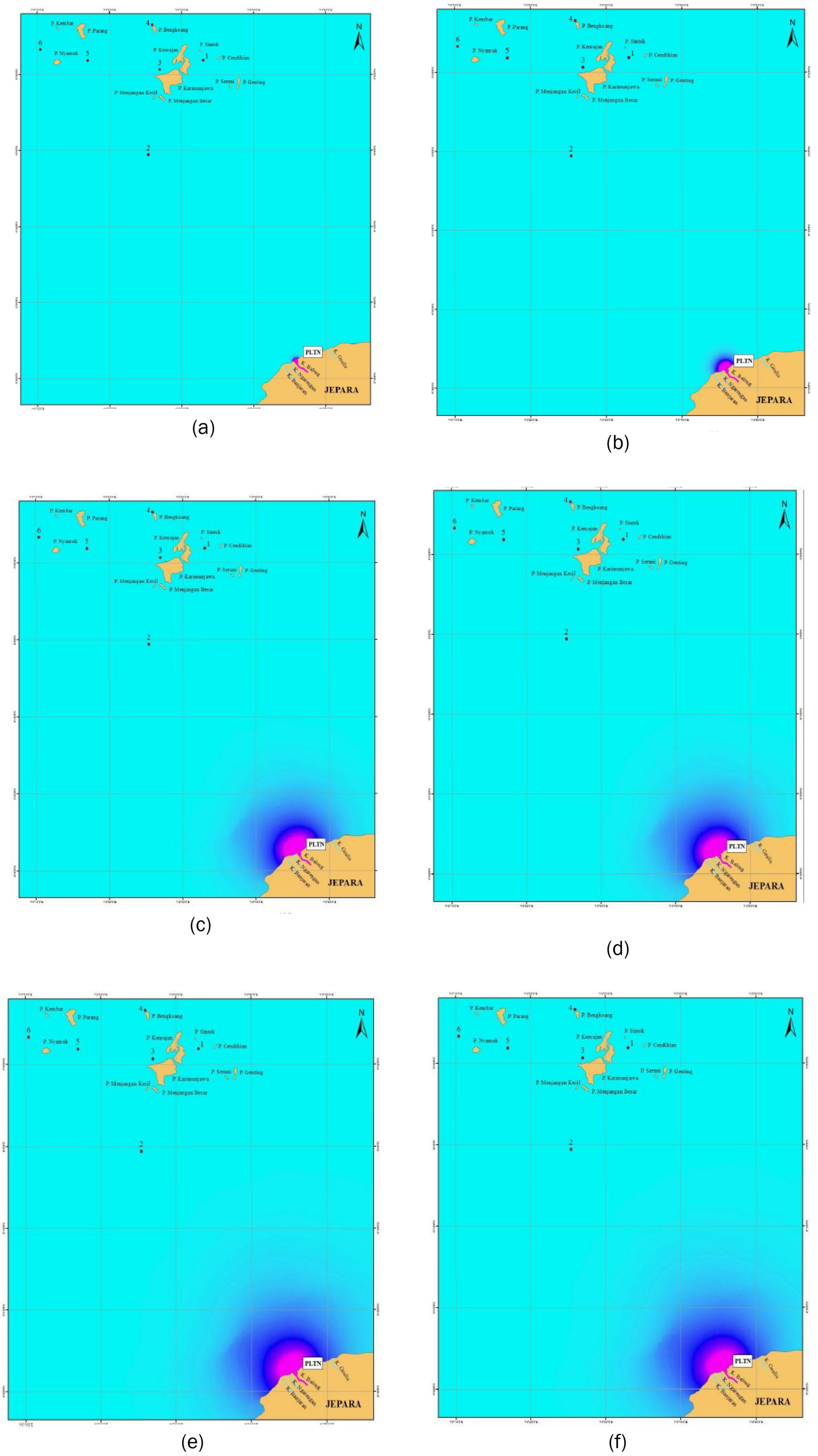


Figure 3. Distribution of ^{137}Cs on the first day (a, b), after 8 days (c, d) and after 15 days (e, f) both at the high and low tide.
Note : Land, Sea, Sampling station, High : 0.701646 Low : 0

Table 3. Current speed and Current direction verification

	Current speed(m/s)			Current direction(°)		
Station	Field	Model	RE (%)	Field	Model	RE (%)
1	0.03	0.02	20.0	227	49.4	78.23
2	0.29	0.16	45.2	187	181.27	3.06
3	0.06	0.08	33.33	134	146.87	9.6
4	0.11	0.05	49.09	73	76.44	4.71
5	0.14	0.09	32.71	348	345.49	0.72
6	0.24	0.22	11.64	146	36.66	74.89
		MRE =	31.99%		MRE =	28.53%

Modeling of ^{137}Cs distribution when NPP Muria Peninsula Jepara is operational

Figure 3 shows the results from modeling the distribution of ^{137}Cs of the site of the proposed nuclear power plant on Muria Peninsula is displayed for three different periods of time, from the moment the radionuclides enter the body of water, until the end of the first day, (t = 1 day), eighth day (t = 8 days) and fifteenth day (t = 15 days) at both high and low tide.

Figures 3a and 3b show the condition of ^{137}Cs released into the body of water the first day (t = 1 day). Figure 3a also shows that the distribution of ^{137}Cs at high tide reached a radius of 2.35 km, whereas, at low tide (Figure 3b), the distribution reaches a radius of 6.84 km. Broad distribution at high tide is smaller than at low tide because at high tide the water moves in the opposite direction of the direction of current flow from the river, so the flow from the river carrying radionuclides is stalled. At the time of low tide, the water from the river moves in the direction of tidal flow, so the spread of radionuclides into the sea is much broader as the current moves toward the northwest (Surbakti, 2012).

Figure 3c and 3d shows the distribution of ^{137}Cs after eight days (t = 8 days), at high tide and low tide. Similarly, the low tide distribution area (33.13 Km) is larger than at high tide (32.11 Km). However, the difference in distribution size between low tide and high tide on the eighth day is only 1.02 km, relatively small when compared with the difference in distribution area on the first day (4.49 km). This is presumably due to the river current direction towards the sea and the relatively weak and uniform speed of the tidal current. According to Duxbury *et al*., (2002) and Arifin *et al*., (2012), the tidal current is more dominant in the mass circulation of coastal waters. The ^{137}Cs distribution is generally westward during the east season when the current moves from the east towards the west. Wyrtki (1961) states that from May to September the Java Sea surface current moves from east to west.

Figure 3e and 3f, the end of the simulation model, describe the distribution of ^{137}Cs after 15 days (t = 15 days). The figure presented is an affirmation of the radius ratio spread of ^{137}Cs at high tide and low tide; at high tide (Figure 3e) the distribution has a smaller radius (44.85 km) than at low tide (45.75 km) (Figure 3f) and the direction of distribution remains toward the southwest in accordance with the direction of current movement in East season.

The results of the model simulation showed that the distribution of the radionuclide ^{137}Cs from the prospective nuclear power plant site Muria Peninsula on the sea surface for 15 days, shows that contamination would not reach the water around Karimunjawa Islands. This occurs because the current is relatively small (Table 3), and flows to the west due during the East season. Zhao *et al.,* (2015) also found that the current strength across the Pacific Ocean that would spread ^{137}Cs is weak. Haryanto (2008) notes that the spread of pollutants in nature involves advection, meaning that pollutant materials are transported by current or fluid flow, where the propagation velocity equals the velocity of fluid flow. Tsumune *et al*., (2012) added that diffusion also influences the spread of pollutants, so ^{137}Cs concentration rapidly decreases with distance.

Conclusion

The results of the analysis of ^{137}Cs in the waters of Karimunjawa Islands show the average value of the activity ^{137}Cs is 0.24 mBq.L^{-1}. The low level of ^{137}Cs activity is due to Indonesia's lack of nuclear reactors that releases radionuclides ^{137}Cs activity detected in Karimunjawa water dominantly come from global fallout from before the Japanese Daichi Fukushima nuclear power plant accident. The ^{137}Cs distribution model simulation shows that radionuclides from the prospective nuclear power plant on the Muria Peninsula do not reach Karimunjawa Islands waters after 15 days leaked because the currents are relatively small and move towards the west during the East season.

Acknowledgement

The author would like to thank the staff of Marine Radioecology laboratory BATAN for the provision of chemicals, and sampling equipment and marine Radioecology laboratory use for radionuclide analysis. We are also sincerely grateful to Susie Vulpas from America for comments this paper and correcting the English. Thank you also to Adrian for confirming the accurateness of our map.

References

Arifin, T., Yulius, Y & Ismail. M.F.A .2012. Kondisi Arus Pasang Surut di Perairan Pesisir Kota Makassar, Sulawesi Selatan. *Depik*, 1(3):183-188.

Ardisasmita, M.S. 2006. Preservation and Enhancement of Nuclear Knowledge Towards Indonesia's Plan to Operate First Nuclear Power Plant By 2016. IAEA-CN-123/04/0/06

Buesseler, K.O., Aoyama, M & Fukasawa, M. 2011. Impacts of the Fukushima Nuclear Power Plants on Marine Radioactivity. *Environ Sci Technol,* 45(23):9931–9935. doi: 10.1021/es202816c

Dietze, H & Kriest, I. 2012. Cs-137 off Fukushima Dai-ichi, Japan-Model Based Estimates of Dilution and Fate. *Ocean Science.* 8(3):319–332. doi: 10.5194/os-8-319-2012

Duxbury, A.B., Duxbury, A.C & Sverdrup, K.A.. 2002. Fundamentals of oceanography. *McGraw Hill Companies, New York.*

Haryanto, B. 2008. Pengaruh Pemilihan Kondisi Batas, Langkah Ruang, Langkah Waktu dan Koefisien Difusi Pada Model Difusi. Aplika *J. Ilmu Pengetahuan dan Teknologi*, 8(1):1-7.

IAEA [International Atomic Energy Agency]. 2001. Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment. Safety Reports Series No. 19. IAEA, Vienna, 216 p.

Inoue, M., Kofuji, H., Hamajima,Y., Nagao, S., Yoshida, K & Yamamoto, M. 2012. ^{134}Cs and ^{137}Cs Activities in Coastal Sea Water Along Northern Sanriku and Tsugaru Strait, North Eastern Japan, After Fukushima Nuclear Power Plant Accident. *J. Environ. Radioact.* 111:116–119. doi: 10.1016/j.jenvrad.2011.09.012

Lambers, B. & Williams, J. 2008. AP1000 Generic Design Prospective Individual Dose Assessment Westinghouse Electric Company. *Serco*., 26 p.

Madigan, D.J., Baumann, Z & Fisher, N.S. 2012. Pacific Bluefin Tuna Transport Fukushima-Derived Radionuclides from Japan to California. *Proceedings of the National Academy of Sciences of the United States of America*. 109(24): 9483–9486

Matsuzawa, T & Iio, Y. 2012. The Reasons Why We Failed to Anticipate M9 Earthquake in Northeast Japan. In: Proceedings of the International Symposium on Engineering Lessons Learned from the 2011 Great East Japan Earthquake: One Year after the 2011 Great East Japan Earthquake, 1-4 March 2012, Tokyo

Miyazawa, Y., Masumoto, Y., Varlamov, S.M., Miyama, T, Takigawa, M., Honda, M & Saino, T. 2013. Inverse Estimation of Source Parameters of Oceanic Radioactivity Dispersion Models Associated with the Fukushima Accident. *Biogeosciences*, 10(4):2349–2363. doi: 10.5194/bg-10-2349-2013

Muslim. 2007. ^{90}Sr Activity in the High Seas and Coastal Regions of Korea-Japan-Russia-China Compared with Exponential Decay of ^{90}Sr Global Fallout. *J. Mar. Sci.*, 12(1):39 – 44. doi : 10.14710/ik.ijms.12.1.39-44

Muslim, Suseno H & Rafsani, F. 2015. Distribution of ^{137}Cs Radionuclide in Industrial Wastes Effluent of Gresik, East Java, Indonesia. *Atom Indonesia*, 41 (1):47-50. doi : 10.17146/aij.2015.355

Nakano, M & Povinec, P.P. 2012. Long-Term Simulations of the ^{137}Cs Dispersion from the Fukushima Accident in the World Ocean. *J. Environ. Radioact*, 111:109–115. doi: 10.1016/j.jenvrad.2011.12.001

Nareh, M. & Warsona A. 1999. Penetuan Konsentrasi Cs-137 dan Pu-239/240 Dalam Sedimen Di Semenanjung Muria Dan Daerah Sekitarnya. *Research and Development Application of Isotopes and Radiation*, 197-201.

Qiao, F., Wang, G.S., Zhao, W., Zhao J.C., Dai, D.J., Song, Y.J & Song, Z.Y. 2011. Predicting the Spread of Nuclear Radiation from the Damaged Fukushima Nuclear Power Plant. *Chinese Sci. Bull.*, 56(18): 1890–1896.

Rahman, A. & Sugianti, Y. 2011. Biodiversitas Ikan Karang di Perairan Kepulauan Karimunjawa. *Dalam*: Prosiding Forum Nasional Pamacuan Sumber Daya Ikan III, Tanggal 18 Oktober 2011, 1-10.

Setiabudi, B. 2010. Dampak Pembangunan Pltn Terhadap Perubahan Tata Ruang Kabupaten Jepara, 16(1):11-15.

Suntoko, H. 2010. Kajian Aspek Keselamatan Tapak PLTN Di Ujunglemahabang, Sebagai Lokasi Yang Aman Dari Bahaya Kejadian Ekternal Alamiah, 12(2):75-85.

Surbakti, H. 2012. Karakteristik Pasang Surut dan Pola Arus di Muara Sungai Musi, Sumatera Selatan. *Jurnal Penelitian Sains.* 15(1):35-39.

Suseno, H. & Umbara, H . 2003. Radioactive Monitoring at Jakarta Bay and Muria Coastal Zone in Indonesia. *Proceed International Conference on Isotopic and Nuclear Analytical Techniques for Health and Environment*, IAEA Vienna (Austria); 10-13 Jun 2003; IAEA-CN-1.

Suseno, H. & Umbara, H. 2006. Pengukuran Radionuklida Alam dan Antropogenik di Kawasan Semenanjung Muria. *Proceed Sem Nas Keselamatan Nuklir*, BAPETEN, 2 - 3 Agustus 2006. 359-373

Suseno, H. 2012. Profil Konsentrasi ^{137}Cs di Pesisir Indonesia yang Ditetapkan Menggunakan Metoda Pemekatan Sampel Melalui Cartridge Filter Berlapis Tembaga Ferosianat. *J. Tek. Peng. Lim* 15(1): 1-6

Suseno, H. 2013. Studi Radioekologi Kelautan Di Pesisir Pantai Selatan Yogyakarta: Monitoring ^{137}Cs Untuk Keperluan Baseline Data dan Untuk Mengantisipasi Kemungkinan Dampak Kecelakaan Nuklir Di Fukushima. *J. Tek. Peng.Lim* 17(2): 52-57.

Suseno, H. & Wisnubroto, D.S. 2014. Radioecological study of $^{239/240}$Pu in Bangka Island and Muria Peninsula: Determination of $^{239/240}$Pu in Marine Sediment and Seawater as Part of Base Line Data Collecting for Sitting of Candidates of First Indonesia NPP. *AIP Conf. Proc*. 1589: 338-345.

Suseno, H, & Prihatiningsih W.R. 2014. Monitoring ^{137}Cs and ^{134}Cs at Marine Coasts in Indonesia Between 2011 and 2013. *Mar. Pollut. Bull*, 88 (1–2):319–324. doi : 10.1016/j.marpolbul.20 14.08.024

Suseno, H., Ikhsan B.W, & Muslim. 2015. Radiocesium Monitoring in Indonesian Waters of the Indian Ocean After the Fukushima Nuclear Accident. *Mar. Pollut. Bull*, 97 (1–2):539–543. doi : 10.1016/j.marpolbul.2015 .05.015

Tsumune, D., Tsubono, T., Aoyama, M & Hirose, K. 2012. Distribution of Oceanic ^{137}Cs from the Fukushima Dai-ichi Nuclear Power Plant Simulated Numerically by a Regional Ocean Model. *J. Environ. Radioact*, 111: 100–108. doi: 10.1016/j.jenvrad.2011.10.007

Tsumune, D., Tsubono, T., Aoyama,M., Uematsu, M., Misumi, K., Maeda, Y., Yoshida, Y & Hayami, H . 2013. One-Year, Regional Scale Simulation of ^{137}Cs Radioactivity in the Ocean Following the Fukushima Dai-ichi Nuclear Power Plant Accident. *Biogeosciences*, 10(8): 5601–5617.

Umbara, H., Suseno, H., Cahyana, C., Hari, B & Prihatiningsih, W R. 2006. Pemantauan Radioekologi Kelautan Di Semenanjung Lemahabang, Jepara Tahun 2006. Dokumen Teknis Kegiatan Riset Pusat Teknologi Pengelolaan Limbah Radioaktif BATAN.

Utomo. 2011. Manajemen Rencana Kegiatan Persiapan Pembangunan PLTN di Indonesia. PRIMA., 8(2):81-88

Windriani, R., Yusibani, E & Safitri, R. 2014. Study of Deposit ^{137}Cs Activity as a Result of Fission Product from the Fukushima Daiichi Nuclear Power Plant at Japan after Earthquake and Tsunami in 2011. *J. Aceh Physics Society*, 3(1):3-4.

Wyrtki, K. 1961. Physical Oceanography of the Southeast Asian Water. Naga Report Volume 2. The University of California L Jolla. California, 195 p.

Wu, J.W., Zhou, K.B, & Dai, M.H. 2013. Impacts of the Fukushima Nuclear Accident on the China Seas: Evaluation Based on Anthropogenic Radionuclide ^{137}Cs. *Chinese. Sci. Bull*, 58 (4-5): 552-558. doi: 10.1007/s11434-012-5426-2

Yuliastuti & Nurlaila. 2007.Kesiapsiagaan Darurat Nuklir Pada Kecelakaan Domestik PLTN. *Prosiding Seminar Nasional ke-13 Teknologi dan Keselamatan PLTN Serta Fasilitas Nuklir* Jakarta on 6 November 2007, 139-148.

Zhao, C., Wang, G., Qiao, F., Wang, G., Jung, K.T & Xia, C. 2015. A Numerical Investigation In to the Long-Term Behaviors of Fukushima-Derived ^{137}Cs in the Ocean. *Acta Oceanol. Sin.* 34(12): 37–43. doi: 10.1007/s13131-015-0775-8