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Baseline

Radiocesium monitoring in Indonesian waters of the Indian Ocean after the Fukushima nuclear accident

Heny Suseno [a,*], Ikhsan Budi Wahono [b], Muslim [c]

[a] Marine Radioecology Group, Center for Technology of Radiation Safety and Metrology, National Nuclear Energy Agency, Jl. Lebak Bulus Raya No. 49, Kotak Pos 7043 JKSKL, Jakarta Selatan 12070, Indonesia

[b] Technology Center for Marine Survey, Agency for Assessment and Application of Technology, Jakarta, Indonesia

[c] Department of Marine Science, Diponogoro University, Semarang, Indonesia

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ABSTRACT

As data on anthropogenic radionuclide concentrations (i.e., ^{134}Cs and ^{137}Cs) in Indonesian marine environments including the Indian Ocean are scarce, offshore monitoring has been performed in the West Sumatra and South Java Seas. The activity concentration of ^{137}Cs ranges from below minimum detectable activity (MDA) to 0.13 Bq m^{-3} in the surface seawater of the South Java Sea and from lower than MDA to 0.28 Bq m^{-3} in the surface seawater of the West Sumatra Sea. The concentrations of ^{137}Cs in the surface seawater of the West Sumatra and South Java Seas are lower than the estimation of ^{137}Cs concentration in the subsurface waters owing to the input of the North Pacific Ocean via the Indonesian Throughflow (ITF). The concentrations of ^{134}Cs in the sampling locations were lower than MDA. These results have indicated that these Indonesian marine waters have not yet been influenced by the Fukushima radioactive release.

Radiocesium (^{134}Cs and ^{137}Cs) is one of the radioactive materials present in the heavily contaminated coolant water that was discharged into marine water following the accident at the Tohoku Fukushima Dai-ichi nuclear power plant (FNPP) (Kaeriyama et al., 2013). The Kuroshio Current has subsequently transported isotopes of radiocesium and other radionuclides from Fukushima to the northwest (NW) Pacific Ocean (Nakano and Povinec, 2012). Due to their biogeochemical properties and oceanic processes, radionuclides from Fukushima can be transported from the NW Pacific Ocean to the Indian Ocean. The exchange of waters occurs in an inter-basin known as the Indonesian Throughflow/ITF (Sprintall et al., 2002, 2010).

Due to its possible impact on Indonesian marine waters and their biota, the accident at Fukushima has become a public concern in the country, as it relies heavily on the production of marine food products. Moreover, marine biota such as fish have the ability to accumulate ^{134}Cs and ^{137}Cs in their edible tissues from seawater, even when present in small concentrations. Java and Sumatra, two large Indonesian islands, lie adjacent to the eastern Indian Ocean, and they show considerable seasonal contrasting characteristics in their surface waters (Murgese et al., 2008). Some researchers have monitored the marine environment in Indonesia in relation to nuclear activities (research and application) and the potential threat posed by Fukushima releases. Radionuclide contaminants could already be influencing open ocean areas, thus calling for further development of a radionuclide-monitoring program in Indonesia. All environmental issues related to contaminants (including radionuclides) require a scientific foundation of understanding, monitoring, and modeling of the marine environment, which has not been established in Indonesian waters so far (Inagoos, 2005). The proposed monitoring program will be crucial to ensuring the safety of marine food products in Indonesia. At present, very limited data have been reported on the levels of anthropogenic radionuclides in the Indian Ocean (Povinec et al., 2011) as well as in the Indonesian marine waters, which are part of the Indian Ocean. The only comprehensive study was carried out in 1978 in the framework of the Geochemical Ocean Sections Study (GEOSECS) program, which included several vertical profiles of tritium in the water column (Povinec et al., 2011).

Analyzing the immediate and continuous records of these radionuclides in the marine environment following the FNPP accident is particularly important for obtaining the initial concentrations of ^{134}Cs and ^{137}Cs, because these are strongly affected by physical processes in seawater such as advection and mixing (Inoue et al., 2012). The ^{134}Cs and ^{137}Cs concentrations of highly contaminated surface seawater samples around the FNPP have been studied extensively (Tsumune et al., 2012; Honda et al., 2012), but such data on the waters surrounding the Indonesian archipelago are scarce. The possible impact of the Fukushima

* Corresponding author.
E-mail address: henis@batan.go.id (H. Suseno).

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release on Indonesian coastal waters was recently studied in some coastal areas extending from the western to eastern regions of the archipelago (Suseno and Prihatiningsih, 2014). As data on offshore marine waters are unavailable, we monitored the ^{137}Cs and ^{134}Cs concentrations in the eastern Indian Ocean off the West Sumatran and South Java Seas. We participated in two scientific cruises of the research vessel *Baruna Jaya*, operated by the Technology Center for Marine Survey, Indonesian Agency for Assessment and Application of Technology. Samplings were carried out in the West Sumatra Sea between 20 and 28 November 2011 and in the South Java Sea between 16 and 20 September 2012. The results of the analysis highlight the possible impact of the accident at Fukushima on the Indonesian marine environment. On the other hand, the ^{137}Cs concentrations off the shore of Indonesia are very important because the elevated ^{137}Cs levels found in the South Indian Ocean subtropical gyre must therefore result from its transport from the North Pacific Ocean via the Indonesian seas.

The methods include surface water sampling and analysis of radiocesium concentration. Seawater sampling was carried out at five locations off West Sumatra and 10 locations off the South Java Sea (Fig. 1). Approximately 150 l of marine water samples were taken from each location. All samples from both regions were held in plastic containers and then transported to the marine radioecology laboratory at the Serpong Nuclear Area, Banten Province, Indonesia. The water samples for ^{137}Cs determination were prepared using methods similar to those of Yamada and Wang (2007) with some modifications. Briefly, the seawater samples were acidified to a pH of 1–2 with concentrated nitric acid. Radiocesium was separated from seawater by coprecipitation with the addition of 200 g of ammonium molybdophosphate (AMP) and an aliquot of CsCl solution containing 0.2–0.4 g of cesium as a carrier. After being left to stand for 24 h, the supernatant was separated out from the precipitate. Finally, the precipitates of AMP that contain ^{137}Cs were dried and placed in a plastic container before gamma counting. ^{137}Cs was determined using gamma rays at the photopeak of 661 keV. Each sample was measured for 259,200–345,600 s. We used three high-purity germanium (HPGe) detectors with counting efficiencies of 20–25% and a full width half maximum (FWHM) of 1.8 keV for a peak of 1332 keV of ^{60}Co. The gamma spectrometers used were Canberra GX2018, Canberra GC2020, and Ortec GMX 25P4-76. The method consisted of detector calibration, determination of detector counting efficiency, cumulative counts of both background and samples at regular intervals of time counted, photopeak smoothing, and linear regression.

Bailly du Bois et al. (2011) estimated the total activity of ^{137}Cs directly released from the Fukushima 1F NPP to be 27 ± 15 PBq. On the other hand, 160 and 15 PBq of ^{131}I and ^{137}Cs were estimated to be discharged into the atmosphere, respectively (Tsumune et al., 2012). More than 80% of the ^{137}Cs released into the atmosphere will also be deposited in the Pacific Ocean (Steinhauser et al., 2014). The FNPP is located within a transition area of the Kuroshio–Oyashio currents, an area between the extensions of the subarctic Oyashio and the subtropical Kuroshio. Therefore, dispersion of radiocesium eastward to the North Pacific is regulated by the Kuroshio Extension (KE) (Kaeriyama et al., 2013). Due to its chemical properties, radiocesium is soluble in seawater, which allows it to easily spread over long distances with marine currents as well as dissipate across oceanic water masses (Povinec et al., 2004). The Kuroshio Current is the dominant current in the NW Pacific Ocean that transports equatorial waters to the north. Furthermore, from the Pacific Ocean, masses of surface water stream down via the Indonesian seas to the Indian Ocean, subsequently penetrating the subtropical gyre (Povinec et al., 2011). The thermocline water from the North Pacific Ocean enters the Makassar Strait, whereas the lower thermocline water from the

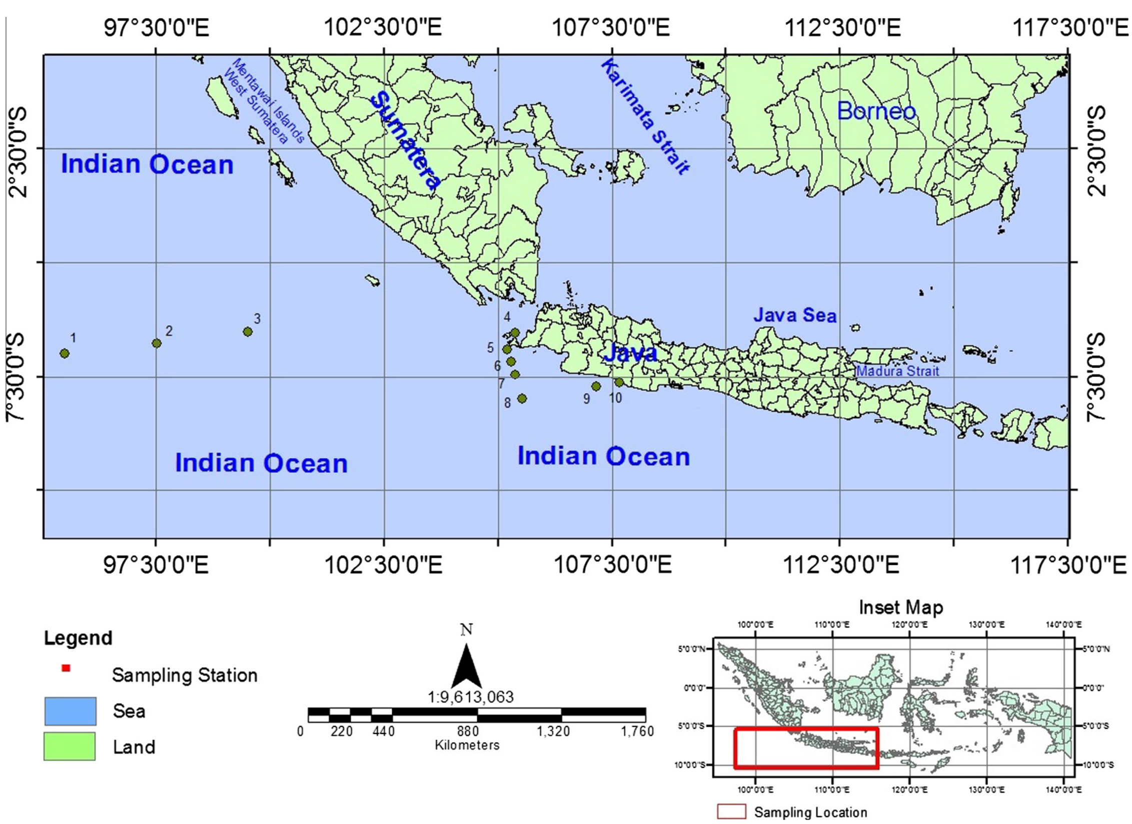

Fig. 1. Sampling locations.