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Bioaccumulation and retention kinetics of cesium in the Milkfish *Chanos chanos* from Jakarta Bay

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ABSTRACT

Laboratory radiotracer experiments were conducted to study the uptake, assimilation, and retention of cesium (^{137}Cs) in milkfish (*Chanos chanos*) from Jakarta Bay. In this study, we have examined the bioaccumulation and distribution of ^{137}Cs in *C. chanos* obtained from ^{137}Cs-labeled seawater and ^{137}Cs-labeled *Artemia sp.* feeding. The uptake of ^{137}Cs via seawater displayed a one-compartment model suggesting that the concentration factors of ^{137}Cs within the milkfish (weight 2.46–9.86 g) at a steady-state period were between 10.66 and 3.98 mL g^{-1} after 10 days of exposure. The depuration rate was observed to be low, with only 22.80–49.14% of ^{137}Cs absorbed by *C. chanos*, which was absent 6 days after exposure. By contrast, depuration occurred quickly for radiolabeled food uptake, reaching 20% of retention within 10 days after exposure. Muscles and viscera of the milkfish exhibited the highest degree of end uptake and end depuration of ^{137}Cs from seawater and feeding.

1. Introduction

Jakarta Bay is ecologically degraded due to high load of biological, chemical, and radioactive pollutants from both marine and inland areas (Rengganis, 2012; Rinawati et al., 2012; Arifin, 2004; Williams et al., 2000). These pollutants were discharged from upland regions transported by 13 rivers flowing into Jakarta Bay, including the Cisadane River (Koropitan et al., 2008; Arifin, 2004). At present, Indonesia has a research power reactor with an output power of 30 MW, and is planning to establish another HTGR-type research power reactor with a capacity of 10 MW at Serpong, near Jakarta (BATAN, 2014). Radionuclides such as ^{137}Cs may potentially be released from the reactor and other nuclear facilities and transported by the Cisadane River into Jakarta Bay, thereby affecting the fishery activities such as capture fishery and aquaculture, which contribute to huge quantities of biota culture (e.g., milkfish, green mussels, shrimps, and seaweeds). Unfortunately, these biotas can accumulate ^{137}Cs. At present, there has been only limited number of studies conducted on the effect of nuclear facilities on bioaccumulation of ^{137}Cs in Indonesia. A study on bioaccumulation of ^{137}Cs by *Perna viridis* at Jakarta Bay was conducted by Suseno in 2004. A similar study was conducted on freshwater snail *Pila ampullaceal* concerning the potential release of ^{137}Cs into the Cisadane River (Suseno and Prihatiningsih, 2014. However, these studies only described the accumulation processes of ^{137}Cs from seawater. Hedouin et al. (2010) investigated metal bioaccumulation of *Isognomon isognomum* and *Malleus regula* exposed to Ag, Cd, Co, Cr, and Zn from three different contamination pathways (seawater, food, and sediment). The biokinetic approach has successfully demonstrated the mechanism of bioaccumulation by marine biotas for both nonradioactive contaminants using radiotracer and radioactive contaminants such as ^{134}Cs, ^{137}Cs, and ^{241}Am (Metian et al., 2007; Rowan, 2013; Bustamante et al., 2006; Baudin et al., 2000).

The milkfish *Chanos chanos* is the sole existing species of the family Chanidae that is widely cultured in Jakarta Bay. Biologically, milkfish is a euryhaline fish species that is extremely resistant to water quality changes. They can absorb and accumulate various contaminants from the environment (Takarina et al., 2012; Palanikumar et al., 2012; Chou et al., 2006). According to the report of the Ministry of Marine and Fisheries of Indonesia in 2010, milkfish is regarded as a high-value food item and the fourth largest aquaculture commodity being cultivated in the country, with seaweed, Nile tilapia, and shrimps being the first three. The rate of production of the milkfish *C. chanos* is approximately 291.300 ton/year. The aquaculture production of this species increased from 212.883 to >291.000 ton from 2006 to 2009, contributing to >6% of the total national seafood production (KKP, 2010). In addition, the demand for milkfish in Indonesia has been increasing every year, with an average increase of 5.96% from 2005 to 2009 (GAIN Report, 2010). Therefore, research on bioaccumulation of ^{137}Cs is required to protect human health from the effects of the research reactor. In order to investigate and better understand the bioaccumulation of ^{137}Cs, this study assesses the uptake and depuration kinetics of *C. chanos* from Jakarta Bay

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that were exposed to ^{137}Cs through seawater and food. It also investigates the distribution of ^{137}Cs in the milkfish body.

2. Materials and methods

2.1. Organisms tested

C. chanos (fish length 3.2–5.8 cm) were collected from a fish farm in Tanjung Pasir, Jakarta Bay, Indonesia, in September 2014. Then, they were shipped to the Marine Radioecology Laboratory, Center for Technology of Radiation Safety and Metrology in South Jakarta, where they were acclimated to laboratory conditions (open circuit, 1000-l aquarium, water renewal: 30% h^{-1}; T: 27 ± 0.5 °C; salinity: 35‰; pH: 8.0 ± 0.1) for 2 months before the experiment. During this period, *C. chanos* were fed LAJU (LJA-3) commercial pellets daily.

2.2. Radiotracers and counting

The uptake and depuration kinetics of ^{137}Cs were determined by high specific activity radiotracers purchased from Polatom, Poland (^{137}Cs as CsCl, $t_{½}$ = 30 years). Activity of the tracers was measured non-destructively using 661.66-keV NaI gamma detector (type 3428, Bicron) equipped with a multichannel analyzer and computer installed with (Genie, 2000) spectra analysis software from Canberra Ind. Standards 300 Bq activity and appropriate fish phantom geometry were used to determine the activity by comparison. Measurements were corrected by considering efficiency and physical radioactive decay. The counting time was adjusted to obtain a propagated counting error <5% (Rodriguez y Baena et al., 2006).

2.3. Seawater exposure

Six samples of similar-sized *C. chanos* were placed in a 10-l closed-circuit constantly aerated glass aquarium (T: 27 ± 0.5 °C; salinity: 35) and exposed to ^{137}Cs radiotracers dissolved in 0.45-μm filtered seawater for 10 days, according to the method described by Metian et al. (2007). In addition, four different-sized *C. chanos* were placed in four 10-l glass aquariums. Six samples of *C. chanos* were placed in the same condition for dissection at the end of uptake and six other specimens in 10-l open-circuit constantly aerated glass aquarium for dissection at the end of depuration (T: 27 ± 0.5 °C; salinity: 35). Nominal activity of ^{137}Cs radiotracer was 2 kBq/l. In terms of stable metal concentration, these additions corresponded to Cs (5.8 pmol l^{-1}), which are one to three orders of magnitude lower than those naturally found in seawater. The seawater was changed and spike was renewed daily during the first week, and then every alternate day to maintain constant activity in the seawater. The activity of the radiotracers in the seawater was checked daily, before and after each spike renewal, to calculate their time-integrated activities (Rodriguez y Baena et al., 2006). Immediately before each renewal of seawater and spike, the *C. chanos* were fed *Artemia sp.* in clean, unspiked seawater (30 min). They were then radiocounted for 15 min. At the end of the 10-day exposure period, six samples of *C. chanos* were selected for the dissection experiment. The viscera and remaining muscle parts were separated, weighed, and radioanalyzed to assess the distribution of ^{137}Cs within the body. The remaining 24 samples were then placed in clean, unspiked conditions (flowing and filtered seawater, flux: 50 l h^{-1}; T: 27 ± 0.5 °C; salinity: 35‰; daily feeding on *Artemia sp.*) for 6 days to determine the depuration of the radiotracers in the whole body. Six individuals of this species were collected at the end of the depuration period and dissected to assess radiotracer distribution between organs.

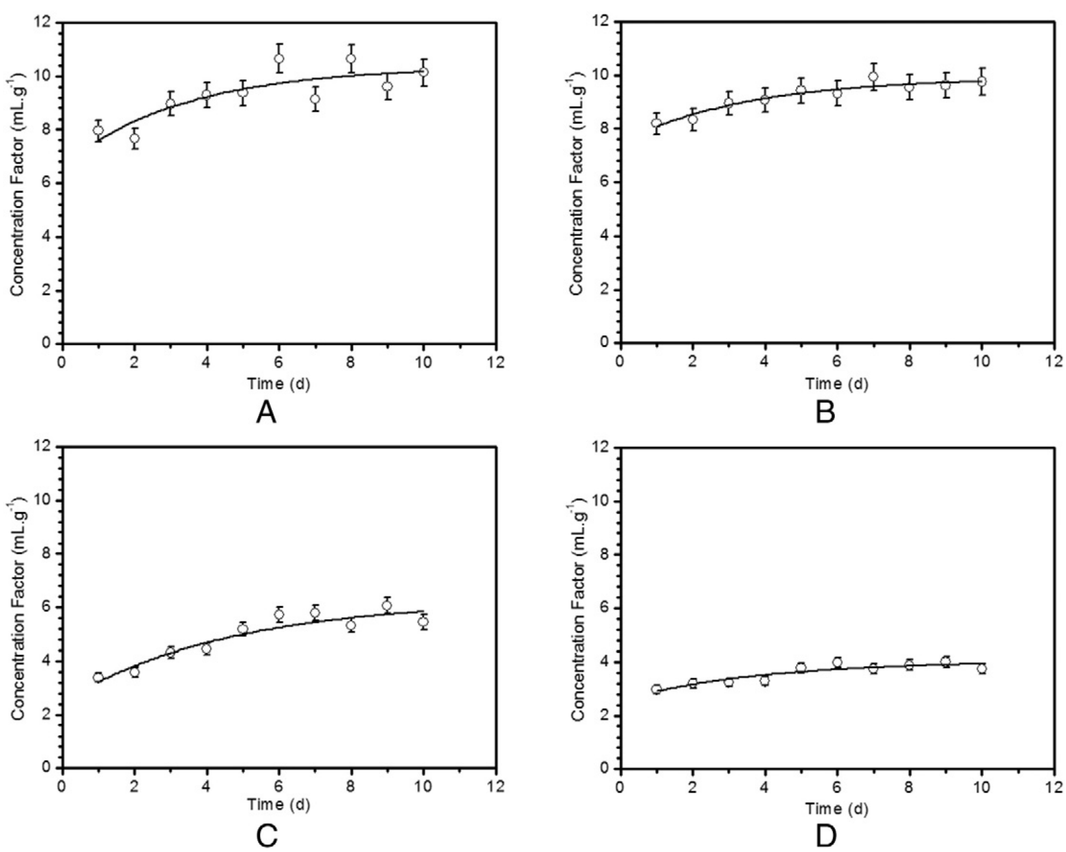

Fig. 1. Uptake kinetics of ^{137}CS in *Chanos chanos* (A. 2.46 g, B. 5.29 g, C. 8.32 g, D. 9.86 g) exposed to ^{137}CS for 10 days via seawater (mean concentration factors, CF ± SD, n = 6 per body size).