Dose Rates Assessment of ^{137}Cs for *Chanos chanos* using ERICA Tool

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Abstract. *In recent years there has been growing international interest in the assessment of doses and risks from ionizing contaminants to organism. In this study The Environmental Risk from Ionizing Contaminants: Assessment and Management (ERICA) Tool was applied to estimate dose rates to Chanos chanos in marine ecosystems from Jakarta Bay exposed to ^{137}Cs from Java sea environmental monitoring data. Data sets consisting of measured Concentration Ratio (CR) in different size of Chanos chanos and all default parameter provided by ERICA database. The uptake of ^{137}Cs via seawater displayed a simple exponential kinetic model suggesting that the CR of ^{137}Cs within Chanos chanos with a weight range of 2.46×10^{-3} - 9.86×10^{-3} kg at steady state period were between 10.66 - 3.98 $L.kg^{-1}$ after 10 days of exposure. The depuration rate for ^{137}Cs accumulated via seawater was slow, only 22.80 - 49.14% of ^{137}Cs were absorbed in whole body of Chanos chanos. Using the CR from laboratory experiment, the total dose rates of ^{137}Cs to Chanos chanos were all below the threshold 10 $\mu Gy.h^{-1}$. Chanos chanos dose rate in the present study were 2.26×10^{-7} – 4.55×10^{-7} $\mu Gy.h^{-1}$.*

Keywords: Erica Tool, Chanos chanos, ^{137}Cs, Dose Rate Assessment

Introduction

Dose assessment for non-human organism from the radioactive release of nuclear facilities is becoming increasing attention. Indonesia has already one Research Nuclear Power Reactor with an output power of 30 MWe and has made a planning project to operate another Research Nuclear Power Reactor of 10 MWe Type HTGR which will be located at Serpong, near Jakarta (BATAN, 2014). Radionuclides such as ^{137}Cs may potentially be released during normal operations from the reactor and other nuclear facilities. When this occurs, these radionuclides would be transported into Cisadane River and finally into Jakarta Bay. There are fishery activities at Jakarta Bay such as capture fishery and aquaculture that cultivate huge quantities of organism culture. According to the report of the ministry of Marine and Fisheries in 2010, milkfish *Chanos chanos* is regarded as a high-value food item and has become the fourth highest aquaculture commodity being cultivated. This organism have the ability to accumulate ^{137}Cs released from a power reactor and accumulate various contaminants from the environment (L. Palanikumar et al., 2012; B.Y. Chou et al., 2006).

Radionuclides can bioaccumulate in the aquatic environment, and studies have been conducted to model the uptake and depuration dynamics of specific radionuclides in various species of fish (E. Dobrovolsky et al., 1995; J.E. Brown et al., 1996; R.A Jeffree et al., 2007). A particular aspect that is missing from previous investigations of radionuclide bioaccumulation in fish is the link between bioaccumulation, exposure and delivered dose. Moreover, previous studies have investigated bioaccumulation of radionuclides in fish (J. Garnier et al. 2007; T. Mathews et al., 2008; R.A Jeffree et al., 2010) and effects of doses of radiation from radiation sources (T. Yabu et al., 2001) but the linkages between radiation dose and bioaccumulation has not been established previously for any fish species.

New techniques in dose estimation and dosimetry modelling can now be applied to expand results of bioaccumulation studies to provide estimates of radiation dose received by fish and other organism exposed to radionuclides (M.D Wood et al., 2009; J.E. Brown et al., 2008). The ERICA Tool has been applied to a various of environmental contamination situations with several types of organism (M.D Wood et al., 2009; K. Stark et al., 2008; N.A. Beresford et al., 2008). However, the application of the ERICA Tool (or any other package of dosimetry modelling) to estimate dose rates over time for *Chanos chanos* exposed to ^{137}Cs has not been conducted.

In this study the ERICA Tool was applied to estimate dose rates to *Chanos chanos* in marine ecosystems from Jakarta Bay. The main purpose of the assessment reported here was to developed risk assessment for non-human organism during operational Nuclear Power Reactor and before newly-built another Research Nuclear Power Reactor. Study was focused to estimate dose rate to different size of *Chanos chanos* exposed with ^{137}Cs under Concentration Ratio (CR) defined from laboratory bioaccumulation experiment.

Materials and Methods

The experiment consist of two works, i.e bioaccumulation study of *Chanos chanos* exposed to ^{137}Cs which is published already in Marine Pollution Journal (W.R. Prihatiningsih et al., 2016) and *Chanos chanos* dose assessment using ERICA Tool (J.E. Brown et al., 2008). The method of ERICA Tool briefly described below.

Erica Risk Assessment

Input data for organisms

The ERICA Tool (www.ceh.ac.uk/PROTECT/ ERICAdeliverables. html, Brown et al., 2008) was used to calculate total, external and internal received by different size of *Chanos chanos*. The ERICA Tool provides a tiered approach allowing the input of site-specific measured activity concentrations in organism and media at Tiers 2 (J.E. Brown et al., 2008). Tier 2 in ERICA 1.2 uses dimensions for organism of interest to calculate dose rate in the whole body. The organism is simplified to a sphere or ellipsoid in the tool. Because the actual shapes of the organisms were irregular, the geometric dimensions were adjusted to match the mass (J.E. Brown et al., 2008).

Dosimetry Calculations

The ERICA Tool is designed to model exposure of wildlife that inhabits aquatic ecosystems and, as such, calculates the external dose in organisms living in the water column from both sediment and water. However, there was no sediment compartment in the experiment therefore the Distribution Coefficient (Kd) was set to zero, to prevent the ERICA Tool from estimating any sediment derived external dose. By setting CR value from bioaccumulation experiment and the sediment and sea water activity concentration 1.75 $Bq.kg^{-1}$ and 2.5 x 10^{-4} $Bq.L^{-1}$[17], the tool calculates weighted DCC for ^{137}Cs for internal and external dose (giving a DCC value as $\mu Gy.h^{-1}.Bq^{-1}.ml^{-1}$, Table 3).

Results and Discussion

The uptake of ^{137}Cs was indicated accumulation that characteristic of one compartment exponential kinetics and appear to approach steady state (Fig. 1 and Table 1). The values estimated for the kinetic parameters and their associated statistics are shown in Table 1. The concentration ratios of ^{137}Cs for the smallest to largest body sizes were 10.66; 9.93; 5.78; and 3.98 $L.kg^{-1}$ in whole-body fish, respectively (W.R. Prihatiningsih et al., 2016).

When non-contaminating conditions were restored, the wholebody depuration kinetics of ^{137}Cs were best described by a single-component exponential model (Fig. 1 and Table 1). The majority of the bioaccumulated ^{137}Cs was absorbed only 49.14; 22.80; 12.70; 39.97 % in *Chanos chanos* for body size smallest to largest. The estimated depuration constant rate of *Chanos chanos* for body size 2.46 x 10^{-3}; 5.29 x 10^{-3}; 8,32 x 10^{-3} and 9.86 x 10^{-3} kg were 0.71; 0.55; 0,49 and 0.46 d^{-1} (W.R. Prihatiningsih et al., 2016).

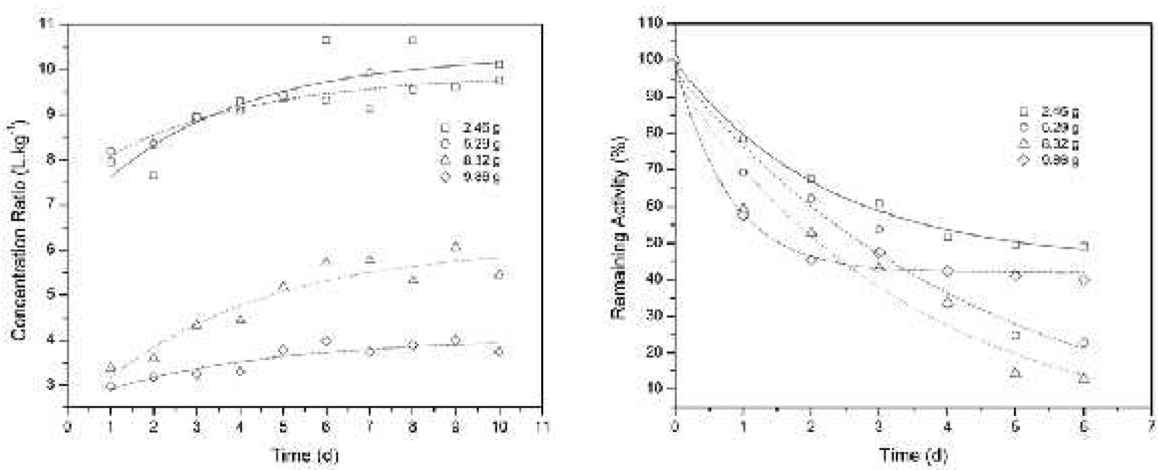

Figure 1. Uptake and depuration kinetic of ^{137}Cs by *Chanos chanos*(W.R. Prihatiningsih et al., 2016)

Table 1. Whole-body uptake and depuration kinetic parameters of ^{137}Cs by *Chanos chanos* (W.R. Prihatiningsih et al., 2016)

Chanos chanos Body Size (kg)	Seawater		
	CR_{ss} (L.kg^{-1})	k_u (d^{-1})	k_e (d^{-1})
2.46 x 10^{-3}	10.66	1.23	0.71
5.29 x 10^{-3}	9.93	0.88	0.55
8.32 x 10^{-3}	5.78	0.65	0.49
9.86 x 10^{-3}	3.98	0.34	0.46

Tabel 2. Results from a Tier 2 assessment using the ERICA Tool

Chanos chanos Body Size (kg)	External Dose Rate (µGy.h^{-1})	Internal Dose Rate (µGy.h^{-1})	Total Dose Rate (µGy.h^{-1})	Risk Quotient (Expected Value) (unit less)	Risk Quotient (Conservative Value) (unit less)	ERICA Tool Consideration
2.46 x 10^{-3}	8.24 x 10^{-8}	3.73 x 10^{-7}	4.55 x 10^{-7}	4.55 x 10^{-8}	1.37 x 10^{-7}	Green
5.29 x 10^{-3}	8.16 x 10^{-8}	3.56 x 10^{-7}	4.37 x 10^{-7}	4.37 x 10^{-8}	1.31 x 10^{-7}	Green
8.32 x 10^{-3}	8.13 x 10^{-8}	2.09 x 10^{-7}	2.90 x 10^{-7}	2.90 x 10^{-8}	8.71 x 10^{-8}	Green
9.86 x 10^{-3}	8.12 x 10^{-8}	1.44 x 10^{-7}	2.26 x 10^{-7}	2.26 x 10^{-8}	6.77 x 10^{-8}	Green

The ERICA Integrated Approach recommends that the input values should be expected value (or best estimate) activity concentrations, i.e. concentrations that are representative of an area in time and space. Assessment chronology in this study using normal ^{137}Cs activity concentration in seawater and sediment (Suseno and Prihatiningsih., 2014), moreover the concentration ratio of Chanos chanos was gained from prevoius bioaccumulation experiment which is described real conditon of Chanos chanos bioaccumu-lation (W.R. Prihatiningsih et al., 2016). The ERICA tool uses UF, the output from the use of a UF is the conservative risk quotient (RQ) value. Table 2 shows both the conservative and expeccted RQ values determined in the hypothetical assessment undertaken here. The ERICA Tool using a system called ‘‘traffic light’’ (see Table 2) to evaluate the conservatives and expected RQ values. For example, if both the conservative and expected RQ values are above 1 it is clear that further investigation would be warranted as it would not be possible to conclude that there is negligible concern (red). Where the conservative RQ value is below 1 but the but the expected value is above 1, there may be few concern about the dose assessment results and further information such as that on natural background or biological effects should be considered by the user before a decision is made about the assessment conclusion (amber). Likewise, if both RQ values were below 1, the assessment has demonstrated that there is negligible concern to the organism considered (green) (J.E. Brown et al., 2008).

The results from the tier 2 assessment (Table 2) show that it is very possible to conclude with confidence that there will be no impact on the *Chanos chanos* because a number of the calculated risk quotients for every different size from smallest to largest C*hanos chanos* listed in Table 2 are lower than 1 when compared to a 10 µGy/h screening level at Tier 2. Given the results shown in Table 3, if ^{137}Cs released condition present in the real next time with activity closed to environmental monitoring data condition the ERICA Tool would suggest that further investigation is not warranted. A range of decisions will then need to be taken, based on suggestions described in the generic ICRP exposure situations (N.A. Beresford et al., 2008).

In the review of Research Nuclear Power Reactor, radiological ecological risk assessment for non-human organism is required by environmental radiation protection authorities as part of the environ-mental radiological impact assessment report, especially for newly-built another Research Nuclear Power Reactor. In this condition, the default values in risk assessment models and conservative values for screening evaluation are widely used to estimate the radiation dose rates to non-human organism (W. Yu et al., 2015).

Conclusions

This study links radionuclide bioaccumulation CR data obtained in laboratory experiments and ^{137}Cs activity in sea water and sediment from marine environmental monitoring data with radiation dose determined by application of a dosimetry modelling tool, an approach that will enable better linkages to be made between effects of radionuclides in organisms dose and exposure. Using the CR from laboratory experiment, the total dose rates of ^{137}Cs to *Chanos chanos* were all below the threshold 10 μGy.h^{-1}. *Chanos chanos* in the present study with dose rate 2.66 x 10^{-7} – 4.55 x 10^{-7} μGy.h^{-1} The results assessment inform that it is very possible to conclude with confidence that there will be no impact on the *Chanos chanos*.

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