Cs-137 radionuclide bioaccumulation study in gold fish (Cyprinus carpio) through freshwater path with variations of potassium ion concentration (K+)

T A Baramanda¹, Budiawan¹, R Bakri¹ and H Suseno²

¹Department of Chemistry, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424, Indonesia
²Center for Technology Radiation Safety and Metrology, National Nuclear Energy Agency (BATAN), Jakarta 12710, Indonesia

Corresponding author’s email: dr.budiawan@sci.ui.ac.id

Abstract. Few anthropogenic radionuclides like Cs-137 are difficult to detect. It needs a method to evaluate the environment quality based on molecular network of an organism exposed to the radionuclide arises, and the said method is called Biomonitoring. In this study, biokinetic experiment is conducted with the determination of Concentration Factor (CF) and Bioaccumulation Factor values of Cs-137 in goldfish (Cyprinus carpio) by means of freshwater influenced by its aquatic environment condition, which is potassium ion concentration (K⁺). CF value of Cs-137 concentration in Cyprinus carpio after the end accumulation in media conditioned with variation of potassium concentration 2.5; 5; 7.5 and 10 ppm, respectively are 2.762; 2.645; 2.637; 2.568 mL.g⁻¹ and Bioconcentration Factor (BCF) for variation of K⁺ ion concentration 2.5; 5; 7.5 and 10 ppm, respectively are 1.32; 2.12; 1.77; 2.07 ml.g⁻¹. Based on those values, goldfish (Cyprinus carpio) cannot be categorized as bioindicator for Cs-137.

Keywords: Cs-137, radionuclide bioaccumulation, gold fish, Cyprinus carpio

1. Introduction
The National Nuclear Energy Agency (BATAN) as an institution in Indonesia that deals with the application of nuclear energy in Indonesia has been operated with RSG 30Mwatt in Pusat Penelitian Ilmu Pengetahuan dan Teknologi (Puspitek), Serpong Area since 1987. This reactor can release elements from the fission elements. Potential contamination is feared to disturb the balance and health of the surrounding environment, especially the nearest aquatic environment such as Cisadane river. Radiocesium is a fission radionuclide, one of which comes from a nuclear reactor [1, 2].

The Serpong Puspitek Nuclear Area has an environmental monitoring system for nuclide radiation that can reach 0 to 5 km from the reactor. However, some anthropogenic radionuclides such as Cs-137 and Pu-241 are difficult to detect, so there is a need for an environmental quality evaluation method based on the analysis of the molecular tissue from the organism exposed to the radionuclides, the method is called Biomonitoring. The presence of Cs-137 radionuclides in waters can then accumulate in some freshwater biota, such as goldfish (Cyprinus Carpio).

Aquatic environment is very dynamic. One of the dynamics is the change in water salinity due to changes in the rainy and dry seasons. One change in salinity is caused by the change in K⁺ concentration.
in water. This result changes the bioaccumulation ability of Cs-137. Some research related to Cs-137 bioaccumulation has been carried out including milkfish (Chanos chanos) [3], teleost [4, 5], and zebra fish [6]. However, there is still limited study concerning the bioaccumulation of Cs-137 in freshwater biotas. In this study, biokinetic experiments were performed with the determination of CF (Concentration Factor) and biokinetic value of Cs-137 in goldfish (Cyprinus carpio) through freshwater channels influenced by their aquatic environment, that is, the concentration of potassium ion (K⁺) by doing the bioaccumulation of the radionuclide in the laboratory.

2. Experimental

2.1. Chemical reagents
Goldfish (Cyprinus carpio) were collected from water around Puspitek, Serpong Area, South Tangerang. Equipment used in this research were beaker glass, gamma spectrometer, cotton, waterstone, aquarium, pump, aerator, aquarium skimmer, digital scales, surgical instrument, syringe, measuring pipette, micropipette (100 μL), stirrer, spray bottle and fishnet. The materials used in this study were N₂ liquid, KCl (2.5; 5; 7.5; 10 ppm), radionuclide Cs-137 (2 Bq/mL) and freshwater.

2.2. Preparation of aquarium and freshwater
Preparation of the aquarium was done by preparing and ensuring the aquarium with a capacity of 50 liters will be used is leak-free. When the aquarium was ready, the aquarium was filled with 40 L of freshwater.

2.3. Acclimatization
Acclimatization was done to give time to the object of research to adapt, in the form of living organisms in the research environment. Acclimatization process was done by placing the research object in the aquarium. During the acclimation process, the biota feeding was done once a day. Acclimatization process was done for 7 days. The condition of the water media is like the natural condition at room temperature, aerated for oxygen supply and lighting 12 h : 12 h.

2.4. Biota contamination through freshwater media and uptake process contaminants with the variation of potassium ion concentration (K⁺)
After the acclimation process was completed, eight goldfishes were taken for the treatment of variation in potassium ion concentration. In the treatment of variations, the goldfish were divided into four glass jars, each containing 2 L of fresh water that has been irrigated, each containing 2 goldfish. Before goldfishes were placed in a glass jar, firstly, into the glass jar 4 mL of a radioactive tracer Cs-137 with activity 2 Bq/mL was added. Replacement of freshwater media was done every two days. The contamination process and contaminant uptake were performed for 9 days.

2.5. Measurement of Cs-137 activity during uptake process
The activity measurement process of Cs-137 in the biota was done every day in a period of 9 days. A HPGe detector was used for the Cs-137 analysis at energy of 666 KeV and counting time of 3 min. The biota to be measured was placed in a plastic cylindrical container containing freshwater contaminants and placed on a sample holder. Each measurement should be made under the same conditions, i.e. the distance of the container with the detector, the water level in the container, and the container geometry used. Measurements were made for 5 min for each goldfish. Measurements were made 3 times.
2.6. Depuration process
The depuration process was done by placing a goldfish in a contaminant-free aquarium completed with the filtration system and aeration for 5 days. During the process of depuration, replacement of freshwater media and goldfish feeding were done every day.

The process of measuring the activity of Cs-137 in the biota was done every day in a period of 3 days. A HPGe detector was used for the Cs-137 analysis at energy of 666 KeV and counting. The biota to be measured was placed in a plastic cylindrical container containing freshwater contaminants and placed on a sample holder. Each measurement should be carried out under the same conditions, i.e. the distance of the container with the detector, the water level in the container, and the container geometry used. Measurements were made for 5 min for each Goldfish. Measurements were made 3 times.

2.7. Preparation of biota standards
Preparation of biota standards was done by taking one goldfish that is free from contamination and weighed. Part of the goldfish (stomach) was slashed and the entrails were removed, then pieces of tissue were inserted into the stomach of goldfish and then dropped the radionuclide Cs-137 (activity 50 Bq/mL) as much as 50 μL. The traceable goldfish standard was then inserted into the plastic, sealed, and placed into a container in the same condition as the container used for the counting uptake and depuration. The prepared standards were then measured using a gamma detector.

2.8. Dissection
In the dissection stage, it was done by placing 5 goldfishes in an aquarium containing 70 L of water, then adding 140 mL of Cs-137 radionuclide contaminant with an activity of 2 Bq/mL. After that, surgery was performed to one goldfish per day. The surgery was performed for five days. In the process of surgery, the parts taken from the body of goldfish were gills, internal organs, and ivory. Then, the taken body parts of the goldfish were placed in a plastic container. Thereafter, the measurement of Cs-137 activity as performed using a gamma detector. The replacement of water media and feeding were done every other day.

3. Results and discussion

3.1. Uptake process
Experimental results of the concentration factor (CF) Cs-137 in *Cyprinus carpio* for 14 days in various concentrations of potassium ions (K⁺) are shown in figure 1.

![Figure 1. Concentration Factor (CF) Cs-137 in Cyprinus carpio in various K ions.](image-url)

Figure 1. Concentration Factor (CF) Cs-137 in *Cyprinus carpio* in various K ions.
Bioaccumulation is a progressive increase in the concentration of a type of compound (including Cs-137) in an organism caused by the uptake rate of the compound is greater than the depuration rate [7]. The bioaccumulation capacity of Cs-137 through freshwater lines by *Cyprinus carpio* is represented by the value of Concentration Factor (CF) which is the ratio between the concentration of contaminants in the biota body and the concentration of contaminants present in the water. CF value represents the ability of aquatic biota to increase the concentration of contaminants from water into the body.

Based on the measurement result of radionuclide Cs-137 with gamma ray detector in *Cyprinus carpio*, the data of count value of energy level in cps (count per second) were calculated. This data is further processed to determine the value of the concentration factor (CF). The concentration factor (CF) is a ratio between the pollutant concentration in the biota body to its concentration in water (mL g⁻¹).

In the environment, salinity waters tend to change with the changing seasons. In the rainy season, salinity tends to decrease and preferably in the dry season, salinity increases. Salinity is related to the concentration of K⁺ ion in water. The experiment results showed an increase in K⁺ ions in water will decrease the ability of Cs-137 bioaccumulation. The CF value at the addition of 2.5 ppm K shows at 2.76 g.mL⁻¹. On the other hand, the addition of K⁺ ions decreases its bioaccumulation ability to 2.58 g.mL⁻¹. The main variable of the aquatic ecosystem is salinity which plays an important role in fish physiology. Fish can compensate for salt levels through an active ion excretion to maintain osmolality. Based on this the physiology, fish is strongly influenced by salinity including in the context of the contaminants bioaccumulation process [8].

The bioaccumulation capacity of a biota is also represented by biokinetic parameters such as kᵤ and kₑ. The uptake rate of the contaminant (kᵤ) in a single compartment is assumed as a contaminant uptake mechanism by the entire body of the biota. However, the speed of its distribution into various types of organs is neglected. The value of kᵤ (mL g⁻¹ day⁻¹) is an uptake rate calculated based on the slope of the CF curve to t (from t = 0 to t under steady state) [9]. The effect of K⁺ ions addition to the rate of Cs-137 uptake is shown in figure 2.

Figure 2 shows that there is no relationship between the increase of K⁺ ions in water and the rate at which Cs-137 is taken by *Cyprinus carpio*. In the condition of the different K⁺ concentration, the uptake constants are varied greatly, which is in the range of 0.08 to 0.13g⁻¹.mL⁻¹. This lack of relationship between K concentration and uptake rate shows that bioaccumulation is more influenced by the physiological conditions of fish that live in various salinities.

### 3.2. Depuration process

The process of release or excretion of Cesium from the body is one of the processes for maintaining the electrolyte balance in the body of a biota. The ability to release contaminants by the biota bodies is represented by the value of % retained. Depuration process of Cs-137 is shown in figure 3.

The depuration process is done after the retrieval process stopped, and the biota is transferred to an aquarium containing contaminant-free freshwater. Depuration is the process of releasing contaminants from the body of a biota when the level of the exposed contaminant is reduced or eliminated. Naturally, this depuration process occurs when the entry of contaminants into the aquatic environment stops or decreases so that the contaminants will be removed from the biota network.

At the time of entry into the body of the biota, cesium will behave like Potassium and will be eliminated in the same way as potassium, i.e. by the mechanism of regulation of ionic composition through renal reabsorption (nephridia) and out with ammonia [10]. The mechanism of excretion or reabsorption of renal ions in general will involve an active transport mechanism so that large ions will be more difficult to excrete or reabsorb. The reduction of Cs-137 in the body of *Cyprinus carpio* is also influenced by the enabling environment, i.e., Cs-137 in low freshwater media.

### 3.3. Dissection

The distribution of Cs-137 in the body part of the golden fish (*Cyprinus carpio*) is represented in the activity value of Cs-137 (Bq/g) and shown in figure 4.
Figure 2. Influence of various concentrations of potassium ions (K⁺) to uptake rate.

Figure 3. Loss Cs-137 (depuration) from in *Cyprinus caprio*. After 10 days of this depuration process Cs-137 is still stuck in the body of goldfish by 57 to 70 %.

Figure 4. Percentage distribution of Cs-137 in golden fish organs (*Cyprinus carpio*) after 9 days of accumulation.
The dissection was conducted only to the important parts of the body of the golden fish that are related to the path of contaminant transfer. The distribution of Cs-137 activity in the *Cyprinus carpio* sample has the same pattern in the flesh > gill > internal organs. The activity of Cs-137 in meat is greater than the gills and internal organs. This is because, the absorption rate of metals in meat is higher than the others. The activity in the internal organs of the fish body is the smallest, since Cs-137 are distributed to other body parts.

### 4. Conclusion

Increasing the concentration of potassium ions (K⁺) will decrease the value of steady state concentration factor (CF). The constant rate of harvest of Cs-137 in golden fish (*Cyprinus carpio*) is not significantly influenced by the variation of potassium ion concentration (K⁺). Increasing the concentration of potassium ions (K⁺) will increase the value of Cs-137 release rate in goldfish (*Cyprinus carpio*). The Concentration Factor (CF) Cs-137 in golden fish (*Cyprinus carpio*) is not significantly affected by the variation of potassium ion concentration. Cs-137 is distributed most often in the meat (muscle). Golden fish (*Cyprinus carpio*) cannot be used for risk assessment of Cs-137 radionuclide pollution due to the BCF <500, but with other bioconic parameters *Cyprinus carpio* can be used as a bioindicator to identify the release of Cs-137 to waters.

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