Sediment Distribution Coefficients (KD) and Concentration Factors (CF) in Fish for Natural Radionuclides in a Pond of a Tropical Region and their Contributions to Estimations of Internal Absorbed Dose Rate in Fish

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ABSTRACT. Attention has been paid only recently to the protection of biota against radiation effects. Protection is being considered through modeling of the calculation of absorbed dose rate. In these models, the inputs are the fluxes of radionuclides of environmental concern and their resulting distribution between environmental compartments. Such distribution is estimated for dispersion models. In freshwater systems and when fish is used as biomaker, relevant environmental transfer parameters are transfer between sediment and water (sediment distribution coefficients KD, in l kg^{-1}), and between water and fish (concentration factor CF, in l kg^{-1}). These coefficients are under the influence of a number o physical, chemical and biological factors, and display following the literature a great variability. The present work establishes the KD's and CF's for uranium, thorium, radium and lead for two ponds: one that receives treated effluents from an ore treatment unit (UTM) situated at Poços de Caldas, Minas Gerais, Brazil and the other pond from the uranium concentration unit (URA) situated at Caetité, Bahia, Brazil, and for fish used as biomarker. It intends also to compare these parameters with the values recommended by IAEA. Depending on considered radionuclide and on the site, CF's (l kg^{-1}) observed values were of the same magnitude as, or one order of magnitude lower than recommended by IAEA. KD's (l kg^{-1}) observed values were found of the same magnitude as those recommended by IAEA, approximately 10 times lower or up to 100 times higher than recommended by IAEA, again depending on the radionuclides and on the site. It can be concluded that local parameters should be established in order to obtain a more accurate estimative of biota exposition from man activities.

Keywords: Environmental Radiation Protection, Dose in Biota, KD, CF

1 - Introduction

Radiation Protection is a relatively recent science branch that deals with the biological effects of ionizing radiation in living beings and the forms of protection from its deleterious effects, among other concerns. Humans' activities have been moving natural radionuclides from their original places, changing their exposure pathways and changing their concentrations in different environmental compartments. These activities caused changes in the exposure of biota to the natural radionuclides of interest, which may result in undesirable effects. In this way, systems of protection must be developed, not only to protect mankind but also the biota. This is the main concern of environmental radiation protection.

The actual environmental radiation protection system is based on the paradigm proposed in 1977 by the International Commission on Radiological Protection, ICRP [1] that states: "*The commission believes that the standard of environmental control needed to protect man to the degree currently thought desirable will ensure that other species are not put at risk*".

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Many authors [2-3] expressed doubts concerning this paradigm and the ICRP itself [4] has reevaluated the paradigm and now believes that "*Occasionally, individual members of non-human species might be harmed, but not to the extent of endangering hole species or creating imbalance between species*".

Presently, there are many different models to calculate the absorbed dose in biota. Some of them calculate dose coefficients that transform radionuclides activity concentrations in absorbed doses [5-6]; others deduce radionuclides dispersions in the environment and predict radionuclides concentrations in determined environmental compartments [7].

Box models are used to estimate radionuclides activity concentrations in environmental compartments [8,9]. These models are based on the division of environment into compartments linked to each other by transfer parameters, which correlate radionuclides concentrations in two consecutive compartments. The transfer parameters used in this work are the Concentration Factor (CF) in fish and the Distribution Coefficient (KD) in sediment.

The values of CF and KD reported in literature [7] are generally determined by monitoring data collected in moderate climate countries of the north hemisphere. Therefore, these values must be used with precautions and as an initial screening in tropical climate countries like Brazil. The transfer parameters change with ecological conditions such as environmental temperatures and nutrients. They also depend on biological conditions like organism specie, maturity, feeding habits, sex, etc. In order to respond to these specificities, the local determination of environmental transfer parameters turns out to be necessary.

This work aims to determine preliminary values of CF's and KD's in tropical regions, in two different biomes, savanna (cerrado) and Atlantic forest. The determined values are compared with the values reported in literature [7]. The absorbed dose in fish per radionuclide activity concentration in sediment is also determined.

2 – Materials and methods

2.1 – Studied sites and fish species

URA: "Unidade de Concentrado de Urânio" (Uranium Concentration Unit). URA is a uranium mining complex in Caetité, Brazil. The studied region is a semi arid region half the way between the biomes savanna and step, in the northeast region of Brazil. The fish specie studied there is the "Tilapia" (*Tilapia nilotica, Linnaeus,* 1758), introduced by man in the pond of URA complex.

UTM: "Unidade de Tratamento de Minério" (Ore Treatment Unit). UTM is a deactivated uranium mine complex in Caldas, Brazil. The studied region is tropical and belongs to the biome Atlantic forest, in the southeast region of Brazil. The studied fish species are: "Cara" (*Geophagus brasiliensis,* Quoy & Gainard,1824) (natural occurrence), "Lambari" (*Astyanax fasciatus,* Cuvier, 1819) (natural occurrence), "Traira" (*Hophias malabaricus,* Block, 1794) (natural occurrence) and "Tilapia" (*Tilapia nilotica,* Linnaeus, 1758) (introduced by man).

2.2 – Biological material collection and preparation

The fish were collected with fishing net from a pond. They were exhaustively washed with water from the pond, put into plastic bags and carried to the lab, where they were weighted and dried at 80°C, until constant weight. Biological material was then reduced to ashes at 450°C to yield a pale residue from which aliquots were taken for analysis.

2.3 - Radionuclides

The analyzed radionuclides of the U-238 series are: U-238, Ra-226 and Pb-210. The analyzed radionuclides of the Th-232 series are: Th-232 and Ra-228. U-238 and Th-232 were analyzed by spectroscopic photometry. Ra-226, Ra-228 and Pb-210 were analyzed by chemical separation and radiometric methods.

2.4 – CF and KD calculation

Calculation of CF and the KD followed IAEA[7], as shown in (1) and (2):

$$CF\ (lKg^{-1}) = \frac{C_f\,(BqKg^{-1})}{C_a\,(Bq\,l^{-1})} \qquad (1)$$

$$KD(lKg^{-1}) = \frac{C_s\,(BqKg^{-1})}{C_a\,(Bql^{-1})} \qquad (2)$$

where:

C_f: radionuclide concentration in fish (Bq kg^{-1});
C_s: radionuclide concentration in sediment (Bq kg^{-1});
C_a: radionuclide concentration in water (Bq l^{-1}).

2.5 – Fish absorbed dose rate calculation

Calculation of absorbed rate dose followed Blaylock *et al.* [5], as shown in (3):

$$D\ (\mu Gy\ h^{-1}) = 5.76 \times 10^{-4}\ E.C \qquad (3)$$

where:

D: absorbed dose rate in fish (μGy h^{-1})
E: emission energy (Ev)
C: radionuclide activity concentration in fish (Bq kg^{-1})

2.6 – Used Model

Calculation of absorbed dose rate by fish followed an elementary model. This model uses as input an activity concentration of 1,000 Bq kg^{-1} for each radionuclide analyzed in the sediment. Then, using the Kd's, the resulting activity concentration in water is estimated. Afterward, from the activity concentration in water one estimates the values of activity concentration in fish, using the CF's.

Finally, using formula (3) and the values of activity concentration in fish obtained above, one estimates the amount of absorbed dose rate in fish.

3 – Measurements and results

Activity concentrations of radionuclides measured in URA and in UTM are shown in Table 1 and Table 2, respectively.

Table 1 – Activity concentrations of radionuclides measured in URA

	U-238	**Th-232**	**Ra-226**	**Ra-228**	**Pb-210**	**n**
Water (Bq l^{-1})	0.16	0.033	0.05	0.22	0.31	20
Sediment (Bq kg^{-1})	145	90.5	87.2	115	74.6	7
Fish (Bq kg^{-1})	0.57	0.14	0.18	1.23	1.6	7

Table 2 – Activities concentrations of radionuclides measured in UTM

	U-238	Th-232	Ra-226	Ra-228	Pb-210	n
Water (Bq l^{-1})	0.0193	0.0014	0.0304	0.0141	0.0310	16
Sediment (Bq kg^{-1})	140	114	171	135	244.5	5
Fish (Bq kg^{-1})	0.53	0.03	1.0195	0.6005	0.353	7

Table 3 shows the calculated values of CF and KD in URA and in UTM. Table 3 shows also the respective values of CF and KD reported in literature [7].

Table 3 – CF and KD values (l kg^{-1})

	U-238		Th-232		Ra-226		Ra-228		Pb-210	
	CF	KD	CF	KD	CF	KD	CF	KD	CF	KD
URA	4	906	4	2742	4	1744	6	523	5	241
UTM	27	7203	24	79443	34	5623	43	9586	11	7886
IAEA	10	50	100	1×10^4	50	500	50	500	300	1×10^5

Modeling of the activity concentration of analyzed radionuclides (U-238, Th-232, Ra-226, Ra-228 e Pb-210) in the water column was simulated using the above calculated values of KD for URA and UTM and the KD values proposed by IAEA, based on an activity concentration in the sediment that was set up as 1,000 Bq kg^{-1}. Results appear in Table 4.

Table 4 – Radionuclides activity concentrations in water estimated from an activity concentration in the sediment equal to 1,000 Bq kg^{-1}

	Radionuclides activity concentrations in water (Bq l^{-1})				
	U-238	Th-232	Ra-226	Ra-228	Pb-210
URA	1.10	0.36	0.57	1.91	4.14
UTM	0.13	0.012	0.17	0.10	0.12
IAEA	20	0.1	2	2	0.01

Then, based on the values obtained for radionuclides activity concentration in the water column, shown in table 4, the activity concentration values for fish were deduced, using the estimated CF's for URA, UTM e recommended by IAEA (shown in Table 3). The final activity concentration values for fish are reported in Table 5.

Table 5 – Radionuclides activity concentrations in fish estimated from an activity concentration in the sediment equal to 1,000 Bq kg^{-1}

	Radionuclides activities concentrations in fish (Bq kg^{-1})				
	U-238	Th-232	Ra-226	Ra-228	Pb-210
URA	4.41	1.45	2.29	11.47	20.74
UTM	3.74	0.30	6.04	4.48	1.39
IAEA	200	10	100	100	3

Table 6 shows the calculated absorbed doses rate in fish, using the values shown in Table 5, above.

Table 6 – Absorbed dose rate in fish

	Absorbed dose rate (μGy h^{-1})
URA	2.13×10^{-2}
UTM	2.69×10^{-2}
IAEA	7.96×10^{-1}

It appears that the absorbed dose value calculated for URA is approximately equal to the absorbed dose value calculated for UTM. It can be noticed also that this value is thirty times lower than IAEA values. In this case, IAEA values are conservative values.

Thus, this work points to the need of more realistic evaluations, considering local determination of environmental transfer parameters.

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