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BIOACCUMULATION OF ^{95m}Tc IN FISH AND SNAILS*

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Abstract—Concentration factors for technetium recommended in radiological assessment models for freshwater biota are default values based on the behavior of iodine in the environment. In this study a small experimental freshwater pond was spiked with ^{95m}Tc to obtain data for calculating concentration factors for fish and snails. A model using the pond data was developed to calculate steady-state body burdens for freshwater biota. The concentration factors based on the calculated body burden for carp (*Caprinus carpio*), mosquitofish (*Gambusia affinis*), and snails (*Helisoma* sp.) were 11, 75 and 121, respectively. The concentration factor for carp was less than the recommended value of 15 listed in the USNRC Regulatory Guide 1.109 for calculating radiation dose to man; however, the concentration factors for mosquitofish and snails exceeded the recommended values by 5 and 25 times, respectively.

INTRODUCTION

MOST technetium in the environment is the result of the fission of ^{235}U or ^{239}Pu in nuclear weapons or nuclear reactors (Ti79). One of the most important technetium isotopes is ^{99}Tc. Although ^{99}Tc has a long half-life (2.14×10^5 yr) and a fission yield approximately equivalent to ^{90}Sr or ^{137}Cs, few measurements of its concentration in the environment are available. This paucity of information is due principally to the difficulties in the separation of the ^{99}Tc β-rays from those of the shorter half-life Ru isotopes and the fact that Tc contamination from nuclear fallout has received limited attention.

The sources of technetium and its environmental behavior were recently reviewed by Wildung *et al.* (Wi79). In addition to weapons testing and nuclear reactors other sources of technetium are fuel reprocessing, nuclear waste storage and pharmaceutical uses. Since technetium is also produced by irradiation of Mo, Nb and Ru with 14 MeV neutrons, isotopes of technetium would be produced in 316 stainless steel and niomic alloy, two materials that are being considered for blanket material in fusion reactors.

A radiological assessment of atmospheric releases from a hypothetical uranium enrichment facility by Till *et al.* (Ti79) indicated a potential for ^{99}Tc exposure through food chain pathways which would exceed proposed standards of the U.S. Environmental Protection Agency in 40 CFR 190 (USEPA77). In their assessment Till *et al.* (Ti79) used a concentration factor of 50 for technetium in vegetation instead of the generally assumed value of 0.25. The higher concentration factor was justified by results from recent laboratory experiments which, at the time of their publication, constituted the only measured values for Tc in soils and vegetation.

In an evaluation of radioactive releases to aquatic environments from nuclear facilities, Blaylock and Witherspoon (Bl75) concluded that ^{99}Tc was the most abundant isotope in the liquid effluents from a uranium enrichment facility. In addition, the 1978 monitoring

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report for the Portsmouth Gaseous Diffusion Plant (An78) showed that the annual release of ^{99}Tc in the liquid effluents was about six times that released to the atmosphere. However, Wildung (Wi79) pointed out, there were virtually no environmental data on technetium for freshwater biota and as a result default values based on iodine concentrations were used in dose assessments for technetium.

The purpose of this paper is to report on the concentrations of Tc in freshwater fish and snails and to develop a model for predicting the concentration factors for technetium in fish and snails. This research is part of a more extensive study that will be reported elsewhere in which technetium was released to a freshwater experimental pond to determine the distribution and concentration of Tc in a freshwater system.

MATERIALS AND METHODS

An isotope of technetium, ^{95m}Tc was released into an experimental freshwater pond. The ^{95m}Tc was obtained from the Oak Ridge National Laboratory in the form of ammonium pertechnetate. The ^{95m}Tc (7.06×10^8 dpm) was diluted in 4 l. of water and poured simultaneously into the pond at several locations. Pond water was agitated by forcing air through airstones at six locations in the pond to ensure complete mixing of the ^{95m}Tc with the pond water.

The experimental pond was an earthen structure, prismoidal in shape, and lined with plastic to prevent seepage. The pond had a surface area of 19.1 m^2, a bottom area of 11.1 m^2, and sides with an area of 10.8 m^2. When the pond was filled to a depth of 0.5 m it contained approx. 7.7 m^3 of water. The bottom of the pond was covered to an average depth of 15 cm with top soil which served as sediment. A continuous supply of well water was used to fill the pond and to maintain approximately the same volume of water.

The total alkalinity of the well water was 122 ppm, and the hardness was 125 ppm. The pH and dissolved oxygen (DO) content of the pond water was measured periodically; the temperature was recorded continuously. The pH ranged from 8.0 to 8.3, the DO from 7 to 11 ppm, and the temperature from 24 to 30°C.

Twelve 200-ml water samples were taken at different depths 1 hr after the ^{95m}Tc was released to the pond to determine the mixing of the ^{95m}Tc in the pond water. Thereafter, four 200-ml samples (two samples near the surface and two samples near the bottom) were collected daily for the first 10 days and at least 5 times weekly for the next 4 weeks. The nonfiltered samples were analyzed in an Armac Auto-Gamma spectrometer for concentrations of ^{95m}Tc. From each sample, 100 ml were filtered through a 0.4-μm Nuclepore filter; the radioactivity then was measured on the filter and in the filtered water.

The fish population in the pond at the time the ^{95m}Tc was released consisted of approx. 37 carp (*Cyprinus carpio*) ranging in standard length from 60 to 130 mm, 23 bluegill (*Lepomis macrochirus*) 60 to 65 mm in length, and more than 50 mosquitofish (*Gambusia affinis*) 5 to 45 mm in length.

To facilitate the rapid capture of the fish, 10 individuals of each species were captured from the pond and placed in a 100-l. wood and plastic mesh cage that rested on the bottom of the pond. Fish were also collected from the pond for comparison with caged fish. Five fish of each species were removed 4 hr after the initial exposure to ^{95m}Tc and live counted in an Armac Auto-Gamma spectrometer to determine the whole body concentration of ^{95m}Tc. Fish were returned to the cage and analyzed daily for the next 3 days for their radioactivity content and weekly thereafter until cessation of the experiment. Fish were also captured from the pond at various times for whole body and tissue analyses of ^{95m}Tc.

After seven days of exposure to ^{95m}Tc five fish of each species were removed from the cage and used for elimination studies. In the elimination studies, mosquitofish were maintained individually in 2-l. plastic containers in which the water was changed daily. Carp and bluegill were fin-clipped for identification and maintained under laboratory conditions in 475-l. holding tanks which received in

1025147

inflow of well water that turned over the volume of water 1.5 times each day. Initially all fish were analyzed daily to determine their ^{95m}Tc content.

At the same time the elimination studies were initiated, at least two fish of each species were removed from the cage for tissue distribution analyses of ^{95m}Tc. The bones of carp and bluegill were separated from the muscle tissue for separate analyses; however, because of the small size of mosquitofish, a similar separation was not attempted. After dissection, each tissue was placed in a test tube and the wet weight determined before analyzing for the ^{95m}Tc content.

One hundred snails (*Helisoma* sp.) were originally stocked in the pond. Although egg masses were found, very few immature snails were observed. This was attributed to predation by fish on the immature snails. Thus, the adult snail population in the pond was probably less than 100 when ^{95m}Tc was released to the pond.

Ten snails were collected by grab sampling 4 hr after the ^{95m}Tc was released to the pond. The whole body concentration of ^{95m}Tc was determined for each snail. In addition an identification number was painted on the shell of each individual, before it was returned to the pond. Five snails were then collected daily during the next 3-day period, and once a week thereafter for the duration of the experiment. Before counting in a γ spectrometer, algae on the snails' shells were removed by brushing and washing.

Seven days after the experiment was iniated, 10 snails were collected for an elimination study. The snails were placed in a 2-l. plastic container with a screen bottom to prevent contamination by fecal material. Macrophytes were placed in the container to serve as a source of food. Individual snails were counted periodically to determine their concentration of ^{95m}Tc.

On days 7 and 22 of the experiment, some individuals were sacrificed to determine the concentration of ^{95m}Tc in the tissue and in the shell. The snails were frozen on dry ice and the body and shell separated. The weights of the tissue and shell were determined before analyzing for ^{95m}Tc.

RESULTS

Concentrations of ^{95m}Tc in water, in three species of fish, and in one species of snail are given in Table 1. The concentrations are listed for ten sampling periods beginning on day 1 extending through day 37 of the study. Since only one release of ^{95m}Tc was made to the pond, the highest level of ^{95m}Tc in the water occurred immediately after the release and the level gradually decreased for the remainder of the study. The initial concentration of ^{95m}Tc in the water was 91.5 dpm/ml and decreased to 2.6 dpm/ml after 49 d. Filtering the water had little effect on the concentration of ^{95m}Tc, because more than 95% of the ^{95m}Tc was in solution. Apparently technetium does not adsorb to the particulates in the water, rather it remains in solution.

Mosquitofish accumulated ^{95m}Tc more rapidly than did bluegill or carp (Table 1). This difference in concentration is probably related to the differences in feeding habits and will be discussed later. Uptake rates for fish and snails were determined from the data in Table 1. The uptake of ^{95m}Tc by carp, mosquitofish and snails is shown in Fig. 1. The uptake and elimination rates are not shown for bluegill because they did not concentrate ^{95m}Tc as readily as did the other species of fish. Methods used to determine the radioactivity in live fish limit the time of analysis; and as a result, as in the case of bluegill, low levels of activity cannot be distinguished from background radiation.

Results of the elimination experiments are shown in Fig. 2. Based on these data, the effective biological half-lives (T_E) of ^{95m}Tc for carp, mosquitofish, and snails are 2.5, 4.3 and 21.3 d, respectively. When corrected for physical decay of the isotope, the biological half-lives (T_B) of technetium for the same organisms would be 2.6, 5.0 and 38.8 d. These latter numbers represent the biological half-lives of the long-lived isotopes of technetium such as ^{97}Tc and ^{99}Tc, providing they occupy the same sites in the organisms as ^{95m}Tc.

Distribution of ^{95m}Tc *in fish*

The distributions of ^{95m}Tc in bluegill, carp and mosquitofish are shown in Table 2. The gastrointestinal (G.I.) tract, which was not

1025148

Table 1. Mean concentrations of ^{95m}Tc in fish, snails (fresh wt.), and water in an experimental pond

	Water[a]		Carp[b]		Bluegill[b]		Mosquitofish[b]		Snails[b]	
Day	dpm/mL	SD	dpm/g	SD	dpm/g	SD	dpm/g	SD	dpm/g	SD
0	91.5	1.7	42.2	23.2	2.0	3.9	96.6	41.3	75.5	30.5
1	77.3	0.9	188.3	66.1	71.2	12.5	641.9	121.3	295.9	116.5
2	69.3	0.1	137.9	42.9	25.7	9.3	1159.3	459.5	583.7	250.4
3	55.6	1.0	174.7	57.2	70.4	74.5	1490.6	487.0	493.9	107.6
6	48.5	0.3	252.8	80.9	31.7	6.4	1189.1	432.4	981.6	290.4
10	30.9	0.4	333.0	91.7	34.9	9.3	1015.9	546.6	1340.6	368.9
16	17.8	0.8	420.5	82.5	74.3	17.6	1245.5	806.1	1169.9	211.4
22	11.4	0.1	369.2	88.7	5.9	8.8	1095.2	589.2	959.5	244.2
30	7.2	0.7	311.4	74.4	56.3	39.7	1370.2	1399.4	617.6	147.5
37	4.5	0.2	259.4	59.7	23.4	20.6	808.6	383.6	494.7	109.7

[a] n = 4.

[b] n = 5.

cleared before analyzing for ^{95m}Tc, had the highest concentration. The G.I. tract in mosquitofish, which constitutes approx. 8% of the body weight, contained an average of 37% of the total body activity.

Mosquitofish also had higher concentrations of ^{95m}Tc than either bluegill or carp in the tissues examined. In both carp and bluegill, bone contained higher concentrations of ^{95m}Tc than did muscle tissue. Bone and muscle tissue were not separated in mosquitofish because of the small size of that species; therefore, the value given in Table 2 is for both bone and muscle.

Analytical results for ^{95m}Tc in the body and shell of snails collected on days 7 and 22 of the experiment are given in Table 3. The concentrations of ^{95m}Tc in both shell and body decreased as the concentration in the water decreased; however, it appears that elimination from body tissue was more rapid than that from shell.

A model for predicting body burden from a chronic dose

The experiment considered only the response of the pond ecosystem to an acute or "spike pulse" dose of ^{95m}Tc. Equally important, however, are the long-term steady-state body burdens of organisms when the waterbody is subjected to chronic input of the isotope. In general, it may often be impractical to carry on experimental studies of this type over time periods long enough for steady state to be reached. In such cases some potential sites in the biota will not saturate with the tracer, and attempts to estimate concentration factors by dividing biomass (dpm/g) by water (dpm/ml) will lead to underestimates. Fortunately, modeling methods have been developed that can use data collected over periods of time short in relation to time to steady state to calculate expected steady-state body burdens (Blau75; Br75).

1025149

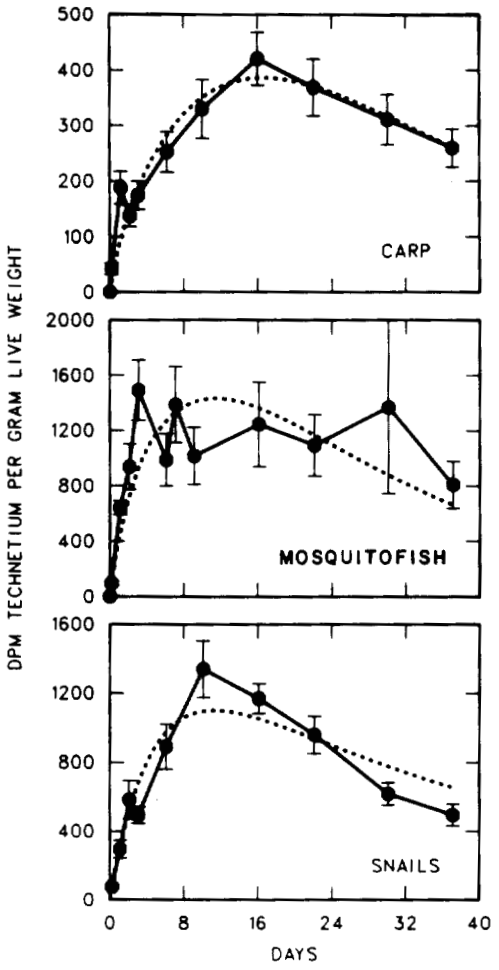

FIG. 1. Uptake of ^{95m}Tc by (a) carp (b) mosquitofish and (c) snails in an experimental freshwater pond that had received an acute or "spike pulse" release of ^{95m}Tc. The data points (±1 S.E.) were used with a Marguardt nonlinear least-squares technique to determine the rate of uptake of the isotope from the water column to the organism. Solid line connects data points; dotted line was generated by model.

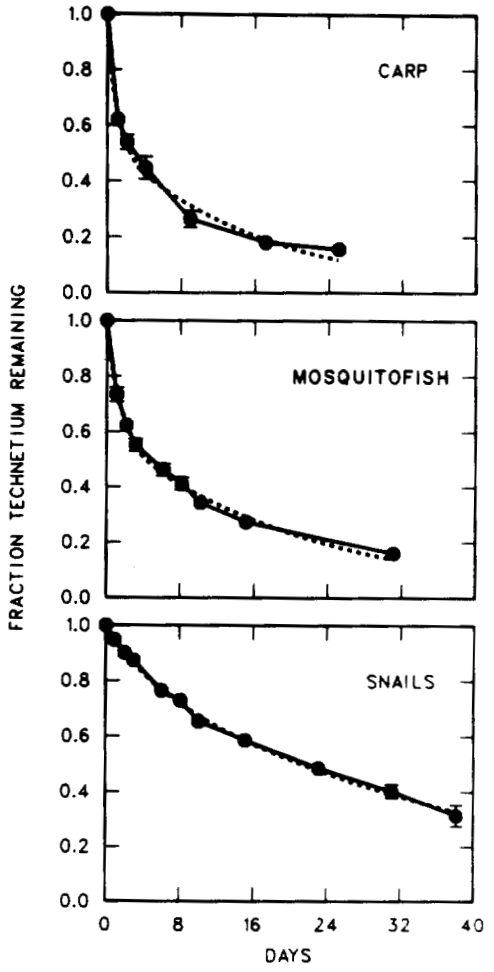

FIG. 2. Elimination of ^{95m}Tc by (a) carp, (b) mosquitofish, and (c) snails that were removed from the experimental freshwater pond. The data points (±1 S.E.) were used with a Marquardt nonlinear least-squares technique to determine the elimination rates of ^{95m}Tc from the G.I. tract and body tissues. Solid line connects data points; dotted line was generated by model. The effective biological half-life (T_E) was 2.5 d for carp, 4.3 d for mosquitofish, and 21.3 for snails.

We constructed a standard model for ^{95m}Tc movement in the pond ecosystems (Fig. 3), taking into account principal physical and biotic components of the ecosystem and processes of isotope transfer. In particular, this model was applied separately to each species, with the water column and other components lumped together to form the "external environment" (labelled "Water Column" in Fig. 3) of the species. It is necessary to divide the organisms into two sub-compartments: (1) a compartment for the

1025150

Table 2. Mean concentrations of ^{95m}Tc (dpm/g *fresh wt.) in three species of fish*

Tissue	Bluegill[a]	SD	Carp[b]	SD	Mosquitofish[b]	SD
Muscle	6.3	3.0	49.2	25.1	323.0[c]	94.3
Bone	26.8	37.9	91.4	20.0		
Gills	8.9	12.5	102.1	18.4	1595.5	185.0
Skin and scales	21.7	2.3	68.5	8.4	1317.4	354.5
G.I. tract	211.8	14.9	1525.5	711.5	4576.4	1483.6

[a] n = 2.

[b] n = 3.

[c] Bone and muscle.

Table 3. Mean concentration of ^{95m}Tc (dpm/g *fresh wt.) in the shell and body tissue of the snail* (Helisoma *sp.*)

Day	n	Shell	SD	Body	SD	Body/shell
7	3	348.9	230.8	2075.3	697.2	5.9
22	3	293.1	160.8	1383.2	598.7	4.7

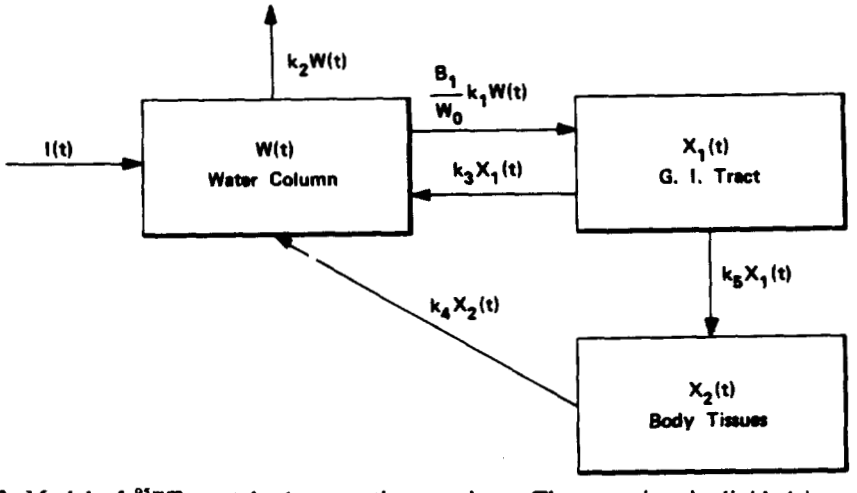

FIG. 3. Model of ^{95m}Tc uptake by aquatic organisms. The organism is divided into two sub-compartments (1) a compartment for the gastrointestinal tract (G.I.), in which isotope turnover is rapid, and (2) a compartment for the body tissues of the organism, in which the isotope turnover is relatively slow. See text for explanation of the transfers.

1025151

G.I. tract, in which isotope turnover is rapid, and (2) a compartment for the body tissues of the organism, in which the isotope turnover is relatively slow. A model of this three-compartment system is depicted in Fig. 3.

Since the components had nearly constant values of biomass during the experiment, a linear, donor-controlled model is adequate for our purposes here. In the mathematical model, let $W(t)$ represent the concentration of ^{95m}Tc (dpm/ml) in the water column, and X_1 and X_2 represent the concentrations (dpm/g) in the organism's G.I. tract and body tissue, respectively. The equations are then assumed to be

$$\frac{\mathrm{d}W(t)}{\mathrm{d}t} = I(t) - \left(\frac{B_1}{W_0}k_1 + k_2\right)W(t) + \frac{B_1}{W_0}k_3X_1(t) + \frac{B_2}{W_0}k_4X_2(t), \quad (1)$$

$$\frac{\mathrm{d}X_1(t)}{\mathrm{d}t} = k_1W(t) - (k_3 + k_5)X_1(t), \quad (2)$$

and

$$\frac{\mathrm{d}X_2}{\mathrm{d}t} = \frac{B_1}{B_2}k_5X_1(t) - k_4X_2(t). \quad (3)$$

In the above equations, $I(t)$ represents an input rate (dpm ml^{-1} d^{-1}) of ^{95}Tc into the water; k_1 is a transfer coefficient of the isotope from water to the organism's G.I. tract; k_2 is a loss rate coefficient from water to sediment and other sinks; k_3 and k_4 are transfer coefficients from G.I. tract and body tissues, respectively, to the water column; and k_5 is the coefficient of transfer from the G.I. tract to body tissues. The factors B_1/W_0 and B_2/W_0 are ratios of grams of G.I. tract and body tissue, respectively, of the modeled organisms in the pond to the total amount of water in the pond in milliliters. The factor B_1/B_2 is the ratio of the G.I. tract biomass to the body tissue biomass. All of these three ratios occur in equations (1)–(3) because $W(t)$, $X_1(t)$ and $X_2(t)$ are concentrations. Hence, a transfer at a given rate of ^{95m}Tc from one compartment to another will affect the concentrations differently. For example, if the concentration in body tissues, $X_2(t)$, is decreasing at a rate $k_4X_2(t)$ due to loss to water, the corresponding rate of increase in water concentration is $(B_2/W_0)k_4X_2(t)$. Note that in Fig. 3 the arrows give the concentration loss rates of the three compartments, not the rates of gain in concentration of the recipient compartments.

Because all terms in each of equations (1)–(3) must be consistent in units, the units of k_1 are (ml g^{-1} d^{-1}). This converts the loss in dpm/ml of water to uptake in dpm/g in the organism. The remaining k_i's are in units of l/d.

From equations (1)–(3), it is possible to determine the body burden of an aquatic organism, subjected to steady chronic input to the water that causes the water to remain at a level W_d. Denoting the steady-state body burdens by $X_{1,ss}$ and $X_{2,ss}$, then

$$X_{1,ss} = \frac{k_1W_d}{k_3 + k_5}$$

$$X_{2,ss} = \frac{k_1k_5B_1W_d}{(k_3 + k_5)k_4B_2}. \quad (4)$$

The next step is to determine the values of the k_i's. This can be done using the experimental data described earlier. First the data from the elimination experiments on the individual species (Fig. 2) can be described by the solution of equations (2) and (3) in the absence of input from the water, $W(t)$, and for $X_1(t)$ set to an initial value of X_{10}. The solution for the concentration in the organism, averaged over the G.I. tract and body tissue, is

$$X_1(t) + \left(\frac{B_2}{B_1}\right)X_2(t) = \frac{X_{10}}{k_4 - k_3 - k_5} \times \{(k_4 - k_3)\,\mathrm{e}^{-(k_3+k_5)t} - k_5\,\mathrm{e}^{-k_4t}\}. \quad (5)$$

Note that in equation (5) that k_3, k_4 and k_5 occur in such a way that they can be determined independently from a least-squares fit of data on $X_1(t) + (B_2/B_1)X_2(t)$ through time. From the elimination data, these three parameters can be determined using a Marquardt nonlinear least-squares technique (see Table 4). The fits of equation (5) to the data are shown in Fig. 2.

1025152

Table 4. Transfer coefficients ($k_1 - k_2$) used in the model for predicting body burden and the steady-state concentration in fish and snails

	Carp	Mosquitofish	Snails
k_1	1.160	5.632	3.452
k_2	0.053	0.125	0.187
k_3	0.521	0.329	0.054
k_4	0.061	0.046	0.025
k_5	0.535	0.403	0.155
$X_{1,22} + (\frac{B_2}{B_1})X_{2,ss}$	989.035[a]	6844.084[a]	11032.651[a]

[a]Steady-state concentration (dpm/g) in biota.

The uptake experiment (Fig. 1) allows determination of the remaining parameters. The results of this experiment are described by the solution of equation (1)–(3), for a spiked pulse, I_0 (dpm/ml) into the water, to yield

$$W(t) = I_0 e^{-k_2 t} \tag{6}$$

$$X_1(t) + \left(\frac{B_2}{B_1}\right) X_2(t) = \frac{I_0 k_1}{k_3 + k_5 - k_2} \left\{\left(\frac{k_5}{k_4 - k_2} + 1\right) e^{-k_2 t} - \left(1 + \frac{k_5}{k_4 - k_3 - k_5}\right) e^{-(k_3+k_5)t} + \left(\frac{k_5}{k_4 - k_3 - k_5} - \frac{k_5}{k_4 - k_2}\right) e^{-k_4 t}\right\}. \tag{7}$$

This solution (equation 7) is only a good approximate solution for the case $B_1/W_0 \ll 1$, $B_2/W_0 \ll 1$. Normally this condition will be satisfied since the amount of radionuclide in the water will usually be much larger than the amount in biotic compartments. The parameters k_1 and k_2 are determined again by using a Marquardt nonlinear least-squares method. Note that for the water to be held at a steady level of I_0 (dpm/ml), a constant input rate of $I_1 = k_2 I_0$ (dpm ml^{-1} d^{-1}) must be applied. The values of k_1 and of $X_{1,ss} + (B_2/B_1)X_{2,ss}$ are given in Table 4. The fits of model results to the data are shown in Fig. 1.

DISCUSSION

This particular experiment was apparently carried out long enough to allow for saturation of potential Tc sites in fish and snails. For example, after 16 d the concentration factor for carp calculated from data in Table 1 (420.5 dpm g^{-1} carp/17.8 dpm ml^{-1} water) is about 24, which exceeds the concentration factor calculated from the model. One would expect that a calculation based on one data point, such as this, would be much less reliable than the model prediction which is based on the whole set of data points. This fact, plus the fact that it may not be efficient to run the experiment to steady state, constitutes the rationale for using the mathematical model.

Predicted concentration factors for carp, mosquitofish, and snails based on predicted equilibrium concentrations (Table 3) were 11, 75 and 121, respectively. The value for carp was less than the concentration factor of 15 which is listed in the regulatory guide (USNRC76) for fish; however, the concentration factor for the mosquitofish was approx. 5 times the value listed in the regulatory guide. The predicted concentration factor for snails deviated the farthest from the regulatory guide value, being 25 times the value listed for invertebrates.

1025153

The difference in the concentrations of ^{95m}Tc observed in the three species of fish appeared to be related to their feeding habits. In the tissue analyses of each species (Table 2), the G.I. tract and contents contained the highest concentration of ^{95m}Tc. The mosquitofish had the highest concentration of ^{95m}Tc in the G.I. tract and also the highest whole-body concentration, while bluegill had the lowest concentration in the G.I. tract and the lowest whole-body concentration of ^{95m}Tc.

Elimination of ^{95m}Tc by the mosquitofish and carp (Fig. 2) indicated that a large percentage of the body burden was in the G.I. tract because at least 40% of the body burden of the carp and mosquitofish was eliminated in one day. The fact that a large percentage of the body burden was in the G.I. tract is also evidence that the fish were accumulating ^{95m}Tc through the food chain and that the difference in feeding habits could affect the whole-body concentration.

With the exception of the data reported in this paper, information on technetium in freshwater biota is practically nonexistent; however, some data are available for marine organisms. Spies (Sp75) found that the whole-body concentration factor for the red abalone, *Haliotis rufescens*, ranged from 135 to 205. Concentration factors in excess of 10^4 were reported for some marine algae (Bi75); however, studies by Gearing *et al.* (Ge71) on three species of blue–green algae did not support accumulation of technetium by algae. Wildung *et al.* (Wi79) concluded that the higher levels of ^{99}Tc used in the earlier studies may have been sufficiently toxic to interfere with uptake. Pentreath *et al.* (Pe80) compared the concentration of ^{99}Tc and ^{137}Cs in the crab (*Cancer pagurus*), the mussel (*Mytilus edulis*), and a brown alga (*Fucus vesiculosus*) collected from the Irish Sea near Windscale. While ^{137}Cs was preferentially accumulated in the claw muscle of the crab by a factor of ten, ^{99}Tc was preferentially accumulated in the digestive gland of the crab and soft parts of the mussel by a factor of three. In the case of the alga, ^{99}Tc was preferentially accumulated over ^{137}Cs by the two orders of magnitude. Although some data have accumulated on the concentration of ^{99}Tc in marine biota, there is still a need for additional data on freshwater biota.

CONCLUSION

A model using data from an acute or "spike pulse" release of ^{95m}Tc to a freshwater experimental pond was used to estimate steady-state body burdens in two species of freshwater fish and one species of freshwater snail. The calculated concentration factors for carp, mosquitofish, and snail were 11, 75 and 121, respectively. The concentration factors for the mosquitofish and the snail exceeded the concentration factors recommended in the Regulatory Guide 1.109 (USNRC76) for freshwater fish and invertebrates.

Tissue analyses of the fish and snails showed that a large proportion of the body burden of ^{95m}Tc was accumulated in the digestive system of fish and the body tissues of snail. The biological half-life of ^{95m}Tc for fish was approx. 3 d; while for snails, it was approx. 21 d.

The values used for concentration factors for technetium to calculate the potential radiation dose to man through the freshwater aquatic food chain are default values based on the behavior of iodine in the environment. The data presented in this paper are some of the first data reported on the concentration of technetium in freshwater biota. For the limited number of species considered, the calculated concentration factors did not greatly exceed the listed values in the Regulatory Guide 1.109 (USNRC76). The calculated value for the snail, which was about 25 times the value listed in 1.109, showed the greatest deviation. However, with the potential exposure to technetium from nuclear facilities and with the recently proposed standards of the U.S. Environmental Protection Agency in 40 CFR 190, additional data on the concentration of technetium in other freshwater biota should be documented in order to assess the potential radiation dose to man.

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