RECEIVED BY DTIC JUN 4 1971

BNW SA-2877
Conf-710501--6

MASTER

CYCLING OF ^{65}Zn

IN A

SIMPLE FOOD-WEB¹

C. E. Cushing and D. G. Watson

Ecosystems Department, Pacific Northwest Laboratory
Battelle Memorial Institute, Richland, Washington

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Abstract

The present experiment was designed to investigate the cycling of ^{65}Zn in a simple water-periphyton-fish food-web under constant flow, light, and ambient radionuclide concentration. Water temperature followed the seasonal pattern of the Columbia River.

Replicate experimental streams containing periphyton and young carp (Cyprinus carpio) were spiked continuously to maintain ^{65}Zn concentrations in the water of approximately 1 and 10 pCi/ml - about 20 and 200 times that of the river water. Periphyton and fish were sampled at intervals to ascertain the time necessary to reach equilibrium. Subsequently, the spike was cut-off and retention of the ^{65}Zn was followed.

Concentrations of ^{65}Zn in periphyton approached equilibrium in about 28 days at levels of 17 and 90 nCi/g wet weight in the low and high level streams, respectively. These represent concentrations of about 23 times and 150 times that of the control periphyton and are very close to the differential spike levels in the water. This means that, under the conditions of this experiment, periphyton concentrate ^{65}Zn in nearly direct proportion to ambient concentrations. The specific activity of the periphyton at equilibrium was 35 and 210 pCi/mg in the low and high level streams, respectively. The estimated effective half-life was about 15 days.

Data on the fish were more variable due to the influence of temperature on metabolic rates. Approximate equilibrium was reached in about 43 days at concentrations of 0.25 and 1.3 nCi/g wet weight in the low and high level streams, respectively. This represents concentrations of 6 and 29 times that of the control fish. Specific activities at this time were 3 and 20 pCi/mg. These data suggest that true equilibrium in the carp had not been reached. Water temperatures varied from 6C to 18C during the experiment which ran from January to June.

Introduction

The accumulation of radionuclides by aquatic organisms has been widely studied; however, studies of the accumulation of radionuclides by various components of food-webs are relatively less well known.

Cushing (1967) and Watson et al. (1971) have presented data on seasonal levels of ^{65}Zn in periphyton and fish in the Columbia River, and some data on specific activities is given in the latter paper. Brungs (1967) reported on cycling of ^{65}Zn in experimental ponds which contained carp and Duke (1967) presents data on movement of ^{65}Zn through an estuarine food-web. Reichle et al. (1970) have published a comprehensive discussion concerning movement of radionuclides in food chains, including information on turnover times and concentrations.

The experiment described here was an attempt at following the passage of ^{65}Zn from its dissolved state in Columbia River water into its initial accumulation by periphyton and thence into a grazing fish, the carp (Cyprinus carpio) in laboratory streams. Two spike levels of ^{65}Zn were maintained in order to study the effects of varying ambient concentrations. Light and current velocity were uniform and water temperatures followed the natural fluctuations of the Columbia River during the period of the test, January to June 1970. ^{65}Zn was selected because it is a biologically important radionuclide present in the Columbia River from the reactor effluents, and concentrated by the biota of the river.

Methods and Materials

Description of streams

The experiment was conducted in standard 10' x 1' x 8" hatchery troughs modified to form artificial stream channels. Rocks with natural organisms were removed from the Columbia River and used as substrates for the streams. Much of the natural growth present on the rocks when they were removed from the river did not survive under the laboratory conditions, and was replaced by organisms tolerant of the artificial conditions. Each stream contained approximately 85 l of untreated Columbia River water and this was maintained with an exchange rate of 1.4 l per min. The paddle wheels were driven so that the average water velocity was 0.65 ft/sec. Adjustable banks of cool-white fluorescent lights provided a 12 hr photoperiod. Average surface illumination in the center of the troughs was about 330 ft-c and decreased to about 280 ft-c at the paddle wheel and 200 ft-c at the outlet end of the troughs. Beckman Model 746 solution metering pumps were used to provide a continuous rate of ^{65}Zn spike to the stream to maintain the desired concentrations in the water. Two streams were maintained at approximately 1 pCi/ml, two at about 10 pCi/ml, and two were used as controls. These levels represented concentrations of about 20 and 200 times that of the ^{65}Zn content of the control streams.

Sampling and processing

Basic samples of water, periphyton, and fish were collected at 2 hr, 4 hr, 8 hr, 2 day, 4 day, and 1 week after spiking and thereafter at 2 weeks intervals until completion of the uptake portion of the study at 14 weeks. When the isotope spike was cut off the retention portion of the study initiated, basic samples were collected at 1 day, 2 days,

1 week and at 2 week intervals thereafter. Details of the sampling are given below under separate headings.

Water

Two types of water samples were collected: (1) a 100 ml grab sample collected at each sampling period, filtered through No. 45 Whatman filter paper, acidified, and analyzed for ^{65}Zn ; and (2) an acidified, 5-day composite sample of 0.5 l collected in 100 ml aliquots daily and analyzed for stable zinc and ^{65}Zn .

Periphyton

Periphyton was scraped from rock surfaces, blotted and weighed prior to counting. After counting for ^{65}Zn , the samples were dried at 60 C, weighed, ashed at 525 C, re-weighed, and an aliquote of the ash submitted for stable zinc analysis. Three samples were collected each time.

Carp

Fish were counted by two methods: (1) whole body, live counting for ^{65}Zn , and (2) destructive analysis of the mascerated fish by conventional gamma spectroscopy for ^{65}Zn . In the latter method, both entire fish and entire fish minus gut contents were counted. As with the periphyton, the fish samples were dried and ashed after counting and the ash used for stable zinc analysis. Generally, 10 fish were whole-body counted and of these, 3 were killed for ^{65}Zn analysis with gut contents and 3 without gut contents. Only data on fish without gut contents is presented in this paper.

Radioactivity measurements were performed on a single channel gamma spectrometer and stable analyses of zinc were done by atomic absorption.

Results and Discussion

Accumulation of ^{65}Zn

Periphyton

Initial uptake rates for the first four days of the experiment were quite high (Fig. 1). This was followed by a decrease in the uptake rate for the next 24 days until equilibrium conditions were approached on day 28. Although some further uptake occurred later in the experiment, day 28 appeared to be the time of initial leveling off. On day 28, mean levels of ^{65}Zn in the periphyton were 17 nCi/g wet weight in the low level streams and 90 nCi/g in the high level streams. Greater variability was found in individual analyses of the high level samples; no reason for this could be found. The ^{65}Zn concentrations in the periphyton on day 28 were of about 23 times and 150 times that of the control periphyton. These concentrations are of the same order of magnitude as were the differential spike levels in the water, indicating that under the conditions of this experiment, periphyton concentrate ^{65}Zn in nearly direct proportion to ambient concentrations. Cushing and Rose (1970) found a similar relationship between periphyton and ^{65}Zn in experimental microcosms.

Carp

Uptake of ^{65}Zn by the carp (without gut contents), as might be expected, was more variable and erratic than was that of the periphyton (Fig. 2). This was due in large part to the effects of changing water temperatures on metabolic rates during the course of the experiment, the uptake portion of which ran from January to late April. Temperatures during this period ranged from 6C to 10C.

Initially, the uptake rates of fish in the low concentration varied more than those in the high level. Equilibrium was approached in both experimental groups in about 43 days. At this time the mean concentrations in the fish were 0.25 and 1.3 nCi/gut weight, respectively, in the high and low level streams, or about 6 and 29 times the concentration in the control fish. In contrast to the findings for periphyton, the ratios of ^{65}Zn concentration in the fish at the two experimental levels differed from that in the water. After about 70 days there was an increase in the concentration of ^{65}Zn at all levels, including the controls. The ratio of the ^{65}Zn concentrations remained approximately the same as that of day 43. Increasing water temperatures accompanied by greater feeding rates by the fish probably was responsible for this rise in zinc uptake (Fig. 2).

Nakatani (1966) found that rainbow trout (Salmo gairdneri) chronically force fed ^{65}Zn reached equilibrium in about 10 weeks. Data from Brungs (1967) showed that flesh of carp in ^{65}Zn spiked ponds reached apparent equilibrium in about 24 to 38 days, not too different from our results.

Table 1 gives the Concentration Factors (pCi/ g wet tissue/pCi/ml water) in the periphyton and carp at selected times.

Retention of ^{65}Zn

Periphyton

After 98 days, the ^{65}Zn supply was cut off and the retention pattern was followed for an additional 35 days. The estimated effective half-life ($T_{e\ 1/2}$) was about 15 days (Fig. 1)

Unpublished data from our periphyton microcosm studies have revealed estimated $T_{e\ 1/2}$ ranging from 7-20 days, depending largely upon the

morphological nature of the community. These data are in general agreement with the estimated T_e 1/2 from the present study.

Carp

The retention of ^{65}Zn by carp (without gut contents) under the conditions of this experiment is similar to that which would be experienced by fish in a natural environment where the supply of radioactive zinc in the water is removed but not that in the food. In other words, the retention pattern is not that seen in a fish removed from a radioactively contaminated environment and placed in one where both the water and food are uncontaminated.

The concentration of ^{65}Zn in carp in the low level streams continued to increase after the introduction of ^{65}Zn into the system was stopped. The increase was similar to that experienced by the control fish during the same time period. The carp in the high level streams remained essentially the same as before the spike was cut off.

The fact that ^{65}Zn levels in the fish increased or remained constant while that of their food, the periphyton, declined is further evidence of the increasing metabolic activity of the fish as water temperatures increased. Water temperatures during the retention portion of the experiment increased from 10C to 18C.

Nakatani (1966) reported an effective half-life of 134 days for chronically ^{65}Zn fed rainbow trout when they were cut off from their contaminated food supply. Brungs (1967) found that the rate of loss of ^{65}Zn by carp was increased when transferred to uncontaminated water.

Specific Activities

Periphyton

The change in specific activity (pCi ^{65}Zn /mg total Zn) of the periphyton during the experiment (Fig. 3) was similar to that of the change in concentration of ^{65}Zn . The specific activity in the periphyton at equilibrium (day 28) was 35 and 210 pCi/mg in the low and high level streams, respectively. Again, the differences are of the same order of magnitude as the differential levels of spike concentrations in the water. These data indicate that knowledge of the ^{65}Zn content of the water, the stable Zn concentration of the periphyton, and the stable Zn concentration in the water would allow one to accurately predict the radionuclide concentration in the periphyton. The assumptions necessary for use of the specific activity concept of predicting radionuclide levels in biota were met in this case (Nelson 1964).

Carp

Specific activity changes in the carp (without gut contents) were also similar to the changes in body burden of ^{65}Zn . Specific activities at the time of the initial plateau of uptake (ca 43 days) were about 3 and 15 pCi/mg in the low and high level troughs, respectively. As with the ^{65}Zn concentrations, these do not reflect the differential spike levels in the water. These data probably indicate that true equilibrium had not been reached in the carp when the isotope was shut off. Therefore, specific activities would not have predicted the radionuclide concentrations found in the carp for our experiment.

These experiments have provided us with basic data regarding the uptake and retention of ^{65}Zn by components of a simple food-web, namely water→periphyton→carp. We are currently attempting to fit the data

to known uptake-retention models in order to determine rate parameters for the data. Future experiments in the experimental streams will involve the use of different radionuclides and, hopefully, more complex food-webs, i.e. water→periphyton→herbivorous insect→carnivorous fish.

We wish to acknowledge the technical assistance of Mr. A.J. Scott in conducting this work.

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Footnotes

¹ Work performed under AEC Contract No. AT(45-1)-1830.

Table 1. Concentration Factors

	<u>Periphyton</u> <u>day 28</u>	<u>Carp</u> <u>day 35</u>	<u>end of uptake</u>
Low level streams	17000	250	220
High level streams	90000	1300	2500

Figure Legends

- Fig. 1. Uptake and retention of ^{65}Zn by periphyton in laboratory streams. Vertical lines represent the ranges of replicate analyses.
- Fig. 2. Uptake and retention of ^{65}Zn by carp in laboratory streams and weekly mean temperatures. Vertical lines represent the ranges of replicate analyses.
- Fig. 3. Specific activity of periphyton.
- Fig. 4. Specific activity of carp.