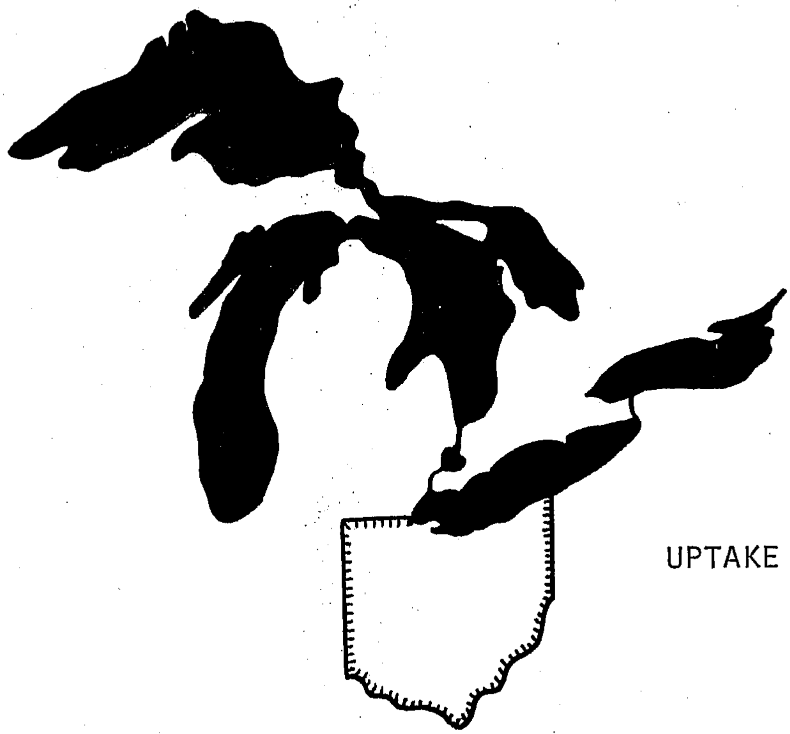


UPTAKE OF ^{137}CS, ^{60}CO, ^{54}MN AND ^{65}ZN BY *CHIRONOMUS RIPARIUS* (MIDGE LARVA) AND *BRANCHIURA SOWERBYI* (AQUATIC OLIGOCHAETE)

CLEAR TECHNICAL REPORT NO. 32

Prepared by

Walter E. Carey
and
Richard D. Myser

Prepared for

American Electric Power Service Corporation
Environmental Engineering Division
Canton, Ohio 44701

CENTER FOR LAKE ERIE AREA RESEARCH
THE OHIO STATE UNIVERSITY
COLUMBUS, OHIO

AUGUST 1975

PREFACE

Whenever a site suitability assessment is made for a potential nuclear power plant, the characteristics of that site which lend themselves to the establishment of an acceptable environmental monitoring program are important components of the total assessment. For that reason, research was undertaken to determine environmental parameters which could be used to develop an optimum monitoring program for Sandusky Bay. A major aspect of that research was an investigation of living organisms, normally found in the bay, which might concentrate radioiostopes involved in effluent release to readily detectable levels. This particular project was part of a comprehensive site study conducted by the Center for Lake Erie Area Research at The Ohio State University and the Columbus Laboratories of Battelle Memorial Institute.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

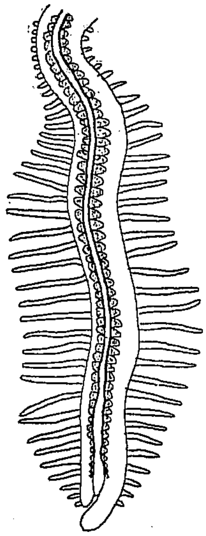
UPTAKE OF ^{137}Cs, ^{60}Co, ^{54}Mn, AND ^{65}Zn BY CHIRONOMUS RIPARIUS (MIDGE LARVA) AND BRANCHIURA SOWERBYI (AQUATIC OLIGOCHAETE)

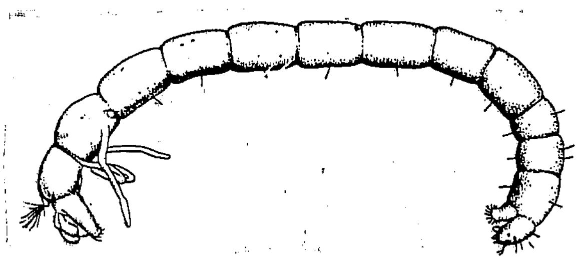
INTRODUCTION

For several reasons midge larvae and aquatic oligochaetes were selected as test organisms in uptake studies on ^{137}Cs, ^{60}Co, ^{54}Mn, and ^{65}Zn. (1) These were the most abundant benthic organisms collected in Phase I of this study. (2) Both "midges" and Branchiura sowerbyi are are easy to identify, even for a relatively inexperienced individual such as a monitoring officer (see Fig. 1). (3) These organisms remain in a specific location; they are available all year and have been collected in the winter as well as in warmer months. (4) The life histories of these benthic organisms are in the literature.[1,2] (5) It has been demonstrated by Copeland and Ayers[3] that benthic organisms do concentrate the above stable trace elements to a great extent. For these reasons an investigation of the usefulness of midge larvae and aquatic oligochaetes as monitors of radioactive releases, specifically into Sandusky Bay, was conducted.

Benthic organisms have been proposed for or are already used as monitors in several other places. Kidd[4] concluded that Pontiporeia affinis (Crustacea, Amphipoda) is a suitable monitor organism for ^{65}Zn and ^{54}Mn. Golden[5] detected both ^{137}Cs and ^{65}Zn in benthic samples from Lake Michigan. He also measured the gross beta activity of the benthos. Research at Whiteshell Nuclear Research Establishment (WNRE) indicated that Chironomidae larvae as well as other benthic organisms would be useful as monitors of effluents from WNRE since the larvae are present in large numbers and do have detectable beta activity.[6] Homeister[7] has also made preliminary investigations of gross beta activity in midge larvae from Put-in-Bay, Ohio. An environmental surveillance of Lake Michigan from July, 1969, to June, 1970, incorporated benthic organisms as monitors of both ^{65}Zn and ^{137}Cs.[8] Copeland and Ayers[3] state that benthic organisms are the aquatic organisms that most likely accumulate the highest activity levels. They also predict maximum concentrations of activity in Lake Michigan benthos for several radionuclides. Since many fish species that are valued by man depend on the bottom fauna, this seems to be further reason for the study of benthic organisms as monitors. For example, the highest concentrations of ^{60}Co from six species of fish were found in young yellow perch (Perca flavescens).[9] These fish feed heavily on Diptera larvae at all ages.[10]

Harvey[11] established concentration factors at various temperatures for two species of midge larvae, Glyptotendipes peripes (Edw.) and Chironomous plumosus (L.), for several radionuclides including ^{54}Mn, ^{65}Zn, and ^{137}Cs. His values are included in Table I. Wilhm[12] has also provided data on the concentration of radioactive material by benthic organisms. He worked with Stictochironomus annulicrus (midge larva) and Limnodrilus hoffmeisteria (aquatic oligochaete) on the transfer of isotopes from detritus into these detritus feeders. The average





b

b. Larvae of Chironomus plumosus (After Lambert). The larvae will be from 1-2 cm in length and usually blood red. Often called "bloodworms."

a

a. Posterior of Branchiura sowerbyi showing filamentous gills. (After Beddard from Avel). A relatively large worm that may reach 185 m in length. The posterior gills are quite characteristic. It most resembles a slender earthworm and will probably be from 4-10 cm in length.

Figure 1. Branchiura sowerbyi and Chironomus plumosus

TABLE I. LARVAE/WATER ACTIVITY RATIOS FOR TWO SPECIES OF MIDGE LARVAE (data from Harvey[11])

Glyptotendipes paripes

Isotope	Water Temp. (°C)	C.F.
^{54}Mn	21	43 ± 8
^{65}Zn	21	55 ± 9
^{137}Cs	21	53 ± 9

Chironomous plumosus

Isotope	Water Temp. (°C)	C.F.
^{54}Mn	20	65 ± 18
^{65}Zn	20	85 ± 28
^{137}Cs	20	21 ± 1

concentration factors of ^{137}Cs and ^{60}Co in the larvae are presented in Table II. Kidd[13] established CF's for four isotopes: ^{54}Mn, ^{137}Cs, ^{65}Zn, and, ^{85}Sr in Chironomidae and Oligochaetes (Table III). Copeland and Ayers[3] established concentration factors for many stable elements in benthos. Those of interest to this study are in Table IV.

TABLE II. ACTIVITY IN DETRITUS AND ORGANISMS ACTIVITY (pCi/ash-free g x 10^3) (data from Wilhm[12])

Isotope	Time Days	Stictochrironomus Activity (C.F.)*	Limnodrilus Activity (C.F.)*	Detritus Activity
^{137}Cs	0	0	0	6.63
	3	.52 (.15)	.80 (.23)	3.44
	7	.47 (.15)	1.06 (.33)	3.21
	10	.36 (.11)	1.11 (.34)	3.22
	14	.44 (.12)	1.13 (.32)	3.52
	21	.48 (.04)	1.05 (.31)	3.40
	28	.43 (.13)	1.07 (.33)	3.24
	$\bar{x}$	.45 (.13)	1.04 (.31)	3.34
^{60}Co	0	0	0	6.88
	3	.46 (.10)	.96 (.20)	4.70
	7	.47 (.12)	1.08 (.27)	4.03
	10	.36 (.08)	1.34 (.32)	4.23
	14	.48 (.12)	1.22 (.30)	4.11
	21	.38 (.10)	1.22 (.31)	3.92
	28	.51 (.14)	1.12 (.30)	3.71
	$\bar{x}$	.44 (.11)	1.16 (.28)	4.12

*Concentration factors in parentheses

TABLE III. ACCUMULATION OF RADIOACTIVE ISOTOPES BY LAKE ERIE BENTHIC WORMS (C. Kidd,[13] 24 July 1969)

Isotope	Sample No.	Type	Wet Weight (g)	7-Day Activity In Water (cpm/ml)	7-Day Activity In Worms (cpm/g)	Concentration Factor
^{54}Mn	1	Chironominae	0.112	4.18	411	98.3
	2	Oligochaetes	0.129		388	93.0
^{137}Cs	3	Chironominae	0.259	3.95	467	118
	4	Oligochaetes	0.201		323	81.7
^{65}Zn	5	Chironominae	0.039	2.30	1692	736
	6	Oligochaetes	0.176		369	160
^{85}Sr	7	Chironominae	---	---	---	---
	8	Oligochaetes	0.071	30.2	676	22.4

TABLE IV. STABLE ELEMENT CONCENTRATION IN BENTHOS (Copeland and Ayers[3])

Element	CF in Benthos
Co	333
Cs	2357
Mn	3700
Zn	875

METHODS AND MATERIALS

Specimens of Branchiura sowerbyi were collected from Lake Erie using a Ponar dredge and from Sandusky Bay and the Olentangy River with an Ekman dredge. They were maintained in a 20-gallon aquarium with about 10 cm of sediment covered by 20 liters of water. The chironomids were originally obtained from an Ohio State University culture and reared in covered, 20-gallon aquaria.

The oligochaetes were tested in 1000 ml Erlenmeyer flasks which contained 500 ml of sediment, 500 ml of water, and 5 oligochaetes. The midge larvae were tested in covered, 20-gallon aquaria. Each aquarium contained 400+ larvae and 2 cm of sediment covered by 20 liters of water. The sediment was from Lake Erie and the water was gently aerated tap water. The larvae and oligochaetes were exposed to radioactive releases of high concentration but short duration. These releases were designed to create a concentration of ten times the maximum permissible concentration (MPC) for each radioisotope as set forth in 10CFR20 Appendix B, Table II, Column II (see Table V). The isotopes ^{137}Cs, ^{60}Co, ^{54}Mn, and, ^{65}Zn in the form of $CsCl$, $CoCl_2$, $MnCl_2$, and $ZnCl_2$ were added from stock solutions with pipettes and propitter. The water in the aquaria and flasks was in the 18-21°C range. Most larvae were 3rd and 4th instar (~ 4.00 mg wet wt; 0.50 mg dry wt). Most oligochaetes were adults (~ 55.6 mg wet wt; 10.3 mg dry wt). In initial tests the five Branchiura sowerbyi were removed from a flask which contained ten MPC of one radioisotope. This was done at 24, 72, 120, and 168 hours of exposure for all four isotopes separately. The midge larvae were also removed after 24, 72, 120, and 168 hr of exposure to one particular isotope. When possible 25 or more larvae were removed for analysis. All organisms were air dried, weighed, and placed in petri dishes for

TABLE V. A LIST OF RADIONUCLIDES USED AND THEIR CONCENTRATIONS IN WATER

Radionuclide	Conc. (μCi/ml)	M.P.C. (10CFR20, Table II Appendix B, Soluble)
^{60}Co	5×10^{-4}	5×10^{-5}
^{137}Cs	2×10^{-4} 5×10^{-4}	2×10^{-5}
^{54}Mn	1×10^{-3}	1×10^{-4}
^{65}Zn	1×10^{-3}	1×10^{-4}

analysis on a 3" x 3" NaI (Tl) scintillation crystal and 512 channel pulse height analyzer for counting of gamma rays. When these tests were completed, tests with the larvae were repeated and on the hours 1, 4, 8, 12, 16, 20, 24, 48, 72, 96, 120, 144, and 168 after exposure larvae were removed from the aquaria. Water and sediment samples were removed simultaneously with the larvae and analyzed for activity. Concentration factors for the organisms were established where the dry weight of the organism was used instead of the wet weight and the initial concentration of an isotope in the water was used throughout the one week testing period. The formula used was

$$C.F. = \frac{\text{conc/g dry wt of organism}}{\text{conc/ml } H_2O}$$

as adapted from Harrison.[14] Two particulars to consider in the application of these CFs are that these are not equilibrium CFs and the isotope concentration in the organisms also includes gut content. Values from the literature may or may not include the above information which will limit its applicability.

RESULTS

The results of tests with B. sowerbyi are shown in Table VI. The uptake of all radionuclides was detectable within 24 hours of the addition of the radioactivity to the flasks. Concentration factors for all sampling times were very low for ^{137}Cs, ^{60}Co, and ^{54}Mn. The concentration of ^{65}Zn was most pronounced with a multiple of 91.0 after 24 hours in trial 1. After seven days the accumulation was 13.5% of the 24-hour level for ^{65}Zn with a CF of 12.3. The second trial showed a slight increase in the concentration of ^{65}Zn through five days. The average 24 hr CF was 50.2 and gradually declined for the one-week testing period.

TABLE VI. RESULTS FROM THE UPTAKE OF INDIVIDUAL 10 x MPC SOLUTIONS OF ^{137}Cs, ^{60}Co, ^{54}Mn, AND ^{65}Zn BY <u>Branchiura sowerbyi</u>

Sample	- Time (hr)	Original Concentration in H_2O (μCi/ml)	Trial 1 Concentration Factor	Trial 2 Concentration Factor
^{137}Cs	24	2×10^{-4}	2.2	1.6
^{137}Cs	72	2×10^{-4}	N.D.*	N.D.*
^{137}Cs	144	2×10^{-4}	N.D.*	N.D.*
^{60}Co	24	5×10^{-4}	1.5	4.0
^{60}Co	72	5×10^{-4}	0.4	6.8
^{60}Co	120	5×10^{-4}	--	2.8
^{60}Co	168	5×10^{-4}	0.6	5.6
^{54}Mn	24	1×10^{-3}	8.1	0.2
^{54}Mn	72	1×10^{-3}	12.5	N.D.*
^{54}Mn	120	1×10^{-3}	1.6	N.D.*
^{54}Mn	168	1×10^{-3}	3.2	--
^{65}Zn	24	1×10^{-3}	91.0	9.4
^{65}Zn	72	1×10^{-3}	38.3	22.0
^{65}Zn	120	1×10^{-3}	25.4	35.6
^{65}Zn	168	1×10^{-3}	12.3	34.2

*N.D. (not detectable)

The original uptake test using *C. riparius* was conducted in a 10 MPC solution of ^{137}Cs over sediment. Results are given in Table VII. The uptake and resultant concentration was only detectable in the 24-hour sample, and all subsequent tests were therefore conducted at a concentration of 25 MPC for ^{137}Cs. The results of three trials conducted in tanks with sediment and water are shown in Table VIII. The average concentration of ^{137}Cs with time is shown in Figure 2. After 8 hours of uptake of ^{137}Cs, the highest average concentration (51.9) occurred. This declined to a level which was 12% of the peak after 168 hours and appeared to be a two component loss. Figure 3 is a graph of the sediment activity and water activity for ^{137}Cs. The activity moved rapidly out of the water and contained less than 10% of the original activity after 48 hours. At this same time the sediment activity was approaching a plateau.

The uptake and concentration of ^{60}Co followed a pattern similar to ^{137}Cs in *C. riparius*. Original test results (Table VII) indicated a rapid uptake to an accumulation factor of 129.5 in 24 hours with a decline through six days. The other tests with ^{60}Co (Table IX) resulted in a similar uptake and accumulation pattern but at a lower 24-hour level. However, another concentration factor of 136.0 was obtained after 4 hours in trial #4 indicating the existence of an early high peak. A graph of the original uptake trial, trials 1, 2, and 3 from Table IX and their averages is found in Figure 4. The first two points are from trial #4 of Table IX. The peak activity was within the first 24 hours, declining through 168 hours in two components. The average activity at 168 hours (CF 6.75) was only 11% of that for 24 hours (CF 60.9). Figure 5 shows the relative activity of ^{60}Co in larvae, sediment, and water for trial #4. After 24 hours the activity in the water was less than 17% of that originally in the water, while activity in the larvae had peaked and sediment activity was at a plateau.

In the first uptake trial with ^{54}Mn, the relative activity peak in the larvae was reached in 24 hours (Table VII). When repeated the peak was still not reached until 24 hours (Table X). Figure 6 shows the average of the two uptake trials with ^{54}Mn as well as the relative activity in the water and sediment with time. The 168-hour average activity (CF 16.65) had declined to 22% of the 24-hour peak (CF 69.85). The activity left the water rapidly and approached a plateau level in the sediment in 48 hours.

The uptake of ^{65}Zn by larvae from the sediment test tank was rapid, as it was for the other isotopes. Peak activity was reached in 24 hours. However, loss of activity was not nearly as rapid in the sediment test tank as it was for the other isotopes (compare Figs. 2, 4, and 6 to Fig. 7). There was no detectable short component or rapid loss of ^{65}Zn, only a long component. After 168 hours the activity in the larvae was still 72.6% of that for 24 hours. The average concentration factor for 24 hours was 80.05 and for 168 hours the factor was 56.8. The effective half-life of ^{65}Zn in larvae living in sediment was 12.5 days. The pattern of ^{65}Zn activity in water and sediment was similar to the other isotopes. Loss was rapid from the water to the sediment and larvae (Fig. 7).

TABLE VII. RESULTS OF ORIGINAL TESTS OF UPTAKE OF ^{137}Cs, ^{60}Co, ^{54}Mn, AND ^{65}Zn BY *Chironomus riparius*. CONCENTRATION OF ISOTOPES 10 MPC IN WATER

Sample	Time (hr)	Original Concentration in H_2O (μCi/ml)	Concentration in Larvae (μCi/g)	Concentration Factor
^{137}Cs	24	2×10^{-4}	39.2×10^{-4}	19.6
^{137}Cs	48	2×10^{-4}	N.D.*	---
^{137}Cs	72	2×10^{-4}	N.D.	
^{60}Co	24	5×10^{-4}	647.5×10^{-4}	129.5
^{60}Co	72	5×10^{-4}	105.0×10^{-4}	21.0
^{60}Co	144	5×10^{-4}	57.5×10^{-4}	11.5
^{65}Zn	24	1×10^{-3}	84.2×10^{-3}	84.2
^{65}Zn	72	1×10^{-3}	66.1×10^{-3}	66.1
^{65}Zn	120	1×10^{-3}	62.0×10^{-3}	62.0
^{65}Zn	168	1×10^{-3}	46.8×10^{-3}	46.8
^{54}Mn	24	1×10^{-3}	81.4×10^{-3}	81.4
^{54}Mn	72	1×10^{-3}	18.7×10^{-3}	18.7
^{54}Mn	120	1×10^{-3}	18.3×10^{-3}	18.3
^{54}Mn	168	1×10^{-3}	11.9×10^{-3}	11.9

*N.D. (not detectable)

TABLE VIII. UPTAKE OF ^{137}Cs BY *Chironomus riparius*

Sample -	Time (hr)	Original Concentration in H_2O (µCi/ml)	Concentration in Larvae (µCi/g)	Concentration Factor
Trial #1				
^{137}Cs	24	5×10^{-4}	131.5×10^{-4}	26.3
"	72	"	40.0×10^{-4}	8.0
"	120	"	30.0×10^{-4}	6.0
"	168	"	23.0×10^{-4}	4.6
Trial #2				
^{137}Cs	1	5×10^{-4}	103×10^{-4}	20.6
"	2	"	87.5×10^{-4}	17.5
"	4	"	184.0×10^{-4}	36.8
"	8	"	319.0×10^{-4}	63.8
"	24	"	105.0×10^{-4}	21.0
"	48	"	54.0×10^{-4}	10.8
"	72	"	50.5×10^{-4}	10.1
"	96	"	20.0×10^{-4}	4.0
"	120	"	35.0×10^{-4}	7.0
"	144	"	N.D.	--
"	168	"	28.5×10^{-4}	5.7
Trial #3				
^{137}Cs	1	5×10^{-4}	103.5×10^{-4}	20.7
"	4	"	137.5×10^{-4}	27.5
"	8	"	200.0×10^{-4}	40.0
"	12	"	130.0×10^{-4}	26.0
"	16	"	46.0×10^{-4}	9.2
"	20	"	166.0×10^{-4}	33.2
"	24	"	204.0×10^{-4}	40.8
"	48	"	245.5×10^{-4}	49.1
"	72	"	33.0×10^{-4}	6.6
"	96	"	88.5×10^{-4}	17.7
"	120	"	60.0×10^{-4}	12.0
"	144	"	72.0×10^{-4}	14.4
"	168	"	42.5×10^{-4}	8.5

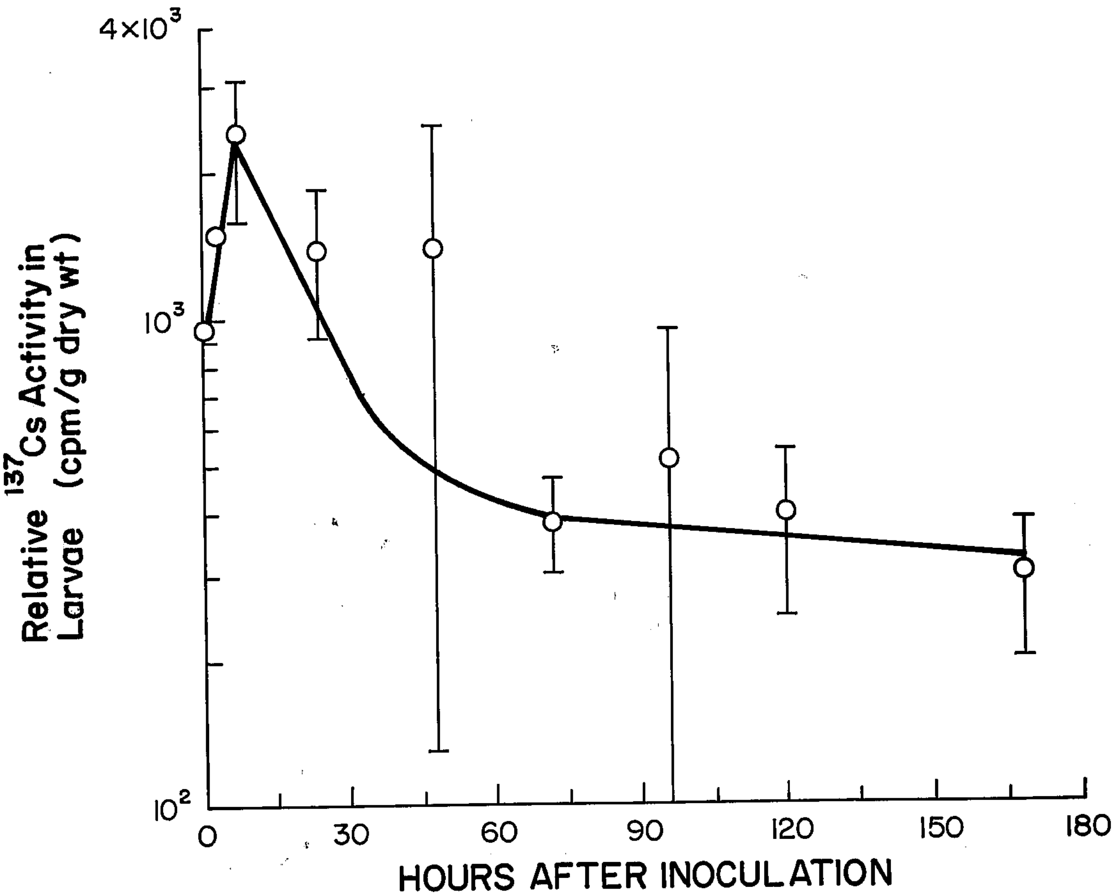


Figure 2 - Relative ^{137}Cs Activity in Larvae

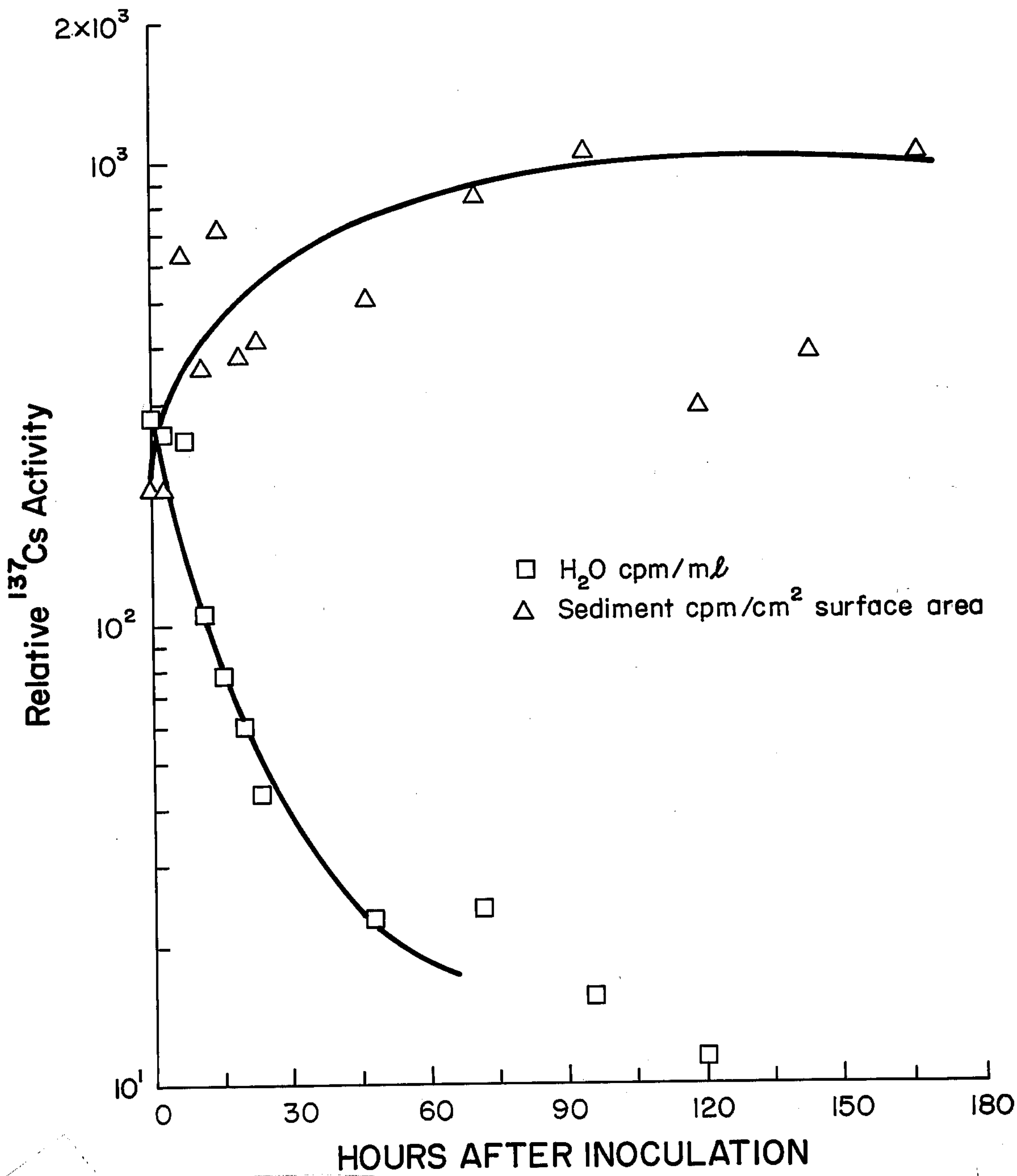


Figure 3 - Relative ^{137}Cs Activity in Sediment and Water

TABLE IX. UPTAKE OF ^{60}Co BY <u>Chironomus riparius</u>

Sample -	Time (hr)	Original Concentration in H_2O ($\mu Ci/ml$)	Concentration in Larvae ($\mu Ci/g$)	Concentration Factor
Trial #1				
^{60}Co	24	5×10^{-4}	224.5×10^{-4}	44.9
"	72	"	40.5×10^{-4}	8.1
"	120	"	41.5×10^{-4}	8.3
"	168	"	24.4×10^{-4}	5.1
Trial #2				
^{60}Co	24	5×10^{-4}	155.5×10^{-4}	31.1
"	72	"	50.7×10^{-4}	10.14
"	120	"	44.5×10^{-4}	8.9
"	168	"	39.5×10^{-4}	7.9
Trial #3				
^{60}Co	24	5×10^{-4}	164×10^{-4}	32.8
"	72	"	79×10^{-4}	15.8
"	120	"	71.5×10^{-4}	14.3
"	168	"	28×10^{-4}	5.6
Trial #4				
^{60}Co	1	5×10^{-4}	333.5×10^{-4}	66.7
"	4	"	680×10^{-4}	136.0
"	8	"	264.5×10^{-4}	52.9
"	12	"	114×10^{-4}	22.8
"	16	"	100×10^{-4}	20.0
"	20	"	125.5×10^{-4}	25.1
"	24	"	332×10^{-4}	66.4
"	48	"	204.5×10^{-4}	40.9
"	72	"	215.5×10^{-4}	43.1
"	96	"	165.5×10^{-4}	33.1
"	120	"	39.5×10^{-4}	7.9
"	168	"	42×10^{-4}	8.4

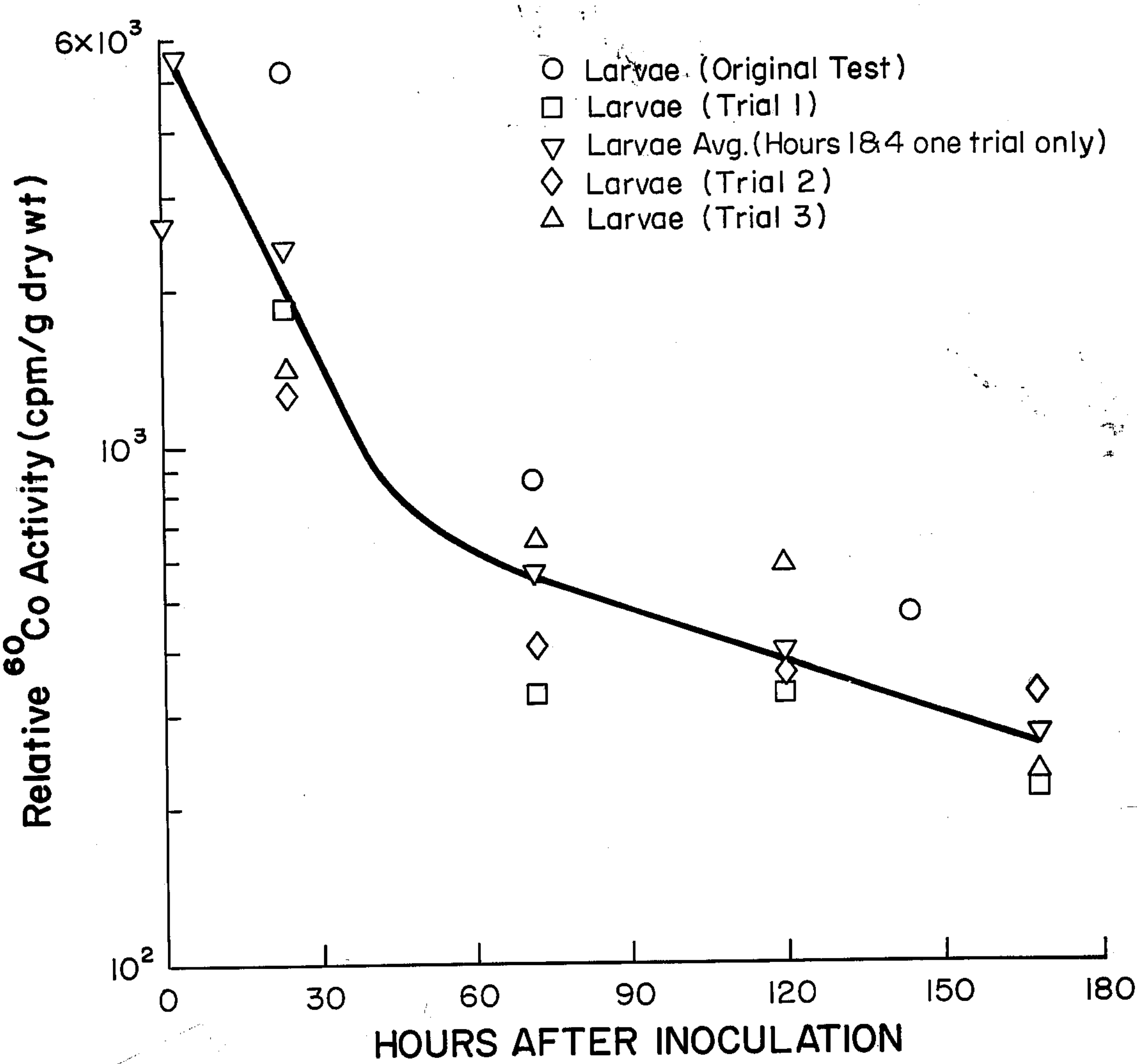


Figure 4 - Relative ^{60}Co Activity in Larvae

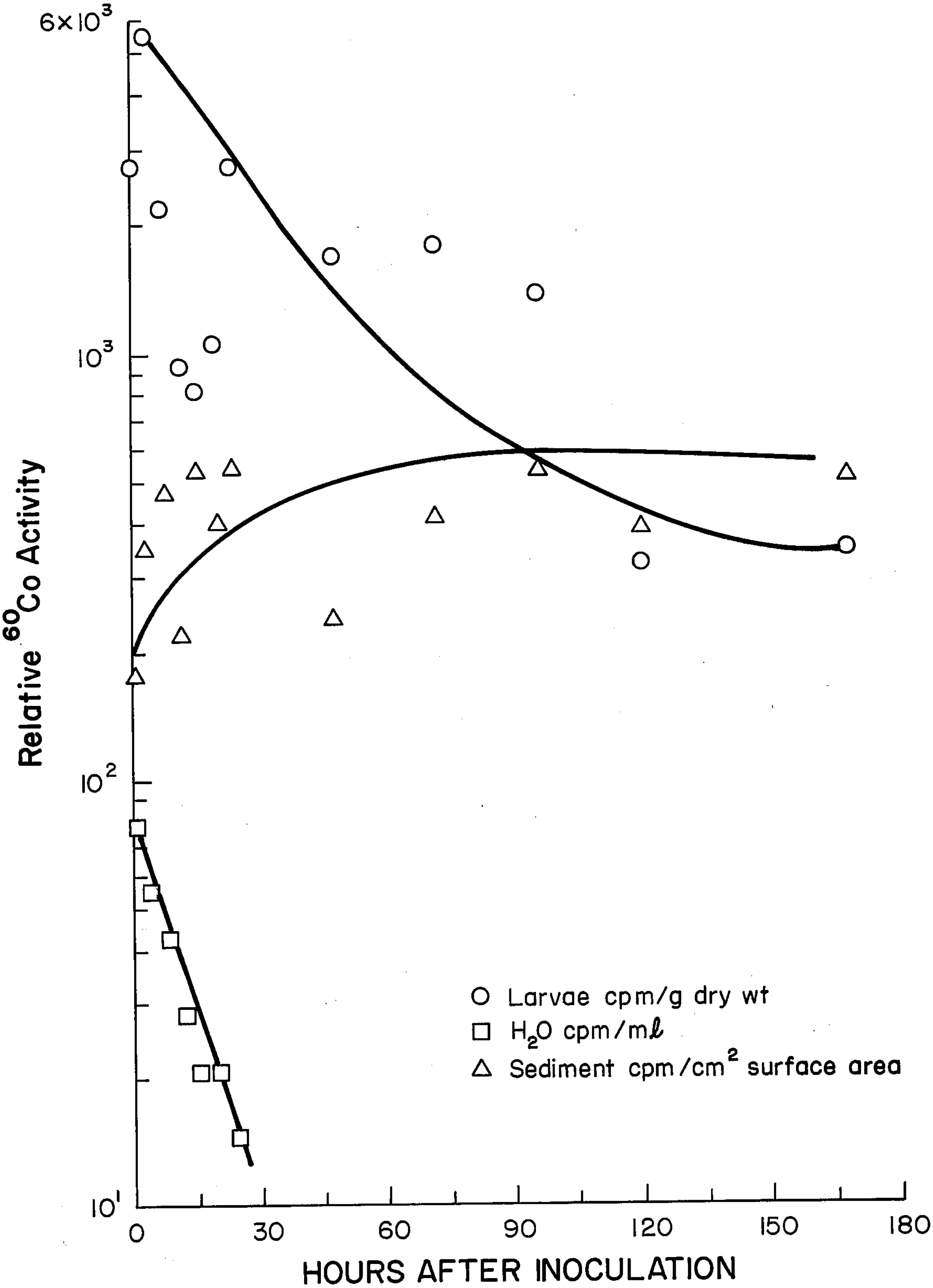


Figure 5 - Relative ^{60}Co Activity in Larvae, Sediment, and Water

TABLE X. UPTAKE OF ^{65}Zn AND ^{54}Mn BY <u>Chironomus riparius</u>

Sample	Time (hr)	Original Concentration in H_2O (μCi/ml)	Concentration in Larvae (μCi/g)	Concentration Factor
^{65}Zn	1	1 x 10^{-3}	6.9 x 10^{-3}	6.9
"	4	"	55.0 x 10^{-3}	55.0
"	8	"	94.2 x 10^{-3}	94.2
"	16	"	74.0 x 10^{-3}	74.0
"	20	"	63.2 x 10^{-3}	63.2
"	24	"	75.9 x 10^{-3}	75.9
"	48	"	65.7 x 10^{-3}	65.7
"	72	"	66.9 x 10^{-3}	66.9
"	96	"	60.3 x 10^{-3}	60.3
"	120	"	69.3 x 10^{-3}	69.3
"	144	"	84.7 x 10^{-3}	84.7
"	168	"	66.8 x 10^{-3}	66.8
^{54}Mn	1	1 x 10^{-3}	2.5 x 10^{-3}	2.5
"	4	"	24.7 x 10^{-3}	24.7
"	8	"	30.7 x 10^{-3}	30.7
"	12	"	48.3 x 10^{-3}	48.3
"	20	"	27.2 x 10^{-3}	27.2
"	24	"	58.3 x 10^{-3}	58.3
"	48	"	17.9 x 10^{-3}	17.9
"	72	"	18.7 x 10^{-3}	18.7
"	96	"	28.9 x 10^{-3}	28.9
"	120	"	23.2 x 10^{-3}	23.2
"	144	"	16.1 x 10^{-3}	16.1
"	168	"	19.4 x 10^{-3}	19.4

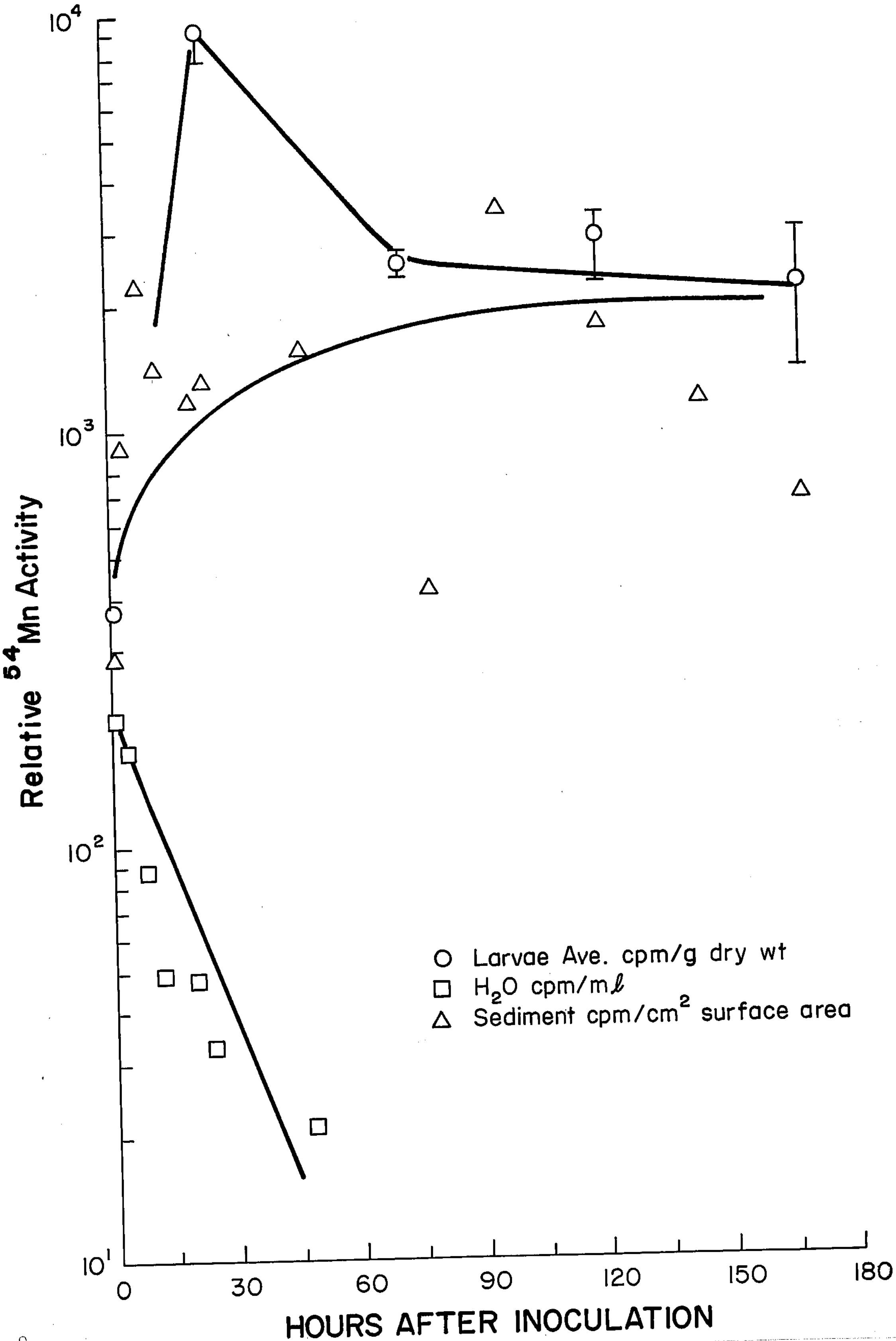


Figure 6 - Relative ^{54}Mn Activity in Larvae, Sediment, and Water

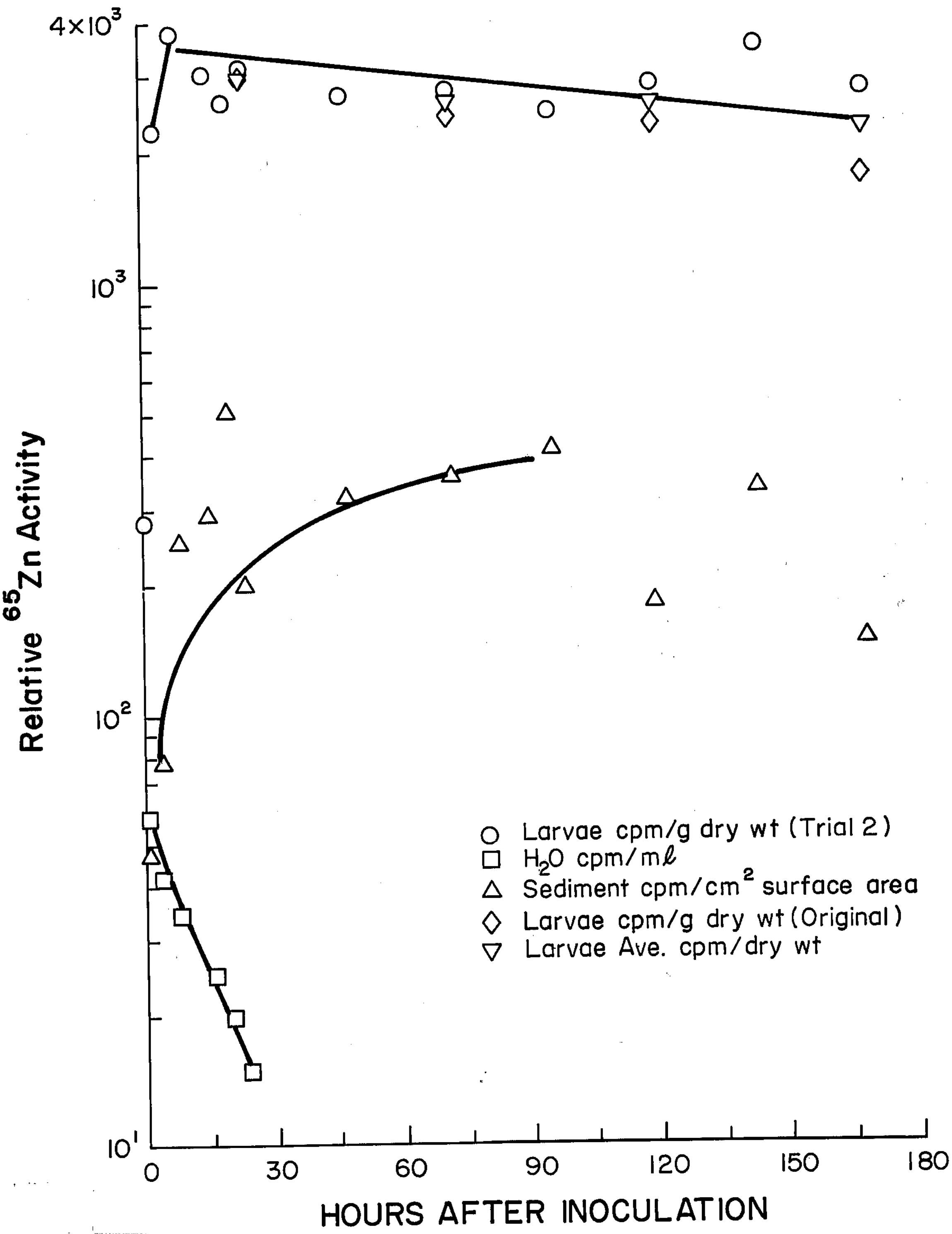


Figure 7 - Relative ^{65}Zn Activity in Larvae, Sediment, and Water

DISCUSSION

Samples of the oligochaete Branchiura sowerbyi appear to be effective monitors for ^{65}Zn if a release would occur at or above MPC for this isotope. Specimens of Chironomus riparius concentrate ^{137}Cs and ^{60}Co as well as ^{65}Zn and ^{54}Mn very effectively during acute releases above MPC.

The CFs found by Harvey for a continuous release and, in this study, for a pulse release, are known to be realistic in that the organisms were tested in sediment as they will be found in monitoring situations. Both studies used the dry weight of the organisms in calculating concentration factors. These factors are much less than those found by Copeland and Ayers[3] for stable elements of the same isotopes. These factors become even smaller in comparison if they are converted to wet weight concentrations as those reported by Copeland and Ayers (Table XI). A conservative estimate of an 80% weight loss due to drying would reduce the concentration factors reported here by 80%.

Although these organisms are relatively poor concentrators of the test isotopes, they can be expected to remain in the most concentrated part of the plume (radiologically) since they do burrow into the sediment. Other organisms (phytoplankton and zooplankton) which may concentrate isotopes to much higher levels would be swept along with the plume while benthic organisms could live their whole lives in a release area.

The clearance of isotopes from larvae after a pulse release is a two components loss for ^{137}Cs, ^{60}Co, and ^{54}Mn and may also be for ^{65}Zn although this was not found. The short component of rapid loss is due to easily exchangable sites such as body water. The long component loss is specific for each tissue and isotope. In a monitoring situation the peak reached before the rapid loss of the short component is the easiest to detect. This peak is also reached rapidly in the larvae and thus would allow the determination of any hazard to be made quickly. Samples collected within 24 hours of the time a pulse release had reached a sample area could provide an estimate of the activity at the point of release. This would include the absolute counting of the larvae, determination of the dilution factor from the point of release to the sample area, and use of concentration factors for indicator isotopes under specified environmental conditions. The use of C. riparius as an indicator organism also allows some lag time in the sampling schedule, since the peak activity will be reached a few hours after pulse contact. This could be advantageous in an emergency or unplanned release situation where the exact release time is not known. If field samples approximate those of the laboratory, samples taken within 24 hours of the pulse contact would contain about 50% and perhaps more of the peak activity.

While the peak activity of the short component of isotope loss is important to pulse monitoring, the long component will be important biologically. After one week an equilibrium may have been approached among the water, sediment, and larvae with one of these isotopes (^{137}Cs, ^{60}Co, or ^{54}Mn). ^{65}Zn was still declining slowly but at a much higher accumulation after seven days than the other isotopes.

TABLE XI. COMPARISON OF CFs FROM HARVEY,[11] COPELAND AND AYERS,[3] AND PRESENT STUDY

Harvey Study 7-21 Day Mean Continuous Release	Copeland and Ayers Equilibrium Stable Element	Present Study 24 Hr Mean Pulse Release
Cs-137 - 4.2 ± .2*	CS - 2357	CS-137 - 5.9*
Zn-65 - 17 ± 5.6*	Zn - 875	Zn-65 - 16.0*
Mn-54 - 13 ± 3.6*	Mn - 3700	Mn-54 - 14.0*

*Changed to CF using wet weight of the organism instead of dry weight. An 80% weight loss in drying was used.

This long component was maintained, at least in part, by activity in the sediment. Since the larvae fed on sediment, there was activity accumulated from the gut contents. Wilhm[12] found that detritus feeders (midge larvae) equilibrated with the activity in whole detritus in a week or less. Also included in the determination of larval activity was the actual activity associated with gut contents. Wilhm[12] also determined that 16% of the dry weight of the midge larvae Stictochironomus annulicrus is in the gut content and that significant activity levels are associated with it. The present study showed that no more than 22% (^{54}Mn) of the peak activity of any radionuclide was due to gut contents. Isotopes may have also been released from sediment back to the water and then accumulated by the larvae.

SUMMARY

The uptake, accumulation, and clearance of ^{137}Cs, ^{60}Co, ^{54}Mn, and ^{65}Zn by B. sowerbyi and C. riparius was investigated to determine the organisms' potential as monitors of pulse releases of the above radioisotopes. The initial concentrations were 10 times the MPC in 1000 ml flasks using B. sowerbyi. Only ^{65}Zn was accumulated to an easily detectable level in the tests conducted. C. riparius reached peak accumulations within 24 hours for all isotopes tested at 10 times the MPC (25 MPC for ^{137}Cs) in 20 liters of water and 2 cm of sediment. Although ^{65}Zn did not reach the highest accumulation multiple in larvae, it was retained at a much higher level for one week. The rapid uptake of isotopes is from the water medium although the presence of sediment keeps this level lower than the uptake in water alone. The activity accumulated by the sediment also maintained a long clearance component for all the isotopes in the larvae.

In the laboratory conditions listed below,

a. 18-21°C

b. 10X MPC or 25X MPC for ^{137}Cs as isotopic concentration

c. 500 ml of gently aerated water over sediment for *B. sowerbyi* or 20 liters for *C. riparius*,

B. sowerbyi could monitor ^{65}Zn and *C. riparius* could monitor ^{137}Cs, ^{60}Co, ^{54}Mn, or ^{65}Zn.

RECOMMENDATIONS

1. Periodic sampling should be carried out to provide pre-operational baseline data on benthic organisms.

2. Benthic organisms should be used for routine monitors of radioactive waste and equilibrium concentration factors between the organisms and water, and sediment should be determined.

3. *B. sowerbyi* and *C. riparius* should be incorporated into a monitoring plan for acute releases of radioactive material where ^{137}Cs, ^{60}Co, ^{54}Mn, and ^{65}Zn are the indicator isotopes.

   a. The monitoring schedule should be constructed to obtain samples within 24 hours of pulse contact. This may require 2 or 3 sample collections in the first 24 hours followed by daily sampling to determine if uptake phenomena in the field parallel those measured in the laboratory. The advantages of sampling the peak activity are at least three-fold.

      i. It will provide the fastest, yet most conservative, assessment of hazard.

      ii. It will provide a short lag time before samples must be taken.

      iii. It will be the easiest to detect.

   b. Counting should be done using the whole dry organism including gut contents. This will eliminate any loss of activity and provide the most conservative estimate of that activity.

   c. It is probably not practical to identify midge larvae to species (often not even to genus) in the field. A composite midge larvae sample is thus recommended. *B. sowerbyi* is very easy to identify even to species and thus could constitute an entire sample.

   d. Using previous collection data from Phase II of this study one or both organisms will be available at sites 6 and 17 (near shore) for yearly collection. While these seem to be the best monitoring sites, others may be selected to provide samples from areas of the bay that would receive effluent during unusual weather conditions or for routine monitoring of effluent leaving the Western Basin of Sandusky Bay (i.e., sites 35 and 36; mid bay).

e. While this study used only 5 *B. sowerbyi* and 25 *C. riparius* per sample, at lower isotope concentrations larger sample sizes may be required to provide easily detectable levels.

REFERENCES

1. Carrol, John H., and Dorris, Troy C., "The Life History of Branchiura sowerbyi," Am. Midland Naturalist, Vol. 87, No. 2 (April, 1972), 413-422.

2. Walshe, B. M., "The Feeding Habits of Certain Chironomid Larvae (subfamily Tendipedinae)," Proc. Zool. Soc. London, Vol. 121 (1951-52), 63-79).

3. Copeland, R. A., and Ayers, J. C., "Trace Element Distributions in Water, Sediment, Phytoplankton, Zooplankton and Benthos of Lake Michigan: A Baseline Study with Calculations of Concentration Factors and Buildup of Radioisotopes in the Food Web," ERG Special Report No. 1 (May, 1972), 126-162.

4. Kidd, Charles C., "Pontoporeia affinis as a Monitor of Radioactivity in Lake Michigan," Ph.D. Thesis, University of Michigan (1970), 1-70.

5. Golden, John C., "Pre-Operational Environmental Monitoring Programs at Nuclear Facilities," Ph.D. Thesis, University of Michigan (1971), 1-100.

6. Ireland, R. E.; Guthrie, J.E.; and Robinson, A. G., "Occurrence, Radioactivity and Diversity of Winnipeg River Benthic Organisms in the Vicinity of Whiteshell Nuclear Research Establishment," AECL 4421 (July, 1973), 1-2.

7. Homeister, William R., "A Survey of Gross Beta Activity in Clams, Chironomidae Larvae, and Bottom Sediments in the Island Region of the Western Basin of Lake Erie," Unpublished report from F. T. Stone Laboratory, The Ohio State University (July, 1974), 1-12.

8. Ayers, J. C. (Project Director) Lake Michigan Environmental Survey, Special Report No. 49, Great Lakes Research Division, The University of Michigan (1970).

9. Ophel, I. L., and Fraser, C. D., "The Fate of Cobalt-60 in a Natural Freshwater Ecosystem," Third National Symposium on Radio-ecology, edited by Nelson, D. J., CONF-710501-P1, Vol. I (May, 1971), 325.

10. Price, John W., "A Study of the Food Habits of Some Lake Erie Fish," Bulletin of the Ohio Biological Survey, Vol. II, No. 1 (1963), 27-34.

11. Harvey, R. S., "Temperature effects on the maturation of midges (Tendipedidae) and their sorption of radionuclides," Health Physics, Vol. 20 (June, 1971), 613-616.

12. Wilhm, Jerry L., "Transfer of radioisotopes between detritus and benthic macroinvertebrates in laboratory microecosystems," Health Physics, Vol. 18 (March, 1970), 277-284.

13. Kidd, Charles C., Davis-Besse Nuclear Power Station Environmental Report, Appendix A (1970), C-66.

14. Harrison, F. L., Concentration Factors - Their Use and Abuse. UCRL-50347 (1967).