Health Physics Pergamon Press 1967. Vol. 13, pp. 455–463. Printed in Northern Ireland

THE UPTAKE AND RETENTION OF ^{32}P AND ^{65}Zn FROM THE CONSUMPTION OF COLUMBIA RIVER FISH*

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(*Received* 13 *May* 1966; *in revised form* 30 *September* 1966)

Abstract—Hanford reactors discharge effluent cooling water into the Columbia River resulting in the incorporation at low concentrations of ^{65}Zn and ^{32}P in aquatic organisms. These radionuclides in the aquatic food chain may ultimately enter man's diet by way of fish caught and eaten by local fishermen. The determination of exposure level from the ingestion of these radionuclides in fish requires evaluation of their absorption and retention by man.

Seven volunteer subjects participated in a study of the uptake and retention of ^{32}P and ^{65}Zn as a result of eating Columbia River fish. Analysis of the fish provided ingestion data while whole-body counting techniques established the resulting body burdens. A beta counter calibrated for ^{32}P body burden measured the retention of this radionuclide. In addition, excreta and blood samples were collected and analyzed to evaluate uptake and transfer parameters. The experiment provided new estimates of the fractional uptake of radiophosphorous (100 per cent) and radiozinc (35 per cent) from fish, as well as their effective half-lives. As a result of utilizing several subjects in the experiment, a measure of the possible variation of the value of these parameters among members of the population is provided.

INTRODUCTION

THE HANFORD plant in Southeastern Washington uses Columbia River water to cool several large plutonium producing reactors. The cooling water, after passing through the reactors, is discharged to the Columbia River. In its passage through the reactors, the water accumulates small concentrations of radioactive materials, largely the result of neutron activation reactions. In the Columbia River these radioactive materials enter into numerous biological, physical, and chemical reactions which affect their distribution. Some entering the algae–insect–fish food chain are reconcentrated and contribute to the radioactivity in some of the food fish removed from the river downstream by fishermen. This pathway of radiation exposure to the public was determined to be the most significant of the several possible pathways which have been examined in detail.[1] The radionuclides ^{32}P and ^{65}Zn enter metabolic processes and are of most interest in this exposure pathway.

From the standpoint of radiation dose resulting from eating Columbia River fish, the radionuclide of greatest significance is ^{32}P. It represents, by far, the majority of the radioactivity in Columbia River fish. Detailed analyses of the possible dose to individuals from this source depend on the amount of Columbia River fish considered to be part of their diet. Of the fish caught in the Columbia River, the major dose contribution is obtained from game fish. Commercial fishing is limited to salmon caught near the mouth of the river and scrap fish, e.g. carp seined from the river during a short season. Salmon spend most of their lives at sea and, thus, do not accumulate significant concentrations of radionuclides from the river. Some of the scrap fish are used for human food, but only in markets several hundred miles from the river where they are mingled with similar fish from several other sources, and the resultant exposure of individuals is, thus, very small. It is the sports fisherman who repetitively catches

* This paper is based on work performed under United States Atomic Energy Commission Contract AT(45-1)-1830. Presented at the 1965 Annual Meeting of the Health Physics Society, Los Angeles, California.

and eats game fish from the river who may receive a significant ^{32}P body burden. Based on liberal assumptions concerning the amount of fish consumed by individuals, it is possible to estimate that they could obtain up to 40 per cent of the permissible body burden of this radionuclide. This experiment studied the uptake and retention of ^{32}P. Similarly, the uptake and retention of ^{65}Zn from these fish was also studied, although ^{65}Zn does not significantly contribute to the absorbed dose from eating Columbia River fish. Sometimes ^{65}Zn is used as a convenient measure of the amount of fish in individual diets, because it is readily measured by whole-body counting.

The amount of radioactive material found in fish from the Columbia River is known to be a complex function of fish species, season, river flow level and temperature, reactor operating conditions, and the location of the catch in the river. The concentrations of a radionuclide in several samples from a selected species of fish taken from a given sampling location on any given date will display a wide variance about their mean. The variance contributed by these factors influences and limits the confidence with which one can estimate the radiation exposure from fish consumption. It is generally necessary to choose some average value for all the fish sampled and to depend on the application of conservative assumptions to assure that the resulting estimate is as high or higher than an actual case is likely to be. In Fig. 1 are shown the ^{32}P and ^{65}Zn concentrations averaged for all

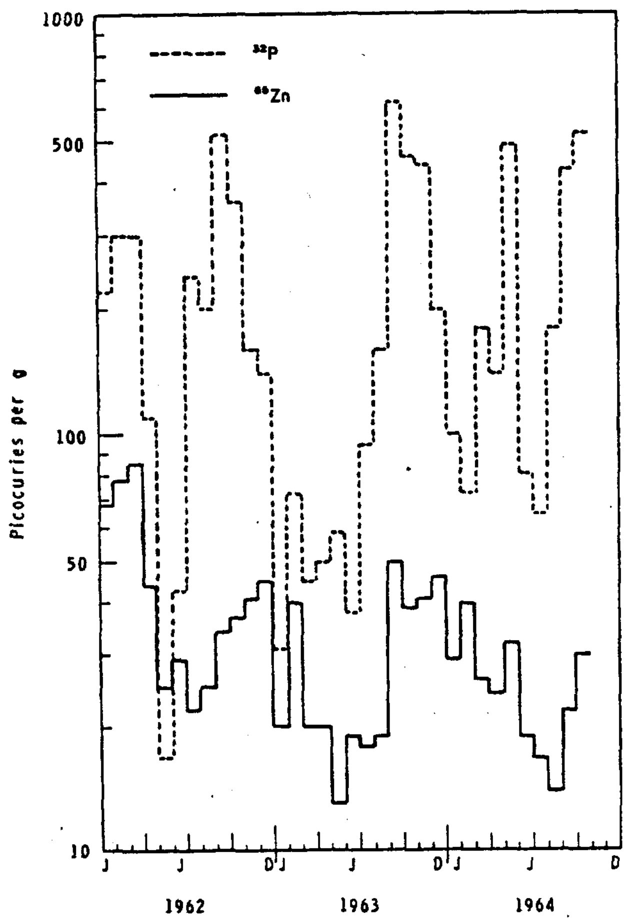

FIG. 1. Concentration of ^{65}Zn and ^{32}P in Columbia River fish.

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fish samples taken from the Columbia River during a 3-year period. No attempt is made here to distinguish species. The seasonal effect on concentration is clearly evident from the monthly averages shown.

The experiment encompassed an 11-week period during which Columbia River fish were eaten by seven volunteer subjects. The subjects were all males between 30 and 45 years of age. In an effort to make sure that sufficient ^{32}P would be present to permit ready analysis of the subjects' body burdens and excreta, a deliberate attempt was made to obtain fish apt to be high in ^{32}P. Columbia River whitefish were chosen because they normally contain the most ^{32}P and are easy to catch during the fall season. The fish were obtained from the sampling sites which were known to provide some of the higher concentration levels. The experiment began with an intense consumption schedule of one meal of fish per day for 5 days followed by a period of one meal of fish per week. During the initial week and immediately following the end of the experiment, excreta were collected from the subjects and analyzed for ^{65}Zn and ^{32}P. Figure 2 displays the course of the experiment. As can be seen from this figure, regular body burden measurements were made for both ^{32}P and ^{65}Zn during the ingestion schedule and during a decay period following.

To simplify the problem of assuring a uniform ingestion rate, a large enough supply of fish for all subjects was obtained and filleted each week. The fillets were then ground in an ordinary food chopper and thoroughly mixed. The chopped fish were sampled for laboratory analyses and the remainder weighed in 200-g portions. These 200-g portions were frozen until they were eaten by the subjects. Analyses of duplicate samples of the mixed ground fish showed excellent uniformity. The subjects ate the entire portion provided them, preparing the fish in the form of stew or a casserole dish to avoid any losses from frying or broiling.

PHOSPHORUS-32

The ^{32}P body burden accumulated as a result of eating Columbia River fish was measured using a special beta counter developed and calibrated for ^{32}P in the human body. A description of the counter and its operation has been reported by PALMER.[2] The development and successful demonstration of this counter made possible the measurement of ^{32}P *in vivo* for the first time and encouraged the design of this experiment. This detector consists of a 6 in. × 6 in. × 1 in. gas flow proportional counter mounted on a 5 in. × 1-mm thick NaI crystal and a photomultiplier tube, the counters connected through a coincidence circuit. Beta rays emerging from the surface of the skin produce pulses in the NaI counter and the proportional counter at the same time and are then accepted by a 400-channel, pulse-height analyzer. Gamma rays and X-rays which do not efficiently produce pulses in the proportional counter are rejected, thereby reducing the background of the counter significantly. The detector was placed at the side of the head of the subject during the counting time of 20 min.

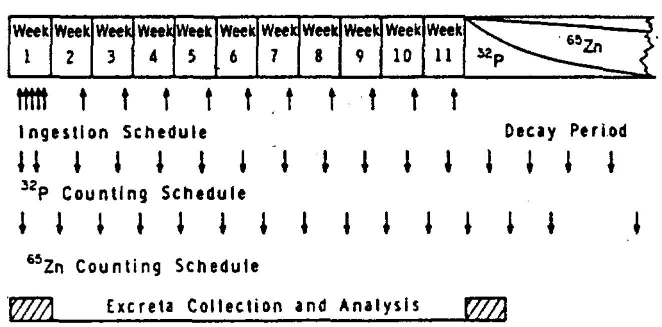

FIG. 2. Experimental design. Uptake and retention of ^{32}P and ^{65}Zn from the consumption of Columbia River fish.

This particular geometry was used to obtain a minimum background from the influence of ^{40}K beta rays. The average counting rate at the side of the head was 1.0 cpm per nCi of ^{32}P in the body and the detection level was 40 nCi of ^{32}P at the 95 per cent confidence level.

The instrument used to make whole-body measurements of ^{32}P actually measures the beta emission from a rather small volume of flesh in the cheek. Thus, the ^{32}P in a combination of body tissues including blood, muscle, and skin is detected. The natural ^{40}K content of these tissues gives a rather high background, equivalent to a body burden of about 150 nCi of ^{32}P. This background is large compared to the ^{32}P concentrations that were obtained as a result of eating Columbia River fish, and represents the most severe limitation on the precision of our data. Also, the instrument does not detect deposition of ^{32}P in deeply buried organs and tissue such as bone, except as this deposition affects the ^{32}P content of blood, muscle, and skin.

The problem of phosphorus metabolism was examined with the analog technique developed by WATSON *et al.*[3] It was possible to make only a single test using the best transfer parameters readily available. The resulting hypothetical ^{32}P concentrations in various tissues were plotted from the analog program. These results are uncertain because of incomplete knowledge of the values of the transfer coefficients. However, the curves probably show the relative positions and shapes of most of these concentration values and give us some idea of how the ^{32}P body burden measurements can be interpreted. The analog data indicate that the concentration of ^{32}P in skin is very low and this was borne out by our failure to detect ^{32}P in samples of skin scrapings. These latter analyses were performed with a detection limit of about 2.6 pCi for skin samples of 5–10 mg. The shapes of the concentration curves for blood and for muscle are shown in Fig. 3. In general, it is evident that blood concentration has a prompt acute peak, while the muscle concentration curve reaches somewhat lower maximum values at a somewhat later time and decays off much more slowly. Using these curves as a guide and actual whole-body counting points (two subjects), a rough composite curve might be shaped as shown in the upper solid line at the left in Fig. 3. The actual points, plotted in the figure, could be reasonably

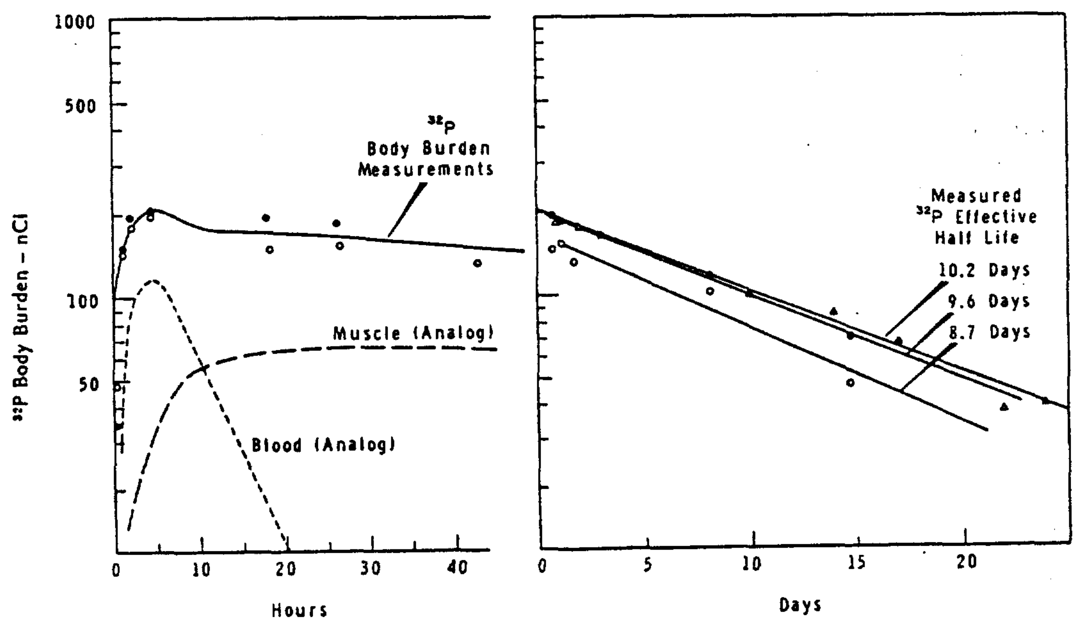

FIG. 3. ^{32}P-retention.

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Table 1. Amount of ^{32}P and ^{65}Zn in the whitefish consumed in the experiment (200-g *meals*)

Week	Meal	^{32}P nCi	^{65}Zn nCi
1	1	90	5.0
1	2	91	4.6
1	3	62	4.5
1	4	57	4.2
1	5	68	3.7
2	1	103	5.2
3	1	101	5.3
4	1	114	5.6
5	1	79	5.0
6	1	59	5.1
7	1	62	5.8
8	1	104	7.2
9	1	52	5.1
10	1	42	5.2
11	1	42	4.6

The amount of ^{32}P and ^{65}Zn ingested during the course of the experiment is shown in Table 1. The ^{32}P excretion of each subject and the resultant accumulated total ^{32}P in his body for the first week of the experiment is shown in Table 2. Except for subject *E*, the amount of ^{32}P accumulated appeared fairly uniform, and seemed to reflect a large fractional absorption. If the fraction absorbed is calculated from the excretion data by assuming an effective half-life of 9.3 days ($\lambda_B = 0.026$) the results are as shown in Table 3. These data appear to indicate an average fractional absorption somewhat higher than the 75 per cent used by the ICRP.[6] Uncertainties in excreta analyses account for much of the observed variance. In view of the analytical uncertainty, the average fractional absorption is indistinguishable from 100 per cent which was assumed to simplify calculations.

Table 2. Accumulation of ^{32}P during first week—calculated from ingestion and excretion data

Subject	Day 6		Day 7		Day 8		Day 9		Day 10		Day 11	
	^{32}P excreted (nCi)	Total in body (nCi)	^{32}P excreted (nCi)	Total in body (nCi)	^{32}P excreted (nCi)	Total in body (nCi)	^{32}P excreted (nCi)	Total in body (nCi)	^{32}P excreted (nCi)	Total in body (nCi)	^{32}P excreted (nCi)	Total in body (nCi)
A	4.0	90	6.5	170	9.5	214	25	236	22	271	6.0	252
B	2.2	90	15	162	10	206	15	238	17	277	—	—
C	2.2	90	8.1	169	14	208	13	242	23	276	—	—
D	2.4	90	9.9	167	13	208	11	244	26	274	41	219
E	2.2	90	23	154	32	176	17	208	34	232	32	188
F	4.3	90	14	163	24	193	27	213	15	256	16	228
G	2.6	90	16	161	16	199	14	232	11	278	8.0	256

Table 3. Calculated fraction of ^{32}P in fish absorbed from GI Tract*

Subject	Per cent ^{32}P Absorbed					
	Day 7	Day 8	Day 9	Day 10	Day 11	Average
A	95	97	90	93	100	95
B	85	96	95	95	—	93
C	93	94	96	93	—	94
D	91	94	97	90	87	92
E	74	81	92	85	88	84
F	86	87	88	95	96	90
G	84	92	95	98	100	94
			OVER-ALL AVERAGE			92

* Calculated from the difference between the amount of ^{32}P excreted and that anticipated from an effective half-life of 9.3 days.

In Fig. 4, the body burden measured for each of seven subjects eating Columbia River fish is shown during the course of the experiment. The points near time zero indicate the measured background for the individuals, which was subtracted from subsequent whole-body measurements. The solid line is a calculated body burden assuming an effective ^{32}P half-life of 9.3 days and a fractional uptake of 1.0. From these data, it is clear that a diet of 200 g of Columbia River fish per week may be expected to result in a ^{32}P body burden of around 200 nCi with the fish concentrations obtained during this experimental period. The scatter in the various points reflects both the individual variations among subjects and the uncertain precision of

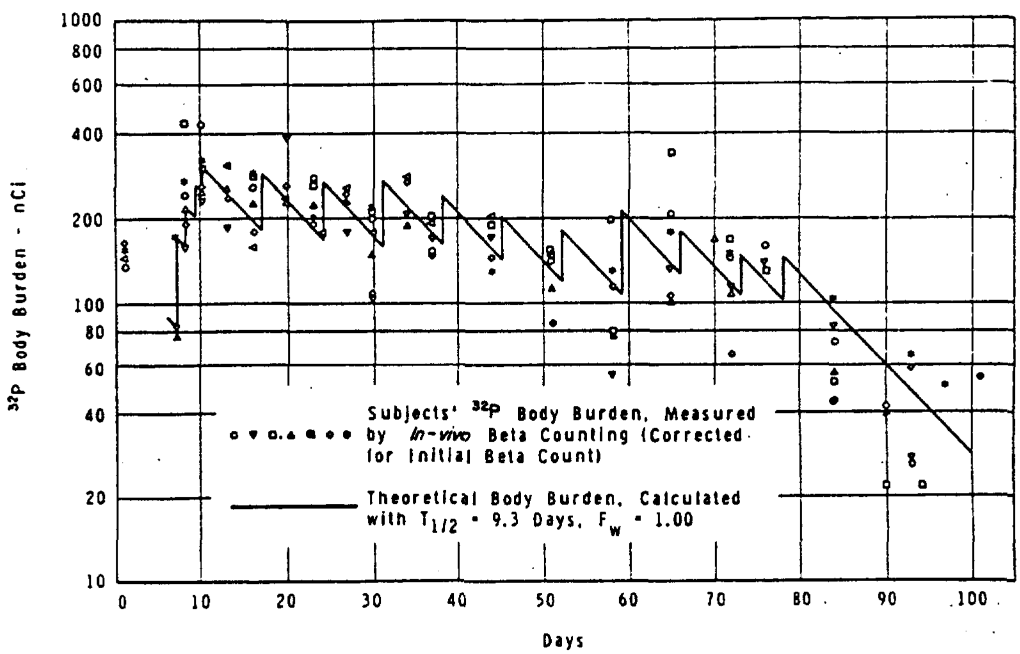

FIG. 4. Measured ^{32}P body burden from consumption of Columbia River fish vs. theoretical estimate.

our measurements. Note that the maximum body burdens attained were little more than four times background. The scatter in the final measurements at the end of the experiment was too great to permit adequate decay measurements with these data. However, they do not seem to be in marked disagreement with the 9.3-day half-life used in the theoretical calculation.

One of the difficult problems encountered in applying health physics data to estimates of absorbed dose for individuals in the population is the uncertainty concerning individual variations in the pertinent metabolic parameters. It was for this reason that seven subjects were utilized in this experiment. The scatter of the whole-body counting data shown in Fig. 4 reflects, at least in part, the individual variations in ^{32}P retention by the subjects of this experiment. All of the subjects had the same ^{32}P ingestion schedule.

ZINC-65

Zinc-65 has a suitable gamma component to permit whole-body measurements using a conventional whole-body counter. The Hanford whole-body counter has been described elsewhere.[4] For purposes of this experiment, a $9\frac{3}{8}$ in. × 4 in. NaI(Tl) crystal shielded by 26 cm of iron was used. A counting time of 20 min per measurement permitted an accuracy of ±5 per cent and a lower detection level of approximately one nCi.

In the absence of a method for measuring ^{32}P *in vivo* it has been our custom in the past[5] to estimate what possible ^{32}P body burdens might result from a fish consumption reflected by the ^{65}Zn body burdens measured. For this reason, it was of considerable interest to us to measure the ^{65}Zn content of the subjects eating Columbia River fish and to compare these data with the ^{32}P levels. An earlier fish consumption experiment at Hanford was conducted using a single subject.[5] In this case, a zinc absorption fraction of 32 per cent and an effective ^{65}Zn half-life of 162 days were obtained. These values may be compared with those reported by the ICRP[6] of 10 per cent and 194 days.

In the experiment reported here, the average ^{65}Zn absorption from fish consumed during the first two days was 40 per cent, ranging from 31 to 50 per cent among the individuals. There was evidence that the individual fractional uptakes changed during the course of the experiment, varying over the range similar to that between individuals. At the end of the experiment, the accumulated body burdens indicated an average fractional absorption of 35 per cent, the individual values ranging from 25 to 45 per cent. The loss of ^{65}Zn from each subject following the period of fish consumption indicated an apparent average effective ^{65}Zn half-life in the total body of 299 days, considerably higher than the 245 days physical half-life of ^{65}Zn, and obviously in error. The cause of this discrepancy is the subjects' continuing ingestion of ^{65}Zn in unmonitored portions of their diet, such as in drinking water. Such ingestion during the decay period would tend to increase the apparent effective half-life of ^{65}Zn in the body. Local residents having occupations similar to the subjects of this experiment are routinely found to have ^{65}Zn body burdens of 2–3 nCi ^{65}Zn from all diet sources.[7]

The measured body burdens of ^{65}Zn of the seven subjects are plotted in Fig. 5. The solid line shown in this figure is the theoretical ^{65}Zn body burden calculated for 32 per cent absorption and 162 days effective half-life. The first set of points at the left appear high, probably because of unabsorbed ^{65}Zn in the subjects' gastrointestinal tracts at the time of counting. All of the subjects had the same fish diet, so the scatter shown must result from differences in their absorption and retention of the radionuclide together with any differences in ^{65}Zn present in other diet items. The intake of low levels of ^{65}Zn from other than fish would not greatly affect the position of points on this plot, but could have a major effect on the calculated effective half-life determined from a least-squares fit of decay data.

DISCUSSION

This experiment provided an opportunity to demonstrate the application of the instrument developed for measuring ^{32}P *in vivo*, and to contribute new information on metabolic parameters for ^{32}P and ^{65}Zn. The experimental application of beta measurements for whole-body ^{32}P determinations was, on the whole,

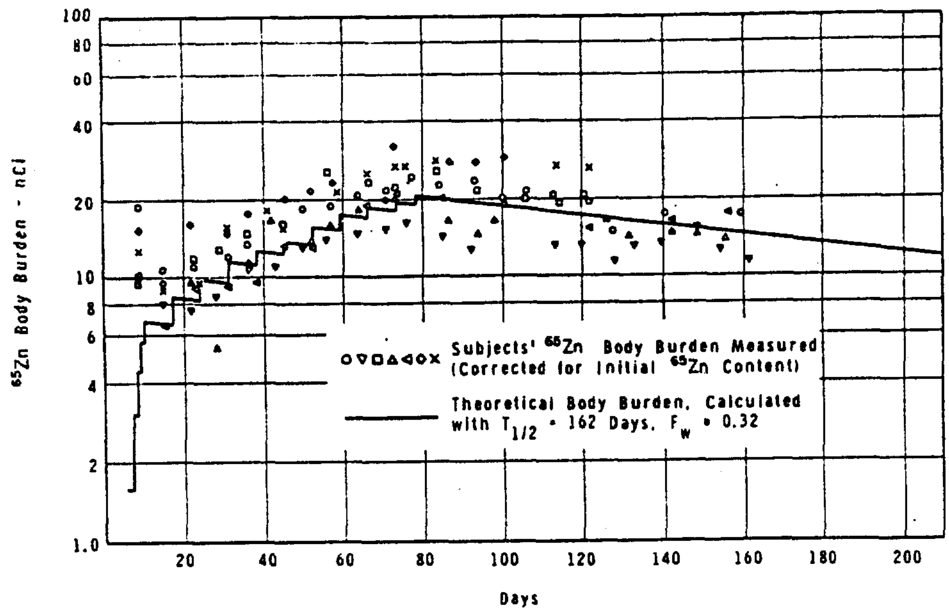

FIG. 5. Measured ^{65}Zn body burden from consumption of Columbia River fish vs. theoretical estimate.

successful. The calibration of the instrument made with other subjects and under different conditions gave whole-body values which seemed to agree well with the analyses of the fish consumed assuming a rather complete absorption of ^{32}P. The analyses of excreta tended to indicate a somewhat lower absorption, but our uncertainty of GI tract retention time and analytical variance of excreta samples made the calculated absorption indistinguishable from 100 per cent. The application of these data to dose calculations must be made judiciously because the instrument can measure ^{32}P only in blood, muscle, and skin. The deposition of ^{32}P in bone is not measurable with this instrument. However, the experiment demonstrated that an equilibrium distribution among other tissues is attained which can be measured. It was shown that the distribution of ^{32}P among various tissues changes with time, so that measurements made soon after ingestion probably will not represent the equilibrium distribution. For such prompt ^{32}P measurements, a special calibration of the instrument is necessary.

The fractional uptake of ^{32}P determined in this study appeared to be slightly higher than that reported by the ICRP, while the effective total body half-life was found to be slightly lower. The over-all effect of these differences on calculated exposure dose from consumption of ^{32}P is not large. The resulting calculated exposure will be little different from that determined previously, the differences remaining within the uncertainties in the determination. Phosphorus-32 is excreted from the body in both urine and feces. While more than half appears in the urine, a surprisingly large fraction of the ^{32}P was eliminated in the feces, even after the end of the ingestion portion of the experiment. Blood samples were obtained from the subjects at the same time that ^{32}P measurements were made. Analyses failed to find significant ^{32}P in blood samples, apparently because the samples were taken too long after eating fish. As is apparent from Fig. 3, the concentration of ^{32}P in blood decreases very rapidly after ingestion. The samples of fish, excreta, and blood were analyzed using a scintillation technique in a well crystal and measuring the ^{32}P Bremsstrahlung. Occasional checks of these analyses were made with chemical separation and beta counting. The difficulty of making accurate determinations of ^{32}P in

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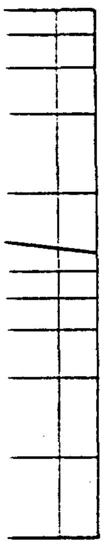

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Zinc-65 analyses were all made with scintillation counting in a well crystal. Approximately 90 per cent of the ^{65}Zn was eliminated from the body in the feces. The whole-body counting for ^{65}Zn is a straightforward procedure, complicated only by the possible presence of unabsorbed ^{65}Zn in the lower digestive tract.

There appeared to be somewhat greater variation of the metabolic parameters of fractional absorption and effective half-life in the case of ^{65}Zn than was apparent for ^{32}P. It is not always possible to distinguish between variations in the two parameters. The data suggests that considerable difference may occur between individuals and also from time to time for the same individual. A subject for whom an effective half-life of 162 days had previously been measured over a 2-year period, was found to exhibit a 197-day half-life during this experiment.

CONCLUSIONS

From this experiment, it may be concluded that the consumption of fish from the Columbia River for extended periods and in sizable amounts provides a radiation exposure dose that is well within the level considered acceptable for non-occupational exposures by competent agencies. The instrument developed for ^{32}P *in vivo* measurements was shown to provide useful data in the range of monitoring interest, particularly if background measurements on the subject are available. Some evidence was obtained of an average fractional assimilation of ^{65}Zn from fish that is significantly higher than that assumed by the ICRP for a drinking water source.[6] The effective half-life of ^{32}P measured in this experiment was 9.3 days. The ^{65}Zn effective half-life measured in this experiment was distorted by ^{65}Zn ingested in unmonitored parts of the subjects' diets.

Acknowledgements—This experiment required the cooperative efforts of numerous scientists and technicians to collect and analyze samples and to operate the whole-body counter. The contribution of the volunteer subjects who manfully ate ground fish on schedule for 11 weeks was of particular importance, and their cooperation is acknowledged with appreciation. In particular, the assistance of the following scientists is acknowledged: Dr. Guy H. Crook, Dr. Thomas D. Mahony, Mr. Claude R. Henle, Mr. Lloyd S. Kellogg, Mr. John J. Jech, and Dr. Richard F. Foster. Technicians whose interested help was invaluable include: Linda Dalton, Jean Warder, Robert Beaver and Charles McCoy.

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NOTES

Uptake and Retention of Zinc-65 from Certain Foods*

(*Received* 15 *August* 1966;
in revised form 31 *October* 1966)

Introduction

Zinc-65 is one of the radionuclides formed by neutron activation in the cooling water circulated through the Hanford reactors. The 245-day half-life of this nuclide is long enough for it to persist in the river all the way to the coast and to enter the food chain of shellfish and other sea organisms which concentrate zinc.

An experiment was conducted in which one of the authors ate fresh oysters collected from the Washington coast, and his uptake and retention of ^{65}Zn from the oysters determined by whole-body counting. The oysters were analyzed for ^{65}Zn before consumption, permitting quantitative evaluation of the appropriate metabolic parameters.

The results indicate an average fractional zinc absorption of 13.5 per cent for this individual. The ^{65}Zn persisted in his body with an effective half-life (including both biological elimination and radioactive decay) of about 100 days. The highest body burden of ^{65}Zn attained during the course of this experiment was 40 nCi and occurred after eighty-one meals of oysters eaten in a period of 570 days. This may be compared with the recommendation of the International Commission on Radiological Protection that the sustained (lifetime) body burden of an individual should not exceed 6000 nCi of ^{65}Zn.

Experimental design

The experiment was designed to evaluate the uptake and retention of ^{65}Zn from the consumption of oysters collected on the Washington coast. The oysters were furnished by a commercial fishery and were analyzed by gamma spectrometry before being eaten. The ^{65}Zn content of the entire oyster meal was determined in this way to avoid the uncertainties of sampling. The analyses were performed in the radiochemical laboratory of the Washington State Department of Health. The oysters were eaten by one of the authors (P. W. Hildebrandt) who was given whole-body counts at irregular intervals to follow the buildup of ^{65}Zn in his body. P. W. H. lives in Seattle and was believed to have little opportunity of acquiring ^{65}Zn from a source other than the oysters.

Figure 1 shows the course of the experiment. The first oyster meal was eaten in October, 1963 but previous to that date, P. W. H. had been counted in the Hanford whole-body counter to establish an initial background count. During the next 20 months he ate eighty-one meals of oysters, an average of about one meal per week. As is evident from Fig. 1, the meals were not uniformly distributed during that time. There was one period of more than 5 months during which fresh oysters were not available and none were eaten. As P. W. H. lives some distance away, he could only be counted in the whole-body counter when visiting in Richland where the counter is installed. A total of 13 whole-body counts were made during the course of the experiment.

The whole-body counter used to observe the buildup of ^{65}Zn utilizes a $9\frac{3}{8}$ in. × 4 in. sodium iodide crystal activated with thallium, in a room shielded with 26 cm of iron.[1] A counting time of 20 min per measurement permitted an accuracy of ±5 per cent and a lower detection limit of approximately 1 nCi in the whole body.

The total ^{65}Zn ingested by P. W. H. during 20 months was 709 nCi included in 17,430 g of oysters. Thus, he ate an average of 215 g of oysters at each meal and the oysters averaged 41 pCi/g. The amount of ^{65}Zn transported by the Columbia River during the period of the experiment is shown in Fig. 2. A seasonal fluctuation resulting from sedimentation processes is clearly evident, the ^{65}Zn load varying from about 25 to more than 150 Ci/day. On the same chart is shown the concentration of ^{65}Zn in the oysters used in this experiment and which were collected near the mouth of the Columbia. The concentrations shown range between 20 and 60 pCi/g. As one might expect, the retention time of ^{65}Zn by oysters is long enough to mask seasonal fluctuations or correlations with the ^{65}Zn burden of the river.

Experimental results

The maximum ^{65}Zn body burden attained by P. W. H. was 40 nCi. The amount of radioactive zinc present in the body as a result of ingesting ^{65}Zn is a function of the fraction of dietary zinc absorbed and

* This paper is based on work performed under United States Atomic Energy Commission Contract AT(45-1)-1830. Permission to publish is gratefully acknowledged.

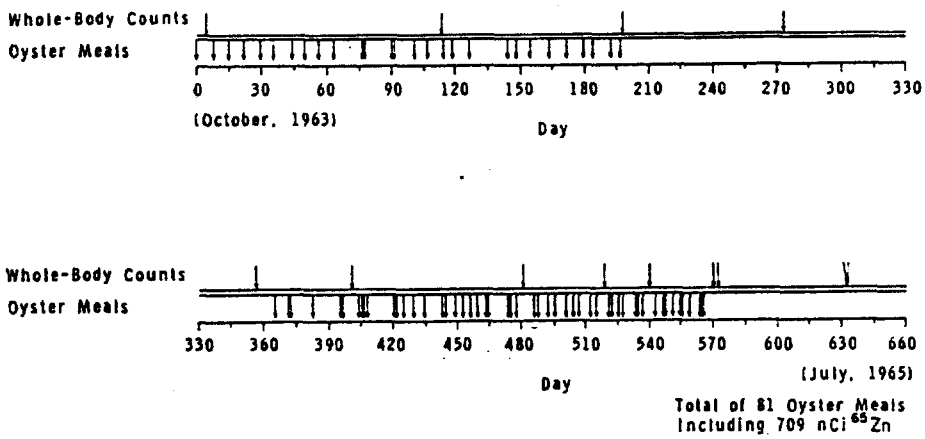

FIG. 1. The chronology of oyster consumption and whole-body counts during this experiment.

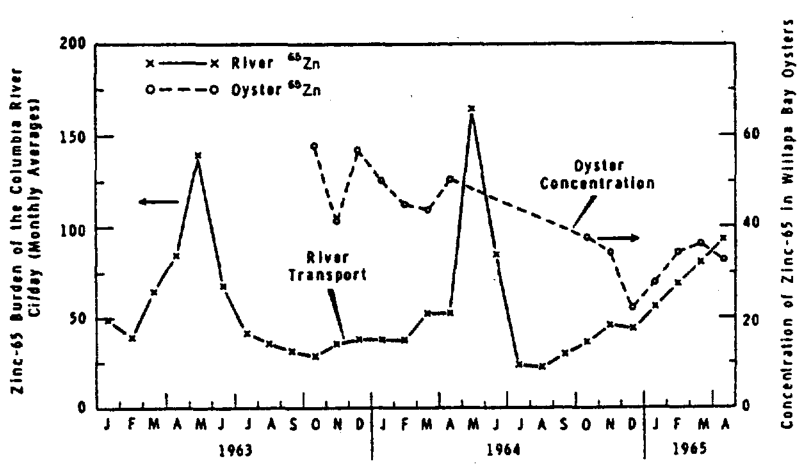

FIG. 2. A chart of ^{65}Zn transported to the Pacific Ocean daily during the period of this experiment. The observed concentrations of ^{65}Zn in Pacific oysters during the period are also shown.

the rate of turnover of zinc in the body. The values for this parameters used by the International Commission on Radiological Protection for calculating acceptable drinking water levels are 10 per cent absorption and an effective whole-body half-life of 194 days (including biological elimination and radioactive decay). These are quoted for a "standard man"; individual values may differ markedly from this average. The best fit values obtained for our experimental data for the case of ^{65}Zn from oysters were 13.5 per cent absorption and 100 days effective half-life.

The whole-body counting data obtained during the course of this experiment are shown in Fig. 3. The solid line is the calculated body burden using a fractional absorption (F_w) of 0.135 and an effective half-life ($T_{1/2}$) of 100 days. The fit of the measured body burdens to this theoretical curve is fairly good except for the first two points. The initial high ^{65}Zn body burdens indicate that possibly P. W. H. had acquired ^{65}Zn from foods other than oysters during this period. While it is possible that he occasionally consumed some ^{65}Zn from other sources, the contribution must have been generally very small. During the period from day 199 to day 366 no oysters were consumed, and the whole-body counts were

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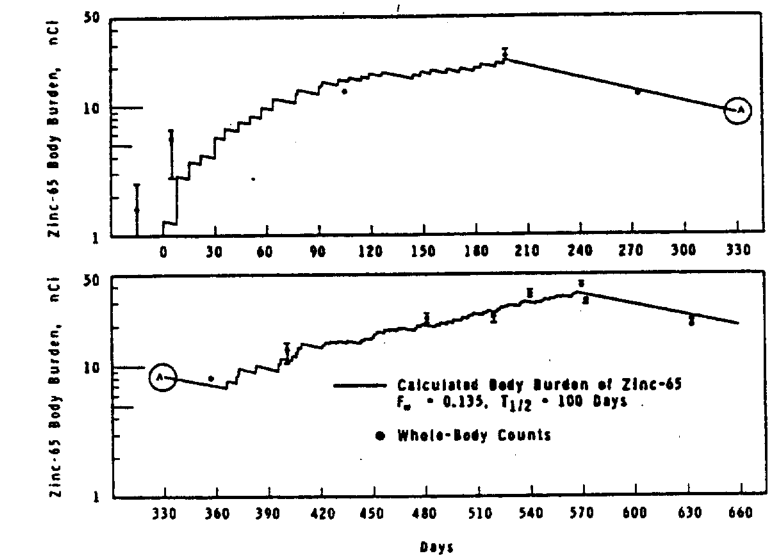

FIG. 3. The solid line is calculated ^{65}Zn body burden based on an assumed fractional absorption of 0.135 and an effective half-life of 100 days as a result of the oyster consumption shown in Fig. 1. The dots are ^{65}Zn body burden measurements in the Hanford whole-body counter.

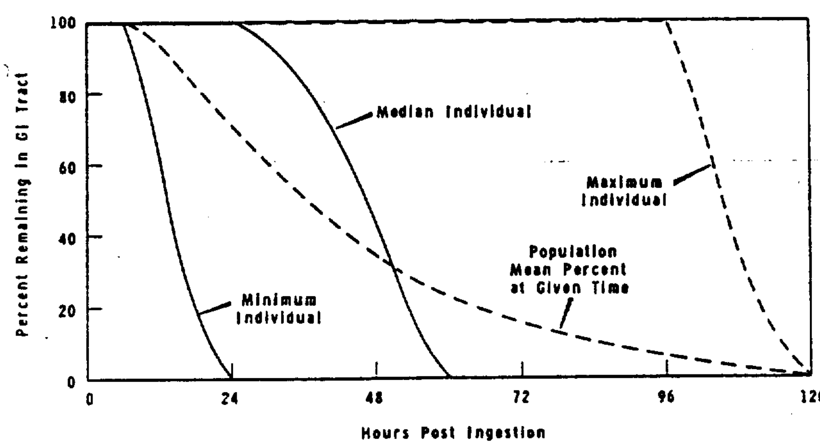

FIG. 4. The passage of insoluble material through the GI tract from the data of WALLACE *et al.*[2] The dotted curve was used to determine the analytical uncertainties shown as vertical bars through points in Fig. 3.

used to calculate an effective half-life for zinc in the body. The 102-day half-life obtained agrees well with the value of 98 days measured during the decay period at the end of the experiment. The apparent fractional uptake of ^{65}Zn from oysters ranged from 0.061 to 0.169 with an average of 0.135 and a standard deviation of 0.027.

The vertical bars on some of the points showing whole-body counts in Fig. 3 reflect an uncertainty resulting from the possible presence of unabsorbed ^{65}Zn in the GI tract contents. The data reported by WALLACE[2] on the passage of barium sulfate through the digestive tract of fifty-five subjects were used to evaluate this uncertainty. The points evaluated were those made within 5 days after an oyster meal. The GI tract retention data are summarized in Fig. 4.

The figure shows the GI tract passage curves for the minimum, median, and maximum individual examined by WALLACE. From these data we derived a population mean (dotted line) which was used to calculate the uncertainties shown in Fig. 3. The size of the bars reflects the amount of ^{65}Zn in the latest oyster meal and the length of time elapsed until the whole-body measurement.

Conclusions

The fractional absorption (13.5 per cent) and effective half-life (100 days) measured for ^{65}Zn from the consumption of Pacific oysters seems to be somewhat different from those values used by the ICRP (10 per cent and 194 days) for calculating permissible drinking water concentrations. However, the experimental results reported here are for a single subject and cannot be used to draw valid conclusions for a "standard man." Values different from these reported by the ICRP were also obtained in earlier experiments which determined the uptake and retention of ^{65}Zn from the consumption of Columbia River fish.[3,4] It was found that the average absorption of ^{65}Zn by seven subjects was 32 per cent and the effective half-life was 162 days. It is probable that the "specific activity" of ^{65}Zn (concentration of ^{65}Zn relative to that of stable zinc) in the flesh of aquatic organisms is actually lower than that in other foods and is responsible for the high turnover rate obtained for zinc from these sources. There is some evidence that zinc is absorbed more readily from such foods than from drinking water. This might reflect some differences in chemical form, but more probably simply indicates individual differences in the metabolisms of the subjects studied.

The accumulation of ^{65}Zn from a very heavy consumption of Pacific oysters resulted in a body burden of only 40 nCi. This may be compared with the maximum permissible body burden recommended by the ICRP of 6000 nCi, based on an assumed lifetime sustained level and for members of the public living in the neighborhood of controlled areas. The ICRP-recommended maximum body burden for occupational exposure is even greater, being ten times that for members of the public. P. W. H. averaged about one meal of oysters per week. To have maintained a body burden equal to the limit recommended by the ICRP would have required him to eat an average of 150 meals of oysters a week. The likelihood of any individual eating more than 70 lb of oysters a week seems small. The results of this experiment thus support the conclusion previously derived from the Hanford environmental evaluation program that the ^{65}Zn in Pacific oysters does not contribute significantly to the radiation exposure of members of the public.

Acknowledgement—The authors wish to express appreciation to R. A. ENGLISH for his assistance with some of the calculations and figures for this paper.

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Health Physics Pergamon Press 1967. Vol. 13, pp. 652–654. Printed in Northern Ireland

Health Physics Technician Training*

(*Received* 21 *June* 1966; *in revised form* 15 *November* 1966)

THE FIRST four certificates of completion of a formal 2-year radiation protection course were granted on 9 September 1966. The course is a joint effort of Idaho State University, the Atomic Energy Commission, and the Idaho Nuclear Corporation. (Idaho Nuclear replaced Phillips Petroleum at the National Reactor Testing Station in this capacity on 1 July 1966.)

After several years of development of a course of training for health physics technicians at the NRTS, the Idaho State Board of Regents approved the cooperative plan in 1964. It is intended to provide young men with adequate skills after four semesters at ISU and two summers at the NRTS. The AEC reimburses ISU for reasonable tuition for each student in the program and provides a minimum income for each student during his training periods at the NRTS.

* Work performed under the auspices U.S. Atomic Energy Commission.

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