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GASTRO-INTESTINAL ABSORPTION OF PLUTONIUM

II. EFFECT OF PLUTONIUM CONCENTRATION IN SOLUTION FED

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GASTRO-INTESTINAL ABSORPTION OF PLUTONIUM
II. EFFECT OF PLUTONIUM CONCENTRATION IN SOLUTION FED

By

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January 4, 1954

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ABSTRACT

The concentration of plutonium in the solution fed had no effect on the gastro-intestinal absorption of plutonium over the range from 10^{-5} μg/ml to 1 μg/ml. The average absorption was 0.0028 per cent of the amount fed, with 0.0025 per cent of the amount fed being deposited in the skeleton.

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GASTRO-INTESTINAL ABSORPTION OF PLUTONIUM
II. EFFECT OF PLUTONIUM CONCENTRATION IN SOLUTION FED

INTRODUCTION

The present series of experiments was undertaken to determine whether concentration of plutonium in the solution administered is an important factor in determining the amount which is absorbed from the intestinal tract and deposited in the tissues of the rat. Solutions fed ranged in plutonium concentration from 10^{-4} μg to 1.2 μg per milliliter. By combining absorption coefficients obtained from previous chronic low level feedings (10^{-6} to 3×10^{-5} μg Pu/ml),[1] with those found from the present higher level feedings, a range of concentrations is covered extending from 0.1 to 10^5 times the presently established maximum permissible concentration of plutonium in drinking water (1.5×10^{-6} μc/ml).[2]

EXPERIMENTAL PROCEDURE

The experimental procedures employed were essentially those described for the earlier studies at lower plutonium concentrations.[1] Young, adult, male Sprague-Dawley rats were used to form 7 experimental groups of 20 animals each. Each rat received a total of 124 - 1 ml doses of plutonium solution by stomach tube at the rate of 2 per day, 5 days a week over a period of about 12 weeks. The solutions fed contained plutonium (IV) nitrate and were adjusted to a pH of 2. Forty control animals were fed similar solutions containing no plutonium.

The average amounts of plutonium fed each group of animals, as determined from samples delivered directly from the gavage apparatus[1] to counting plates, before and after each feeding, are shown in Table I.

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TABLE I

SCHEDULE OF PLUTONIUM FEEDINGS

	Plutonium Fed		
	Average Dose		Total
Group	(μg)	Multiple of MPC	(μg)
I[1]	.00015	6	.019
II	.0021	90	.27
III	.011	450	1.4
IV	.11	4,500	13.
V	.22	9,200	27.
VI	.44	18,000	55.
VII	1.1	47,000	140.

[1]Group I received Pu^{238}, all other groups, Pu^{239}. The estimate of mass of Pu fed to group I may be low by as much as 25 per cent (see text).

Plutonium-239 was administered to all animals, except those at the lowest dosage level (Group I). These animals received plutonium-238, the higher specific activity of which made possible the assay of plutonium absorbed at this low concentration. A slight isotopic impurity of Pu^{239}, below radiochemically detectable limits, may have been present in the Pu^{238} employed. This could have increased the weight of plutonium fed to Group I by as much as 25 per cent over the values listed in Table I.

Upon completion of the feedings, both experimental and control animals were fasted for 72 hours, sacrificed, and analyzed for plutonium in skeletons and soft tissue. Pelts and gastro-intestinal tracts, which would likely be contaminated with unabsorbed plutonium, were carefully removed and discarded prior to analysis.

RESULTS AND DISCUSSION

Results of the present study, combined with the data previously obtained at lower plutonium concentrations[1] are shown in Table II.

TABLE II

PERCENTAGE ABSORPTION OF PLUTONIUM FROM SOLUTIONS OF DIFFERENT CONCENTRATION

Group	Conc. of Pu in sol'n fed (μg/ml)	Per Cent of Fed Plutonium Deposited ($\times 10^4$ with 95% confidence limits)		
		Skeleton	Soft Tissue	Total
A[1]	.000001	0 ± 19	27 ± 28	27 ± 34
B[1]	.000003	19 ± 5	0.7 ± 3.2	20 ± 6
C[1]	.00001	25 ± 3	4.4 ± 4.0	29 ± 5
D[1]	.00003	22 ± 2	2.1 ± 1.0	24 ± 4
I	.00015	22 ± 5	0.1 ± 13	22 ± 13
II	.0021	0 ± 69	0 ± 242	0 ± 251
III	.011	11 ± 17	3.6 ± 47	15 ± 51
IV	.11	28 ± 4	1.7 ± 4.5	30 ± 7
V	.22	28 ± 4	3.5 ± 2.7	32 ± 4
VI	.44	24 ± 4	1.8 ± 1.2	26 ± 4
VII	1.1	28 ± 4	4.6 ± 0.8	33 ± 4
Pooled Average		25 ± 3[2]	3.7 ± 7.2	28 ± 8
Pooled Tolerance Limit (99% of rats, 90% of the time)		47	55	82

[1]These data obtained in an earlier experiment.[1]

[2]Value obtained omitting data from groups A and B (see text).

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There is no statistically significant effect of concentration, except in the two lowest levels (Groups A and B), where plutonium deposition in the skeleton appears to be significantly lower than at higher concentrations. The effect here is small, however, and from 10^{-5} μg/ml to 1 μg/ml, no effect of concentration is observed. Results obtained from Groups II and III are of little interest because of the wide variation observed. These were the lowest concentration levels at which Pu^{239} was employed, and the counting rates obtained were too low for precise evaluation.

It may be concluded that within the concentration range from 10^{-5} μg/ml to 1 μg/ml the absorption of plutonium from the gastro-intestinal tract of rats is not a function of plutonium concentration. The average amount absorbed over this range is 0.0028 ± 0.0008 per cent of the amount fed, with approximately 90 per cent of this being deposited in the skeleton. This figure is somewhat lower than values previously reported from less extensive acute administration studies, and is a factor of nearly 40 times lower than the conservative value[1] employed in the calculation of the presently established maximum permissible concentration for plutonium in drinking water.(2) For a review of previous work in this field, reference is made to the first paper in this series.(1)

Except for those concentration levels at which deposition of plutonium was too small to permit precise analysis, the variation in bone deposition of plutonium between animals was remarkably small. It would be predicted from statistical consideration of the data that in 90 per cent of experiments performed, only one rat in a hundred would show a bone deposition of plutonium greater than twice the average deposition for all rats.

[1] Although Handbook 52 (ref. (2)) lists a value of 0.0001 for the fraction of plutonium reaching the critical organ by ingestion, a ten-fold higher value is used in calculation of the maximum permissible concentration in drinking water.

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It is important to note that all data reported in this and the previous paper in the series were obtained by feeding a particular type of plutonium solution: plutonium (IV) in nitric acid solution, adjusted with sodium hydroxide to pH 2. It is quite possible that other solutions of different plutonium valence state, of different pH, or with different complexing ions present, might exhibit different degrees of absorption. It is probable that the plutonium in the solution employed in this study was present, at least partially, in a polymeric state.[3] There was no tendency, however, for the plutonium to precipitate or plate out on the walls of containing vessels. The choice of type of plutonium solution to be used was made on the basis of the type of solution most apt to be encountered in contamination of drinking water supplies. Less extensive studies are planned to compare absorption from different types of solutions.

ACKNOWLEDGMENTS

We wish to acknowledge the technical assistance of Joan O. Hess and Elizabeth C. Desposato, who performed the animal feedings. Radiochemical analyses were performed under the direction of A. C. Case. Statistical analyses of data were made by F. H. Tingey and D. W. Gaylor.

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