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Battelle

Pacific Northwest Laboratories
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ABSORPTION OF URANIUM-233, NEPTUNIUM-237, PLUTONIUM-238,
AMERICIUM-241, CURIUM-244, AND EINSTEINIUM-253 FROM
THE GASTROINTESTINAL TRACT OF NEWBORN AND ADULT RATS

Investigators:

M. F. Sullivan and A. L. Crosby

Absorption of the nitrates of ^{233}U , ^{237}Np , ^{238}Pu , ^{241}Am , ^{244}Cm , and ^{253}Es by the adult rat was estimated at 0.03%, 1.0%, 0.006%, 0.012%, 0.04%, and 0.014%, respectively; absorption of the oxides of ^{241}Am and ^{244}Cm was estimated at 0.01% and 0.003%, respectively. These estimates are based on retention in skeleton and liver. Absorption of the nitrates of ^{237}Np , ^{238}Pu , ^{241}Am , ^{244}Cm , and ^{253}Es by the newborn rat was estimated at 6.6%, 2.9%, 5.0%, 2.0%, and 5.1%, respectively; absorption of the oxides of ^{241}Am and ^{244}Cm was estimated at 1.1% and 1.7%, respectively. The amount retained by the lower small intestine of newborn rats was frequently several times more than the amount absorbed, which could be a significant factor in evaluating the hazard potential of these radionuclides.

Preliminary observations on the enhanced absorption of curium and californium from the gastrointestinal tract of newborn rats were reported in the 1973 Annual Report. Plutonium absorption is also known to be enhanced in the newborn. We have now completed observations on a number of actinide elements and compounds.

"Soluble" forms of the radionuclides were prepared by diluting nitric acid solutions and adjusting the acidity to pH 2. Americium oxide was suspended in water a few days before administration. Curium oxide was administered either as a fresh

suspension or after standing in water for several months. Adults were administered, by gavage, 5 to 8 μCi contained in 0.5 to 1.0 ml of solution. Two-day-old rats received about 2 μCi in a volume of 0.05 to 0.1 ml, administered carefully through a 0.024 in. polyethylene stomach tube. Higher radionuclide concentrations were administered to some rats whose tissues were used for preparation of autoradiographs. Excreta from adult rats was collected daily for 4 days and pooled for the next 3 days. All animals were killed at 7 days and tissues sampled for analysis.

Distribution and excretion data for adult rats are shown in Table 9.1. The sum of skeletal and liver retention is probably the best estimate of total absorption. Urinary excretion during the 7-day period between gavage and sacrifice should also be included; however, it seems likely that a major portion of the radioactivity

measured in the urine results from fecal contamination. The urine values in Table 9.1 are usually several times larger than skeleton plus liver, which is not in accord with many observations of minimal urinary excretion following parenteral administration of these radionuclides.

TABLE 9.1. Distribution of Radionuclides in Adult Rats Seven Days After Administration by Gavage of Nitrates and Oxides of ^{233}U , ^{237}Np , ^{238}Pu , ^{241}Am , ^{244}Cm , and ^{253}Es .

Radio-Nuclide	Number of Rats	Percent of Gavage Dose				Skeleton + Liver + Urine
		Skeleton (a)	Liver	Skeleton + Liver	Urine	
Nitrates						
²³³ U	11	0.03	0.003	0.03	0.13	0.16
²³⁷ Np	11	1	0.06	1.1	0.4	1.5
²³⁸ Pu	12	0.006	0.001	0.007	0.02	0.03
²⁴¹ Am	11	0.012	0.003	0.015	0.05	0.06
²⁴⁴ Cm	14	0.04	0.004	0.04	0.08	0.12
²⁵³ Es	6	0.014	0.001	0.015	0.02	0.04
Oxides						
²⁴¹ Am	6	0.003	0.01	0.013	0.11	0.12
²⁴⁴ Cm	3	0	0.003	0.003	0.03	0.03
	11 (b)	(0.02)	(0.014)	(0.04)	(0.06)	(0.1)

(a) Skeleton estimated as 23 X single femur content.

(b) Values in parentheses obtained using curium oxide suspended in water for 4 months prior to administration. Values not in parentheses were obtained using freshly suspended material.

The approximately 1% gastrointestinal absorption of neptunium in adult rats is markedly higher than that of the other actinides studied, which fall within a rather narrow range of about 0.005% to 0.05%. Absorption of americium and curium oxides was not greatly different from absorption of the nitrates, except

that freshly prepared curium oxide was absorbed to a 10-fold lower degree than an aged suspension. The enhanced absorption of the aged suspension is consistent with other observations of increased biological mobility of high specific activity oxides, due presumably to radiolytic decomposition of the oxide.

Of particular interest is the high retention of actinides by the newborn within the intestine--both in the contents and within the intestinal wall (Figure 9.1). While this material cannot be considered to be absorbed, it may be of hazard significance, as indicated by substantial damage observed, particularly in the lower small intestine (Figure 9.2). These observations are being extended.

Absorbed actinide nitrates show a preference for deposition in bone

rather than liver, in the case of both adult and newborn rats. This preference is reversed when oxides are fed to adult rats, but no such reversal is observed in the newborn. This argues, again, for a different mechanism of absorption in the newborn. Closer study of such differences might lead to a basic understanding of the mechanisms involved, and the factors that may influence these mechanisms.

FIGURE 9.1. Autoradiograph of an Ileum Section From a Newborn Rat Given 10 μ Ci of ^{238}Pu Nitrate 2 Days Before Sacrifice.

FIGURE 9.2. Histologic Section of the Ileum From a Newborn Rat Given 5 μ Ci of ^{253}Es Nitrate 7 Days Before Sacrifice. H&E.

Distribution data for the newborn rats are shown in Table 9.2. Excreta were not collected from these animals. The column headed "total absorbed" is therefore a minimum estimate, not including re-excreted material. Absorption in the newborn is enhanced over that in the adult by factors of 50 to 500, except for a factor of only 6 for neptunium. This

low enhancement ratio in the case of neptunium is quite possibly due to the older rats (8 days) employed in the neptunium experiments. The newborns did not seem to discriminate between the aged and fresh suspensions of curium oxide, suggesting that the mechanism of absorption in the newborn is different from that in the adult.

TABLE 9.2. Distribution of Radionuclides Seven Days After Administration by Gavage to Two-Day-Old Rats of Nitrates and Oxides of ^{237}Np , ^{238}Pu , ^{241}Am , ^{244}Cm , and ^{253}Es .

Radio-nuclide	Number of Rats	Percent of Gavage Dose				Total Absorbed ^(b)
		Skeleton ^(a)	Liver	Intestine Wall	Intestine Contents	
Nitrates						
²³⁷ Np	10 ^(c)	3.6	0.10	5.5	7.5	6.6
²³⁸ Pu	11	2.6	0.3		13	2.9
²⁴¹ Am	8	4.5	0.3	11	11	5
²⁴⁴ Cm	7	1.8	0.2			2
²⁵³ Es	8	4.4	0.4	0.8	6.8	5.1
Oxides						
²⁴¹ Am	10	0.14	0.02	0.8	0.8	1.1
²⁴⁴ Cm	5	1.9	0.16	2.2	2.8	1.7
	(4) ^(d)	(2.3)	(0.16)	(7.0)	(11.)	(1.8)

(a) Skeleton estimated as $0.22 \times \text{body wt (g)} \times \text{concentration in femur (\%/g)}$

(b) Total absorbed estimated as sum of separate analyses on femur, liver, and residual carcass (not including intestinal wall or contents).

(c) Gavigated at 8 days of age.

(d) Values in parentheses obtained using curium oxide suspended in water for 4 months prior to administration. Values not in parentheses were obtained using freshly suspended material.