9-10

719964

August 14, 1963

To: Those Listed Below

Subject: Internal Dose Estimation Seminar, Thursday at 3:00 p.m.

The enclosed are examples of reviews prepared recently by the Internal Dose Group. The meeting this Thursday is concerned with the format, key words, and other problems concerning their preparation and use.

I hope these examples may help you to formulate your thoughts on the subject and your opinions will be very much appreciated.

WSS:mgw

W. S. Snyder/mgw

W. S. Snyder

K. Z. Morgan
B. R. Fish
S. R. Bernard
M. J. Cook
M. R. Ford
W. S. Snyder
M. G. Wright

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1148229

A-00413

Human Studies Project

Ce^{144}- Pr^{144}; $Ce^{144}Cl_3$; Rat; Intratracheal injection; Lung retention; Lung cancer; Solubility; MPC Discussion

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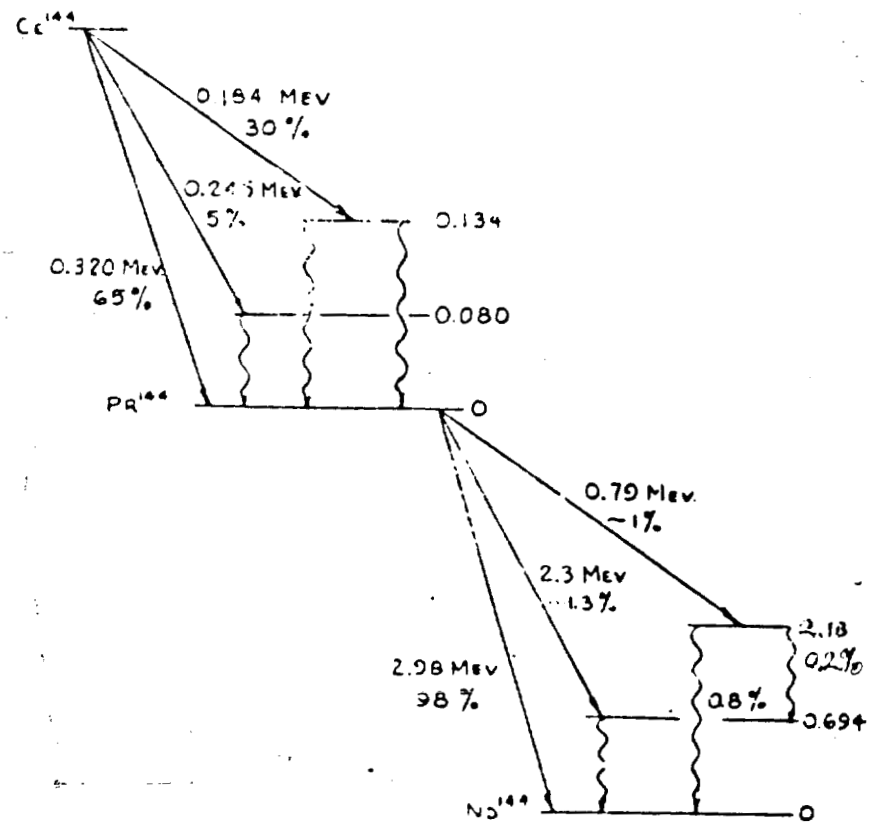
Cember, Herman: "Lung cancer in rats from intratracheally injected radioactive cerium as $Ce^{144}F_3$ and $Ce^{144}Cl_3$", NYOO-10096, March 31, 1962 or Health Physics, 1963

Rats given $CeCl_3$ or $Ce^{144}Cl_3$ in solution by intratracheal injection

Mean wt. of rats 283 ± 33 grams, sacrificed only when near death

Decay scheme

CE^{144}-PR^{144} DECAY SCHEME



Dose Schedule

Summary of $Ce^{144}Cl_3$ Induced Lung Cancer

Treatment*	Number rats observed	Number of Primary Lung Tumors Seen	Days Until Observation of First Tumor	Absorbed Dose Rad, for First Tumor
Control	21	0	-	-
10 uc	61	9	306	14,400
15 uc	52	31	197	19,650
30 uc	37	26	70	25,000

* At all treatment levels, including the controls, the same amount of cerium, 21.3 µg was injected into each rat. (This corresponds to the amount of cerium in the 30 µg CeF_3 doses)

1148230

In computing the daily dose rate due to the radioactive lung burden at the time of injection, it was assumed that all the energy from the Ce-144 β particles is absorbed in the lung, but due to the high energy of the Pr-144 β particles, only 45% of the Pr-144 β energy is dissipated in the lungs.

According to these calculations, a concentration of 1 μc Ce-144-Pr-144 per gram tissue results in beta ray dose rate of 27.85 rad per day to the lung. The contribution of the γ rays to the total dose (very much less) was neglected.

The absorbed doses to the lungs of rats exposed to Ce-144 Cl_3 were computed in the same manner as for Ce F_3, except that the pulmonary retention function for $CeCl_3$ was used. The total absorbed dose in this case is computed from

$$D = \frac{D_o \times 0.88 \times q_i}{1.5} \int_0^T e^{-0.11t}\, dt,$$

where the constant 0.88 represents that fraction of the injected dose that remained in the deep lung.

Found a single exponential, $e^{-0.011t}$, for lung clearance; T_b = 80.5 days

$CeCl_3$ considered soluble, but behaves in rat lung as an "insoluble" compound.

Considers MPC for "soluble" Ce as too high for $CeCl_3$

1148231

Ce^{144} - Pr^{144}; $Ce^{144}F_3$; Rat; Intratracheal injection; Lung retention; Lung cancer; Metastatic cancers; Mean particle diameter, 1 micron; MPC Discussion

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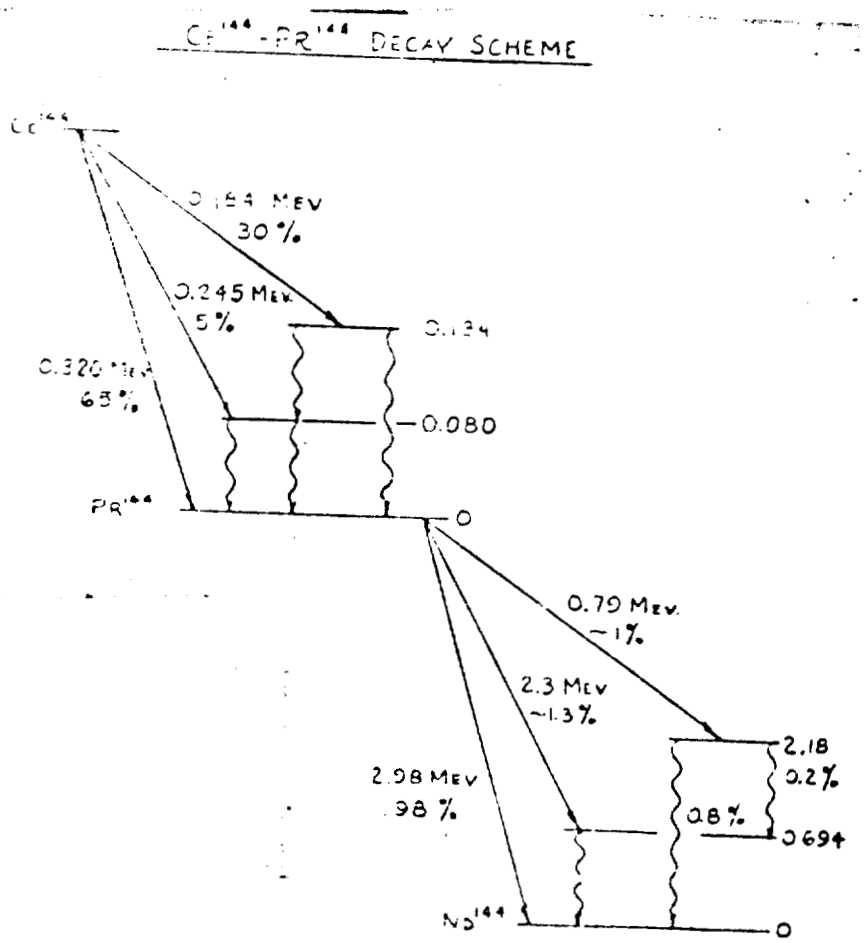
Cember, Herman: "Lung cancer in rats from intratracheally injected radioactive cerium as $Ce^{144}F_3$ and $Ce^{144}Cl_3$", NYOO-10096, March 31, 1962 or Health Physics, 9, 539-544, 1963.

Rats given Ce F_3 or $Ce^{144}F_3$ particles by intratracheal injection.

Mean particle diameter 1 micron , standard deviation 1.4 microns.

Mean wt. of rats 283 ±33 grams, sacrificed only when near death.

Decay scheme of Ce^{144}:



Dose schedule:

Summary of $Ce^{144}F_3$ Induced Lung Cancer

Treatment μg* μc	Number rats observed	Number of Primary Lung Tumors Seen	Days Until Observation of First Tumor	Absorbed Dose, Rad, for First Tumor
Control	29	0	--	-
0.5 uc	41	8	528	600
1	44	6	367	1100
2	34	4	620	2500
4	42	14	381	4400

1148232

* In all treatment levels, the quantity of CeF_3 that was administered to the rats was kept constant at 30 μg.

Found 77% deposited in deep lung and retention of deep-lung deposition given by

$$.75\ e^{-0.29t} + 0.25\ e^{-0.0036t}$$

The corresponding biological half-lives are T_b = 26 days; T_b = 578 days

Ranges of β from Ce^{144} and Pr^{144} are:

The dose calculation neglects dose from γ ray (very small) and assumes only 45% of energy of Pr-144 β is absorbed, but all of energy of Ce-144 β.

Considers $(MPC)_a$ for insoluble Ce^{144} particles as too large

1148233

Tritium; T_b; total body water; urinary excretion;

Wylic, K. F., W. A. Bigler, G. R. Grove: "Biological Half-life of Tritium"
HEALTH PHYSICS

Seven cases of inhalation of tritiated vapor reported, and biological half-life, urinary excretion, and total body water are estimated.

Assumes urine represents 60% of total water output by standard man. Gives T_b of 6.4 - 12.1 days, average 8.5 days. Finds single exponential retention. Data corrected for effective weight - and average body-water turnover period found to be 12.2 days consistant with T_b = 8.5 days. Recognized uncertanity of some of the analytical methods.

1148234

Sr; Ca (stable); P; Exchangable pool; metabolism; excretion; human; IV

Mazzuoli, Gianfranco, Ezio Biagi and Giorgio Coen: "Comparison of Intravenous Infusion of Stable Strontium with the Calcium Tolerance Test", Acta Medica Scandinavica, V.170, fasc. 1, 1961.

The calcium tolerance tests is bases on comparison of urinary Ca on three sucessive days with an IV injection of Ca being given on the second day.

Equivalent amounts of Sr were injected in 9 non-normal patients. Found that Ca and Sr produce the same modifications of phosphorus metabolism. Suggests Sr and Ca metabolism controlled by same hemeostatic mechanism. Percentage of Ca retained appeared to be independent of the magnitude of the exchangable pool.

1148235

Uranium; surface contamination; air concentration; urinary excretion; U_{nat};

Schultz, N. B., A. F. Becher:"Correlation of Uranium Alpha Surface Contamination, Air-Borne concentrations, and Urinary Excretion Rates"
HEALTH PHYSICS

Correlates surface contamination, air activity measurements, and urinary excretion for some 70 employees over 2-3 years of operation of a uranium hexafluoride facility at ORGDP.

Statistically significant correlation of urinary excretion and "removable" surface Activity.

Suggests 40,000 d/min/100 cm^2 as surface level corresponding to 240 μg/l in urine and to NCRP $(MPC)_a$ for soluble uranium.

1148236

Rn^{222}; Aerosol; Measurement

Tsivoglou, E. C., H. E. Ayer and D. A. Holaday

"Occurrence of Nonequilibrium Atomopheric Mixtures of Radon and Its Daughters"

Nucleonics, Vol 11, No. 9, 40-45, September, 1953

Describes a method of determining the degree of quilibrium of Rn^{222} and daughters

1148237

Human Lung; Phagocytosis; Diameter; Retention; Deposition; Chemical form; Physical form;

C. N. Davies
London School of Hygiene and Tropical Medicine, Univ. of London

THE HANDLING OF PARTICLES BY THE HUMAN LUNGS

British Medical Bulletin, volume 19, No. 1, January 1963 (p. 49-52)

Summarizes, often qualitatively, the deposition, retention and effects of aerosols.

Cites some deposition data on silica: in ashed lung only one particle of 10.5 μ av.. dia., very few above 8.5 μ, and 70% below 1 μ. Only one particle in 10^5 as large as 14 μ. For every particle above 8 μ, 3,000 smaller seen, about 80% below 2 μ. Cites Drinker as finding phagocytes yield a similar distribution, but some selectivity on chemical or physical basis. Particle of 6 μ diam. cleared 6 times faster than those of 2 μ. Cites data relating exposure period and lung burden. Considers that a damaged lung accumulates at a faster rate thereafter.

Relates elimination to air concentrations by the following table:

	Air-borne Concentration in particles below 5 μ	Elimination from Lungs
(a)	< 10 particles/cm^3	Complete
(b)	$\sim 1{,}000$ particles/cm^3	$\sim 90\%$
(c)	$\sim 1{,}000{,}000$ particles/cm^3	Inadequate

1148238

Sr (stable); Sr^{90}; power function; Retention; Power function; Exp. model; Bone turnover rate

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G. W. Dolphin and I. S. Eve

"Some Aspects of Radiostrontium Dosimetry"

Physics in Medicine and Biology, Vol. 8, No. 2, 205-214, June, 1963

Calculations from the exponential model for long-term retention of Sr in bone; calculations from a power function model of retention; and considerations of the amount of radiostrontium relative to stable calcium in the diet are discussed. Sources of information are: accumulation by the skeleton of Sr-90 from fallout; human experiments involving intakes of Sr-85 by patients and volunteers; and retention by the skeleton of other alkaline earths, e.g., radium

Data from measurements of fallout, Sr-90, in bones show that the turnover rate varies from bone to bone. Measurements of Sr-85 retention in humans have been made over a period of up to 400 days. These two sets of measurements both support the use of a power function

$$R(t) = 50t^{-0.2} \text{ for } t \geq 1$$

for the percentage retention after t days following an injection.

Power functions which represent the retention in bone of calcium, strontium and radium.

Element	Power function	Duration of measurement	Reference
Calcium	$R = 0{\cdot}96t^{-0.12}$	60 days	Bronner, Harris, Meletskos and Benda (1956)
Strontium	$R = 0{\cdot}51t^{-0.215}$	300 days	Bishop *et al.* (1960)
Strontium	$R = 0{\cdot}52t^{-0.175}$	400 days	Cohn *et al.* (1962)
Radium	$R = 0{\cdot}54t^{-0.52}$	20 years	Miller and Marmelli (1961)

Measured and calculated values of the exponent in the power function $R = At^{-b}$

Element	Measured exponent	Renal discrimination factor	Fraction redeposited	True value of exponent	Assumed values		Calculated from assumed values
	$b(1-f)$		f	b	b	f	$b(1-f)$
Calcium	0·12	–	0·53	0·26	0·6	0·8	0·12
Strontium	0·21	2	0·41	0·36	0·6	0·6	0·24
Strontium	–	4	0·29	0·30	0·6	0·43	0·34
Radium	0·52				0·6	0·1	0·54

ICRP recommendations for dosimetry of radium-226 and strontium-90

Nuclide	Body burden (μc)	Annual mean dose to bone (rem or effective rem/year)	RBE	Relative damage factor, s	Annual mean dose to bone (rad/year)
Radium-226	0·1	30	10	1	3
Strontium-90	2	30	1	5	6

1148239

Arguments are put forward mainly to show that there are more similarities in the time pattern of retention of these alkaline earths than appear from the measurements. This similarity of retention is taken as some justification for the use of a power function retention for strontium.

Calculated values of $(MPC)_w$ and $(MPC)_a$ of strontium-90 for continuous exposure

Model for long-term retention of ^{90}Sr	Equation used for retention of injection	$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)
ICRP, exponential model	$0{\cdot}3\exp(-0{\cdot}693/6400)t$	1×10^{-5}	1×10^{-10}
ICRP, power function	$0{\cdot}95t^{-0{\cdot}25}$	$2{\cdot}5\times10^{-5}$	3×10^{-10}
ICRP, power function	$0{\cdot}65t^{-0{\cdot}35}$	8×10^{-5}	7×10^{-10}
This paper	$0{\cdot}5t^{-0{\cdot}2}$	$4{\cdot}5\times10^{-5}$	5×10^{-10}

Calculated values of the $(MPC)_w$ and $(MPC)_a$ for continuous intake of strontium-90 based on the specific activity of radioactive and stable strontium

$(MPC)_w$	$4{\cdot}5\times10^{-6}\ \mu c/cm^3$
$(MPC)_a$	$3{\cdot}2\times10^{-10}\ \mu c/cm^3$

Calculated values of $(MPC)_w$ and $(MPC)_a$ for continuous exposure to strontium-89 compared with the current ICRP (1959) values

Model for long-term retention	$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)
ICRP (1959) exponential model	1×10^{-4}	1×10^{-8}
ICRP (1959) power law $0{\cdot}95t^{-0{\cdot}25}$	2×10^{-4}	2×10^{-8}
ICRP (1959) power law $0{\cdot}65t^{-0{\cdot}35}$	4×10^{-4}	4×10^{-8}
Power function $0{\cdot}50t^{-0{\cdot}2}$	$5{\cdot}1\times10^{-4}$	$3{\cdot}0\times10^{-8}$

Comparison of MRC (1959) dietary contamination levels for strontium-90 with ICRP (1959) recommendations for environmental populations

	Permissible daily ingestion (μc)	$(MPC)_w$ ($\mu c/cm^3$)	Dose to sites of highest concentration (rad/yr)	Comments
MRC (1959)	2×10^{-3}	9×10^{-7}†	1·5	Based on dose to sites of highest concentration. $(MPC)_w$ calculated using intake of 2·2 l. per day
ICRP (1959) Group B(c)	$0{\cdot}22\times10^{-3}$	10^{-7}	0·11†	Based on 1/10 of mean dose to bone of 30 rem/yr after 50 years of continuous intake
ICRP (1959) Radiation worker	$2{\cdot}2\times10^{-3}$†	10^{-6}	1·1†	Based on 30 rem/yr after 50 years occupational exposure

† Calculated value.

affect a population more than once in a lifetime. This essential difference between the MRC and ICRP recommendations should be noted and the use of the MRC dose criteria for continuous intake of activity conflicts with ICRP recommendations which are based on a comparison with radium.

SUMMARY

The current methods of the dosimetry of radiostrontium are critically reviewed with reference to the models proposed by Dolphin and Eve (1963) and the most recent experimental measurements of body retention of the alkaline earths. It is concluded that the current ICRP (1959) Recommendations for the $(MPC)_a$ and $(MPC)_w$ are less restrictive by a factor of around 3 or 4.

1148240

BONE TURNOVER DATA

It is well established that bone minerals turn over very slowly. Bryant and Loutit (1961 estimate from measurements of the incorporation of Sr-90 from fallout, that in an adult the annual turnover rate in bone mineral ranges from 1% in the skull and tibia to 8% in the vertebra. The mean of their values for 11 subjects, weighted for the proportion of the total skeleton, is between 2 and 3%. Data collected in the United States by Kulp and Schulert (1962) give a similar value of about 2 1/2% skeletal (2.5%) turnover per year. This rate of turnover is equivalent to a half-life of 10^4 days if a single component exponential model is assumed.

There seems to be an error in the equation given on page 206. It consists of an exponential representing 28% of the injected dose and a power-function term representing 51%. A sentence below refers to 49% as being retained with the exponential of 2.7 days as half-life.

A discussion and comparison of the power function for the elements Ca, Sr, and Ra is given and the different values of the exponent can be explained by the re-utilization of the isotope when excreted from bone into the blood.

Bryant and Loutit (1961) point out that the daily Ca intake remains fairly constant throughout life in spite of dietary variations.

In the case of radium deposits in human one, hot spots have been measured which have activities many times higher than the mean activity (Lloyd 1961) so that some small volumes of bone may receive up to and higher than 100 rads per year although the mean value averaged over the whole skeleton is only 3 rads/yr. The longer range of β-particles from Sr-90 tends to make the dose throughout the bone more uniform. Dolphin and Eve (1961) reviewed the available evidence which suggests that the dose received by Haversian canals in bones may be up to seven times the mean bone dose, ie., up to 40 rads/yr in some hot spots compared with a mean value of 6 rads/yr.

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1148241

LIST OF KEY WORKS FOR THE IDEIC

- ISOTOPE (Every isotope, e.g. Sr^{85}, Sr^{90}, etc., is a key word)

ELEMENT (Every stable element is a key word, e.g. Sr (stable), U_{nat} and Th_{nat})

CHEMICAL FORM

Acetate

Carbonate

Citrate

Halide

Nitrate

Oxide

Phosphate

Sulphate

Thymidine

Organic

Other Chemical Forms

PHYSICAL CHARACTERISTICS

Soluble
- Acid
- Blood
- G.I. tract
- Lung
- Water

Insoluble
- Acid
- Blood
- G.I. tract
- Lung
- Water

1148242

PHYSICAL CHARACTERISTICS (Cont'd)

Aerosol

Gas

Particle Data (physical)

Solid

Solution

Suspension or Colloid

ANIMAL

Man

Cow

Dog

Goat

Guinea Pig

Monkey

Mouse

Rabbit

Rat

Sheep

Other Mammals

Other vertebrates

Cells and microorganisms

1148243

BIOLOGICAL CHARACTERISTICS

Foetus

Infant

Young

Adult

Aged

Pathological (condition)

Grossly normal (condition)

Sex

MODELS

Exponential

Power Function

Intake (discussed)

MPC's (discussed)

Toxicity (discussed)

1148244

STANDARD MAN DATA

Foetus

Infant

Youth

Adult

Aged

Composition and Mass

Intake

Air

Food

Water

Elimination

Air

Food

Water

Variability

1148245

BIBLIOGRAPHY

RADIOSENSITIVITY

RBE and/or MF

ADMINISTRATION

Single

Multiple

Continuous

Inhalation

Oral

IV

IM

IP

SC

IT

Surface absorption

1148246

DATA AND RESULTS

Deposition

Organs of reference
- skeleton
- lung
- whole body
- soft tissues
- etc.

Retention

Organs of reference
- skeleton
- lung
- whole body
- soft tissues
- etc.

Elimination

Organs of reference
- skeleton
- lung
- whole body
- soft tissues
- etc.

Burden

Organ of reference
- skeleton
- lung
- whole body
- soft tissues
- etc.

Urinary elimination

Fecal elimination

Breath elimination

Prespiration

1148247

DATA AND RESULTS (cont'd)

Distribution

Toxicity

1148248

Key words:

Sr^{90}; Sr^{89}; Cs^{137}; Ca; Food; Man; Wheat; Milk; Youth; Grossly normal; Infrared

Variability

Irving Michelson
Consumers Union of U. S., Inc., Mount Vernon, New York

RADIOISOTOPES IN THE 1962 DIET

Health Physics (in proof)

Abstractor: WSS

Typical weekly diets of teen-agers and 1 yr old infants were prepared as to be eaten, to represent typical intake of foods by these age groups in each of 30 cities of the U. S. in 1962. Analyzed for Sr-90, Sr-89, Cs-137, Ca. Contributions of these isotopes from wheat and from milk estimated also. In particular, gives the estimated intake of milk and wheat products by the teen ager as well as the total daily intake of food in kg. Percentage of Ca by weight of total diet can be inferred.

1148249

Key Words:

La^{140}; Citrate; pH7; GI tract; Solution; Particle; Man; Young; Adult; Aged; Grossly normal; Variability; Single administration; Oral administration; Fecal elimination

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R. L. Hayes, J. E. Carlton and W. R. Butler, Jr.

RADIATION DOSE TO THE HUMAN INTESTINAL TRACT FROM INTERNAL EMITTERS

HEALTH PHYSICS (in proof)

Abstracted by WSSnyder:

Estimates dose to the lower large intestine from tracer doses of La^{140}- citrate, orally administered to 54 patients. Ages varied from 7 - 76 years. All patients considered normal so far as the G I tract is concerned. Total recovery 90% or better. Assuming activity uniform in stool samples and neglecting decay in the LLI obtains an estimate of dose. Defines a dose index:

$$I = \frac{D\ (\text{individual})}{D\ (\text{standard man})} .$$

The distribution of the dose index for some or all of these patients is given (1) on repeated trials (2) by magnitude (variation 0 - 7.5) (3) by plotting:

Max (I, 1/I) (the distribution appears approximately normal)

(4) and variation of the average dose index with half-life of the radionuclide. A significant difference ($P \leq 0.10$) was found in I when the dose is given with the noon meal and when taken 2 hours before breakfast. Age did not seem of great importance although there was some increase in motility with age. A aizable proportion of the population may experience doses many times in excess of that assumed for standard man. The measurements indicate that about 15% of the general population may experience a dose three times that of standard man. Average dose 1.70 times that of standard man for long-lived materials, and for a radioactive half-life of 12 hours was equal to the dose to standard man. Suggests entry time to LLI to be 18 hours instead of 13 hours.

1148250