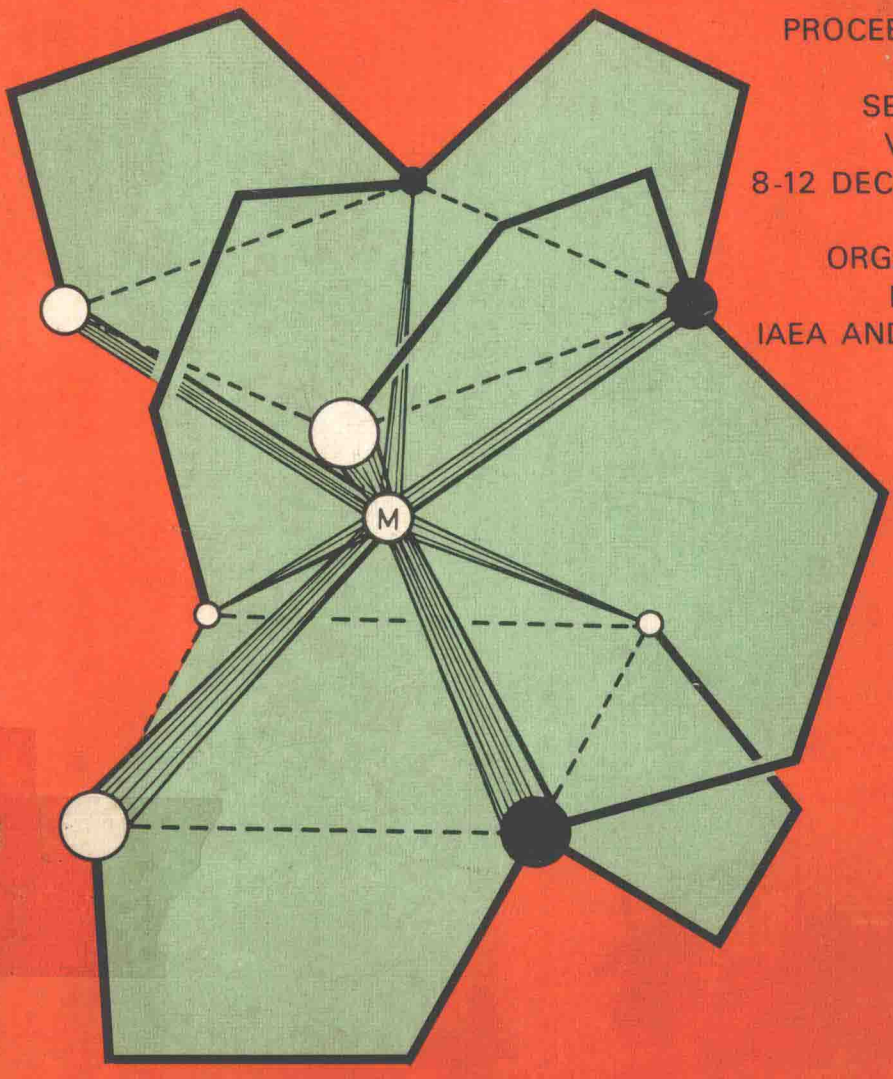
Diagnosis and Treatment of Incorporated Radionuclides

PROCEEDINGS OF A SEMINAR VIENNA 8-12 DECEMBER 1975 ORGANIZED BY THE IAEA AND WHO



INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1976

PROCEEDINGS SERIES

DIAGNOSIS AND TREATMENT OF INCORPORATED RADIONUCLIDES

PROCEEDINGS OF AN INTERNATIONAL SEMINAR ON
DIAGNOSIS AND TREATMENT OF INCORPORATED RADIONUCLIDES
ORGANIZED BY
THE INTERNATIONAL ATOMIC ENERGY AGENCY AND
THE WORLD HEALTH ORGANIZATION
AND HELD IN VIENNA, 8 - 12 DECEMBER 1975

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The cover picture shows the probable structure
of a DTPA-metal chelate.
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DIAGNOSIS AND TREATMENT OF INCORPORATED RADIONUCLIDES

FOREWORD

With expanding nuclear programmes throughout the world and increasing use of radioactive nuclides in many fields, more attention must be given to the question of how best to deal with accidents involving radioactive contamination of man.

The International Atomic Energy Agency and the World Health Organization jointly held a scientific meeting on the Diagnosis and Treatment of Radioactive Poisoning in Vienna in 1962. Since that time important studies both on the metabolic behaviour of radionuclides as well as on methods and techniques for diagnosing and evaluating the body or organ content have been made. There have also been important advances in methods of handling patients and implementing the necessary therapeutic measures.

The present Seminar on the Diagnosis and Treatment of Incorporated Radionuclides, organized by the Agency and the World Health Organization, serves to bring information and knowledge in this field up to date. The subject of the treatment of incorporated transuranics, especially plutonium, received great attention during the Seminar, a round table discussion being almost exclusively devoted to it.

The Seminar also brought together scientists with experience in biological experiments aimed at substantiating clinical procedures. Certain papers provide new information on apparatus and calibration techniques that can be used for detecting small fractions of the maximum permissible body burden as well as for evaluating the efficacy of treatment.

It is hoped that the published proceedings of this Seminar will be of help to the medical practitioner and health physicist who may be called upon to handle cases where radionuclides have been accidentally incorporated.

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METABOLISM OF SOME IMPORTANT RADIONUCLIDES INCLUDING THE ELIMINATION AND RETENTION PATTERN

(Sessions I and II)

Session I

Chairman: A. Catsch (Federal Republic of Germany)

ALEXANDER CATSCH

It is with regret that the IAEA and WHO record the sudden death, on 16 February 1976, of Alexander Catsch. Professor Catsch was one of the most outstanding personalities in the field of chelate therapy and thus also played an important part in this Seminar on the Diagnosis and Treatment of Incorporated Radionuclides. Much of the work reported at the Seminar resulted from his efforts to introduce Zn-DTPA instead of the more toxic Ca-DTPA into chelate therapy, and from his resourcefulness in suggesting and applying new ways of thinking, and thus opening up new paths, in decorporation treatment.

Session II

Chairman: G.C. Butler (Canada)

Review paper

METABOLIC EXCRETION AND RETENTION PATTERNS OF INCORPORATED RADIONUCLIDES IN REFERENCE MAN

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Abstract

METABOLIC EXCRETION AND RETENTION PATTERNS OF INCORPORATED RADIONUCLIDES IN REFERENCE MAN.

The paper gives formulae for calculating the total expected 50-year dose (TED_{50}) and excretion rate for four patterns of uptake as well as numerical descriptions of the ICRP "gut model" and "lung model".

INTRODUCTION

The purpose of this paper is to describe the quantitative information on retention and excretion of radionuclides in Reference Man and how it is used in radiation protection for internal contamination. The information must provide the basis for making numerical estimates of levels of contamination, dose rates and total doses required for

- calculating the dose commitments resulting from releases of radioactive materials to the environment,
- estimating the doses of radionuclides to be administered for diagnostic or radiotherapeutic procedures,
- personnel monitoring of workers.

It is the third of the activities listed with which this seminar is concerned.

BODY OR ORGAN CONTENT

For the kind of calculations required in the assessment of radiation doses it is necessary to have a formula describing the body (or organ) content (usually in μCi) as a function of the time following the beginning of intake. If information about the retention of organs and tissues is needed and is not available specifically for the organ, one can use the whole body retention equation multiplied by the fraction of the body content deposited in the organ. By calculating the integrated content over 50 years resulting from an intake during some period of interest, one obtains the 50-year exposure in μCi-days from which is calculated the Total Expected Dose in 50 years (TED_{50}), the period of interest. This can then be compared with the appropriate dose limit.

To express this in mathematical terms, as formulated in Reference [1],

$$q(t) = \int_0^t I(\zeta)\, r_s(t - \zeta)\, d\zeta \qquad (1)$$

where $q(t)$ is the amount of radionuclide in the body (or organ) at time t
$I(\zeta)$ is the rate of uptake at time ζ
$r_s(t - \zeta)$ is the retention equation for a single uptake

and $$r_s(t - \zeta) = R_s(t - \zeta)\, e^{-\lambda_r (t - \zeta)}$$

where $R_s(t - \zeta)$ is the fraction retained in the body (or organ) following a single uptake at time ζ
λ_r is the radioactive decay constant

$$\tilde{q}\ (18250)\ (\mu\text{Ci-days}) = \int_0^{18250} q(t)\, dt$$

$$= \int_0^{18250} I(\zeta) \left[\int_0^{18250 - \zeta} r_s(u)\, du \right] d\zeta \qquad (2)$$

$$TED_{50} = 3.2 \times 10^{9}\ \tilde{q}\ (18250) \times 1.6 \times 10^{-8}\ SEE \qquad (3)$$

$$= \tilde{q}\ (18250) \times 51\ SEE$$

$$= \tilde{q}\ (18250) \times SE$$

where 3.2×10^{9} = disintegrations per μCi-day
1.6×10^{-8} = g-rads per MeV
SEE = equivalent MeV per g of irradiated tissue per disintegration
Equivalent MeV = MeV modified for quality and other factors
SE = rems per μCi-day

Values of SE calculated for various target and source organs will be provided by ICRP Committee 2. These will be based on the latest quality and other modifying factors, dosimetric models and organ masses of Reference Man [2].

From the above it can be seen that this paper should now deal in turn with intake and uptake, retention and excretion.

INTAKE

At the outset "intake" and "uptake" must be differentiated; intake refers to the entry of radioactive material into the gastrointestinal tract (GI tract), the lungs and cutaneous and subcutaneous tissues. Uptake means the entry of the radionuclide into blood and other extracellular fluids leading to systemic contamination. The patterns of intake and uptake as a function of time following an exposure are not necessarily the same.

Ingestion

The basic data for dosimetry of the GI tract were developed by Eve [3] and are now adopted in the ICRP Report on Reference Man [2]; they are summarized in Table I. There are two things to note about these data:

- the time of passage through the GI tract (42 hrs) tells us the rate of excretion, of an ingested and unabsorbed radionuclide, in the faeces;
- because of the low total mass (walls + contents) and long residence time in the lower large intestine (LLI), this tissue will usually receive the highest total dose of radiation.

In addition to Table I, one other piece of information is required for calculation of doses to the GI tract, uptake and excretion resulting from ingestion of radionuclides, i.e., f_1, the fraction of the radionuclide absorbed during the four-hour passage through the small intestine. Since the absorption of radionuclide from the small intestine is assumed to be an exponential process the absorption can never, theoretically, be 100% so a maximum value of $f_1 = 0.95$ is adopted.

Values of f_1 for each element of interest in one or two "standard" chemical forms are given for ingestion by Reference Man. Thus, from knowledge of the amount ingested the magnitude of the short-term uptake can be calculated and the amount not taken up will be excreted within 2 or 3 days in the faeces.

Inhalation

One of the attributes of Reference Man added in 1966 [4] by the ICRP Task Group on Lung Dynamics is the so-called Lung Model. Its most important features to be used in internal dosimetry are summarized in Figure 1; this embodies the most recent revisions and displays values for "standard" particles with an activity median aerodynamic diameter of 1 μm.

Inhaled substances are grouped into three classes, D (days), W (weeks), and Y (years), according to their transportability (see ICRP Publication 10, p. 2). If these data are rearranged into the form presented in Table II they become more immediately useful for dosimetry and monitoring.