TECHNICAL NOTE
ORP/CSD—77—4

PLUTONIUM AIR INHALATION DOSE (PAID)

A Code for Calculating Organ Doses Due to the Inhalation and Ingestion of Radioactive Aerosols

U.S.Environmental Protection Agency
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by

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June 1977

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INTRODUCTION

This technical note describes a computer code, PAID, developed to determine time dependent dose rates and doses from inhaled or ingested radionuclides. The main purpose of this code is to determine the dose rates and doses caused by the intake of transuranic nuclides and their decay products.

The two primary modes leading to internal radiation exposure are the inhalation and ingestion of radioactive materials. The estimation of organ burden and exposure,* as well as of the resulting dose rates and doses, due to uptake by these pathways is relatively complicated and requires the adoption of mathematical models which depend on many parameters. A computer code which implements the lung model described by the ICRP Task Group on Lung Dynamics is presented below. This model has been augmented to also include the dose due to the transfer of radioactivity to other organs from ingested materials.

A. Inhalation

Industrial hygienists have recognized for many years that the inhalation of an aerosol carrying radioactive nuclides was a potential mechanism for damage to the respiratory tract as well as a possible pathway for the translocation of inhaled radioactive material to other reference organs. The complexity of the biological phenomena which govern transmission and elimination of such material complicates the consideration of potential health effects due to inhalation of radioactive materials. Even a first order analysis of the process must consider the factors enumerated below:

*The time integral of the burden has been referred to as the exposure by the ICRP.

(1) The fractional deposition of inhaled material in the respiratory tract depends on properties of the aerosol - size and mass distribution, chemical form and charge - as well as on the breathing rate and such physiological characteristics of the lung as its surface properties and configuration.

(2) The duration and extent of the exposure depends on the biological and physical mechanisms which transport the deposited material and its decay product within the body. These include the various clearance paths, the nuclide half-lives, the chemical form, the solubility, and the degree of retention in each reference organ of interest.

(3) The dose depends on the time integrals of the activity of both parent and daughter in the organ, the organ mass, the emitted energy of each nuclide, and the fraction of that energy absorbed by the organ tissues. For alpha emitters, this absorbed fraction is assumed to be unity. At present, the organ mass, breathing rate, and clearance times in the PAID code correspond to those of a 30-year old working male (1). Specific parameters are given in the text below. The dose is calculated in rads - neither quality factors nor other dose modifying factors are included in this program.

B. Ingestion

The ingestion of radioactive material represents another pathway by which radioactivity may be transferred to blood and, subsequently, to other organs. While description of this pathway is simpler than for inhalation, due to the direct deposition of the ingested material into the gastrointestinal tract, treatment of the balance of the biological - physical processes involved suffers from the same uncertainties in biological parameters as were discussed for the inhalation model. The dose to the gastrointestinal tract itself is not calculated by this program, nor is the normally negligible time delay associated with transfer of the material through the stomach and small intestine considered.

In the ingestion model, the critical transfer mechanism is the absorption of radioactive material into the systemic blood from the small intestine. Values for the fraction, f_1, of ingested radioactivity transferred to blood have been studied in animals and, to a very limited extent, in man but are still subject to large uncertainties which strongly affect projected doses to the reference internal organs, i.e., bone, liver, etc.

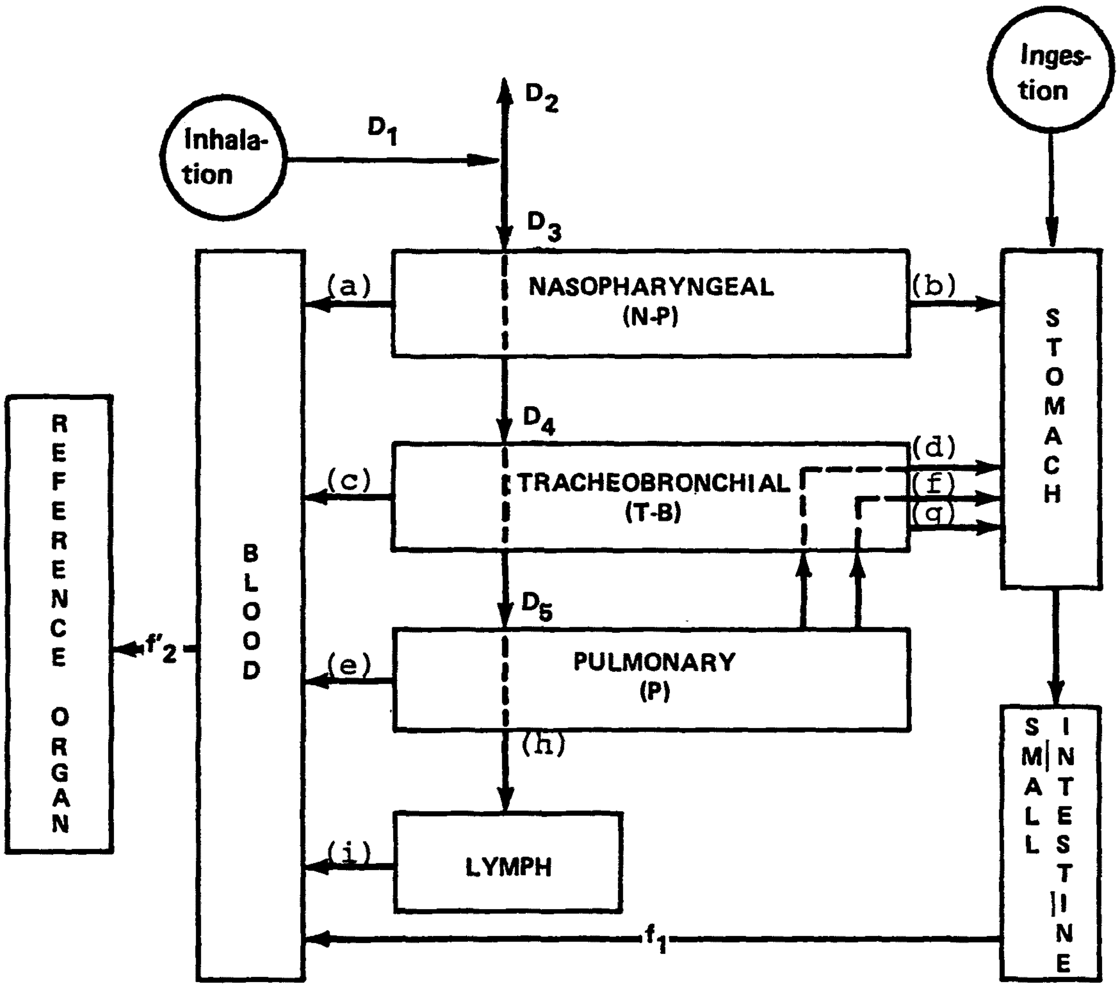
C. The Physical Model

Reasonable estimates of internal radiation doses due to inhalation and ingestion require that a consistent model for both the respiratory and gastrointestinal tracts be employed. While a large amount of theoretical and experimental work on such models has been done, the most widely accepted models have been those developed by members of the respective International Commission on Radiological Protection (ICRP) working groups.

The ICRP Task Group on Lung Dynamics (TGLD) has proposed a model for the respiratory tract which has been well documented (2). Parameters suggested for use in the model have been extensively reviewed and, to some extent, improved in later ICRP publications (3). Details of this model are given by Morrow and the revised parameters

have been collected by the ICRP in reference (3). Therefore, only a brief outline of the model is presented here. The ICRP TGLD proposed model comprises three major compartments: the nasopharyngeal, the tracheobronchial and the pulmonary, as shown in Figure I.
Each of these major compartments is divided into subcompartments, corresponding to various transfer mechanisms, which are treated as essentially independent processes. In addition, the associated lymph nodes are appended to the pulmonary compartment in one of the transfer chains. Direct deposition through inhalation is only to the three major compartments with the fractional deposition in each a function of the aerosol properties. Subsequent transfer and/or clearance is governed by the parameters specified for each subcompartment, as shown in Table I, taken from reference (3). Pathways are indicated in Figure I.

FIGURE 1



D_1 is the total aerosol inhaled; D_2 is the aerosol in the exhaled air; D_3, D_4, and D_5 are the amounts deposited in the nasopharyngeal, tracheobronchial, and pulmonary lung respectively. The letters (a) through (i) indicate the process which translocates material from one compartment to another. Values for these parameters are listed in Table I.

Table I

Biological Half-lives in Days and Transfer

Fractions for Use with TGLD Clearance Model

Region	Pathway	Compound Class (D)	(W)	(Y)
N-P	(a)	0.01 d/0.5	0.01 d/0.1	0.01 d/0.01
	(b)	0.01 d/0.5	0.4 d/0.9	0.4 d/0.99
T-B	(c)	0.01 d/0.95	0.01 d/0.5	0.01 d/0.01
	(d)	0.2 d/0.05	0.2 d/0.5	0.2 d/0.99
P	(e)	0.5 d/0.8	50 d/0.15	500 d/0.05
	(f)	---	1 d/0.4	1 d/0.4
	(g)	---	50 d/0.4	500 d/0.4
	(h)	0.5 d/0.2	*50 d/0.05	500 d/0.15
L	(i)	0.5 d/1.0	50 d/1.0	1000 d/0.9

*A value of 50.01 is substituted in the code.

In connection with this table, it should be noted that the code described in Appendices I and II is not suitable for decay chains in which the parent and daughter are in different classes. Its use is also restricted to the analysis of compartments not having identical biological half-lives. However, the decay of the parent into a radioactive daughter is explicitly treated for the case in which both are Class Y or Class W compounds. While not contained in the present code, the solutions for Class D compounds are contained within the general equations derived below.

An ICRP gastrointestinal tract model has been documented (4). The model comprises a four compartment tract consisting of the stomach, small intestine and lower and upper large intestine. The times involved in the passage of material through the stomach and small intestine (the only compartment from which transfer into the blood occurs) are negligible compared to the half-lives associated with most class Y compounds and are neglected when considering doses due to ingestion.

Although both these models are described exhaustively in words, neither of the ICRP groups has given mathematical descriptions for the various processes involved. This lack has led to some confusion in attempting to calculate doses and effects using the models. For the present treatment, several of the previous analyses, (5,6,7), have been reviewed and discrepancies or omissions in their equations compared with the "official" verbal descriptions of the models. While some ambiguities may remain, the present treatment has attempted to reconcile differences between the ICRP descriptions and these earlier codes. Several features, not common to all previous codes, which have been incorporated into PAID include: (1) explicit calculation of the dose rates and doses due to both parent and daughter products, (2) inclusion of the dose to the tracheobronchial region due to the clearance of material deposited in the pulmonary region, (3) calculation of the dose from material permanently retained in the lymph nodes, (4) separate calculation (and printout) of the percentage of the total dose to a reference organ due to absorption from the gastrointestinal tract for both parent and daughter. This latter feature allows various values of f_1 to be substituted without repeating the whole calculation.

D. The Mathematical Model

The PAID code used by the Environmental Protection Agency (EPA) corresponds to descriptions of the physiological processes as contemplated by the originating ICRP working group. In addition, an attempt has been made to keep the resulting mathematical relationships as simple and understandable as possible. To this end, the respiratory and gastrointestinal tract models have been coupled as outlined below:

The ICRP TGLD model implicitly assumes that the physiological processes associated with each subcompartment operate independently. The simplest mathematical treatment of the model is to consider a chain consisting of up to three components for both parent and daughter. The first component in each chain represents a lung subcompartment, the second either the reference organ or the lymph nodes, and the last the reference organ for the lung-lymph node pathway. For the ingestion pathway only one component - representing the reference organ - is used since the dose to the gastrointestinal tract is not calculated. A general differential equation governing the behavior of each series - connected component in a chain of arbitrary length may be written as:

$$\dot{q}^n(t) = S^n(t) - \lambda^n q^n(t) \qquad (1)$$

where $q^n(t)$ = the organ or subcompartment burden (curies) for the nth subcompartment

$S^n(t)$ = the source term for the nth compartment (curies/yr)

λ^n = the total, or effective, decay constant for the radionuclide in the nth compartment (yr^{-1})

The source term will vary, depending on the position of the compartment in the chain and whether the parent or daughter is under consideration. Direct deposition within the lung is through inhalation of the parent and is into the major compartments; nasopharyngeal, tracheobronchial and pulmonary. These major compartments are further divided into subcompartments and their associated pathways; (a) through (i) listed in Table I.

Consider first the equations for the organ burden due to the parent, S_p. The source term in the first compartment (subcompartment) of the lung will be:

$$S_p^1 (t) = I_c D_k f_\ell$$

where D_k is the deposition fraction for the major compartment as shown in (2); f_ℓ is the fraction of D_k translocated through pathway ℓ, Table I and I_c is the rate (curies/year) of constant chronic intake based on the breathing rate given in Table II. Thus, I_c = (Breathing Rate) x (Air Concentration). Mathematically, any acute intake is presumed to be present at time zero, i.e.,

$$q(t = 0) = I_A D_k f_\ell \qquad (2)$$

where the subscript A denotes acute and q (t=0) is inserted as a boundary condition.

Table II

Breathing Rate - Male Adult ICRP Report #23 (ICRP 1975)

	Minute Volume (liters/minute)	Duration (hours/day)
Light Activity	20.0	16
Resting	7.5	8

Average Daily Intake = 2.3×10^4 liters.

For ingestion, the only component is the reference organ and the source here is:

$$S_p^1 (t) = I_c$$

where, again, I is the annual intake in curies for constant, continuous ingestion. Any acute intake is, again, treated as a boundary condition.

For succeeding components in the chain, the only source for parent radionuclides is material transmitted from the preceeding compartment. All organs (subcompartments) inferior in position to the first are presumed to have no initial radionuclide content, q(o) = 0. Therefore, for all subsequent organs

$$S_p^n (t) = f_p^n \, {}^b\lambda_p \, q^{n-1} \tag{3}$$

where n-1 refers to the preceeding member of the chain and ${}^{b}\lambda_p$ is the biological decay constant of the parent. It is obvious, from the last equation, that each equation in the chain is coupled to all preceeding equations through the source term.

Coupled equations of this type are most readily solved by using Laplace transforms. (8) Application of a Laplace transform to Equation 1 yields, using s as the transformed variable,

$$sq^n(s) - q_o^n = S^n(s) - \lambda^n q^n(s) \tag{4}$$

where, to simplify the notation $\mathcal{L}\{q(t)\}$ is written as q(s). Then,

$$q^n(s) = \frac{S^n(s)}{s(s + \lambda^n)} + \frac{q_o^n}{(s + \lambda^n)}$$

and q_o^n is the initial burden, due to acute intake. The initial organ burden for all organs inferior to the first is set equal to zero. Furthermore, the source terms for the first organ (or subcompartment) are constant and their transforms will be:

$$S_p^1 (s) = \frac{I_c D_k f_\ell^1}{s} \tag{5}$$

for inhalation or

$$S_p^1 (s) = \frac{I_c}{s} \tag{6}$$

for ingestion. Again I_c represents a constant, continuous intake (Ci/yr). The general equation then becomes, in transform space,

$$q_p^1(s) = \frac{I_c D_k f_p^1}{s(s + \lambda_p^1)} + \frac{q_o^1}{(s + \lambda_p^1)} \tag{7}$$

for the first component of the chain, where q_o^1, if present, is given by equation 2. Using the transformed Equation 7 as the source in Equation 3, the equation for the second member of the chain is seen to be

$$q_p^2(s) = \frac{{}^b\lambda_p^1 f_p^2}{(s + \lambda_p^2)} \left[\frac{I_c D_k f_p^1}{s(s + \lambda_p^1)} + \frac{q_o^1}{(s + \lambda_p^1)} \right] \tag{8}$$

from which it is obvious that the equation for each succeeding component differs only by an additional factor $(s + \lambda)$ and, of course, by modification of the coefficient by the terms f_p^n and λ^{n-1}, the translocation fraction to the next organ and the biological decay constant of the previous, respectively. The general equation for the nth organ or subcompartment may then be written as:

$$q_p^n(s) = \prod_{i=1}^{n} f_p^i \, {}^b\lambda_p^{i-1} \left\{ \frac{I_C D_k}{s\left[\prod_{i=1}^{n} (s + \lambda_p^i)\right]} + \frac{q_o^1}{\left[\prod_{i=1}^{n} (s + \lambda_p^i)\right]} \right\} \tag{9}$$

where λ^o is defined as 1 and the first term corresponds to the continuous intake case and the last to the acute intake case.

The governing equations for the daughter product are similar to those for the parent with appropriate changes in the source terms. One question, which has not been addressed by the ICRP, is whether the decay product remains in the parental chain, or whether the total decay product in a given compartment should be reapportioned according to its transfer fractions. In the PAID code, the former assumption has been made, i.e., the daughter formed by decay of the parent in a given clearance pathway is assumed to continue to clear through that pathway although governed by its own physical parameters. For the first component in the chain, the only source is decay of the parent and equation (1) becomes

$$\dot{q}_D^n(t) = S_D^n(t) - \lambda_D^n q_D^n(t) \tag{10}$$

where the symbols are as for the parent with D denoting the daughter product. Taking the transform of this, noting that $S_D^1 = {}^r\lambda_D q_p^1(t)$ and substituting $q_p^1(s)$ from equation 7,

$$q_D^1(s) = {}^r\lambda_D \left[\frac{I_C D_k f_p^1}{s(s + \lambda_p^1)(s + \lambda_D^1)} + \frac{I_A D_k f_p^1}{(s + \lambda_p^1)(s + \lambda_D^1)}\right] \tag{11}$$

where ${}^r\lambda$ is the physical decay constant.

For the second, and succeeding components, the source term comprises two parts; that describing the decay of the parent in the same compartment and that describing translocation of the daughter from the preceeding compartment, thus

$$q_D^2(t) = {}^r\lambda_D q_p^2(t) + {}^b\lambda_D^1 f_D^2 q_D^1(t) \tag{12}$$

and

$$q_D^2(s) \left[s + \lambda_D^2\right] = {}^r\lambda_D q_p^2(s) + {}^b\lambda_D^1 f_D^2 q_D^1(s) \tag{13}$$

Substituting the $q_p^2(s)$ and the $q_D^1(s)$ derived above, the second compartment daughter burden becomes

$$\begin{aligned} q_D^2(s) = {}^r\lambda_D & \left[\frac{{}^b\lambda_p^1 f_p^2 I_c D_k f_p^1}{s(s + \lambda_p^1)(s + \lambda_p^2)(s + \lambda_D^2)} + \frac{{}^b\lambda_p^1 f_p^2 I_A D_k f_p^2}{(s + \lambda_p^1)(s + \lambda_p^2)(s + \lambda_D^2)}\right] \\ + {}^b\lambda_D^1 f_D^2 & \left[\frac{{}^r\lambda_D I_c D_k f_p^1}{s(s + \lambda_p^1)(s + \lambda_D^1)(s + \lambda_D^2)} + \frac{{}^r\lambda_D I_A D_k f_p^1}{(s + \lambda_p^1)(s + \lambda_D^1)(s + \lambda_D^2)}\right] \end{aligned} \tag{14}$$

For the third compartment, the governing equation is the same but the source term becomes

$$s_D^3(t) = {}^r\lambda_D q_p^3(t) + {}^b\lambda_D^2 f_D^3 q_D^2(t) \tag{15}$$

from whence, again using the $q_p^3(s)$ and $q_D^2(s)$ obtained previously

$$
\begin{aligned}
q_D^3(s) = {} & \frac{\alpha}{s(s+\lambda_p^1)(s+\lambda_p^2)(s+\lambda_p^3)(s+\lambda_D^3)} + \frac{\beta}{(s+\lambda_p^1)(s+\lambda_p^2)(s+\lambda_p^3)(s+\lambda_D^3)} \\
& + \frac{b\lambda_D^2 f_D^3\, A}{s(s+\lambda_p^1)(s+\lambda_p^2)(s+\lambda_D^2)(s+\lambda_D^3)} + \frac{b\lambda_D^2 f_D^3\, B}{(s+\lambda_p^1)(s+\lambda_p^2)(s+\lambda_D^2)(s+\lambda_D^3)} \\
& + \frac{b\lambda_D^2 f_D^3\, C}{s(s+\lambda_p^1)(s+\lambda_D^1)(s\pm\lambda_D^2)(s+\lambda_D^3)} + \frac{b\lambda_D^2 f_D^3\, D}{(s+\lambda_p^1)(s+\lambda_D^1)(s+\lambda_D^2)(s+\lambda_D^3)}
\end{aligned}
\tag{16}
$$

where α, β, A, B, C, and D are given in Appendix I.

From both the parent and daughter derivations it is apparent that, although these equations may readily be extended to describe additional compartments and/or decay products, the resulting equations rapidly become quite prolix. As presently constituted, the PAID code comprises the first three compartments for both parent and daughter since these are sufficient to handle the problem under consideration.

However, the transformed differential equations are all similar, regardless of the number of compartments involved, i.e., the time (s) dependent terms are of the form

$$\frac{1}{(s-k_1)(s-k_2)\dots(s-k_m)} \qquad (17)$$

where k_1, k_2,...k_m are constants which may be positive, negative or zero. When k_1 is zero, the terms assume the form

$$\frac{1}{s(s-k_2)\dots(s-k_m)} \qquad (18)$$

It is easily noted that these terms differ only by the factor s in the denominator of the first. A well known theorem in transform theory states that division of the transformed equation by s corresponds to integration of the inverse transform between the limits 0 and t (8). Therefore, the solution to the continuous time intake case is the integral of the acute intake case.

The time integral of the organ burden, q(t), has been defined as the "exposure," Q (T), by the ICRP (9). Thus,

$$Q(T) = \int_0^t q(t)\,dt \qquad (19)$$

The general equation for the exposure, in transform space, to any organ requires another integration over t. Again, this is obtained by dividing both terms of Equation q by s, corresponding to this integration. Thus quadratic, or higher terms,

$$\frac{1}{(s-k_1)^r(s-k_2)\dots(s-k_m)} \qquad (20)$$

where k_1 may be zero, are obtained.

Inverse transforms for equations of this form are readily found using an extension of the Heaviside partial fraction expansion and several well-known theorems from transform theory presented in reference (8). For the burden, q(t), equations, which do not involve quadratic or higher order terms, applying the expansion to equations of the form (17) yields a general solution:

$$\mathcal{L}^{-1}\left[\frac{1}{g(s)}\right] = \sum_{m=1}^{M} \frac{e^{k_m t}}{g(k_m)} \tag{21}$$

for both the acute case, corresponding to the equation (17) and the chronic case, equation (18). Solutions to equation (18), as mentioned, are also general solutions for the exposure, Q(T), for the case of acute intake.

Inverse transforms for equations containing repeated linear factors, while somewhat more tedious to calculate, are still straightforward (8). The general solution for terms having the form of equation (20) for the exposure, may be found by noting that (20) may be rewritten as:

$$\frac{\phi(s)}{(s - k_1)^r} \tag{22}$$

where the inverse transform corresponding to the rth power term is:

$$F(t) = \sum_{r=0}^{n} \frac{\phi^{n-r}}{(n-r)!r!} \quad t^r \exp(k_1 t) \tag{23}$$

These solutions may, perhaps, be more readily verified by conventional integration of the burden equation.

One advantage of Laplace transforms is that an unlimited number of subcompartments, in series, may easily be treated, in a computer program loop, by addition of the appropriate term to the solution of the previous subcompartment. In addition, inverse transforms for the equations for Class D and Class W compounds, which contain terms in the denominator of the form $(s - k)^r$ are also found using the formulae in equation (23). Thus, it is possible, if the required parameters are known, to solve for transfer from the lung to a first reference organ (i.e. liver, bone, etc.) followed by subsequent translocation to another reference organ. Since the biological half-lives currently utilized with ICRP models are the net result of such processes as apposition and resorption, this feature is not used in the current version of the PAID code. However, use of this feature would provide a means of testing more general models of intercompartmental transfer than those proposed by the ICRP and, for this reason, may be of interest to investigators studying a range of metabolic problems.

For the lung, the dose is defined here as the average dose to a pulmonary compartment of 570 grams which is the mass of the pulmonary lung, including capillary blood, ICRP #23 (1). This dose may be used to estimate the risk of lung cancer. The dose rate, $\dot{D}$, and dose, D, are defined in terms of the organ burden, q, and exposure, Q, in uCi and uCi days, respectively:

$$\dot{D}(t) = 51.2 \frac{\varepsilon}{m} q(t) \text{ rad per day}$$

and

$$D(t) = 51.2 \frac{\varepsilon}{m} Q(t) \text{ rad}$$

where

ε = the absorbed energy (MeV) per disintergration for a particular isotope and organ pair.

m = the mass of the organ (grams)

Finally, health effects may be estimated by multiplying the dose to each organ by the number of effects expected per unit dose.

E. Computer Program

As previously stated, only the first three compartments for parent and daughter radionuclides, both of the same class, are presently contained in the PAID code. The complete solutions for these cases, obtained by applying formulae 21 and 23 to the transformed equations derived above, are presented in Appendix I. Appendix III is a listing of the code for Class Y compounds and Appendix II contains the input/output for a sample problem. The listing for Class W would be identical but for substituting the appropriate parameters from Table I.

To simplify the coding as much as possible, the procedure followed is to obtain the solution for each subcompartment in a chain. When the solutions for all chains are found, the subcompartments are then summed over to obtain total dose rates and doses for each major compartment or reference organ.

For ingestion, where the delay in the stomach and small intestine is neglected there is only one compartment, the reference organ.

Finally, two additional modifiers for the equations must be considered. First, for material which is transferred through the gastrointestinal tract, the additional fraction f_1 (transfer from small intestine to blood) must be used as a multiplier for organs inferior to the small intestine. Second, for material transferred through the systemic blood, the fraction f_2' (the fraction from blood to reference organ) must be incorporated into the product of the transmission fractions. These parameters are automatically inserted by the program.

Summary

The equations in Appendix I have been programmed for the IBM 360 computer in FORTRAN IV. Either the acute or constant continuous intake cases may be solved for both parent and daughter dose rate and dose. Built-in controls allow selection of the inhalation or ingestion case. The parameters for the ICRP model, shown in Table I, are built into the code. Only the reference organ parameters, i.e., fractional transmissions and biological half-lives, must be supplied as input. The assumption for the lymph nodes is that material not translocated to the reference organ remains in place and is lost only by radioactive decay. Explicit dose rates and doses to the tracheobronchial lung due to clearance of material from the pulmonary lung are printed out separately for both parent and daughter. The percentage of total dose due to transfer of material through the gastrointestinal tract is given for inhalation cases. General input instructions for the code are given in Appendix II.

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APPENDIX I

This Appendix gives the inverse transforms (time dependent solutions) of both parent and daughter for the first three compartments. The differential equations are derived in the text and the solutions found using the formula of equation (21). The solutions, as shown, are for the organ burden q(t), since these comprise the time dependent portion of the dose rate, equation (24). The exposures, Q(T), are not given since the integral of all terms in q(t) is either of the form

$$Q(T) = \frac{1}{k} \int_o^t dt = \frac{t}{k}$$

or

$$Q(T) = \frac{1}{k} \int_o^t \exp(-\lambda t) \; dt = \frac{1 - \exp(-\lambda t)}{k\lambda}$$

both of which are integrable by inspection. The organ burdens, q(t), for the parent compartments are:

(1)

$$q_P^1(t) = I_C D_k f_P^1 \left[\frac{1}{\lambda_P^1} + \frac{\exp(-\lambda_P^1 t)}{\lambda_P^1} \right] + I_A D_k f_P^1 \exp(-\lambda_P^1 t)$$

(2)

$$q_P^2(t) = b_{\lambda_P^1} f_P^2 f_P^1 I_C D_k \left[\frac{1}{\lambda_P^1 \lambda_P^2} + \frac{\exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_P^2)} + \frac{\exp(-\lambda_P^2 t)}{-\lambda_P^2(-\lambda_P^2+\lambda_P^1)} \right] +$$

$$b_{\lambda_P^1} f_P^2 f_P^1 I_A D_k \left[\frac{\exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_P^2)} + \frac{\exp(-\lambda_P^2 t)}{(-\lambda_P^2+\lambda_P^1)} \right]$$

(3)

$$q_P^3(t) = {}^{b}\lambda_P^{2b}\lambda_P^{1} f_P^{3} f_P^{2} f_P^{1} \left\{ \left[\frac{I_c D_k}{\lambda_P^1 \lambda_P^2 \lambda_P^3} + \frac{I_c D_k \exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_P^3)} + \frac{I_c D_k \exp(-\lambda_P^2 t)}{-\lambda_P^2(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_P^3)} + \frac{I_c D_k \exp(-\lambda_P^3 t)}{-\lambda_P^3(-\lambda_P^3+\lambda_P^1)(-\lambda_P^3+\lambda_P^2)} \right] + \left[\frac{I_A D_k \exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_P^3)} + \frac{I_A D_k \exp(-\lambda_P^2 t)}{(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_P^3)} + \frac{I_A D_k \exp(-\lambda_P^3 t)}{(-\lambda_P^3+\lambda_P^1+)(-\lambda_P^3+\lambda_P^2)} \right] \right\}$$

and for the daughter compartments:

(1)

$$q_D^1(t) = {}^{r}\lambda_D \left[\frac{I_c D_k f_P^1}{\lambda_P^1 \lambda_D^1} + \frac{I_c D_k f_P^1 \exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_D^1)} + \frac{I_c D_k f_P^1 \exp(-\lambda_D^1 t)}{-\lambda_D^1(-\lambda_D^1+\lambda_P^1)} + \frac{I_A D_k f_P^1 \exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_D^1)} + \frac{I_A D_k f_P^1 \exp(-\lambda_D^1 t)}{(-\lambda_D^1+\lambda_P^1)} \right]$$

(2)

$$
\begin{aligned}
q_D^2(t) = A \Bigg[& \frac{1}{\lambda_P^1 \lambda_P^2 \lambda_D^2} + \frac{\exp\,(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_P^2)\,(-\lambda_P^1+\lambda_D^2)} \quad \frac{\exp\,(-\lambda_P^2 t)}{-\lambda_P^2(-\lambda_P^2+\lambda_P^1)\,(-\lambda_P^2+\lambda_D^2)} + \\
& \frac{\exp\,(-\lambda_D^2 t)}{-\lambda_D^2(-\lambda_D^2+\lambda_P^1)\,(-\lambda_D^2+\lambda_P^2)} \Bigg] + B \Bigg[\frac{\exp\,(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_P^2)\,(-\lambda_P^1+\lambda_D^2)} + \frac{\exp\,(-\lambda_P^2 t)}{(-\lambda_P^2+\lambda_P^1)\,(-\lambda_P^2+\lambda_P^2)} + \\
& \frac{\exp\,(-\lambda_D^2 t)}{(-\lambda_D^2+\lambda_P^1)\,(-\lambda_D^2+\lambda_P^2)} \Bigg] + C \Bigg[\frac{1}{\lambda_P^1 \lambda_D^1 \lambda_D^2} + \frac{\exp\,(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_D^1)\,(-\lambda_P^1+\lambda_D^2)} + \\
& \frac{\exp\,(-\lambda_D^1 t)}{-\lambda_D^1(-\lambda_D^1+\lambda_P^1)\,(-\lambda_D^1+\lambda_D^2)} + \frac{\exp\,(-\lambda_D^2 t)}{-\lambda_D^2(-\lambda_D^2+\lambda_P^1)\,(-\lambda_D^2+\lambda_D^1)} \Bigg] + D \Bigg[\frac{\exp\,(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_D^1)\,(-\lambda_P^1+\lambda_D^2)} + \\
& \frac{\exp\,(-\lambda_D^1 t)}{(-\lambda_D^1+\lambda_P^1)\,(-\lambda_D^1+\lambda_D^2)} + \frac{\exp\,(-\lambda_D^2 t)}{(-\lambda_D^2+\lambda_P^1)\,(-\lambda_D^2+\lambda_D^1)} \Bigg]
\end{aligned}
$$

(3)

$$q_D^3(t) = \alpha \left[\frac{1}{\lambda_P^1 \lambda_P^2 \lambda_P^3 \lambda_D^3} + \frac{\exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_P^3)(-\lambda_P^1+\lambda_D^3)} + \right.$$

$$\frac{\exp(-\lambda_P^2 t)}{-\lambda_P^2(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_P^3)(-\lambda_P^2+\lambda_D^3)} + \frac{\exp(-\lambda_P^3 t)}{-\lambda_P^3(-\lambda_P^3+\lambda_P^1)(-\lambda_P^3+\lambda_P^2)(-\lambda_P^3+\lambda_D^3)} +$$

$$\left. \frac{\exp(-\lambda_D^3 t)}{-\lambda_D^3(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_P^2)(-\lambda_D^3+\lambda_P^3)} \right] + \beta \left[\frac{\exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_P^3)(-\lambda_P^1+\lambda_D^3)} \right.$$

$$+ \frac{\exp(-\lambda_P^2 t)}{(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_P^3)(-\lambda_P^2+\lambda_D^3)} + \frac{\exp(-\lambda_P^3 t)}{-\lambda_P^3(-\lambda_P^3+\lambda_P^1)(-\lambda_P^3+\lambda_P^2)(-\lambda_P^3+\lambda_D^3)}$$

$$\left. + \frac{\exp(-\lambda_D^3 t)}{(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_P^2)(-\lambda_D^3+\lambda_P^3)} \right] + A \left[\frac{b_{\lambda_D^2} f_2^3}{\lambda_P^1 \lambda_P^2 \lambda_D^2 \lambda_D^3} + \right.$$

$$\frac{b_{\lambda_D^2} f_2^3 \exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_D^2)(-\lambda_P^1+\lambda_D^3)} + \frac{b_{\lambda_D^2} f_2^3 \exp(-\lambda_P^2 t)}{-\lambda_P^2(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_D^2)(-\lambda_P^2+\lambda_D^3)}$$

$$\left. + \frac{b_{\lambda_D^2} f_2^3 \exp(-\lambda_D^2 t)}{-\lambda_D^2(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_P^2)(-\lambda_D^2+\lambda_D^3)} + \frac{b_{\lambda_D^2} f_2^3 \exp(-\lambda_D^3 t)}{-\lambda_D^3(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_P^2)(-\lambda_D^3+\lambda_D^2)} \right]$$

$$+ B \left[\frac{b_{\lambda_D^2} f_2^3 \exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_D^2)(-\lambda_P^1+\lambda_D^3)} + \frac{b_{\lambda_D^2} f_2^3 \exp(-\lambda_P^2 t)}{(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_D^2)(-\lambda_P^2+\lambda_D^3)} \right.$$

$$\left. + \frac{b_{\lambda_D^2} f_2^3 \exp(-\lambda_D^2 t)}{(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_P^2)(-\lambda_D^2+\lambda_D^3)} + \frac{b_{\lambda_D^2} f_2^3 \exp(-\lambda_D^3 t)}{(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_P^2)(-\lambda_D^3+\lambda_D^2)} \right] +$$

$$C\left[\frac{{}^{b}\lambda_D^2 f_2^3}{\lambda_P^1\lambda_D^1\lambda_D^2\lambda_D^3} + \frac{{}^{b}\lambda_D^2 f_2^3 \exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_D^1)(-\lambda_P^1+\lambda_D^2)(-\lambda_P^1+\lambda_D^3)}\right.$$

$$+ \frac{{}^{b}\lambda_D^2 f_2^3 \exp(-\lambda_D^1 t)}{-\lambda_D^1(-\lambda_D^1+\lambda_P^1)(-\lambda_D^1+\lambda_D^2)(-\lambda_D^1+\lambda_D^3)} + \frac{{}^{b}\lambda_D^2 f_2^3 \exp(-\lambda_D^2 t)}{-\lambda_D^2(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_D^1)(-\lambda_D^2+\lambda_D^3)} +$$

$$\left.\frac{{}^{b}\lambda_D^2 f_2^3 \exp(-\lambda_D^3 t)}{-\lambda_D^3(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_D^1)(-\lambda_D^3+\lambda_D^2)}\right] + D\left[\frac{{}^{b}\lambda_D^2 f_2^3 \exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_D^1)(-\lambda_P^1+\lambda_D^2)(-\lambda_P^1+\lambda_D^3)}\right. +$$

$$\frac{{}^{b}\lambda_D^2 f_2^3 \exp(-\lambda_D^1 t)}{(-\lambda_D^1+\lambda_P^1)(-\lambda_D^1+\lambda_D^2)(-\lambda_D^1+\lambda_D^3)} + \frac{{}^{b}\lambda_D^2 f_2^3 \exp(-\lambda_D^2 t)}{(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_D^1)(-\lambda_D^2+\lambda_D^3)} +$$

$$\left.\frac{{}^{b}\lambda_D^2 f_2^3 \exp(-\lambda_D^3 t)}{(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_D^1)(-\lambda_D^3+\lambda_D^2)}\right]$$

$$\alpha = {}^{r}\lambda_D\, {}^{b}\lambda_P^2\, {}^{b}\lambda_P^1 f_P^3 f_P^2 f_P^1 I_c D_k \qquad B = {}^{r}\lambda_D\, {}^{b}\lambda_P^1 f_P^2 I_a D_k f_1^1$$

$$\beta = {}^{r}\lambda_D\, {}^{b}\lambda_P^2\, {}^{b}\lambda_P^1 f_P^3 f_P^2 f_P^1 I_a D_k \qquad C = {}^{b}\lambda_D^1 f_D^2\, {}^{r}\lambda_D I_c D_k f_P^1$$

$$A = {}^{r}\lambda_D\, {}^{b}\lambda_P^1 f_P^2 I_c D_k f_1^1 \qquad D = {}^{b}\lambda_D^1 f_D^2\, {}^{r}\lambda_D I_a D_k f_P^1$$

and $\lambda_{P,D}^n$ is the decay constant for the parent or daughter in the n^{th} compartment.

APPENDIX II

Contained below is a listing of the FORTRAN IV PAID code. In general, as described in the text, the code yields dose rates and doses to the lung, using the ICRP TGLD model, and any selected reference organ. The printout of a sample case is included.

A description of the input parameters, format, and options available is given below. An attempt has been made to keep the input as simple as possible and the program will run multiple cases if another set of input data is added. All of the data pertaining to the lung are set within the code based on reference (3).

<u>Card 1</u>

	One title card for identification of the problem.	20A4

<u>Card 2</u>

NTT	Number of times for which solutions are desired.	I10
IHG -1/0/+1	(Ingestion/Inhalation/Inhalation) case	I10
IFLAG -1/0/+1	(Omit/Print/Print) To supress output for lung compartments. Used for inhalation cases only.	I10

<u>Card 3</u>

LRP	Physical half-life (years) of the parent.	E12.5
LBP	Biological half-life (years) of the parent.	E12.5
F1PR	GI Tract to blood (f_1) fraction for the parent.	E12.5
F2PPR	Blood to reference organ (f_2') fraction for the parent.	E12.5
EPSPL	Average energy (meV) for the parent decay in the lung.	E12.5
EPSPR	Average energy (meV) for the parent decay in the reference organ.	E12.5

Card 4

(Same as card 3 but for daughter instead of parent.

Card 5

TIN(I)	Times for which solutions are required (years).	6E12.5

Card 6

IA	The acute intake (Ci)	E12.5
IC	The chronic intake (Ci/yr)	E12.5
UTA3 UTA4 UTA5	The deposition fractions for the N-P, T-B and P compartment respectively	E12.5 E12.5 E12.5
ØRGMR	Reference organ mass (g).	E12.5

Return to Card 1 for the next case.

SAMPLE CASE

PU-239/U-235 AEROSOL CONC. 1.0 (FCI/CUBIC METER AMAD=0.05 R.O.=LIVER

ACUTE INTAKE (CI)	CHRONIC INTAKE (CI/YR)	N - P DEPOSITION	T - B DEPOSITION	P DEPOSITION	REFERENCE ORGAN MASS (G)
0.0	8.32770E-12	1.00000E-03	8.00000E-02	5.90000E-01	1.80000E+03

FOR THE PARENT--

PHYSICAL HALF-LIFE (YEARS)	BIOLOGICAL HALF-LIFE (YEARS)	TRANSMISSION FRACTION (GIT-BLOOD)	TRANSMISSION FRACTION (BLOOD-R.O.)	AVERAGE ENERGY-LUNG (MEV)	AVERAGE ENERGY-R.O. (MEV)
2.44000D+04	4.00000D+01	1.00000E-04	4.50000E-01	5.15000E+00	5.15000E+00

FOR THE DAUGHTER--

PHYSICAL HALF-LIFE (YEARS)	BIOLOGICAL HALF-LIFE (YEARS)	TRANSMISSION FRACTION (GIT-BLOOD)	TRANSMISSION FRACTION (BLOOD-R.O.)	AVERAGE ENERGY-LUNG (MEV)	AVERAGE ENERGY-R.O. (MEV)
7.10000D+06	2.74000D-01	1.00000E-02	1.10000E-01	4.40000E+00	4.40000E+00

THE FOLLOWING CASE IS FOR UPTAKE DUE TO INHALATION.

AT TIME 1.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	3.93312E-08	5.21315E-18	5.19660E-18	3.93937E-08	3.93312E-08

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	1.25992E-06	8.34120E-17	8.32796E-17	1.26092E-06	1.25992E-06

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
2.57801E-05	2.23527E-05	2.85821E-13	1.07341E-13	2.57801E-05	2.23527E-05

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.92202E-04	2.13152E-04	1.49313E-11	5.41047E-12	3.92202E-04	2.13152E-04

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT	PARENT	DAUGHTER	DAUGHTER	TOTAL	TOTAL

DOSE RATE	DOSE	DOSE RATE	DOSE	DOSE RATE	DOSE
8.40843E-04	2.98284E-04	4.52451E-11	1.19691E-11	8.40843E-04	2.98284E-04

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.01809E-04	3.53171E-05	5.36360E-12	1.44634E-12	1.01809E-04	3.53171E-05

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.58)	DAUGHTER DOSE RATE	DAUGHTER DOSE (1.66)	TOTAL DOSE RATE	TOTAL DOSE (0.58)
1.71491E-06	5.96853E-07	3.47688E-14	1.04372E-14	1.71491E-06	5.96853E-07

AT TIME 5.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	1.96906E-07	5.21315E-18	2.60492E-17	3.93937E-08	1.96906E-07

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	6.30359E-06	8.34120E-17	4.16927E-16	1.26092E-06	6.30359E-06

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.54360E-05	1.50893E-04	2.19222E-12	5.38419E-12	3.54360E-05	1.50893E-04

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.07419E-04	3.13829E-03	1.16653E-10	2.85694E-10	9.07419E-04	3.13829E-03

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
8.67108E-03	1.92681E-02	2.00876E-09	3.29601E-09	8.67108E-03	1.92681E-02

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.50491E-03	2.93922E-03	3.15821E-10	4.76682E-10	1.50491E-03	2.93922E-03

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.16)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.68)	TOTAL DOSE RATE	TOTAL DOSE (0.16)
3.68285E-05	6.43889E-05	1.27893E-12	2.09867E-12	3.68285E-05	6.43889E-05

AT TIME 10.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	3.93875E-07	5.21315E-18	5.21150E-17	3.93937E-08	3.93875E-07

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	1.26082E-05	8.34120E-17	8.33987E-16	1.26092E-06	1.26082E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.67897E-05	3.32751E-04	2.93097E-12	1.87231E-11	3.67897E-05	3.32751E-04

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.79649E-04	7.92503E-03	1.56071E-10	9.95832E-10	9.79649E-04	7.92503E-03

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.42583E-02	7.89133E-02	5.30992E-09	2.20530E-08	1.42583E-02	7.89133E-02

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.80168E-03	1.61402E-02	1.20973E-09	4.14608E-09	3.80168E-03	1.61402E-02

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.10)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.37)	TOTAL DOSE RATE	TOTAL DOSE (0.10)
1.16482E-04	4.38825E-04	4.17767E-12	1.54630E-11	1.16482E-04	4.38825E-04

AT TIME 15.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	5.90844E-07	5.21315E-18	7.81807E-17	3.93937E-08	5.90844E-07

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	1.89127E-05	8.34120E-17	1.25105E-15	1.26092E-06	1.89127E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.68976E-05	5.17073E-04	3.03486E-12	3.37230E-11	3.68976E-05	5.17073E-04

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85406E-04	1.28432E-02	1.61614E-10	1.79460E-09	9.85406E-04	1.28432E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.60859E-02	1.55668E-01	7.14067E-09	5.37807E-08	1.60859E-02	1.55668E-01

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
6.16126E-03	4.10425E-02	2.30476E-09	1.28925E-08	6.16126E-03	4.10425E-02

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.08)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.26)	TOTAL DOSE RATE	TOTAL DOSE (0.08)
2.05681E-04	1.24387E-03	7.29602E-12	4.41827E-11	2.05681E-04	1.24387E-03

AT TIME 20.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	7.87812E-07	5.21315E-18	1.04247E-16	3.93937E-08	7.87812E-07

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT	PARENT	DAUGHTER	DAUGHTER	TOTAL	TOTAL

DOSE RATE	DOSE	DOSE RATE	DOSE	DOSE RATE	DOSE
1.26092E-06	2.52173E-05	8.34120E-17	1.66811E-15	1.26092E-06	2.52173E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.69062E-05	7.01590E-04	3.04673E-12	4.89372E-11	3.69062E-05	7.01590E-04

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85865E-04	1.77718E-02	1.62248E-10	2.60480E-09	9.85865E-04	1.77718E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.66217E-02	2.37709E-01	7.90025E-09	9.16817E-08	1.66218E-02	2.37709E-01

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
8.52554E-03	7.77592E-02	3.45426E-09	2.72793E-08	8.52554E-03	7.77592E-02

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.07)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.20)	TOTAL DOSE RATE	TOTAL DOSE (0.07)
2.92287E-04	2.49088E-03	1.02395E-11	8.81170E-11	2.92287E-04	2.49088E-03

AT TIME 30.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	1.18175E-06	5.21315E-18	1.56378E-16	3.93937E-08	1.18175E-06

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	3.78265E-05	8.34120E-17	2.50223E-15	1.26092E-06	3.78265E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.69069E-05	1.07066E-03	3.04808E-12	7.94152E-11	3.69069E-05	1.07066E-03

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85905E-04	2.76308E-02	1.62320E-10	4.22785E-09	9.85905E-04	2.76308E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.68179E-02	4.05282E-01	8.27811E-09	1.73193E-07	1.68179E-02	4.05282E-01

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.32539E-02	1.86658E-01	5.78689E-09	7.34712E-08	1.32539E-02	1.86658E-01

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.06)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.15)	TOTAL DOSE RATE	TOTAL DOSE (0.06)
4.47541E-04	6.21106E-03	1.54289E-11	2.17215E-10	4.47541E-04	6.21106E-03

AT TIME 40.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	1.57569E-06	5.21315E-18	2.08510E-16	3.93937E-08	1.57569E-06

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	5.04357E-05	8.34120E-17	3.33635E-15	1.26092E-06	5.04357E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.69069E-05	1.43973E-03	3.04809E-12	1.09896E-10	3.69069E-05	1.43973E-03

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85905E-04	3.74898E-02	1.62321E-10	5.85105E-09	9.85905E-04	3.74898E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.68336E-02	5.73569E-01	8.32140E-09	2.56265E-07	1.68336E-02	5.73570E-01

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.79810E-02	3.42834E-01	8.12620E-09	1.43036E-07	1.79810E-02	3.42834E-01

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.06)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.12)	TOTAL DOSE RATE	TOTAL DOSE (0.06)
5.78664E-04	1.13609E-02	1.97863E-11	3.93923E-10	5.78664E-04	1.13609E-02

AT TIME 50.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	1.96962E-06	5.21315E-18	2.60641E-16	3.93937E-08	1.96962E-06

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	6.30449E-05	8.34120E-17	4.17046E-15	1.26092E-06	6.30449E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.69069E-05	1.80880E-03	3.04809E-12	1.40377E-10	3.69069E-05	1.80880E-03

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85905E-04	4.73489E-02	1.62321E-10	7.47426E-09	9.85905E-04	4.73489E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.68349E-02	7.41914E-01	8.32590E-09	3.39510E-07	1.68349E-02	7.41914E-01

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
2.27068E-02	5.46274E-01	1.04661E-08	2.35997E-07	2.27068E-02	5.46274E-01

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.06)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.11)	TOTAL DOSE RATE	TOTAL DOSE (0.06)
6.88946E-04	1.77149E-02	2.34480E-11	6.10624E-10	6.88946E-04	1.77149E-02

AT TIME 70.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	2.75750E-06	5.21315E-18	3.64904E-16	3.93937E-08	2.75750E-06

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	8.82632E-05	8.34120E-17	5.83870E-15	1.26092E-06	8.82632E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.69069E-05	2.54693E-03	3.04809E-12	2.01339E-10	3.69069E-05	2.54693E-03

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85905E-04	6.70670E-02	1.62321E-10	1.07207E-08	9.85905E-04	6.70670E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.68350E-02	1.07861E+00	8.32639E-09	5.06036E-07	1.68350E-02	1.07861E+00

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.21542E-02	1.09489E+00	1.51458E-08	4.92116E-07	3.21543E-02	1.09489E+00

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.06)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.10)	TOTAL DOSE RATE	TOTAL DOSE (0.06)
8.59609E-04	3.32990E-02	2.91139E-11	1.13951E-09	8.59609E-04	3.32990E-02

END OF CASE

APPENDIX III

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FORTRAN IV G LEVEL  21                MAIN              DATE = 77039          15/17/51                 PAGE 0001

0001              REAL    IA,IC
0002              REAL * 8          LTP1,LTD1,LRP,LBP,LRD,LBD,LTP2,LTD2,LTP3,LTD3,
                 1  NPT1,NPT2,NPT3,NDT1,NDT2,NDT3,IPT1,IPT2,IPT3,IDT1,IDT2,IDT3
0003              REAL * 8          P12,P13,P23,P21,P31,P32,P1D1,P1D2,P1D3,P2D1,
                 1  P2D2,P2D3,P3D1,P3D2,P3D3,D1P1,D2P2,D3P1,D1P2,D3P2,D1P3,D2P3,
                 2  D3P3,D2P1,D12,D13,D21,D23,D31,D32
0004              REAL * 8  B1D,B2D,B3D,A2D,A3D,A4D,D1D,D2D,D3D,C2D,C3D,C4D
0005              REAL * 8  BE1,BE2,BE3,BE4,AL2,AL3,AL4,AL5,B1,B2,B3,B4,A2,A3,A4,A5,
                 1D1,D2,D3,D4,C2,C3,C4,C5
0006              REAL * 8  NPT2R,NDT2R,IPT2R,IDT2R,B1DR,B2DR,B3DR,A2DR,A3DR,A4DR,          R
                 1D1DR,D2DR,D3DR,C2DR,C3DR,C4DR,P12R,P21R
0007              REAL * 8          LB,Z,ODP,DPLN2
0008              DIMENSION  DX(10),LB(15),FD(15),ORGM(15),HOLL(20),TIN(25)
            C
            C     THIS PROGRAM REPRESENTS THE ICRP TGLD LUNG MODEL MODIFIED BY ICRP-19.
            C     IT USES SUB-CHAINS CONSISTING OF  1. A LUNG COMPARTMENT (A-H),
            C     2. FOR A-G, THE REFERENCE ORGAN.  FOR H, THE LYMPH NODES.
            C     3.   FOR H ONLY, THE REFERENCE ORGAN.
            C     THE PROGRAM ALLOWS THE PARENT AND ONE DAUGHTER TO BE CALCULATED.
            C
            C
            C     CARDS WITH A CTB WERE ADDED TO GET P/T-B CLEARANCE DOSE.
            C     CARDS WITH AN R WERE ADDED TO GET LYMPH NODE RETENTION DOSE.
            C
0009           50 READ (5,155,END=800) (HOLL(K),K=1,20)
0010          275 FORMAT(3I10)
0011          100 READ (5,275) NTT,IHG,IFLAG
0012          155 FORMAT(20A4)
0013              WRITE(6,255) (HOLL(K),K=1,20)
0014          255 FORMAT(1H1,24X,20A4///)
0015          355 FORMAT(6E12.5)
0016              READ (5,355) LRP,LBP,F1PR,F2PPR,EPSPL,EPSPR
0017              READ (5,355) LRD,LBD,F1DR,F2PDR,EPSDL,EPSDR
0018              READ (5,355) (TIN(I),I=1,NTT)
0019              READ (5,355) IA,IC,UTA3,UTA4,UTA5,ORGMR
0020              WRITE(6,305)
0021          305 FORMAT(1H ,12X,5HACUTE,15X,7HCHRONIC,14X,5HN - P,15X,5HT - B,17X,1
                 1HP,14X,9HREFERENCE/9X,11HINTAKE (CI),9X,14HINTAKE (CI/YR),8X,10HDE
                 2POSITION,10X,10HDEPOSITION,10X,10HDEPOSITION,7X,14HORGAN MASS (G))
0022              WRITE(6,315)IA,IC,UTA3,UTA4,UTA5,ORGMR
0023          315 FORMAT(1PE21.5,1PE20.5,1PE21.5,1PE20.5,1P2E19.5//)
0024              WRITE(6,310)
0025          310 FORMAT(1H ,25X,16HFOR THE PARENT--/)
0026              WRITE(6,320)
0027          320 FORMAT(1H ,11X,8HPHYSICAL,11X,10HBIOLOGICAL,9X,12HTRANSMISSION,8X,
                 112HTRANSMISSION,9X,9H AVERAGE ,11X,9H AVERAGE /10X,9HHALF-LIFE,12X
                 2,9HHALF-LIFE,11X,8HFRACTION,12X,8HFRACTION,11X,11HENERGY-LUNG,9X,1
                 31HENERGY-R.O./12X,7H(YEARS),13X,7H(YEARS),12X,11H(GIT-BLOOD),8X,12
                 4H(BLOOD-R.O.),11X,5H(MEV),15X,5H(MEV))
0028              WRITE(6,315)LRP,LBP,F1PR,F2PPR,EPSPL,EPSPR
0029              WRITE(6,325)
0030          325 FORMAT(1H ,25X,18HFOR THE DAUGHTER--/)
0031              WRITE(6,320)
0032              WRITE(6,315)LRD,LBD,F1DR,F2PDR,EPSDL,EPSDR
0033              DX(1)=UTA3
0034              DX(2)=UTA4
0035              DX(3)=UTA5
0036              DX(4)=UTA3
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0037          DX(5)=UTA4
0038          DX(6)=UTA5
0039          DX(7)=UTA5
0040          DX(8)=UTA5
0041          LB(1)=2.74D-5
0042          LB(2)=2.74D-5
0043          LB(3)=1.37D+0
0044          LB(4)=1.1D-3
0045          LB(5)=5.5D-4
0046          LB(6)=2.7D-3
0047          LB(7)=1.37D+0
0048          LB(8)=1.37D+0
0049          LB(9)=2.74D+0
0050          FD(1)=0.01D+0
0051          FD(2)=0.01D+0
0052          FD(3)=0.05D+0
0053          FD(4)=0.99D+0
0054          FD(5)=0.99D+)
0055          FD(6)=0.4D+0
0056          FD(7)=0.4D+0
0057          FD(8)=0.15D+0
0058          FD(9)=0.9D+0
0059          ORGM(1)=32.0
0060          ORGM(2)=40.0
0061          ORGM(3)=570.0
0062          ORGM(4)=32.0
0063          ORGM(5)=40.0
0064          ORGM(6)=570.0
0065          ORGM(7)=570.0
0066          ORGM(8)=570.0
0067          ORGM(9)=15.0
0068          TEFF = 0.0039                                                    CTB
0069          OMTB=ORGM(2)                                                     CTB
0070          ODP=1.0D+0
0071          DPLN2=6.93D-1
0072          CON=1.87E+10
0073          LRP=DPLN2/LRP
0074          LBP=DPLN2/LBP
0075          LRD=DPLN2/LRD
0076          LBD=DPLN2/LB)
0077          DO 400 K=1,9
0078      400 LB(K)=DPLN2/LB(K)
0079          IF(IHG.GT.0) WRITE(6,360)
0080          IF(IHG.LT.0) WRITE(6,365)
0081      360 F3RMAT(1H ,40X,51HTHE FOLLOWING CASE IS FOR UPTA<E DUE TO INHALATI
             1ON.//)
0082      365 FORMAT(1H ,40X,50HTHE FOLLOWING CASE IS FOR UPTAKE DUE TO INGESTIO
             1N.//)
        C     START EACH TIME LOOP
0083          DO 700 NT=1,NTT
0084          T=TIN(NT)
0085          IF(T.LT.0.0) GO TO 700
0086          WRITE(6,455) T
0087      455 FORMAT(1H ,5X,7HAT TIME,F6.2,1X,50HYEARS, DOSE RATES (RADS/YR) AND
             1 DOSES (RADS) ARE--/)
0088          Z=T
0089          DRPNP=0.0
0090          DRDNP=0.0
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 0091          DRPTB=0.0
 0092          DRDTB=0.0
 0093          DRPP=0.0
 0094          DRDP=0.0
 0095          DRPL=0.0
 0096          DRDL=0.0
 0097          DRPRO=0.0
 0098          DRDRO=0.0
 0099          DPNP=0.0
 0100          DDNP=0.0
 0101          DPTB=0.0
 0102          DDTB=0.0
 0103          DPP=0.0
 0104          DDP=0.0
 0105          DPL=0.0
 0106          DDL=0.0
 0107          DPRO=0.0
 0108          DDRO=0.0
 0109          DPGIT=0.0
 0110          DDGIT=0.0
 0111          QLPCTB=0.0                                                    CTB
 0112          QUPCTB=0.0                                                    CTB
 0113          QLDCTB=0.0                                                    CTB
 0114          QUDCTB=0.0
 0115          JT=8
 0116          IF(IHG.LT.0) JT=1
         C     START EACH SUB-COMPARTMENT CHAIN
 0117          DO 600 J=1,JT
         C     DX(J) SET OUTSIDE LOOP.
         C     WHOLE PROGRAM PREDICATED ON PARENT AND DAUGHTER BEING CLASS Y.
 0118          DK=DX(J)
 0119          LTP1=LRP+LB(J)
 0120          IF(IHG.LT.0) LTP1=LRP+LBP
 0121          LTD1=LRD+LB(J)
 0122          IF(IHG.LT.0) LTD1=LRD+LBD
 0123          LTP2=LRP+LB(J+1)
 0124          LTD2=LRD+LB(J+1)
 0125          LTP3=LRP+LBP
 0126          LTD3=LRD+LBD
 0127          IF(J.LT.8)LTP2=LRP+LBP
 0128          IF(J.LT.8)LTD2=LRD+LBD
         C     NOW SET ORGAN MASSES.
 0129          OMAS=ORGM(J)
 0130          IF(IHG.LT.0) OMAS=ORGMR
 0131          TMAS=ORGMR
 0132          THMAS=ORGMR
 0133          IF(J.EQ.8)TMAS=ORGM(J+1)
 0134          FL=FD(J)
 0135          F2PP=F2PPR
 0136          IF(J.EQ.8) F2PP = 1.0
 0137          F1P=F1PR
 0138          F2PD=F2PDR
 0139          IF(J.EQ.8) F2PD = 1.0
 0140          F1D=F1DR
 0141          FP2=1.0
 0142          IF(J.EQ.8)FP2=FD(J+1)
 0143          FD2=1.0
 0144          IF(J.EQ.8)FD2=FD(J+1)
```

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0145           FP3=1.0
0146           FD3=1.0
         C     SET F2P AND F1 FOR BLOOD AND GIT.  J=1,2,3,8 ARE BLOOD ONLY.
         C     J=4,5,6,7 ARE BLOOD AND GIT (F2P*F1) BOTH.
0147           IF(J.LE.3.OR.J.EQ.8) F1P=1.0
0148           IF(J.LE.3.OR.J.EQ.8) F1D=1.0
         C     DO ALL PARAMETERS IN EQUATIONS.
0149           NPT1=0.0D+0
0150           IF(LTP1*Z.GT.88.0D+0) GO TO 460
0151           NPT1 =DEXP(-LTP1*Z)
0152       460 CONTINUE
0153           NPT2=0.0D+0
0154           IF(LTP2*Z.GT.88.0D+0) GO TO 470
0155           NPT2 =DEXP(-LTP2*Z)
0156       470 CONTINUE
0157           NPT2R=0.0D+0                                              CYB
0158           IF(LRP*Z.GT.88.0D+0) GO TO 463                            CTB
0159           NPT2R=DEXP(-LRP*Z)                                        CTB
0160       463 CONTINUE                                                  CTB
0161           NPT3=0.0D+0
0162           IF(LTP3*Z.GT.88.0D+0) GO TO 480
0163           NPT3 =DEXP(-LTP3*Z)
0164       480 CONTINUE
0165           NDT1=0.0D+0
0166           IF(LTD1*Z.GT.88.0D+0) GO TO 465
0167           NDT1 =DEXP(-LTD1*Z)
0168       465 CONTINUE
0169           NDT2=0.0D+0
0170           IF(LTD2*Z.GT.88.0D+0) GO TO 475
0171           NDT2 =DEXP(-LTD2*Z)
0172       475 CONTINUE
0173           NDT2R=0.0D+0                                              CTB
0174           IF(LRD*Z.GT.88.0D+0) GO TO 473                            CTB
0175           NDT2R=DEXP(-LRD*Z)                                        CTB
0176       473 CONTINUE                                                  CTB
0177           IF(LTD3*Z.GT.88.0D+0) GO TO 485
0178           NDT3 =DEXP(-LTD3*Z)
0179           NDT3=0.0D+0
0180       485 CONTINUE
0181           IPT1 = ODP - NPT1
0182           IPT2 = ODP - NPT2
0183           IPT2R = ODP - NPT2R                                       CTB
0184           IPT3 = ODP - NPT3
0185           IDT1 = ODP - NDT1
0186           IDT2 = ODP - NDT2
0187           IDT2R = ODP - NDT2R                                       CTB
0188           IDT3 = ODP - NDT3
0189           P12 = -LTP1 + LTP2
0190           P12R = -LTP1 + LRP                                          R
0191           P21R = -P12R                                                R
0192           P13 = -LTP1 + LTP3
0193           P23 = -LTP2 + LTP3
0194           P21 = -P12
0195           P31 = -P13
0196           P32 = -P23
0197           P1D1 = -LRP+LRD
0198           IF(IHG.LT.0) P1D1=-LTP1+LTD1
0199           P1D2 = -LTP1 + LTD2
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0200        P1D3 = -LTP1 + LTD3
0201        P2D1 = -LTP2 + LTD1
0202        P2D2 = -LTP2+LTD2
0203        IF(J.EQ.8) P2D2 = -LRP+LRD
0204        P2D3 = -LTP2 + LTD3
0205        P3D1 = -LTP3 + LTD1
0206        P3D2 = -LTP3 + LTD2
0207        P3D3 = -LTP3+LTD3
0208        D1P1 = -P1D1
0209        D2P1 = -P1D2
0210        D3P1 = -P1D3
0211        D1P2 = -P2D1
0212        D2P2 = -P2D2
0213        D3P2 = -P2D3
0214        D1P3 = -P3D1
0215        D2P3 = -P3D2
0216        D3P3 = -P3D3
0217        D12 = -LTD1 + LTD2
0218        D13 = -LTD1 + LTD3
0219        D21 = -D12
0220        D23 = -LTD2 + LTD3
0221        D31 = -D13
0222        D32 = -D23
      C     PARENT ACTIVITY IN FIRST SUB-COMPARTMENT.
0223        CONA = IA*DK*FL
0224        CONC = IC*DK*FL
0225        IF(IHG.LT.0) CONA=IA*F1PR*F2PPR
0226        IF(IHG.LT.0) CONC=IC*F1PR*F2PPR
0227        QLPA1 = CONA*NPT1
0228        QLPC1 = CONC*(IPT1/LTP1)
0229        QUPA1 = CONA*(IPT1/LTP1)
0230        QUPC1 = CONC*(( Z /LTP1)+(IPT1/(-LTP1*LTP1)))
0231        IF(J.LT.6.OR.J.GT.7) GO TO 505
0232        QLPCTB=QLPCTB+TEFF*LB(J)*(QLPA1+QLPC1)                        CTB
0233        QUPCTB=QUPCTB+TEFF*LB(J)*(QUPA1+QUPC1)                        CTB
0234    505 CONTINUE
0235        IF(J.EQ.8) DRPCTB=CON*(EPSPL/OMTB)*QLPCTB                     CTB
0236        IF(J.EQ.8) DPCTB=CON*(EPSPL/OMTB)*QUPCTB                      CTB
0237        IF(IHG.LT.0) EPSPL=EPSPR
0238        DRP1 = CON*(EPSPL/OMAS)*(QLPA1+QLPC1)
0239        DP1 = CON*(EPSPL/OMAS)*(QUPA1+QUPC1)
0240        IF(IHG.LT.0) GO TO 333
      C     PARENT IN SECOND SUB-COMPARTMENT.
0241        CONA=CONA*LB(J)*FP2*F1P*F2PP
0242        CONC=CONC*LB(J)*FP2*F1P*F2PP
0243        QLPA2=CONA*((NPT1/P12)+(NPT2/P21))
0244        QLPC2=CONC*((ODP/(LTP1*LTP2))+(NPT1/(-LTP1*P12))+(NPT2/(-LTP2*P21)
           1))
0245        QUPA2=CONA*((IPT1/(LTP1*P12))+(IPT2/(LTP2*P21)))
0246        QUPC2=CONC*((Z/(LTP1*LTP2))+(IPT1/(-LTP1*LTP1*P12))+(IPT2/(-LTP2*L
           1TP2*P21)))
0247        EPV=EPSPR
0248        IF(J.EQ.8) EPV=EPSPL
0249        IF(J.NE.8) GO TO 558                                             R
0250        COARET=(CONA/FP2)*(1.0-FP2)
0251        COCRET=(CONC/FP2)*(1.0-FP2)
0252        QLPA2R=COARET*((NPT1/P12R)+(NPT2R/P21R))                         R
0253        QLPC2R=COCRET*((ODP/(LTP1*LRP))+(NPT1/(-LTP1*P12R))+(NPT2R/(-LRP*P  R
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                 121R)))                                                          R
0254             QUPA2R=COARET*((IPT1/(LTP1*P12R))+(IPT2R/(LRP*P21R)))            R
0255             QUPC2R=COCRET*((Z/(LTP1*LRP))+(IPT1/(-LTP1*LTP1*P12R))+(IPT2R/(-LR R
                1P*LRP*P21R)))                                                    R
0256             DRP2R=CON*(EPSPL/TMAS)*(QLPA2R+QLPC2R)                           R
0257             DP2R=CON*(EPSPL/TMAS)*(QUPA2R+QUPC2R)                            R
0258         558 CONTINUE                                                         R
0259             DRP2=CON*(EPV/TMAS)*(QLPA2+QLPC2)
0260             DP2=CON*(EPV/TMAS)*(QUPA2+QUPC2)
           C     THIRD SUB-COMPARTMENT.  ONLY USE IF LYMPH NODES IN CHAIN.
0261             QLPA3 = 0.0
0262             QLPC3 = 0.0
0263             QUPA3 = 0.0
0264             QUPC3 = 0.0
0265             DRP3=0.0
0266             DP3=0.0
0267             IF(J.NE.8) GO TO 333
0268             CONA=CONA*LB(J+1)*F1P*F2PPR
0269             CONC=CONC*LB(J+1)*F1P*F2PPR
0270             QLPA3=CONA*((NPT1/(P12*P13))+(NPT2/(P21*P23))+(NPT2/(P31*P32)))
0271             QLPC3=CONC*((ODP/(LTP1*LTP2*LTP3))+(NPT1/(-LTP1*P12*P13))+(NPT2/(-
                1LTP2*P21*P23))+(NPT3/(-LTP3*P31*P32)))
0272             QUPA3=CONA*((IPT1/(LTP1*P12*P13))+(IPT2/(LTP2*P21*P23))+(IPT3/(LTP
                13*P31*P32)))
0273             QUPC3=CONC*((Z/(LTP1*LTP2*LTP3))+(IPT1/(-LTP1*LTP1*P12*P13))+(IPT2
                1/(-LTP2*LTP2*P21*P23))+(IPT3/(-LTP3*LTP3*P31*P32)))
0274             DRP3=CON*(EPSPR/THMAS)*(QLPA3+QLPC3)
0275             DP3=CON*(EPSPR/THMAS)*(QUPA3+QUPC3)
           C
           C     END ALL PARENT (THREE SUB-COMPARTMENT CHAIN LIMIT).
           C
0276         333 CONTINUE
           C     DAUGHTER IN FIRST SUB-COMPARTMENT.
0277             CONAR=IA*DK*FL*LRD
0278             CONCR=IC*DK*FL*LRD
0279             IF(IHG.LT.0) CONAR=IA*LRD*F1PR*F2PPR
0280             IF(IHG.LT.0) CONCR=IC*LRD*F1PR*F2PPR
0281             QLDA1=CONAR*((NPT1/P1D1)+(NDT1/D1P1))
0282             QLDC1=CONCR*((ODP/(LTP1*LTD1))+(NPT1/(-LTP1*P1D1))+(NDT1/(-LTD1*D1
                1P1)))
0283             QUDA1=CONAR*((IPT1/(LTP1*P1D1))+(IDT1/(LTD1*D1P1)))
0284             QUDC1=CONCR*((Z/(LTP1*LTD1))+(IPT1/(-LTP1*LTP1*P1D1))+(IDT1/(-LTD1
                1*LTD1*D1P1)))
0285             IF(J.LT.6.OR.J.GT.7) GO TO 605                                   CTB
0286             QLDCTB=QLDCTB+TEFF*LB(J)*(QLDA1+QLDC1)                           CTB
0287             QUDCTB=QUDCTB+TEFF*LB(J)*(QUDA1+QUDC1)                           CTB
0288         605 CONTINUE
0289             IF(J.EQ.8) DRDCTB=CON*(EPSDL/OMTB)*QLDCTB                        CTB
0290             IF(J.EQ.8) DDCTB=CON*(EPSDL/OMTB)*QUDCTB                         CTB
0291             IF(IHG.LT.0) EPSDL=EPSDR
0292             DRD1=CON*(EPSDL/OMAS)*(QLDA1+QLDC1)
0293             DD1=CON*(EPSDL/OMAS)*(QUDA1+QUDC1)
0294             IF(IHG.LT.0) GO TO 444
           C     DAUGHTER IN SECOND SUB-COMPARTMENT.
0295             A=IC*DK*FL*LRD*LB(J)*FP2*F1P*F2PP
0296             B=IA*DK*FL*LRD*LB(J)*FP2*F1P*F2PP
0297             C=IC*DK*FL*LB(J)*LRD*FD2*F1D*F2PD
0298             D=IA*DK*FL*LB(J)*LRD*FD2*F1D*F2PD
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0299          B1D=P12*P1D2
0300          B2D=P21*P2D2
0301          B3D=D2P1*D2P2
0302          A2D=-LTP1*B1D
0303          A3D=-LTP2*B2D
0304          A4D=-LTD2*B3D
0305          D1D=P1D1*P1D2
0306          D2D=D1P1*D12
0307          D3D=D2P1*D21
0308          C2D=-LTP1*D1D
0309          C3D=-LTD1*D2D
0310          C4D=-LTD2*D3D
0311          IF(J.NE.8) GO TO 337                                              R
0312          B1DR=P12*(-LTP1+LRD)                                              R
0313          B2DR=P21*(-LTP2+LRD)                                              R
0314          B3DR=(-LRD+LTP1)*(-LRD+LTP2)                                      R
0315          A2DR=-LTP1*B1DR                                                   R
0316          A3DR=-LTP2*B2DR                                                   R
0317          A4DR=-LRD*B3DR                                                    R
0318          D1DR=P1D1*(-LTP1+LRD)                                             R
0319          D2DR=D1P1*(-LTD1+LRD)                                             R
0320          D3DR=(-LRD+LTP1)*(-LRD+LTD1)                                      R
0321          C2DR=-LTP1*D1DR                                                   R
0322          C3DR=-LTD1*D2DR                                                   R
0323          C4DR=-LRD*D3DR                                                    R
0324      337 CONTINUE                                                          R
0325          QLA=A*((ODP/(LTP1*LTP2*LTD2))+(NPT1/A2D)+(NPT2/A3D)+(NDT2/A4D))
0326          QLB=B*((NPT1/B1D)+(NPT2/B2D)+(NDT2/B3D))
0327          QLC=C*((ODP/(LTP1*LTD1*LTD2))+(NPT1/C2D)+(NDT1/C3D)+(NDT2/C4D))
0328          QLD=D*((NPT1/D1D)+(NDT1/D2D)+(NDT2/D3D))
0329          QLDA2=QLB+QLD
0330          QLDC2=QLA+QLC
0331          QUA=A*((Z/(LTP1*LTP2*LTD2))+(IPT1/(LTP1*A2D))+(IPT2/(LTP2*A3D))+(I
             1DT2/(LTD2*A4D)))
0332          QUB=B*((IPT1/A2D)+(IPT2/A3D)+(IDT2/A4D))
0333          QUC=C*((Z/(LTP1*LTD1*LTD2))+(IPT1/(LTP1*C2D))+(IDT1/(LTD1*C3D))+(I
             1DT2/(LTD2*C4D)))
0334          QUD=D*((IPT1/C2D)+(IDT1/C3D)+(IDT2/C4D))
0335          QUDA2=QUB+QUD
0336          QUDC2=QUA+QUC
0337          EPU=EPSDR
0338          IF(J.EQ.8) EPU=EPSDL
0339          IF(J.NE.8) GO TO 658                                              R
0340          AR=IC*DK*FL*LRD*LB(J)*(1.0-FP2)*F1P*F2PP                          R
0341          BR=IA*DK*FL*LRD*LB(J)*(1.0-FP2)*F1P*F2PP                          R
0342          CR=IC*DK*FL*LB(J)*LRD*(1.0-FD2)*F1D*F2PD                          R
0343          DR=IA*DK*FL*LB(J)*LRD*(1.0-FD2)*F1D*F2PD                          R
0344          QLAR=AR*((ODP/(LTP1*LTP2*LRD))+(NPT1/A2DR)+(NPT2/A3DR)+(NDT2R/A4DR R
             1))                                                                R
0345          QLBR=BR*((NPT1/B1DR)+(NPT2/B2DR)+(NDT2R/B3DR))                    R
0346          QLCR=CR*((ODP/(LTP1*LTD1*LRD))+(NPT1/C2DR)+(NDT1/C3DR)+(NDT2R/C4DR R
             1))                                                                R
0347          QLDR=DR*((NPT1/D1DR)+(NDT1/D2DR)+(NDT2R/D3DR))                    R
0348          QLDA2R=QLBR+QLDR                                                  R
0349          QLDC2R=QLAR+QLCR                                                  R
0350          QUAR=AR*((Z/(LTP1*LTP2*LRD))+(IPT1/(LTP1*A2DR))+(IPT2/(LTP2*A3DR)) R
             1+(IDT2R/(LRD*A4DR)))                                              R
0351          QUBR=BR*((IPT1/A2DR)+(IPT2/A3DR)+(IDT2R/A4DR))                    R
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0352          QUCR=CR*((Z/(LTP1*LTD1*LRD))+(IPT1/(LTP1*C2DR))+(IDT1/(LTD1*C3DR))    R
             1+(IDT2R/(LRD*C4DR)))                                                   R
0353          QUDR=DR*((IPT1/C2DR)+(IDT1/C3DR)+(IDT2R/C4DR))                         R
0354          QUDA2R=QUBR+QUDR                                                       R
0355          QUDC2R=QUAR+QUCR                                                       R
0356          DRD2R=CON*(EPSDL/TMAS)*(QLDA2R+QLDC2R)                                 R
0357          DD2R=CON*(EPSDL/TMAS)*(QUDA2R+QUDC2R)                                  R
0358      658 CONTINUE                                                               R
0359          DRD2=CON*(EPU/TMAS)*(QLDA2+QLDC2)
0360          DD2=CON*(EPU/TMAS)*(QUDA2+QUDC2)
        C     END ALL DAUGHTER ACTIVITY USING EPSD.
        C     DAUGHTER IN THIRD SUB-COMPARTMENT.
0361          QLAL=0.0
0362          QLAP=0.0
0363          QLBP=0.0
0364          QLCP=0.0
0365          QLDP=0.0
0366          QLDA3=0.0
0367          QLDC3=0.0
0368          QUAL=0.0
0369          QUAP=0.0
0370          QUBE=0.0
0371          QUAP=0.0
0372          QUBP=0.0
0373          QUCP=0.0
0374          QUDP=0.0
0375          QUDA3=0.0
0376          QUDC3=0.0
0377          DRD3=0.0
0378          DD3=0.0
0379          IF(J.NE.8) GO TO 444
0380          AL=IC*DK*FL*FP2*FP3*LB(J)*LB(J+1)*LRD*F2PPR
0381          BE=IA*DK*FL*FP2*FP3*LB(J)*LB(J+1)*LRD*F2PPR
0382          AP=LB(J+1)*FD3*A*F2PDR
0383          BP=LB(J+1)*FD3*B*F2PDR
0384          CP=LB(J+1)*FD3*C*F2PDR
0385          DP=LB(J+1)*FD3*D*F2PDR
0386          BE1=P12*P13*P1D3
0387          BE2=P21*P23*P2D3
0388          BE3=P31*P32*P3D3
0389          BE4=D3P1*D3P2*D3P3
0390          AL2=-LTP1*BE1
0391          AL3=-LTP2*BE2
0392          AL4=-LTP3*BE3
0393          AL5=-LTD3*BE4
0394          B1=B1D*P1D3
0395          B2=B2D*P2D3
0396          B3=B3D*D23
0397          B4=D3P1*D3P2*D32
0398          A2=-LTP1*B1
0399          A3=-LTP2*B2
0400          A4=-LTD2*B3
0401          A5=-LTD3*B4
0402          D1=D1D*P1D3
0403          D2=D2D*D13
0404          D3=D3D*D23
0405          D4=D3P1*D31*D32
0406          C2=-LTP1*D1
```

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0407            C3=-LTD1*D2
0408            C4=-LTD2*D3
0409            C5=-LTD3*D4
0410            QLAL=AL*((DDP/(LTP1*LTP2*LTP3*LTD3))+(NPT1/AL2)+(NPT2/AL3)+(NPT3/A
               1L4)+(NDT3/AL5))
0411            QLBE=BE*((NPT1/BE1)+(NPT2/BE2)+(NPT3/BE3)+(NDT3/BE4))
0412            QLAP=AP*((DDP/(LTP1*LTP2*LTD2*LTD3))+(NPT1/A2)+(NPT2/A3)+(NDT2/A4)
               1+(NDT3/A5))
0413            QLBP=BP*((NPT1/B1)+(NPT2/B2)+(NDT2/B3)+(NDT3/B4))
0414            QLCP=CP*((DDP/(LTP1*LTD1*LTD2*LTD3))+(NPT1/C2)+(NDT1/C3)+(NDT2/C4)
               1+(NDT3))
0415            QLDP=DP*((NPT1/D1)+(NDT1/D2)+(NDT2/D3)+(NDT3/D4))
0416            QLDA3=QLBE+QLBP+QLDP
0417            QLDC3=QLAL+QLAP+QLCP
0418            QUAL=AL*((Z/(LTP1*LTP2*LTP3*LTD3))+(IPT1/(LTP1*AL2))+(IPT2/(LTP2*A
               1L3))+(IPT3/(LTP3*AL4))+(IDT3/(LTD3*AL5)))
0419            QUBE=BE*((IPT1/(LTP1*BE1))+(IPT2/(LTP2*BE2))+(IPT3/(LTP3*BE3))+(ID
               1T3/(LTD3*BE4)))
0420            QUAP=AP*((Z/(LTP1*LTP2*LTD2*LTD3))+(IPT1/(LTP1*A2))+(IPT2/(LTP2*A3
               1))+(IDT2/(LTD2*A4))+(IDT3/(LTD3*A5)))
0421            QUBP=BP*((IPT1/(LTP1*B1))+(IPT2/(LTP2*B2))+(IDT2/(LTD2*B3))+(IDT3/
               1(LTD3*B4)))
0422            QUCP=CP*((Z/(LTP1*LTD1*LTD2*LTD3))+(IPT1/(LTP1*C2))+(IDT1/(LTD1*C3
               1))+(IDT2/(LTD2*C4))+(IDT3/(LTD3*C5)))
0423            QUDP=DP*((IPT1/(LTP1*D1))+(IDT1/(LTD1*D2))+(IDT2/(LTD2*D3))+(IDT3/
               1(LTD3*D4)))
0424            QUDA3=QUBE+QUBP+QUDP
0425            QUDC3=QUAL+QUAP+QUCP
0426            DRD3=CON*(EPSDR/THMAS)*(QLDA3+QLDC3)
0427            DD3=CON*(EPSDR/THMAS)*(QUDA3+QUDC3)
          C
          C     THIS ENDS PARENT AND DAUGHTER FOR THREE COMPARTMENTS.
          C
0428        444 CONTINUE
0429            IF(J.EQ.1.OR.J.EQ.4) DRPNP=DRPNP+DRP1
0430            IF(J.EQ.2.OR.J.EQ.5) DRPTB=DRPTB+DRP1
0431            IF(J.EQ.3.OR.J.GE.6) DRPP=DRPP+DRP1
0432            IF(J.LT.8) DRPRO=DRPRO+DRP2
0433            IF(J.EQ.8) DRPL=DRP2
0434            IF(J.EQ.8) DRPRO=DRPRO+DRP3
0435            IF(J.EQ.1.OR.J.EQ.4) DRDNP=DRDNP+DRD1
0436            IF(J.EQ.2.OR.J.EQ.5) DRDTB=DRDTB+DRD1
0437            IF(J.EQ.3.OR.J.GE.6) DRDP=DRDP+DRD1
0438            IF(J.LT.8) DRDRO=DRDRO+DRD2
0439            IF(J.EQ.8) DRDL=DRD2
0440            IF(J.EQ.8) DRDRO=DRDRO+DRD3
0441            IF(J.EQ.1.OR.J.EQ.4) DPNP=DPNP+DP1
0442            IF(J.EQ.1.OR.J.EQ.4) DDNP=DDNP+DD1
0443            IF(J.EQ.2.OR.J.EQ.5) DPTB=DPTB+DP1
0444            IF(J.EQ.2.OR.J.EQ.5) DDTB=DDTB+DD1
0445            IF(J.EQ.3.OR.J.GE.6) DPP=DPP+DP1
0446            IF(J.EQ.3.OR.J.GE.6) DDP=DDP+DD1
0447            IF(J.LT.8) DPRO=DPRO+DP2
0448            IF(J.LT.8) DDRO=DDRO+DD2
0449            IF(J.GE.4.AND.J.LE.7) DPGIT=DPGIT+DP2
0450            IF(J.GE.4.AND.J.LE.7) DDGIT=DDGIT+DD2
0451            IF(J.EQ.8) DPL=DP2
0452            IF(J.EQ.8) DDL=DD2
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0453            IF(J.EQ.8) DPRO=DPRO+DP3
0454            IF(J.EQ.8) DDRO=DDRO+DD3
0455        600 CONTINUE
          C
          C     ALL CTB AND RET L DR AND D CALCULATED AB INITIO EACH J IFF J.EQ.8.
          C
0456            DRTNP = DRPNP+DRDNP
0457            DRTTB=DRPTB+DRDTB
0458            DRTCTB=DRPCTB+DRDCTB
0459            DRTP=DRPP+DRDP
0460            DRTL=DRPL+DRDL
0461            DRT2R=DRP2R+DRD2R
0462            DRTRO=DRPRO+DRDRO
0463            DTNP=DPNP+DDNP
0464            DTTB=DPTB+DDTB
0465            DTCTB=DPCTB+DDCTB
0466            DTP=DPP+DDP
0467            DTL=DPL+DDL
0468            DT2R=DP2R+DD2R                                                        R
0469            DTRO=DPRO+DDRO
0470            IF(IHG.LT.0) GO TO 666
0471            DTGIT=DPGIT+DDGIT
0472            DPRAT=1.0E+2*(DPGIT/DPRO)
0473            DDRAT=1.0E+2*(DDGIT/DDRO)
0474            DTRAT=1.0E+2*(DTGIT/DTRO)
0475            IF(IFLAG.LT.0) GO TO 660
0476            WRITE(6,615)
0477        615 FORMAT(1H ,10X,34HFOR THE NASOPHYRINGIAL COMPARTMENT/)
0478            WRITE(6,655) DRPNP,DPNP,DRDNP,DDNP,DRTNP,DTNP
0479            WRITE(6,625)
0480        625 FORMAT(1H ,10X,36HFOR THE TRACHEOBRONCHIAL COMPARTMENT/)
0481            WRITE(6,655) DRPTB,DPTB,DRDTB,DDTB,DRTTB,DTTB
0482            WRITE(6,627)
0483        627 FORMAT(1H ,10X,80HFOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEA    R
               1RANCE FROM PULMONARY COMPARTMENT/)                                    R
0484            WRITE(6,655) DRPCTB,DPCTB,DRDCTB,DDCTB,DRTCTB,DTCTB                   R
0485            WRITE(6,635)
0486        635 FORMAT(1H ,10X,29HFOR THE PULMONARY COMPARTMENT/)
0487            WRITE(6,655) DRPP,DPP,DRDP,DDP,DRTP,DTP
0488            WRITE(6,645)
0489        645 FORMAT(1H ,10X,41HFOR THE LYMPH NODES, TRANSMITTED FRACTION/)         R
0490            WRITE(6,655) DRPL,DPL,DRDL,DDL,DRTL,DTL
0491            WRITE(6,647)
0492        647 FORMAT(1H ,10X,38HFOR THE LYMPH NODES, RETAINED FRACTION/)
0493            WRITE(6,655) DRP2R,DP2R,DRD2R,DD2R,DRT2R,DT2R                         R
0494        660 CONTINUE
0495            WRITE(6,665)
0496        665 FORMAT(1H ,10X,80HFOR THE REFERENCE ORGAN, PARENTHESES INDICATE PE
               1RCENT OF TOTAL DOSE VIA GI TRACT/)
0497            WRITE(6,657) DPRAT,DDRAT,DTRAT,DRPRO,DPRO,DRDRO,DDRO,DRTRO,DTRO
0498            IF(IHG.GT.0) GO TO 700
0499        666 WRITE(6,670)
0500        670 FORMAT(1H ,10X,23HFOR THE REFERENCE ORGAN)
0501            WRITE(6,655) DRPNP,DPNP,DRDNP,DDNP,DRTNP,DTNP
0502        655 FORMAT(1H ,12X,6HPARENT,13X,6HPARENT,13X,8HDAUGHTER,12X,8HDAUGHTER
               1,14X,5HTOTAL,14X,5HTOTAL/11X,10HDOSE  RATE,12X,4HDOSE,13X,10HDOSE
               2 RATE,13X,4HDOSE,14X,10HDOSE  RATE,11X,4HDOSE/9X,1PE12.5,1P5E20.5/
               3/)
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```
0503          657 FORMAT(1H ,12X,6HPARENT,13X,6HPARENT,13X,8HDAUGHTER,12X,8HDAUGHTER
                 1,14X,5HTOTAL,14X,5HTOTAL/11X,10HDOSE  RATE,8X,6HDOSE (,F5.2,1H),9X
                 2,10HDOSE  RATE,9X,6HDOSE (,F5.2,1H),10X,10HDOSE  RATE,9X,6HDOSE (,
                 3F5.2,1H)/9X,1PE12.5,1P5E20.5//)
0504          700 CONTINUE
0505              WRITE(6,755)
0506          755 FORMAT(1H ,60X,11HEND OF CASE)
0507              GO TO 50
0508          800 CALL EXIT
0509              STOP
0510              END
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