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Early Mortality Estimates for Different Nuclear Accidents

Final Phase I Report
October 1977 - April 1979

Prepared by F. F. Hahn

Inhalation Toxicology Research Institute
Lovelace Biomedical & Environmental Research Institute

Prepared for
U. S. Nuclear Regulatory Commission

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EXECUTIVE SUMMARY

Several studies have previously been made of the number of early deaths which might be expected in a population exposed to a cloud of radionuclides which could result from a nuclear accident. These analyses, however, have been limited to a one accident scenario or exposure to a limited number of radionuclides. The purpose of this Phase I study was to examine the existing data on early health effects of inhaled radioactive materials and determine what, if any, new studies were needed to make reasonable estimates of early mortality after exposure of a population radionuclides released under any conditions of accident or sabotage.

The approach taken to analyze the problem was to examine existing data and models for predicting early deaths, develop data bases, develop a new, more precise model and identify deficiencies that require additional study or examination. Data are available in man on the early effects of acute whole body exposure but, there are no data on the early effects of inhaled radioactive materials. Thus, the data base developed for effects is based on experiments in which animals were irradiated or exposed to radioactive materials.

A computer-based simulation model was developed which predicts early mortality in populations exposed under known conditions. The first part of the model determines the dose to critical organs from external irradiation or the internal deposition of radionuclides. The steps taken in the model are shown in Figure 1. This portion of the model is based on deposition and retention functions and transfer rates between body organs developed by the International Commission on Radiological Protection. The resulting doses to various organs are determined using dosimetry models developed at Oak Ridge National Laboratory.

The second part of the simulation model estimates the health effects based on the radiation doses to various organs. To do this, empirical dose-response relationships were developed for lung, bone and gastrointestinal tract. In most cases, these relationships were resolved from experimental data using a hazard function method. This method does not require that data on animals receiving similar doses be grouped, but allows the use of data on each individual animal in determining a dose-response relationship and thus permits a better definition of the dose-response curve. It also allows the addition of hazards to different organs and from different radionuclides so that effects of mixtures of radionuclides in the body can be determined.

Figure 2 shows the steps used in predicting the frequency of radiation effects. Cumulative organ doses are obtained from the DOSE program. For each organ and each type of radiation (high linear energy transfer (LET) or low LET) the effects are estimated and added together. Figure 1 shows an example of the procedure for lung. For a given small time interval, a dose and half-life of dose accumulation are estimated. For each dose increment, a hazard function increment is estimated for low- and high-LET radiation and these increments added. This procedure is repeated as many times as necessary to reach the desired time after exposure. A similar procedure is conducted for the other critical organ, bone. The end result is an estimate of frequency of effects as a function of the doses to critical organs.

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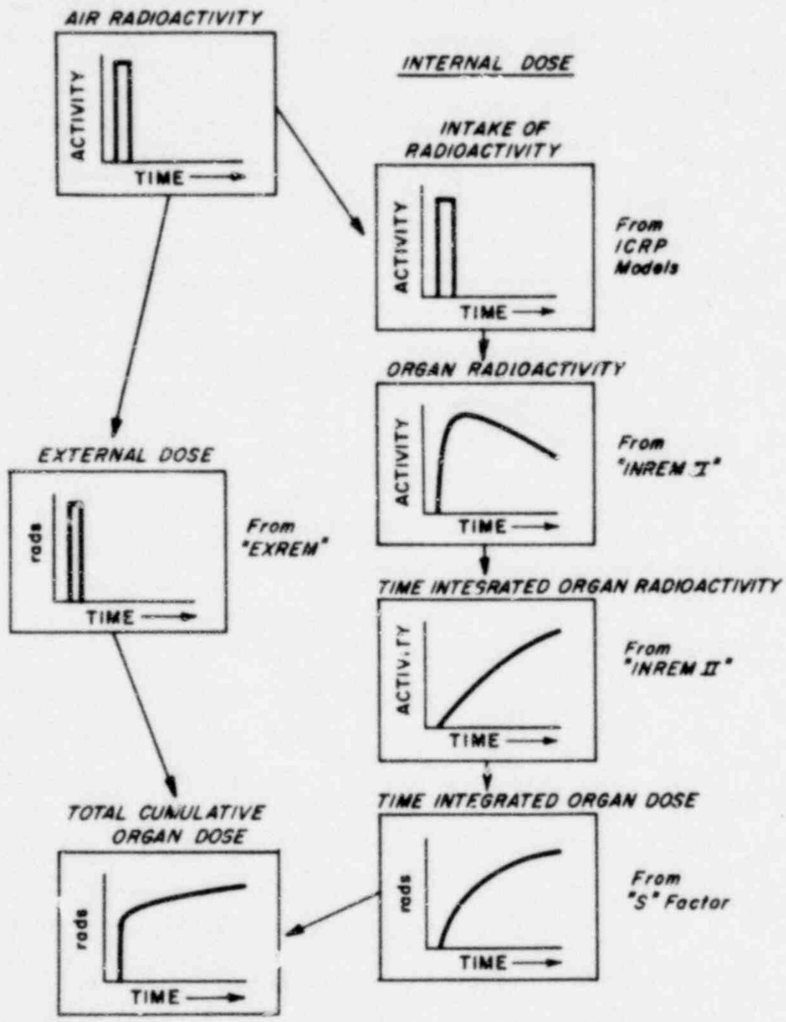

Figure 1. Steps in estimating cumulative radiation dose to an organ.

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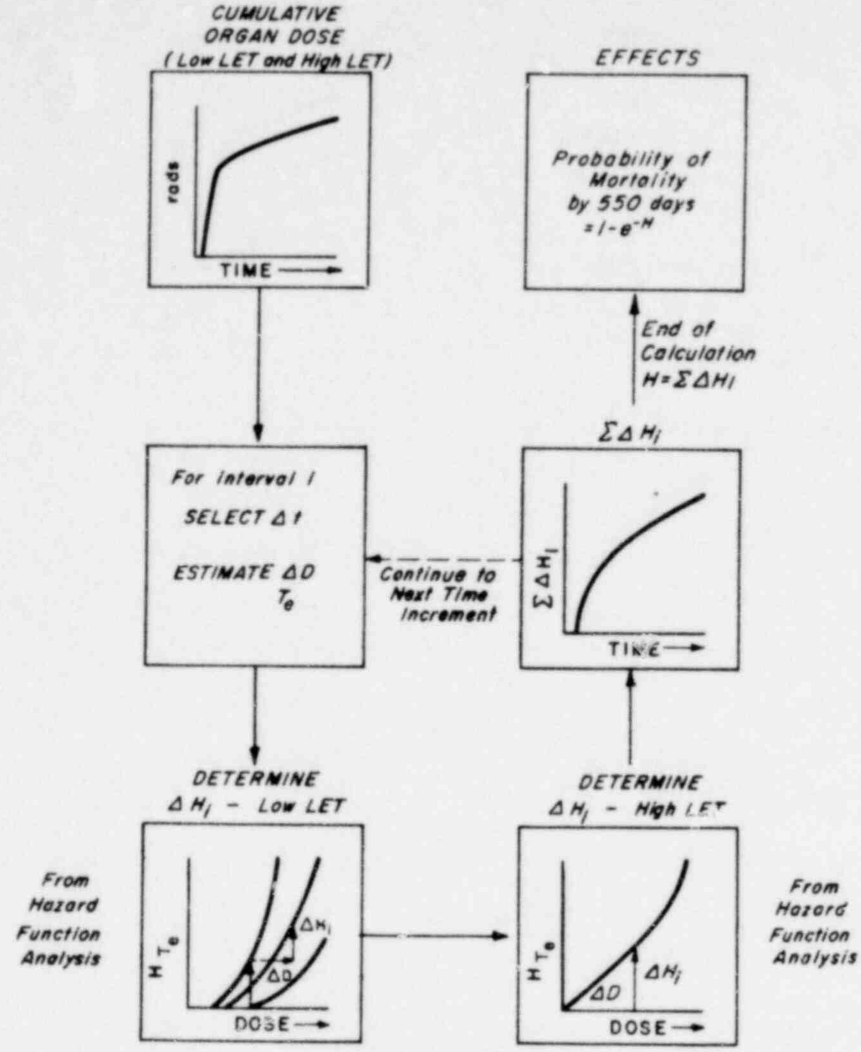

Figure 2. Steps in projecting occurrence of radiation effects.

The results of the computer simulation model were compared with those obtained by Wells, Goldman and the Reactor Safety Study. The results could not be rigorously compared in all cases since the various models were developed with slightly different purposes and scopes. However, when all the models were used to predict the results of accomplished studies in experimental animals, the ITRI computer simulation model made the best predictions.

A major problem in determining the adequacy of any given model is the fact that all models are based primarily upon data obtained in laboratory animal studies and few data from man exists for comparison. Thus, a major thrust of proposed Phase II work will be to test the ITRI computer simulation model. The proposed studies are also designed to improve the simulation model for predicting the effects of mixtures of alpha and beta emitters deposited in the lung as well as the combined effects of lung and whole-body irradiation.

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CHAPTER I. STATEMENT OF PROBLEM AND GENERAL APPROACH

Statement of Problem

A major responsibility of the Nuclear Regulatory Commission is to evaluate the safety of activities, operations and facilities using radiation-emitting devices and radionuclides. These evaluations must include estimates of potential human health effects from radiation exposures which might occur in the event of accidents or sabotage causing the release of radionuclides to the working environment or to the atmosphere. This study was initiated because existing models did not adequately estimate the early effects of radiation in human populations after exposure to a cloud of radionuclides.

The "Reactor Safety Study" (WASH-1400) provided predictions of the probability of fatalities which could result from reactor accidents such as a core meltdown. A more general evaluation of early radiation health effects is needed, however, which is not tied to one specific accident scenario but can be applied to any feasible accident situation. For example, the "Reactor Safety Study" placed heavy emphasis on the early mortality resulting from exposure to fission product radionuclides, which are mostly beta-gamma emitters. Thus, the dose-response model for early mortality developed in the "Reactor Safety Study" cannot be used for accident scenarios which have other source terms and release patterns.

A more general model for estimating the survival of people after inhaling radioactive particles has been published by Wells (1976). It is based on analyses of dose-response data obtained from animals that inhaled radioactive materials. The model depends on the mean energy of the emission from the inhaled particle, the nature of the emission (alpha or beta), the half-life of the material in the lung or body, the amount of radioactivity inhaled and the solubility of the material. Using this information, the probability of early death is related to the initial lung or body burden of radionuclide. The initial lung or body burden differs by a factor of 5-7 for nearly 100% survival to 100% death. The Wells model is a valid attempt to integrate many of the variables which determine the early response from inhaling radioactive materials. It is difficult to apply, however, to different accident scenarios where a number of radionuclides with differing half-lives are deposited in the lung or where external whole-body radiation is involved.

Estimates of early mortality resulting from brief inhalation exposure to selected insoluble beta-emitting radionuclides have been made by Hahn (1975) and from a brief inhalation exposure to plutonium by Goldman and Raabe (1977). These analyses deal only with death within one year after inhalation exposure to single radionuclides.

In order to provide estimates of early mortality and morbidity in man which would result from exposure to radionuclides released in an accident or sabotage involving any phase of the nuclear fuel cycle, a model is needed which is not tied to a specific accident scenario but takes into account all reasonable modes of exposure (e.g., inhalation and whole body), includes exposures from all types of radioactive emissions, accounts for any synergism of multiple organ irradiation and predicts the expected number of individuals affected in a given population.

General Approach to Problem

The problem of estimating early mortality and morbidity from exposures to radionuclides released in accident or sabotage situations is being approached in two phases. This report describes the activities of Phase I which included reviewing published data concerning early mortality from radiation exposures, developing a quantitative model for predicting early mortality from such exposures, and identifying the most critical deficiencies in our knowledge of early morbidity and mortality caused by short-term exposures in nuclear accidents. The activities proposed for Phase II of the project include experiments to refine specific factors in the overall mortality model and to verify the initial estimates made by the model.

Phase I involved parallel efforts by personnel at the Lovelace Inhalation Toxicology Research Institute (ITRI) and the Battelle Pacific Northwest Laboratories (PNL). The groups worked together to summarize the available early mortality data, especially those which were available from studies conducted at their respective laboratories. Thus, a combination of independent and joint efforts were utilized to maximize individual initiative and group evaluation of early radiation mortality information.

In an early meeting of personnel from PNL, ITRI and the NRC, a general approach to the problem and ground rules for the approach were agreed upon. A conceptual scheme for the model was developed and is shown in Figure I-1. There are five basic elements in the overall model. Their characteristics, as incorporated in the ITRI model, are:

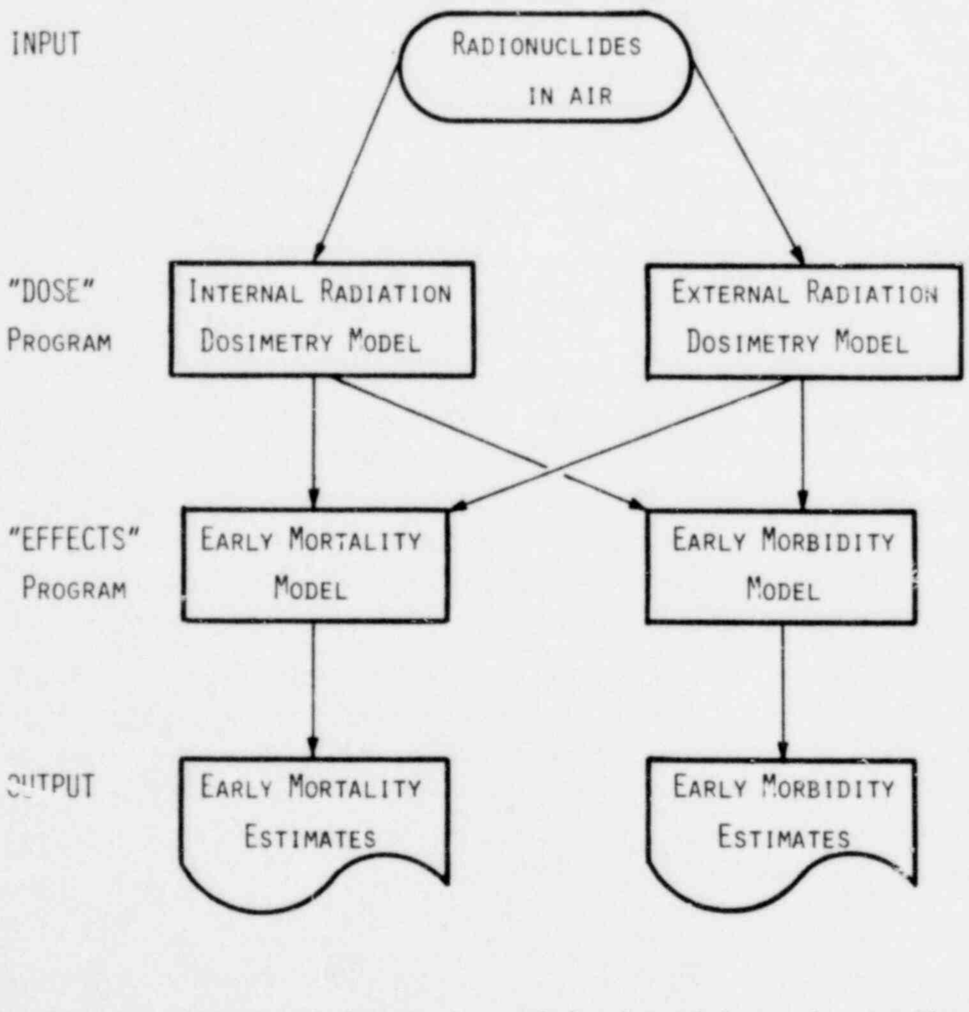

Figure I-1. Computer programs and elements in model for determining early mortality and morbidity estimates from different nuclear accidents.

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1. Radionuclides in the Air

The user of the program must specify the radionuclide inventory, expected particle size distribution and atmospheric concentration as well as the length of time during which the population of interest is exposed to the atmospheric cloud. The radionuclides considered initially are those present in the irradiated fuel of a light water reactor. The 54 radionuclides listed in the "Reactor Safety Study" were selected as those most likely to be released in an accident situation, but the program can be used for other isotopes which may be present in the radionuclide inventories of alternative fuel cycles.

2. Dosimetry for Internally Deposited Radionuclides

This model uses input information on the exposure times and air concentrations of specific radionuclides to predict the doses to each organ as a function of time. It is assumed that inhalation is the only important mode of exposure since evacuation of the contaminated area is likely to occur within hours after a severe accident that could cause early morbidity or mortality. This model, based on the International Commission on Radiological Protection, ICRP, Task Group on Lung Dynamics model (ICRP, 1966, 1972), predicts aerosol deposition in the lung and transfer rates to the tracheobronchial lymph nodes, blood and gut. In addition, the absorption of material from the gut to the blood, bone, thyroid and liver are derived from models developed at Oak Ridge National Laboratory, ORNL, (Killough, *et al.*, 1978 and Dunning *et al.*, 1978). The output of the internal dosimetry model gives the organ uptake and retention functions and the time-integrated levels of radioactivity in each organ.

3. Dosimetry for External Irradiation

Inputs for this model are the air concentrations of radionuclides. Abosrbed doses here are in the range of 0 to 400 rads. Higher doses will result in acute deaths even without including other sources of irradiation. The dose is considered to be delivered over a short period of time from an aerosol cloud. Dose conversion values from the EXREM computer code of ORNL (Dunning *et al.*, 1977; Snyder *et al.*, 1974) are used for these calculations. The output is the absorbed dose to each individual organ.

4. Early Mortality Model

The inputs to this model are the radiation doses to critical organs as a function of time. To determine the absorbed dose in rads to each organ from internally deposited radionuclides, factors accounting for interorgan and intraorgan irradiation were applied. These so called "S" factors were developed at ORNL (Turbey and Kaye, 1973; Killough and McKay, 1976). The organs of primary interest are the lung and bone marrow. Secondly, the gastrointestinal tract is of interest. The output of the model is an estimate of the probability for death from early effects as a function of the doses to these critical organs. The model does not require determination of the relative biological effectiveness, RBE, of the different emissions, but relies on combining hazard functions for each organ to achieve a total hazard (i.e., the negative of the natural log of the dose survival probability). At present, each organ at risk is assumed to be independent of all other organs at risk.

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5. Early Morbidity Model

This program will require the input of radiation doses to critical organs as a function of time and will provide an estimate of the cumulative hazard for illness from early effects as a function of organ specific doses. Endpoints which may be examined include weight loss, lymphopenia, pulmonary functional changes and need for nonspecific treatment. This portion of the model has not yet been implemented.

These five elements are combined to form an integrated model which can be used to predict estimates for the probability of death from early effects can be projected based on a knowledge of the aerosol parameters from any feasible accident or sabotage scenario. The model will be tested and refined in experimental studies in Phase II.

CHAPTER II. INTERNAL DOSIMETRY

Introduction

This chapter describes the human dosimetry model used to predict doses to various organs after inhalation of a mixture of radionuclides. The doses from this model are output to an early effects model to predict the number of fatalities which could result from an accident involving radioactive materials. The model has been implemented using a computer code in FORTRAN IV on a DEC PDP-11/70.

The form of the dosimetry model is the same as that used at ORNL in the INREM II and EXREM computer codes. These codes calculate the internal and external radiation doses to various organs of a reference adult man following inhalation of radionuclides or immersion in a cloud of radionuclides. The INREM II code (Killough *et al.*, 1978b) uses dynamic models to describe interorgan transfers of radionuclides and their decay chains of daughter radionuclides. Each daughter nuclide is treated according to the metabolic information about its own transfer within the body. The EXREM code (Turbey and McKay, 1973) calculates external radiation doses for various organs from individual radionuclides from immersion in contaminated water and air, and from ground contamination.

To describe the metabolism of radionuclides of interest, both the code developed in this project for human dosimetry and the INREM II code use the ICRP Task Group Lung Model (Morrow *et al.*, 1964), Eve's (1966) model of mass through the gastrointestinal tract, and an organ uptake model for the material absorbed into the blood from the lung and gastrointestinal tract. The ICRP Task Group Lung Model is used to estimate the deposition and retention of the inhaled radionuclides in the lung and their absorption into blood and clearance to the gastrointestinal tract. The gastrointestinal tract is described by a four-compartment model using data from Eve to estimate the transit times. The mass transit through the gastrointestinal tract and absorption from the gastrointestinal tract to the blood are approximated by first order kinetics. The amount of a radionuclide absorbed into the blood from the lung and gastrointestinal tract is allocated to the liver, skeleton and thyroid based on models developed by ORNL to describe the metabolism of each isotope in the body. Since the parent radionuclide may decay through a chain of daughter products, each daughter is transferred according to its own transfer rates.

The computer dosimetry code developed for this project differs from ORNL codes in that it calculates the combined dose rates for a mixture of radionuclides such as might occur in a nuclear accident. The dose rates are in rads/day and are classified as to whether they came from high or low linear energy transfer radiation. The internal dose rates are calculated using the metabolism model outlined above and multiplying the microcurie days by S-FACTORS calculated by ORNL (Snyder *et al.*, 1974, Snyder *et al.*, 1975, Dunning *et al.*, 1977) for interorgan doses. The S-FACTORS also include radiation quality factors and radionuclide distribution factors. These were divided out so that, instead of rem, the doses were expressed in rad which was the necessary form of input into the early effects model. The external dose was calculated by using the EXREM factor calculated by ORNL for air immersion in a cloud of a radionuclides. Air immersion was considered to be the major contributor of external dose to individuals exposed to a passing cloud of radionuclides.

Dynamic Metabolism Model

As described in the *Introduction*, the radionuclide metabolism model can be regarded as consisting of three commonly accepted models for radionuclide retention. These are the respiratory tract model, the gastrointestinal tract model and the internal organ uptake model. The respiratory tract model uses the ICRP Task Group Lung Model, the gastrointestinal tract model uses Eve's description of the gastrointestinal tract, and the organ uptake model uses Oak Ridge's model of the amount of a radionuclide transferred to the liver, skeleton, and thyroid. The relationships between these models are shown in Figure II-1 which is a direct adaptation of Figure 2.1 in Killough *et al.*, 1978b. Each part of the model can be conceptually thought of as consisting of a set of compartments which correspond to a system of first order, ordinary differential equations. Each compartment represents either an organ of the body or a specific anatomical region of the lung. The system of differential equations can be more specifically described by considering the differential equation for one compartment and one radionuclide

$$\frac{dA(t)}{dt} = \dot{A}(t) = - \lambda_{out} A(t) - \lambda_{decay} A(t) + \rho(t)$$

where $A(t)$ = the activity in the compartment at time t.

λ_{out} = the sum of the transfer rate constants (constant over time) leading out of the compartment.

λ_{decay} = rate of physical decay (constant over time)

$\rho(t)$ = sum of the rates at which activity enters the compartment.

and $A(t), \rho(t), \lambda_{out}, \lambda_{decay} \geq 0$.

It should be noted that λ_{out} and λ_{decay} are constant over time. The term $\lambda_{out} A(t)$ is the rate at which activity is being transferred out of the compartment and into other compartments, thus becoming part of the $\rho(t)$ for other compartments. The term $\lambda_{decay} A(t)$ is the rate at which the radionuclide in the compartment decays to its daughter radionuclide.

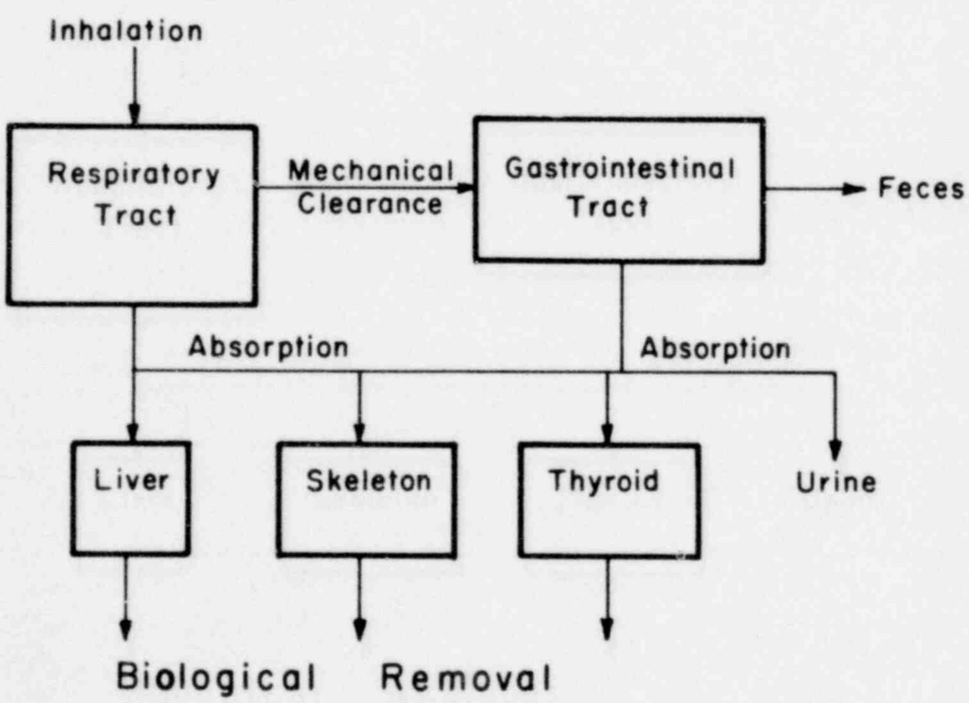

Figure II-1. Schematic representation of the transport of radionuclides in the body (from Killough *et al.*, 1978b).

The ICRP Task Group Lung Model (Morrow *et al.*, 1966), as updated in ICRP-19 (ICRP, 1972), was used to describe how material is deposited, retained and absorbed in the respiratory tract. This is shown in Figure II-2. In this model, the respiratory tract is considered to be divided into three major anatomical regions, the nasopharyngeal region, the tracheobronchial region, and the pulmonary region. An inhaled aerosol is deposited into each of these regions based upon its aerodynamic particle size distribution. The fraction of the inhaled aerosol deposited into each of these regions can be estimated from the empirical curves shown on the graph in Figure II-3.

COMPARTMENT		CLASS D		CLASS W		CLASS Y	
		T	F	T	F	T	F
N-P	a	0.01	0.5	0.01	0.1	0.01	0.01
(D_3 = 0.30)	b	0.01	0.5	0.4	0.9	0.4	0.99
T-B	c	0.01	0.95	0.01	0.5	0.01	0.01
(D_4 = 0.08)	d	0.2	0.05	0.2	0.5	0.2	0.99
	e	0.5	0.8	50	0.15	500	0.05
P	f	n.a.	n.a.	1.0	0.4	1.0	0.4
(D_5 = 0.25)	g	n.a.	n.a.	50	0.4	500	0.4
	h	0.5	0.2	50	0.05	500	0.15
L	i	0.5	1.0	50	1.0	1000	0.9

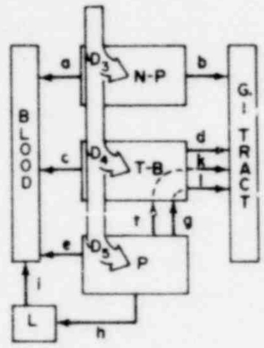

Figure II-2. The ICRP Task Group Lung Model for Particulates (Morrow *et al.*, 1966; ICRP, 1972). The columns labeled D, W, and Y correspond, respectively, to rapid, intermediate, and slow clearance of the inspired material. The symbols T and F denote the biological half-time (days) and coefficient, respectively of a term in the appropriate retention function. The symbols N-P, T-B, P and L, respectively, denote the nasopharyngeal region, tracheobronchial region, pulmonary region and pulmonary lymph nodes. The values shown for D_3, D_4 and D_5 correspond to activity median aerodynamic diameter AMAD = 1 μm. Differential equations for pathways a, b, ..., ℓ are (1) through (12). The notation n.a. indicates that pathways f and g do not exist for a class D compound.

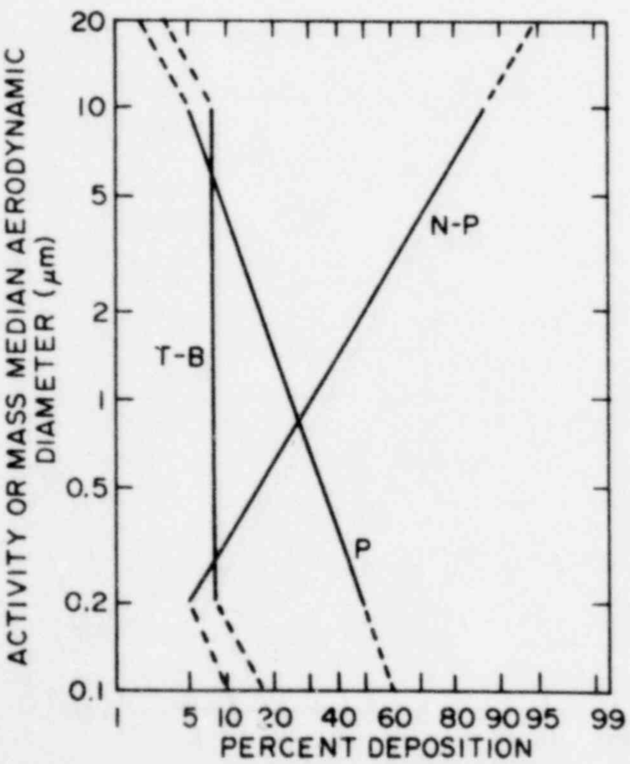

Figure II-3. Deposition model [after Figure VI D-1, Appendix VI, Reactor Safety Study (1975)]. The radioactive or mass fraction of an aerosol that is deposited in the nasopharyngeal, tracheobronchial and pulmonary regions is shown relative to the activity or mass median aerodynamic diameter (AMAD or MMAD) of the aerosol distribution. The model is intended for use with aerosol distributions that have an AMAD or MMAD between 0.2 and 10 μm with geometric standard deviations less than 4.5. Provisional deposition estimates further extending the size range are given by the broken lines. For the unusual distribution having AMAD or MMAD greater than 20 μm, complete nasopharyngeal deposition can be assumed. The model does not apply to aerosols with AMAD or MMAD below 0.1 μm.

An aerosol is considered to belong to one of the three solubility classifications shown in Figure II-2. These solubility classifications describe the retention pattern in the respiratory tract as being class D if the aerosol is retained with a half-time of days, class W if the aerosol is retained with a half-time of weeks, or class Y if the retention half-time is years. The interpretation of the particular mathematical formulation of this model is the same as outlined in Section 2.2.1 of Killough *et al.*, 1978a.

The formal description of the equations follows:

$$\dot{A}_{a,i} = -\lambda_{a,i}A_{\;,i} + F_{a,i}\lambda_i^R \sum_{j=1}^{i-1} B_{ij}\,(A_{a,j} + A_{b,j}), \tag{1}$$

$$\dot{A}_{b,i} = -\lambda_{b,i}A_{b,i} + F_{b,i}\lambda_i^R \sum_{j=1}^{i-1} B_{ij}\,(A_{a,j} + A_{b,j}), \tag{2}$$

$$\dot{A}_{c,i} = -\lambda_{c,i}A_{c,i} + F_{c,i}\lambda_i^R \sum_{j=1}^{i-1} B_{ij}\,(A_{c,j} + A_{d,j}), \tag{3}$$

$$\dot{A}_{d,i} = -\lambda_{d,i}A_{d,i} + F_{d,i}\lambda_i^R \sum_{j=1}^{i-1} B_{ij}\,(A_{c,j} + A_{d,j}), \tag{4}$$

$$\dot{A}_{e,i} = -\lambda_{e,i}A_{e,i} + F_{e,i}\lambda_i^R \sum_{j=1}^{i-1} B_{ij}\,(A_{e,j} + A_{f,j} + A_{g,j} + A_{h,j}), \tag{5}$$

$$\dot{A}_{f,i} = -\lambda_{f,i}A_{f,i} + F_{f,i}\lambda_i^R \sum_{j=1}^{i-1} B_{ij}\,(A_{e,j} + A_{f,j} + A_{g,j} + A_{h,j}), \tag{6}$$

$$\dot{A}_{g,i} = -\lambda_{g,i}A_{g,i} + F_{g,i}\lambda_i^R \sum_{j=1}^{i-1} B_{ij}\,(A_{e,j} + A_{f,j} + A_{g,j} + A_{h,j}), \tag{7}$$

$$\dot{A}_{h,i} = -\lambda_{h,i}A_{h,i} + F_{h,i}\lambda_i^R \sum_{j=1}^{i-1} B_{ij}\,(A_{e,j} + A_{f,j} + A_{g,j} + A_{h,j}), \tag{8}$$

$$\dot{A}_{i,i} = -\lambda_{i,i}A_{i,i} + F_{i,i}\;\lambda_i^R \sum_{j=1}^{i-1} B_{ij}\,(A_{i,j} + A_{j,j}) + \lambda^B_{h,i}A_{h,i}\;, \tag{9}$$

$$\dot{A}_{j,i} = -\lambda_i^R A_{j,i} + (1 - F_{i,i})\;\lambda_i^R \sum_{j=1}^{i-1} B_{ij}\,(A_{i,j} + A_{j,j}) + \lambda^B_{h,i}A_{h,i}\;, \tag{10}$$

$$\dot{A}_{k,i} = -\lambda_{d,i}A_{k,i} + \lambda_i^R \sum_{j=1}^{i-1} B_{ij}A_{k,j} + \lambda^B_{f,i}A_{f,i}, \tag{11}$$

$$\dot{A}_{l,i} = -\lambda_{d,i}A_{l,i} + \lambda_i^R \sum_{j=1}^{i-1} B_{ij}A_{l,j} + \lambda^B_{g,i}A_{g,i}, \tag{12}$$

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where

$A_{\varepsilon,i}$ = amount of activity of radionuclide i in a decay chain cleared by pathway $\varepsilon = a, b, c, \ldots, l$

B_{ij} = branching ratio of radionuclide j to radionuclide i

$F_{\varepsilon,i}$ = fraction of radionuclide i cleared by pathway $\varepsilon = a, b, c, \ldots, l$

$\lambda_{\varepsilon,i}$ = rate constant for clearance of radionuclide i by pathway $\varepsilon = a, b, c, \ldots, l$

λ_i^R = radioactive decay rate for radionuclide i.

The notation for this description is borrowed from Killough *et al.*, 1978a.

Gastrointestinal Tract

The model for transport of material through the gastrointestinal tract is an adaptation of Eve's (1966) data on transit times through various regions of the gastrointestinal tract. The gastrointestinal tract can be conceptually thought of as consisting of four compartments corresponding to the stomach, small intestine, upper large intestine, and the lower large intestine. Inhaled or ingested material enters the model through transport to the stomach and then proceeds sequentially through the compartments in the above named order. Material leaves the system either through fecal excretion from the lower large intestine or through absorption from the small intestine to the blood. All transfers between compartments of the gastrointestinal tract, absorption into the blood, and fecal excretion are modeled by first order rate equations. The rate constants used for transport between compartments are the same as used by ORNL in interpreting the data of Eve. They are 24/day for stomach to small intestine, 6/day for small intestine to upper large intestine, 1.85/day for upper large intestine to lower large intestine, and 1/day for fecal excretion from the lower large intestine.

The formal description of the equations follows:

stomach (S)

$$\dot{A}_{S,i} = -(\lambda_S + \lambda_i^R + \lambda_{SI}^{ab})\, A_{S,i} + \lambda_i^R \sum_{j=1}^{i-1} B_{ij}\, A_{S,j} + (\lambda_{b,i}^B\, A_{b,i} + \lambda_{d,i}^B\, A_{d,i} + \lambda_{d,i}^B\, A_{k,i} + \lambda_{d,i}^B\, A_{l,i}), \tag{13}$$

small intestine (SI)

$$\dot{A}_{SI,i} = -(\lambda_{SI} + \lambda_i^R + \lambda_{SI,i}^{ab})\, A_{SI,i} + \lambda_S\, A_{S,i} + \lambda_i^R \sum_{j=1}^{i-1} B_{ij}\, A_{SI,j}, \tag{14}$$

upper large intestine (ULI)

$$\dot{A}_{ULI,i} = -(\lambda_{ULI} + \lambda_i^R + \lambda_{ULI,i}^{ab})\, A_{ULI,i} + \lambda_{SI}\, A_{SI,i} + \lambda_i^R \sum_{j=1}^{i-1} B_{ij}\, A_{ULI,j}, \tag{15}$$

lower large intestine (LLI)

$$\dot{A}_{LLI,i} = -(\lambda_{LLI} + \lambda_i^R + \lambda_{LLI,i}^{ab})\, A_{LLI,i} + \lambda_{ULI}\, A_{ULI,i} + \lambda_i^R \sum_{j=1}^{i-1} B_{ij}\, A_{LLI,j}, \tag{16}$$

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where $\lambda^B_{\varepsilon,i}$ = rate constants for biological clearance of material from the gastrointestinal tract by the pathways in the respiratory tract model (ε = b,d)

$A_{\varepsilon,i}$ = amount of activity of daughter or parent i in the compartment of the gastrointestinal tract (ε = S, SI, ULI, LLI) or in compartments b, d, k or l of the respiratory tract.

λ_ε = rate constant for transport of activity between compartments of the gastrointestinal tract (ε = S, SI, ULI, LLI)

λ^R_i = radioactive decay rate of daughter or parent nuclide i

$\lambda^{ab}_{\varepsilon,i}$ = rate of absorption of daughter or parent nuclide from the compartments of the gastrointestinal tract (ε = S, SI, ULI, LLI)

B_{ij} = branching ratio of nuclide j to nuclide i.

Organ Uptake Model

The organ uptake model used in this project is the same as the one used by the INREM II computer code (Killough *et al.*, 1978b). This model approximates the uptake of a particular radionuclide by an organ as a fraction of the amount of nuclide absorbed from the lung into the blood and from the small intestine into the blood. The amount of the radionuclide retained by the organ is then described by its radioactive decay and a sum of exponentials fitted to experimental data for the particular element. Each daughter product of a parent radionuclide is described by its particular uptake and the retention functions. In this implemetation of the model, only the liver, skeleton and thyroid were considered since these are the only organs for which early effects have been implicated.

The differential equation which describes the dynamics of this process for a radionuclide i in a particular organ, k, is

$$A_{ik}(t) = -A_{ik}(t) \sum_{S=1}^{L_{ik}} (\lambda^B_{iks} + \lambda^R_i)\, A_{ik}(t) + p_{ik}(t) + \lambda^R_i \sum_{j=1}^{i-1} B_{ij}\, A_{jk}(t), \tag{17}$$

which can be solved for $A_{ik}(t)$

$$A_{ik}(t) = A_{ik}(0)\, R_{ik}(t) + \int_0^t [p_{ik}(\tau) + \lambda^R_i \sum_{j=1}^{i-1} B_{ij}\, A_{jk}(\tau)] \times R_{ik}(t-\tau)\, d\tau, \tag{18}$$

where:

$A_{ik}(t)$ = amount of activity present in compartment k due to the i^{th} radionuclide in a radioactive decay chain,

λ^R_i = the radioactive decay constant of the i^{th} radionuclide in a decay chain,

B_{ij} = the radioactive branching ratio from radionuclide j to radionuclide i in a radioactive decay chain where j < i,

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$p_{ik}(t)$ = the rate at which activity of radionuclide i enters compartment k at time t,

$R_{ik}(t) = \sum_{S=1}^{Lik} C_{iks} \exp [-(\lambda_i^R + \lambda_{iks}^B) t]$. The retention function for organ k.

c_{iks} = the fraction of the activity of radionuclide i which is retained in organ k with a biological half time of $\ln 2/\lambda_{iks}^B$

λ_{iks}^B = s^{th} biological rate constant for radionuclide in organ k ($S = 1,2,...L_i$).

L_{ik} = number of components used in fitting biological retention function.

The function $p_{ik}(t)$ is approximated by considering a fraction of the activity which enters into the blood to be immediately absorbed by the particular organ k. While it would be desirable to describe this process by using rate constants for the transport of the radionuclide between the blood and the organ, adequate information does not exist for the majority of the radionuclides. The formal description of the approximation used for $p_{ik}(t)$ is

$$p_{ik}(t) = f'_{2,ik} [A_{LB,i}(t) + A_{GB,i}(t)] \tag{19}$$

where

$f'_{2,ik}$ = fraction of the absorbed activity of radionuclide i transported to organ k,

$A_{GB,i}$ = $\lambda_{\varepsilon,i}^{ab} A_{\varepsilon,i}$ rate of absorption of activity of radionuclide i by the blood from the gastrointestinal tract from compartment ε = S, SI, ULI, LLI

$A_{LB,i}$ = $\lambda_{a,i} A_{a,i} + \lambda_{c,i} A_{c,i} + \lambda_{e,i} A_{e,i} + \lambda_{i,j} A_{i,i}$ rate of absorption of activity of radionuclide i by the blood from the respiratory tract.

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CHAPTER III. RESOLUTION OF RADIATION DOSE-RESPONSE RELATIONSHIPS

Introduction

Several methods of resolving radiation dose-response relationships are discussed. These methods can be categorized as follows: (1) methods that utilize conditional probabilities, and (2) those that do not. In methods not using conditional probabilities, one can obtain the dose response relationship simply by taking the quotient of the number of members affected to the number treated at a given dose level. However, in inhalation studies it is unlikely that a large number of members will receive the ame dose. Thus, in order to use these methods to obtain the dose-response relationship, members receiving different doses must be combined into the same dose group. As a result, the dose-response curve may depend heavily on how the members are grouped. To avoid this unwanted dependence of the do_e response curve on the way in which animals were grouped, it is desirable to have alternative methods of resolving radiation dose-response relationships. One alternative method is the hazard-function method described below and in detai. elsewhere (Scott, 1979). With the hazard-function method, it is unnecessary to combine members affected by different doses into the same dose group; each exposed member can be treated individually. However, with this method of analysis, it is necessary to use probabilistic concepts.

Radiation Hazard Functions

For a given temporal and spatial distribution of the dose, let F(D) represent the probability that the spatial average dose D produces injury sufficient to cause a specific biological effect; this injury is referred to as *critical injury*. The term dose will hereafter refer to the spatial average dose. The dose D is referred to as a *critical dose* if F(D) is greater than zero. It is assumed that zero dose produces no critical injury; thus F(0) will be equal to zero. If critical injury occurs at zero dose, it must be corrected for. It is assumed that an infinite dose (i.e., a very large dose) will always induce critical injury; thus F(∞) will be equal to one.

The cause-specific *radiation hazard function* h(D) can be defined as

$$h(D) = \frac{f(D)}{1-F(D)}, \tag{1}$$

where the cause-specific probability density function f(D) is equal to the dose derivative of F(D), i.e.,

$$f(D) = \frac{dF(D)}{dD}. \tag{2}$$

The cause-specific *partial cumulative radiation hazard function* $g(D_1,D_2)$ for D_2 greater than D_1 can be defined as

$$g(D_1,D_2) = \int_{D_1}^{D_2} h(D)dD. \tag{3}$$

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The cause-specific *cumulative radiation hazard function* H(D) is equal to g(0,D) and is related to F(D) through the expression (Nelson, 1969; Gehan, 1969; Hahn and Shapiro, 1967)

$$F(D) = 1 - e^{-H(D)}. \tag{4}$$

It is convenient to define the cause-specific *median critical dose* D_{50} according to the relationship

$$F(D_{50}) = 0.5. \tag{5}$$

A method of estimating g(D,D+δ), H(D), and F(D) that is similar to the method used by Nelson (1969) is discussed in the following section.

Estimates for the Hazard Functions

Among the members of the population who receive dose in the interval D_i to $D_i + \delta$, some will receive critical injury, some will die from competing effects and other will survive. The random variable n_i represents the total number of individuals who received a dose in this interval. The random variable d_i represents the number of those individuals who received the critical injury in this interval D_i to $D_i+\delta$, where $(D_i + \delta)/D_i$ has a value almost identical to one, and where D_{i+1} is greater than D_i for $i = 1,2,\ldots,v-1$, for v distinct doses. An estimate of the conditional probability of receiving critical injury in the interval is g_i where

$$g_i = \frac{d_i}{m_i} \tag{6}$$

$$\text{where } m_i = \sum_{j=i}^{v} n_j.$$

Since g_i is an estimate of the conditional probability, its standard deviation $s(g_i)$ can be calculated by assuming the number of critical injuries, $m_i g_i$, to occur in the interval from D_i to $D_i+\delta$ to be distributed according to the binomial distribution. When g_i equals zero, $s(g_i)$ can be determined using the procedure proposed by Marshall (1970). The resultant expression for $s(g_i)$ is

$$s(g_i) = \begin{cases} \left[\dfrac{g_i(1-g_i)}{m_i}\right]^{1/2} & , g_i > 0 \\ (m_i+1)^{-1} & g_i = 0. \end{cases} \tag{7}$$

The quantity $(m_i+1)^{-1}$ is the value of g_i for which $s(g_i) = g_i$ when g_i is greater than zero. For $g_i = 0$, equation (7) differs slightly from the equation derived by Marshall (1970) because g_i is a conditional probability in this case; for $g_i > 0$, it is identical in form to the equation derived by Chiang (1961).

An estimate of the cause-specific cumulative radiation hazard $H(D_i)$ is H_i with standard deviation $s(H_i)$, where

$$H_i = \sum_{j=1}^{i} g_j. \tag{8}$$

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Assuming the random variables g_i and g_{i+1} to be independent for i = 1, 2,...v-1, $s(H_i)$ will be given by the root-sum-square (Lindgren, 1966) of $s(g_j)$, i.e.,

$$s(H_i) = \left[\sum_{j=1}^{i} s(g_j)^2 \right]^{1/2} . \tag{9}$$

It follows that an estimate of $F(D_i)$ is F_i, where

$$F_i = 1 - e^{-H_i}. \tag{10}$$

One can calculate the standard deviation of F_i, $s(F_i)$ using the approximation (Paratt, 1960)

$$s(F_i)^2 \approx \left(\frac{dF_i}{dH_i} \right)^2 s(H_i)^2, \tag{11}$$

or

$$s(F_i) \approx e^{-H_i} \; s(H_i). \tag{12}$$

Alternative estimates of F(D) have been described elsewhere, (Chiang, 1961; Kaplan and Meier, 1958; Cutler and Ederer, 1958) provided time is replaced by dose as the independent variable in their formulas.

Comparison of Hazard Function and Binomial Estimates

The binomial estimate is useful where large numbers are exposed to the same dose and where individuals are not lost to follow up. The binomial estimate F_i^+ is defined as

$$F_i^+ = \frac{d_i^+}{N} . \tag{13}$$

where N is the number at risk and d_i^+ the number affected. The random variable d_i^+ is related to the random variable d_i in equation (6) through the equation

$$d_i^+ = \sum_{j=1}^{i} d_j . \tag{14}$$

For small samples sizes, F_i is slightly less than F_i^+. For a given sample size, the difference between the two increases as the number affected increases. However, for a given number affected, the difference between F_i^+ and F_i decreases in magnitude as a sample size increases. For a given sample size N, the maximum value for the difference $F_i^+ - F_i$ is defined as $\max(F_i^+ - F_i)$. A curve for $\max(F_i^+ - F_i)$ as a function of N is shown in Figure III-1. For $10 \leq N \leq 100$, $\max(F_i^+ - F_i)$ decreases in proportion to N to the -0.98 power. Figure III-1 also suggests that for $N \geq 10$, $F_i^+ \approx F_i$ regardless of the number of members affected.

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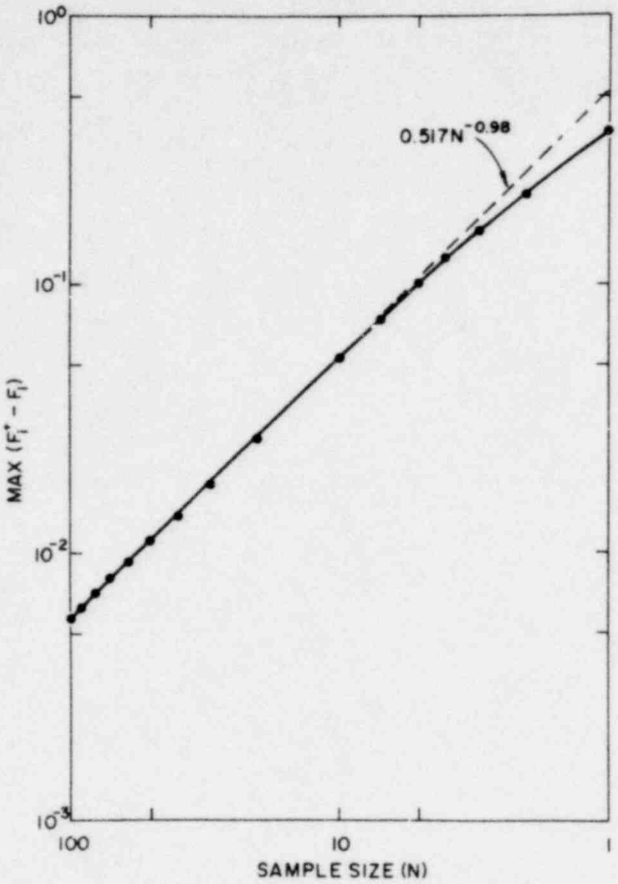

Figure III-1. Maximum difference between estimates F_i^+ and F_i, max $(F_i^+ - F_i)$, as a function of the sample size N.

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CHAPTER IV. EMPIRICAL DOSE-RESPONSE MODEL FOR LUNG

Introduction

Large absorbed radiation doses (i.e., spatial averaged doses) to the lung can cause the early effects of radiation pneumonitis and pulmonary fibrosis (Hahn, 1975). These early effects can cause death from cardiopulmonary insufficiency. Presently available data suggest that the absorbed radiation dose responsible for these early effects is a random variable that depends on the temporal and spatial distribution of energy deposition events and on radiation quality (Scott, 1978a; Scott, 1978b; Clark and Bair, 1964, Park *et al.*, 1970). Age at exposure may also be an important variable.

In this section, an empirical model for radiation-induced pulmonary injury sufficient to cause death within 18 months from early effects is described and is based on certain radionuclide-specific, dose-response relationships.

Distribution Function for Early Death

For a spatial distribution and temporal distribution of the absorbed radiation dose D (i.e., the spatial average dose) to the lung, for radiation of quality Q, the radionuclide-specific cumulative distribution function of the dose θ to the production of pulmonary injury sufficient to cause early death is given by prob(θ < D).

It has been found that early radiation responses in the lung, bone or gastrointestinal tract are adequately represented by the Weibull distribution, i.e.,

$$\text{prob}(\theta < D) = F(D,v,k) = 1 - e^{-kD^{v}} \tag{1}$$

where k and v are positive constants that depend on the conditions S, T and Q which describe θ. Equation (1) is based on exposure to single radiation sources rather than to combined sources. It follows from equation (1) that the appropriate cumulative hazard-function estimate for the model is given by the Weibull function.

$$H(D,v,k) = kD^{v}. \tag{2}$$

Analysis of Experiments With Animals Exposed to Beta-Emitting Radioactive Aerosols

A major problem associated with the analysis of dose-response relationships involving internal radiation sources is wasted dose. For low-LET radiation, wasted dose is of two general types: (1) *Wasted dose of the first kind.* If, for a given temporal and spatial distribution of the dose, a dose D_1 is necessary and sufficient to cause an effect of interest but the actual dose delivered, D_2, is greater than D_1, then the dose D_2-D_1 is wasted and represents *wasted dose of the first kind;* (2) *Wasted dose of the second kind.* If a dose is delivered at dose rates low enough to allow correction of significant amounts of induced reversible injury during radiation exposure (e.g., repair of intracellular injury, cell repopulation), and thus, higher doses are required to achieve a given level of injury than would be required had the dose been delivered at higher dose rates, then the additional dose required to produce the level of injury at lower dose rates represents *wasted dose of the second kind.*

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For high-LET radiation sources, there is a third type of wasted dose. When the local dose to tissue is in excess of that necessary to cause local injury, a certain amount of local dose is wasted and represents *wasted dose of the third kind.*

It was observed in the cases involving the inhalation by Beagle dog of ^{90}Y, ^{91}Y, ^{144}Ce or ^{90}Sr in a relatively insoluble form that for initial dose rates to the lung less than or equal to a given subcritical dose rate, R_{sc}, none of the exposed members died within 18 months from pulmonary injury, regardless of the dose. Data in this range of dose rates were excluded in the analysis that follows. R_{sc} depends on the effective half-life of the radioactive material in the lung and on sample size and, therefore, was different for each type of radioactive material inhaled. Values for R_{sc} are given in Table IV-1. For dose rates greater than R_{sc}, it was also observed that for an array of doses (doses to the lung at death) greater than or equal to a dose D_{co} (cutoff dose), all doses were sufficient to induce critical injury in the sample. Thus, some members that received radiation doses just below D_{co} did not die of early radiation effects while all members that received radiation doses greater than or equal to D_{co} died of early radiation effects. The cutoff dose was different for each type of radioactive material inhaled.

It was also noted that for lung doses greater than or equal to D_{co}, larger doses to the lung at death generally corresponded with larger initial dose rates. This suggests that dose wasting of the first kind occurs in the dose range from D_{co} to infinity. One would expect the higher initial dose rates to cause injury at lower doses because of less repair of intracellular injury and less cell repopulation at the higher dose rates. Doses greater than the cutoff dose D_{co} were excluded in the analysis that follows to correct for wasted dose of the first kind. Including the data at initial dose rates less than R_{sc} and at doses greater than D_{co} would have resulted in an underestimate of the effectiveness of the radiation.

After correcting for wasted dose, dose-response curves for early death following inhalation of radioactive materials were generated using the hazard-function method described in Chapter III. As an example, Table IV-2 shows the analysis of early mortality data for Beagle dogs after inhalation of ^{91}Y in fused aluminosilicate particles based on data from Hobbs *et al.*, (1978). The random variable D_i represents the cumulative absorbed radiation dose to death for individuals that die within 18 months. For those that do not die within 18 months, D_i represents the cumulative radiation dose at 18 months. The random variable n_i represents the number of animals with a cumulative absorbed radiation dose at death equal to D_i. The random variable d_i represents the number of the n_i animals that died within 18 months from cardiopulmonary insufficiency caused by radiation pneumonitis and pulmonary fibrosis. The random variable g_i was defined in Chapter III and is given by

$$g_i = d_i / \text{ number of members with radiation dose at death equal to or greater than } D_i. \quad (3)$$

For i = 1, 2, and 3, g_i is given by

$$g_1 = 1/43 \quad (4)$$

$$g_2 = 0/42 \quad (5)$$

$$g_3 = 0/41. \quad (6)$$

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Table IV-1

Values for R_{sc}[a] for Some Radioactive Aerosols With Low Linear Energy Transfer Emissions

Material	R_{sc}	Effective Half-Life T_e[c] (days)	References
^{90}Y (FAP)[b]	1.5 rads/min	2.6	Merickel *et al.*, 1978
^{91}Y (FAP)	8.3×10^{-2} rads/min	53	Hobbs *et al.*, 1978
^{144}Ce (FAP)	1.2×10^{-1} rads/min	200	Hahn *et al.*, 1978
^{90}Sr (FAP)	9.0×10^{-2} rads/min	400	Snipes *et al.*, 1978

[a]For initial dose rates to the lung less than or equal to a value R_{SC}, it was observed that no animals died within 18 months regardless of the dose to their lungs.

[b]FAP = Fused aluminosilicate particles.

[c]All effective half-lives are from Hahn *et al.*, (1975).

Table IV-2

Estimates of Radiation Hazard Functions for Beagle Dogs[a] Exposed to Aerosols of ^{91}Y (FAP)[b]

D_i (Krads)	i	n_i	d_i	g_i	H_i	F_i
8.3[c]	1	1	1	1/43	0.0233	0.023
9.1	2	1	0	0/42	0.0233	0.023
9.6	3	1	0	0/41	0.0233	0.023
9.7	4	1	0	4/40	0.0233	0.023
11.0	5	1	0	0/39	0.0233	0.023
12.0	6	3	0	0/38	0.0233	0.023
13.0	7	1	0	0/35	0.0233	0.023
15.0	8	3	0	0/34	0.0233	0.023
16.0	9	4	0	0/31	0.0233	0.023
17.0	10	3	0	0/27	0.0233	0.023
18.0	11	3	2	2/24	0.1066	0.101
19.0	12	3	1	1/21	0.1542	0.143
20.0	13	2	0	0/18	0.1542	0.143
21.0	14	5	3	3/16	0.3417	0.289
22.0	15	3	3	3/11	0.6144	0.459
23.0	16	3	1	1/ 8	0.7394	0.523
24.0	17	1	1	1/ 5	0.9394	0.609
25.0	18	2	0	0/ 4	0.9394	0.609
26.0[c]	19	2	2	2/ 2	1.9394	0.856

[a]Based on data from Hobbs *et al.*, 1978.

[b]Fused aluminosilicate particles.

[c]D_{co}

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The random variable H_i is an estimate of the cumulative radiation hazard function and is given by

$$H_i = \sum_{j=1}^{i} g_j. \tag{7}$$

Thus,

$$H_1 = 1/43 \tag{8}$$

$$H_2 = (1/43) + (0/42) = H_1 + (0/42) \tag{9}$$

$$H_3 = (1/43) + (0/42) + (0/41) = H_2 + (0/41). \tag{10}$$

The random variable F_i is an estimate of the proportion of the exposed population with pulmonary injury sufficient to cause death from early effects and is related to H_i through the expression

$$F_i = 1 - e^{-H_i}. \tag{11}$$

For small values of H_i (i.e., $H_i < 0.1$),

$$F_i \approx H_i. \tag{12}$$

Values for H_i have been determined for Beagle dogs exposed by inhalation to relatively insoluble, low-LET, radioactive aerosols based on data reported elsewhere (Merickel *et al.*, 1978, Hobbs *et et.*, 1978; Hahn *et al.*, 1978; Rebar *et al.*, 1978). These curves and their associated probability estimates are shown in Figure IV-1 and are adequately represented by the Weibull cumulative distribution function since data or H_i vs the absorbed radiation dose are well characterized by straight lines or logarithmic paper. According to equation 2, a plot of $\ln(H_i)$ vs $\ln(D_i)$ should be linear with a slope approximately equal to v and a zero log-dose intercept approximately equal to ln(k). Values for v and ln(k) are given in Table IV-3. Effective half-lives for the aerosols shown in Figure IV-1 are given in Table IV-1. The probability estimates in Figure IV-1 are based on the estimate F_i. These curves indicate that the distribution of radiation doses that produce injury to the lung sufficient to cause death within 18 months is related to the effective half-life of the low-LET radioactive materials in the lung. The efficiency of the low-LET radioactive materials in causing early death decreases as the effective half-life of the radioactive substances in the lung increases. In the limit, as the effective half-life in the lung approaches zero, it is expected that the dose-response curve will approach a limiting form which can be estimated from data for brief exposure of the lung to external gamma or X-rays. This limiting form has been estimated using data of Dunjic *et al.*, (196[illegible]) for thoracic exposure of rats to 250-kVp X-rays at high dose rates. Assuming the rad doses to the thorax to be approximately equal to the exposure in R, linear regression was used to derive the following limiting distribution function F_o:

$$F_o = 1 - \exp\,(8.3 \times 10^{-3} D^{4.56}) \tag{13}$$

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Figure IV-1. Estimated cumulative radiation hazard functions and associated probability estimates for death of Beagle dogs within 18 months following inhalation of several low-LET radionuclides in a relatively insoluble form.

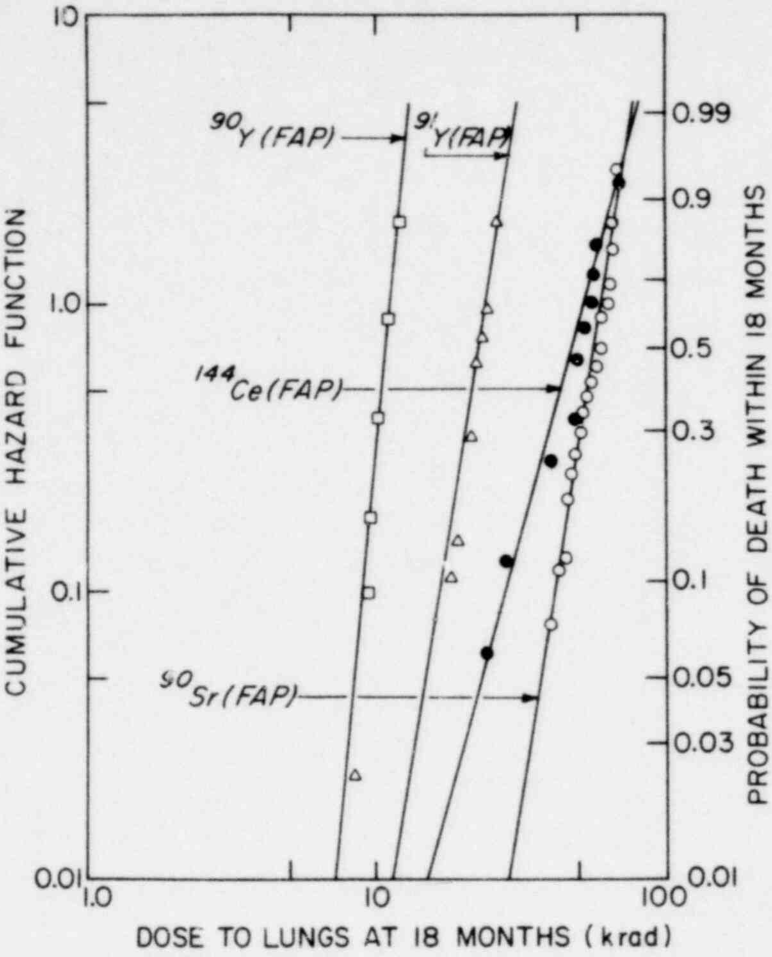

Table IV-3

Estimated Values[a] for ln(k) and v for the Wiebull Distribution

Radiation Source	ln(k)	v
^{90}Y(FAP)[b]	-25.4	10.51
^{91}Y(FAP)	- 9.5	6.15
^{144}Ce(FAP)	-14.8	3.41
^{90}Sr(FAP)	-25.3	6.01

[a]Where D_i is in krad.

[b]Fused aluminosilicate particles.

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with the corresponding cumulative hazard function H_0 given by

$$H_0 = 8.3 \times 10^{-3} D^{4.56}, \tag{14}$$

where the absorbed radiation dose D is in krad.

Analysis of Experiments with Animals Exposed to Alpha-Emitting Radioactive Aerosols

Regression curves for H_i vs D_i and associated probability estimates for early death from pulmonary injury following inhalation of high-LET radioactive aerosols are shown in Figure IV-2, and are based on data reported elsewhere (Bair *et al.*, 1978; Mewhinney *et al.*, 1978; Mewhinney *et al.*, 1976, Hobbs *et al.*, 1976). These curves indicate that baboon, Syrian hamster and Beagle dog lungs show similar sensitivity to high-LET radiation. The curve for Beagle dogs exposed to $^{239}PuO_2$ aerosols shown in Figure IV-2 resulted from a similar long effective half-life (i.e., temporal distribution of the absorbed radiation dose) as the curve for ^{90}Sr in fused aluminosilicate particles. For the same absorbed radiation dose, alpha particles from $^{239}PuO_2$ were far more effective in causing early death than were beta particles from ^{90}Sr. This indicates that radiation quality (i.e., LET) is an important determinant of the biological effectiveness of radiation sources in the lung. Furthermore, the probability estimate for Beagle dogs exposed to $^{238}PuO_2$ aerosols shown in Figure IV-2 differs markedly from the curve for Beagle dogs exposed to $^{239}PuO_2$ aerosols, indicating that factors in addition to radiation quality may also be important. Since the specific activity of $^{238}PuO_2$ is considerably higher than for $^{239}PuO_2$, the difference between the $^{238}PuO_2$ and $^{239}PuO_2$ responses may be due to a greater wasting of local dose (i.e., wasted dose of the third kind) around the $^{238}PuO_2$ particles. For a given particle size, the same absorbed radiation dose for $^{238}PuO_2$ and $^{239}PuO_2$ would be delivered to the lung by a smaller number of $^{238}PuO_2$ particles than for $^{239}PuO_2$. This would result in irradiation of a smaller proportion of the lung in the case of $^{238}PuO_2$. In view of the experimental data, the fraction of the lung irradiated may be an important

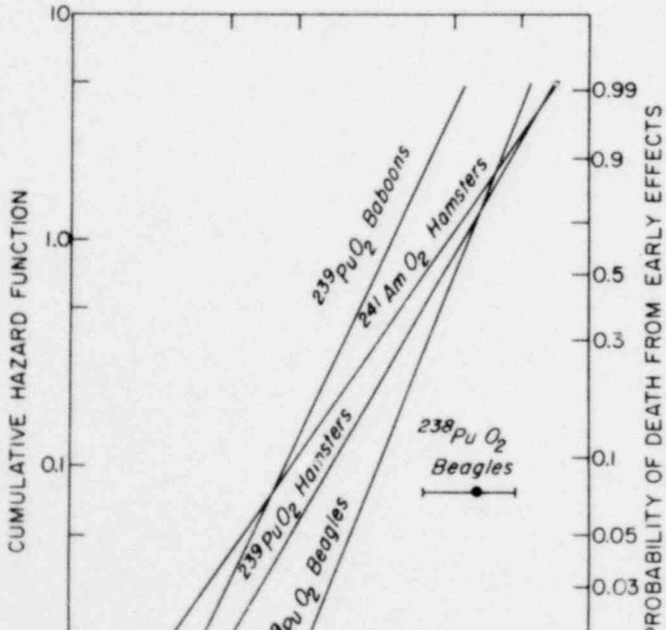

Figure IV-2. Regression lines for the cumulative radiation hazard function and for the probability of early death from pulmonary injury after inhalation exposure to high-LET radiations for several species and for several radionuclides.

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determinant of the biological effectiveness of high-LET radiation sources in the lung. In Figure IV-2, with the exception of the $^{238}PuO_2$ curve, all curves appear similar, indicating that the temporal distribution of the absorbed radiation dose is of less importance for high-LET radiation sources in the lung than for low-LET radiation sources.

Distribution of Time to Death

Results from an analysis of presently available data from this Institute suggest that, for inhalation exposure to insoluble radionuclides with effective half-lives in the lung on the order of days to weeks, death from early effects generally occur within one year after inhalation exposure. In these instances, it is reasonable to calculate the dose to the lung at one year after inhalation exposure to estimate the probability of death from early effects in the lung. However, results from an analysis of data after inhalation exposure to insoluble radionuclides with retention half-times on the order of hundreds of days, suggest that the dose which builds up after one year may also cause death from early effects. In these instances, death from early pulmonary effects may occur at post-inhalation exposure times considerably longer than one year (see Table IV-4) and, therefore, compete with late effects.

Death from early effects caused by the dose that builds up after one year for radionuclides with retention half-times on the order of hundreds of days might be expected if one examined the magnitude of the radiation doses that could build up after one year. Figure IV-3 illustrates calculated dose build-ups after one year for inhalation exposure to ^{90}Sr in a relative insoluble form (effective half-life = 400 days). The magnitude of this dose depends on the initial dose rate. For an initial dose rate equal to 100 rads/day, about 31 krad of dose could build up after one year.

Table IV-4

Data for Death of ITRI Beagles After One Year
Following Inhalation Exposure to Radionuclides with
Lung Retention Half-Times on the Order of Hundreds of Days[a]

Aerosol Form	Animal Number	Initial Dose Rate (rads/day)	DPE	Cause of Death[b]	Page in LF-60
^{144}Ce Insoluble	211E	290	410	D-Pul Inj	493
^{90}Sr Insoluble	354W	150	477	D-Pul Inj	503
	397S	83	2373	D-Rad Pneum, Pul Fibrosis	503
	411S	47	2596	D-Pul Inj	503
$^{238}PuO_2$ (1.5 μm AD)	746B	33	792	D-Rad Pneum, Pul Fibrosis	507
	726A	30	1107	E-Rad Pneum, Pul Fibrosis	507
	877C	20	536	D-Rad Pneum, Pul Fibrosis	507
	708T	15	1104	D-Rad Pneum	507
$^{238}PuO_2$ (3 μm AD)	667T	56	1213	D-Rad Pneum, Pul Fibrosis	509
	710C	51	631	E-Rad Pneum, Pul Fibrosis	509
	647B	31	1683	D-Rad Pneum	509
	736S	20	966	D-Rad Pneum, Pul Fibrosis	509

[a]Data are from Inhalation Toxicology Research Institute Annual Report, LF-60, 1978.
[b]D = Died, E = Euthanized, Pul Inj = Pulmonary Injury, Rad Pneum = Radiation Pneumonitis.

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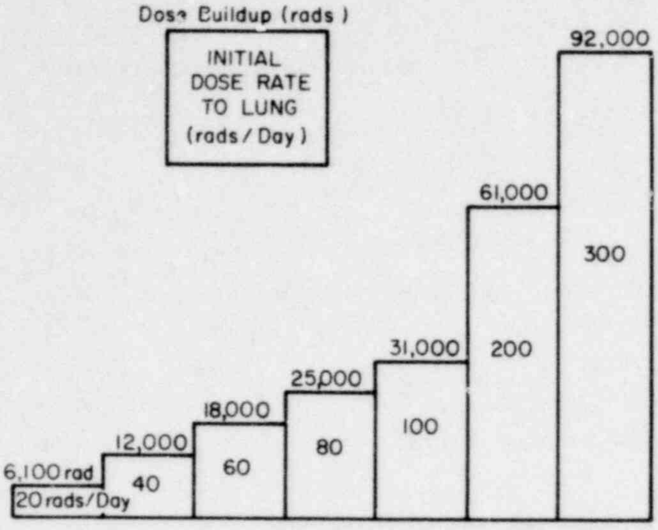

Figure IV-3. Radiation dose to the lung that builds up after one year following inhalation exposure to ^{90}Sr in a relatively insoluble form (effective half-life of 400 days). The numbers within boxes represent initial dose rates (rads/day) to the lung. The numbers on top of the boxes represent the dose build up in rads.

For the above reasons, the ITRI model for lung is not based on the dose at one year but rather is based on the radiation dose to the lung at 18 months, since no tumor deaths occurred in this time period. The resultant probability estimates represent the probability of death within one year only for radionuclides with lung retention half-times considerably less than one year; otherwise, they represent the probability of death within 18 months.

Empirical Equations for Dose-Response Relationships for Inhaled Low-LET Radionuclides

An analysis of the radiation dose-response data following exposure of the lung to internal and external radiation sources resulted in empirical relationships for the D_{50} and D_{10} (i.e., the doses which affect 50 and 10 percent of the exposed population, respectively), given by $D_{50}(T_e)$ and $D_{10}(T_e)$, respectively, where the effective half-life T_e of the radioactive substance in the lung is in days and $D_{50}(T_e)$ and $D_{10}(T_e)$ are in krad. Values for $D_{10}(T_e)$ and $D_{50}(T_e)$ are determined by linear extrapolation between the values shown in Table IV-5. For $t \geq 400$ days, the $D_{10}(T_e)$ and $D_{50}(T_e)$ are assumed to be the same as for inhalation exposure to ^{90}Sr in an insoluble form. Empirical equations can be derived for the Weibull parameters k and v as functions of $D_{50}(T_e)$ and $D_{10}(T_e)$. The equations are

$$v(T_e) = \frac{1.8834}{\ln\left(\frac{D_{50}(T_e)}{D_{10}(T_e)}\right)} \tag{15}$$

and

$$k(T_e) = \frac{0.6931}{D_{50}(T_e)^{v(T_e)}}. \tag{16}$$

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Table IV-5

Estimated D_{10} and D_{50} Values (in Krads) for Death Within 18 Months After Exposure of the Lung to Low-LET Radiation

Radionuclide Form	Effective Half-Life T_e (days)	D_{10} (krad)	D_{50} (krad)
^{90}Y Insoluble	2.6	9	11
^{91}Y Insoluble	53	16.5	22.5
^{144}Ce Insoluble	200	29	48
^{90}Sr Insoluble	4[illegible]	42	57
Low-LET External	0	1.75	2.64

Based on equations (15)-(16) and Equation (2), the empirical cumulative radiation hazard function $H(D,T_e)$ can be defined according to the equation

$$H(D,T_e) = k(T_e)D^{v(T_e)}. \tag{17}$$

Similarly, the empirical distribution function $F(D,T_e)$ is given by

$$F(D,T_e) = 1 - e^{-H(D,T_e)}. \tag{18}$$

Equations (15)-(18) can be used to simulate radionuclide-specific radiation dose-response curves for Beagle dogs or for man for inhalation exposure to low-LET radiation sources in relatively insoluble forms. Figure IV-4 shows data for H_i vs D_i for mice after inhalation of ^{144}Ce in a relatively insoluble form based on the data of Lundgren *et al.*, (1974). The smooth curve was generated using equation (17) with the effective half-life in the lungs, T_e, equal to 21 days. The close agreement between the response and the smooth curve suggest that apparent species dependent differences in radiation responses may be caused by differences in the temporal distribution of the absorbed radiation dose.

Most dose-response curves presented in this chapter were derived using the hazard-function method and were based on dose at death as an estimate of the dose that caused early death. For this reason, the resultant curves may underestimate the risk of early death.

Exposure to Multiple Radionuclide Aerosols

In this section an estimate of H_A is described which is the cumulative radiation hazard function estimate for early death from pulmonary injury as a result of combined inhalation exposure to a mixture of low-LET radioactive sources and whole-body exposure to sublethal doses of external gamma rays at high dose rates. If D_E represents the dose to the lung from external gamma rays, then $H_0(D_E)$ is calculated where H_0 is defined by equation (14). For small time intervals (x, $x + \Delta x$) about the postinhalation time x, the effective half-life can be determined at which the low-LET radiation dose from all sources is delivered. Based on this time-dependent effective half-life T_e, the empirical Weibull parameters $k(T_e)$ and $v(T_e)$ are calculated according to equations (15) and

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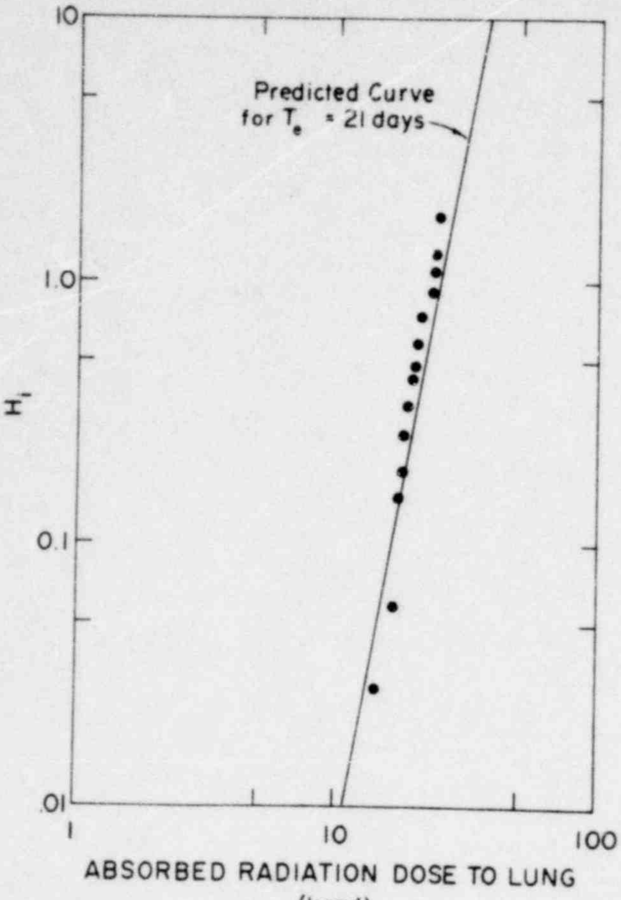

Figure IV-4. Predicted and observed dose-response relationships for the cumulative radiation hazard function for mice after inhalation exposures to low-LET radiation from $^{144}CeO_2$. Differences between the predicted and estimated values are not significant for the range of doses shown.

(16). Based on the cumulative radiation hazard function $H_A(x)$ at post-inhalation time x, the equivalent dose $D_{eq}(x)$ is calculated according to the equation

$$D_{eq}(x) = \left[\frac{H_A(x)}{k(T_e)}\right]^{\frac{1}{v(T_e)}} \tag{19}$$

where $v(T_e)$ and $k(T_e)$ are evaluated at a value of T_e equal to the effective half-live for all radioactive substances in the lung for the interval $(x, x + \Delta x)$. At $x = 0$, $H_A(0)$ is equal to $H_o(D_E)$. Using the equivalent dose at time x, the cumulative radiation hazard function at time $x + \Delta x$ is calculated according to the following equation:

$$H_A(x + \Delta x) = k(T_e)\,[D_{eq}\,(x) + D\,(x + \Delta x) - D(x)]^{v(T_e)} \tag{20}$$

where D(x) represents the cumulative absorbed radiation dose at post-inhalation exposure time x. This procedure is repeated for time periods to 18 months after exposure. The resultant estimate H(18 months) is used to determine the probability of death within 18 months. The procedure for including high-LET radiation doses is described in Chapter VII.

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Major Inadequacies of Presently Available Data

Presently available data for early death from radiation induced pulmonary injury are insufficient for determining the following:

1. An appropriate method of predicting dose-response relationships for inhalation exposure to complex mixtures of low-LET radiation sources.

2. An appropriate method of predicting dose-response relationships for inhalation exposure to a mixture of alpha-emitting particles when the distribution of activity per particle is radionuclide specific and differs markedly.

3. An appropriate method of determining dose-response relationships for mixed-field exposures (i.e., exposure to both high- and low-LET radiations).

4. A method of accounting for the modification of dose-response relationships caused by wasted local dose around alpha-particle sources in the lung.

5. An appropriate procedure for accounting for the modification of dose-response relationships for lung caused by injury to other body organs (i.e., interorgan synergism).

CHAPTER V. EMPIRICAL DOSE-RESPONSE MODEL FOR BONE

Introduction

Early death after irradiation of the skeleton is usually caused by aplasia of the marrow, which results from killing of hemopoietic stem cells. After brief exposures, major reactions can be classified into (Upton, 1969): (a) a transitory prodromal phase, which develops within a few hours after exposure, (b) an ensuing latent period, which is relatively aysmptomatic, and (c) the main phase of illness. The level of injury induced by radiation generally depends on the absorbed radiation dose, age at exposure, sex, species, radiation quality, and the temporal distribution of the radiation energy deposition events (Scott, 1977). Expected early effects of whole-body exposure to ionizing radiation have been outlined elsewhere (Webb, 1962) and are given in Table V-1. Physiological consequences of irradiation of bone marrow include (Upton, 1969): (a) greater susceptibility to bleeding (resulting from thrombocytopenia), (b) greater susceptibility to infection (resulting from leukopenia), (c) anemia (resulting from hemorrhage or depression of erythropoiesis), and (d) lowering of immunity (presumably associated with the destruction of lymphoid cells). The tissue dose (absorbed radiation dose) which causes early death for 50% of the sample exposed within 30 days following whole-body exposure to ionizing radiation is referred to as the $LD_{50/30}$ and is a useful measure for interspecies comparison. Estimated values for the $LD_{50/30}$ for several species and several types of radiation have been reported by Bond *et al.* (1965) and are given in Table V-2. The $LD_{50/30}$ for whole-body exposure of man to gamma rays is estimated to be about 300 rad. The value of 300 rad is the same as that reported in WASH-1400 for the dose that affects 50% of the sample exposed within 60 days ($LD_{50/60}$), but is somewhat less than what one would estimate from the dose-response curve for man reported in the NASA Life Science Data Book (Webb, 1962). Figure V-1 shows an estimated dose-response curve for man for the probability of dying in 60 days vs the absorbed radiation dose that was redrawn from Webb (1962). The $LD_{50/60}$ is about 450 rad based on this curve. Since the $LD_{50/60}$ is always less than or equal to the $LD_{50/30}$, Figure V-1 suggests that the $LD_{50/30}$ is greater than or equal to 450 rad, which is considerably higher than the value given in Table V-2. In the development of an empirical model for early death of man from radiation induced hematological dyscrasia, we have used the value of 300 rad for the $LD_{50/30}$ for brief (i.e., high dose rate) whole-body exposure to low-LET radiation.

Analysis of Experimental Data

Dose-response relationships for early death from radiation-induced injury to the hemopoietic system have been resolved from available data for exposure to external or internal sources of low-LET radiation. All relevant data are given in the Appendices with their associated references. Figures V-2 and V-3 show estimated cumulative radiation hazard functions for death from radiation induced injury to the hemopoietic system for mice, monkeys and dogs after brief whole-body exposures to external low-LET radiation sources. The cumulative radiation hazard function estimate H_i^+ is given by

$$H_i^+ = -\ln(1 - F_i^+) \qquad (1)$$

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Table V-1

Expected Effects in Man Following Brief Whole-Body Exposure to Ionizing Radiation[a]

Dose in Rems	Probable Effect
0 to 50	No obvious effect, except, possibly, minor blood changes.
50 to 100	Vomiting and nausea for about 1 day in 5 to 10 percent of exposed individuals. Fatigue, but no serious disability.
100 to 150	Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 25 percent of individuals. No deaths anticipated.
150 to 200	Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 50 percent of individuals. No deaths anticipated.
200 to 350	Vomiting and nausea in nearly all individuals on first day, followed by other symptoms of radiation sickness. About 20 percent deaths within 2 to 6 weeks after exposure; survivors convalescent for about 3 months.
350 to 550	Vomiting and nausea in all individuals on first day, followed by other symptoms of radiation sickness. About 50 percent deaths within 1 month; survivors convalescent for about 6 months.
550 to 750	Vomiting and nausea in all individuals within 4 hours from exposure, followed by other symptoms of radiation sickness. Up to 100 percent deaths; few survivors convalescent for about 6 months.
1000	Vomiting and nausea in all individuals within 1 to 2 hours. Probably no survivors from radiation sickness.
5000	Incapacitation almost immediately. All individuals will be fatalities within one week.

[a]From Webb (1962).

Table V-2

Estimated $LD_{50/30}$ Values for Brief Whole-Body Exposures to Ionizing Radiation[a]

Types of Radiation	$LD_{50/30}$ (rad)	Mean Survival Time of 30-Day Decedents (days)	Species
200 kVp X-Rays	640	≈ 13	Mouse
250 kVp X-Rays	705		Mouse (Germ-free)
250 kVp X-Rays	714	≈ 12	Rat
X-Rays	250	≈ 15	Dog
250 kVp X-Rays	600	≈ 14	Monkey (Macaca mulatta)
250 kVp X-Rays	750	≈ 10	Rabbit
200 kVp X-Rays	450	≈ 12	Guinea Pig
200 kVp X-Rays	610		Hamster (Mesocricetus auratus)
1000 kVp X-Rays	250	≈ 17	Swine
200 kVp X-Rays	240		Goat
1.1 MeV Gamma Rays	255		Burro
Neutron-Gamma Rays	374		Burro
Gamma Rays	300 (?)		Man

[a]From Bond *et al.*, 1965.

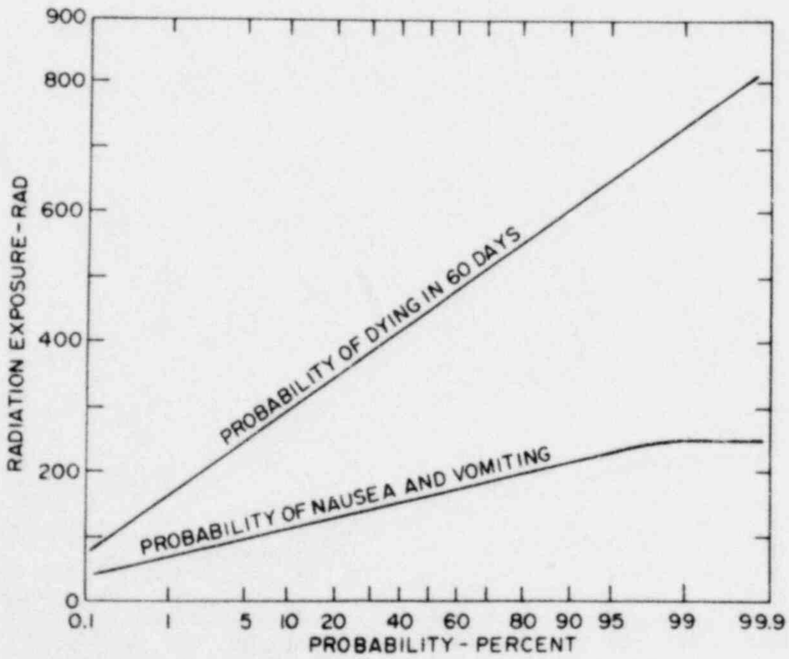

Figure V-1. Relationships between whole-body radiation dose and the probability of early death or nausea and vomiting. These curves are based on Japanese casualties, accidental exposure to fallout, and reactor incidents. Redrawn from Webb (1962).

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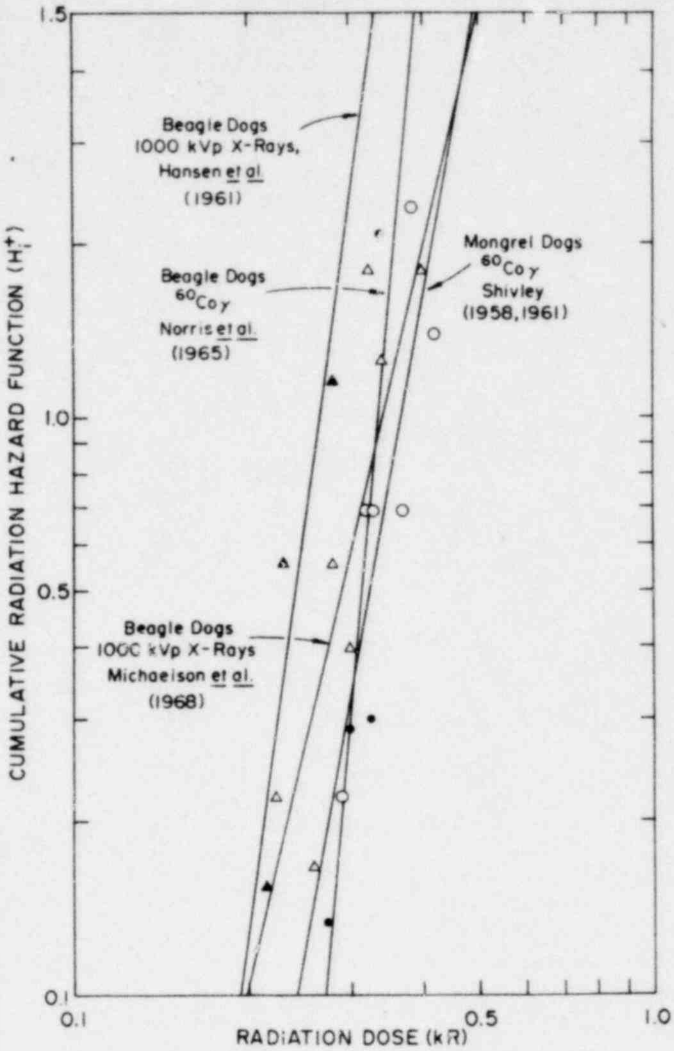
Figure V-2. Cumulative radiation hazard function estimates H_i^+ for early death from injury to the hemopoietic system and associated regression lines for dogs following brief whole-body exposure to low-LET radiations.



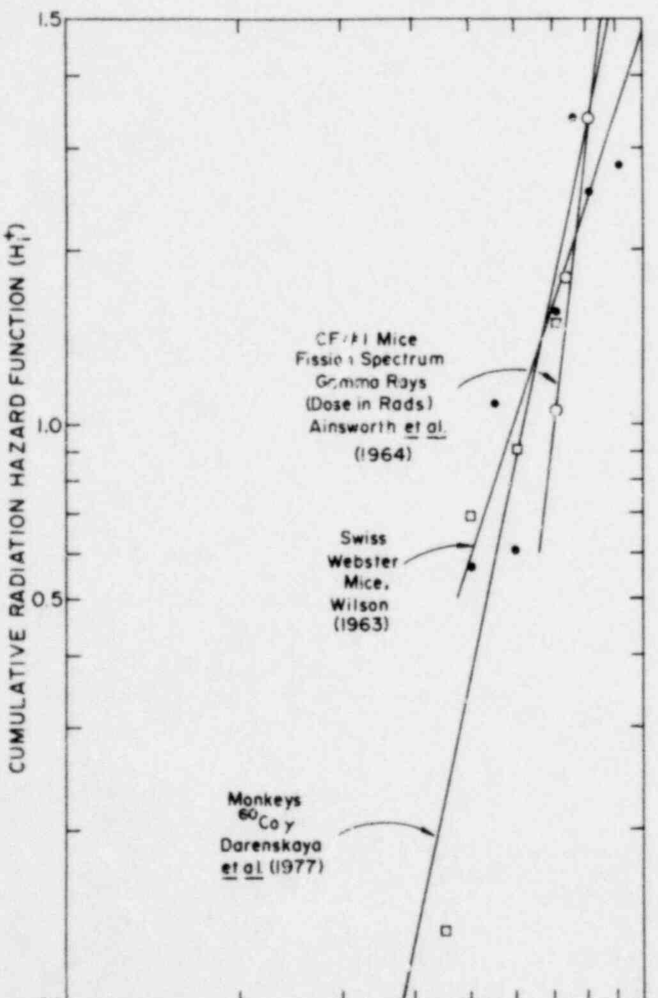


Figure V-3. Cumulative radiation hazard function estimates H_i^+ for early death from injury to the hemopoietic system and associated regression lines for mice and monkeys following brief whole-body exposure to low-LET radiation. The Swiss Webster mice were irradiated with 260-kVp X-rays.

where F_i^+ is the ratio of the number of early deaths from injury to the hemopoietic system to the number irradiated, for a given exposure level. The dose-response curves in Figures V-2 and V-3 appear to be species specific. Mice and monkeys appear to be equally sensitive while both appear to be relatively resistant in comparison to dogs.

Figure V-4 shows similar curves resolved using the hazard-function method for Beagle dogs after inhalation or injection of radionuclides in a relatively soluble form. Table V-3 shows ranges of initial dose rates to the skeleton, initial body burdens, or inital dose rate to the whole body for which early deaths from radiation-induced hematological dyscrasia were observed for the radiation sources in Figure V-4. To obtain conservative dose-response relationships, only data in the ranges shown in Table V-3 were used in resolving the dose-response curves shown in Figure V-4. As a third example of the use of the hazard-function method, Table V-4 illustrates the derivation of the $^{137}CsCl$ data in Figure V-4.

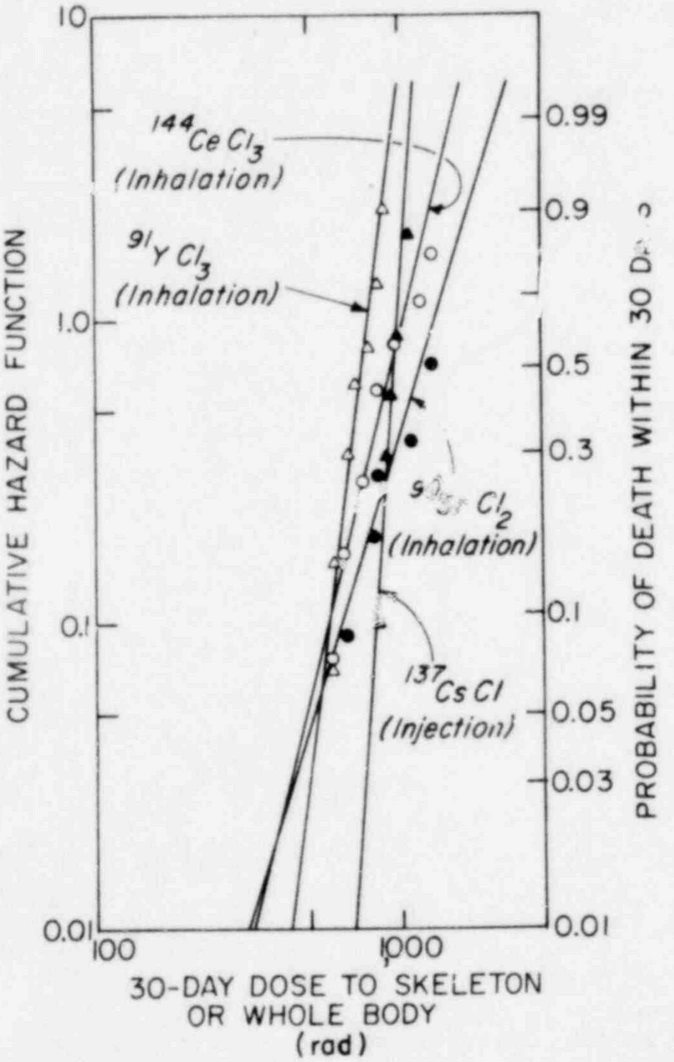


Figure V-4. Cumulative radiation hazard function estimate and associated probability estimate for death from the hemopoietic syndrome (i.e., 30-day mortality) for Beagle dogs after inhalation of $^{91}YCl_3$, $^{144}CeCl_3$ or $^{90}SrCl_2$, or after injection of $^{137}CsCl$.

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Table V-3

Hematological Dyscrasia Data for Beagle Dogs Which Inhaled Aerosols of Beta-Gamma Emitting Radionuclides

Material	Range of Occurrence	Reference
$^{90}SrCl_2$	31 rads/day $\leq$ I.D.R.S.[a] $\leq$ 55 rads/day	Muggenburg *et al.*, 1978
$^{144}CeCl_3$	330 μCi/kg $\leq$ I.B.B.[b] $\leq$ 740 μCi/kg	Merickel *et al.*, 1978
$^{91}YCl_3$	430 μCi/kg $\leq$ I.B.B. $\leq$ 1300 μCi/kg	Muggenburg *et al.*, 1978
$^{137}CsCl$	36 rads/day $\leq$ I.D.R.W.B.[c] $\leq$ 72 rads/day	Hanika-Rebar *et al.*, 1978

[a]Initial dose rate to skeleton.
[b]Initial body burden.
[c]Initial dose rate to whole body.

Table V-4

Hazard Function Method of Analysis of Data for Beagle Dogs for Early Death from Hematological Dyscrasia after Injection of $^{137}CsCl$

Dose[a] (krad)	n_i	d_i	g_i	H_i	F_i
0.86	1	1	1/10 = 0.100	0.100	0.095
0.90	1	0	0/9 = 0.000	0.100	0.095
0.91	2	2	2/8 = 0.250	0.350	0.295
0.92	1	0	0/6 = 0.000	0.350	0.295
0.95	2	1	1/5 = 0.200	0.550	0.423
1.0	2	1	1/3 = 0.333	0.883	0.587
1.1	1	1	1/1 = 1.000	1.883	0.848

[a]Dose at death for members dying within approximately 30 days. For individuals that die at times much longer than 30 days, the dose represents an estimate of the 30-day dose.

Empirical Equations for Low-LET Radiation

An analysis of early mortality radiation dose-response data following whole-body exposure of Beagle dogs to ^{60}Co-gamma rays (Norris, 1965) at high dose rates resulted in D_{10} and D_{50} estimates of 0.21 krad and 0.25 krad, respectively, for early mortality from injury to bone. For man, the D_{50} for whole-body exposure to gamma rays at high dose rates is estimated to be 0.30 krad. The D_{10} for man for whole-body exposure to gamma rays at high dose rates was estimated to be 0.25 krad by assuming that the ratio of the D_{50} to the D_{10} is the same for man and dog. The D_{10} and D_{50} for exposure of the red marrow to internal low-LET radiation sources are based on exposure of Beagle dogs to ^{137}CsCl (Redman *et al.*, 1972).

Presently available data for man are insufficient for estimating the D_{10} and D_{50} for early mortality from injury to bone for internal low-LET radiation sources. These values were estimated for man by assuming that the ratio of the D_{10} or D_{50} for high dose rate whole-body exposure to gamma rays to the 30-day dose D_{10} or D_{50} for exposure to internal low-LET radiation sources is the same for man and dog. Values for dogs are based on the ^{137}CsCl curve for dogs in Figure V-4 and the curve representing the data of Norris *et al.* in Figure V-2. The resultant estimates of the D_{10} and D_{50} for man for internal radiation are 1.0 krad and 1.2 krad, respectively.

For internal emitters in the bone, the hazard function was only computed for the first 30 days. This is because presently available data suggest that the dose sufficient to kill Beagle dogs accumulates within 30 days.

Major Inadequacies in Presently Available Data

Presently available data for early death from radiation-induced injury to bone are insufficient for determining the following:

1. The radiation dose to bone marrow from internal low-LET radiation sources.

2. Appropriate dose-response relationships for early death from injury to the hemopoietic system following exposure to internal high-LET radiation sources.

3. An appropriate method of predicting dose-response relationships for early death from injury to the hemopoietic system following exposure to multiple low- and high-LET radiation sources.

4. The influence of age at exposure on the dose response relationship for man for early death from radiation induced injury to the hemopoietic system.

5. Shape of dose-response relationships for external radiation doses in the region of low incidence of mortality (less than 5%) from radiation injury to the hemopoietic system.

CHAPTER VI. EMPIRICAL DOSE-RESPONSE MODEL FOR GASTROINTESTINAL TRACT

Introduction

Results from early studies of the effects on the gastrointestinal system of brief exposure to large radiation doses from external sources suggest that the likelihood of early death from radiation-induced gastrointestinal injury depends on characteristic processes at four levels of organization (Quastler, 1956):

1. Cellular (stem cells in intestinal crypts): Irradiation inhibits the production of viable new cells.

2. Tissue (intestinal epithelium): The lack of new cells combined with the necrosis of differentiated cells leads to the depletion of intestinal epithelial cells.

3. Systemic (small bowel): The loss of the epithelial lining leads to denudation and breakdown of the barrier which separates the intestinal lumen from the interior of the body.

4. Organismic: The loss of the intestinal barrier leads to early death.

The time of death, which coincides with the denudation of the intestinal epithelium occurs characteristically 3-5 days after irradiation in the conventionally reared mouse, rat, dog, swine and goat; 6-8 days after irradiation in monkeys and germ-free mice; and perhaps even later in man (Upton, 1969).

Cell kinetics in the gastrointestinal tract under both normal and perturbed conditions has more recently been discussed by Hagemann and Concannon (1976). Based on the recent works of many investigators, they have attempted to define the salient factors and interrelationships operating in the response of the small intestinal epithelium to cytotoxic agents. These factors and interrelationships were outlined in a flow chart which is reconstructed in Figure VI-1 and are described as follows.

Radiation-induced abdominal injury involves the two pathways (A and B) shown in Figure VI-1. Beginning with A (Figure VI-1, top), a diminished cell flux into the villus may be caused by killing of crypt cells or by a reduced cell proliferation rate, or by both. Coupled with continued apical cell loss, this will result in a partial depletion of the functional compartment. A negative feedback loop causes a decrease in the mean cell cycle transit time (primarily by shortening the G_1 phase) and an increase in the size of the crypt proliferative compartment (at the expense of the maturation zone in the upper portion of the crypt). The combination of these responses causes a marked increase in the cell production rate per surviving crypt, which after a period of time, leads to the production of differentiated cells. This is augmented by a return to pretreatment proliferative compartment size by emphasizing the likelihood of differentiation over proliferation.

Returning to the top of Figure VI-1 (B pathway), the likelihood of cell killing depends on the cellular age response of the proliferative population, the efficiency of repair of damage and the inherent sensitivity of the cells. Together, these largely determine the level of the crypt progenitor cells (CPC). A CPC is a cell which can, through successive divisions reconstitute a functional crypt.

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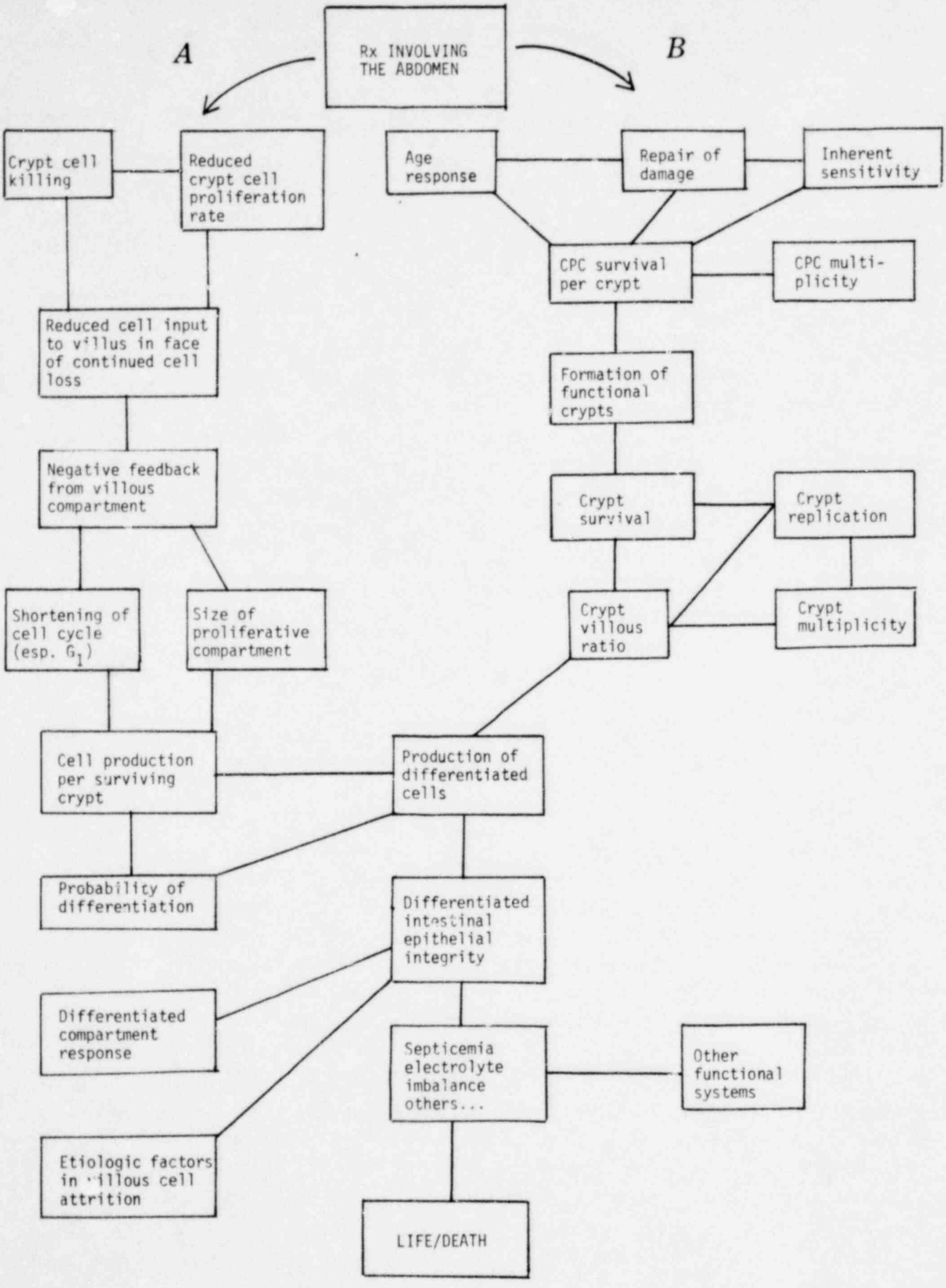

Figure VI-1. Factors involved in the intestinal response to cytotoxic agents. (Hagemann and Concannon, 1975).

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The production of differentiated cells per unit surface area, can be traced directly to the production rate per surviving crypt and to the crypt to villus ratio. This production is necessary for maintenance of the integrity of the functional intestinal epithelium. Lapses in functional epithelial integrity may result in varying degrees of septicema, electrolyte imbalance and other pathophysiological conditions. When significant epithelial denudation has occurred, extraintestinal functional systems assume roles of great importance. It is the systemic effects resulting from intestinal epithelial incontinuities, and to the extent to which they are abrogated by ancillary systems, which determine the outcome.

It is well known that in circumstances where repair of intracellular or systemic injury occurs, the level of biological effect of irradiation depends on the temporal distribution of the radiation dose. This is clearly shown by the data of Hagemann and Concannon (1975) given in Table VI-1 for the dose to 50% mortality for mice after fractionated exposure of the abdomen to 250 kVp x-rays. In these studies, the mice were exposed until death. The results in Table VI-1 suggest that the likelihood of early death following fractionated exposure of the gastrointestinal tract depends on fraction size and frequency of exposure.

Sullivan *et al.*, (1959) reported LD_{50} values for early death from radiation-induced gastrointestinal injury following brief exposure of rats to 250 kVp x-rays (gastrointestinal tract *in situ* or exteriorized). Results of the study suggest that, for exposure of exteriorized intestines, the LD_{50} was 1550 R. The corresponding mean survival time and range were 7.1 days (5.6 to 7.8) for doses from 1300 R to 2100 R. After abdominal irradiation (i.e., *in situ*), Sullivan *et al.*, estimated the LD_{50} to be 1620 R. The corresponding mean survival time and range were 5.7 days (4.0 to 7.8) for doses from 1300 R to 2100 R. Differences between the LD_{50} values were attributed to shielding of the intestines *in situ*.

If the doses to 50% mortality in Table VI-1 are used as estimates of the LD_{50} for fractionated exposures, then the LD_{50} for early death from gastrointestinal injury can vary by a factor of 11,500/1550 or 7 times due to changes in the temporal distribution of the radiation dose.

Internal Radiation Sources

Sullivan *et al.*, (1978) have more recently examined the toxicity of ingested beta-emitting radionuclides which have low absorption from the gastrointestinal tract to blood. The toxicity of ingested, poorly absorbed radionuclides depends on the energy of the emitted radiation, radiation quality, the mass of the intestinal contents, and the time that the nuclide remains in the bowel segment. The energy and quality dependence results because the critical cells (crypt cells) are located at various depths beneath the surface of the mucosa. Sullivan *et al.*, (1978) have made several relevant observations concerning the consequence of ingesting a lethal dose of poorly absorbed beta-emitting radionuclides which are as follows:

1. When ^{106}Ru-^{106}Rh was administered by gavage on a body weight basis, the order of sensitivity of the rats to the lethal effects were newborn > adults > weanlings.

2. The transit time of the intestinal contents of non-fasted rats is much slower than that for fasted rats. In non-fasted rats, the critical segment of the lower bowel may be the cecum rather than the lower large intestine.

3. Dogs fed sufficient ^{106}Ru-^{106}Rh died from injury to the large intestine but did not exhibit the early death (less than 8 days) that is usually associated with the gastrointestinal syndrome.

Table VI-1

Time Dose Schedules for Abdomen-Only Irradiation, and Exposure, Days and Fractions to Reach 50 Percent Animal Lethality[g]

Code Number	Exposure Per Fraction (R)	Fractions Per Day	Irradiation (Days Per Week)	Exposure Per Week (R)	Exposure (R) to 50% Mortality	Days to 50% Mortality	Fractions to 50% Mortality
1	200	1	5[a]	1,000	11,500	79	58
2	300	1	5	1,500	7,900	35	26
3	400	1	5	2,000	4,700	15	11.8
4	500	1	5	2,500	3,250	7.7	6.5
5	600	1	5	3,000	4,350	8.8	7.3
6	300	1	3[b]	900	5,300	38.9	17.7
7	300	1	4[c]	1,200	9,600	54.3	32.0
8	400	1	3[b]	1,200	2,800	14.0	7.0
9	500	1	2[d]	1,000	3,500	21.0	7.0
10	500	1	3[b]	1,500	3,700	15.2	7.5
11	800	1	1	800	2,650	16.2	3.3
12	900	1	1	900	1,800	7.0	2.0
13	1,000	1	1	1,000	1,800	5.6	1.8
14	200	2[e]	1.75[f]	700	9,400	90	47
15	200	3[e]	1.75[f]	1,050	8,700	54	44
16	300	2[e]	1.75[f]	1,050	10,400	65	35
17	300	3[e]	1.75[f]	1,575	8,350	33	28

[a] M T W Th F

[b] M W F

[c] M T W Th

[d] MF

[e] Separated by 4 hours.

[f] Every 4 days.

[g] From Hagemann and Concannon (1975).

Sullivan *et al.*, (1978) estimated the LD_{50} dose to crypt cells to be approximately the same (3500 rad) for beta particles from ^{106}Ru-^{106}Rh or from ^{147}Pm. Because of the short range of alpha particles in tissue, and the depth of the critical crypt cells, early death from gastrointestinal injury caused by alpha irradiation is unlikely (Sullivan *et al.*, 1960).

Gastrointestinal Tract Model

Because of the magnitude and complexity of the problem of early mortality modeling for inhalation exposure, our major effort in Phase I has been devoted to injury to the lung and to a lesser extent, injury to bone. Consequently, our model for the gastrointestinal is incomplete at this stage. Results from an analysis of presently available data suggest that the cumulative radiation hazard function for early death from injury to the gastrointestinal tract is adequately represented by the Weibull cumulative hazard function. We have fitted this function to data reported by Sullivan *et al.*, (1959) for x-ray exposure of the intestines of rats (intestines exteriorized) assuming the rad doses to the gastrointestinal tract to be approximately equal to the R values reported. The resultant cumulative hazard function H_o represents our best estimate of the limiting cumulative hazard function at high dose rates (i.e., worst case exposure) and is given by (see Figure VI-2)

$$H_o = 4.6 \times 10^{-3} D^{11}, \qquad (1)$$

where D is the radiation dose to the critical cells in the gastrointestinal tract in krad. The proportion of the exposed population with gastrointestinal injury sufficient to cause early death is given by F_o, where

$$F_o = 1 - e^{-H_o} \qquad (2)$$

For internal emitters, a D_{50} of 3.5 krad was used based on data from Sullivan *et al.*, (1978). The D_{10} for internal emitters is estimated to be about 2.9 krad assuming the ratio of the D_{50} to the D_{10} to be the same as for exposure to external radiation at high dose rates. The resultant hazard function estimate H_I for internal emitters in the gastrointestinal tract is given by

$$H_I = 2.5 \times 10^{-6} D^{10}, \qquad (3)$$

where D is in krads.

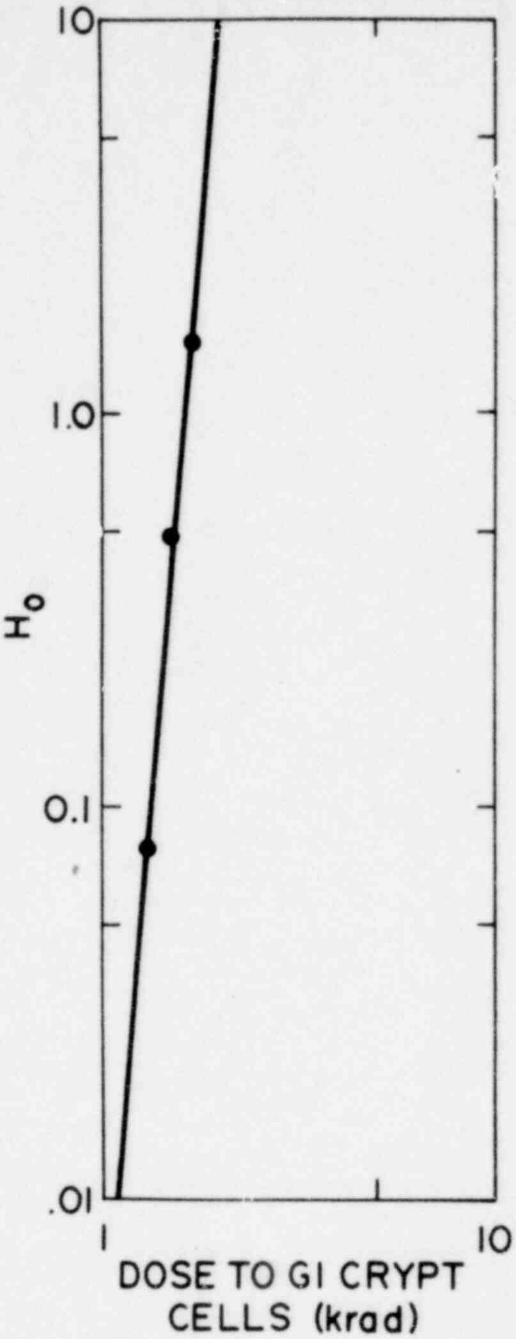

Figure VI-2. Cumulative radiation hazard function for gastrointestinal injury sufficient to cause early death. Based on data reported by Sullivan *et al.*, (1959) for X-ray exposure of the intestines of rats (intestines exteriorized).

Major Inadequacies in Present Gastrointestinal Tract Model

A major problem with the present model for the gastrointestinal tract is that it does not adequately take into account dose rate effects. Another problem is that the dosimetry model of the gastrointestinal tract overestimates the radiation dose because the task group lung model overestimates the amount of a radionuclide which is cleared from the respiratory to the gastrointestinal tract.

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CHAPTER VII. COMPOSITE EXPOSURE MORTALITY MODEL

The most common accidents resulting in high-level exposure of people have involved external irradiation or internal deposition of single radionuclides. In handling irradiated reactor fuel materials in the future, the most probable high-level exposures will also include mixtures of external irradiation and internally deposited beta- and gamma-emitting fission products. Significant exposures to alpha-emitting radionuclides are also possible; however, these would probably be of lesser importance in producing acute lethality in people. A matrix of the most important radiation exposure modes and the organs irradiated is outlined in Table VII-1. A computer simulation program for estimating early mortality which could be anticipated after very high-levels of these types radiation exposures of people is described in this chapter. This computer program is more complete in dealing with irradiation of the whole body, bone marrow and lungs, but is less developed for irradiation of the gastrointestinal tract, liver, thyroid and combinations of all the internal organs. A major goal in Phase II of this research program will be to improve these current deficiencies.

The overall design of the computer simulation model for developing early mortality estimates is illustrated in Figures VII-1 and VII-2. It is composed of two computer programs, DOSE and EFFECT. Radiation exposures of people are assumed to result only from a passing cloud of radioactive isotopes. This could produce external gamma ray exposures and inhalation exposures to alpha-, beta- and gamma-emitting radionuclides. Ingestion of radionuclides is not considered to be a major exposure mode since preventative measures should intervene.

To initiate the simulation, the user must supply the information listed in Table VII-2 for each exposure and for each isotope in the radioactive cloud. The first computer program, DOSE, (Figure VII-1) is used to calculate the deposition of radionuclides in the respiratory tract, subsequent interorgan translocation, and the radiation doses for lung, bone marrow, liver and gastrointestinal tract. It also estimates the magnitudes of external radiation doses to individual organs. These calculations are described in detail in Chapter II of this report. All of the low-LET radiations for single organs are summed and output to a disc file providing doses as functions of time after exposure. The same procedures are followed for high-LET radiations in producing a second disc file. The two resulting disc files provide the input information for the second computer program which estimates the potential early mortality related to the radiation exposures.

The second program, EFFECT, first reads the input radiation dose functions and divides these functions into time increments, Figure VII-2. The first time increment is the duration of the initial exposure event. Subsequent time increments are one-day intervals. The organ doses, D_i, dose rates, R_i, and effective half-times for the decreases in dose rates, $T_{1/2}$, are then determined for each time interval and each body organ. The mortality hazard functions (i.e., the negative logarithms of the dose survival probabilities) are then calculated for each organ separately, but the hazards from simultaneous high- and low-LET radiations to single organs are summed for each dose increment.

The method for obtaining the cumulative radiation hazard function for a given radiation exposure of the lung was discussed in Chapter IV. Thus, only the sequence steps used in the computer simulation program will be discussed here. The hazard function based on an assumed Weibull

Table VII-1

Summary of Most Important Radiation Exposure Modes and Organs Irradiated Following Hypothetical Nuclear Fuel Cycle Accidents

Exposure Mode[a]	Radiation Injury to: GI Tract	Lung	Bone	Total Body
External γ	X	X	X	X
Internal β_{sol}	X	X	X	
Internal β_{insol}	X	X		
External $\gamma + \beta_{sol} + \beta_{insol}$	X	X	X	X
Internal α_{sol}		X	X	
Internal α_{insol}		X		
External $\gamma + \beta_{sol} + \beta_{insol} + \alpha_{sol} + \alpha_{insol}$	X	X	X	X

[a]External = external exposure; internal = internal deposition of radionuclides; α,β or γ = type of irradiation; sol = soluble form of radionuclide, insol = insoluble form of radionuclide.

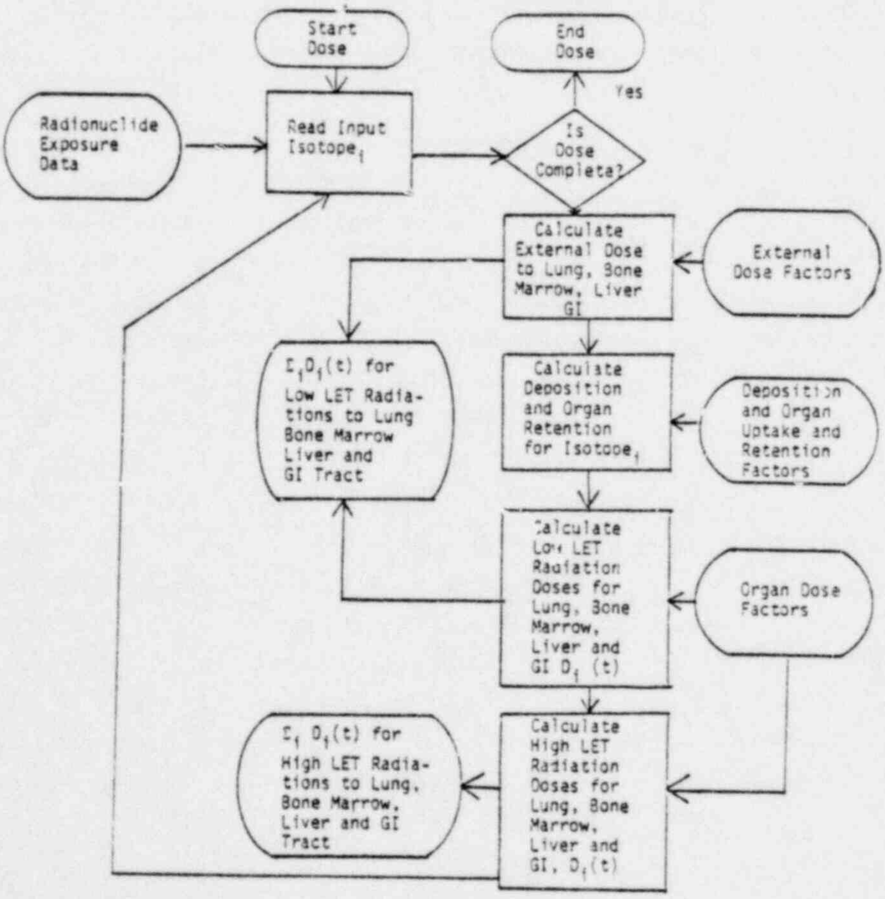

Figure VII-1. Flow diagram used in computer program, DOSE.

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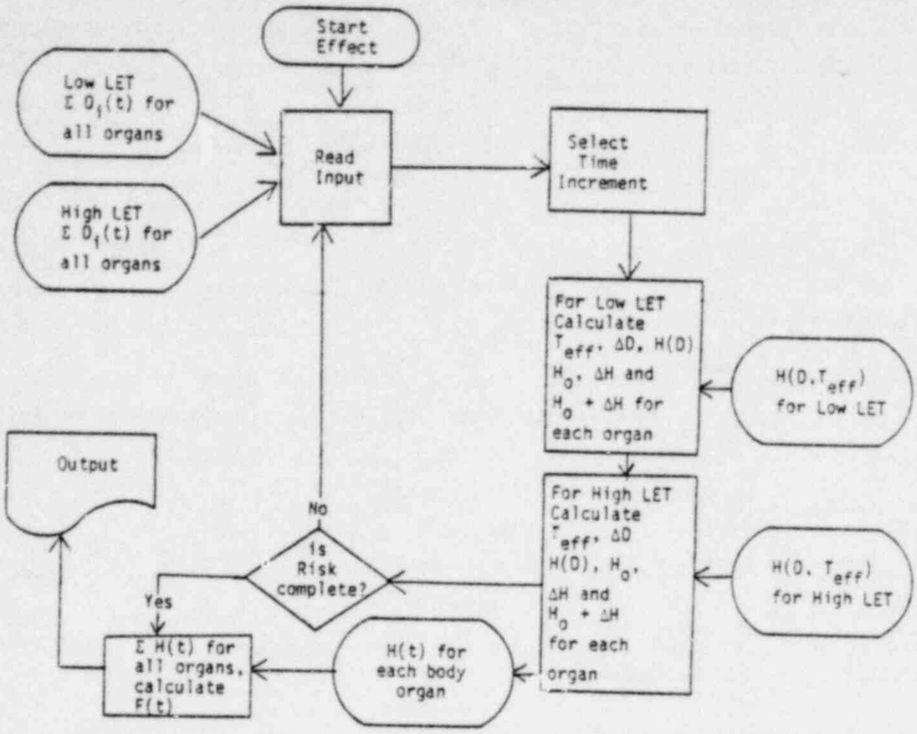

Figure VII-2. Flow diagram used in computer program, EFFECT.

Table VII-2

Sample of Data Input Necessary to Initiate Simulation of DOSE Computer Program

Input Information	Sample Input	Comment
Exposure Duration	0.1	Duration of exposure is specified in days.
Number of Output Times	5	Number of times on the next line at which output is desired.
Output Times	1, 10, 50, 100, 365	Times at which doses and cumulative hazard function is printed.
GASP IV Control File	DBZISIMULZ.DAT	Name of GASP I. control file used by the program.
Isotope	Pu238	Isotopes are specified by element symbol and atomic weight.
Particle Solubility	Y	Solubility classes refer to the ICRP Task Group on Lung Dynamics; D, W, or Y.
Aerosol Concentration	5.7 E-4	Isotope concentrations are given in Ci/m^3.
Aerosol Size	1	Particle sizes are specified in μm AMAD.

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distribution, can be written as a function of the D_{10} and D_{50} doses (the doses required to kill 10% or 50% of the exposed populations). A simplified expression of this function is:

$$H = (\ln 2)\,(D/D_{50})^{1.88/\ln\,(D_{50}/D_{10})} \tag{1}$$

where D is the radiation dose delivered to the organ during some increment of time. For low-LET radiation, the D_{10} and D_{50} doses were related to the effective half-lives for retention of the radionuclides in the lung or the radiation dose rates for bone or for the gastrointestinal tract.

For lung, the method of obtaining the cumulative radiation hazard from an accident is illustrated in Figure VII-3. The exposure to gamma rays during passage of the radioactive cloud is assumed to be brief. The gamma-ray dose to the whole-body is used to calculate the cumulative hazard, H_1, which is the cumulative radiation hazard for lung up to the end of the exposure period. The cumulative hazard is then calculated for radionuclides in lung over the next time increment to give $\Delta H_1 + \Delta H_2$. This process is continued such that cumulative radiation hazard function for lung up to some time, t, after the inhalation exposure is given by $H(t) = \sum_1^n \Delta H_i$. For each time increment, a new hazard function is derived from the above equation as described in detail for low-LET radiation in Chapter IV.

Figure VII-3 gives an example for a mixture of insoluble beta emitters in the lung. Increments in H(t) are represented by ΔH_1, ΔH_2 and ΔH_3 for consecutive time intervals. Mean T_e values for these time intervals are represented by $(T_e)_1$, $(T_e)_2$ and $(T_e)_3$, respectively. For the first time interval, the radiation dose increment is given by D_1. For this time interval, H(t) is

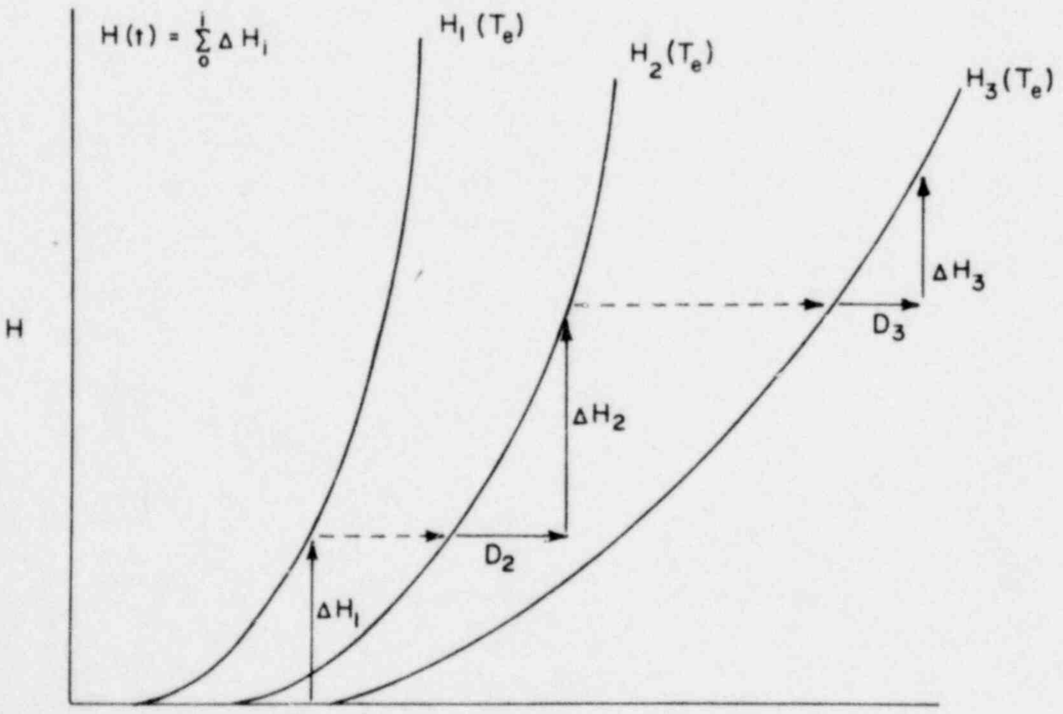

Figure VII-3. Illustration of the method used in determining the total hazard for beta emitters in the lung. Here, hazard function increments H_i for time and dose increments i = 1,2,3... are combined to obtain the total hazard function H(t).

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determined by the dose-dependent curve for $H_1[(T_e)_1]$. The radiation dose D_1, delivered with a mean T_e equal to $(T_e)_1$, is equivalent to the second dose delivered with a mean T_e equal to $(T_e)_2$. This is the dose at which the horizontal dashed line from curve $H_1[(T_e)_1]$ in Figure VII-3 intersects the curve $H_2[(T_e)_2]$. Since for the second time interval the mean value of T_e is $(T_e)_2$, the appropriate curve for this interval is $H_2[(T_e)_2]$. The appropriate dose for the start of the second time interval is the equivalent dose. With the proposed method of estimating early mortality probabilities, the use of RBE values is avoided. The above procedure is continued for subsequent time intervals until the end of the period of time for early mortality, approximately 18 months.

When alpha emitters are also present in the lung, it is necessary to determine two hazard function increments for each time interval; one caused by an increment in the high-LET dose over the time interval and a second caused by an increment in the low-LET dose over the interval. The two increments are summed to determine the total increment for that time interval. Equivalent doses must then be determined for both low- and high-LET sources. The equivalent doses depend on H(t) at the end of the time interval and are determined in the same manner as described above for a mixture of low-LET radiation sources. Different hazard function curves are used for high- and low-LET radiation sources; however, we have used only one curve for high-LET radiation since no effect of retention half-time has been reported to date.

The total cumulative hazard, H, calculated by the EFFECT program can be used to calculate the probability of mortality by using the following formula

$$\text{Pr. of mortality} = 1 - e^{-H}. \tag{2}$$

This is the probability of dying from early effects by 1.5 years after exposure. This is the only time period for which the calculations are valid because it was the period used to derive the hazard functions. This period was decided upon because most of the animals in the studies died before this time.

For reasons discussed in Chapter V, only low-LET radiation doses are considered for bone. The cumulative radiation hazard function for bone is based on the 30-day dose to bone and is estimated in a manner similar to that used for lung. The cumulative radiation hazard for bone from external gamma rays from the radioactive cloud is determined from whole body, dose-response relationships which have been developed for people. Relevant formulas are given in Chapter V. For the gastro-intestinal tract, the cumulative radiation hazard after inhalation exposure is assumed to depend only on the radiation dose to critical cells. Relevant formulas are given in Chapter VI. The output information from EFFECT includes the total cumulative hazard for the lung, bone, and gastro-intestinal tract.

Examples of the computer outputs from the DOSE and EFFECTS programs are shown in Figures VII-4 and VII-5, respectively. The first output lists the input information to the exposure calculation for a single isotope, ^{90}Y. Next the output lists the external radiation doses to the various internal organs, which in this case are zero because there is no gamma radiation component. Finally, the high- and low-LET radiation doses are listed for the various organs as functions of time after exposure. These doses, only in shorter increments of time, are input into the EFFECTS program.

The sample output from the EFFECTS program in Figure VII-5 summarizes the organ dose functions and the total cumulative hazard at 550 days after exposure. The program is executed for 550 days (1.5 years) because the vast majority of early deaths will occur with this time after exposure. Both of the computer outputs can be obtained for single isotopes or for mixtures of isotopes (about 50 isotopes at the present time). When mixtures of isotopes are present in the exposure cloud of radionuclides, the cumulative hazard is related to total mixture and not single isotopes.

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SIMULATION FOR ISOTOPE Y90
DISSOLUTION-DISTRIBUTION PARAMETERS FROM DB2:TGLMY.DAT

CALCULATIONS ARE FOR THE ISOTOPE IN A Y-CLASS COMPOUND.

ISOTOPE HALF-LIFE (DAYS) = 2.67
ISOTOPE IS A BETA-GAMMA EMITTER
ATMOSPHERIC CONCENTRATION (MICROCURIES/L) = 150.
PARTICLE SIZE (MICRONS) = 1.00
LENGTH OF ATMOSPHERIC EXPOSURE (DAYS) = 0.100

TASK GROUP LUNG MODEL DEPOSITION EFFICIENCIES.

FOR A PARTICLE SIZE OF 1.00 MICRON,
THE EXPECTED DEPOSITION FRACTIONS ARE :

NASOPHARYNGEAL	=	0.310
BRONCHIAL	=	0.800E-01
PULMONARY	=	0.249

BREATHING RATE (LITERS/DAY) = 0.160E+05

INTERNAL DOSES IN RADS (TIME IN DAYS AFTER BEGINNING OF EXPOSURE)

DOSE HIGH LET (RADS)
DOSE LOW LET (RADS)

TIME	LUNG	BONE	BONE MAR.	LIVER	TBLN	THYROID	L. LG. INT.
5.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.793E+04	11.5	4.44	10.5	215.	0.000	0.114E+05
10.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.925E+04	14.8	5.71	13.5	426.	0.000	0.116E+05
50.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.974E+04	16.1	6.20	14.7	583.	0.000	0.116E+05
100.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.974E+04	16.1	6.20	14.7	583.	0.000	0.116E+05
200.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.974E+04	16.1	6.20	14.7	583.	0.000	0.116E+05
400.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.974E+04	16.1	6.20	14.7	583.	0.000	0.116E+05
550.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.974E+04	16.1	6.20	14.7	583.	0.000	0.116E+05

Figure VII-4. Sample output for computer program DOSE. This simulation was for ^{90}Y only and extended for 400 days.

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TABLE OF DOSES IN KILORADS AT TIMES IN DAYS AFTER BEGINNING OF THE EXPOSURE

	******* HIGH LET DOSE ******			******* LOW LET DOSE ******		
TIME	LUNG	MARROW	GI TRACT	LUNG	MARROW	GI TRACT
5.	0.000	0.000	0.000	7.93	0.444E-02	11.4
10.	0.000	0.000	0.000	9.25	0.571E-02	11.6
50.	0.000	0.000	0.000	9.74	0.620E-02	11.6
100.	0.000	0.000	0.000	9.74	0.620E-02	11.6
200.	0.000	0.000	0.000	9.74	0.620E-02	11.6
400.	0.000	0.000	0.000	9.74	0.620E-02	11.6
550.	0.000	0.000	0.000	9.74	0.620E-02	11.6

FRACTION SURVIVING AT 550 DAYS = 0.0000

Figure VII-5. Sample output of computer program EFFECT. This output is for ^{90}Y only and follows the exposure data given in Figure VII-4.

Examples of hazard calculations from use of the EFFECTS program are described in Chapter VIII. These calculations are for single isotope exposures in laboratory animals and are given to illustrate the use of these computer programs. Unfortunately, we do not have data from animal exposures to mixed radiations to test the present model, but this will be a major goal for Phase II studies.

Example of Hazard Function Calculation

This section will show how simple calculations can be performed using the hazard function model in a manner similar to the calculations performed in the EFFECT program. The purpose of this example is to show the general steps that the computer program uses and to provide the user with a simple method to apply the hazard functions if he does not have access to the computer model. In this example, the curve for the dose rate to lung and cumulative dose to lung shown in Figure VII-6 will be used. These curves represent a hypothetical mixture of a Class W (^{90}Y) aerosol and a Class Y (^{90}Sr) aerosol deposited in the lung. For the purposes of our example, we have not included the calculations for organs other than the lung since their radiation doses are small by comparison and no mortality from early effects would be expected.

The calculation consists of four different steps. First, the dose rate curve for the lung is divided into regions with different effective half-lives. Second, these half-lives are used to calculate the hazard functions used to derive the total cumulative hazard. The third step, which is the most involved step, uses the hazard function for each region of the dose rate curve and the dose curve to derive the total cumulative hazard. Fourth, the probability of mortality from early effects by 1.5 years after exposure is calculated. The calculation can only estimate mortality within 1.5 years after exposure since this was the time period used in deriving the hazard functions.

In Figure VII-6 the dose rate curve was divided into four regions for the example shown. The number of regions depends upon how many are necessary for the effective half-life to be relatively constant over each region. Here it was found that four regions with effective half-lives of 2.1, 14, 180 and 500 days gave a good representation of the dose rate curve as shown in Table VII-3.

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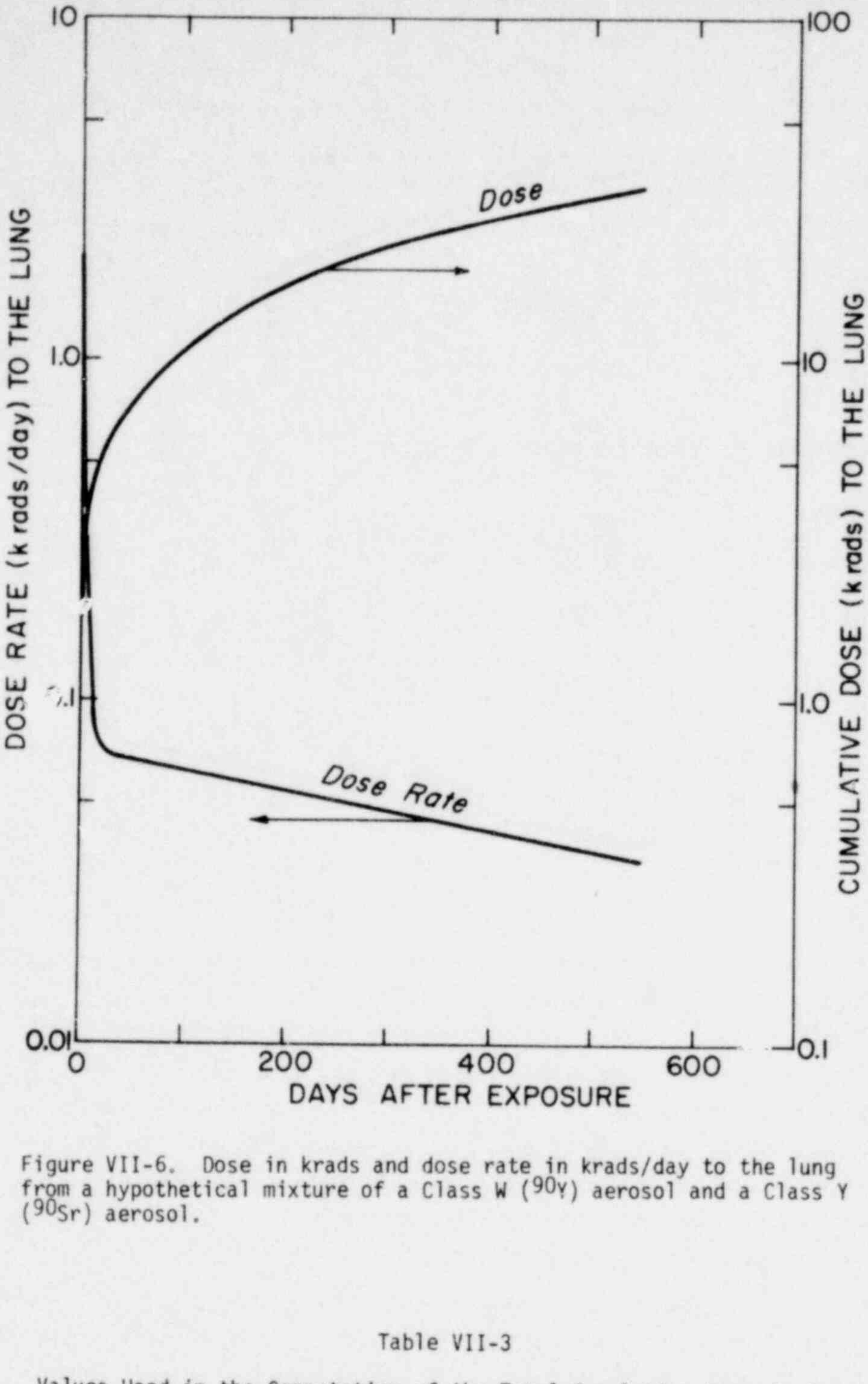

Figure VII-6. Dose in krads and dose rate in krads/day to the lung from a hypothetical mixture of a Class W (^{90}Y) aerosol and a Class Y (^{90}Sr) aerosol.

Table VII-3

Values Used in the Computation of the Total Cumulative Hazards for the Regions of the Dose Rate Curve

Region (days)	Half-Life (days)	Hazard Function D_{10} (krads)	D_{50} (krads)	Dose at end of region (krads)	Equivalent dose (krads)	H	Probability of Mortality
0-10	2.1	7.5	9.4	4.34	-	0.00111	-
10-20	14	11	13	5.22	7.34	0.00396	-
20-40	180	27	44	6.61	11.5	0.00616	-
40-550	500	42	57	31.5	26.5	0.365	0.31

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The D_{10} and D_{50} values for the hazard function for each region were obtained by linearly extrapolating between values shown in Table IV-5 for the half-lives in Table VII-3. The hazard functions in Figure VII-7 were generated using the derived D_{10} and D_{50} values.

The hazard functions are next used in conjunction with the dose curve to derive the total cumulative hazard. This is shown graphically in Figure VII-7 by the dashed lines and the circle on curve IV to indicate the total cumulative hazard. The calculations necessary to find this point are outlined below. The first step in the process is to find the total cumulative dose at the end of the first region in Figure VII-6. This is 4.34 krads at 10 days. This dose is used to calculate ΔH_1 using the first hazard function.

$$\Delta H_1 = (\ln 2)\left(\frac{\text{Dose}}{D_{50}}\right)^{1.88/\ln (D_{50}/D_{10})} \qquad (3)$$

$$\Delta H_1 = (\ln 2)\left(\frac{4.34}{9.4}\right)^{1.88/\ln (9.4/7.5)} \qquad (4)$$

$$\Delta H_1 = 0.00111 \qquad (5)$$

The value of ΔH_1 is now used to find what dose gives the same hazard for the second hazard function. This equivalent dose, D_{eq}, can be calculated using the following formula

$$D_{eq} = D_{50}\left(\frac{D_{50}}{D_{10}}\right)^{\ln(\Delta H_1/\ln 2)/1.88}$$

$$= 13\left(\frac{13}{11}\right)^{\ln(0.00111/\ln 2)/1.88} \qquad (6)$$

$$= 7.34 \text{ krads}$$

To find the total hazard at end of the second region, the total dose accumulated between 10 and 20 days, 0.880 krads, is added to D_{eq} to obtain 8.22 krads. This dose is used to calculate $\Delta H_1 + \Delta H_2$

$$\Delta H_1 + \Delta H_2 = (\ln 2)\left(\frac{8.22}{13}\right)^{1.88 \ln (13/11)}$$

$$= 0.00396 \qquad (7)$$

The value of $\Delta H_1 + \Delta H_2$ is used to calculate the equivalent does for the third hazard function

$$D_{eq} = 44\left(\frac{44}{27}\right)^{\ln(0.00396/\ln 2)/1.88}$$

$$= 11.5 \text{ krads} \qquad (8)$$

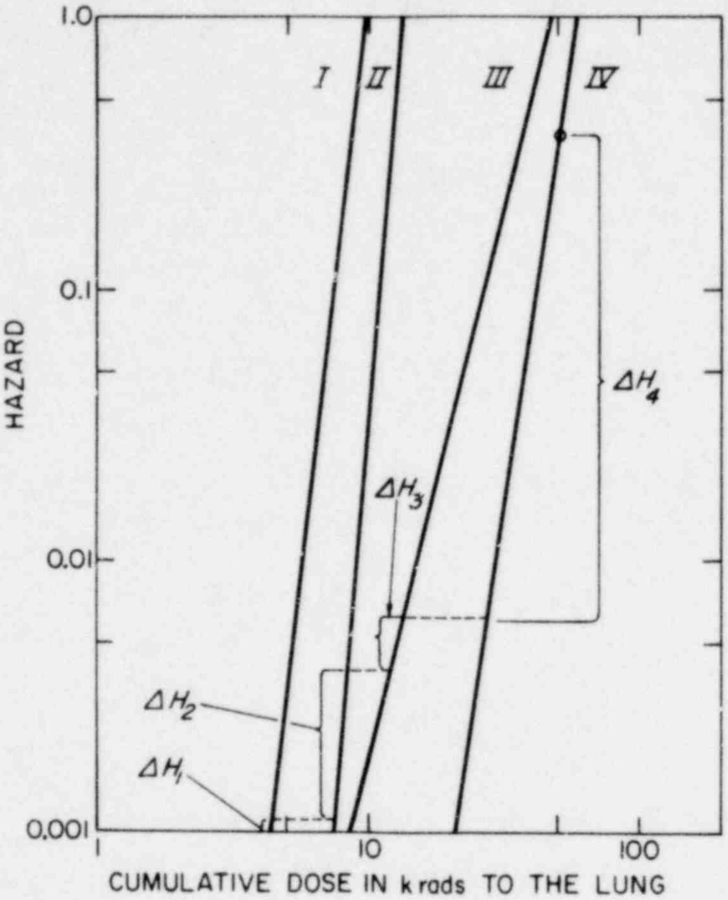

Figure VII-7. Hazard functions for the four regions of the dose rate curve as shown in Table VII-3. Curve I is for the first region (0-10 days) which has an effective half life of 2.1 days and hazard function parameters of D_{10} = 7.5 krads and D_{50} = 9.4 krads. Curve II is for the second region (10-20 days) which has an effective half life of 14 days and hazard function parameters of D_{10} = 11 krads and D_{50} = 13 krads. Curve III is for the third region (20-40 days) which has an effective half life of 180 days and hazard function parameters of D_{10} = 27 krads and D_{50} = 44 krads. Curve IV is for the fourth region (40-550 days) which has an effective half life of 500 days and hazard function parameters of D_{10} = 57 krads and D_{50} = 42 krads. The dashed lines snow the graphical derivation of total cumulative hazard for mortality from early effects by 550 days (1.5 years) after exposure.

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Proceeding with the steps outlined above, we calculate

$$\Delta H_1 + \Delta H_2 + \Delta H_3 = \ln 2 \left(\frac{11.5 + 1.4}{44}\right)^{1.88 \ln(44/27)}$$

$$= 0.00616 \tag{9}$$

For the fourth hazard function, we calculate

$$D_{eq} = 57 \left(\frac{57}{42}\right)^{\ln (0.00616/\ln 2)1.88}$$

$$= 26.5 \text{ krads} \tag{10}$$

$$H = \Delta H_1 + \Delta H_2 + \Delta H_3 + \Delta H_4 = \ln 2 \left(\frac{26.5 + 24.9}{57}\right)^{1.88 \ln(57/42)}$$

$$= 0.365 \tag{11}$$

This is the total cumulative hazard for mortality from early effects by 550 days after exposure. This value can be used to calculate the probability of death in this time period.

$$\text{Probability of mortality} = 1 - e^{-H}$$

$$= 1 - e^{-0.365}$$

$$= 0.31$$

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CHAPTER VIII. COMPARISON OF ITRI MODEL WITH OTHER EARLY MORTALITY MODELS

Mathematical models for estimating early mortality in people exposed to high levels of external irradiation or internally deposited radionuclides have been developed by Wells (1976), Goldman (1977) and the Health Effects Advisory Committee for the Reactor Safety Study (1975). Most of the data on early radiation mortality used in developing these models were derived from the same groups of studies on human populations and dogs exposed to external radiations or inhaled radioactive aerosols. The major differences in these models relate to their degrees of flexibility and completeness for dealing with complex mixtures of radiations and with injuries to the different internal body organs. In this chapter, the general approaches used in each model will be outlined and a comparison of model projections for test radiation exposure situations will be presented.

Early Mortality Projections in the Reactor Safety Study

The mortality model used in the Reactor Safety Study identifies injuries to the bone marrow, lung, gastrointestinal tract, thyroid and fetus as the important causes of early mortality in irradiated people. For accidents leading to releases of irradiated nuclear fuel materials (Reactor Safety Study, 1975), injuries to bone marrow and the hematopoietic system dominated the early mortality projections, Figure VIII-1. Most of the projected radiation dose was derived from exposure to contaminated ground surfaces (≈ 65%) along with direct irradiation from passing cloud (≈ 15%) and internal radiation from absorption of inhaled radionuclides (≈ 20%). The critical dose to bone marrow was taken to be the sum of;

1. external dose from the passing cloud
2. external dose from contaminated soil
3. internal dose to bone marrow for first 7 days
4. 1/2 of the dose to bone marrow from 8 to 30 days.

The percent mortality from bone marrow irradiation was estimated from the critical dose and the radiation-response curve (B) reproduced in Figure VIII-2.

Early mortality from injury to the lung was projected from laboratory animal studies in which dogs inhaled either ^{90}Y or ^{91}Y. These are shortlived radionuclides (half-lives of 64 hours and 59 days, respectively) which, if inhaled, would produce a similar radiation dose rate pattern to lung over the first year as would fresh mixed fission products. The radiation dose-response criterion for early lung injury derived from these studies is shown in Figure VIII-3. The critical dose to lung was calculated by adding;

1. external dose from the passing cloud
2. external dose from ground contamination
3. internal dose from inhaled radionuclides within 365 days.

Although the internal dose to lung was integrated for 365 days, most of this was projected to occur in less than 60 days.

Early mortality from irradiation of the gastrointestinal tract was mainly projected from studies in dogs since no data from human populations were available. The dose to regenerative cells of the lower large intestine was taken to be the critical dose and this was the sum of;

1. external dose from the passing cloud
2. external dose from contaminated ground
3. internal dose within 7 days from inhaled radionuclides.

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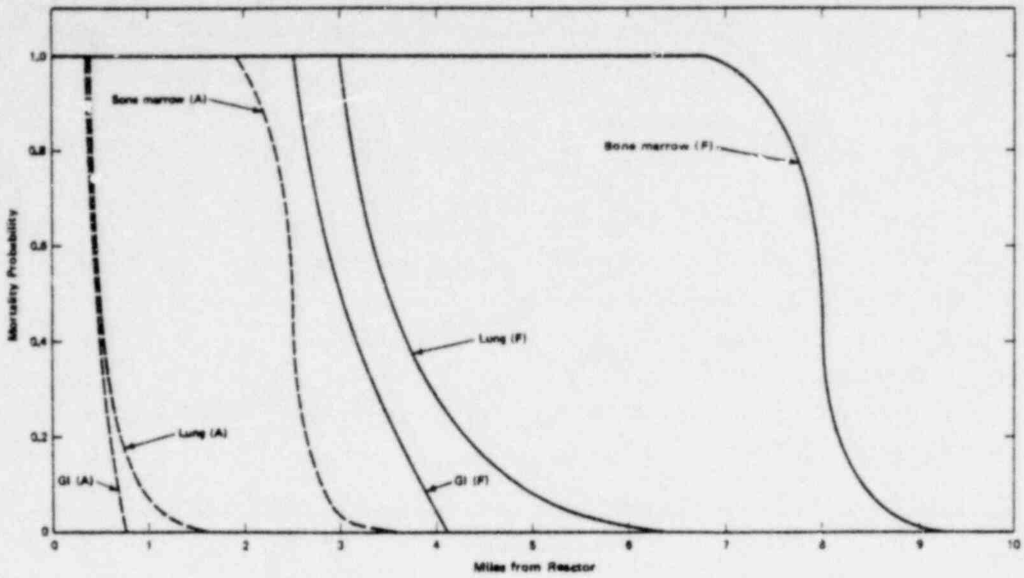

Figure VIII-1. Mortality probability for an affected population versus distance from reactor for two hypothetical weather conditions: stability category A, wind speed = 0.5 m/sec; stability category F, wind speed = 2.0 m/sec. (From "Reactor Safety Study," WASH-1400, Appendix VI, p. 13-9.

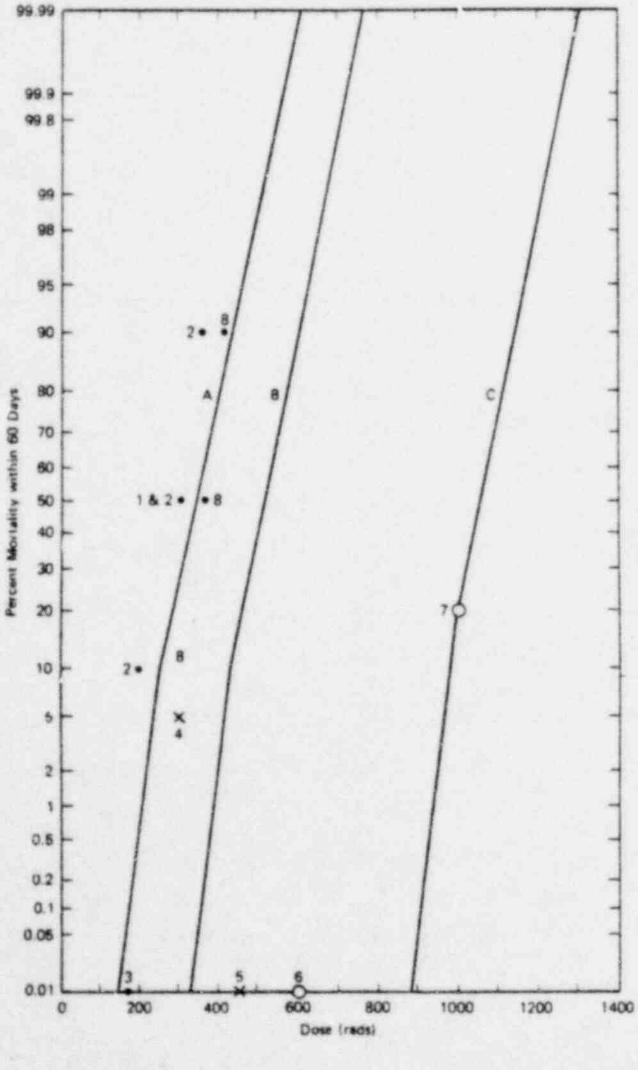

Figure VIII-2. Estimated dose-response curves for 50% mortality in 60 days with minimal treatment (curve A), supportive treatment (curve B), and heroic treatment (curve C). Origin of data points: 1, NCRP Report 42 (converted to rads using factor given in NRC Report 42); 2, Langhorn (1957, Table 12, estimate for "normal man?"); 3, Marshall Islanders (protracted exposure); 4, radiation therapy series, 22 patients (Rider and Hasselback, 1968); 5, clinical group III accident patients (Thomas and Wald, 1959, with newer cases added); 6, Pittsburgh accelerator accident patient (E. D. Thomas, 1971; Wald, 1975); 7, 37 leukemia patients (E. D. Thomas, 1975); 8, "best estimate" of the Biomedical and Environmental Assessment Group at the Brookhaven National Laboratory. (From "Reactor Safety Study," WASH 1400 Appendix VI, p. 9-4).

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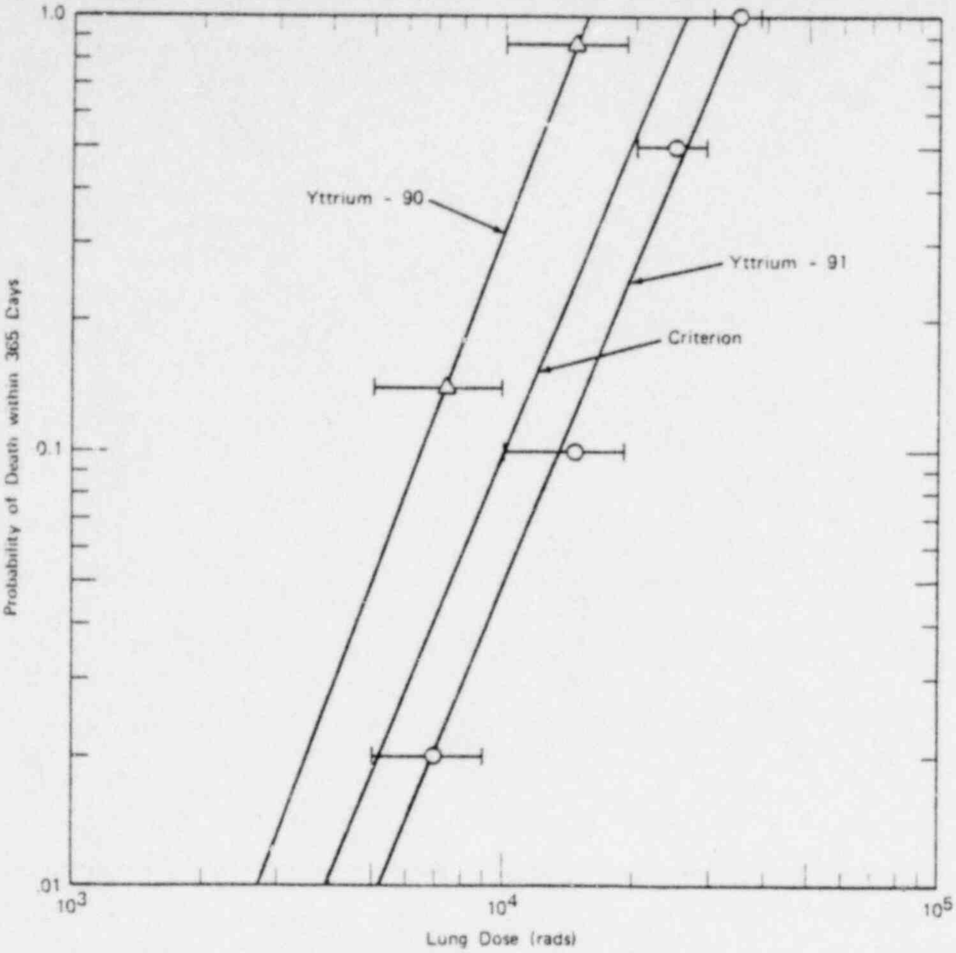

Figure VIII-3. Dose-response curves for yttrium-90 and yttrium-91 and criterion used in consequence model. (From "Reactor Safety Study," WASH-1400, Appendix VI, p. 97).

The internal dose was computed for a tissue depth of 500 μm. These doses were used with the dose-response curve shown in Figure VIII-4 to project injury to the gastrointestinal tract. In light of the importance of injury to the lung, injury to the gastrointestinal tract had negligible contribution to the overall projections of early mortality from exposures to mixed fission products (Reactor Safety Study, 1975).

Early mortality from irradiation of the thyroid and of an embryo was also studied. Because of the high radiation doses needed in the thyroid to produce acute lethal injury, this cause of early mortality was not significant in the overall projected numbers of early deaths from reactor accidents.

Early Mortality Projections of Wells (1976)

The mortality model for acute radiation injury developed by Wells considered only doses from inhaled radionuclides and only injuries to the lung and bone marrow. For inhaled insoluble particles (similar to Class Y aerosols), the lung was considered the critical organ and for relatively soluble particles (similar to Class D and W aerosols), the bone marrow was considered the critical organ. Two dose parameters were used to project mortality from injuries to the lungs:

1. the initial dose rate to lung (rem/min),
2. the effective, long-term, half-life of the radionuclide in the lung (days).

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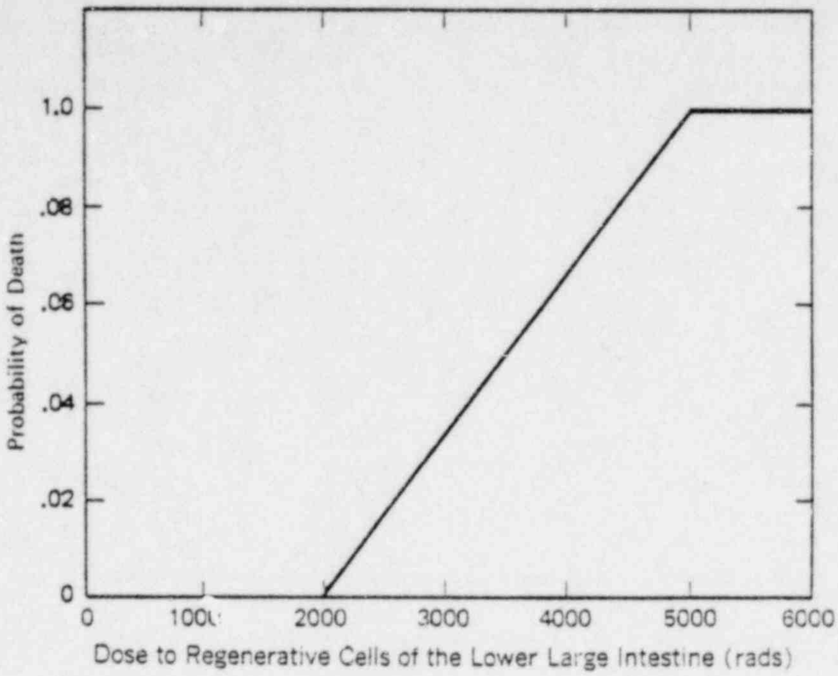

Figure VIII-4. Dose-mortality criterion for irradiation of the lower large intestine. (From "Reactor Safety Study," WASH-1400, Appendix VI, p. 99).

Two dose parameters were also used to project mortality from injuries to bone marrow;

1. the initial "whole body" dose (μCi·Mev/kg) (Initial Body Burden X Mean Energy X RBE),
2. the effective half-life in the body (days)

Information on lethality related to radiation exposures of lung and bone marrow was taken from studies in which laboratory animals inhaled;

1. ^{90}Sr, ^{144}Ce, ^{91}Y and ^{90}Y in a relatively insoluble form (dogs)
2. $^{239}PuO_2$ (baboons)
3. $^{144}CeO_2$ and ^{90}Y in a relatively insoluble form (mice)
4. $^{238}PuO_2$ (hamsters)
5. $^{144}CeCl_3$, $^{90}YCl_3$ and $^{137}CsCl$ (dog).

Also, two studies in which rats were injected intravenously with ^{210}Po and hamsters were injected intraperitoneally with ^{90}Sr citrate, were used in developing the relationships for bone marrow injury. Data from radiotherapy studies in people were also used to project lethal doses for upper-body irradiation related to lung injuries and for whole-body irradiation related to bone marrow injuries.

Wells projected two doses for each type of acute radiation injury. First was the dose below which an individual would probably have long term survival and, second was the dose above which the individual would die within a short time after exposure. These doses were functions of the dose and dose rate. An illustration of these functions is given in Figure VIII-5. For the function representing injury to bone marrow, Wells stated that the upper curve representing probable lethality was less certain than the other curves. This is because short-lived isotopes could undergo considerable radioactive decay before the material was translocated to bone. Thus, probable lethality could require considerably higher doses than indicated.

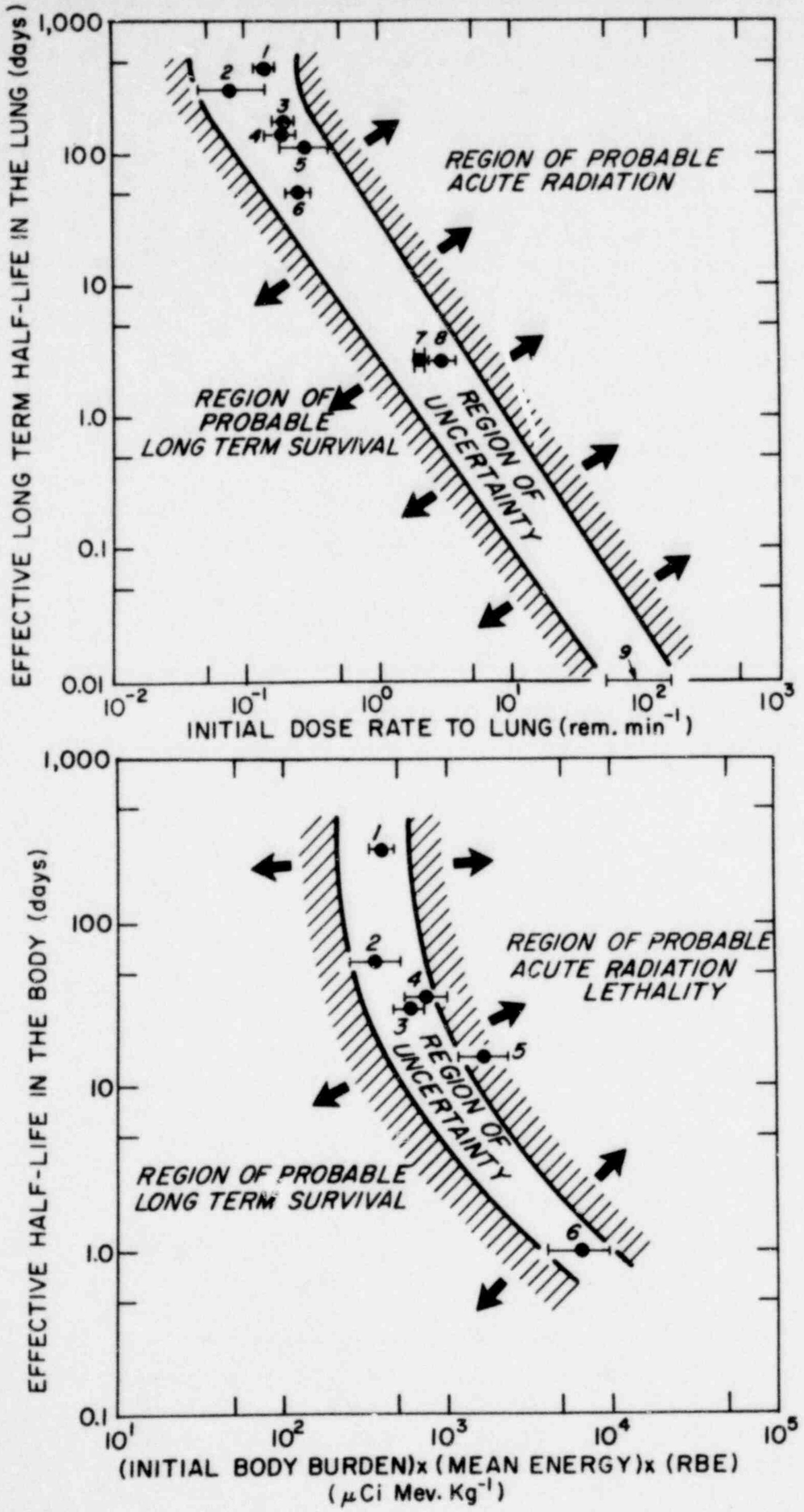

Figure VIII-5. Relationships developed by Wells (1976) to project mortality from radiation injury to the lung (upper graph) and bone marrow (lower graph).

In order to compare Wells' model with the others discussed in this chapter, it was assumed that the fractional lethality between the points of probable survival and probable lethality could be projected from a linear relationship connecting the two extreme points. Also, in a conservative assumption, Wells' caution about the upper curve of probable lethality related to injury to bone marrow was neglected.

Early Mortality Projection of Goldman (1977)

Early mortality projections were also developed by Goldman, specifically for exposures to inhaled plutonium. His projections could also be extended to other long-lived radionuclides that are retained avidly in the lung such as an insoluble aerosol containing ^{90}Sr-^{90}Y, although this was not the intention of his original report. Information on acute radiation injury to the lung was taken from studies in which Beagle dogs inhaled either $^{239}PuO_2$ particles or ^{90}Sr-^{90}Y in fused aluminosilicate particles. The dose response curves used by Goldman are shown in Figure VIII-6. Doses to the lung from ^{90}Sr-^{90}Y were taken to the time of death or, for surviving dogs, to one year after exposure. For $^{239}PuO_2$, the doses were calculated from measurements of the lung burdens at the times of death assuming a constant lung burden or no clearance after the initial inhalation exposure. This, as Goldman states, underestimates the doses to lung from ^{239}Pu.

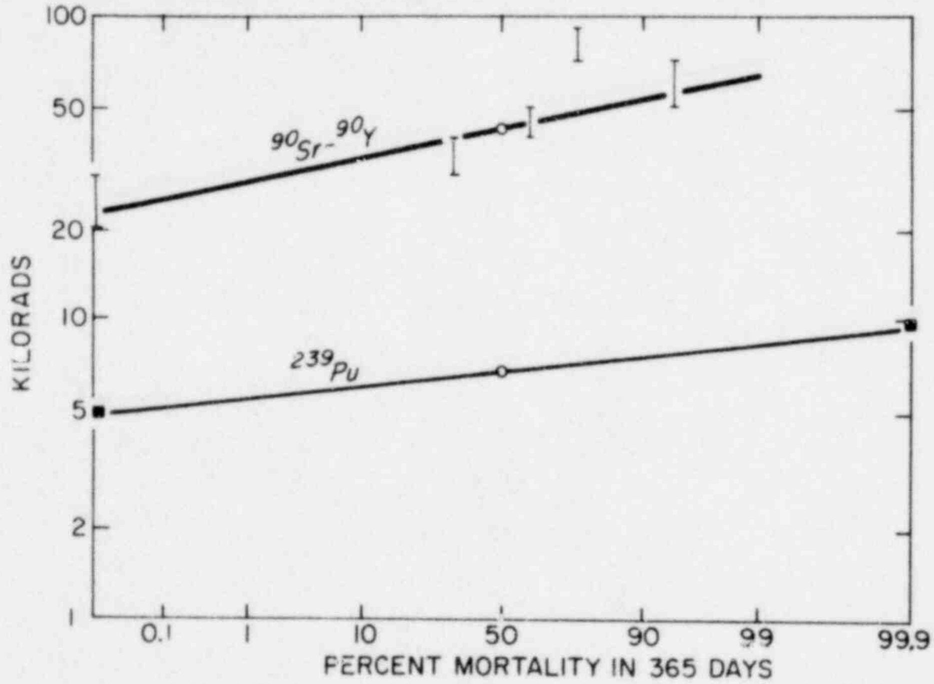

Figure VIII-6. Acute lethality in Beagle dogs from long-lived insoluble inhaled particles (from Goldman, 1977).

Comparison of Model Projections for Early Mortality from Radiation Exposure

Each model discussed in this Chapter was designed for a different purpose and has different overall capabilities. Thus, it is difficult to arrive at a set of initial definitions which permits a comparison of their final mortality projections for test radiation exposure circumstances. A summary chart of the functions performed by each of the early mortality models is given in Table VIII-1.

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Table VIII-1

Functions Performed by Individual Models for Projecting Early Mortality From Radiation Due to Releases of Radionuclides into the Atmosphere

E, Model Projects Exposure Levels Given Source Term

D, Model Projects Organ Doses Given Exposure Levels

M, Model Projects Mortality Given Organ Doses[a]

Radiation Mode	Reactor Safety Study	Wells	Goldman	ITRI
External Sources:				
a. Passing Cloud	E, D, M	M	-	D, M
b. Ground Contamination	E, D, M	M	-	M
Internally Deposited Radionuclides in:				
a. Lung	E, D, M	M	M[b]	D, M
b. Bone	E, D, M	M	-	D, M
c. Gastrointestinal Tract	E, D, M	-	-	D, M
d. Thyroid	E, D, M	-	-	-
e. Fetus	E, D, M	-	-	-

[a]Unless otherwise indicated, exposures and mortality projections can be made for all beta- and gamma-emitting radionuclides.

[b]For long-lived radionuclides avidly retained in the lung.

Only the Reactor Safety Study and the ITRI models were designed to calculate radiation exposure levels and the internal organ uptakes of radionuclides. The model used in the Reactor Safety Study begins with the release of radionuclides into the atmosphere, calculates local air concentrations of radionuclides as a function of distance from the source and calculates external radiation levels from both radionuclides in the air and those deposited on the ground. The model being developed in the current research project, the ITRI Model, begins with the air concentrations of radionuclides at the point of an exposed individual and calculates the external dose from radionuclides in air but does not include possible doses from contamination on ground surfaces. Both the Reactor Safety Study Model and the ITRI Model calculate radionuclide buildup in internal body organs and the subsequent radiation doses as functions of time after exposure. The models of Wells and Goldman do not account for external irradiation in estimating early mortality although the model of Wells can be extended to account for this injury to bone marrow if the doses from external sources are known.

All of these models can project early mortality for radionuclides deposited in the lung. The model of Goldman is primarily for plutonium deposited in the lung, but it can be extended to other long-lived, alpha and beta-emitting radionuclides that are avidly retained in the lung. The model used in the Reactor Safety Study, the Wells Model and the ITRI Model can all project early mortality from irradiation of bone marrow, however, the Wells Model does not attempt to estimate retention of radionulcides in the lung or their translocation to and retention in bone. The ITRI Model estimates radiation doses to the gastrointestinal tract but does not project doses or injury to the thyroid or to a fetus. The model used in the Reactor Safety Study considers all of these but the risks from injuries to the gastrointestinal tract, thyroid and fetus had little impact upon the overall projections of mortality.

No data on early mortality in people are available for testing or verifying the acceptability of these models for projecting the consequences of accidental radiation exposures. Further, there are no large groups of data from studies in laboratory animals that have not been used in formulating these models. Thus, there are few possible tests of these model projections beyond showing their relative capabilities for reproducing the data that were originally used to build the models.

Summaries of the model projections for the levels of early mortality seen in Beagle dogs exposed by inhalation to aerosols containing different radionuclides are shown in Tables VIII-2 and VIII-3. The radionuclides range in half-life from 64 hours to 25,000 years, and, for equal organ radiation doses, the radiation dose rates varied by orders of magnitude. Similar dose groupings were taken for all of these studies, but some differences occurred where the ranges of doses that were studied differed markedly. Mortality was expressed as the number of animals in each group that died or were predicted to die within 1 or 1.5 years of the radiation exposure.

Table VIII-2

Comparison of Predictions of Models of Early Mortality with Studies of Various Radionuclides in Insoluble Particles Deposited in the Lungs of Beagle Dogs.
Ranges of Lung Doses in Rads at 1 Year were Used to Group Dogs

					Model Predictions			
					Number Dead at 1 Year			Number Dead at 1.5 Years
Aerosol Form	Range of Lung Doses (krads at 1 year)	Number of Animals	Number Dead 1 Year	Number Dead 1.5 Years	Reactor Safety	Wells	Goldman	ITRI
^{90}Y Insoluble	30-90	5	5	5	5	5		5
	20-30	10	10	10	9	9		10
	10-20	21	18	19	4	6		15
	5-10	21	3	3	1	1		1
	1-5	32	0	0	0	0		0
^{91}Y Insoluble	30-70	23	23	23	23	12		23
	20-30	22	11	13	18	4		12
	10-20	19	1	2	6	1		2
	5-10	18	1	1	1	0		0
	1-5	14	0	0	0	0		0
^{144}Ce Insoluble	30-70	25	16	18	25	13		17
	20-30	8	0	0	7	1		0
	10-20	19	0	0	2	1		0
	5-10	9	0	0	0	0		0
	1-5	12	0	0	0	0		0
^{90}Sr Insoluble	30-70	39	27	31	39	31	35	35
	20-30	12	0	0	10	2	0	0
	10-20	12	0	0	2	0	0	0
	1-10	30	0	0	2	0	0	0
	0.1-1	13	0	0	0	0	0	0
$^{239}PuO_2$	30-70	3	3	3	3	3	3	3
	20-30	6	6	6	6	6	6	6
	10-20	12	12	12	12	12	12	12
	5-10	8	7	7	8	6	4	8
	1-5	13	2	2	7	1	0	2
	0-1	25	0	0	1	0	0	0

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Table VIII-3

Comparison of Predictions of Models of Early Mortality with Studies of Various Radionuclides Deposited in the Skeleton of Beagle Dogs.

Ranges of Doses in Rads at 1 Year were Used to Group the Dogs

Radionuclide	Range of Bone Doses (krads at 1 year)	Number of Animals	Number Dead at 1 Year	Model Predictions for Number Dead at 1 Year		
				Reactor Safety	Wells	ITRI
$^{137}CsCl$ (injected)	2.5-3.0	6	6	6	6	6
	2.0-2.5	6	4	5	6	2
	1.5-2.0	12	1	6	11	2
	1.0-1.5	10	0	1	7	0
	0-1.0	20	0	0	8	0
$^{91}YCl_3$ (inhaled)	3.0-7.0	7	7	6	4	6
	2.5-3.0	5	2	2	2	3
	2.0-2.5	3	0	0	1	0
	1.5-2.0	2	0	0	0	0
	1.0-1.5	6	0	0	0	0
	0-1.0	19	0	0	0	0
$^{144}CeCl_3$ (inhaled)	10-15	3	2	3	3	3
	3-10	15	6	3	6	3
	2-3	6	0	0	0	0
	1-2	6	0	0	0	0
	0-1	25	0	0	0	0
$^{90}SrCl_2$ (inhaled)	8-17	10	4	10	1	6
	3-8	10	1	1	0	1
	2-3	4	0	0	0	0
	0-2	24	0	0	0	0

Mortality predictions based on the ITRI model were closest to the actual observed mortalities in most cases. In the Reactor Safety Study model, there was no correction for dose rate. Thus, mortality predictions for the long lived isotopes, ^{144}Ce and ^{90}Sr, were much higher than observed. In applying the model to studies with ^{144}Ce and ^{90}Sr, 80 and 90% mortality was projected for the groups of animals receiving 2000-3000 rads, but no early mortality was observed. The model of Wells (as applied here) tended to underestimate early mortality for exposures to the short-lived radionuclides, ^{90}Y and ^{91}Y, but was closer to the observed data for the longer-lived radionuclides. Since the ITRI model corrected for changing dose rates in time, or half-lifes, its mortality predictions for acute lung injury were closer to the observed mortalities over the entire range of radionuclides.

All of the models projected early mortality from injury to bone marrow which were close to the mortalities observed in dogs exposed to $^{137}CsCl$, $^{91}YCl_3$, $^{144}CeCl_3$ and $^{90}SrCl_2$ (Table 3). This was probably due to the heavy reliance of the models on early doses to bone, during the first 30 days or, in Wells' model, reliance on an estimate of the initial body burden. The model of Goldman is not applicable to estimating injury from bone marrow irradiation.

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CHAPTER IX. SUMMARY

Several studies have previously been made of the number of early deaths which might be expected in a population exposed to a cloud of radionuclides which could result from a nuclear accident. These analyses, however, have been limited to one accident scenario or to exposures involving limited numbers of radionuclides. The purpose of this Phase I study was to examine the existing data on the early health effects of inhaled radioactive materials and determine what, if any, new studies were needed to make reasonable estimates of early mortality after exposure of a population to a cloud of radionuclides of any type.

The approach used in the Phase I project was to analyze the data bases available on the health effects of inhaled radioactive materials and document those which were adequate and useful. Using these data, a computer based simulation model was developed depicting exposure to a radioactive aerosol, the dose to an individual exposed to the aerosol and the probability of dying from early effects.

The inputs into the model are the characteristics of the exposure aerosol including the specific isotope or isotopes, the solubility class of each isotope, the aerosol concentration, the aerosol particle size distribution and the duration of the exposure. Any of 54 radionuclides most commonly found in nuclear reactors (derived from WASH-1400) can be chosen at the present time. From this information, doses to the lung, bone, gastrointestinal tract, liver and thyroid are determined for both external and internal irradiation. These calculations are based on already published models for deposition and retention of aerosols in the body (ICRP Task Group Lung Model), transport of radionuclides through various organs of the body (ICRP Committee 2) and determinations of dose from external irradiation or internally deposited materials (ORNL).

To determine the probability of early effects from the calculated doses, it was necessary to develop quantitative measures of the dose-response relationships. No data are available from man on the dose-response for early health effects from inhaled radionuclides. Thus, data from experimental animals exposed to radionuclides were used. A hazard function method was developed and used to characterize dose-response relationships for inhalation exposure to radionuclides. This method has the advantage of using each datum point in determining the hazard function and permits a better definition of the dose-response curve.

In assessing the most likely modes and radionuclides involved in accidental exposures, it was determined that external. whole-body exposure to γ rays which affects mainly the bone marrow and exposure of the lung from inhaled internal γ or β emitting radionuclides were the important modes and organs involved. Effects in these two organs were used in the simulation model.

Except for age at exposure, factors which significantly modify the response or effects in the lung and bone were examined. For lung, the quality of the radiation is a factor as is the temporal distribution of dose (for low-LET emissions) and possibly spatial distribution of dose (for high-LET emissions). When corrections are made for differences in temporal distribution, the responses of dogs and mice to lung irradiation from internal low-LET emitters are similar. This indicates that the response of the lung may be independent of species and helps to strengthen the extrapolation of the data to man.

In developing the simulation model, a number of research needs have been identified which must be filled to refine estimates of early mortality for different nuclear accidents. A summary of these needs is shown in Table IX-1 in relation to the type of accidental exposure. The most essential data which are needed fall in the following areas:

1. The combined effects on the lung of inhaled beta-emitting radionuclides of various solubilities which result in a complex retention pattern in the lung.

2. The combined effects on the lung of various inhaled alpha-emitting radionuclides which have different specific activities.

3. The combined effects on the lung of alpha-emitting and beta-emitting radionuclides inhaled at the same time.

4. The combined effects of inhaled beta-emitting radionuclides and whole-body irradiation.

5. The combined effects of inhaled soluble and insoluble forms of beta-emitting radionuclides where there is damage to both lung and bone marrow.

Further analyses of existing data are needed in several areas to complete certain aspects of estimating early mortality. These are:

1. The estimates of mortality from external whole-body irradiation.

2. The determination of corrections needed for wasted radiation dose in the lung.

3. The determination of accurate bone marrow doses in rat, dog and man so that comparable doses can be used in analysis.

Analyses of existing data and of data from experiments designed to fill these needs will allow completion of a comprehensive model based on use of hazard functions to estimate early mortality from different nuclear accidents.

Table IX-1

Summary of Research Needs to Refine Estimates of Early Mortality for Different Nuclear Accidents

Types of Accidental Exposure	Exposure Radioactivity	Organ Effects: Lung	Bone	Gastrointestinal	Whole-Body
I. External gamma	λ	x	x	x	x
II. External gamma +	β_i	x	x	x	
Inhalation beta	β_s	x	x	x	
	$\beta_{i_1} + \dots \beta_{i_n}$	0			
	$\beta_i + \lambda$	0			0
	$\beta_i + \beta_s$	0	0		
	$\beta_{GI} + \lambda$		0	0	
III. External gamma +	α_i	x	x	x	
Inhalation beta +	α_s	x	x	x	
Inhalation alpha	$\alpha_{i_1} + \dots \alpha_{i_n}$	0			
	$\alpha_i + \beta_i$	0			0
	$\alpha_i + \beta_i + \lambda$	0			

x = data sufficient.
0 = data needed.
i = insoluble form.
s = soluble form.
GI = gastrointestinal.

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APPENDIX A

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A1.1 TOXICITY OF INHALED 239-PUO2 IN BABOONS

ANIMAL NUMBER	SEX	DAYS P.E. (DEATH)	EFFECTIVE HALF-LIFE	I.L.B. NCI/GM. LUNG	DOSE TO LUNG TO DEATH (RADS)
3437	F	15	45	643	2350
103	F	28	110	90.9	633
3424	M	33	71	281	2180
14	F	37	211	134	1280
104	F	50	79	131	1450
3429	M	54	126	121	1550
3428	M	57	194	131	1820
138	F	67	208	732	12000
4413	F	107	598	121	3360
62	M	119	503	114	3330
93	M	130	277	81	2380
3434	M	130	280	134	4090
3410	M	131	192	76.5	2190
3426	M	131	192	76.5	21[illegible]
4408	M	133	464	71.5	236[illegible]
68	M	143	881	176	6520
64	M	144	483	95.4	3060
4403	F	146	453	62.1	2230
3420	M	167	316	42.9	1640
4409	M	180	459	63.8	2500
65	M	184	571	87	3710
3435	M	219	394	181	9020
150	F	229	2190	39	2360
19	F	243	604	40.9	3260
11	F	250	491	57.5	3060
21	M	252	136	51	1880
4	F	284	848	7.5	470
20	M	290	462	40.9	2440
15	F	401	348	11.7	780
13	F	448	1440	38.7	3660
65	M	520	520	122	9710
157	M	549	1390	13.9	1270
136	M	721	3590	49.5	6900
156	M	735	735	104	10400
54	M	849	479	45.3	3550
152	F	850	1010	20.9	2840
155	M	870	3480	71.2	11100
88	M	872	872	77	9470
67	M	1035	3500	67.2	10400
12	M	1044	1220	22.2	3230
63	M	119	711	136	4200

(DATA FORM W.J.BAIR ET AL., 1977.) SEE REFERENCE #2.

A1.2 TOXICITY OF INHALED 239-PUO2 IN BEAGLE DOGS

ANIMAL NUMBER	SEX	DAYS P.E. (DEATH)	EFFECTIVE HALF-LIFE	I.L.B. NCI/GM. LUNG	DOSE TO LUNG TO DEATH (RADS)
75	F	55	224	382	5100
176	F	53	254	316	4480
195	F	58	240	571	8040
179	F	63	220	406	6120
211	F	63	236	536	8140
16	F	65	251	206	3240
196	M	65	246	368	5770
177	F	75	262	155	2790
197	F	75	305	488	8890
175	F	76	276	210	3830
8	M	78	316	436	8260
82	F	79	300	280	5340
91	M	79	318	424	8120
123	F	79	315	280	5350
124	F	80	254	249	4720
126	F	82	314	198	3920
20	F	90	324	210	4550
9	M	96	196	390	8380
68	F	97	346	235	5460
3	M	105	405	202	5130
159	F	105	364	44	1120
194	F	107	433	109	2830
105	F	120	361	105	2970
207	F	121	363	105	2990
199	F	124	398	254	7470
219	F	140	537	90	3050
2	M	150	516	176	6320
121	F	163	552	75	3010
4	F	230	734	67	3660
200	F	346	724	70	5450
107	F	384	780	70	6020
192	F	412	762	60	5460
182	F	855	1176	27	4810
184	F	933	1312	22	4270
272	M	988	1024	23	4280
215	F	1151	882	14	2720
83	F	1184	1109	17	3680
268	F	1202	842	10	1990
173	F	1339	935	25	5510
106	F	1357	1034	29	6730
183	F	1379	1097	8	2040
120	F	1446	923	16	3610
76	F	1549	1100	14	3690

(DATA FROM W.J. BAIR ET AL., 1977.) SEE REFERENCE #2.

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A1.3 TOXICITY OF INHALED 238-PUO2 IN BEAGLE DOGS

ANIMAL	INITIAL DOSE RATE (RADS/DAY)	DAYS POST EXPOSURE	RADIATION PNEUMONITIS AND/OR PULMONARY FIBROSIS	DOSE TO LUNG TO DEATH(RADS)
701A	38	1351	NO	10800
857V	38	1026*	NO	10600
746B	33	792	YES	9000
718U	30	1182	NO	8500
726A	30	1107	YES	8400
690S	30	1380	NO	8500
684A	21	1503	NO	6000
887C	20	536	YES	5000
747S	19	1479*	NO	5400
726T	17	1565*	NO	4800
746T	16	1377	NO	4500
708T	15	1104	YES	4200
723C	24	1553	NO	6800

(DATA FROM J.F. PARK ET AL., 1970.) SEE REFERENCE #43.

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A1.4 TOXICITY OF INHALED 241AMO2 IN SYRIAN HAMSTERS

NUMBER EXPT.	ANIMAL	TO DEATH (DAYS)	I.L.B. (NCI)	DOSE TO LUNG TO DEATH (RADS)
1515	30	183	10	240
1515	17	95	25	370
1515	18	75	533	6700
1515	25	134	86	1700
1515	39	326	177	5500
1515	27	324	190	5900
1515	10	140	120	2400
1515	19	116	133	2300
1515	22	68	164	1900
1515	20	102	146	2300
1515	41	121	152	2700
1515	13	113	170	2900
1515	38	113	171	2900
1515	28	69	218	2600
1515	8	102	194	3100
1515	40	146	192	3900
1515	45	115	194	3400
1515	31	101	224	3500
1515	2	122	236	4200
1515	43	94	249	3700
1515	4	88	262	3700
1515	5	131	252	4800
1515	35	103	269	4300
1515	44	102	281	4400
1515	36	64	359	4000
1515	34	78	348	4500
1515	12	91	347	5000
1515	37	88	354	5000
1515	48	85	366	5000
1515	29	80	401	5300
1515	9	94	407	6100
1515	24	80	493	6500
1515	47	98	468	7200
1515	46	80	557	7300
1515	23	449	1450	50000
1515	14	59	710	7300
1515	26	67	1010	12000
1515	21	168	1620	36000

(DATA FROM J.A. MEWHINNEY ET AL., 1976.) SEE REFERENCE #36.

A1.5 TOXICITY OF INHALED 144-CEO2 IN MICE

R.B.#	ANI.#	SEX	DATE	TYPE	DPE	AGE	UCI	DOSE	SITE	TUMOR	LESION	CAUSE OF DEATH
			---------------DEATH-------									
1158	236						4.4		LUNG		PNEU	RAD PNEU
1158	219	F	73145	R	0	70	8.4	0	LUNG		PNEU	RAD PNEU
1154	28	F	75311	D	899	969	0.11	558	LUNG	ADENOMA		UNKNOWN
1154	85	F	75158	D	746	816	0.13	658	LUNG		PNEU	UNKNOWN
1154	69	F	75130	D	718	788	0.17	860	LUNG		PNEU	RE CELL
1154	37	F	75199	D	787	857	0.17	861	LUNG		PNEU	PNEU
1154	78	F	75225	D	813	883	0.18	912	LUNG		PNEU	PNEU
1154	73	F	75305	D	893	963	0.18	913	LUNG		PNEU	UNKNOWN
1154	11	F	75343	D	931	1001	0.18	913	LUNG		PNEU	UNKNOWN
1154	31	F	76006	D	959	1029	0.18	913	LUNG		PNEU	UNKNOWN
1154	74	F	75267	D	855	925	0.19	963	LUNG	ADENOMA		UNKNOWN
1154	71	F	75310	D	898	968	0.19	963	LUNG		PNEU	RE CELL
1154	57	F	75065	D	653	723	0.20	1009	LUNG		PNEU	LYMPHOMA
1154	53	F	75173	D	761	831	0.20	1012	LUNG		PNEU	UNKNOWN
1154	76	F	75194	D	782	852	0.20	1013	LUNG		PNEU	PNEU
1154	81	F	75273	D	861	931	0.20	1014	LUNG		PNEU	RE CELL
1154	35	F	75037	D	625	695	0.21	1058	LUNG		PNEU	PUL HEMORRHAGE
1154	19	F	75108	D	696	766	0.21	1061	LUNG		PNEU	UNKNOWN
1154	44	F	75233	D	821	891	0.21	1064	LUNG		PNEU	UNKNOWN
1154	46	F	75246	D	834	904	0.21	1064	LUNG		PNEU	PNEU
1154	32	F	75272	D	860	930	0.21	1064	LUNG		PNEU	PNEU
1154	18	F	75302	D	890	960	0.21	1065	LUNG		PNEU	PNEU
1154	30	F	75071	D	659	729	0.22	1110	LUNG		PNEU	PLASMACYTOMA
1154	48	F	75254	D	842	912	0.22	1115	LUNG		PNEU	PNEU
1154	16	F	75341	D	929	999	0.22	1116	LUNG		PNEU	PNEU
1154	13	F	74103	D	326	396	0.24	1145	LUNG		PNEU	UNKNOWN
1154	62	F	75204	D	792	862	0.23	1165	LUNG		PNEU	LOC LYMPHOMA
1154	52	F	74292	D	515	585	0.24	1199	LUNG		PNEU	PNEU
1154	25	F	74299	D	522	592	0.24	1200	LUNG	ADENOMA		PUL ADENOMA
1154	45	F	75131	D	719	789	0.24	1214	LUNG		PNEU	UNKNOWN
1154	80	F	75236	D	824	894	0.24	1216	LUNG		PNEU	UNKNOWN
1154	22	F	75146	D	734	804	0.25	1265	LUNG		PNEU	UNKNOWN
1154	55	F	75204	D	792	862	0.25	1266	LUNG		PNEU	PNEU
1154	43	F	75352	D	940	1010	0.25	1268	LUNG		PNEU	UNKNOWN
1154	63	F	75271	D	859	929	0.27	1369	LUNG		PNEU	UNKNOWN
1155	126	F	73161	D	19	89	1.0	1467	LUNG		PNEU	PNEU
1154	15	F	75135	D	723	793	0.49	2478	LUNG		PNEU	UNKNOWN
1156	210	F	73312	D	169	239	1.0	4144	LUNG		PNEU	UNKNOWN
1156	210	F	73312	D	169	239	1.0	4144	LUNG		PNEU	UNKNOWN
1156	121	F	74106	D	328	398	1.0	4774	LUNG	CARCINOMA	SQUAMOUS	PUL CARCINOMA
1156	121	F	74106	D	328	398	1.0	4774	LUNG	CARCINOMA	SQUAMOUS	PUL CARCINOMA
1156	164	F	74140	D	362	432	1.0	4838	LUNG		PNEU	PNEU

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A1.5 TOXICITY OF INHALED 144-CEO2 IN MICE (CONT'D)

				---------------DEATH-------								
R.B.#	ANI.#	SEX	DATE	TYPE	DPE	AGE	UCI	DOSE	SITE	TUMOR	LESION	CAUSE OF DEATH
1156	164	F	74140	D	362	432	1.0	4838	LUNG		PNEU	PNEU
1156	165	F	74167	D	389	459	1.0	4880	LUNG		PNEU	PNEU
1156	165	F	74167	D	389	459	1.0	4880	LUNG		PNEU	PNEU
1156	243	F	74220	D	442	512	1.0	4941	LUNG	ADENOMA	PNEU	PUL ADENOMA
1156	243	F	74220	D	442	512	1.0	4941	LUNG	ADENOMA	PNEU	PUL ADENOMA
1156	209	F	74238	D	460	530	1.0	4957	LUNG		PNEU	UNKNOWN
1156	209	F	74238	D	460	530	1.0	4957	LUNG		PNEU	UNKNOWN
1156	236	F	74247	D	469	539	1.0	4964	LUNG	CARCINOMA	ADENO-	CARCINOMA
1156	236	F	74247	D	469	539	1.0	4964	LUNG		PNEU	CARCINOMA
1156	236	F	74247	D	469	539	1.0	4964	LUNG	CARCINOMA	ADENO-	CARCINOMA
1156	236	F	74247	D	469	539	1.0	4964	LUNG		PNEU	CARCINOMA
1156	205	F	74261	D	483	553	1.0	4975	LUNG	ADENOMA		UNKNOWN
1156	205	F	74261	D	483	553	1.0	4975	LUNG	ADENOMA		UNKNOWN
1156	188	F	74274	D	496	566	1.0	4984	LUNG		PNEU	UNKNOWN
1156	188	F	74274	D	496	566	1.0	4984	LUNG		PNEU	UNKNOWN
1156	230	F	74321	D	543	613	1.0	5010	LUNG		PNEU	UNKNOWN
1156	230	F	74321	D	543	613	1.0	5010	LUNG		PNEU	UNKNOWN
1156	201	F	74323	D	545	615	1.0	5011	LUNG	ADENOMA		HEP TELANGIECTASIS
1156	201	F	74323	D	345	615	1.0	5011	LUNG	ADENOMA		HEP TELANGIECTASIS
1156	175	F	74348	D	570	640	1.0	5021	LUNG	RE CELL	TYPE A	RE CELL
1156	175	F	74348	D	570	640	1.0	5021	LUNG	RE CELL	TYPE A	RE CELL
1156	242	F	74358	D	580	650	1.0	5025	LUNG		PNEU	UNKNOWN
1156	242	F	74358	D	580	650	1.0	5025	LUNG		PNEU	UNKNOWN
1156	181	F	74365	D	587	657	1.0	5027	LUNG	CARCINOMA	METAS	HEP CARCINOMA
1156	181	F	74365	D	587	657	1.0	5027	LUNG	CARCINOMA	METAS	HEP CARCINOMA
1156	177	F	75007	D	594	664	1.0	5030	LUNG	CARCINOMA	ADENO-	PUL CARCINOMA
1156	177	F	75007	D	594	664	1.0	5030	LUNG	CARCINOMA	ADENO-	PUL CARCINOMA
1156	195	F	75017	D	604	674	1.0	5033	LUNG		SQ META	UNKNOWN
1156	195	F	75017	D	604	674	1.0	5033	LUNG		SQ META	UNKNOWN
1156	213	F	75022	D	609	679	1.0	5034	LUNG	ADENOMA		UNKNOWN
1156	213	F	75022	D	609	679	1.0	5034	LUNG	ADENOMA		UNKNOWN
1156	183	F	75044	D	631	701	1.0	5040	LUNG		PNEU	PNEU
1156	183	F	75044	D	631	701	1.0	5040	LUNG		PNEU	PNEU
1156	192	F	75063	D	650	720	1.0	5045	LUNG	ADENOMA		HEP NECROSIS
1156	192	F	75063	D	650	720	1.0	5045	LUNG	ADENOMA		HEP NECROSIS
1156	237	F	75065	D	652	722	1.0	5045	LUNG		PNEU	PNEU
1156	237	F	75065	D	652	722	1.0	5045	LUNG		PNEU	PNEU
1156	178	F	75077	D	664	734	1.0	5048	LUNG		PNEU	PNEU
1156	178	F	75077	D	664	734	1.0	5048	LUNG		PNEU	PNEU
1156	238	F	75080	D	667	737	1.0	5048	LUNG		PNEU	PNEU
1156	238	F	75080	D	667	737	1.0	5048	LUNG		PNEU	PNEU
1156	194	F	75081	D	668	738	1.0	5048	LUNG		PNEU	PNEU

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R.B.#	ANI.#	SEX	DATE	TYPE	DPE	AGE	UCI	DOSE	SITE	TUMOR	LESION	CAUSE OF DEATH
			---------------DEATH-------									
1156	194	F	75081	D	668	738	1.0	5048	LUNG		PNEU	PNEU
1156	163	F	75084	D	671	741	1.0	5049	LUNG		PNEU	PNEU
1156	163	F	75084	D	671	741	1.0	5049	LUNG	ADENOMA		PNEU
1156	163	F	75084	D	671	741	1.0	5049	LUNG		PNEU	PNEU
1156	163	F	75084	D	671	741	1.0	5049	LUNG	ADENOMA		PNEU
1156	170	F	75098	D	685	755	1.0	5052	LUNG		PNEU	PNEU
1156	170	F	75098	D	685	755	1.0	5052	LUNG		PNEU	PNEU
1156	187	F	75101	D	688	758	1.0	5052	LUNG		PNEU	RAD PNEU
1156	187	F	75101	D	688	758	1.0	5052	LUNG		PNEU	RAD PNEU
1156	239	F	75112	D	699	769	1.0	5054	LUNG		PNEU	RE CELL
1156	239	F	75112	D	699	769	1.0	5054	LUNG		PNEU	RE CELL
1156	235	F	75113	D	700	770	1.0	5054	LUNG		PNEU	PNEU
1156	235	F	75113	D	700	770	1.0	5054	LUNG		PNEU	PNEU
1156	222	F	75115	D	702	772	1.0	5054	LUNG	RE CELL	TYPE A	RE CELL
1156	222	F	75115	D	702	772	1.0	5054	LUNG	RE CELL	TYPE A	RE CELL
1156	182	F	75139	D	726	796	1.0	5058	LUNG		PNEU	PNEU
1156	182	F	75139	D	726	796	1.0	5058	LUNG		PNEU	PNEU
1156	232	F	75143	D	730	800	1.0	5058	LUNG		PNEU	PNEU
1156	232	F	75143	D	730	800	1.0	5058	LUNG		PNEU	PNEU
1156	169	F	75144	D	731	801	1.0	5058	LUNG		PNEU	HEP TELANGIECTASIS
1156	169	F	75144	D	731	801	1.0	5058	LUNG		PNEU	HEP TELANGIECTASIS
1156	226	F	75144	D	731	801	1.0	5058	LUNG		PNEU	PNEU
1156	226	F	75144	D	731	801	1.0	5058	LUNG		PNEU	PNEU
1156	250	F	75147	D	734	804	1.0	5059	LUNG		PNEU	PNEU
1156	250	F	75147	D	734	804	1.0	5059	LUNG		PNEU	PNEU
1156	227	F	75152	D	739	809	1.0	5059	LUNG		PNEU	UNKNOWN
1156	227	F	75152	D	739	809	1.0	5059	LUNG		PNEU	UNKNOWN
1156	184	F	75158	D	745	815	1.0	5060	LUNG		PNEU	PNEU
1156	184	F	75158	D	745	815	1.0	5060	LUNG		PNEU	PNEU
1156	214	F	75163	D	750	820	1.0	5060	LUNG		PNEU	PNEU
1156	214	F	75163	D	750	820	1.0	5060	LUNG		PNEU	PNEU
1156	180	F	75166	D	753	823	1.0	5061	LUNG		PNEU	PNEU
1156	180	F	75166	D	753	823	1.0	5061	LUNG		PNEU	PNEU
1156	247	F	75170	D	757	827	1.0	5061	LUNG		PNEU	PNEU
1156	247	F	75170	D	757	827	1.0	5061	LUNG		PNEU	PNEU
1156	228	F	75171	D	758	828	1.0	5061	LUNG		PNEU	PNEU
1156	228	F	75171	D	758	828	1.0	5061	LUNG		PNEU	PNEU
1155	95	F	75171	D	759	829	1.0	5061	LUNG		PNEU	RE CELL
1156	240	F	75176	D	763	833	1.0	5062	LUNG		PNEU	PNEU
1156	240	F	75176	D	763	833	1.0	5062	LUNG		PNEU	PNEU

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A1.5 TOXICITY OF INHALED 144-CEO2 IN MICE (CONT'D)

R.B.#	ANI.#	SEX	DATE	TYPE	DPE	AGE	UCI	DOSE	SITE	TUMOR	LESION	CAUSE OF DEATH
			---------------DEATH-------									
1156	221	F	75180	D	767	837	1.0	5062	LUNG		PNEU	HEP NECROSIS
1156	221	F	75180	D	767	837	1.0	5062	LUNG		PNEU	HEP NECROSIS
1156	176	F	75185	D	772	842	1.0	5063	LUNG		PNEU	RE CELL
1156	176	F	75185	D	772	842	1.0	5063	LUNG	ADENOMA		RE CELL
1156	176	F	75185	D	772	842	1.0	5063	LUNG		PNEU	RE CELL
1156	176	F	75185	D	772	842	1.0	5063	LUNG	ADENOMA		RE CELL
1156	203	F	75201	D	788	858	1.0	5064	LUNG	ADENOMA		RE CELL
1156	203	F	75201	D	788	858	1.0	5064	LUNG	ADENOMA		RE CELL
1156	211	F	75202	D	789	859	1.0	5064	LUNG		PNEU	HEP NECROSIS
1156	211	F	75202	D	789	859	1.0	5064	LUNG	ADENOMA		HEP NECROSIS
1156	211	F	75202	D	789	859	1.0	5064	LUNG		PNEU	HEP NECROSIS
1156	211	F	75202	D	789	859	1.0	5064	LUNG	ADENOMA		HEP NECROSIS
1156	231	F	75206	D	793	863	1.0	5064	LUNG		PNEU	PNEU
1156	231	F	75206	D	793	863	1.0	5064	LUNG		PNEU	PNEU
1156	251	F	75209	D	796	866	1.0	5065	LUNG		PNEU	UNKNOWN
1156	251	F	75209	D	796	866	1.0	5065	LUNG		PNEU	UNKNOWN
1156	186	F	75215	D	802	872	1.0	5065	LUNG		PNEU	RAD PNEU
1156	186	F	75215	D	802	872	1.0	5065	LUNG		PNEU	RAD PNEU
1156	172	F	75227	D	814	884	1.0	5066	LUNG		PNEU	PNEU
1156	172	F	75227	D	814	884	1.0	5066	LUNG		PNEU	PNEU
1156	193	F	75228	D	815	[illegible]	1.0	5066	LUNG	ADENOMA	PNEU	PNEU
1156	193	F	75228	D	815	[illegible]	1.0	5066	LUNG	ADENOMA	PNEU	PNEU
1156	223	F	75228	D	815	[illegible]	1.0	5066	LUNG		PNEU	PNEU
1156	223	F	75228	D	815	885	1.0	5066	LUNG		PNEU	PNEU
1156	196	F	75232	D	819	889	1.0	5066	LUNG		PNEU	PNEU
1156	196	F	75232	D	819	889	1.0	5066	LUNG		PNEU	PNEU
1156	200	F	75233	D	820	890	1.0	5066	LUNG		PNEU	PNEU
1156	200	F	75233	D	820	890	1.0	5066	LUNG		PNEU	PNEU
1156	234	F	75234	D	821	891	1.0	5066	LUNG		PNEU	PNEU
1156	234	F	75234	D	821	891	1.0	5066	LUNG	ADENOMA		PNEU
1156	234	F	75234	D	821	891	1.0	5066	LUNG		PNEU	PNEU
1156	234	F	75234	D	821	891	1.0	5066	LUNG	ADENOMA		PNEU
1156	185	F	75235	D	822	892	1.0	5067	LUNG		PNEU	RAD PNEU
1156	185	F	75235	D	822	892	1.0	5067	LUNG		PNEU	RAD PNEU
1156	216	F	75235	D	822	892	1.0	5067	LUNG		PNEU	PNEU
1156	216	F	75235	D	822	892	1.0	5067	LUNG		PNEU	PNEU
1156	190	F	75246	D	833	903	1.0	5067	LUNG		SQ META	UNKNOWN
1156	190	F	75246	D	833	903	1.0	5067	LUNG		SQ META	UNKNOWN
1155	91	F	75247	D	835	905	1.0	5067	LUNG		PNEU	HEP TELANGIECTASIS
1156	219	F	75248	D	835	905	1.0	5067	LUNG	ADENOMA		UNKNOWN

A1.5 TOXICITY OF INHALED 144-CEO2 IN MICE (CONT'D)

R.B.#	ANI.#	SEX	DATE	TYPE	DPE	AGE	UCI	DOSE	SITE	TUMOR	LESION	CAUSE OF DEATH
			---------------	---DEATH---	-------							
1156	219	F	75248	D	835	905	1.0	5067	LUNG	ADENOMA		UNKNOWN
1156	212	F	75251	D	838	908	1.0	5068	LUNG		PNEU	PNEU
1156	212	F	75251	D	838	908	1.0	5068	LUNG		PNEU	PNEU
1156	202	F	75257	D	844	914	1.0	5068	LUNG	ADENOMA	PNEU	RE CELL
1156	202	F	75257	D	844	914	1.0	5068	LUNG	ADENOMA	PNEU	RE CELL
1156	252	F	75257	D	844	914	1.0	5068	LUNG		PNEU	UNKNOWN
1156	252	F	75257	D	844	914	1.0	5068	LUNG		PNEU	UNKNOWN
1156	166	F	75266	D	853	923	1.0	5068	LUNG		PNEU	UNKNOWN
1156	166	F	75266	D	853	923	1.0	5068	LUNG		PNEU	UNKNOWN
1155	90	F	75281	D	869	939	1.0	5069	LUNG		PNEU	RE CELL
1156	248	F	75283	D	870	940	1.0	5069	LUNG		PNEU	PNEU
1156	248	F	75283	D	870	940	1.0	5069	LUNG		PNEU	PNEU
1156	191	F	75288	D	875	945	1.0	5069	LUNG		PNEU	HEP CARCINOMA
1156	191	F	75288	D	875	945	1.0	5069	LUNG		PNEU	HEP CARCINOMA
1156	207	F	75296	D	883	953	1.0	5070	LUNG		PNEU	PNEU
1156	207	F	75296	D	883	953	1.0	5070	LUNG		PNEU	PNEU
1156	197	F	75299	D	886	956	1.0	5070	LUNG		PNEU	RE CELL
1156	197	F	75299	D	886	956	1.0	5070	LUNG		PNEU	RE CELL
1156	173	F	75354	D	941	1011	1.0	5072	LUNG	ADENOMA		UNKNOWN
1156	173	F	75354	D	941	1011	1.0	5072	LUNG	ADENOMA		UNKNOWN
1157	115	F	?	D	16	86	4.43	5710	LUNG	ADENOMA	PNEU	RAD PNEU
1158	248	F	73255	D	110	180	2.45	8924	LUNG		PNEU	RAD PNEU
1157	101	F	75129	D	715	785	1.91	9657	LUNG	ADENOMA		UNKNOWN
1158	181	F	73257	D	112	182	3.26	11944	LUNG		PNEU	RAD PNEU
1157	130	F	74285	D	506	576	2.4	11976	LUNG		PNEU	RAD PNEU
1158	137	F	73231	D	86	156	3.7	12372	LUNG		PNEU	PNEU
1157	84	F	74274	D	495	565	2.6	12956	LUNG		PNEU	RAD PNEU
1157	84	F	74274	D	495	565	2.6	12956	LUNG		SQ META	RAD PNEU
1157	18	F	74095	D	316	386	2.76	13102	LUNG		PNEU	PNEU
1157	138	F	73221	D	77	147	4.1	13150	LUNG		PNEU	RAD PNEU
1157	36	F	73281	D	137	207	3.37	13152	LUNG		SQ META	THROMBOSIS
1157	105	F	73250	D	106	176	3.70	13312	LUNG		PNEU	RAD PNEU
1158	91	F	73206	D	61	171	4.6	13404	LUNG		SQ META	RAD PNEU
1157	53	F	73233	D	89	159	4.0	13543	LUNG		PNEU	HEP NECROSIS
1157	20	F	75165	D	751	821	2.68	13562	LUNG	CARCINOMA	ADENO-	PNEU
1157	13	F	73207	D	63	133	4.7	13869	LUNG		SQ META	UNKNOWN

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A1.5 TOXICITY OF INHALED 144-CEO2 IN MICE (CONT'D)

R.B.#	ANI.#	SEX	DATE	TYPE	DPE	AGE	UCI	DOSE	SITE	TUMOR	LESION	CAUSE OF DEATH
				-----------------	DEATH	-------						
1158	161	F	73293	D	148	218	3.51	14014	LUNG		PNEU	RAD PNEU
1158	66	F	74319	D	539	609	2.8	14022	LUNG		PNEU	RAD PNEU
1157	156	F	73302	D	158	228	3.47	14116	LUNG		PNEU	RAD PNEU
1158	242	F	73211	D	66	136	4.9	14769	LUNG		PNEU	RAD PNEU
1157	141	F	73310	D	166	236	3.62	14929	LUNG		PNEU	RAD PNEU
1157	74	F	73278	D	134	204	3.86	14964	LUNG		SQ META	RAD PNEU
1157	122	F	73243	D	99	169	4.3	15116	LUNG		PNEU	RAD PNEU
1158	59	F	73228	D	83	153	4.6	15181	LUNG		PNEU	RAD PNEU
1157	86	F	73319	D	175	245	3.65	15269	LUNG		PNEU	RAD PNEU
1157	73	F	73271	D	127	197	4.09	15597	LUNG		PNEU	RAD PNEU
1157	58	F	73254	D	110	180	4.29	15626	LUNG		FIBROSIS	RAD PNEU
1157	58	F	73254	D	110	180	4.29	15626	LUNG		SQ META	RAD PNEU
1157	98	F	73264	D	120	190	4.19	15697	LUNG		PNEU	RAD PNEU
1157	98	F	73264	D	120	190	4.19	15697	LUNG		FIBROSIS	RAD PNEU
1157	98	F	73264	D	120	190	4.19	15697	LUNG		SQ META	RAD PNEU
1157	100	F	73235	D	91	161	4.6	15700	LUNG		PNEU	RAD PNEU
1157	100	F	73235	D	91	161	4.6	15700	LUNG		FIBROSIS	RAD PNEU
1157	100	F	73235	D	91	161	4.6	15700	LUNG		SQ META	RAD PNEU
1157	92	F	74127	D	348	418	3.28	15789	LUNG		FIBROSIS	RAD PNEU
1157	92	F	74127	D	348	418	3.28	15789	LUNG		SQ META	RAD PNEU
1157	113	F	73290	D	146	216	4.02	15987	LUNG		PNEU	RAD PNEU
1157	114	F	73293	D	149	219	4.02	16082	LUNG		PNEU	RAD PNEU
1158	222	F	73257	D	112	182	4.42	16195	LUNG		PNEU	RAD PNEU
1158	247	F	73225	D	80	150	5.0	16273	LUNG		PNEU	RAD PNEU
1157	68	F	73255	D	111	181	4.46	16293	LUNG		PNEU	RAD PNEU
1157	68	F	73255	D	111	181	4.46	16293	LUNG		FIBROSIS	RAD PNEU
1157	68	F	73255	D	111	181	4.46	16293	LUNG		SQ META	RAD PNEU
1157	71	F	73279	D	135	205	4.21	16358	LUNG		PNEU	RAD PNEU
1157	71	F	73279	D	135	205	4.21	16358	LUNG		FIBROSIS	RAD PNEU
1157	149	F	73277	D	133	203	4.25	16439	LUNG		PNEU	RAD PNEU
1158	230	F	73298	D	153	223	4.08	16447	LUNG		PNEU	UNKNOWN
1157	136	F	73239	D	95	165	4.8	16634	LUNG		PNEU	RAD PNEU
1157	102	F	73225	D	81	151	5.1	16677	LUNG		PNEU	RAD PNEU
1157	56	F	73263	D	119	189	4.5	16813	LUNG		FIBROSIS	RAD PNEU
1157	56	F	73263	D	119	189	4.5	16813	LUNG		SQ META	RAD PNEU
1158	114	F	74042	D	262	332	3.7	16999	LUNG		PNEU	RAD PNEU
1158	171	F	73269	D	124	194	4.52	17109	LUNG		PNEU	RAD PNEU
1158	168	F	73292	D	147	217	4.36	17374	LUNG		PNEU	RAD PNEU
1157	112	F	73240	D	96	166	5.0	17391	LUNG		PNEU	RAD PNEU
1158	207	F	[illegible]267	D	122	192	4.62	17399	LUNG		PNEU	UNKNOWN
1157	119	F	73237	D	93	163	5.1	17542	LUNG		PNEU	RAD PNEU

			---------------		DEATH	-------					
R.B.#	ANI.#	SEX	DATE	TYPE	DPE	AGE	UCI	DOSE	SITE	TUMOR	LESION	CAUSE OF DEATH
1158	196	F	73257	D	112	182	4.81	17624	LUNG		PNEU	RAD PNEU
1158	231	F	73291	D	146	216	4.46	17737	LUNG		PNEU	UNKNOWN
1158	95	F	73320	D	175	245	4.24	17737	LUNG		PNEU	RAD PNEU
1157	55	F	7[illegible]74	D	130	200	4.63	17784	LUNG		PNEU	RAD PNEU
1157	55	F	73274	D	130	200	4.63	17784	LUNG		FIBROSIS	RAD PNEU
1157	55	F	73274	D	130	200	4.63	17784	LUNG		SQ META	RAD PNEU
1158	162	F	73289	D	144	214	4.5	17824	LUNG		PNEU	RAD PNEU
1157	110	F	73248	D	104	174	5.0	17875	LUNG		PNEU	RAD PNEU
1157	137	F	73249	D	105	175	5.0	17932	LUNG		PNEU	RAD PNEU
1157	144	F	73266	D	122	192	4.77	17963	LUNG		PNEU	RAD PNEU
1157	144	F	73266	D	122	192	4.77	17963	LUNG		PNEU	RAD PNEU
1157	79	F	73304	D	160	230	4.41	18003	LUNG		PNEU	RAD PNEU
1157	79	F	73304	D	160	230	4.41	18003	LUNG		FIBROSIS	RAD PNEU
1158	156	F	73324	D	179	249	4.28	18012	LUNG		PNEU	RAD PNEU
1157	106	F	73262	D	118	188	4.86	18110	LUNG		PNEU	RAD PNEU
1158	186	F	73257	R	112	182	4.97	18210	LUNG		PNEU	RAD PNEU
1157	146	F	73269	D	125	195	4.81	18253	LUNG		PNEU	RAD PNEU
1157	126	F	73255	D	111	181	5.0	18266	LUNG		PNEU	RAD PNEU
1158	172	F	73266	D	121	191	4.9	18405	LUNG		PNEU	RAD PNEU
1157	80	F	73268	D	124	194	4.88	18472	LUNG		PNEU	RAD PNEU
1157	80	F	73268	D	124	194	4.88	18472	LUNG		FIBROSIS	RAD PNEU
1157	80	F	73268	D	124	194	4.88	18472	LUNG		SQ META	RAD PNEU
1158	148	F	73253	D	108	178	5.11	18500	LUNG		PNEU	RAD PNEU
1157	111	F	73278	D	134	204	4.82	18686	LUNG		PNEU	RAD PNEU
1158	176	F	73235	D	90	160	5.5	18697	LUNG		PNEU	RAD PNEU
1158	208	F	73217	D	72	142	6.0	18741	LUNG		PNEU	UNKNOWN
1158	200	F	73275	D	130	200	4.9	18821	LUNG		PNEU	UNKNOWN
1157	54	F	74122	D	343	413	3.93	18881	LUNG		FIBROSIS	RAD PNEU
1158	215	F	73248	D	103	173	5.3	18885	LUNG		PNEU	RAD PNEU
1158	191	F	73277	D	132	202	4.9	18909	LUNG		PNEU	RAD PNEU
1158	220	F	?	D	135	205	4.87	1892[illegible]	LUNG		PNEU	RAD PNEU
1157	140	F	73248	D	104	174	5.3	18947	LUNG		PNEU	RAD PNEU
1158	62	F	73234	D	89	159	5.6	18961	LUNG		PNEU	RAD PNEU
1158	146	F	73282	D	137	207	4.87	19006	LUNG		PNEU	RAD PNEU
1158	163	F	73305	D	160	230	4.66	19023	LUNG		PNEU	RAD PNEU
1158	9	F	73217	D	72	142	6.1	19053	LUNG		PNEU	RAD PNEU
1157	60	F	74297	D	518	588	3.82	19088	LUNG		PNEU	RAD PNEU
1157	60	F	74297	D	518	588	3.82	19088	LUNG		FIBROSIS	RAD PNEU
1158	195	F	73236	D	91	161	5.6	19113	LUNG		PNEU	RAD PNEU
1158	93	F	73282	D	137	207	4.92	19201	LUNG		PNEU	RAD PNEU

A1.5 TOXICITY OF INHALED 144-CEO2 IN MICE (CONT'D)

R.R.#	ANI.#	SEX	DATE	TYPE	DEATH DPE	DEATH AGE	DEATH UCI	DOSE	SITE	TUMOR	LESION	CAUSE OF DEATH
1158	109	F	73244	D	99	169	5.5	19335	LUNG		PNEU	RAD PNEU
1158	94	F	73250	D	105	175	5.4	19367	LUNG		PNEU	RAD PNEU
1158	61	F	73235	D	90	160	5.7	19377	LUNG		PNEU	RAD PNEU
1158	128	F	73246	D	101	171	5.5	19468	LUNG		PNEU	RAD PNEU
1158	241	F	73362	D	217	287	4.42	19508	LUNG		PNEU	RAD PNEU
1157	48	F	73228	D	84	154	5.9	19558	LUNG		PNEU	RAD PNEU
1157	129	F	73262	D	118	188	5.25	19563	LUNG		PNEU	RAD PNEU
1158	232	F	73256	D	111	181	5.36	19581	LUNG		PNEU	UNKNOWN
1158	180	F	73263	D	118	188	5.3	19749	LUNG		PNEU	RAD PNEU
1158	214	F	73283	D	138	208	5.08	19869	LUNG		PNEU	RAD PNEU
1157	133	F	73247	D	103	173	5.6	19954	LUNG		PNEU	RAD PNEU
1158	226	F	73243	D	98	168	5.7	19968	LUNG		PNEU	UNKNOWN
1157	57	F	73275	D	131	201	5.19	19982	LUNG		PNEU	RAD PNEU
1157	57	F	73275	D	131	201	5.19	19982	LUNG		FIBROSIS	RAD PNEU
1157	57	F	73275	D	131	201	5.19	19982	LUNG		SQ META	RAD PNEU
1157	95	F	73234	D	90	160	5.9	20057	LUNG		PNEU	RAD PNEU
1157	95	F	73234	D	90	160	5.9	20057	LUNG		FIBROSIS	RAD PNEU
1157	95	F	73234	D	90	160	5.9	20057	LUNG		SQ META	RAD PNEU
1157	91	F	73244	D	100	170	5.7	20107	LUNG		PNEU	RAD PNEU
1157	91	F	73244	D	100	170	5.7	20107	LUNG		FIBROSIS	RAD PNEU
1158	133	F	73245	D	100	170	5.7	20107	LUNG		PNEU	RAD PNEU
1158	136	F	73241	D	96	166	5.8	20173	LUNG		PNEU	PNEU
1157	121	F	73282	D	138	208	5.16	20182	LUNG		PNEU	RAD PNEU
1158	92	F	73290	D	145	215	5.13	20361	LUNG		SQ META	RAD PNEU
1158	228	F	73259	D	114	184	5.55	20452	LUNG		PNEU	UNKNOWN
1158	237	F	73296	D	151	221	5.13	20601	LUNG		PNEU	UNKNOWN
1158	178	F	73295	D	150	220	5.2	20843	LUNG		PNEU	RAD PNEU
1157	109	F	73288	D	144	214	5.28	20913	LUNG		PNEU	RAD PNEU
1157	147	F	73264	D	140	210	5.33	20936	LUNG		PNEU	RAD PNEU
1157	139	F	73312	D	168	238	5.07	20977	LUNG		PNEU	RAD PNEU
1158	173	F	73282	D	137	207	5.44	21231	LUNG		PNEU	RAD PNEU
1157	103	F	73261	D	117	187	5.73	21293	LUNG		PNEU	RAD PNEU
1158	142	F	73270	D	125	195	5.63	21364	LUNG		PNEU	RAD PNEU
1158	225	F	73261	D	116	186	5.8	21494	LUNG		PNEU	RAD PNEU
1158	63	F	73259	D	114	184	5.89	21705	LUNG		PNEU	RAD PNEU
1157	142	F	73247	D	103	173	6.1	21736	LUNG		PNEU	RAD PNEU
1158	149	F	73288	D	143	213	5.5	21740	LUNG		PNEU	RAD PNEU
1157	154	F	73321	D	177	247	5.19	21777	LUNG		PNEU	RAD PNEU
1157	148	F	73276	D	132	202	5.66	21842	LUNG		PNEU	RAD PNEU
1158	179	F	73228	D	83	153	6.7	22111	LUNG		PNEU	RAD PNEU
1158	130	F	73312	D	167	237	5.37	22183	LUNG		PNEU	RAD PNEU

A1.5 TOXICITY OF INHALED 144-CEO2 IN MICE (CONT'D)

R.B.#	ANI.#	SEX	DATE	DEATH TYPE	DEATH DPE	DEATH AGE	DEATH UCI	DOSE	SITE	TUMOR	LESION	CAUSE OF DEATH
1158	221	F	73259	D	114	184	6.04	22258	LUNG		PNEU	RAD PNEU
1158	204	F	73269	D	124	194	5.89	22295	LUNG		PNEU	UNKNOWN
1157	89	F	74273	D	494	564	4.5	22421	LUNG	CARCINOMA	UNDIFF	CARCINOMA
1158	197	F	73250	D	105	175	6.3	22595	LUNG		PNEU	RAD PNEU
1157	59	F	74360	D	581	651	4.5	22614	LUNG		PNEU	RAD PNEU
1157	59	F	74360	D	581	651	4.5	22614	LUNG		FIBROSIS	RAD PNEU
1157	59	F	74360	D	581	651	4.5	22614	LUNG		SQ META	RAD PNEU
1157	104	F	73274	D	130	200	5.89	22624	LUNG		PNEU	RAD PNEU
1158	158	F	75108	D	693	763	4.5	22738	LUNG	ADENOMA		UNKNOWN
1158	229	F	73235	D	90	160	6.7	22777	LUNG		PNEU	UNKNOWN
1158	213	F	73282	D	137	207	5.9	23026	LUNG		PNEU	RAD PNEU
1158	51	F	73247	D	102	172	6.5	23085	LUNG		PNEU	RAD PNEU
1158	104	F	73244	D	99	169	6.6	23202	LUNG		PNEU	RAD PNEU
1158	132	F	73280	D	135	205	5.98	23235	LUNG		PNEU	RAD PNEU
1158	189	F	73252	D	107	177	6.44	23243	LUNG		PNEU	RAD PNEU
1158	150	F	73288	D	143	213	5.96	23558	LUNG		PNEU	RAD PNEU
1158	239	F	73260	D	115	185	6.38	23578	LUNG		PNEU	RAD PNEU
1157	134	F	73286	D	142	212	6.05	23865	LUNG		PNEU	RAD PNEU
1158	49	F	73237	D	92	162	7.0	23984	LUNG		PNEU	RAD PNEU
1158	217	F	73293	D	148	218	6.02	24036	LUNG		PNEU	RAD PNEU
1158	78	F	73243	D	98	168	6.9	24172	LUNG		PNEU	RAD PNEU
1158	246	F	73277	D	132	202	6.29	24273	LUNG		PNEU	RAD PNEU
1157	143	F	73237	D	93	163	7.1	24421	LUNG		PNEU	RAD PNEU
1157	135	F	73235	D	91	161	7.2	24574	LUNG		PNEU	RAD PNEU
1158	107	F	73310	D	165	235	5.97	24580	LUNG		PNEU	RAD PNEU
1158	240	F	73220	D	75	145	7.9	25079	LUNG		PNEU	RAD PNEU
1158	29	F	73253	D	108	178	6.96	25198	LUNG		PNEU	RAD PNEU
1157	33	F	73246	D	102	172	7.1	25216	LUNG		PNEU	PNEU
1158	23	F	73271	D	126	196	6.64	25260	LUNG		PNEU	RAD PNEU
1157	96	F	73224	D	80	150	7.8	25387	LUNG		PNEU	RAD PNEU
1157	96	F	73224	D	80	150	7.8	25387	LUNG		FIBROSIS	RAD PNEU
1157	96	F	73224	D	80	150	7.8	25387	LUNG		SQ META	RAD PNEU
1158	84	F	73220	D	75	145	8.0	25396	LUNG		PNEU	RAD PNEU
1158	234	F	73236	D	91	161	7.8	26621	LUNG		PNEU	UNKNOWN
1158	227	F	73266	D	121	191	7.28	27345	LUNG		PNEU	UNKNOWN
1158	88	F	73288	D	143	213	7.06	27906	LUNG		PNEU	RAD PNEU
1158	218	F	73232	D	87	157	8.39	28174	LUNG		PNEU	RAD PNEU
1158	177	F	73274	D	129	199	7.55	28931	LUNG		PNEU	RAD PNEU
1158	233	F	73260	D	115	185	421	1555828	LUNG		PNEU	UNKNOWN

(DATA FROM D.L. LUNDGREN ET AL., 1974.) SEE REFERENCE #32.

1060 356

A1.6 TOXICITY OF 90-Y INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS

NUMBER			INHALATION EXP				I.L.B.			I.B.B.		RADIATION DOSE TO LUNG						DAYS		
												RATE (RADS/MIN)		CUMULATIVE (RADS)						
TT00	RADBIO	SEX	BLK	DATE	AGE DAYS	WT KG	RNK	UCI KG	UCI	UCI KG	UCI	INITIAL	TO DEATH	INFIN.	AT DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
333A	02-661	M	A	69266	415	10.3	1	5200	53000	6100	62000	15.0	3	81000	70000	69273		7	D-PULMONARY INJURY
333T	01-661	F	B	69266	415	8.6	2	3600	31000	4800	42000	10.0	0.5	57000	55000	69278		12	D-PULMONARY INJURY
347S	02-684	F	D	69322	379	9.8	3	2800	27000	3500	34000	8.0	0	44000	44000	70004		47	D-PULMONARY INJURY
340C	03-684	M	C	69322	419	10.6	4	2600	28000	3500	37000	7.6	0	41000	41000	69353		31	D-PULMONARY INJURY
332V	01-662	F	B	69267	418	[illegible].5	5	2400	13000	4100	23000	6.0	0	37000	37000	69342		75	D-PULMONARY INJURY
339A	04-684	M	C	69322	422	[illegible].8	6	1900	19000	2400	23000	5.6	0	30000	30000	70021		64	D-PULMONARY INJURY
335S	03-661	F	B	69266	399	9.6	7	1900	18000	2600	25000	5.5	0	29000	29000	69336		70	D-PULMONARY INJURY
334A	04-661	M	A	69266	406	11.4	8	1700	19000	2300	26000	4.8	0	27000	27000	69304		38	E-PULMONARY INJURY
341T	03-685	F	D	69323	417	9.0	9	1700	15000	2500	22000	4.8	0	27000	27000	70033		75	D-PULMONARY INJURY
340U	01-684	F	D	69322	419	9.8	10	1600	16000	4600	45000	4.8	0	25000	25000	70045		88	D-PULMONARY INJURY
341C	02-685	M	C	69323	417	10.1	11	1500	15000	1800	18000	4.4	0	24000	24000	70043		85	D-PULMONARY INJURY
340B	05-685	M	C	69323	421	10.6	12	1400	15000	1700	18000	4.2	0	23000	23000	70048		90	D-PULMONARY INJURY
334B	02-662	M	A	69267	407	10.6	13	1400	15000	1900	20000	4.1	0	23000	23000	69290		23	D-PULMONARY INJURY
332T	04-662	F	B	69267	418	8.0	14	1400	11000	1900	15000	4.1	0	22000	22000	69356		89	E-PULMONARY INJURY
347B	04-685	M	C	69323	380	8.5	15	1300	11000	1500	13000	3.8	0	20000	20000	70033		75	D-PULMONARY INJURY
335A	03-662	M	A	69267	400	9.6	16	1100	11000	1600	15000	3.2	0	18000	18000	69358		91	D-PULMONARY INJURY
343V	01-685	F	D	69323	395	7.1	17	1100	7500	2600	18000	3.0	0	17000	17000	70050		92	D-PULMONARY INJURY
406U	04-820	F	H	70258	409	8.4	18	1100	8800	1400	12000	3.0	0	17000	17000	70349		91	D-PULMONARY INJURY
339S	05-662	F	B	69267	367	7.7	19	1000	7800	1800	14000	2.9	0	17000	17000	69349		82	D-PULMONARY INJURY
406A	03-820	M	G	70258	409	12.0	20	980	12000	1500	18000	2.7	0	15000	15000	71001		108	D-PULMONARY INJURY
448U	02-874	F	L	71089	411	8.4	21	900	7600	1800	15000	2.7	0	14000	14000	71230		141	D-PULMONARY INJURY
439A	03-863	M	I	71053	402	13.1	22	850	11000	1300	17000	2.4	0	14000	14000	71158.		105	D-PULMONARY INJURY
343C	03-686	M	C	69325	397	9.3	23	760	7100	860	8000	2.2	0	12000	12000	70077		117	D-PULMONARY INJURY
437T	01-863	F	J	71053	406	7.6	24	740	5600	820	6200	2.2	0	12000	12000	71175		122	D-PULMONARY INJURY
380B	01-746	M	E	70124	394	9.0	25	730	6600	970	8700	2.2	0	12000	12000	70323		199	D-PULMONARY INJURY
451B	04-874	M	K	71089	401	9.5	26	730	6900	1100	10000	2.2	0	12000	12000	71232		143	D-PULMONARY INJURY
403T	02-820	F	H	70258	416	6.9	27	710	4900	910	6300	2.0	0	11000	11000	71023		130	D-PULMONARY INJURY
449U	01-874	F	L	71089	408	5.9	28	710	4200	1200	7100	2.0	0	11000	11000	73261		903	D-SEE NOTE AT END
452B	03-874	M	K	71089	401	9.8	29	700	6900	1100	11000	2.0	0	11000	11000	71210		121	D-PULMONARY INJURY
341S	02-686	F	D	69325	419	9.8	30	690	6800	940	9200	2.0	0	11000	11000	70123		163	D-PULMONARY INJURY
413A	01-821	M	G	70259	383	11.2	31	680	7600	780	8700	2.0	0	11000	11000	71108		214	D-PULMONARY INJURY
333B	06-662	M	A	69267	416	11.9	32	680	8000	980	12000	1.9	0	11000	11000	70028		126	D-PULMONARY INJURY
448B	04-86[illegible]	M	I	71053	375	9.8	33	670	6600	850	8300	1.9	0	10000	10000	77139		2278	E-SEE NOTE AT END
402C	01-820	M	G	70258	417	7.0	34	660	4700	790	5500	1.9	0	10000	10000	71356		463	D-PULMONARY INJURY
404U	03-821	F	H	70259	416	5.8	35	640	3700	860	5100	1.9	0	10000	10000	71114		220	D-PULMONARY INJURY
434T	02-863	F	J	71053	415	7.3	36	640	4700	810	5900	1.9	0	10000	10000	71176		123	D-PULMONARY INJURY
446C	03-864	M	I	71054	380	11.2	37	600	6700	670	7600	1.8	0	9500	9500	71291		237	D-PULMONARY INJURY
436U	01-864	F	J	71054	412	9.1	38	590	5300	930	8500	1.8	0	9300	9300	71259		205	D-PULMONARY INJURY
371S	03-746	F	F	70124	423	7.8	39	590	4600	670	5200	1.8	0	9300	9300	70306		182	D-PULMONARY INJURY
400T	04-821	F	H	70259	426	6.5	40	500	3300	560	3600	1.5		7900			2936		
378B	04-746	M	E	70124	410	10.3	41	490	5100	700	7000	1.4	0	7700	7700	77194		2627	E-SEE NOTE AT END
333S	02-663	F	B	69268	417	7.6	42	460	3500	590	4400	1.4		7200	7200	75327		2250	D-BRONC. ALV. CARC.
450B	03-875	M	K	71090	406	9.4	43	450	4200	560	5300	1.3		7100			2740		
446S	04-864	F	J	71054	380	8.1	44	420	3400	560	4500	1.2	0	6600	6600	77239		2377	E-SEE NOTE AT END
332C	01-663	M	A	69268	419	8.5	45	410	3500	500	4300	1.2		6500		78013		3032	E-SEE NOTE AT END
449S	04-875	F	L	71090	409	7.9	46	400	3200	560	4400	1.2		6400			2740		
400U	01-817	F	H	70251	418	7.6	47	400	3000	530	4000	1.2		6200			2944		
411C	02-821	M	G	70259	394	9.2	48	380	3500	570	5200	1.1		6000			2936		
439C	02-864	M	I	71054	403	9.7	49	380	3700	700	6800	1.1		6000			2776		
411D	04-817	M	G	70251	386	9.8	50	380	3700	420	4100	1.1		6000			2944		

1060 357

A1.6 TOXICITY OF 90-Y INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

NUMBER TT00	NUMBER RADBIO	INHALATION EXP SEX	BLK	DATE	AGE DAYS	WT KG	I.L.B. RNK	I.L.B. UCI KG	I.L.B. UCI	I.B.B. UCI KG	I.B.B. UCI	RADIATION DOSE TO LUNG RATE (RADS/MIN) INITIAL	RATE (RADS/MIN) TO DEATH	CUMULATIVE (RADS) INFIN.	CUMULATIVE (RADS) AT DEATH	DEATH DATE	DAYS 9-30 1978	DAYS DEATH	COMMENT
452A	01-875	M	K	71090	402	9.6	51	380	3600	530	5100	1.1		6000			2740		
449T	02-875	F	L	71090	409	8.2	52	380	3100	540	4400	1.1		6000			2740		
374T	02-746	F	F	70124	414	8.0	53	370	3000	460	3700	1.1		5800			3071		
348C	04-686	M	C	69325	376	8.7	54	360	3200	670	5800	1.1		5700			3235		
343T	01-686	F	D	69325	397	8.5	55	360	3100	440	3700	1.1		5700			3235		
434S	01-867	F	J	71055	417	9.4	56	340	3200	440	4100	.96		5300			2775		
407S	02-817	F	H	70251	402	7.2	57	320	2300	440	3200	.93		5100			2944		
380D	01-747	M	E	70125	395	9.4	58	300	2900	400	3800	.90		4800			3070		
406B	03-817	M	G	70251	402	12.0	59	300	3600	480	5700	.88		4800			2944		
446D	04-867	M	I	71055	381	11.4	60	300	3400	460	5200	.88		4800			2775		
375U	02-747	F	F	70125	415	7.6	61	290	2200	390	3030	.88		4800			3070		
437S	03-867	F	J	71055	408	8.4	62	280	2300	430	3600	.80		4400			2775		
441A	02-867	M	I	71055	399	9.0	63	270	2400	340	3100	.79		4300			2775		
399A	02-818	M	G	70252	422	9.0	64	260	2300	280	2500	.75		4100			2943		
377B	03-747	M	E	70125	412	9.0	65	250	2300	340	3100	.72		3900			3070		
450C	01-876	M	K	71091	407	10.4	66	250	2600	270	2800	.72		3900			2739		
339U	04-687	F	D	69328	428	7.2	67	240	1750	220	2300	.69		3800			3232		
372S	04-747	F	F	70125	423	9.6	68	230	2200	320	3100	.69		3600			3070		
339B	01-687	M	C	69328	428	9.1	69	230	2100	230	2100	.65		3600			3232		
332S	03-663	F	B	69268	419	8.6	70	220	1900	280	2400	.65		3600			3292		
447U	04-876	F	L	71091	414	6.6	71	220	1500	270	1800	.65		3400			2739		
335B	04-663	M	A	69268	401	9.8	72	190	1900	280	2700	.56		3000			3292		
408U	01-818	F	H	70252	395	9.0	73	190	1700	260	2400	.56		3000			2943		
438S	01-868	F	J	71056	405	9.7	74	190	1800	420	4100	.55		3000			2774		
447B	03-868	M	I	71056	370	7.3	75	180	1300	290	2100	.52		2800			2774		
377S	01-748	F	F	70126	413	9.9	76	150	1500	190	1900	.43		2400			3069		
380C	03-748	M	E	70126	396	10.2	77	140	1500	180	1900	.43		2300			3069		
339T	02-665	F	B	69269	369	6.4	78	130	830	190	1200	.38		2000			3291		
407B	03-818	M	G	70252	403	10.6	79	130	1300	190	2000	.37		2000			2943		
450E	03-876	M	K	71091	407	10.2	80	130	1300	170	1700	.37		2000			2739		
448T	02-876	F	L	71091	413	8.3	81	120	960	140	1200	.33		1900			2739		
343A	01-687	M	C	69328	400	9.3	82	110	1000	120	1100	.33		1800			3232		
405U	04-818	F	H	70252	403	6.8	83	110	720	150	1000	.30		1700			2943		
334C	01-665	M	A	69269	409	8.3	84	100	850	140	1200	.30		1700			3291		
436V	04-868	F	J	71056	414	7.4	85	100	750	180	1300	.29		1500			2774		
438B	02-868	M	I	71056	405	8.6	86	98	840	150	1300	.28		1500			2774		
379B	02-748	M	E	70126	402	10.7	87	90	960	110	1200	.27		1400			3069		
372T	04-748	F	F	70126	424	10.4	88	83	860	92	960	.23		1300			3069		
340T	02-687	F	D	69328	425	10.2	89	80	810	100	1100	.23		1300			3232		
333E	01-660	M	A	69265	414	9.4	C	0	0	0	0	0		0			3295		
334T	02-660	F	B	692[illegible]5	405	8.5	C	0	0	0	0	0		0			3295		
349B	01-683	M	C	69321	372	12.2	C	0	0	0	0	0		0			3239		
348S	02-683	F	D	69321	372	9.0	C	0	0	0	0	0		0			3239		
378A	01-745	M	E	70121	407	11.6	C	0	0	0	0	0		0			3074		
383U	02-745	F	F	70121	375	6.0	C	0	0	0	0	0		0			3074		
407T	01-812	F	H	70247	398	8.0	C	0	0	0	0	0		0			2948		
401A	02-812	M	G	70247	413	9.2	C	0	0	0	0	0		0			2948		
441B	01-862	M	I	71050	394	8.6	C	0	0	0	0	0		0			2780		
438U	02-862	F	J	71050	399	7.8	C	0	0	0	0	0		0			2780		
448A	01-873	M	K	71085	407	10.0	C	0	0	0	0	0		0			2745		
447W	02-873	F	L	71085	408	6.6	C	0	0	0	0	0		0			2745		

UCI/KG: KG REFERS TO TOTAL BODY WEIGHT.
COMMENT: D,E,OR S: DIED,EUTHANIZED,OR SACRIFICED WITH THE MOST PROMINENT FEATURES ASSOCIATED WITH DEATH.

NOTES:

DOG 449U: D-PULMONARY FIBROSIS AND PULMONARY ADENOMA
DOG 448B: E-PULMONARY FIBROSARCOMA; PULMONARY HYPERTROPHIC OSTEOARTHROPATHY
DOG 378B: E-MULTIPLE BROCHIOLO ALVEOLAR CARCINOMAS, PARAOSTEAL OSTEOSARCOMA
DOG 446S: E-CARCINOMA - SITE UNDETERMINED
DOG 332C: E-SQUAMOUS CELL CARCINOMA - LUNG

(DATA ARE FROM LF-60, 1978 AND REPRESNET AN UPDATE OF DATA FROM B.S. MERICKEL ET AL., 1978.) SEE REFERENCE #34

1060 358

A1.7 TOXICITY OF 91-Y INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS

NUMBER		INHALATION EXP					I.L.B.			I.B.B.		RADIATION DOSE TO LUNG									
												RATE (RADS/DAY)					CUMULATIVE (RADS)				
TT00	RADBIO	SEX	BLK	DATE	AGE DAYS	WT KG	RNK	UCI KG	UCI	UCI KG	UCI	INIT	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	9-30 1978	POTENT. INFIN.
386T	04-759	F	D	70154	400	13.5	1	360	4900	1000	14000	990	440			210	41000				73000+
375A	01-722	M	A	70079	369	10.4	2	320	3300	870	9000	880	360	150		110	35000	49000			59000+
384A	02-758	M	C	70153	404	12.0	3	300	3600	770	9200	830	390	180		69	35000	51000			65000+
383S	01-760	F	B	70155	409	11.0	4	300	3300	840	9200	830	360	150		85	34000	48000			59000+
384S	02-759	F	B	70154	405	10.9	5	300	3300	700	7700	820	360	160		51	34000	48000			60000+
372A	03-724	M	A	70082	380	11.2	6	270	3100	670	7500	750	320	130		53	3000	43000			52000+
384B	03-758	M	C	70153	404	10.2	7	260	2700	640	6500	720	320	140		30	30000	43000			53000+
392U	01-761	F	D	70156	368	9.4	8	260	2400	470	4400	710	320	140		91	29000	42000			53000+
385A	03-759	M	C	70154	401	11.0	9	230	2600	350	3900	640	280	120		59	26000	38000			46000+
393S	01-758	F	B	70153	362	10.8	10	210	2300	390	4300	570	250	110		48	23000	33000			41000+
374A	03-722	M	A	70079	369	10.8	11	200	2100	290	3100	530	240	110		75	22000	32000			40000+
387V	02-760	F	D	70155	399	7.1	12	190	1300	400	2800	520	230	100		96	21000	30000			38000+
489C	01-951	M	K	71257	382	7.6	13	190	1500	360	2800	520	220	96		7.8	21000	30000			37000
484E	01-953	M	K	71259	398	9.1	14	180	1700	310	2800	510	210	90		24	20000	29000			35000+
423C	03-835	M	E	70342	391	8.9	15	170	1500	230	2000	460	200	86		49	19000	27000			33000+
426S	04-834	F	F	70341	386	7.9	16	170	1300	320	2600	430	190	81		28	18000	25000			31000+
491A	04-952	M	I	71258	368	9.8	17	170	1700	380	3700	470	200	84		29	19000	27000			33000+
483T	04-951	F	L	71257	396	6.4	18	170	1100	270	1700	450	200	88		4.1	18000	27000			33000
484S	03-952	F	J	71258	397	7.2	19	170	1200	370	2600	450	190	82		39	18000	26000			32000+
374B	01-724	M	A	70082	372	9.4	20	160	1500	320	3000	430	190	82		64	18000	25000			31000+
385D	01-759	M	C	70154	401	9.4	21	160	1500	340	3200	430	190	84		36	18000	26000			32000+
385S	04-758	F	B	70153	400	8.8	22	150	1300	470	4100	400	180	78		9.7	16000	24000			29000
420C	01-834	M	G	70341	401	10.9	23	150	1700	350	3800	420	190	84		55	17000	25000			31000+
419V	04-835	F	H	70342	415	7.1	24	150	1100	170	1200	420	180	79		50	17000	24000			30000+
491B	01-952	M	I	71258	368	9.0	25	150	1300	200	1800	410	170	72		30	16000	23000			28000+
390V	02-761	F	D	70156	376	7.6	26	140	1100	450	3400	380	170	77		13	16000	23000			29000+
492A	03-956	M	I	71264	374	11.3	27	140	1500	300	3200	370	150	60		14	14000	20000			24000+
422C	02-834	M	E	70341	397	10.8	28	130	1400	200	2200	370	160	69		30	15000	21000			26000+
485U	02-951	F	J	71257	394	6.2	29	130	830	220	1400	360	150	65	1.9		15000	21000	25000		25000
489B	01-954	M	K	71260	386	10.0	30	130	1300	240	2400	360	150	64	1.9		14000	20000	25000		25000
420U	01-836	F	F	70343	403	7.3	31	120	880	250	1800	330	150	66		42	14000	20000			25000+
420B	01-837	M	G	70344	404	10.4	32	120	1300	210	2200	330	150	64		30	14000	20000			24000+
422S	02-835	F	H	70342	398	11.3	33	120	1400	280	3200	330	140	58		27	13000	19000			23000+
490T	02-952	F	J	71258	369	7.9	34	120	920	140	1100	320	140	62	2.2		13000	19000	23000		23000
430A	01-835	M	E	70342	372	10.8	35	110	1200	560	6500	300	130	60		5.9	12000	18000			22000
425T	03-834	F	F	70341	387	8.2	36	110	940	360	2900	330	140	61	2.0		13000	19000	23000		23000
484V	04-953	F	L	71259	398	6.0	37	110	680	180	1100	300	130	56	1.5		12000	18000	21000		21000
376B	02-724	M	A	70082	370	8.4	38	110	900	280	2300	300	130	56	1.8	.004	12000	17000	21000		21000
422B	03-838	M	E	70348	404	11.4	39	110	1200	160	1800	290	130	56	2.0		12000	17000	21000		21000
428A	02-841	M	G	70351	393	9.4	40	110	1100	200	1900	310	130	57	1.8	.016	13000	18000	22000		22000
484B	03-951	M	I	71257	396	8.6	41	110	930	170	1500	290	120	52	1.5		12000	17000	20000		20000
489S	02-956	F	J	71264	390	8.1	42	110	890	180	1400	300	130	52	1.5		12000	17000	20000		21000
387S	01-767	F	D	70162	406	7.7	43	100	800	330	2600	280	120	51	1.6		11000	16000	20000		20000
419T	02-838	F	F	70348	421	7.8	44	100	800	250	1900	280	120	54		35	11000	17000			20000+
490S	03-954	F	L	71260	372	8.1	45	100	850	190	1500	290	120	51		15	11000	16000			20000+
390T	04-766	F	B	70161	381	8.6	46	97	830	200	1700	260	120	51	1.8		11000	16000	19000		19000
483D	02-953	M	I	71259	398	7.7	47	94	720	140	1100	250	110	48	1.6		10000	15000	18000	18000	18000
490A	02-954	M	K	71260	372	9.2	48	92	840	150	1400	250	110	45		43	10000	14000			18000+
492S	04-956	F	J	71264	374	8.0	49	90	720	270	2300	250	94	36	.70		9500	13000	15000	15000	15000
428S	03-837	F	H	70344	386	7.1	50	89	640	210	1500	250	110	51	2.0		10000	15000	19000		19000

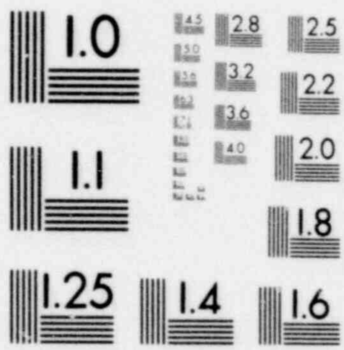
1060 359

A1.7 TOXICITY OF 91-Y INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS

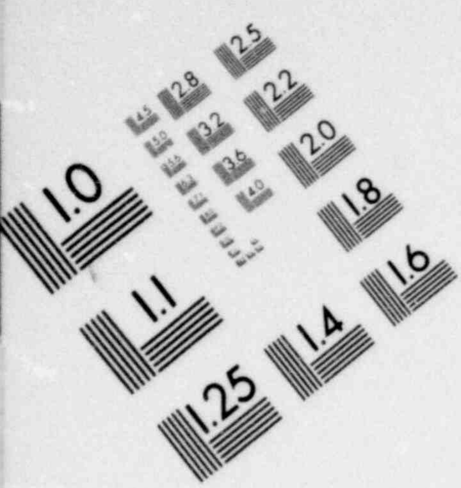
EXP WT KG	RNK	I.L.B. UCI/KG	I.L.B. UCI	I.B.B. UCI/KG	I.B.B. UCI	RADIATION DOSE TO LUNG: RATE (RADS/DAY) INIT	RATE 60 DAYS	RATE 120 DAYS	RATE 365 DAYS	RATE AT DEATH	CUMULATIVE (RADS) 60 DAYS	CUM. 120 DAYS	CUM. 365 DAYS	CUM. 9-30 1978	CUM. POTENT. INFIN.	CUM. TO DEATH	DEATH DATE	DAYS 9-30 1978	DAYS DEATH	COMMENT
13.5	1	360	4900	1000	14000	990	440			210	41000				73000+	57000	70267		113	D-PULMONARY INJURY
10.4	2	320	3300	870	9000	880	360	150		110	35000	49000			59000+	51000	70219		140	D-PULMONARY INJURY
12.0	3	300	3600	770	9200	830	390	180		69	35000	51000			65000+	60000	70347		194	D-PULMONARY INJURY
11.0	4	300	3300	840	9200	830	360	150		65	34000	48000			59000+	53000	70317		162	D-PULMONARY INJURY
10.9	5	300	3300	700	7700	820	360	160		51	34000	48000			60000+	56000	70356		202	D-PULMONARY INJURY
11.2	6	270	3100	670	7500	750	320	130		53	3000	43000			52000+	49000	70267		185	D-PULMONARY INJURY
10.2	7	260	2700	640	6500	720	320	140		30	30000	43000			53000+	51000	71024		236	D-PULMONARY INJURY
9.4	8	260	2400	470	4400	710	320	140		91	29000	42000			53000+	46000	70309		153	D-PULMONARY INJURY
11.0	9	230	2600	350	3900	640	280	120		59	26000	38000			46000+	42000	70327		173	D-PULMONARY INJURY
10.8	10	210	2300	390	4300	570	250	110		48	23000	33000			41000+	37000	70330		177	D-PULMONARY INJURY
10.8	11	200	2100	290	3100	530	240	110		75	22000	32000			40000+	34000	70226		147	D-PULMONARY INJURY
7.1	12	190	1300	400	2800	520	230	100		96	21000	30000			38000+	31000	70278		123	D-PULMONARY INJURY
7.6	13	190	1500	360	2800	520	220	96		7.8	21000	30000			37000	37000	72190		298	D-PULMONARY INJURY
9.1	14	186	1700	310	2800	510	210	90		24	20000	29000			35000+	34000	72107		213	D-PULMONARY INJURY
8.9	15	170	1500	230	2000	460	200	86		49	19000	27000			33000+	29000	71137		160	D-PULMONARY INJURY
7.9	16	170	1300	320	2600	430	190	81		28	18000	25000			31000+	29000	71172		196	D-PULMONARY INJURY
9.8	17	170	1700	380	3700	470	200	84		29	19000	27000			33000+	31000	72089		196	D-PULMONARY INJURY
6.4	18	170	1100	270	1700	450	200	88		4.1	18000	27000			33000	33000	72238		346	D-PULMONARY INJURY
7.2	19	170	1200	370	2600	450	190	82		39	18000	26000			32000+	29000	72065		172	D-PULMONARY INJURY
9.4	20	160	1500	320	3000	430	190	82		64	18000	25000			31000+	26000	70219		137	D-PULMONARY INJURY
9.4	21	160	1500	340	3200	430	190	84		36	18000	26000			32000+	29000	70335		181	D-PULMONARY INJURY
8.8	22	150	1300	470	4100	400	180	78		9.7	16000	24000			29000	29000	71062		274	D-PULMONARY INJURY
10.9	23	150	1700	350	3800	420	190	84		55	17000	25000			31000+	27000	71128		152	D-PULMONARY INJURY
7.1	24	150	1100	170	1200	420	180	79		50	17000	24000			30000+	27000	71130		153	D-PULMONARY INJURY
9.0	25	150	1300	200	1800	410	170	72		30	16000	23000			28000+	26000	72074		181	E-PULMONARY INJURY
7.6	26	140	1100	450	3400	380	170	77		13	16000	23000			29000+	28000	71043		252	E-PULMONARY INJURY
11.3	27	140	1500	300	3200	370	150	60		14	14000	20000			24000+	23000	72115		216	D-PULMONARY INJURY
10.8	28	130	1400	200	2200	370	160	69		30	15000	21000			26000+	24000	71155		179	D-PULMONARY INJURY
6.2	29	130	830	220	1400	360	150	65	1.9		15000	21000	25000		25000	25000	74276		1115	D-BRONC.ALV.CARCINOMA
10.0	30	130	1300	240	2400	360	150	64	1.9		14000	20000	25000		25000	25000	75234		1435	E-SEE NOTE AT END
7.3	31	120	880	250	1800	330	150	66		42	14000	20000			25000+	22000	71137		159	E-PULMONARY INJURY
10.4	32	120	1300	210	2200	330	150	64		30	14000	20000			24000+	22000	71153		174	D-PULMONARY INJURY
11.3	33	120	1400	280	3200	330	140	58		27	13000	19000			23000+	21000	71150		173	D-PULMONARY INJURY
7.9	34	120	920	140	1100	320	140	62	2.2		13000	19000	23000		23000	23000	76293		1861	D-BRONC.ALV.CARCINOMA
10.8	35	110	1200	560	6500	300	130	60		5.9	12000	18000			22000	22000	71272		295	E-PULMONARY INJURY
8.2	36	110	940	360	2900	330	140	61	2.0		13000	19000	23000		23000	23000	74268		1388	D-BRONCHOG. ADENOCARC.
6.0	37	110	680	180	1100	300	130	56	1.5		12000	18000	21000		21000	21000	75178		1380	E-SEE NOTE AT END
8.4	38	110	900	280	2300	300	130	56	1.8	.004	12000	17000	21000		21000	21000	72162		810	D-PULMONARY INJURY
11.4	39	110	1200	160	1800	290	130	56	2.0		12000	17000	21000		21000	21000	72153		535	D-PULMONARY INJURY
9.4	40	110	1100	200	1900	310	130	57	1.8	.016	13000	18000	22000		22000	22000	72325		704	D-PULMONARY INJURY
8.6	41	110	930	170	1500	290	120	52	1.5		12000	17000	20000		20000	20000	75138		1342	D-BRONC.ALV.CARCINOMA
8.1	42	110	890	180	1400	300	130	52	1.5		12000	17000	20000		21000	21000	76321		1883	E-BRONC.ALV.CARCINOMA
7.7	43	100	800	330	2600	280	120	51	1.6		11000	16000	20000		20000	20000	77119		2514	D-BRONC.ALV.CARCINOMA
7.8	44	100	800	250	1900	280	120	54		35	11000	17000			20000+	18000	71135		152	D-PULMONARY INJURY
8.1	45	100	850	190	1500	290	120	51		15	11000	16000			20000+	19000	72101		206	D-PUL. VASCULAR INJURY
8.6	46	97	830	200	1700	260	120	51	1.8		11000	16000	19000		19000	19000	76307		2337	E-BRONC.ALV.CARCINOMA
7.7	47	94	720	140	1100	250	110	48	1.6		10000	15000	18000	18000	18000			2571		
9.2	48	92	840	150	1400	250	110	45		45	10000	14000			18000+	15000	72019		124	D-PUL. VASCULAR INJURY
8.0	49	90	720	270	2300	250	94	36	.70		9500	13000	15000	15000	15000			2566		
7.1	50	89	640	210	1500	250	110	51	2.0		10000	15000	19000		19000	19000	77163		2376	D-SEE NOTE AT END

1060 360

IMAGE EVALUATION
TEST TARGET (MT-3)



6″



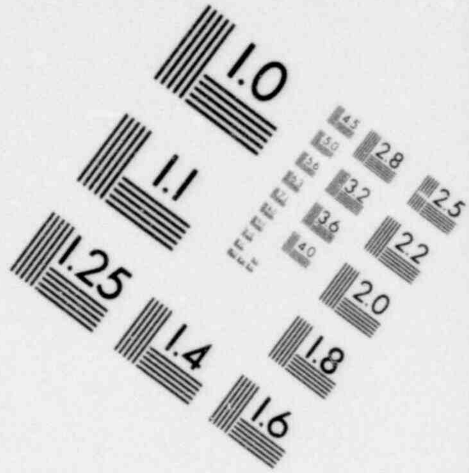
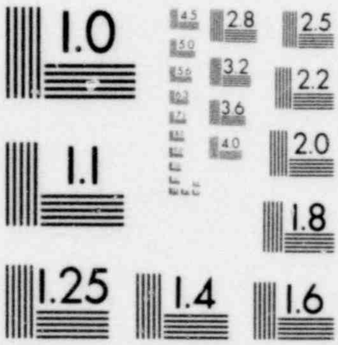


IMAGE EVALUATION TEST TARGET (MT-3)



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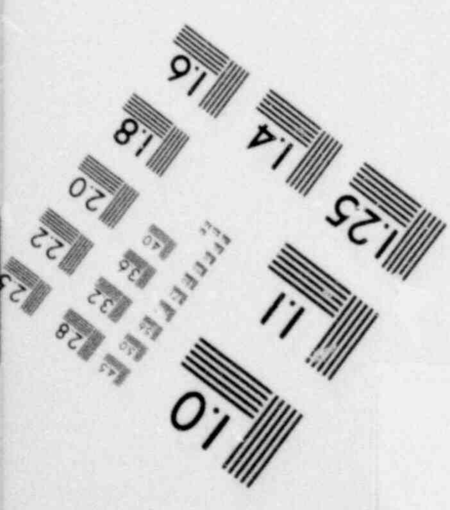


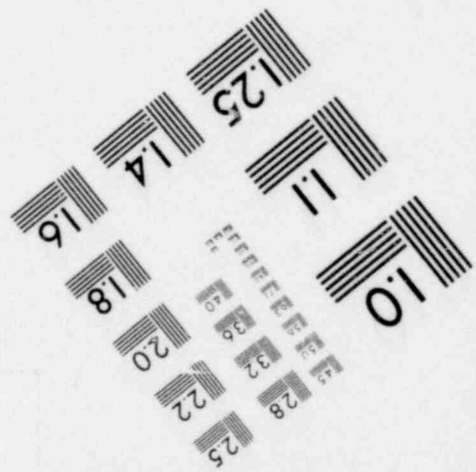
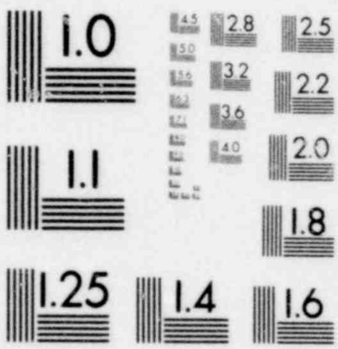


IMAGE EVALUATION TEST TARGET (MT-3)



6″

A1.7 TOXICITY OF 91-Y INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

NUMBER		INHALATION EXP					I.L.B.			I.B.B.		RADIATION DOSE TO LUNG: RATE (RADS/DAY)					CUMULATIVE (RADS)							
TT00	RADBIO	SEX	BLK	DATE	AGE DAYS	WT KG	RNK	UCI KG	UCI	UCI KG	UCI	INIT	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	9-30 1978	POTENT. INFIN.	TO DEATH	DEATH DATE	9- 19
484D	01-956	M	I	71264	401	7.7	51	88	670	170	1300	240	100	44	1.4		9600	14000	17000	17000	17000			25
488U	03-953	F	L	71259	389	8.5	52	87	740	120	1100	240	100	45	1.3		9700	14000	17000		17000	17000	77356	
420A	04-841	M	E	70351	411	12.4	53	82	1000	210	2600	220	110	51	2.4	1.1	9500	14000	18000		18000	18000	72047	
383C	01-766	M	C	70161	415	10.1	54	80	820	160	1600	220	95	41	1.3		9000	13000	16000		16000	16000	77353	
432A	04-838	M	E	70348	367	9.7	55	80	780	130	1200	220	99	44	1.7		9000	13000	16000	16000	16000			28
426A	01-838	M	G	70348	393	11.5	56	79	910	160	1900	220	96	42	1.5		8900	13000	16000		16000	16000	75135	
485W	04-954	F	J	71260	398	6.6	57	76	500	130	870	210	98	46	2.1		8800	13000	16000	17000	17000			25
422T	03-841	F	F	70351	407	9.9	58	75	740	230	2300	200	93	42	1.7		8500	12000	15000		15000	16000	78212	
425S	04-837	F	H	70344	390	10.5	59	73	760	270	2800	200	88	39	1.4		8100	12000	14000		15000	15000	78263	
491S	02-958	F	J	71265	376	8.1	60	69	560	110	900	190	75	30	.75		7400	10000	12000	12000	12000			25
426T	02-837	F	F	70344	389	7.4	61	67	490	200	1500	180	79	34	1.2		7400	11000	13000	13000	13000			28
487B	01-958	M	K	71265	396	7.2	62	59	430	140	1000	160	72	32	1.2		6700	9700	12000	12000	12000			25
391T	02-766	F	D	70161	375	8.4	63	59	500	190	1600	160	70	31	1.0		6500	9400	12000	12000	12000			30
382B	03-766	M	C	70161	417	6.8	64	57	390	120	850	160	69	30	1.1		6400	9200	11000	11000	11000			30
431A	01-839	M	E	70349	376	10.1	65	49	500	100	1000	130	59	26	.89		5500	7900	9700		9700	9700	76005	
492C	03-958	M	I	71265	375	7.2	66	47	340	92	660	130	54	23		9.3	5200	7400			9000+	8300	72083	
421T	02-836	F	F	70343	402	9.6	67	45	430	120	1100	120	54	24	.91		5000	7200	9000	9100	9100			28
489T	04-958	F	L	71265	391	7.7	68	44	340	97	750	120	50	21	.60		4700	6700	8100	8200	8200			25
396X	03-767	F	B	70162	363	7.9	69	44	340	200	1600	120	57	27	1.2		5100	7500	9500	9600	9600			30
430C	04-836	M	G	70343	373	7.9	70	42	340	90	710	110	48	20	.58		4600	6500	7800	7900	7900			28
428T	02-840	F	H	70350	392	5.7	71	41	230	110	610	110	49	22	.76		4500	6500	8100	8100	8100			28
488B	04-959	M	I	71266	396	8.1	72	39	310	57	460	100	47	21	.78		4300	6200	7700	7800	7800			25
372B	02-722	M	A	70079	377	11.6	73	35	400	270	3100	93	38	15	.37		3700	5200	6100	6200	6200			31
387U	02-767	F	B	70162	406	7.8	74	34	260	93	730	91	39	17	.59		3700	5300	6400	6400	6400			30
396S	04-767	F	D	70162	363	8.8	75	33	300	78	690	93	42	19	.75		3800	5600	7000	7000	7000			30
489D	02-959	M	K	71266	392	9.6	76	33	320	65	630	91	37	15	.41		3600	5100	6100	6100	6100			25
424S	03-839	F	H	70349	396	9.3	77	31	290	37	340	85	37	16	.58		3500	5000	6200	6200	6200			28
488S	01-960	F	J	71267	397	7.3	78	31	230	76	560	85	37	16	.50		3400	4900	6000	6000	6000			25
386A	03-763	M	C	70159	405	11.0	79	30	330	38	420	83	37	17	.63		3400	4900	6100	6200	6200			30
376A	03-725	M	A	70084	372	8.4	80	29	240	40	340	80	34	15	.55		3200	4600	5600	5600	5600			31
420D	03-836	M	E	70343	403	9.3	81	27	250	110	1000	72	32	15	.55		3000	4300	5400	5400	5400			28
429S	04-839	F	F	70349	382	10.2	82	27	270	86	880	72	32	14	.48		3000	4200	5200	5300	5300			28
484T	03-960	F	L	71267	406	6.6	83	27	180	67	440	73	30	12	.30		2900	4000	4800	4800	4800			25
383V	04-763	F	D	70159	413	7.3	84	23	170	51	370	64	27	11	.36		2600	3600	4400	4400	4400			30
422A	02-839	M	G	70349	405	11.6	85	19	230	37	430	53	23	9.6	.29		2100	3100	3700	3700	3700			28
425A	01-840	M	G	70350	396	9.1	86	19	180	57	520	52	23	10	.39		2100	3100	3900	3900	3900			28
487S	04-960	F	J	71267	398	6.6	87	19	130	45	290	52	23	9.9	.42		2100	3000	3800	3800	3800			25
420S	04-840	F	H	70350	410	7.6	88	18	140	42	320	50	23	11	.45		2100	3100	3900	3900	3900			28
382C	02-763	M	C	70159	415	7.4	89	18	130	27	200	49	21	9.1	.37		2000	2800	3500	3500	3500			30
487A	03-959	M	I	71266	397	8.1	90	16	130	30	240	42	19	8.3	.30		1700	2500	3100	3100	3100			25
492B	02-960	M	K	71267	377	8.9	91	16	140	30	270	43	18	7.8	.23		1700	2500	3000	3000	3000			25
435T	01-959	F	L	71266	404	7.4	92	16	120	27	200	41	19	8.6	.35		1700	2500	3100	3100	3100			25
373A	02-725	M	A	70084	378	9.0	93	15	140	37	330	42	18	7.4	.27		1700	2400	2900	2900	2900			31
383W	01-763	F	B	70159	413	7.8	94	14	110	43	340	39	16	6.6	.28		1600	2200	2600	2600	2600			30
423U	03-840	F	F	70350	399	8.3	95	13	110	36	220	35	15	6.6	.22		1400	2000	2500	2500	2500			28
432B	01-841	M	E	70351	370	8.1	96	11	92	25	210	31	14	6.5	.26		1300	1900	2400	2400	2400			28
370A	01-725	M	A	70084	393	9.6	C	0	0	0	0													31
385T	01-755	F	B	70147	394	8.1	C	0	0	0	0													30
389W	02-755	F	D	70147	381	8.4	C	0	0	0	0													30
381B	03-755	M	C	70147	414	11.2	C	0	0	0	0													30

1061 001

A1.7 TOXICITY OF 91-Y INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

.B. I G	UCI	I.B.B. UCI/KG	I.B.B. UCI	RATE (RADS/DAY) INIT	RATE 60 DAYS	RATE 120 DAYS	RATE 365 DAYS	RATE AT DEATH	CUMULATIVE (RADS) 60 DAYS	CUMULATIVE 120 DAYS	CUMULATIVE 365 DAYS	CUMULATIVE 9-30 1978	CUMULATIVE POTENT. INFIN.	CUMULATIVE TO DEATH	DEATH DATE	DAYS 9-30 1978	DAYS DEATH	COMMENT
8	670	170	1300	240	100	44	1.4		9600	14000	17000	17000	17000			2566		
7	740	120	1100	240	100	45	1.3		9700	14000	17000		17000	17000	77356		2289	D-SQUAM.CELL CARC.LUNG
2	1000	210	2600	220	110	51	2.4	1.1	9500	14000	18000		18000	18000	72047		426	D-PULMONARY INJURY
0	820	160	1600	220	95	41	1.3		9000	13000	16000		16000	16000	77353		2749	E-SEE NOTE AT END
0	780	130	1200	220	99	44	1.7		9000	13000	16000	16000	16000			2847		
9	910	160	1900	220	96	42	1.5		8900	13000	16000		16000	16000	75135		1613	D-SEE NOTE AT END
6	500	130	870	210	98	46	2.1		8800	13000	16000	17000	17000			2570		
5	740	230	2300	200	93	42	1.7		8500	12000	15000		16000	16000	78212		2783	D-SEE NOTE AT END
3	760	270	2800	200	88	39	1.4		8100	12000	14000		15000	15000	78263		2841	E-SEE NOTE AT END
9	560	110	900	190	75	30	.75		7400	10000	12000	12000	12000			2565		
7	490	200	1500	180	79	34	1.2		7400	11000	13000	13000	13000			2851		
9	430	140	1000	160	72	32	1.2		6700	9700	12000	12000	12000			2565		
9	500	190	1600	160	70	31	1.0		6500	9400	12000	12000	12000			3034		
7	390	120	850	160	69	30	1.1		6400	9200	11000	11000	11000			3034		
9	500	100	1000	130	59	26	.89		5500	7900	9700		9700	9700	76005		1847	E-HEMANGIOSARC. SPLEEN
7	340	92	660	130	54	23		9.3	5200	7400			9000+	8300	72083		183	D-PUL. VASCULAR INJURY
5	430	120	1100	120	54	24	.91		5000	7200	9000	9100	9100			2852		
4	340	97	750	120	50	21	.60		4700	6700	8100	8200	8200			2565		
4	340	200	1600	120	57	27	1.2		5100	7500	9500	9600	9600			3033		
2	340	90	710	110	48	20	.58		4600	6500	7800	7900	7900			2852		
1	230	110	610	110	49	22	.76		4500	6500	8100	8100	8100			2845		
9	310	57	460	100	47	21	.78		4300	6200	7700	7800	7800			2564		
5	400	270	3100	93	38	15	.37		3700	5200	6100	6200	6200			3116		
4	260	93	730	91	39	17	.59		3700	5300	6400	6400	6400			3033		
3	300	78	690	93	42	19	.75		3800	5600	7000	7000	7000			3033		
3	320	65	630	91	37	15	.41		3600	5100	6100	6100	6100			2564		
1	290	37	340	85	37	16	.58		3500	5000	6200	6200	6200			2846		
1	230	76	560	85	37	16	.50		3400	4900	6000	6000	6000			2563		
0	330	38	420	83	37	17	.63		3400	4900	6100	6200	6200			3036		
9	240	40	340	80	34	15	.55		3200	4600	5600	5600	5600			3111		
7	250	110	1000	72	32	15	.55		3000	4300	5400	5400	5400			2852		
7	270	86	880	72	32	14	.48		3000	4200	5200	5300	5300			2846		
7	180	67	440	73	30	12	.30		2900	4000	4800	4800	4800			2563		
3	170	51	370	64	27	11	.36		2600	3600	4400	4400	4400			3036		
9	230	37	430	53	23	9.6	.29		2100	3100	3700	3700	3700			2846		
9	180	57	520	52	23	10	.39		2100	3100	3900	3900	3900			2845		
9	130	45	290	52	23	9.9	.42		2100	3000	3800	3800	3800			2563		
8	140	42	320	50	23	11	.45		2100	3100	3900	3900	3900			2845		
8	130	27	200	49	21	9.1	.37		2000	2800	3500	3500	3500			3036		
6	130	30	240	42	19	8.3	.30		1700	2500	3100	3100	3100			2564		
6	140	36	270	43	18	7.8	.23		1700	2500	3000	3000	3000			2563		
6	120	27	200	41	19	8.6	.35		1700	2500	3100	3100	3100			2564		
5	140	37	330	42	18	7.4	.27		1700	2400	2900	2900	2900			3111		
4	110	43	340	[illegible]	16	6.6	.28		1600	2200	2600	2600	2600			3036		
3	110	36	220	35	15	6.6	.22		1400	2000	2500	2500	2500			2845		
1	92	25	210	31	14	6.5	.26		1300	1900	2400	2400	2400			2844		
0	0	0	0													3111		
0	0	0	0													3048		
0	0	0	0													3048		
0	0	0	0													3048		

1061 002

A1.7 TOXICITY OF 91-Y INHALED IN A RELATIVELY

NUMBER		INHALATION EXP					I.L.B.			I.B.B.		RA RATE (RADS/DAY)				
TTOO	RADBIO	SEX	BLK	DATE	AGE DAYS	WT KG	RNK	UCI/KG	UCI	UCI/KG	UCI	INIT	60 DAYS	120 DAYS	365 DAYS	A DEA
420T	01-833	F	H	70338	398	8.7	C	0	0	0	0					
424A	02-833	M	E	70338	387	9.8	C	0	0	0	0					
431B	03-833	M	G	70338	365	9.2	C	0	0	0	0					
428U	04-833	F	F	70338	380	6.3	C	0	0	0	0					
488T	01-950	F	L	71256	386	8.6	C	0	0	0	0					
483A	02-950	M	K	71256	395	9.1	C	0	0	0	0					
485S	03-950	F	J	71256	394	8.3	C	0	0	0	0					
488C	04-950	M	I	71256	386	8.2	C	0	0	0	0					

UCI/KG: KG REFERS TO TOTAL BODY WEIGHT.
DOSE RATE: DAYS REFER TO DAYS AFTER INHALATION EXPOSURE.
COMMENT: D,E,OR S: DIED,EUTHANIZED,OR SACRIFICED WITH THE MOST PROMINENT FEATURES ASSOCIATED WITH DEATH.
+ DIED BEFORE POTENTIAL INFINITE DOSE RECEIVED.

DOG 489B: E HEMANGIOSARCOMA-MEDIASTINUM; BRONCHIOLO ALVEOLAR CARCINOMA
DOG 484V: E-COMBINED SQUAMOUS CELL-BRONCHIOLO ALVEOLAR CARCINOMA
DOG 428S: D-SQUAMOUS CELL CARCINOMA - LUNG
DOG 383C: E-SQUAMOUS CELL CARCINOMA WITH OSTEOCARCINOMA - LUNG
DOG 426A: D-COMBINED SQUAMOUS CELL-BRONCHIOLO ALVEOLAR CARCINOMA
DOG 422T: D-BRONCHIOLO ALVEOLAR CARCINOMA WITH OSTEOCARCINOMA - LUNG
DOG 425S: E-SQUAMOUS CELL CARCINOMA - LUNG WITH BRONCHIOLOALVEOLAR CARCINOMA

(DATA ARE FORM LF-60, 1978 AND REPRESENT AN UPDATE OF DATA FROM C.H. HOBBS ET AL., 1978.) SEE REFERENCE #22

1061 003

INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

DIATION DOSE TO LUNG

T	CUMULATIVE (RADS)							DAYS		
TH	60 DAYS	120 DAYS	365 DAYS	9-30 1978	POTENT. INFIN.	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
								2857		
								2857		
								2857		
								2857		
								2574		
								2574		
								2574		
								2574		

1061 004

[Series I]

NUMBER		INHALATION EXP.					I.L.B.		I.B.B.		RADIATION DOSE TO LUNG: RATE (RADS/DAY)					CUMULATIVE (RADS)							DA
TT00	RADBIO	SEX	BLK	DATE	AGE DAYS	WT KG	RNK	UCI KG	UCI	UCI KG	UCI	INIT	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	TOTAL	POTENT. INFIN.	TO DEATH	DEATH DATE	9- 19
228B	02-490	M	C	68029	372	8.4	1	210	1700	550	4600	1300	880	720		700	64000	110000			670000+	130000	68172	
210B	01-474	M	A	67348	419	7.9	2	190	1500	430	3400	1100	860	670		580	58000	100000			270000+	140000	68156	
209B	02-474	M	A	67348	421	9.1	3	190	1700	300	2800	1000	770	610		470	53000	94000			240000+	130000	68164	
208B	01-478	F	B	67355	432	11.0	4	180	2000	450	5000	1000	840	670		550	56000	100000			290000+	140000	68172	
211G	02-478	F	B	67355	424	7.5	5	120	890	270	2000	690	530	420		340	37000	65000			170000+	84000	68161	
226C	01-490	M	C	68029	374	7.8	6	96	740	300	2400	550	420	320		240	29000	51000			120000+	70000	68213	
217A	01-491	M	C	68030	407	8.8	7	68	600	130	1100	380	290	220		170	20000	36000			83000+	48000	68216	
211A	03-473	M	A	67347	416	8.1	8	66	540	99	800	380	290	230		120	20000	36000			88000+	58000	68239	
211E	03-477	F	B	67354	423	8.6	9	51	440	120	1100	290	220	170	66	57	15000	27000	53000		72000+	56000	69[illegible]	
228A	02-491	M	C	68030	373	9.1	10	34	330	67	670	190	140	110	42	1.5	9800	17000	34000		46000	46000	71252	
211D	02-473	M	A	67347	416	7.1	11	27	190	54	380	150	100	74	24	1.2	7600	13000	23000		30000+	29000	71071	
211F	02-477	F	B	67354	423	8.7	12	19	170	37	320	110	79	60	23		5600	9700	19000	25000	25000	25000	76317	
223A	03-491	M	C	68030	382	9.8	13	15	150	34	330	89	60	44	16		4400	7500	14000	19000	19000	19000	74309	
208D	01-477	F	B	67354	431	5.9	14	15	91	26	150	89	68	53	20	.015	4700	8300	17000		22000	22000	74193	
209C	01-473	M	A	67347	420	9.0	15	11	100	27	240	64	49	38	15		3400	6000	12000	16000	16000			39
208A	01-476	M	A	67353	430	8.9	C	0	0	0	0													39
209D	02-476	F	B	67353	426	7.9	C	0	0	0	0													39
220C	01-492	M	C	68032	391	10.2	C	0	0	0	0													38

UCI/KG: KG REFERS TO TOTAL BODY WEIGHT.
DOSE RATE: DAYS REFER TO DAYS AFTER INHALATION EXPOSURE.
COMMENT: D,E,OR S: DIED,EUTHANIZED,OR SACRIFICED WITH THE MOST PROMINENT FEATURES ASSOCIATED WITH DEATH.
+ DIED BEFORE POTENTIAL INFINITE DOSE RECEIVED.

NOTES:

DOG 211F: E-MIXED TUMOR OF THE LUNG. PULMONARY OSTEOSARCOMA ARISING FROM BRONCHIOLO ALVEOLAR CARCINOMA

1061 005

A1.8 TOXICITY OF 144-CE INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS

	I.L.B.		I.D.B.		RADIATION DOSE TO LUNG															
					RATE (RADS/DAY)					CUMULATIVE (RADS)								DAYS		
NK	UCI KG	UCI	UCI KG	UCI	INIT	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	TOTAL	POTENT. INFIN.	TO DEATH	DEATH DATE	9-30 1979	DEATH	COMMENT
1	210	1700	550	4600	1300	880	720		700	64000	110000			670000+	130000	68172		143	D-PULMONARY INJURY
2	190	1500	430	3400	1100	860	670		530	58000	100000			270000+	140000	68156		173	D-PULMONARY INJURY
3	190	1700	300	2800	1000	770	610		470	53000	94000			240000+	130000	68164		181	D-PULMONARY INJURY
4	180	2000	450	5000	1000	840	670		550	56000	100000			290000+	140000	68172		182	D-PULMONARY INJURY
5	120	890	270	2000	690	530	420		340	37000	65000			170000+	84000	68161		171	D-PULMONARY INJURY
6	96	740	300	2400	550	420	320		240	29000	51000			120000+	70000	68218		189	D-PULMONARY INJURY
7	68	600	130	1100	380	290	220		170	20000	36000			83000+	48000	68216		186	D-PULMONARY INJURY
8	66	540	99	800	380	290	230		120	20000	36000			88000+	58000	68239		257	D-PULMONARY INJURY
9	51	440	120	1100	290	220	170	66	57	15000	27000	53000		72000+	56000	69033		410	D-PULMONARY INJURY
10	34	330	67	670	190	140	110	42	1.5	9800	17000	34000		46000	46000	71252		1318	E-HEMANGIOSARCOMA LUNG
11	27	190	54	380	150	100	74	24	1.2	7600	13000	23000		30000+	29000	71071		1185	D-HEMANGIOSARCOMA LUNG
12	19	170	37	320	110	79	60	23		5600	9700	19000	25000	25000	25000	76317		3250	E-SEE NO[illegible] AT END
13	15	150	34	330	89	60	44	16		4400	7500	14000	19000	19000	19000	74309		2471	E-HEMANGIOSARCOMA BONE
14	15	91	26	150	89	68	53	20	.015	4700	8300	17000		22000	22000	74193		2396	D-HEMANGIOSARCOMA MEDIASTINUM
15	11	100	27	240	64	49	38	15		3400	6000	12000	16000	16000			3944		
C	0	0	0	0													3938		
C	0	0	0	0													3938		
C	0	0	0	0													3894		

ATION EXPOSURE.
CRIFICED WITH THE MOST PROMINENT

IVED.

MONARY OSTEOSARCOMA ARISING FROM

1061 006

A1.8 TOXICITY OF 144-CE INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

[Series II]

NUMBER TTOO	NUMBER RADBIO	SEX	INHALATION EXP BLK	INHALATION EXP DATE	INHALATION EXP AGE DAYS	INHALATION EXP WT KG	I.L.B. RNK	I.L.B. UCI KG	I.B.B. UCI	I.B.B. UCI KG	UCI	RATE (RADS/DAY) INIT	RATE (RADS/DAY) 60 DAYS	RATE (RADS/DAY) 120 DAYS	RATE (RADS/DAY) 365 DAYS	RATE (RADS/DAY) AT DEATH	CUMULATIVE (RADS) 60 DAYS	CUMULATIVE (RADS) 120 DAYS	CUMULATIVE (RADS) 365 DAYS	CUMULATIVE (RADS) TOTAL	CUMULATIVE (RADS) POTENT. INFIN.	CUMULATIVE (RADS) TO DEATH	DEATH DATE	DAYS 9-30 197[illegible]
315V	02-595	F	D	69149	398	7.2	1	66	470	170	1200	370	270	200		130	19000	33000			89000+	53000	70030	
298B	02-586	M	A	69121	399	9.1	2	65	590	130	1200	370	290	240		150	20000	36000			100000+	57000	69355	
327A	01-642	M	E	69213	387	9.4	3	56	520	120	1100	320	240	180		99	17000	29000			84000+	50000	70121	
479U	04-947	F	L	71225	379	6.8	4	54	360	180	1200	320	190	140	57	12	14000	24000	47000		62000+	59000	73284	
330S	02-642	F	F	69213	374	8.3	5	53	440	110	920	300	230	180		91	15000	28000			71000+	50000	70127	
297S	03-586	F	B	69121	402	10.4	6	46	470	170	1800	270	200	150	60	15	14000	24000	50000		66000+	61000	71141	
470A	03-947	M	K	71225	397	11.0	7	44	480	67	730	270	200	150		69	14000	24000			53000+	41000	72135	
465S	03-918	F	J	71176	382	7.9	8	41	330	100	820	240	180	130		91	12000	22000			46000+	28000	71361	
465A	04-918	M	I	71176	382	11.4	9	41	460	61	700	230	180	140		66	12000	22000			57000+	41000	72122	
330U	03-641	F	F	69212	373	6.0	10	37	220	85	510	220	150	110	43	3.2	11000	18000	[illegible]		47000+	46000	72194	
315A	01-595	M	C	69149	398	10.9	11	35	380	130	400	200	130	100	43	6.0	9500	17000	33000		46000+	43000	71335	
330B	04-641	M	E	69212	373	6.3	12	34	220	72	460	200	140	110	38		10000	18000	34000	44000	44000		75334	
303A	01-586	M	A	69121	422	9.[illegible]	13	33	320	76	720	190	140	110		74	9800	17000			39000+	24000	69314	
454A	03-883	M	G	71106	402	8.8	14	32	280	68	600	190	140	97	31	1.2	9800	17000	31000		38000	38000	74238	
453S	04-883	F	H	71106	408	8.0	15	29	230	[illegible]	300	170	130	100	41	1.8	[illegible]	[illegible]	33000		44000+	43000	74236	
464B	01-918	M	I	71176	385	9.4	16	27	250	45	420	160	110	[illegible]	29	.30	8000	[illegible]4000	26000		33000	33000	75238	
310T	02-594	F	D	69148	421	8.9	17	26	230	130	1100	150	110	86	33	7.9	7700	14000	27000		36000+	34000	71183	
460S	02-918	F	J	71176	419	7.9	18	24	190	80	630	150	97	71	27		7200	12000	23000		30000	30000	76160	
480S	02-947	F	L	71225	373	8.[illegible]	19	[illegible]	200	51	430	150	100	77	29	.91	7300	[illegible]	25000		32000	32000	75017	
312B	03-594	M	C	69148	399	9.0	20	24	210	49	440	140	100	79	31	.15	7200	13[illegible]00	25000		34000	34000	74217	
298S	03-585	F	B	69120	398	10.4	21	23	240	62	650	130	97	73	29		6800	12000	23000	32000	32000	32000	77199	
455B	01-883	M	G	71106	402	11.7	22	19	220	60	700	110	83	63	23		5800	10000	20000	26000	26000	26000	77093	
471A	01-947	M	K	71225	397	7.5	23	19	150	34	260	120	80	59	22		5700	9900	19000	25000	25000	25000	77216	
453T	02-883	F	H	71106	408	6.4	24	18	110	46	290	100	75	57	20		5300	9200	18000	23000	23000			2724
315U	01-594	F	D	69148	397	8.3	25	18	150	51	420	100	77	58	21		5400	9400	18000	24000	24000			3412
304S	01-585	F	B	69120	386	7.4	26	17	120	35	260	98	72	55	21	.018	5000	8800	17000		23000	23000	75256	
311B	03-593	M	C	69147	400	9.3	27	14	130	20	190	79	57	43	16	.060	4000	7000	14000		18000	18000	74295	
328T	02-641	F	F	69212	385	10.6	28	13	140	26	270	76	55	41	15		3900	6800	13000	17000	17000			3348
467A	03-916	M	I	71175	373	12.2	29	13	160	26	310	77	55	41	14		3900	6800	1300		16000	16000	76112	
467T	04-946	F	L	71224	422	6.4	30	13	81	18	120	78	55	43	17		3900	6800	14000		18000	18000	76147	
297B	02-585	M	A	69120	401	9.6	31	12	110	50	480	68	45	34	14		3300	5600	11000		15000	15000	76065	
326C	01-641	M	E	69212	391	9.4	32	12	110	18	170	70	51	38	14		3600	6200	12000	16000	16000	16000	78205	
463A	02-916	M	I	71175	411	10.9	33	12	130	20	220	74	50	37	14		3600	6200	12000	15000	15000			2655
480B	03-946	[illegible]	K	71224	372	8.2	34	11	91	20	170	68	46	35	14		3300	5700	11000	15000	15000			2606
454S	04-882	F	H	71105	401	9.6	35	10	95	40	390	60	44	33	12	.13	3100	5400	10000		13000	13000	75171	
454E	03-682	M	G	71105	401	8.9	36	9.8	87	21	190	60	42	32	12		[illegible]000	5200	10000	13000	13000	13000	77278	
305V	02-584	F	B	69119	382	6.9	37	9.8	67	18	120	57	37	27	10		2800	4600	8700	12000	12000			3441
460T	04-916	F	J	71175	418	7.4	38	9.5	70	30	330	56	42	32	12		2900	5100	10000	13000	13000			2655
327B	01-640	M	E	69211	385	9.0	39	8.0	72	16	140	46	32	24	9.7		2300	4000	7800	11000	11000			3349
323V	02-640	F	F	69211	408	7.8	40	7.8	60	12	91	45	33	25	9.2	.010	2300	4000	7900		10000	10000	75127	
303B	03-584	M	A	69119	389	6.7	41	7.6	51	17	120	44	34	27	12		2300	4100	8600	12000	12000		76133	
310S	02-593	F	D	69147	420	9.1	42	6.3	57	9.4	86	36	26	20	7.7		1800	3200	630[illegible]	[illegible]	3500			3413
469S	02-946	F	L	71224	397	7.2	43	5.8	42	13	91	35	26	20	8.0		1800	3200	6[illegible]00	8600	8600			2606
478B	01-946	M	K	71224	379	9.6	44	5.7	54	10	99	33	26	21	8.3		1800	3100	6[illegible]0	8700	8700	8700	78169	
[illegible]8B	01-593	M	C	69147	402	10.3	45	5.4	55	7.4	76	31	23	18	.028		1600	2800	5700		7700	7700		3413
454[illegible]	01-882	M	G	71105	401	9.5	46	5.4	51	14	130	32	24	18	6.7		1700	2900	5700	7800	7800			2725
464T	[illegible]-916	F	J	71175	384	7.4	47	5.0	37	12	86	29	21	15	5.3		1500	2500	4800	6200	6200			2655
455T	02-[illegible]	F	H	71105	401	10.4	48	4.9	51	16	170	30	21	15	5.0		1500	2500	4700		6000	6000	76072	
313S	01-598	F	D	69160	411	7.9	49	2.4	19	8.2	64	14	9.8	7.4	2.9		700	1200	2400	3200	3200			3400
296B	01-592	[illegible]	A	69135	418	10.0	50	2.1	21	3.8	38	12	8.9	6.9	2.8		620	1100	2200	3000	3000			3425

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A1.8 TOXICITY OF 144-CE INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

	I.B.B.		RADIATION DOSE TO LUNG: RATE (RADS/DAY)					CUMULATIVE (RADS)							DAYS		
UCI	UCI/KG	UCI	INIT	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	TOTAL	POTENT. INFIN.	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
470	170	1200	370	270	200		130	[illegible]	[illegible]			89000+	53000	70030		246	D-PULMONARY INJURY
590	130	1200	370	290	240		150	20000	36000			100000+	57000	69355		234	D-PULMONARY INJURY
520	120	1100	320	240	180		99	17000	29000			84000+	50000	70121		273	D-PULMONARY INJURY
360	180	1200	320	190	140	57	12	14000	24000	47000		62000+	59000	73284		790	E-HEMANGIOSARCOMA LUNG
440	110	920	300	230	180		91	15000	28000			71000+	50000	70127		279	D-PULMONARY INJURY
470	170	1800	270	200	150	60	15	14000	24000	50000		66000+	61000	71141		750	E-HEMANGIOSARC. FIBROSARC. LUNG
480	67	730	270	200	150		69	14000	24000			53000+	41000	72135		275	D-PULMONARY INJURY
330	100	820	240	180	130		91	12000	22000			46000+	28000	71361		185	D-PULMONARY INJURY
460	61	700	230	180	140		66	12000	22000			57000+	41000	72122		311	D-PULMONARY INJURY
220	85	510	220	150	110	43	3.2	11000	18000	36000		47000+	46000	72194		1077	E-HEMANGIOSARCOMA LUNG
380	130	400	200	130	100	43	6.0	9500	17000	33000		46000+	43000	71335		916	D-SEE NOTE AT END
220	72	460	200	140	110	38		10000	18000	34000	44000	44000		75334		2313	D-SEE NOTE AT END
320	76	720	190	140	110		74	9800	17000			39000+	24000	69314		193	D-PULMONARY VASCULAR INJURY
280	68	600	190	140	97	31	1.2	9800	17000	31000		38000	38000	74238		1228	[illegible]-SEE NOTE AT END
230	38	[illegible]	170	130	100	41	1.8	8900	16000	33000		44000+	43000	74236		1226	D-SEE NOTE AT END
250	45	420	160	110	80	29	.30	8000	14000	26000		33000	33000	75238		1523	D-BRONCHIOLO ALVEOLAR CARCINOMA
230	130	1100	150	110	86	33	7.9	7700	14000	27000		36000+	34000	71183		765	E-HEMANGIOSARCOMA LUNG
190	80	630	150	97	71	27		7200	12000	23000		30000	30000	76160		1819	D-SEE NOTE AT END
200	51	430	150	100	77	29	.91	7300	13000	25000		32000	32000	75017		1253	E-SQUAM.CELL CARC.NASAL CAVITY
210	49	440	140	100	79	31	.15	7200	13000	25000		34000	34000	74217		1895	D-HEMANGIOSARCOMA SPLEEN
240	62	650	130	97	73	29		6800	12000	23000	32000	32000	32000	77159		3001	[illegible]-SEE NOTE AT END
220	60	700	110	83	63	23		5800	10000	20000	26000	26000	26000	77093		2179	D-EPILEPSY
150	34	260	120	80	59	22		5700	9900	19000	25000	25000	25000	77216		2183	E-HEMANGIOSARCOMA - BONE
110	46	290	100	75	57	20		5300	[illegible]	18000	23000	23000			2724		
150	51	420	100	77	58	21		5400	9400	18000	24000	24000			3412		
120	35	260	98	72	55	21	.018	5000	8800	17000		23000	23000	75256		2327	D-HEMANGIOSARCOMA LIVER
130	20	190	79	57	43	16	.060	4000	7000	14000		18000	18000	74295		1974	E-HEMANGIOSARCOMA BOTH HUMERII
140	26	270	76	55	41	15		3900	6800	13000	17000	17000			3348		
160	26	310	77	55	41	14		3900	6800	1300		16000	16000	76112		1763	D-SEE NOTE AT END
81	18	120	78	55	43	17		3900	6800	14000		18000	18000	76147		1749	D-ACCIDENTAL DEATH
110	50	480	68	45	34	14		3300	5600	11000		15000	15000	76065		2501	D-PLEURITIS (NOCARDIA SP.)
110	18	170	70	51	38	14		3600	6200	12000	16000	16000	16000	78205		3280	E-HEMANGIOSARCOMA MEDIASTINUM
130	20	220	74	[illegible]	37	14		3600	6200	12000	15000	15000			2655		
91	20	170	68	[illegible]	35	14		3300	5700	11000	15000	15000			2606		
95	40	390	60	[illegible]	33	12	.13	3100	5400	10000		13000	13000	75171		1527	D-HEMANGIOSARCOMA HEART
87	21	190	60	42	32	12		3000	5200	10000	13000	13000	13000	77278		2365	E-HEMANGIOSARC. DERMIS
67	18	120	57	37	27	10		2800	4600	8700	12000	12000			3441		
70	30	330	56	42	32	12		2900	5100	10000	13000	13000			2655		
72	16	140	46	32	24	9.7		2300	4000	7800	11000	11000			3349		
60	12	91	45	33	25	9.2	.010	2300	4000	7900		10000	10000	75127		2107	D-HEMANGIOSARCOMA MEDIASTINUM
51	17	120	44	34	27	12		2300	4100	8600	12000	12000		76133		2570	E-HEMANGIOSARCOMA LIVER
57	9.4	86	36	26	20	7.7		1800	3200	6300	8500	8500			3413		
42	13	91	35	26	20	8.0		1800	3200	6400	8600	8600			2606		
54	10	99	33	26	21	8.3		1800	3100	6400	8700	8700	8700	78169		2502	D-HEMANGIOSARC. MEDIASTINUM
55	7.4	76	31	23	18	.028		1600	2800	5700		7700	7700		3413		
51	14	130	32	24	18	6.7		1700	2900	5700	7800	7800			2725		
37	12	86	29	21	15	5.3		1500	2500	4800	6200	6200			2655		
51	16	170	30	21	15	5.0		1500	2500	4700		6000	6000	76072		1793	E-SEE NOTE AT END
19	8.2	64	14	9.8	7.4	2.9		700	1200	2400	3200	3200			3400		
21	3.8	38	12	8.9	6.9	2.8		620	1100	2200	3000	3000			3425		

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A1.8 TOXICITY OF 144-CE INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

Series II [cont'd.]

NUMBER TT00	NUMBER RADBIO	INHALATION EXP SEX	INHALATION EXP BLK	INHALATION EXP DATE	INHALATION EXP AGE DAYS	INHALATION EXP WT KG	I.L.B. RNK	I.L.B. UCI/KG	I.L.B. UCI	I.B.B. UCI/KG	I.B.B. UCI	RATE (RADS/DAY) INIT	RATE 60 DAYS	RATE 120 DAYS	RATE 365 DAYS	RATE AT DEATH	CUMULATIVE (RADS) 60 DAYS	CUMULATIVE 120 DAYS	CUMULATIVE 365 DAYS	CUMULATIVE TOTAL	CUMULATIVE POTENT. INF IN.	CUMULATIVE TO DEATH	DEATH DATE
466V	04-915	F	J	71174	380	7.9	51	2.0	15	4.5	36	11	8.6	6.6	2.5		590	1000	2100	2700	2700		
313C	02-598	M	C	69160	411	9.6	52	1.8	17	3.8	37	10	7.9	6.2	2.5		540	960	1900		2600	2600	76083
304T	02-592	F	B	69135	401	7.8	53	1.6	12	2.5	19	9.2	6.8	5.3	2.2		470	840	1700	2300	2300		
324V	03-638	F	F	69210	402	7.2	54	1.5	11	3.9	28	8.3	6.7	5.3	2.1		450	810	1700	2200	2200		
331A	04-638	M	E	69210	370	9.0	55	1.3	11	2.2	20	7.3	5.9	4.7	1.9		390	710	1500	2000	2000		
461B	03-915	M	I	71174	417	11.1	56	1.2	13	3.0	33	7.1	5.2	4.0	1.6		360	640	1300	1700	1700		
467U	04-945	F	L	71223	421	6.6	57	1.2	7.[illegible]	2.7	18	6.7	5.0	3.8	1.4		350	610	1200	1600	1600		
477A	03-945	M	K	71223	380	11.0	58	1.1	12	1.8	30	6.6	5.0	3.8	1.3		340	610	1200	1500	1500		
329C	03-642	M	E	69213	386	8.3	59	.71	5.9	1.2	9.9	4.1	3.0	2.3	.96		210	370	750	1000	1000		
453B	03-881	M	G	71104	406	8.1	60	.63	5.1	1.4	12	3.7	2.8	2.2	.84		190	340	680	910	910		
463S	02-915	F	J	71174	410	10.4	61	.53	5.5	.77	8.0	3.7	2.3	1.8	.68		160	280	560	740	740		
452U	04-881	F	H	71104	416	8.2	62	.52	4.2	4.7	38	4.0	2.4	1.9	.72		170	290	590	770	770		
314S	04-597	F	D	69157	407	9.7	63	.45	4.4	.82	7.9	2.6	1.8	1.3	.51		130	220	430	570	570		
296U	02-591	F	B	69134	417	8.4	64	.44	3.7	.81	6.8	2.4	1.8	1.4	.49		120	220	420		550	550	76260
313B	03-597	M	C	69157	408	10.1	65	.37	3.7	1.1	11	2.1	1.5	1.1	.42		110	190	360	470	470		
461A	01-915	M	I	71174	417	12.0	66	.35	4.3	.49	5.9	2.2	1.5	1.2	.48		110	190	380	500	500		
322V	02-638	F	F	69210	409	6.4	67	.32	2.0	.70	4.4	1.9	1.4	1.1	.44		96	170	340	470	470		
476C	01-945	M	K	71223	387	9.0	68	.30	2.7	.58	5.2	1.8	1.4	1.1	.47		94	170	350	480	480		
471S	02-945	F	L	71223	395	6.3	69	.2[illegible]	1.6	.90	5.7	1.4	1.1	.87	.34		74	130	270	360	360		
297A	01-591	M	A	69134	415	11.0	70	.18	2.0	.38	4.2	1.1	.80	.61	.23		37	98	190	250	250		
453U	02-881	F	H	71104	406	5.8	71	.18	1.1	.42	2.4	1.1	.87	.71	.30		58	110	220	310	310		
457B	01-881	M	G	71104	374	8.3	72	.17	1.4	.37	3.1	1.1	.78	.63	.26		52	94	200	270	270		
472W	02-942	F	L	71222	390	8.0	73	.16	1.3	.36	2.9	.95	.74	.58	.21		50	90	180	230	230		
298U	02-590	F	B	69129	407	9.4	74	.12	1.2	.36	3.4	.71	.56	.43	.16		38	67	130	170	170		
462C	02-914	M	I	71173	409	9.0	75	.083	.75	.16	1.[illegible]	.49	.38	.30	.11		26	46	93	120	120		
476B	01-942	M	K	71222	386	8.5	76	.079	.67	.11	.96	.47	.37	.29	.11		25	44	88	110	110		
303S	02-589	F	B	69128	398	8.9	77	.077	.68	.23	2.1	.46	.36	.28	.10		24	43	86	110	110		
308U	01-597	F	D	69157	412	10.1	78	.076	.77	.13	1.3	.45	.35	.28	.10		24	4[illegible]	85	110	110		
464S	01-914	F	J	71173	382	8.1	79	.062	.50	.12	1.0	.37	.29	.22	.083		19	35	69	90	90		
451T	04-880	F	H	71103	415	6.0	80	.057	.45	.088	.70	.34	.26	.21	.076		18	32	64	82	82		
310A	02-597	M	C	69157	430	11.5	81	.051	.59	.21	2.4	.30	.24	.18	.068		16	29	57	74	74		
304A	01-590	M	A	69129	395	11.3	82	.044	.50	.15	1.7	.26	.20	.16	.059		14	25	49	64	64		
310U	03-596	F	D	69156	429	8.0	83	.041	.33	.30	2.4	.24	.19	.15	.055		13	23	46	59	59		
323T	05-636	F	F	69209	383	8.4	84	.039	.33	.15	1.2	.23	.18	.14	.052		12	22	44	56	56		
306A	01-589	M	A	69128	389	9.5	85	.033	.31	.19	1	.20	.15	.12	.044		10	18	37	48	48		
312A	04-596	M	C	69156	406	11.0	86	.025	.27	.050	[illegible]	.15	.12	.091	.033		7.9	14	28	36	36		
472U	02-941	F	L	71221	389	8.5	87	.020	.17	.036	[illegible]	.12	.093	.072	.027		6.3	11	22	29	29		
465B	01-912	M	I	71172	378	11.2	88	.018	.20	.040	.45	.11	.083	.065	.024		5.7	10	20	26	26		
450D	03-880	M	G	71103	419	11.1	89	.018	.20	.067	.74	.11	.083	.065	.024		5.7	10	20	26	26		
327D	06-636	M	E	69209	383	8.7	90	.016	.14	.078	.68	.095	.074	.058	.021		5.0	9.0	18	23	23		
462S	02-912	F	J	71172	408	8.1	91	.014	.11	.040	.32	.083	.065	.051	.019		4.4	7.8	16	20	20		
327C	03-636	M	E	69209	383	9.4	92	.0096	.090	.061	.58	.057	.044	.035	.013		3.0	5.4	11	14	14		
478C	01-941	M	K	71221	376	8.9	93	.0092	.081	.025	.22	.054	.043	.033	.012		2.9	5.2	10	13	13		
324T	04-636	F	F	69209	401	10.8	94	.0063	.068	.053	.57	.037	.029	.023	.0084		2.0	3.5	7.1	9.1	9.1		
453A	01-880	M	G	71103	405	9.0	95	.0030	.027	.0051	.046	.018	.014	.011	.0040		.94	1.7	3.4	4.3	4.3		
452T	02-880	F	H	71103	415	9.4	96	.0024	.023	.0019	.18	.014	.011	.0087	.0032		.75	1.3	2.7	3.5	3.5		
303V	01-588	F	B	69127	397	7.5	C	0	0	0	0												
306D	02-588	M	A	69127	388	9.4	C	0	0	0	0												
310B	01-596	M	C	69156	429	11.0	C	0	0	0	0												
308T	02-596	F	D	69156	411	9.3	C	0	0	0	0												

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A1.8 TOXICITY OF 144-CE INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

		I.L.B.		I.B.B.		RADIATION DOSE TO LUNG: RATE (RADS/DAY)					RADIATION DOSE TO LUNG: CUMULATIVE (RADS)							DAYS		
T G	RNK	UCI/KG	UCI	UCI/KG	UCI	INIT	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	TOTAL	POTENT. INFIN.	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
9	51	2.0	15	4.5	36	11	8.6	6.6	2.5		590	1000	2100	2700	2700			2656		
6	52	1.8	17	3.8	37	10	7.9	6.2	2.5		540	960	1900		2600	2600	76083		2479	D-PERITONITIS (NOCARDIA SP.)
8	53	1.6	12	2.5	19	9.2	6.8	5.3	2.2		470	840	1700	2300	2300			3425		
2	54	1.5	11	3.9	28	8.3	6.7	5.3	2.1		450	810	1700	2200	2200			3350		
0	55	1.3	11	2.2	20	7.3	5.9	4.7	1.9		390	710	1500	2000	2000			3350		
1	56	1.2	13	3.0	33	7.1	5.2	4.0	1.6		360	640	1300	1700	1700			2656		
6	57	1.2	7.5	2.7	18	6.7	5.0	3.8	1.4		350	610	1200	1600	1600			2607		
0	58	1.1	12	1.8	30	6.6	5.0	3.8	1.3		340	610	1200	1500	1500			2607		
3	59	.71	5.9	1.2	9.9	4.1	3.0	2.3	.96		210	370	750	1000	1000			3347		
1	60	.63	5.1	1.4	12	3.7	2.8	2.2	.84		190	340	680	910	910			2726		
4	61	.53	5.5	.77	8.0	3.7	2.3	1.8	.68		160	280	560	740	740			2656		
2	62	.52	4.2	4.7	38	4.0	2.4	1.9	.72		170	290	590	770	770			2726		
7	63	.45	4.4	.82	7.9	2.6	1.8	1.3	.51		130	220	430	570	570			3403		
4	64	.44	3.7	.81	6.8	2.4	1.8	1.4	.49		120	220	420		550	550	76260		2682	D-TRANS. CELL CARC. BLADDER
1	65	.37	3.7	1.1	11	2.1	1.5	1.1	.42		110	190	360	470	470			3403		
0	66	.35	4.3	.49	5.9	2.2	1.5	1.2	.48		110	190	380	500	500			2656		
4	67	.32	2.0	.70	4.4	1.9	1.4	1.1	.44		96	170	340	470	470			3350		
0	68	.30	2.7	.58	5.2	1.8	1.4	1.1	.47		94	170	350	480	480			2607		
3	69	.25	1.6	.90	5.7	1.4	1.1	.87	.34		74	130	270	360	360			2607		
0	70	.18	2.0	.38	4.2	1.1	.80	.61	.23		57	98	190	250	250			3426		
8	71	.18	1.1	.42	2.4	1.1	.87	.71	.30		58	110	220	310	310			2726		
3	72	.17	1.4	.37	3.1	1.1	.78	.63	.26		52	94	200	270	270			2726		
0	73	.16	1.3	.36	2.9	.95	.74	.58	.21		50	90	180	230	230			2608		
4	74	.12	1.2	.36	3.4	.71	.56	.43	.16		38	67	130	170	170			3431		
0	75	.083	.75	.16	1.4	.49	.38	.30	.11		26	46	93	120	120			2657		
5	76	.079	.67	.11	.96	.47	.37	.29	.11		25	44	88	110	110			2608		
9	77	.077	.68	.23	2.1	.46	.36	.28	.10		24	43	86	110	110			3432		
1	78	.076	.77	.13	1.3	.45	.35	.28	.10		24	43	85	110	110			3403		
1	79	.062	.50	.12	1.0	.37	.29	.22	.083		19	35	69	90	90			2657		
0	80	.057	.45	.088	.70	.34	.26	.21	.076		18	32	64	82	82			2727		
5	81	.051	.59	.21	2.4	.30	.24	.18	.068		16	29	57	74	74			3403		
3	82	.044	.50	.15	1.7	.26	.20	.16	.059		14	25	49	64	64			3431		
0	83	.041	.33	.30	2.4	.24	.19	.15	.055		13	23	46	59	59			3404		
4	84	.039	.33	.15	1.2	.23	.18	.14	.052		12	22	44	56	56			3551		
5	85	.033	.31	.19	1.7	.20	.15	.12	.044		10	18	37	48	48			3432		
0	86	.025	.27	.050	.53	.15	.12	.091	.033		7.9	14	28	36	36			3404		
5	87	.020	.17	.036	.30	.12	.093	.072	.027		6.3	11	22	29	29			2609		
2	88	.018	.20	.040	.45	.11	.083	.065	.024		5.7	10	20	26	26			2658		
1	89	.018	.20	.067	.74	.11	.083	.065	.024		5.7	10	20	26	26			2727		
7	90	.016	.14	.078	.68	.095	.074	.058	.021		5.0	9.0	18	23	23			3351		
1	91	.014	.11	.040	.32	.083	.065	.051	.019		4.4	7.8	16	20	20			2658		
4	92	.0096	.090	.061	.58	.057	.044	.035	.013		3.0	5.4	11	14	14			3351		
9	93	.0092	.081	.025	.22	.054	.043	.033	.012		2.9	5.2	10	13	13			2609		
8	94	.0063	.068	.053	.57	.037	.029	.023	.0084		2.0	3.5	7.1	9.1	9.1			3351		
0	95	.0030	.027	.0051	.086	.018	.014	.011	.0040		.94	1.7	3.4	4.3	4.3			2727		
4	96	.0024	.023	.0019	.18	.014	.011	.0087	.0032		.75	1.3	2.7	3.5	3.5			2727		
5	C	0	0	0	0													3433		
4	C	0	0	0	0													3433		
0	C	0	0	0	0													3404		
3	C	0	0	0	0													3404		

1061 010

Series II (cont'd.)

NUMBER		INHALATION EXP					I.L.B.			I.B.B.		RADIATION DOSE TO LUNG: RATE (RADS/DAY)					CUMULATIVE (RADS)							
TTOO	RADBIO	SEX	BLK	DATE	AGE DAYS	WT KG	RNK	UCI KG	UCI	UCI KG	UCI	INIT	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	TOTAL	POTENT. INFIN.	TO DEATH	DEATH DATE	DAYS 9-30 1978
324B	01-636	M	E	69209	401	8.8	C	0	0	0	0													3351
322U	02-636	F	F	69209	408	6.8	C	0	0	0	0													3351
450A	01-878	M	G	71099	415	11.8	C	0	0	0	0													2731
452S	02-878	F	H	71099	411	10.2	C	0	0	0	0													2731
467R	01-911	M	I	71169	367	6.9	C	0	0	0	0													2661
464U	02-911	F	J	71169	378	8.9	C	0	0	0	0													2661
477B	01-940	M	K	71218	375	8.7	C	0	0	0	0													2612
479T	02-940	F	L	71218	372	8.0	C	0	0	0	0													2612

UCI/KG: KG REFERS TO TOTAL BODY WEIGHT.
DOSE RATE: DAYS REFER TO DAYS AFTER INHALATION EXPOSURE.
COMMENT: D,E,OR S: DIED,EUTHANIZED,OR SACRIFICED WITH THE MOST PROMINENT FEATURES ASSOCIATED WITH DEATH.
+ DIED BEFORE POTENTIAL INFINITE DOSE RECEIVED.

NOTES:

DOG 315A: D-HEMANGIOSARCOMA AND BRONCHIOLO ALVEOLAR CARCINOMA LUNG
DOG 330B: D-HEMANGIOSARCOMA,PRIMARY SITE UNDETERMINED; BRONCHIOLO ALVEOLAR CARCINOMA
DOG 454A: D-PULMONARY THROMBOSIS ASSOCIATED WITH AMYLOIDOSIS
DOG 453S: D-PULMONARY HEMANGIOSARCOMA; BRONCHIOLO ALVEOLAR CARCINOMA; BRONCHOGENIC CARCINOMA
DOG 460S: D-MALIGNANT MIXED TUMOR OF LUNG; BRONCHIOLO ALVEOLAR CARCINOMA
DOG 298S: E-MIXED TUMOR OF THE LUNG. PULMONARY OSTEOSARCOMA ARISING FROM BRONCHIOLO ALVEOLAR CARCINOMA
DOG 467A: D-HEMANGIOSARCOMA ANTERIOR MEDIASTINUM
DOG 455T: E-HEMANGIOSARCOMA PRIMARY SITE UNDETERMINED

(DATA ARE FROM LF-60, 1978 AND REPRESENT AN UPDATE OF DATA FROM F.F. HAHN ET AL., 1978.) SEE REFERENCE #17.

A1.8 TOXICITY OF 144-CE INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

.B. UCI KG	UCI	I.B.B. UCI KG	UCI	RADIATION DOSE TO LUNG: RATE (RADS/DAY) INIT	RATE 60 DAYS	RATE 120 DAYS	RATE 365 DAYS	RATE AT DEATH	CUMULATIVE (RADS) 60 DAYS	CUMULATIVE 120 DAYS	CUMULATIVE 365 DAYS	CUMULATIVE TOTAL	CUMULATIVE POTENT. INFIN.	CUMULATIVE TO DEATH	DEATH DATE	DAYS 9-30 1978	DAYS DEATH	COMMENT
0	0	0	0													3351		
0	0	0	0													3351		
0	0	0	0													2731		
0	0	0	0													2731		
0	0	0	0													2661		
0	0	0	0													2661		
0	0	0	0													2612		
0	0	0	0													2612		

EXPOSURE.
CED WITH THE MOST PROMINENT

EOLAR CARCINOMA LUNG
ERMINED: BRONCHIOLO ALVEOLAR

TH AMYLOIDOSIS
OLO ALVEOLAR CARCINOMA:

NCHIOLO ALVEOLAR CAR [illegible]NOMA
Y OSTEOSARCOMA ARIS[illegible] FROM

UM
ERMINED

TE OF DATA FROM

1061 012

A1.9 TOXICITY OF 90-SR INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS

NUMBER TTOO	NUMBER RADBIO	SEX	INHALATION EXP BLK	INHALATION EXP DATE	INHALATION EXP AGE DAYS	INHALATION EXP WT KG	I.L.B. RNK	I.L.B. UCI KG	I.L.B. UCI	I.B.B. UCI KG	I.B.B. UCI	RADIATION DOSE TO LUNG RATE (RADS/DAY) INIT	RATE 60 DAYS	RATE 120 DAYS	RATE 365 DAYS	RATE 9-30 1978	RATE AT DEATH	CUMULATIVE (RADS) 60 DAYS	CUMULATIVE 120 DAYS	CUMULATIVE 365 DAYS	CUMULATIVE 9-30 1978	POTENT. 5000 D.	TO DEATH	DEATH DAT
417A	04-828	M	H	70288	379	10.6	1	94	1000	250	2700	500	460	430			390	29000	55000			410000+	86000	7111
415T	01-828	F	I	70288	396	9.2	2	88	810	120	1100	460	390	330			250	26000	[illegible]7000			170000+	76000	711-
403A	03-809	M	E	70238	396	7.0	3	81	570	140	970	430	320	260	180		180	22000	39000	92000		250000+	96000	7125
393A	01-792	M	C	70218	427	10.3	4	81	830	100	1000	430	340	270			230	23000	41000			110000+	51000	7101
397T	04-792	F	D	70218	409	8.6	5	78	670	150	1300	410	280	230			180	20000	35000			130000+	56000	7107
416B	02-828	M	H	70288	382	11.6	6	77	890	210	2400	400	360	330			300	23000	44000			240000+	64000	7110
435A	01-856	M	J	71032	391	11.5	7	73	840	140	1700	380	350	310			260	22000	42000			220000+	73000	7126
417T	03-828	F	I	70288	379	9.5	8	72	680	300	2800	380	300	270			210	20000	37000			200000+	71000	7119
500B	04-964	M	L	71300	369	8.6	9	70	600	150	1300	370	290	250			210	19000	35000			260000+	66000	7219
398U	02-792	F	D	70218	393	6.8	10	68	460	94	640	360	270	250			200	18000	34000			270000+	80000	7118
432T	01-855	F	K	71029	413	8.2	11	67	550	190	1600	350	270	240			190	18000	33000			[illegible]80000+	65000	7129
403U	01-809	F	F	70238	396	6.8	12	66	45[illegible]	150	100[illegible]	350	300	270			200	20000	37000			170000+	70000	7113
355S	01-703	F	B	70036	424	8.6	13	63	540	[illegible]	1300	330	270	240			170	18000	33000			200000+	78000	7101
405X	01-824	F	G	70266	416	8.6	14	63	540	130	1100	330	280	250			180	18000	34000			130000+	60000	7114
355B	02-703	M	A	70036	424	9.4	15	62	580	100	940	330	270	240	180		180	18000	33000	84[illegible]00		260000+	85000	7104
433A	02-854	M	J	71028	411	11.0	16	61	670	110	1300	320	290	260			210	18000	35000			190000+	66000	7128
408T	02-824	F	G	70266	408	8.6	17	58	5[illegible]	100	890	310	260	[illegible]30			170	17000	32000			130000+	55000	7113
398A	03-792	M	C	70218	393	11.4	18	57	650	81	930	300	270	240			180	17000	32000			170000+	67000	7113
418S	03-827	F	I	70286	365	10.0	19	56	560	90	900	290	240	200			150	16000	29000			90000+	43000	7112
402D	02-809	M	E	70238	397	6.7	20	55	370	190	1300	290	230	200			170	16000	29000			360000+	61000	7117
357A	01-702	M	A	70035	421	9.8	21	54	530	150	1400	280	230	200			170	15000	28000			520000+	69000	7101
361T	03-701	F	B	7003[illegible]	415	8.4	22	54	450	90	750	280	250	230			170	16000	30000			150000+	59000	7029
494A	03-964	M	L	71300	404	9.4	23	53	500	100	970	280	190	170			140	14000	24000			200000+	54000	7224
403S	04-809	F	F	70238	396	7.0	24	53	370	140	970	280	250	220			180	16000	30000			150000+	52000	7110
431U	02-855	F	K	71029	421	7.2	25	49	350	240	1800	260	220	200			170	14000	26000			170000+	46000	7125
437D	03-855	M	J	71029	382	8.3	26	47	390	100	860	250	200	180	110		110	13000	25000	60000		120000+	61000	7204
411A	01-827	M	H	70286	421	14.2	27	44	630	260	3600	230	210	1[illegible]			160	13000	25000			130000+	40000	7112
400S	04-808	F	F	70237	404	9.1	28	42	380	84	770	220	200	1[illegible]			120	12000	24000			110000+	48000	7115
402A	01-808	M	E	70237	396	9.5	29	42	400	56	530	220	1[illegible]	1[illegible]			99	11000	20000			120000+	45000	7121
411T	03-824	F	G	70266	400	7.6	30	39	300	69	530	210	180	160			110	12000	22000			89000+	40000	7116
433S	04-854	F	K	71028	411	9.0	31	39	350	62	560	200	190	170			140	12000	23000			150000+	47000	7130
398D	02-790	M	C	70216	391	9.5	32	36	340	51	490	190	150	120	89		66	9900	16000	43000		130000+	65000	7213
497B	02-964	M	L	71300	375	8.8	33	35	310	49	430	190	140	120	81		50	9600	17000	41000		110000+	68000	7335
396T	03-790	F	D	70216	417	8.6	34	34	290	80	680	180	140	120	75		45	9400	17000	40000		93000+	60000	7220
751A	03-1581	M	O	74338	429	10.0	35	30	300	47	470	160	110	97	72		53	8000	14000	34000		110000+	58000	7635
354W	02-702	F	B	70035	425	7.5	36	29	220	61	460	150	130	120	86		75	8400	16000	40000		110000+	49000	7114
355A	04-701	M	A	70034	422	10.6	37	25	270	98	1000	130	110	95	66		39	7000	13000	33000		77000+	51000	7201
759S	03-1586	F	P	74347	415	10.0	38	24	240	47	470	130	91	77	58		41	6300	11000	28000		85000+	52000	7713
433C	01-854	M	J	71028	411	9.8	39	24	240	29	280	130	120	110	77		58	7300	14000	36000		210[illegible]0+	58000	7235
414T	04-827	F	I	70286	397	7.0	40	23	160	53	370	120	96	86	66		40	6300	12000	30000		97000+	57000	7306
416C	02-827	M	H	70286	380	10.7	41	22	240	42	450	120	88	78	54		18	6000	11000	27000		65000+	[illegible]2600	7331
430S	03-854	F	K	71028	423	7.7	42	22	170	30	230	120	98	85	58		44	6400	12000	29000		160000+	51000	7310
398B	01-790	M	C	70216	391	11.2	43	20	220	28	320	100	89	77	50		32	5800	11000	26000		140000+	51000	7315
748S	01-1580	F	N	74337	446	7.6	44	20	150	41	310	100	76	64	48		34	5300	9400	23000		71000+	41000	7708
399U	03-808	F	F	70237	407	7.2	45	19	140	53	380	100	85	74	53		26	5600	10000	25000		84000+	56000	7331
401B	02-808	M	E	70237	403	9.0	46	19	170	50	450	99	84	77	59		30	5500	10000	27000		84000+	55000	7316
404S	01-823	F	G	70265	438	8.6	47	19	160	24	200	98	75	63	44		10	5100	9200	22000		63000+	57000	7604
748A	02-1581	M	M	74338	447	8.2	48	18	150	25	200	95	68	58	43	22		4700	8400	21000	49000	64000		
495C	01-964	M	L	71300	385	8.0	49	18	140	24	190	92	62	56	36		7.5	4200	7700	19000		39000+	37000	7629
397S	04-790	F	D	70216	407	8.3	50	16	130	26	220	83	71	62	38		15	4600	8600	20000		88000+	60000	7703

1061 013

A1.9 TOXICITY OF 90-SR INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS

	I.L.B.		I.B.B.		RADIATION DOSE TO LUNG: RATE (RADS/DAY)						RADIATION DOSE TO LUNG: CUMULATIVE (RADS)							DAYS		
RNK	UCI/KG	UCI	UCI/KG	UCI	INIT	60 DAYS	120 DAYS	365 DAYS	9-30 1978	AT DEATH	60 DAYS	120 DAYS	365 DAYS	9-30 1978	POTENT. 5000 D.	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
1	94	1000	250	2700	500	460	430			390	29000	55000			410000+	86000	71118		195	D-PULMONARY INJURY
2	88	810	120	1100	460	390	330			250	26000	47000			170000+	76000	71143		220	D-PULMONARY INJURY
3	81	570	140	970	430	320	260	180		180	22000	39000	92000		250000+	[illegible]	71259		386	D-PULMONARY INJURY
4	81	830	100	1000	430	340	270			230	23000	41000			110000+	[illegible]	71012		159	D-PULMONARY INJURY
5	78	670	150	1300	410	280	230			180	20000	35000			130000+	56000	71071		218	D-PULMONARY INJURY
6	77	890	210	2400	400	360	330			300	23000	44000			240000+	64000	71107		184	D-PULMONARY INJURY
7	73	840	140	1700	380	350	310			260	22000	42000			220000+	73000	71263		231	E-PULMONARY INJURY
8	72	680	300	2800	380	300	270			210	20000	37000			200000+	71000	71190		267	E-PULMONARY INJURY
9	70	600	150	1300	370	290	250			210	19000	35000			260000+	66000	72190		255	D-PULMONARY INJURY
10	68	460	94	640	360	270	250			200	18000	34000			270000+	80000	71182		329	D-PULMONARY INJURY
11	67	550	190	1600	350	270	240			190	18000	33000			180000+	65000	71297		268	D-PULMONARY INJURY
12	66	450	150	1000	350	300	270			200	20000	37000			170000+	70000	71131		258	D-PULMONARY INJURY
13	63	540	150	1300	330	270	240			170	18000	33000			200000+	78000	71013		342	D-PULMONARY INJURY
14	63	540	130	1100	330	280	250			180	18000	34000			130000+	60000	71144		243	D-PULMONARY INJURY
15	62	580	100	940	330	270	240	180		180	18000	33000	84000		260000+	85000	71044		373	D-PULMONARY INJURY
16	61	670	110	1300	320	290	260			210	18000	35000			190000+	66000	71280		252	E-PULMONARY INJURY
17	58	500	100	890	310	260	230			170	17000	32000			130000+	55000	71139		238	D-PULMONARY INJURY
18	57	650	81	930	300	270	240			180	17000	32000			170000+	67000	71136		283	D-PULMONARY INJURY
19	56	560	90	900	290	240	200			150	16000	29000			90000+	43000	71121		200	D-PULMONARY INJURY
20	55	370	190	1300	290	230	200			170	16000	29000			360000+	61000	71173		300	D-PULMONARY INJURY
21	54	530	150	1400	280	230	200			170	15000	28000			520000+	69000	71011		341	D-PULMONARY INJURY
22	54	450	90	750	280	250	230			170	16000	30000			150000+	59000	70299		265	D-PULMONARY INJURY
23	53	500	100	970	280	190	170			140	14000	24000			200000+	54000	72245		310	D-PULMONARY INJURY
24	53	370	140	970	280	250	220			180	16000	30000			150000+	52000	71105		232	D-PULMONARY INJURY
25	49	350	240	1800	260	220	200			170	14000	26000			170000+	46000	71255		226	D-PULMONARY INJURY
26	47	390	100	860	250	200	180	110		110	13000	25000	60000		120000+	61000	72040		376	E-PULMONARY INJURY
27	44	630	260	3600	230	210	190			160	13000	25000			130000+	40000	71122		201	D-PULMONARY INJURY
28	42	380	84	770	220	200	170			120	12000	24000			110000+	48000	71158		286	D-PULMONARY INJURY
29	42	400	56	530	220	160	140			99	11000	20000			120000+	45000	71212		340	D-PULMONARY INJURY
30	39	300	69	530	210	180	160			110	12000	22000			89000+	40000	71160		259	D-PULMONARY INJURY
31	39	350	62	560	200	190	170			140	12000	23000			150000+	47000	71307		279	D-PULMONARY INJURY
32	36	340	51	490	190	150	120	89		66	9900	18000	43000		130000+	65000	72130		644	E-HEMANGIOSARCOMA LUNG
33	35	310	49	430	190	140	120	81		50	9600	17000	41000		110000+	68000	73357		788	D-HEMANGIOSARCOMA LUNG
34	34	290	80	680	180	140	120	75		45	9400	17000	40000		93000+	60000	72204		718	D-HEMANGIOSARCOMA LUNG
35	30	300	47	470	160	110	97	72		53	8000	14000	34000		110000+	58000	76355		747	E-HEMANGIOSARCOMA LUNG
36	29	220	61	460	150	130	120	86		75	8400	16000	40000		110000+	49000	71147		477	D-PULMONARY INJURY
37	25	270	98	1000	130	110	93	66		39	7000	13000	33000		77000+	51000	72019		715	D-HEMANGIOSARCOMA LUNG
38	24	240	47	470	130	91	[illegible]	58		41	6300	11000	28000		85000+	52000	77133		842	E-HEMANGIOSARCOMA LUNG
39	24	240	29	280	130	120	110	77		58	7300	14000	36000		210000+	58000	72356		693	E-HEMANGIOSARCOMA LUNG
40	23	160	53	370	120	96	86	66		40	6300	12000	30000		97000+	57000	73064		874	D-HEMANGIOSARCOMA LUNG
41	22	240	42	450	120	88	78	54		18	6000	11000	27000		65000+	[illegible]	73318		1128	E-SEE NOTE AT END
42	22	170	30	230	120	98	85	58		44	6400	12000	29000		160000+	51000	73106		809	E-HEMANGIOSARCOMA LUNG
43	20	220	28	320	100	89	77	50		32	5800	11000	26000		140000+	51000	73152		1032	E-SEE NOTE AT END
44	20	150	41	310	100	76	64	48		34	5300	9400	23000		71000+	41000	77084		843	E-HEMANGIOSARCOMA LUNG
45	19	140	53	380	100	85	74	53		26	5600	10000	25000		84000+	56000	73311		1170	E-HEMANGIOSARCOMA LUNG
46	19	170	50	450	99	84	77	59		30	5500	10000	27000		84000+	55000	73166		1025	D-HEMANGIOSARCOMA LUNG
47	19	160	24	200	98	75	63	44		10	5100	9200	22000		63000+	57000	76042		1968	D-HEMANGIOSARCOMA HEART
48	18	150	25	200	95	68	58	[illegible]	22		4700	8400	21000	49000	64000			1396		
49	18	140	24	190	92	62	56	36		7.5	4200	7700	19000		39000+	37000	76295		1821	E-SEE NOTE AT END
50	16	130	26	220	83	71	62	38		15	4600	8600	20000		88000+	60000	77032		2373	D-SEE NOTE AT END

1061 014

A1.9 TOXICITY OF 90-SR INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

NUMBER TT00	NUMBER RADBIO	INHALATION EXP SEX	INHALATION EXP BLK	INHALATION EXP DATE	INHALATION EXP AGE DAYS	INHALATION EXP WT KG	I.L.B. RNK	I.L.B. UCI/KG	I.L.B. UCI	I.B.B. UCI/KG	I.B.B. UCI
354A	01-701	M	A	70034	424	10.[illegible]	51	15	160	49	510
362T	02-701	F	B	70034	413	[illegible].8	52	15	100	36	240
413B	02-826	M	H	70285	409	10.9	53	15	160	23	250
415V	01-826	F	I	70285	393	7.5	54	15	110	23	180
405A	02-806	M	E	70236	387	9.7	55	11	110	21	210
358T	01-704	F	B	70037	422	9.0	56	10	90	24	210
438A	04-853	M	J	71027	376	9.9	57	9.8	97	20	200
413C	03-826	M	H	70285	409	12.1	58	9.0	110	12	140
411S	03-823	F	G	70265	400	8.1	59	8.9	72	23	190
399T	01-806	F	F	70236	406	8.0	60	8.9	71	13	110
754T	02-1580	F	N	74337	410	7.0	61	8.0	56	11	74
393T	03-789	F	D	70215	424	6.6	62	8.0	53	15	86
393C	02-789	M	C	70215	424	8.2	63	8.0	66	11	92
367H	04-700	M	A	70033	385	8.6	64	7.9	68	27	230
494D	01-963	M	L	71299	403	8.0	65	7.5	60	12	97
430V	02-853	F	K	71027	422	7.2	66	7.2	52	22	160
759C	01-1586	M	Q	74347	415	10.9	67	7.0	76	9.8	110
405S	02-823	F	G	70265	416	9.9	68	6.7	66	14	140
413S	04-826	F	I	70285	409	10.4	69	6.0	62	16	170
754B	03-1580	M	M	74337	410	8.1	70	5.0	40	9.1	73
755A	01-1581	M	O	74338	409	7.1	71	5.0	35	6.8	49
352B	02-704	M	A	70037	433	7.9	72	4.9	39	8.5	67
398S	04-789	F	D	70215	390	9.6	73	4.9	47	9.6	92
494B	02-963	M	L	71299	403	9.4	74	4.9	46	11.0	100
431T	01-853	F	K	71027	419	6.6	75	4.7	31	9.9	65
399S	04-[illegible]	F	F	70236	406	9.7	76	4.3	42	8.3	83
403B	03-8[illegible]	M	E	70236	394	7.3	77	4.2	31	7.0	51
393D	01-789	M	C	70215	424	10.5	78	4.2	44	7.4	78
360T	02-700	F	B	70033	414	7.9	79	4.1	32	25	200
758U	04-1586	F	P	74347	417	7.0	80	4.0	28	13	89
435C	03-853	M	J	71027	386	9.0	81	3.7	33	6.8	61
755U	02-1586	F	R	74347	418	6.2	82	3.0	19	13	83
762B	01-1583	M	Q	74344	407	6.7	83	1.9	13	3.8	25
756C	02-1584	M	Q	74345	416	11.0	84	1.9	21	2.3	26
756F	04-1578	M	O	74331	402	10.6	85	1.8	19	2.3	2[illegible]
751U	03-1583	F	P	74344	435	10.2	86	1.8	18	2.4	24
749S	01-1577	F	N	74330	430	8.2	87	1.6	13	2.5	20
762U	01-1584	F	R	74345	408	6.9	88	1.6	11	3.1	22
749B	03-1579	M	M	74336	436	8.8	89	1.5	13	2.5	22
755[illegible]	04-1584	F	R	74345	416	10.0	90	1.2	12	2.7	27
752A	03-1578	M	M	74331	414	6.7	91	1.1	7.3	1.5	10
748B	02-1579	M	O	74336	445	8.7	92	1.1	9.5	2.0	17
754S	04-1585	F	P	74346	419	8.3	93	.99	8.2	4.0	33
[illegible]2V	03-1584	F	R	74345	408	6.3	94	.79	4.9	1.8	11
751T	03-1577	F	N	74330	421	9.3	95	.73	6.8	2.3	2[illegible]
763S	02-1583	F	P	74344	406	8.2	96	.70	5.7	.90	7.4
758T	03-1585	F	P	74346	416	7.0	97	.42	2.9	.46	3.2
759D	01-1585	M	Q	74346	414	9.1	98	.42	9.1	.88	8.0
751V	04-1583	F	R	74344	435	8.4	99	.40	3.3	.84	7.0
754A	01-1579	M	M	74336	409	9.7	100	.38	3.7	.64	6.3

RADIATION DOSE TO LUNG

NUMBER TT00	RATE (RADS/DAY) INIT	RATE 60 DAYS	RATE 120 DAYS	RATE 365 DAYS	RATE 9-30 1978	RATE AT DEATH	CUMULATIVE (RADS) 60 DAYS	CUMULATIVE 120 DAYS	CUMULATIVE 365 DAYS	CUMULATIVE 9-30 1978	CUMULATIVE POTENT. 5000 D.	CUMULATIVE TO DEATH	DEATH DATE	DA[illegible] 9-3[illegible] 197[illegible]
354A	81	70	61	[illegible]		18	4500	8400	20000		64000+	43000	76152	
362T	78	69	62	[illegible]		17	4400	8300	21000		58000+	44000	73123	
413B	77	61	51	30		13	4100	7500	17000		48000+	34000	74037	
415V	77	58	52	35		5.8	3800	7100	18000		39000+	37000	74285	
405A	60	42	33	19		2.6	3000	5200	11000		24000+	23000	76358	
358T	52	48	44	33		9.4	3000	5800	15000		65000+	46000	76275	
438A	52	36	30	22		6.5	260[illegible]	4500	11000		35000+	34000	78223	
413C	47	41	36	24		3.9	2600	4900	12000		[illegible]8000+	27000	77224	
411S	47	41	37	24		5.5	2600	5000	12000		34000+	33000	77304	
399T	47	38	33	24		7.0	2500	4700	12000		36000+	31000	75217	
754T	42	30	26	19	11		2100	3800	9200	23000	28000			139
393T	42	34	29	19	3.0		2300	4200	9900	24000	25000			298
393C	42	33	29	21		5.0	2200	4000	10000		27000+	24000	75072	
367H	42	37	33	24		5.7	2400	4500	11000		35000+	34000	77091	
494D	39	32	30	25		11	2100	4000	11000		41000+	34000	76176	
430V	38	31	29	21		5.8	2000	3800	9900		28000+	27000	77140	
759C	37	26	23	17	8.1		1800	3300	8000	19000	25000			138
405S	35	27	21	12	3.5		1800	3200	7000	19000	20000			293
413S	31	29	26	18		3.0	1800	3400	8900		21000+	21000	77177	
754B	26	19	16	12	7.0		1300	2400	5700	14000	18000			139
755A	26	19	16	12	7.0		1300	2400	5700	14000	18000			139
352B	26	24	22	18		6.8	1500	2900	7700		38000+	35000	77310	
398S	26	18	16	12		2.1	1300	2300	5700		14000+	13[illegible]00	77223	
494B	26	21	17	11	5.5		1400	2500	5900	22000	24000			253
431T	25	23	22	18		7.0	1400	2800	7700		27000+	25000	76295	
399S	23	21	19	14		6.5	1300	2500	6400	23000	34000+	25000	76201	
403B	22	20	18	12		1.1	1300	2400	6100		13000+	12000	77[illegible]15	
393D	22	17	16	12	2.5		1100	2100	5600	16000	17000			298
360T	21	18	15	9.8	3.6		1200	2200	5100	20000	21000			316
758U	21	15	13	9.6	6.3		1100	1900	4600	11000	14000			138
435C	19	18	17	13		3.9	1100	2200	[illegible]800		17000+	16000	77076	
755U	16	11	9.7	7.2	4.5		790	1400	3400	9000	11000			138
762B	10	[illegible]	6.2	4.6	2.1		500	890	2200	5300	6700			139
756C	10	[illegible]	6.1	4.5	2.6		500	890	2100	5300	6600			138
756F	9.6	[illegible].8	5.8	4.3	2.6		470	850	2100	5200	6400			140
751U	9.5	6.7	5.7	4.2	2.5		470	850	2000	5200	6300			139
749S	8.5	6.1	5.2	3.9	2.4		430	760	1900	4800	5700			140
762U	8.8	6.0	5.1	3.4	2.1		420	750	1800	4600	5600			138
749B	7.9	5.7	4.8	3.6	2.2		390	710	1700	4400	5300			139
755[illegible]	6.3	4.5	3.9	2.9	1.8		310	570	1400	3600	4200			130
752A	5.8	4.2	3.5	2.7	1.6		290	520	1300	3300	3900			140
748B	5.8	4.1	3.4	2.6	1.4		280	510	1200	2800	3800			139
754S	5.2	3.7	3.2	2.4	1.4		260	470	1100	2800	3500			138
[illegible]2V	4.2	3.0	2.5	1.9	1.1		210	370	910	2300	2800			138
751T	3.8	2.8	2.4	1.8	.90		190	340	840	1900	2600			140
763S	3.7	2.6	2.3	1.7	.90		180	330	800	1900	2500			139
758T	2.2	1.7	1.4	1.0	.52		110	200	490	1100	1500			138
759D	2.2	1.6	1.4	1.0	.51		110	190	480	1100	1400			138
751V	2.1	1.5	1.3	.96	.45		100	190	460	1100	1400			139
754A	2.0	1.4	1.2	.92	.46		100	180	440	940	1300			139

A1.9 TOXICITY OF 90-SR INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

.L.B.		I.B.B.		RADIATION DOSE TO LUNG: RATE (RADS/DAY)						CUMULATIVE (RADS)							DAYS		
UCI KG	UCI	UCI KG	UCI	INIT	60 DAYS	120 DAYS	365 DAYS	9-30 1978	AT DEATH	60 DAYS	120 DAYS	365 DAYS	9-30 1978	POTENT. 5000 D.	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
15	160	49	510	81	70	61	40		18	4500	8400	20000		64000+	43000	76152		2309	E-SEE NOTE AT END
15	100	36	240	78	69	62	44		17	4400	8300	21000		58000+	44000	73123		1185	E-HEMANGIOSARCOMA LUNG
15	160	23	250	77	61	51	30		13	4100	7500	17000		48000+	34000	7[illegible]937		1213	D-HEMANGIOSARCOMA LUNG
15	110	23	180	77	58	52	35		5.8	3800	7100	18000		39000+	37000	74285		1461	D-HEMANGIOSARCOMA HEART
11	110	21	210	60	42	33	19		2.6	3000	5200	11000		24000+	23000	76358		2313	E-HEMANGIOSARCOMA HEART
10	90	24	210	52	48	44	33		9.4	3000	5800	15000		65000+	46000	76275		2429	D-SEE NOTE AT END
.8	97	20	200	52	36	30	22		6.5	2600	4500	11000		35000+	34000	78223		2753	E-SEE NOTE AT END
.0	110	12	140	47	41	36	24		3.9	2600	4900	12000		28000+	27000	77224		2496	E-SEE NOTE AT END
.9	72	23	190	47	41	37	24		5.5	2600	5000	12000		34000+	33000	77304		2596	D-SEE NOTE AT END
.9	71	13	110	47	38	33	24		7.0	2500	4700	12000		36000+	31000	75217		1807	D-HEMANGIOSARC. MEDIASTINUM
.0	56	11	74	42	30	26	19	11		2100	3800	9200	23000	28000			1397		
.0	53	15	86	42	34	29	19	3.0		2300	4200	9900	24000	25000			2980		
.0	66	11	92	42	33	29	21		5.0	2200	4000	10000		27000+	24000	75072		1683	E-SEE NOTE AT END
.9	68	27	230	42	37	33	24		5.7	2400	4500	11000		35000+	34000	77091		2615	D-SEE NOTE AT END
.5	60	12	97	39	32	30	25		11	2100	4000	11000		41000+	34000	76176		1703	D-HEMANGIOSARCOMA HEART
.2	52	22	160	38	31	29	21		5.8	2000	3800	9900		28000+	27000	77140		2305	E-HEMANGIOSARCOMA HEART
.0	76	9.8	110	37	26	23	17	8.1		1800	3300	8000	19000	25000			1387		
.7	66	14	140	35	27	21	12	3.5		1800	3200	7000	19000	20000			2930		
.0	62	16	170	31	29	26	18		3.0	1800	3400	8900		21000+	21000	77177		2449	D-HEMANGIOSARCOMA HEART
.0	40	9.1	73	26	19	16	12	7.0		1300	2400	5700	14000	18000			1397		
.0	35	6.8	49	26	19	16	12	7.0		1300	2400	5700	14000	18000			1396		
.9	39	8.5	67	26	24	22	18		6.8	1500	2900	7700		38000+	35000	77310		2830	D-SEE NOTE AT END
.9	47	9.6	92	26	18	16	12		2.1	1300	2300	5700		14000+	13000	77223		2565	E-HEMANGIOSARCOMA LUNG
.9	46	11.0	100	26	21	17	11	5.5		1400	2500	5900	22000	24000			2531		
.7	31	9.9	65	25	23	22	18		7.0	1400	2800	7700		27000+	25000	76295		2094	D-HEMANGIOSARCOMA HEART
.3	42	8.3	83	23	21	19	14		6.5	1300	2500	6400	23000	34000+	25000	76201		2156	D-HEMANGIOSARCOMA HEART
.2	31	7.0	51	22	20	18	12		1.1	1300	2400	6100		13000+	12000	77315		2636	E-SEE NOTE AT END
.2	44	7.4	78	22	17	16	12	2.5		1100	2100	5600	16000	17000			2980		
.1	32	25	200	21	18	15	9.8	3.6		1200	2200	5100	20000	21000			3162		
.0	28	13	89	21	15	13	9.6	6.3		1100	1900	4600	11000	14000			1387		
.7	33	6.8	61	19	18	17	13		3.9	1100	2200	5800		17000+	16000	77076		2241	E-HEMANGIOSARCOMA HEART
.0	19	13	83	16	11	9.7	7.2	4.5		790	1400	3400	9000	11000			1387		
.9	13	3.8	25	10	7.2	6.2	4.6	2.1		500	890	2200	5300	6700			1390		
.9	21	2.3	26	10	7.1	6.1	4.5	2.6		500	890	2100	5300	6600			1389		
.8	19	2.3	25	9.6	6.8	5.8	4.3	2.6		470	850	2100	5200	6400			1403		
.8	18	2.4	24	9.5	6.7	5.7	4.2	2.5		470	850	2000	5200	6300			1390		
.6	13	2.5	20	8.5	6.1	5.2	3.9	2.4		430	760	1900	4800	5700			1404		
.6	11	3.1	22	8.8	6.0	5.1	3.4	2.1		420	750	1800	4600	5600			1389		
.5	13	2.5	22	7.9	5.7	4.8	3.6	2.2		390	710	1700	4400	5300			1398		
.2	12	2.7	27	6.3	4.5	3.9	2.9	1.8		310	570	1400	3600	4200			1389		
.1	7.3	1.5	10	5.8	4.2	3.5	2.7	1.6		290	520	1300	3300	3900			1403		
.1	9.5	2.0	17	5.8	4.1	3.4	2.6	1.4		280	510	1200	2800	3800			1398		
99	8.2	4.0	33	5.2	3.7	3.2	2.4	1.4		260	470	1100	2800	3500			1388		
79	4.9	1.8	11	4.2	3.0	2.5	1.9	1.1		210	370	910	2300	2800			1389		
73	6.8	2.3	21	3.8	2.8	2.4	1.8	.90		190	340	840	1900	2600			1404		
70	5.7	.90	7.4	3.7	2.6	2.3	1.7	.90		180	330	800	1900	2500			1390		
42	2.9	.46	3.2	2.2	1.7	1.4	1.0	.52		110	200	490	1100	1500			1388		
42	9.1	.88	8.0	2.2	1.6	1.4	1.0	.51		110	190	480	1100	1400			1388		
40	3.3	.84	7.0	2.1	1.5	1.3	.96	.45		100	190	460	1100	1400			1390		
38	3.7	.64	6.3	[illegible]	1.4	1.2	.92	.46		100	180	440	940	1300			1398		

1061 016

A1.9 TOXICITY OF 90-SR INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

NUMBER TTDO	NUMBER RADBIO	INHALATION EXP SEX	BLK	DATE	AGE DAYS	WT KG	RNK	I.L.B. UCI/KG	I.L.B. UCI	I.B.B. UCI/KG	I.B.B. UCI	RADIATION DOSE TO LUNG: RATE (RADS/DAY) INIT	RATE 60 DAYS	RATE 120 DAYS	RATE 3[illegible] DAYS	RATE 9-30 1978	RATE AT DEATH	CUMULATIVE (RADS) 60 DAYS	CUM. 120 DAYS	CUM. 365 DAYS	CUM. 9-30 1978	CUM. POTENT. 5000 D.	CUM. TO DEATH	DEATH DATE	DA[illegible] 9-[illegible] 19[illegible]
748T	04-1579	F	N	74336	445	5.8	101	.34	2.0	.70	4.1	1.8	1.3	1.1	.82	.45		89	160	390	930	1200			13[illegible]
763A	02-1585	M	Q	74346	408	9.9	102	.34	3.4	.65	6.4	1.8	1.3	1.1	.82	.44		89	160	390	920	1200			13[illegible]
750A	01-1577	M	M	74330	428	10.[illegible]	103	.26	2.7	.59	6.2	1.4	.98	.84	.63	.36		69	130	300	600	1000			14[illegible]
756A	02-1578	M	O	74331	402	10.2	104	.26	2.7	.65	6.6	1.4	.98	.83	.62	.36		68	120	290	730	920			14[illegible]
758C	01-1578	M	O	74331	401	7.7	105	.24	1.8	.58	4.5	1.3	.91	.77	.58	.33		63	110	280	680	850			14[illegible]
749T	04-1577	F	N	74330	430	7.9	106	.21	1.7	.74	5.8	1.1	.79	.68	.51	.28		55	99	240	590	740			14[illegible]
361B	01-699	M	A	70027	408	12.0	C	0	0	0	0														31[illegible]
354S	02-699	F	B	70027	417	7.8	C	0	0	0	0														31[illegible]
397U	01-788	F	D	70212	403	7.5	C	0	0	0	0														29[illegible]
399B	02-788	M	C	70212	382	10.9	C	0	0	0	0														29[illegible]
401S	01-811	F	F	70240	406	8.5	C	0	0	0	0														29[illegible]
402B	02-811	M	E	70240	399	11.1	C	0	0	0	0														29[illegible]
405W	01-816	F	G	70247	398	6.8	C	0	0	0	0														29[illegible]
413U	01-830	F	I	70289	413	9.4	C	0	0	0	0														29[illegible]
418C	02-830	M	H	70289	368	11.4	C	0	0	0	0														29[illegible]
437A	01-851	M	J	71025	378	10.9	C	0	0	0	0														28[illegible]
431S	02-851	F	K	71025	417	7.4	C	0	0	0	0														28[illegible]
497A	01-962	M	L	71299	374	11.1	C	0	0	0	0														25[illegible]
754C	01-1576	M	M	74329	402	6.7	C	0	0	0	0														14[illegible]
751S	02-1576	F	N	74329	420	11.6	C	0	0	0	0														14[illegible]
758A	02-1576	M	O	74329	399	11.2	C	0	0	0	0														14[illegible]
762T	02-1582	F	P	74343	406	7.2	C	0	0	0	0														13[illegible]
758B	03-1582	M	Q	74343	413	10.4	C	0	0	0	0														13[illegible]
761S	01-1582	F	R	74343	407	9.8	C	0	0	0	0														1[illegible]

UCI/KG: KG REFERS TO TOTAL BODY WEIGHT.
DOSE RATE: DAYS REFER TO DAYS AFTER INHALATION EXPOSURE.
COMMENT: D,E,OR S: DIED,EUTHANIZED,OR SACRIFICED WITH THE MOST PROMINENT FEATURES ASSOCIATED WITH DEATH.
+ DIED BEFORE POTENTIAL INFINITE DOSE RECEIVED.

NOTES:

DOG 416C: E-EPIDERMOID CARCINOMA; HEMANGIOSARCOMA LUNG
DOG 398B: E-HEMANGIOSARCOMA LUNG; BRONCHIOLO ALVEOLAR CARCINOMA
DOG 495C: E-HEMANGIOSARCOMA SPLEEN; BRONCHIOLO ALVEOLAR CARCINOMA
DOG 397S: D-RADIATION PNEUMONITIS; PULMONARY FIBROSIS
DOG 354A: E-HEMANGIOSARCOMA LUNG; SQUAMOUS CELL CARCINOMA NASAL CAVITY
DOG 358T: E-HEMANGIOSARCOMA HEART; BROCHIOLO ALVEOLAR CARCINOMA
DOG 438A: E-HEMANGIOSARCOMA RIB; BRONCHIOLOALVEOLAR CARCINOMA LUNG
DOG 413C: E-SQUAMOUS CELL CARCINOMA NASAL CAVITY
DOG 411S: D-PULMONARY INJURY; COMBINED CARCINOMA LUNG
DOG 393C: E-HEMANGIOSARCOMA SITE UNDETERMINED
DOG 367[illegible]: D-ASPIRATION PNEUMONIA; BRONCHIOLO ALVEOLAR CARCINOMA
DOG 352B: D-SQUAMOUS CELL CARCINOMA LUNG; HEMANGIOSARCOMA TRACHEOBRONCHIAL LYMPH NODES
DOG 403B: E-HEMANGIOSARCOMA - PRIMARY SITE UNDETERMINED BRONCHIOLOALVEOLAR CARCINOMA

(DATA ARE FROM LF-60, 1978 AND REPRESENT AN UPDATE OF DATA FROM M.B. SNIPES ET AL., 1978.) SEE REFERENCE #55.

1061 017

A1.9 TOXICITY OF 90-SR INHALED IN A RELATIVELY INSOLUBLE FORM BY BEAGLE DOGS (CONT'D).

	I.L.B.		I.B.B.		RADIATION DOSE TO LUNG: RATE (RADS/DAY)						RADIATION DOSE TO LUNG: CUMULATIVE (RADS)							DAYS		
NK	UCI/KG	UCI	UCI/KG	UCI	INIT	60 DAYS	120 DAYS	365 DAYS	9-30 1978	AT DEATH	60 DAYS	120 DAYS	365 DAYS	9-30 1978	POTENT. 5000 D.	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
01	.34	2.0	.70	4.1	1.8	1.3	1.1	.82	.45		89	160	390	930	1200			1398		
02	.34	3.4	.65	6.4	1.8	1.3	1.1	.82	.44		89	160	390	920	1200			1388		
03	.26	2.7	.59	6.2	1.4	.98	.84	.63	.36		[illegible]	130	300	600	1000			1404		
04	.26	2.7	.65	6.6	1.4	.98	.83	.62	.36		68	120	290	730	920			1403		
05	.24	1.8	.58	4.5	1.3	.91	.77	.58	.33		63	110	280	680	850			1403		
06	.21	1.7	.74	5.8	1.1	.79	.68	.51	.28		55	99	240	590	740			1404		
C	0	0	0	0														3168		
C	0	0	0	0														3168		
C	0	0	0	0														2983		
C	0	0	0	0														2983		
C	0	0	0	0														2955		
C	0	0	0	0														2955		
C	0	0	0	0														2948		
C	C	0	0	0														2906		
C	0	0	0	0														2906		
C	0	0	0	0														2805		
C	0	0	0	0														2805		
C	0	0	0	0														2531		
C	0	0	0	0														1405		
C	0	0	0	0														1405		
C	0	0	0	0														1405		
C	0	0	0	0														1391		
C	0	0	0	0														1391		
C	0	0	0	0														1391		

ATION EXPOSURE.
CRIFICED WITH THE MOST PROMINENT

IVED.

IOSARCOMA LUNG
OLO ALVEOLAR CARCINOMA
CHIOLO ALVEOLAR CARCINOMA
NARY FIBROSIS
US CELL CARCINOMA NASAL CAVITY
IOLO ALVEOLAR CARCINOMA
OLOALVEOLAR CARCINOMA LUNG
CAVITY
ARCINOMA LUNG
INED
IOLO ALVEOLAR CARCINOMA
HEMANGIOSARCOMA TRACHEOBRONCHIAL

E UNDETERMINED

UPDATE OF DATA FROM
#55.

1061 018

A2.1 THIRTY-DAY MORTALITY AFTER EXPOSURE OF THE THORAX OF RATS TO 250 KVP X-RAYS

DOSE (R)	DOSE RATE (R/MIN)	NUMBER DEAD IN 30 DAYS	NUMBER EXPOSED
1500	90	2	40
1750	90	4	20
2000	90	3	40
2200	90	10	38
2500	90	26	40
3000	90	16	20
3250	90	17	20
4000	90	31	32

(DATA FROM A.J. DUNJIC ET AL., 1960.) SEE REFERENCE #9.

A3.1 TOXICITY OF INHALED 90-SRCL2 IN BEAGLE DOGS

NUMBER TT00	NUMBER RADBIO	INHALATION EXP SEX	INHALATION EXP DATE	INHALATION EXP AGE DAYS	INHALATION EXP WT KG	I.B.B. RNK	I.B.B. UCI/KG	I.B.B. UCI	L.T.F B. RNK	L.T.F B. UCI/KG	RADIATION DOSE TO SKELETON: RATE (RADS/DAY) INITIAL	RATE 730 DAYS	RATE 9-30 1978	RATE POTENT.AT 5000 D	RATE AT DEATH	CUMULATIVE (RADS) 730 DAYS	CUMULATIVE 9-30 1978	CUMULATIVE POTENT.TO 5000 D	CUMULATIVE TO DEATH	DEATH DATE	
157E	01-416	F	67115	431	9.7	1	280	2700	1	120	55	21		7.0	21	18000		73000+	19000	69143	
164A	02-419	M	67124	387	9.0	9	210	1900	2	190	54			1.3	24			52000+	17000	68344	
158E	02-416	F	67115	429	10.2	6	240	2400	3	120	54	16		5.3	15	14000		55000+	17000	69311	
195C	03-456	F	67275	397	9.3	3	270	2500	4	110	48				30				810	67296	
195B	02-456	M	67275	389	10.1	4	260	2600	5	100	48				34				1100	67303	
162F	01-419	F	67124	436	11.2	2	270	3000	6	100	47	21		3.7	20	18000		61000+	22000	69279	
158B	03-416	M	67115	429	9.3	5	240	2200	7	100	47				36				1300	67146	
159B	02-417	F	67117	430	9.8	8	220	2200	8	98	45				29				660	67135	
160B	02-418	M	67122	435	9.5	7	230	2200	9	97	44	18		6.2	17	15000		62000+	17000	69255	
23C	01-261	M	65229	408	9.1	11	160	1500	10	83	37	15		5.7	14	13000		54000+	18000	68233	
159A	01-417	M	67117	430	11.3	10	180	2000	11	74	34				25				850	67146	
160C	03-417	F	67117	430	10.4	12	160	1700	12	69	31	7.5		3.2	6.8	7000		28000+	9900	70163	
23B	02-256	M	65208	387	8.0	17	110	880	13	59	27	8.1		2.3	5.9	7600		27000+	15000	70169	
26F	03-263	F	65231	384	7.8	15	120	940	14	52	24	9.0		2.7	6.4	8900		33000+	18000	70343	
13A	02-228	M	65123	381	8.3	19	99	820	15	51	25	6.6		1.9	5.4	6400		22000+	10000	69023	
12F	01-228	F	65123	401	8.1	18	110	890	16	50	26	8.6		4.5	8.0	7900		35000+	10000	68074	
162A	01-418	M	67122	434	11.9	13	130	1500	17	50	23	9.5		2.3		8800		32000+	17000	71363	
22E	02-257	F	65205	396	6.7	21	93	620	18	44	20	4.7		1.5	2.4	4700		16000+	13000	74044	
26A	01-262	M	65230	383	7.8	14	120	940	19	41	19	6.4		2.4	5.3	6400		23000+	10000	69173	
19B	01-252	M	65201	404	6.4	23	84	540	20	40	18	3.8		1.3	2.1	3900		14000+	10000	73243	
22F	01-256	F	65208	395	8.8	16	120	1100	21	34	16	6.2		2.6	5.1	5900		23000+	10000	69287	
19C	02-252	F	65201	404	7.8	22	87	680	22	28	15	3.3		1.4	1.9	3300		12000+	9500	74151	
22A	02-253	M	65202	389	10.5	20	98	1000	23	28	12	6.1		1.5	3.5	6100		20000+	13000	71258	
19D	01-253	F	65202	405	8.7	24	71	620	24	27	12	3.4		1.3	2.1	3500		12000+	8500	72279	
40E	03-283	F	65301	383	6.3	28	27	170	25	9.6	4.4	1.5		.61	.68	1500	4900	56000+	4900	76278	
28C	02-271	M	65256	406	7.6	26	30	230	26	9.3	4.3	1.4		.56	.84	1500		5100+	3300	72136	
39C	02-283	F	65301	385	8.7	29	27	230	27	9.1	4.2	4.2	.36	.35		1100	3600	3700			4
38E	01-283	F	65301	391	6.5	27	29	190	28	8.9	4.0	.81	.18	.25		840	2700	2800			4
30C	02-272	M	65257	395	8.8	32	19	160	29	8.3	3.7	1.1		.33		1200		3900	3800	77327	
30B	01-272	M	65257	395	8.2	35	17	140	30	7.9	3.6	.90	.33	.30		950	3100	3200			47
42D	01-284	F	65302	377	7.8	30	25	200	31	7.7	3.6	1.1	.32	.30		1100	3600	3700			47
28B	01-271	M	65256	406	7.2	25	32	230	32	7.1	3.2	1.0		.30	.50	1100		3500+	2800	74046	
22D	01-257	M	65209	396	9.1	36	16	150	33	6.8	3.1	.88	.33	.31		930	2900	3100			46
30D	03-272	M	65257	395	8.9	31	23	200	34	6.6	3.0	.91		.28	.39	930		3200+	2900	76114	
42E	02-284	F	65302	377	8.7	33	19	170	35	6.1	2.8	.83		.28	.33	830		3000+	2700	76211	
42F	03-284	F	65302	377	7.3	34	17	120	36	5.7	2.6	.59	.20	.19		670	2000	2100			47
26B	01-266	M	65238	391	9.0	37	6.6	59	37	3.2	1.5	.41	.09	.077		410	1200	1300			47
35E	02-277	F	65271	380	7.5	38	5.5	41	38	2.3	1.0	.33		.16		350		1300	1200	78107	
30G	01-277	F	65271	409	7.0	39	4.6	32	39	2.2	1.0	.37	.13	.12		380	1200	1300			47
27D	02-267	F	65239	390	10.6	41	4.1	43	40	2.2	.98	.19		.035		190		570	560	78235	
27A	03-266	M	65238	389	9.1	43	4.0	36	41	1.9	.87	.18		.047	070	180		600	530	75248	
26G	02-266	F	65238	391	7.0	46	3.3	23	42	1.9	.86	.19	.041	.035		180	560	580			47
23E	01-265	M	65237	416	7.8	45	3.3	26	43	1.7	.79	.29		.057	.16	270		890	610	71293	
24B	03-265	M	65237	398	8.2	42	4.0	33	44	1.6	.55	.24	.085	.074		220	790	830			47
37F	01-282	F	65300	400	8.1	44	3.3	30	45	1.1	.48	.19		.058	.070	190		660	600	77034	
24A	02-265	M	65237	398	8.0	40	4.2	34	46	1.0	.47	.17	.041	.038		170	530	540			47
30E	01-276	M	65270	408	8.1	47	2.8	23	47	1.0	.46	.17		.033		180		530	430	74016	
30F	02-276	F	65270	408	10.4	48	2.6	27	48	0.97	.43	.13		.031		140		430	420	78228	
19A	01-254	M	65203	406	8.7	C	0	0	C	0										73021	
21C	02-254	F	65203	398	8.5	C	0	0	C	0										78057	

1061 020

A3.1 TOXICITY OF INHALED 90-SRCL2 IN BEAGLE DOGS

I.B.B.			L.T.R.B.		RADIATION DOSE TO SKELETON: RATE (RADS/DAY)					CUMULATIVE (RADS)					DAYS		
RNK	UCI/KG	UCI	RNK	UCI/KG	INITIAL	730 DAYS	9-30 1978	POTENT.TO 5000 D	AT DEATH	730 DAYS	9-30 1978	POTENT.TO 5000 D	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
1	280	2700	1	120	55	21		7.0	21	18000		73000+	19000	69143		759	E-FIBROSARCOMA PELVIS
9	210	1900	2	190	54			1.3	24			52000+	17000	68344		585	D-EPILEPTIC SEIZURES
6	240	2400	3	120	54	16		5.3	15	14000		55000+	17000	69311		927	E-HEMANGIOSARC.-UNDETERM.SITE
3	270	2500	4	110	48				30				810	67296		21	D-HEMATOLOGICAL DYSCRASIA
[illegible]	260	2600	5	100	48				34				1100	67303		28	D-HEMATOLOGICAL DYSCRASIA
2	270	3000	6	100	47	21		3.7	20	18000		61000+	22000	69279		886	E-OSTEOCHONDROFIBROSARC. ILIUM
5	240	2200	7	100	47				36				1300	67146		31	E-HEMATOLOGICAL DYSCRASIA
8	220	2200	8	98	45				29				660	67135		18	E-HEMATOLOGICAL DYSCRASIA
7	230	2200	9	97	44	18		6.2	17	15000		62000+	17000	69255		864	E-SEE NOTE AT END
11	160	1500	10	83	37	15		5.7	14	13000		54000+	18000	682[illegible]		1099	E-OSTEOCHONDROSARCOMA RIBS
10	180	2000	11	74	34				25				850	67146		29	D-HEMATOLOGICAL DYSCRASIA
12	160	1700	12	69	31	7.5		3.2	6.8	7000		28000+	9900	70163		1142	E-HEMANGIOSARCOMA HUMERUS
17	110	880	13	59	27	8.1		2.3	5.9	7600		27000+	15000	70169		1787	E-OSTEOSARCOMA HUMERUS
15	120	940	14	52	24	9.0		3.7	6.4	8900		33000+	18000	70343		1938	E-SEE NOTE AT END
19	99	820	15	51	25	6.6		1.9	5.4	6400		22000+	10000	69023		1361	D-CEREBELLAR HEMORRHAGE
18	110	890	16	50	26	8.6		4.5	8.0	7900		35000+	10000	68074		1046	E-HEMANGIOSARCOMA PELVIS
13	130	1500	17	50	23	9.5		2.3		8800		32000+	17000	71363		1702	E-OSTEOCHONDROSARCOMA MAXILLA
21	93	620	18	44	20	4.7		1.5	2.4	4700		16000+	13000	74044		3122	E-OSTEOSARCOMA VERTEBRAE
14	120	940	19	41	19	6.4		2.4	5.3	6400		23000+	10000	69173		1404	D-FIBROSARCOMA SACRUM
23	84	540	20	40	18	3.8		1.3	2.1	3900		14000+	10000	73243		2964	D-OSTEOSARCOMA MAXILLA
16	120	1100	21	34	16	6.2		2.6	5.1	5900		23000+	10000	69287		1540	E-OSTEOSARCOMA MAXILLA
22	87	680	22	28	13	3.3		1.4	1.[illegible]	3300		12000+	9500	74151		3237	D-OSTEOGENIC SARCOMA MANDIBLE
20	98	1000	23	28	12	6.1		[illegible].5	3.5	6100		20000+	13000	71258		2247	E-HEMANGIOSARCOMA RIB
24	71	620	25	27	12	3.4		1.3	2.1	3500		12000+	8500	72279		2633	E-OSTEOSARCOMA SKULL
28	27	170	25	9.6	4.4	1.5		.61	.68	1500	4900	56000+	4900	76278		3994	E-PULMONARY FIBROSIS
26	30	230	26	9.3	4.3	1.4		.56	.84	1500		5100+	3300	72136		2436	D-MYELO-MONOCYTIC LEUKEMIA
29	27	230	27	9.1	4.2	4.2	.36	.35		1100	3600	3700			4720		
27	29	190	28	8.9	4.0	.81	.28	.25		840	2700	2800			4720		
32	19	160	29	8.3	3.7	1.1		.33		1200		3900	3800	77327		4453	E-SEE NOTE AT END
35	17	140	30	7.9	3.6	.90	.33	.30		950	3100	3200			4764		
30	25	200	31	7.7	3.6	1.1	.32	.30		1100	3600	3700			4719		
25	32	230	32	7.1	3.2	1.0		.30	.50	1100		3500+	2800	74046		3077	E-MYXOSARCOMA SKULL
36	16	150	33	6.8	3.1	.88	.33	.31		930	2900	3100			4812		
31	23	200	34	6.6	3.0	.91		.28	.39	930		3200+		76114		3874	E-HEMANGIOSARCOMA HEART
33	19	170	35	6.1	2.8	.83		.28	.33	830		3000+	[illegible]	76211		3926	D-MALABSORPTION SYNDROME
34	17	120	36	5.7	2.6	.59	.20	.19		670	2000	2100			4719		
37	6.6	59	37	3.2	1.5	.41	.09	.077		410	1200	1300			4783		
38	5.5	41	38	2.3	1.0	.33		.16		350		1300	1200	78107		4584	D-CONG.HEART FAIL.: PUL. EDEMA
39	4.6	32	39	2.2	1.0	.37	.13	.12		380	1200	1300			4750		
41	4.1	43	40	2.2	.98	.19		.035		190		570	560	78235		4744	E-MALIGNANT EPENDYMOMA
43	4.0	36	41	1.9	.87	.18		.047	.070	180		600	530	75248		3662	E-MALABSORPTION SYNDROME
46	3.3	23	42	1.9	.86	.19	.041	.035		180	560	580			4783		
45	3.3	26	43	1.7	.79	.29		.057	.16	270		890	610	71293		2247	D-BRONCHO PNEUMONIA
42	4.0	33	44	1.6	.55	.24	.085	.074		220	790	830			4784		
44	3.3	30	45	1.[illegible]	.48	.19		.058	.070	190		660	600	77034		4117	E-BRONCHIOLO ALVEOLAR CARC.
40	4.2	34	46	1.0	.47	.17	.041	.038		170	530	540			4784		
47	2.8	23	47	1.0	.46	.17		.033		180		530	430	74016		3033	D-SEE NOTE AT END
48	2.6	27	48	0.97	.43	.13		.031		140		430	420	78228		4706	E-DISSEM. MAMMARY CARCINOMA
C	0	0	C	0										73021		2740	D-GLOMERULONEPHRITIS & PNEUM.
C	0	0	C	0										78057		4602	D-HEART FAILURE

1061 021

NUMBER TT00	NUMBER RADBIO	INHALATION EXP SEX	INHALATION EXP DATE	INHALATION EXP AGE DAYS	INHALATION EXP WT KG	I.B.B. RNK	I.B.B. UCI/KG	I.B.B. UCI	L.T.R.B. RNK	L.T.R.B. UCI/KG	RADIATION DOSE TO SKELETON RATE (RADS/DAY) INITIAL	RATE 730 DAYS	RATE 9-30 1978	RATE POTENT.AT 5000 D	RATE AT DEATH	CUMULATIVE (RADS) 730 DAYS	CUMULATIVE 9-30 1978	CUMULATIVE POTENT.TO 5000 D	CUMULATIVE TO DEATH	DEATH DATE	DAYS 9-30 1978	DAYS DEATH
24E	01-264	F	65232	393	8.6	C	0	0	C	0										77357		4508
26E	02-264	F	65232	385	6.9	C	0	0	C	0											4789	
28A	01-273	M	65258	408	9.1	C	0	0	C	0											4763	
30A	03-273	M	65258	396	9.5	C	0	0	C	0										75045		3439
31A	01-278	M	65272	400	9.1	C	0	0	C	0										74008		3023
32A	02-278	M	65272	394	8.9	C	0	0	C	0										77125		4236
33B	03-278	M	65272	[illegible]	8.9	C	0	0	C	0											4749	
35F	01-285	F	65305	414	8.1	C	0	0	C	0										74030		3012
40D	02-285	F	65305	387	9.4	C	0	0	C	0										75307		3654
42C	03-285	F	65305	380	10.3	C	0	0	C	0											4716	
158A	01-420	M	67115	438	10.2	C	0	0	C	0											4176	
160A	02-420	M	67117	437	9.9	C	0	0	C	0											4174	
162E	03-420	F	67122	436	10.2	C	0	0	C	0											4169	

UCI/KG: KG REFERS TO TOTAL BODY WEIGHT.
DOSE RATE: DAYS REFERS TO DAYS AFTER 90SRCL2 INHALATION.
COMMENT: D,E,OR S: DIED,EUTHANIZED,OR SACRIFICED WITH THE MOST PROMINENT FEATURES ASSOCIATED WITH DEATH.
+ DIED BEFORE POTENTIAL INFINITE DOSE RECEIVED.

NOTES:

DOG 160B: E-OSTEOSARCOMA RIBS; HEMANGIOSARCOMA SCAPULA
DOG 26F: E-OSTEOSARCOMA VERTEBRA; HEMANGIOSARCOMA RIB, MANDIBLE
DOG 30C: E-HISTIOCYTIC LYMPHOMA - CUTANEOUS
DOG 30E: D-TRANSITIONAL CELL CARCINOMA URINARY BLADDER
DOG 30A: E-EPIDERMAL CYST SKULL; ENCEPHALOMALACIA
DOG 31A: D-ARTERIOSCLEROSIS; MYOCARDIAL INFARCTS; HYPOTHRYROIDISM

(DATA ARE FROM LF-60, 1978 AND REPRESENT AN UPDATE OF DATA FROM B.A. MUGGENBURG ET AL., 1978.) SEE REFERENCE #40

			RADIATION DOSE TO SKELETON												
	L.T.R.B.			RATE (RADS/DAY)				CUMULATIVE (RADS)					DAYS		
UCI	RNK	UCI/KG	INITIAL	730 DAYS	9-30 1978	POTENT. AT 5000 D	AT DEATH	730 DAYS	9-30 1978	POTENT. TO 5000 D	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
0	C	0										77357		4508	E-MAM.ADENOCARC. THYROID CARC.
0	C	0											4789		
0	C	0											4763		
0	C	0										75045		3439	E-SEE NOTE AT END
0	C	0										74008		3023	D-SEE NOTE AT END
0	C	0										77125		4236	E-LYMPHOMA
0	C	0											4749		
0	C	0										74030		3012	D-ASPIRATION PNEUMONIA
0	C	0										75307		3034	D-MAMMARY ADENOCARCINOMA
0	C	0											4716		
0	C	0											4176		
0	C	0											4174		
0	C	0											4169		

ALATION.
D WITH THE MOST PROMINENT

CAPULA
A RIB, MANDIBLE

LADDER
A
S HYPOTHRYROIDISM

E OF DATA FROM

POOR ORIGINAL

A3.2 TOXICITY OF INHALED 144-CECL3 IN BEAGLE DOGS

NUMBER		INHALATION EXP.					L.T.R.B.		I.B.B.	RADIATION DOSE TO TISSUE: LUNG CUMULATIVE (RADS)				LIVER CUMULATIVE (RADS)				SKELETON CUMULATIVE (RADS)					D
TTOO	RADBIO	SEX	DATE	AGE DAYS	WT KG	RNK	UCI KG	UCI	UCI KG	365 DAYS	730 DAYS	TOTAL	TO DEATH	365 DAYS	730 DAYS	TOTAL	TO DEATH	365 DAYS	730 DAYS	TOTAL	TO DEATH	DEATH DATE	9-30 1978
152C	02-407	F	67094	428	8.3	1	360	2900	740			21000+	21000			24000+	24000			7000+	7000	67238	
156B	03-408	M	67096	418	8.6	2	320	2800	520			7400+	7400			3200+	3200			960+	960	67117	
151B	01-407	M	67094	431	9.8	3	270	2700	460			7600+	7600			4100+	4100			1200+	1200	67125	
156D	01-408	F	67096	418	10.0	4	210	2100	420			4800+	4800			2100+	2100			610+	610	67118	
198E	01-457	F	67278	392	8.6	5	210	1800	400	17000		17000+	17000	28000		28000+	28000	8200		8400+	8400	68288	
151C	03-407	F	67094	431	10.0	6	190	1900	380			5200+	5200			3000+	3000			860+	860	67125	
197D	02-458	F	67279	393	9.0	7	190	1700	360			5200+	5200			3000+	3000			860+	860	67311	
199A	02-462	M	67285	397	8.5	8	190	1600	340			6400+	6400			4400+	4400			1300+	1300	67329	
201G	02-463	F	67290	385	8.3	9	170	1400	310			4400+	4400			2200+	2200			650+	650	6731[illegible]	
153A	02-408	M	67096	430	10.3	10	150	1500	290			8600+	86[illegible]			9600+	9600			2900+	2900	67234	
195A	01-458	M	67279	401	10.0	11	150	1500	240			12000+	12000			19000+	19000			5600+	5600	68250	
198A	01-462	M	67285	399	8.5	12	140	1200	310	11000	12000	12000+	12000	18000	26000	27000+	27000	5500	7800	8100+	8100	69353	
203F	03-463	F	67290	377	6.3	13	140	870	360			4200+	4200			2500+	[illegible]			740+	740	67326	
197C	03-462	M	67285	399	8.3	14	150	1100	260			9800+	9800			16000+	16000			4600+	4600	68229	
200A	02-460	M	67283	390	10.2	15	120	1300	190	9500		10000+	10000	16000		19000+	19000	4900		5800+	5800	69062	
199E	01-460	F	67283	395	7.5	16	110	[illegible]	330	8700	9700	9900	9900	15000	20000	24000	24000	4300	6200	7400	7400	72265	
62F	02-322	F	66082	388	9.6	17	100	960	200	7900	8800	8800+	8800	13000	19000	20000+	20000	3900	5600	6000+	6000	68226	
201C	03-460	M	67283	378	8.8	18	94	830	280	7400	8300	8500	8500	12000	17000	21000	21000	3700	5300	6300	6300	72216	
64A	01-326	M	66096	391	9.0	19	74	660	220	5800	6500	6700	6700	9800	14000	16000	16000	2900	4100	5000	5000	72069	
60B	01-320	F	66075	402	8.6	20	69	590	130	5500	6100	6200	6200	9100	13000	15000	15000	2700	3900	4600	4600	70246	
200E	01-463	F	67290	397	8.3	21	68	560	250	5400	6000	6100	6100	9000	13000	15000	15000	2700	3800	4600	4600	72247	
62E	01-322	M	66082	388	8.1	22	67	540	130	5300	5900	6000	6000	8800	12000	15000	15000	2600	3800	4500	4500	70356	
64C	03-323	F	66084	379	9.3	23	55	520	140	4300	4800	5000	5000	7300	10000	12000	12000	2100	3100	3700	3700	71064	
62B	02-321	M	66080	386	9.9	24	51	500	110	4000	4500	4600	4600	6700	9400	11000	11000	2000	2900	3400	3400	72356	
63C	02-323	F	66084	385	6.8	25	44	300	170	3500	3900	3900	3900	5800	8100	9700	9700	1700	2900	2900	2900	78041	
66B	03-326	M	66096	385	8.8	26	43	380	120	3400	3900	3900	3900	5700	8000	9500	9500	1700	2900	2900	2900	73312	
65B	02-326	M	66096	386	10.9	27	39	430	110	3100	3400	3500	3500	5100	7200	8600	8600	1500	2200	2600	2600	73151	
61B	01-321	M	66080	397	9.5	28	31	300	68	2400	2700	2800	2800	4100	5700	6800	6800	1200	2100	2100	2100	75287	
60C	02-320	F	66075	402	10.2	29	28	280	130	2200	2500	2500	2500	3700	5200	6200	6200	1100	1900	1900	1900	75093	
63B	01-323	M	66084	383	8.1	30	26	210	130	2100	2300	2300		3400	4800	5700		1000	1700	1700			4572
54A	01-305	M	66027	407	10.2	31	25	250	43	2000	2200	2300		3300	4600	5500		980	1700	1700			[illegible]
54B	02-305	F	66027	407	11.6	32	24	280	43	1900	2100	2200	2200	3200	4400	5300	5300	940	1600	1600	1600	76351	
52D	01-302	F	66025	410	7.7	33	21	170	43	1700	1800	1900		2800	3900	4600		820	1400	1400			4631
55D	02-306	F	66028	407	8.7	34	17	150	45	1300	1500	1500	1500	2200	3100	3700	3700	660	1100	1100	1100	[illegible]	
60D	03-320	F	66075	402	8.8	35	16	140	150	1300	1400	1400	1400	2100	3000	3500	620	620	1100	1100	[illegible]		
57A	02-308	M	66034	392	8.2	36	15	130	34	1200	1300	1400	1400	2000	2800	3300	3300	590	840	1000	[illegible]		
53B	02-301	F	66024	404	11.0	37	14	150	42	1100	1200	1300	1300	1800	2600	3100	3100	550	940	940	[illegible]		
53C	02-302	F	66025	405	9.0	38	14	130	42	1100	1200	1300	1300	1900	2600	3100	3100	550	780	940	940	[illegible]	
56B	01-308	M	66034	402	10.9	39	14	150	34	1100	1200	1300	1300	1900	2600	3100	3100	550	780	940	940	71019	
52C	01-301	F	66024	409	9.0	40	13	120	44	1000	1100	1200	1200	1700	2400	2900	2900	510	730	870	870	75298	
55A	01-306	M	66028	407	10.8	41	12	130	33	950	1100	1100	[illegible]	1600	2200	2600	2600	470	670	800	800	76070	
57C	02-309	M	66035	393	8.2	42	12	95	24	950	1100	1100	1100	1600	2200	2600	2600	470	670	800	800	77102	
51B	01-299	M	66021	408	8.4	43	8.1	68	14	640	710	730		1100	1500	1800		320	450	540			463[illegible]
57B	01-309	M	66035	393	9.3	44	6.9	64	30	550	610	620		910	1300	1500		270	390	460			4621
50E	03-297	F	66018	411	8.1	45	6.3	51	12	500	550	570	570	830	1200	1400	1400	250	350	420	420	74213	
50A	01-297	M	66018	411	8.0	46	6.2	50	13	490	550	560	560	820	1200	1400	1400	240	350	420	420	74031	
49A	01-294	M	66013	407	9.9	47	5.5	55	11	430	480	500	500	730	1000	1200	1200	220	310	370	370	78012	
52B	02-299	M	66021	406	10.9	48	5.2	56	10	410	460	470		690	960	1100		200	290	350			4635
49B	02-[illegible]	M	66013	407	8.8	49	4.9	43	13	390	430	440		650	910	1100		190	270	330			4643
49D	0[illegible]295	F	66014	408	10.9	50	4.7	52	11	370	410	420		620	870	1000		180	260	310			4642

1061 024

A3.2 TOXICITY OF INHALED 144-CECL3 IN BEAGLE DOGS

L.T.R.B.		I.B.B.	RADIATION DOSE TO TISSUE: LUNG CUMULATIVE (RADS)				LIVER CUMULATIVE (RADS)				SKELETON CUMULATIVE (RADS)					DAYS		
UCI KG	UCI	UCI KG	365 DAYS	730 DAYS	TOTAL	TO DEATH	365 DAYS	730 DAYS	TOTAL	TO DEATH	365 DAYS	730 DAYS	TOTAL	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
360	2900	740			21000+	21000			24000+	24000			7000+	7000	67238		144	D-PULMONARY INJURY
320	2800	520			7400+	7400			3200+	3200			960+	960	67117		21	E-HEMATOLOGICAL DYSCRASIA
270	2700	460			7600+	7600			4100+	4100			1200+	1200	67125		31	E-HEMATOLOGICAL DYSCRASIA
210	2100	420			4800+	4800			2100+	2100			610+	610	67118		22	E-HEMATOLOGICAL DYSCRASIA
210	1800	400	17000		17000+	17000	28000		28000+	28000	8200		8400+	8400	68288		375	D-PULMONARY FIBROSIS
190	1900	380			5200+	5200			3000+	3000			860+	860	67125		31	E-HEMATOLOGICAL DYSCRASIA
190	1700	360			5200+	5200			3000+	3000			860+	860	67311		32	D-HEMATOLOGICAL DYSCRASIA
190	1600	340			6400+	6400			4400+	4400			1300+	1300	67329		44	D-HEMATOLOGICAL DYSCRASIA
170	1400	310			4400+	4400			2200+	2200			650+	650	67317		27	D-HEMATOLOGICAL DYSCRASIA
160	1500	280			8600+	8600			9600+	9600			2900+	2900	67234		138	D-PULMONARY INJURY
150	1500	240			12000+	12000			19000+	19000			5600+	5600	68250		336	D-HEPATIC INJURY
140	1200	310	11000	12000	12000+	12000	18000	26000	27000+	27000	5500	7800	8100+	8100	69353		799	E-OSTEOSARCOMA VERTEBRA
140	870	360			4200+	4200			2500+	2500			740+	740	67326		36	D-HEMATOLOGICAL DYSCRASIA
130	1100	260			9800+	9800			16000+	16000			4600+	4600	68229		309	D-HEPATIC INJURY
120	1300	190	9500		10000+	10000	16000		19000+	19000	4900		5800+	5800	69062		510	D-MARROW APLASIA
110	810	330	8700	9700	9900	9900	15000	20000	24000	24000	4300	6200	7400	7400	72265		1808	D-HEMANGIOSARCOMA LIVER
100	960	200	7900	8800	8600+	8800	13000	19000	20000+	20000	3900	5600	6000+	6000	68226		874	D-HEPATIC INJURY
94	830	280	7400	8300	8500	8500	12000	17000	21000	21000	3700	5300	6300	6300	72216		1759	E-HEMANGIOSARCOMA LIVER
74	660	220	5800	6500	6700	6700	9800	14000	16000	16000	2900	4100	5000	5000	72069		2164	E-SQUAMOUS CARCINOMA NASAL CAVITY
69	590	130	5500	6100	6200	6200	9100	13000	15000	15000	2700	3900	4600	4600	70246		1632	E-SEE NOTE AT END
68	560	250	5400	6000	6100	6100	9000	13000	15000	15000	2700	3800	4600	4600	72247		1783	D-HEMANGIOSARCOMA LIVER
67	540	130	5300	5900	6000	6000	8800	12000	15000	15000	2600	3800	4500	4500	70356		1735	D-HEMANGIOSARCOMA LIVER; HEPATIC FIBROMA
55	520	140	4300	4800	5000	5000	7300	10000	12000	12000	2100	3100	3700	3700	71064		1806	E-MYELOGENOUS LEUKEMIA
51	500	110	4000	4500	4600	4600	6700	9400	11000	11000	2000	2900	3400	3400	72356		2467	D-HEMANGIOSARCOMA LIVER
44	300	170	3500	3900	3900	3900	5800	8100	9700	9700	1700	2900	2900	2900	78041		4340	E-BILE DUCT ADENOMA; ATYPICAL
43	380	120	3400	3900	3900	3900	5700	8000	9500	9500	1700	2900	2900	2900	73312		2773	E-SEE NOTE AT END
39	430	110	3100	3400	3500	3500	5100	7200	8600	8600	1500	2200	2600	2600	73151		2612	E-HEMANGIOSARCOMA NASAL CAVITY
31	300	68	2400	2700	2800	2800	4100	5700	6800	6800	1200	2100	2100	2100	75287		3494	D-SQUAMOUS CELL CARCINOMA NASAL CAVITY
28	280	130	2200	2500	2500	2500	3700	5200	6200	6200	1100	1900	1900	1900	75093		3305	E-MALIGNANT MELANOMA; EPENDYMOMA
26	210	130	2100	2300	2300		3400	4800	5700		1000	1700	1700			4572		
25	250	43	2000	2200	2300		3300	4600	5500		980	1700	1700			4629		
24	280	43	1900	2100	2200	2200	3200	4400	5300	5300	940	1600	1600	1600	76351		3976	E-MAMMARY CARCINOMA
21	170	43	1700	1800	1900		2800	3900	4600		820	1400	1400			4631		
17	150	45	1300	1500	1500	1500	2200	3100	3700	3700	660	1100	1100	1100	77062		4052	E-SEE NOTE AT END
16	140	150	1300	1400	1400	1400	2100	3000	3500	620	620	1100	1100	1100	77251		419[illegible]	E-HEMANGIOSARCOMA-LIVER; LUNG
15	130	34	1200	1300	1400	1400	2000	2800	3300	3300	590	840	1000	1000	71034		182[illegible]	E-MYELOPROLIFERATIVE DISORDER
14	150	42	1100	1200	1300	1300	1800	2600	3100	3100	550	940	940	940	77064		4058	D-CONGESTIVE HEART FAILURE
14	130	42	1100	1200	1300	1300	1900	2600	3100	3100	550	780	940	940	78116		4474	E-MULTIPLE MAMMARY CARCINOMA
14	150	34	1100	1200	1300	1300	1900	2600	3100	3100	550	780	940	940	71019		1811	D-MYELOGENOUS LEUKEMIA
13	120	44	1000	1100	1200	1200	1700	2400	2900	2900	510	730	870	870	75298		3561	D-MAMMARY ADENOCARCINOMA
12	130	33	950	1100	1100	1100	1600	2200	2600	2600	470	670	800	800	76070		3694	E-BROCHOGENIC ADENOCARCINOMA
12	95	24	950	1100	1100	1100	1600	2200	2600	2600	470	670	800	800	77102		4085	E-SEE NOTE AT END
8.1	68	14	640	710	730		1100	1500	1800		320	450	540			4635		
6.9	64	30	550	610	620		910	1300	1500		270	390	460			4621		
6.3	51	12	500	550	570	570	830	1200	1400	1400	250	350	420	420	74213		3117	D-HEPATIC LIPIDOSIS & DEGENERATION
6.2	50	13	490	550	560	560	820	1200	1400	1400	240	350	420	420	74031		2935	D-EPENDYMOMA; CNS
5.5	55	11	430	480	500	500	730	1000	1200	1200	220	310	370	370	78012		4382	D-MALIGNANT MELANOMA; SOFT PALATE
5.2	56	10	410	460	470		690	960	1100		200	290	350			4635		
4.9	43	13	39[illegible]	430	440		650	910	1100		190	270	330			4643		
4.7	52	11	37[illegible]	410	420		620	870	1000		180	260	310			4642		

1061 025

A3.2 TOXICITY OF INHALED 144-CECL3 IN BEAGLE DOGS (CONT'D).

NUMBER TTOO	NUMBER RADBIO	INHALATION EXP. SEX	INHALATION EXP. DATE	INHALATION EXP. AGE DAYS	INHALATION EXP. WT KG	RNK	L.T.R.B. UCI/KG	L.T.R.B. UCI	I.B.B. UCI/KG	LUNG CUMULATIVE (RADS) 365 DAYS	LUNG 730 DAYS	LUNG TOTAL	LUNG TO DEATH	LIVER CUMULATIVE (RADS) 365 DAYS	LIVER 730 DAYS	LIVER TOTAL	LIVER TO DEATH	SKELETON CUMULATIVE (RADS) 365 DAYS	SKELETON 730 DAYS	SKELETON TOTAL	SKELETON TO DEATH	DEATH DATE	DAYS 9-30 1978	DAYS DEATH
50F	01-298	F	66020	413	8.3	51	4.2	35	13	330	370	380	380	550	780	920	920	160	240	280	280	74038		2940
49E	02-295	F	66014	408	9.1	52	3.9	36	15	310	340	350	350	520	720	860	860	150	220	260	260	75213		3486
51A	02-298	M	66020	407	11.1	53	3.6	40	8.6	280	320	320	320	480	670	790	790	140	200	240	240	74309		3211
50D	02-297	F	66018	411	6.9	54	2.9	20	13	230	260	260	260	380	540	6[illegible]0	640	110	160	190	190	76358		3992
49G	01-296	F	66017	411	8.4	55	2.6	[illegible]	7.5	210	230	230		340	480	570		100	150	170			4639	
49C	01-300	M	66013	407	8.7	C	0	0	0													74156		3065
50C	02-300	F	66017	414	9.1	C	0	0	0														4639	
51C	03-300	M	66021	408	10.4	C	0	0	0													76103		3734
51E	04-300	F	66021	408	8.4	C	0	0	0														4635	
52A	05-300	M	66021	405	8.5	C	0	0	0													76189		3820
53A	01-310	F	66024	415	9.3	C	0	0	0														4632	
53D	02-310	F	66024	415	8.1	C	0	0	0													78073		4432
54C	03-310	F	66027	415	9.2	C	0	0	0														4629	
56A	04-310	M	66034	403	11.8	C	0	0	0														4622	
60A	01-327	F	66075	423	10.1	C	0	0	0														4581	
61C	02-327	F	66080	413	10.0	C	0	0	0														4576	
62A	03-327	M	66080	402	13.2	C	0	0	0													73068		2545
153D	01-412	F	67094	437	9.3	C	0	0	0													67243		149
156E	02-412	F	67094	425	6.7	C	0	0	0													67243		149
197B	01-465	M	67289	410	9.0	C	0	0	0														4002	
198C	02-465	F	67289	410	9.0	C	0	0	0														4002	
201A	03-465	M	67289	391	12.6	C	0	0	0														4002	

UCI/KG: KG REFERS TO TOTAL BODY WEIGHT.
DOSE RATE: DAYS REFER TO DAYS AFTER INHALATION EXPOSURE.
COMMENT: D,E,OR S: DIED,EUTHANIZED,OR SACRIFICED WITH THE MOST PROMINENT FEATURES ASSOCIATED WITH DEATH.
+ DIED BEFORE POTENTIAL INFINITE DOSE RECEIVED.

NOTES:

DOG 60B: E-SQUAMOUS CARCINOMA NASAL CAVITY; PULMONARY ADENOMA
DOG 66B: E-SQUAMOUS CELL CARCINOMA NASAL CAVITY; BRONCHOGENIC ADENOCARCINOMA
DOG 55D: E-INTERVERTEBRAL DISC DISEASE; THYROID AND ADRENAL CARCINOMA
DOG 57C: E-SQUAMOUS CELL CARCINOMA-NASAL AND SINUSOIDAL CAVITY
DOG 49A: D-MALIGNANT MELONOMA; SOFT PALATE
DOG 50D: D-CONGESTIVE HEART FAILURE; CHRONIC INTERSTITIAL NEPHRITIS

(DATA ARE FROM LF-60, 1978 AND REPRESENT AN UPDATE OF DATA FROM B.S. MERICKEL ET AL., 1978.) SEE REFERENCE #35

A3.2 TOXICITY OF INHALED 144-CECL3 IN BEAGLE DOGS (CONT'D).

.B. UCI	I.B.B. UCI KG	LUNG 365 DAYS	LUNG 730 DAYS	LUNG TOTAL	LUNG TO DEATH	LIVER 365 DAYS	LIVER 730 DAYS	LIVER TOTAL	LIVER TO DEATH	SKELETON 365 DAYS	SKELETON 730 DAYS	SKELETON TOTAL	SKELETON TO DEATH	DEATH DATE	DAYS 9-30 1978	DAYS DEATH	COMMENT
35	13	330	370	380	380	550	780	920	920	160	240	280	280	74038		2940	D-MYELOMALACIA
36	10	310	340	350	350	520	720	860	860	150	220	260	260	75213		3486	D-PULMONARY EDEMA
40	8.6	280	320	320	320	480	670	790	790	140	200	240	240	74309		3211	D-CONGESTIVE HEART FAILURE
20	13	230	260	260	260	380	540	640	640	110	160	190	190	76358		3992	D-SEE NOTE AT END
22	7.5	210	230	230		340	480	570		100	150	170			4639		
0	0													74156		3065	D-ASPIRATION PNEUMONIA
0	0														4639		
0	0													76103		3734	D-ACCIDENTAL DEATH
0	0														4635		
0	0													76189		3820	D-RENAL AMYLOIDOSIS; UREMIA
0	0														4632		
0	0													78073		4432	E-SPINAL CORD DEGENERATON; L3-L5
0	0														4629		
0	0														4622		
0	0														4581		
0	0														4576		
0	0													73068		2545	E-THYROID CARCINOMA
0	0													67243		149	S-
0	0													67243		149	S-
0	0														4002		
0	0														4002		
0	0														4002		

EXPOSURE.
CED WITH THE MOST PROMINENT

ULMONARY ADENOMA
Y: BRONCHOGENIC ADENOCARCINOMA
D AND ADRENAL CARCINOMA
INUSOIDAL CAVITY

NTERSTITIAL NEPHRITIS

ATE OF DATA FROM

POOR ORIGINAL

1061 027

A3.3 TOXICITY OF INHALED 91-YCL3 IN BE[illegible] DOGS

NUMBER TTOO	NUMBER RADBIO	INHALATION EXP SEX	INHALATION EXP DATE	INHALATION EXP AGE DAYS	WT KG	I.L.B. RNK	I.L.B. UCI KG	I.B.B. UCI	I.B.B. UCI KG	LUNG CUMULATIVE RADS 30 DAYS	LUNG 120 DAYS	LUNG TOTAL	LUNG TO DEATH	LIVER CUMULATIVE RADS 30 DAYS	LIVER 120 DAYS	LIVER TOTAL	LIVER TO DEATH	SKELETON CUMULATIVE RADS 30 DAYS	SKELETON 120 DAYS	SKELETON TOTAL	SKELETON TO DEATH	DEATH DATE
118E	02-380	F	66320	415	9.3	1	540	5100	1300			+	4300			+	340			+	910	66332
122C	01-383	M	66333	410	9.8	2	300	3000	750			+	2800			+	300			+	800	66353
118F	01-382	F	66326	419	8.0	3	290	2300	780			+	2500			+	250			+	670	66343
119C	01-384	F	66335	423	8.2	4	250	2100	550			+	2400			+	270			+	730	66357
164B	01-423	M	67146	409	9.5	5	250	2300	430			+	2400			+	270			+	730	67168
119D	02-382	F	66326	414	6.5	6	240	1600	720			+	2500			+	320			+	860	66354
123A	02-383	M	66333	409	11.0	7	240	2600	890			+	2300			+	250			+	670	66354
118A	01-381	M	66322	415	8.1	8	220	1800	550	2400	3000	3300	3300	310	810	1000	1000	840	2100	2900	2900	72143
119A	03-381	M	66322	409	8.3	9	220	1800	550	2400	3000	3500		310	810	1000		840	2100	2900		
118D	02-381	F	66322	415	8.6	10	200	1800	510	2200	2800	3100		280	700	970		760	1900	2600		
120C	02-384	F	66335	420	9.3	11	200	1900	630			+	2000			+	230			+	600	66358
164F	02-423	F	67146	409	9.0	12	200	1800	450			+	2000			+	230			+	620	67170
165A	01-426	M	67153	392	11.0	13	160	1700	540	1800	2300	2400		230	590	760		610	1500	2100		
171F	02-434	F	67163	391	6.3	14	160	1000	710	1800	2300	2400	2400	230	590	760	760	610	1500	2100	2100	74173
169C	01-434	M	67163	397	8.7	15	150	1300	460	1700	2200	2300	2300	210	540	700	700	570	1400	2000	2000	77202
118B	01-380	M	66320	413	7.9	16	140	1100	340	1500	1900	2000		190	510	650	650	530	1300	1800	1800	78261
120A	02-384	M	66335	420	10.6	17	130	1400	550	1400	1800	2000		180	470	590	590	490	1200	1700	1700	78038
164C	03-422	M	67144	407	9.3	18	110	1100	280	1200	1500	1700	1700	160	400	520	520	420	1100	1400	1400	68252
169D	01-432	F	67159	393	5.9	19	100	610	140	1100	1400	1500		140	360	480		380	960	1300		
164G	01-425	F	67151	414	7.7	20	94	730	170	1000	1300	1400	1400	130	340	450	450	360	900	1200	1200	73217
174A	01-438	M	67172	385	9.6	21	92	880	190	1000	1300	1400		130	330	440		350	880	1200		
171B	02-435	M	67166	394	9.0	22	90	820	230	980	1300	1400		120	320	430		340	860	1200		
165F	03-426	F	67153	392	9.2	23	82	750	220	900	1100	1200		110	300	390		310	790	1100		
166E	02-426	F	67153	390	11.1	24	73	820	410	800	1000	1100		100	260	350		280	700	950		
172A	03-435	M	67166	385	8.8	25	68	600	180	740	950	1000		97	250	320		260	650	880		
134C	02-385	F	66354	408	9.9	26	66	650	230	720	930	1000	1000	92	240	310	310	250	630	860	860	76054
134A	01-385	M	66354	408	9.7	27	62	600	230	670	860	940		86	230	300		240	600	810		
176D	03-438	F	67172	384	9.2	28	60	550	250	660	840	910		86	220	290		230	580	780		
169A	01-435	M	67166	400	10.3	29	58	600	240	640	810	890	890	81	210	280	280	220	560	750	750	68165
172C	01-433	F	67160	379	7.1	30	53	380	120	580	740	810		76	190	250	250	200	510	690	690	78257
173G	02-433	F	67160	376	7.2	31	52	370	130	570	720	790		76	190	250		200	500	680		
174E	02-438	F	67172	385	8.7	32	51	450	200	560	710	770		70	180	240		190	490	660		
167B	01-431	M	67158	394	10.5	33	51	540	130	560	710	770		70	180	240		190	490	660		
171E	03-429	F	67156	384	6.4	34	48	310	140	520	670	740	740	65	170	230	230	180	460	620	620	77117
165G	02-422	F	67144	383	8.2	35	46	380	92	510	650	700		65	170	220	220	170	440	600	600	78223
169B	01-429	M	67156	390	9.9	36	44	440	80	480	610	670		59	160	210	210	170	420	570	570	78025
164D	01-422	M	67144	407	9.3	37	43	400	130	470	600	660		59	160	210		160	410	560		
176E	01-437	F	67170	382	6.8	38	41	280	150	440	570	620		59	150	190		160	390	530		
171A	02-429	M	67156	384	8.2	39	40	320	94	430	560	610		54	150	190		150	380	520		
166C	02-425	M	67151	388	11.0	40	31	350	64	340	430	470		4[illegible]	110	150		120	300	400		
174F	02-437	F	67170	381	6.2	41	16	97	85	180	230	240	240	23	59	76	76	61	150	210	210	74276
167C	04-426	M	67153	389	9.9	42	14	140	64	150	190	220		19	51	65		53	130	180		
118C	01-386	F	66320	447	10.2	C	0	0	0													
119B	02-386	M	66322	442	9.4	C	0	0	0													
121A	04-386	M	66335	435	9.4	C	0	0	0													
164E	01-430	F	67151	420	8.8	C	0	0	0													77203
165D	02-430	M	67151	396	11.4	C	0	0	0													
165E	03-430	F	67151	396	9.0	C	0	0	0													
166B	04-430	M	67153	394	10.3	C	0	0	0													
167A	01-441	M	67156	413	10.3	C	0	0	0													73205

RADIATION DOSE TO TISSUE

1061 028

A3.3 TOXICITY OF INHALED 91-YCL3 IN BEAGLE DOGS

	I.L.B.	I.B.B.	I.B.B.	RADIATION DOSE TO TISSUE: LUNG, CUMULATIVE RADS				LIVER, CUMULATIVE RADS				SKELETON, CUMULATIVE RADS					DAYS		
RNK	UCI/KG	UCI	UCI/KG	30 DAYS	120 DAYS	TOTAL	TO DEATH	30 DAYS	120 DAYS	TOTAL	TO DEATH	30 DAYS	120 DAYS	TOTAL	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
1	540	5100	1300			+	4300			+	340			+	410	66332		12	D-HEMATOLOGICAL DYSCRASIA
2	300	3000	750			+	2800			+	300			+	800	66353		20	D-HEMATOLOGICAL DYSCRASIA
3	290	2300	780			+	2500			+	250			+	670	66343		17	E-HEMATOLOGICAL DYSCRASIA
4	250	2100	550			+	2400			+	270			+	730	66357		22	D-HEMATOLOGICAL DYSCRASIA
5	250	2300	430			+	2400			+	270			+	730	67168		22	D-HEMATOLOGICAL DYSCRASIA
6	240	1600	720			+	2500			+	320			+	860	66354		28	D-HEMATOLOGICAL DYSCRASIA
7	240	2600	890			+	2300			+	250			+	670	66354		21	D-HEMATOLOGICAL DYSCRASIA
8	220	1800	550	2400	3000	3300	3300	310	810	1000	1000	840	2100	2900	2900	72143		2012	E-SQUAM.CELL CARC. NASAL CAVITY
9	220	1800	550	2400	3000	3300		310	810	1000		840	2100	2900			4334		
10	200	1800	510	2200	2800	3100		280	700	970		760	1900	2600			4334		
11	200	1900	630			+	2000			+	230			+	600	66358		23	E-HEMATOLOGICAL DYSCRASIA
12	200	1800	450			+	2909			+	230			+	620	67170		24	D-HEMATOLOGICAL DYSCRASIA
13	160	1700	540	1800	2300	2400		230	590	760		610	1500	2100			4138		
14	160	1000	710	1800	2300	2400	2400	230	590	760	760	610	1500	2100	2100	74173		2567	E-SQUAM.CEL. CARC. NASAL CAVITY
15	150	1300	460	1700	2200	2300	2300	210	540	700	700	570	1400	2000	2000	77202		3692	E-VISCERAL LYMPHOMA
16	140	1100	340	1500	1900	2000		190	510	650	650	530	1300	1800	1800	78261		4324	E-RIGHT HEART FAILURE
17	130	1400	550	1400	1800	2000		180	470	590	590	490	1200	1700	1700	78038		4086	E-NEPHROSCLEROSIS
18	110	1100	280	1200	1500	1700	1700	160	400	520	520	420	1100	1400	1400	68252		473	D-EPILEPTIC SEIZURE
19	100	610	140	1100	1400	1500		140	360	480		380	960	1300			4132		
20	94	730	170	1000	1300	1400	1400	130	340	450	450	360	900	1200	1200	73217		2258	D-MAST CELL SARCOMA
21	92	880	190	1000	1300	1400		130	330	440		350	880	1200			4119		
22	90	820	230	980	1300	1400		120	320	430		340	860	1200			4125		
23	82	750	220	900	1100	1200		110	300	390		310	790	1100			4138		
24	73	820	410	800	1000	1100		100	260	350		280	700	950			4138		
25	68	600	180	740	950	1000		97	250	320		260	650	880			4125		
26	66	650	230	720	930	1000	1000	92	240	310	310	250	630	860	860	76054		3352	E-SEE NOTE AT END
27	62	600	230	670	860	940		86	230	300		240	600	810			4302		
28	60	550	250	660	840	910		86	220	290		230	580	780			4119		
29	58	600	240	640	810	890	890	81	210	280	280	220	560	750	750	68165		364	D-EPILEPTIC SEIZURE
30	53	380	120	580	740	810		76	190	250	250	200	510	690	690	78257		4115	E-CHEMODECTOMA
31	52	370	130	570	720	790		76	190	250		200	500	680			4131		
32	51	450	200	560	710	770		70	180	240		190	490	660			4119		
33	51	540	130	560	710	770		70	180	240		190	490	660			4133		
34	48	310	140	520	670	740	740	65	170	230	230	180	460	620	620	77117		3614	D-DISSEMINATED MAMMARY CARCINOMA
35	46	380	92	510	650	700		65	170	220	220	170	440	600	600	78223		4097	E-AMELOANOTIC MELANOSARCOMA - MOUTH
36	44	440	80	480	610	670		59	160	210	210	170	420	570	570	78[illegible]25		3887	D-AUTOIMMUNE HEMOLYTIC ANEMIA
37	43	400	130	470	600	660		55	160	210		160	410	560			4147		
38	41	230	150	440	570	620		59	150	190		160	390	530			4121		
39	40	320	94	430	560	610		54	150	190		150	380	520			4135		
40	31	350	64	340	430	470		[illegible]	110	150		120	300	400			4140		
41	16	97	85	180	230	240	240	23	59	76	76	61	150	210	210	74276		266[illegible]	D-GLOMERULONEPHRITIS: RENAL FAIL.
42	14	140	64	150	190	220		19	51	65		53	130	180			4138		
C	0	0	0														[illegible]		
C	0	0	0														4334		
C	0	0	0														4321		
C	0	0	0													77203		3705	E-DISSEMINATED MAMMARY CARCINOMA
C	0	0	0														4140		
C	0	0	0														4140		
C	0	0	0														4138		
C	0	0	0													73205		2241	D-SUPPURATIVE PLEURITIS

1061 029

A3.3 TOXICITY OF INHALED 91-YCL3 IN BEAGLE DOGS (CONT'D).

NUMBER TTOO	NUMBER RADBIO	SEX	INHALATION EXP DATE	INHALATION EXP AGE DAYS	INHALATION EXP WT KG	I.L.B. RNK	I.L.B. UCI/KG	I.B.B. UCI	I.B.B. UCI/KG	LUNG CUMULATIVE RADS 30 DAYS	LUNG 120 DAYS	LUNG TOTAL	LUNG TO DEATH	LIVER CUMULATIVE RADS 30 DAYS	LIVER 120 DAYS	LIVER TOTAL	LIVER TO DEATH	SKELETON CUMULATIVE RADS 30 DAYS	SKELETON 120 DAYS	SKELETON TOTAL	SKELETON TO DEATH	DEATH DATE	DAYS 9-30 1978	DAYS DEAT
167E	02-441	F	67156	413	10.3	C	0	0	0														4135	
171D	03-441	F	67163	405	7.8	C	0	0	0													78187		404
174D	04-441	F	67166	390	13.1	C	0	0	0													78107		395
176B	05-441	M	67195	389	10.4	C	0	0	0														4096	

UCI/KG: KG REFERS TO TOTAL BODY WEIGHT.
COMMENT: D,E,OR S: DIED,EUTHANIZED,OR SACRIFICED WITH THE MOST PROMINENT FEATURES ASSOCIATED WITH DEATH.
+ DIED BEFORE POTENTIAL INFINITE DOSE RECEIVED.

NOTES:

DOG 134C: SQUAMOUS CELL CARCINOMA, NASAL CAVITY; HEMANGIOSARCOMA, UNDETERMINED SITE

(DATA ARE FORM LF-60,1978 AND REPRESENT AN UPDATE OF DATA FROM B.A. MUGGENBURG ET AL., 1978.) SEE REFERENCE #41.

A3.3 TOXICITY OF INHALED 91-YCL3 IN BEAGLE DOGS (CONT'D).

I.B.B.		RADIATION DOSE TO TISSUE: LUNG CUMULATIVE RADS				LIVER CUMULATIVE RADS				SKELETON CUMULATIVE RADS					DAYS		
UCI	UCI KG	30 DAYS	120 DAYS	TOTAL	TO DEATH	30 DAYS	120 DAYS	TOTAL	TO DEATH	30 DAYS	120 DAYS	TOTAL	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
0	0														4135		
0	0													78187		4042	D-LIVER CONG.; CONG. HEART FAILURE
0	0													78107		3959	E-GASTROENTERITIS
0	0														4096		

) WITH THE MOST PROMINENT

HEMANGIOSARCOMA.

OF DATA FROM
1.

1061 031

A3.4 TOXICITY OF INJECTED 137-CSCL IN BEAGLE DOGS

NUMBER		INJECTION EXP					INITIAL BODY BURDEN			RADIATION DOSE TO WHOLE BODY								
										DOSE RATE (RADS/DAYS)					CUMULATIVE (RADS)			
TTOO	RADBIO	SEX	BLK	DATE	AGE DAYS	WT KG	RANK	UCI KG	UCI	INITIAL	30 DAYS	180 DAYS	365 DAYS	AT DEATH	30 DAYS	180 DAYS	365 DAYS	TO DEATH
271D	12-558	F	F	68330	421	7.2	1	4000	29000	72				31				110[illegible]
244B	06-522	M	A	68164	402	8.8	2	3900	34000	72	31			30	1300			140[illegible]
241F	06-523	F	B	68165	419	8.2	3	3900	32000	71				38				100[illegible]
273A	11-558	M	E	68330	405	9.4	4	3800	36000	69				43				95[illegible]
249D	06-540	M	D	68215	422	10.1	5	3600	36000	68				35				130[illegible]
253C	06-539	F	C	68214	393	9.5	6	3500	33000	65				38				97[illegible]
277F	09-560	F	H	68354	392	7.1	7	3000	21000	54	19	.20	.002		920	1500	1500	
284B	09-562	M	I	69028	394	8.5	8	2900	25000	52	18	.20	.001		900	1500	1500	
282C	10-562	F	J	69028	402	7.6	9	2900	22000	53	25	.59	.020		1000	2000	20[illegible]	200[illegible]
280C	09-567	F	L	69052	429	7.9	10	2900	23000	53				32				91[illegible]
292A	10-567	M	K	69052	377	8.5	11	2900	25000	52	17	.30	.003		790	1500	1500	
241G	05-523	F	B	68165	419	8.6	12	2800	24000	51				27				86[illegible]
247E	05-539	F	C	68214	428	7.9	13	2800	22000	51				27				91[illegible]
266C	09-558	M	E	68330	435	7.4	14	2800	21000	50	23	.25	.005		950	1700	1700	1700
273E	10-558	F	F	68330	405	8.3	15	2800	23000	51	26	.75	.030		1000	2200	2200	
245B	05-522	M	A	68164	392	9.1	16	2700	25000	51	18			5.1	860			1400
279D	10-560	M	G	68354	383	8.1	17	2700	22000	48	22	.50	.010		950	1800	1800	1800
248A	05-540	M	D	68215	428	9.6	18	2600	25000	48	23	.30	.003		1000	1900	1900	
244E	04-523	F	B	68165	403	7.5	19	2100	16000	37	16	.35	.004		700	1500	1500	
266D	08-558	F	F	68330	435	7.8	20	2100	16000	37	15	.20	.005		670	1200	1200	1200
279B	07-560	M	G	68354	383	9.9	21	2000	20000	36	19	.60	.020		780	1500	1500	
275E	08-560	F	H	68354	410	7.8	22	2000	16000	37	15	.20	.003		700	1200	1200	
283D	08-562	F	J	69028	423	8.8	23	2000	18000	37	13	.25	.004		640	1100	1100	
292C	08-567	F	L	69052	377	9.0	24	1900	17000	36	14	.40	.008		670	1200	1200	1200
241A	04-522	M	A	68164	418	10.0	25	1900	19000	36	18			9.0	710			1300
271A	07-558	M	E	68330	421	9.8	26	1900	19000	35	19	.40	.010	.0003	730	1500	1500	1500
283A	07-562	M	I	69028	423	11.2	27	19[illegible]	21000	35	14	.30	.005		730	1200	1200	
291A	07-567	M	K	69052	382	10.8	28	1900	21000	35	12	.28	.003		630	1000	1000	
253B	04-539	F	C	68214	393	9.7	29	1800	17000	34	15	.40	.006		650	1300	1300	
247A	04-540	M	D	68215	429	9.8	30	1800	18000	34	17	.60	.010		720	1500	1500	
244C	03-522	M	A	68164	402	6.7	31	1600	11000	28	9.0	.13	.001		430	770	770	
280D	06-562	F	J	69028	405	6.8	32	1600	11000	28	9.8	.25	.003		500	840	850	
279A	05-560	M	G	68354	383	9.5	33	1500	14000	27	11	.11	.002		470	830	840	840
278F	06-560	F	H	68354	391	8.4	34	1500	13000	26	13	.30	.010		560	1000	1000	
286D	05-567	F	L	69052	417	8.8	35	1500	13000	27	10	.22	.004		480	820	830	
241E	03-523	F	B	68165	419	9.4	36	1400	13000	26	14	.50	.015		550	1200	1200	
26[illegible]	05-558	M	E	68330	435	11.2	37	1400	16000	26	15	.60	.020		580	1300	1300	1300
26[illegible]	06-558	F	F	68330	433	11.0	38	1400	15000	26	17	1.4	.060		630	1500	1500	
289D	05-562	M	I	69028	376	9.7	39	1400	14000	26	9.9	.30	.005		480	870	880	
247C	03-540	M	D	68215	429	8.8	40	1300	11000	25	12	.18	.003		470	980	990	
291C	06-567	M	K	69052	382	7.7	41	1200	9200	22	11	.41	.005		520	970	990	
252C	03-539	F	C	68214	407	9.3	42	1200	11000	21	12	.25	.005		480	950	970	
244F	02-523	F	B	68165	403	5.8	43	1100	6400	20	7.2	.083	.001		340	590	590	
278B	04-560	M	G	68354	391	9.5	44	1100	10000	21	10	.20	.003		440	810	820	
241B	02-522	M	A	68164	418	9.8	45	1000	9800	19	7.9	.13	.001		330	640	650	
273F	04-558	F	F	68330	405	8.4	46	1000	8400	19	10	.45	.040		420	880	910	
278D	03-560	F	H	68354	391	10.3	47	1000	10000	19	8.4	.13	.004		350	640	650	
281C	04-562	F	J	69028	404	8.4	48	1000	8400	19	6.5	.15	.006		320	560	570	
281B	03-567	F	L	69052	428	9.6	49	940	9200	17	8.1	.30	.008		350	690	710	
285A	03-562	M	I	69028	393	10.5	50	920	9700	17	6.3	.20	.002		310	540	550	

1061 032

A3.4 TOXICITY OF INJECTED 137-CSCL IN BEAGLE DOGS

EXP DATE	AGE DAYS	WT KG	INITIAL BODY BURDEN RANK	UCI KG	UCI	DOSE RATE (RADS/DAYS) INITIAL	30 DAYS	180 DAYS	365 DAYS	AT DEATH	CUMULATIVE (RADS) 30 DAYS	180 DAYS	365 DAYS	TO DEATH	DEATH DATE	DAYS 9-30 1978	DEATH	COMMENT
330	421	7.2	1	4000	29000	72				31				1100	68356		26	D-HEMATOLOGICAL DYSCRASIA
164	402	8.8	2	3900	34000	72	31			30	1300			1400	68197		33	D-HEMATOLOGICAL DYSCRASIA
165	419	8.2	3	3900	32000	71				38				1000	68187		22	D-HEMATOLOGICAL DYSCRASIA
630	405	9.4	4	3800	36000	69				[illegible]				950	68349		19	D-HEMATOLOGICAL DYSCRASIA
215	422	10.1	5	3600	[illegible]	68				35				1300	68242		27	D-HEMATOLOGICAL DYSCRASIA
214	393	9.5	6	3500	33000	65				38				970	68236		22	D-HEMATOLOGICAL DYSCRASIA
554	392	7.1	7	3000	21000	54	19	.20	.002		920	1500	1500			3572		
028	394	8.5	8	2900	25000	52	18	.20	.001		900	1500	1500			3532		
028	402	7.6	9	2900	22000	53	25	.59	.020		1000	2000	2000	2000	73271		1704	E-SEE NOTE AT END
052	429	7.9	10	2900	23000	53				32				910	69076		24	E-HEMATOLOGICAL DYSCRASIA
052	377	8.5	11	2900	25000	52	17	.30	.003		790	1500	1500			3508		
165	419	8.6	12	2800	24000	51				27				860	68190		25	D-HEMATOLOGICAL DYSCRASIA
214	428	7.9	13	2800	22000	51				27				910	68241		27	D-HEMATOLOGICAL DYSCRASIA
330	435	7.4	14	2800	21000	50	23	.25	.005		950	1700	1700	1700	73097		1594	D-SEE NOTE AT END
630	405	8.3	15	2800	23000	51	26	.75	.030		1000	2200	2200		77343		3301	E-SUPPURATIVE ENDOMETRITIS
164	392	9.1	16	2700	25000	51	18			5.1	860			1400	68245		81	D-HEMATOLOGICAL DYSCRASIA
554	383	8.1	17	2700	22000	48	22	.50	.010		950	1800	1800	1800	76139		2707	E-MAST CELL SARCOMA
215	428	9.6	18	2600	25000	48	23	.30	.003		1000	1900	1900		77313		3386	D-SEE NOTE AT END
165	403	7.5	19	2100	16000	37	16	.33	.004		700	1500	1500			3761		
730	435	7.8	20	2100	16000	37	15	.20	.005		670	1200	1200	1200	77204		3162	D-SEE NOTE AT END
554	383	9.9	21	2000	20000	36	19	.60	.020		780	1500	1500			3572		
554	410	7.8	22	2000	16000	37	15	.20	.003		700	1200	1200			3572		
028	423	8.8	23	2000	18000	37	13	.25	.004		640	1100	1100			3532		
052	377	9.0	24	1900	17000	36	14	.40	.008		670	1200	1200	1200	77277		3147	D-HEMANGIOSARCOMA HEART
164	418	10.0	25	1900	19000	36	18			9.0	710			1300	68241		77	D-HEMATOLOGICAL DYSCRASIA
330	421	9.8	26	1900	19000	35	19	.40	.010	.0003	730	1500	1500	1500	70292		693	D-SHOCK
028	423	11.2	27	1900	21000	35	14	.30	.005		730	1200	1200			3532		
052	382	10.8	28	1900	21000	35	12	.28	.003		630	1000	1000			3508		
214	393	9.7	29	1800	17000	34	15	.40	.006		650	1300	1300			3712		
215	429	9.8	30	1800	18000	34	17	.60	.010		720	1500	1500			3711		
164	402	6.7	31	1600	11000	28	9.0	.13	.001		430	770	770			3762		
028	405	6.8	32	1600	11000	28	9.8	.25	.003		500	840	850			3532		
554	383	9.5	33	1500	14000	27	11	.11	.002		470	830	840	840	74310		2148	D-RENAL AMYLOIDOSIS
554	391	8.4	34	1500	13000	26	13	.30	.010		560	1000	1000			3572		
052	417	8.8	35	1500	13000	27	10	.22	.004		480	820	830			3508		
165	419	9.4	36	1400	13000	26	14	.50	.015		550	1200	1200			3761		
330	435	11.2	37	1400	16000	26	15	.60	.020		580	1300	1300	1300	78206		3529	E-SEE NOTE AT END
330	433	11.0	38	1400	15000	26	17	1.4	.060		630	1500	1500			3596		
028	376	9.7	39	1400	14000	26	9.9	.30	.005		480	870	880			3532		
215	429	8.8	40	1300	11000	25	12	.18	.003		470	980	990			3711		
052	382	7.7	41	1200	9200	22	11	.41	.005		520	970	990			3508		
214	407	9.3	42	1200	11000	21	12	.25	.005		480	950	970			3712		
165	403	5.8	43	1100	6400	20	7.2	.083	.001		340	590	590			3761		
554	391	9.5	44	1100	10000	21	10	.20	.003		440	810	820			3572		
164	418	9.8	45	1000	9800	19	7.9	.13	.001		330	640	650			3762		
330	405	8.4	46	1000	8400	19	10	.45	.040		420	880	910			3596		
554	391	10.3	47	1000	10000	19	8.4	.13	.004		350	640	650			3572		
026	404	8.4	48	1000	8400	19	6.5	.15	.006		320	560	570			3532		
052	428	9.8	49	940	9200	17	8.1	.30	.008		350	690	710			3508		
028	393	10.5	50	920	9700	17	6.3	.20	.002		310	540	550			3532		

1061 033

A3.4 TOXICITY OF INJECTED 137-CSCL IN BEAGLE DOGS (CONT'D).

NUMBER		INJECTION EXP					INITIAL BODY BURDEN			RADIATION DOSE TO WHOLE BODY: DOSE RATE (RADS/DAYS)					CUMULATIVE (RADS)					DAYS	
TTQQ	RADBIO	SEX	BLK	DATE	AGE DAYS	WT KG	RANK	UCI KG	UCI	INITIAL	30 DAYS	180 DAYS	365 DAYS	AT DEATH	30 DAYS	180 DAYS	365 DAYS	TO DEATH	DEATH DATE	9-30 1978	DEA
287A	04-567	M	K	69052	410	10.2	51	900	9200	17	8.0	.28	.007		360	670	690	690	75332		24
249C	02-540	M	D	68215	422	8.8	52	900	7900	17	8.6	.22	.002		340	700	710			3711	
266A	03-558	M	E	68330	435	9.1	53	890	8100	16	7.9	.15	.004		330	630	640			3596	
248C	02-539	F	C	68214	427	8.3	54	880	7300	16	7.6	.11	.002		330	610	610			3712	
241C	01-522	M	A	68164	418	9.7	C	0	0											3762	
244D	01-523	F	B	68165	403	7.2	C	0	0										70081		6
251D	01-539	F	C	68214	408	6.8	C	0	0											3712	
247B	01-540	M	D	68215	429	9.4	C	0	0											3711	
270B	01-558	M	E	68330	423	8.4	C	0	0											3596	
267D	02-558	F	F	68330	435	7.4	C	0	0											3596	
277A	02-560	M	G	68354	392	9.4	C	0	0										75239		24
274E	01-560	F	H	68354	419	7.1	C	0	0										77154		30
282A	01-562	M	I	69028	402	8.6	C	0	0											3532	
283C	02-562	F	J	69028	395	8.8	C	0	0											3532	
286C	01-567	M	K	69052	417	8.4	C	0	0											3508	
282D	02-567	F	L	69052	426	6.9	C	0	0										78030		32

UCI/KG: KG REFERS TO TOTAL BODY WEIGHT.
DOSE RATE: DAYS REFER TO DAYS AFTER INJECTION EXPOSURE.
COMMENT: D,E,OR S: DIED,EUTHANIZED,OR SACRIFICED WITH THE MOST PROMINENT FEATURES ASSOCIATED WITH DEATH.

NOTES:

DOG 282C: E-DEGENERATIVE ARTHRITIS; PNEUMONIA; NECROTIC PHARYNGITIS
DOG 266C: D-ASPIRATION PNEUMONIA; NECROTIC PHARYNGITIS
DOG 248A: D-SQUAMOUS CELL CARRCINOMA; MAXILLARY SINUS
DOG 266D: D-CONGESTIVE HEART FAILURE; PULMONARY EDEMA
DOG 267A: E-BRAIN EDEMA; UNCERTAIN ORIGIN
DOG 244D: D-AUTOIMMUNE HEMOLYTIC ANEMIA; BACTERIAL ENDOCARDITIS

(DATA ARE FROM LF-60, 1978 AND REPRESENT AN UPDATE OF DATA FROM C. HANIKA-REBAR ET AL., 1978.) SEE REFERENCE #20

A3.4 TOXICITY OF INJECTED 137-CSCL IN BEAGLE DOGS (CONT'D).

AL BODY BURDEN			RADIATION DOSE TO WHOLE BODY												
			DOSE RATE (RADS/DAYS)					CUMULATIVE (RADS)					DAYS		
K	UCI KG	UCI	INITIAL	30 DAYS	180 DAYS	365 DAYS	AT DEATH	30 DAYS	180 DAYS	365 DAYS	TO DEATH	DEATH DATE	9-30 1978	DEATH	COMMENT
1	900	9200	17	8.0	.28	.007		360	670	690	690	75332		2471	E-NEUROFIBROSARCOMA LIVER
32	900	7900	17	8.6	.22	.002		340	700	710			3711		
33	890	8100	16	7.9	.15	.004		330	630	640			3596		
34	880	7300	16	7.6	.11	.002		330	610	610			3712		
C	0	0											3762		
C	0	0										70081		647	D-SEE NOTE AT END
C	0	0											3712		
C	0	0											3711		
C	0	0											3596		
C	0	0											3596		
C	0	0										75239		2442	D-RENAL AMYLOIDOSIS
C	0	0										77154		3088	D-MAMMARY CARCINOMA
C	0	0											3532		
C	0	0											3532		
C	0	0											3508		
C	0	0										78030		3265	E-RENAL FAILURE-UREMIA

POSURE.
D WITH THE MOST PROMINENT

NECROTIC PHARYNGITIS
YNGITIS
SINUS
EDEMA

IAL ENDOCARDITIS

OF DATA FROM

1061 035

A4.1 SIXTY-DAY MORTALITY OF BEAGLE DOGS AFTER WHOLE-BODY EXPOSURE TO 1000-KVP X-RAYS

DOSE (R)	DOSE RATE (R/MIN)	NUMBER DEAD IN 60 DAYS	NUMBER EXPOSED
215	50-65	1	7
230	50-65	3	7
280	50-65	5	7
800	50-65	4	4
1000	50-65	4	4
1500	50-65	4	4
1750	50-65	1	1
2000	50-65	1	1

(DATA FROM C.L. HANSEN ET AL., 1961.)
SEE REFERENCE #21.

A4.2 SIXTY-DAY MORTALITY OF BEAGLE DOGS AFTER BILATERAL WHOLE-BODY EXPOSURE TO 1000-KVP X-RAYS

DOSE (R)	DOSE RATE (R/MIN)	NUMBER DEAD IN 60 DAYS	NUMBER EXPOSED
150	50-65	0	5
225	50-65	1	5
260	50-65	2	13
280	50-65	3	7
300	50-65	2	6
325	50-65	5	6
340	50-65	5	7
400	50-65	5	6

(DATA FROM S.M. MICHAELSON ET AL., 1968.)
SEE REFERENCE #38.

A4.3 THIRTY-DAY MORTALITY OF MONGREL DOGS AFTER BILATERAL WHOLE-BODY EXPOSURE TO 60-CO-GAMMA RAYS

DOSE (R)	DOSE RATE (R/MIN)	NUMBER DEAD IN 30 DAYS	MEAN NUMBER EXPOSED	SURVIVAL (DAYS)+-SE
292	6	2	10	24.5+-1.8
336	6	5	10	18.2+-1.1
385	6	9	10	17.8+-0.9
436	6	10	10	14.9+-0.8

(DATA FROM J.N. SHIVELY ET AL., 1958.) SEE REFERENCE #53.

A4.4 THIRTY-DAY MORTALITY OF MONGREL DOGS AFTER BILATERAL WHOLE-BODY EXPOSURE TO 60-CO-GAMMA RAYS

DOSE (R)	DOSE RATE (R/MIN)	NUMBER DEAD IN 30 DAYS	NUMBER EXPOSED	MEAN SURVIVAL (DAYS)+-SE
292	6	2	10	19.0+-2.0
320	6	6	12	20.5+-1.2
370	6	6	12	15.8+-1.3
420	6	9	12	18.0+-1.8

(DATA FROM J.N. SHIVELY ET AL., 1961.) SEE REFERENCE #54.

A4.5 THIRTY-DAY MORTALITY OF SWISS WEBSTER MICE AFTER WHOLE-BODY EXPOSURE TO 260-KVP X-RAYS

DOSE (R)	DOSE RATE (R/MIN)	NUMBER DEAD IN 30 DAYS	NUMBER EXPOSED	MEAN SURVIVAL (DAYS)+-SE
500	50	10	23	12.5+-2.96
550	50	10	15	10.4+-1.04
600	50	11	24	11.0+-1.31
650	50	9	9	9.9+-1.17
710	50	19	24	8.1+-0.72
750	50	29	30	8.8+-0.89
800	50	23	25	9.1+-0.62
850	50	10	10	8.7+-0.45
900	50	16	17	9.23+-0.66
950	50	10	10	8.95+-0.52
1000	50	13	14	7.8+-0.47
1250	50	8	8	3.9+-0.23
1500	50	10	10	3.4+-0.10
1750	50	9	9	3.1+-0.07
2000	50	9	9	3.3+-0.13
2250	50	10	10	3.2+-0.07
2500	50	10	10	3.0+-0.06
2750	50	10	10	3.1+-0.08
3000	50	10	10	3.4+-[illegible]06

(DATA FROM B.R. WILSON, 1963.) SEE REFERENCE #65.

1061 037

A4.6 THIRTY-DAY MORTALITY OF BEAGLE DOGS AFTER WHOLE-BODY EXPOSURE TO 60-CO-GAMMA RAYS

DOSE (R)	DOSE (RADS)	NUMBER DEAD IN 30 DAYS	NUMBER EXPOSED	MEAN SURVIVAL TIME (DAYS)
275	214	1	8	29
300	234	2	8	23
325	254	5	19	22
340	265	7	8	19
350	273	9	9	17
365	285	9	9	17

(DATA FROM W.P. NORRIS ET AL., 1965.) SEE REFERENCE #43.

A4.7 THIRTY-DAY MORTALITY OF (CF#1) MICE AFTER WHOLE-BODY EXPOSURE TO FISSION-SPECTRUM GAMMA RAYS

DOSE (RAD)	NUMBER DEAD IN 30 DAYS	NUMBER EXPOSED
706	16	25
728	21	25
790	15	15
814	14	15

(DATA FROM E.J. AINSWORTH ET AL.,1964.) SEE REFERENCE #1.

A4.8 THIRTY-SIX DAY MORTALITY IN MONKEYS AFTER WHOLE-BODY EXPOSURE TO 60-CO-GAMMA RAYS

DOSE (R)	NUMBER DEAD IN 36 DAYS	NUMBER EXPOSED
250	0	5
300	0	6
380	0	6
450	1	8
500	5	10
600	6	10
700	7	9

(DATA FROM N.G. DARENSKAYA ET AL.,1977.)
SEE REFERENCE #8.

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APPENDIX B

A. Publications

1. Scott, B. R., "Hazard-Function Method of Resolving Radiation Dose-Response Curves, Health Physics, 36: 323-332, 1979.

2. Scott, B. R., "Resolution of Radiation Dose-Response Relationships: Hazard Method," Radiation Research 74: 535, 1978 (abstract).

3. Scott, B. R., "A Model for Early Death Caused by Radiation Pneumonitis and Pulmonary Fibrosis After Inhaling Insoluble Radioactive Particles," submitted to Bulletin of Mathematical Biology, accepted for publication.

4. Scott, B. R., "Proposed Estimates of the Probability of Inducing Pulmonary Injury Sufficient to Cause Death from Radiation Pneumonitis and Pulmonary Fibrosis after Briefly Inhaling a Mixture of Insoluble Beta-Emitting Particles," submitted to Radiation Research.

B. Presentations

1. Scott, B. R., "Resolution of Radiation Dose-Response Relationships: Hazard Method," Radiation Research Society Annual Meeting, Toronto, Ontario, May 14-18, 1978.

APPENDIX C

Personnel

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R. J. Jaramillo, BS	Sr. Res. Technologist

Such a listing is rarely comprehensive in acknowledging all the individuals who have made important contributions to the research that has been performed. Included in the unnamed category are many other highly skilled technical, computer, administrative, secretarial and editorial personnel whose efforts are essential to the conduct of a study such as this.

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16. ABSTRACT *(200 words or less)* Several studies have been made of early deaths that might occur in a population exposed to a cloud of radionuclides released in a major nuclear accident. The resulting mortality analyses were oriented to specific accident scenarios. A more flexible model was desired that could be used for a variety of scenarios involving different proportions of irradiation from external sources and internally-deposited beta and alpha-emitting radionuclides. Phase I of this report involved an extensive review and analysis of the early mortality data currently in existence. Computerized simulation models based on the GASP IV simulation language were derived to compute the doses to different body organs and project the subsequent occurrence of radiation effects. Relationships between absorbed doses and biological effects were determined using a hazard function method. These formulations make it possible to add the expected frequency of effects from external irradiation with low LET and high LET internal irradiation of different organs without using any RBE values. These Phase I models give better predictions of the mortality seen in several studies with laboratory animals than do other existing models. Important gaps in our knowledge relating to these models have been identified for additional study in Phase II of this work.

17. KEY WORDS AND DOCUMENT ANALYSIS
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