Experimental Studies of the Early Effects of Inhaled Beta-Emitting Radionuclides for Nuclear Accident Risk Assessment

Phase II Report

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F. F. Hahn, Inhalation Toxicology Research Institute, "Early Mortality Estimates for Different Nuclear Accidents," USNRC Report NUREG/CR-0774, August 1979. Available for purchase from National Technical Information Service, Springfield, VA 22161.

ABSTRACT

This report summarizes a series of experiments concerning the effect of linear energy transfer and temporal radiation dose pattern to the lung from inhaled beta-emitting radionuclides. The results were used to test the validity of a hazard-function mathematical model for predicting death from radiation pneumonitis. Both morbidity and mortality within 18 months after exposure were examined in rats exposed to beta-emitting radionuclides, giving brief or protracted irradiation of the lung or having weak or strong beta emissions. Protraction of the radiation dose to the lung from a half-time in the lung of less than three days to a half-time with a long-term component of about 150 days has a sparing effect. The median lethal dose for the protracted irradiation is about 1.7 times the median lethal dose for the brief irradiation. Low energy beta emissions (from ^{147}Pm) have a similar effectiveness in producing lethal injury as high energy beta emissions (from ^{90}Sr). Changes in three parameters of morbidity were measured: body weight, hematology and pulmonary function; only changes in pulmonary function correlated well with pulmonary radiation injury. The doses of radiation required to produce impaired function, however, were not significantly different from those that produced death.

The hazard-function model for predicting death from radiation pneumonitis, which was developed from previously obtained data for inhalation exposures of dogs to beta-emitting radionuclides, adequately predicted the median lethal doses for rats receiving one of several different beta dose rate patterns to the lung, thus strengthening the validity of the mathematical model. Future research is expected to lead to development of more general models. The data provided in this report can be used to develop and validate such models.

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EXECUTIVE SUMMARY

A major concern of the Nuclear Regulatory Commission (NRC) and general public is the potential for health effects from nuclear accidents. In Phase I of this project, a mathematical model was developed at the Inhalation Toxicology Research Institute (ITRI) for the NRC for predicting the fatalities from early and continuing effects of exposure of persons to radiation that might occur following an accident at a light water nuclear power plant (Hahn 1979). The model initially developed for overall lethality contained three organ-specific modes for lethality: (1) injury to the bone marrow, (2) injury to the colon and (3) injury to the lungs. Subsequent analysis efforts led to refinement of the overall lethality model which included the addition of a mode for lethality from injury to the small intestine.

In Phase II of the project, three specific inhalation exposure studies were carried out at the ITRI. The purposes of the studies were two-fold: (1) to validate and improve the lethality model for death from early and continuing effects in lung after exposure to different dose rate patterns from beta-emitting radionuclides, and (2) to provide data for developing a morbidity model when lung is the target organ.

This document provides a detailed description of two of the three studies on early and continuing effects in lung, resulting from inhalation of radionuclides. In the first study, the influence of cross-organ irradiation was examined by exposing rats to aerosols of ^{147}Pm that irradiated only the lung because of the weak-energy betas emitted. In a second study, the influence of different dose accumulation patterns on morbidity and mortality were examined. Results of another study in which rats were exposed via inhalation to mixtures of alpha emitters and beta emitters (^{147}Pm and ^{238}Pu incorporated into insoluble particles), will be presented in a subsequent report.

Each radionuclide was delivered within an insoluble fused aluminosilicate particle (FAP) matrix and resulted in a different dose rate pattern of irradiation of the lung. Initial dose rates were highest for ^{90}Y , followed by the mixture $^{90}\text{Y} + ^{90}\text{Sr}$, ^{90}Sr ,^a and ^{147}Pm , respectively. Initial dose rates and lung clearance patterns were similar for ^{147}Pm and ^{90}Sr but the energies of the beta emissions from ^{147}Pm were much lower than for those from ^{90}Sr and thus the range in tissue was much less. Therefore, the dose from ^{147}Pm was delivered mostly to the lung, while a major fraction of the dose from ^{90}Sr or ^{90}Y was delivered to tissues adjacent to the lung.

The rats were observed for signs of illness and for survival out to 1.5 years after exposure. Periodic measurements obtained as potential indicators of illness were hematocrit, red and white blood cell counts, and differential white blood cell counts, as well as several pulmonary function parameters including vital capacity, carbon monoxide diffusing capacity, and quasistatic compliance of the lung. Body weights of all rats were measured periodically throughout each study. Pulmonary function evaluations were carried out on a preselected group of rats throughout the ^{90}Sr experiment and at the end of both the ^{90}Sr and ^{90}Y experiments. Hematological evaluations were also carried out on preselected rats throughout each experiment.

Major findings of these studies of irradiation of lungs of rats by internally deposited beta emitters were as follows:

1. Low-energy beta emissions from ^{147}Pm have similar effectiveness in producing lethal injury as high-energy beta emissions from ^{90}Sr indicating that the high-energy beta particles escaping the lung of rats and irradiating surrounding tissues do not significantly alter lethality.

^aAs used in this text, the term ^{90}Sr refers to an equilibrium mixture of ^{90}Sr and ^{90}Y . The term $^{90}\text{Y} + ^{90}\text{Sr}$ refers to an equilibrium mixture of $^{90}\text{Sr} + ^{90}\text{Y}$ to which additional ^{90}Y had been added.

2. Unlike high-energy beta emitters, low-energy beta emissions from ^{147}Pm were not effective in producing injury to the hematopoietic system. While a slight temporary reduction in lymphocytes was observed after exposure to the high-energy beta emitters, none was observed after exposure to the low-energy beta emissions of ^{147}Pm .

3. Protraction of the radiation dose to the lung from a half-time in the lung of less than 3 days to a half-time with a long-term component of about 150 days has a sparing effect. The median lethal dose for the protracted irradiation is about 1.7 times the medial lethal dose for the brief irradiation.

4. Doses of beta irradiation required to produce impaired pulmonary function were similar to those required for lethality.

5. Individuals with impaired pulmonary function shortly after inhalation exposure to beta emitters have, or are likely to accumulate, lethal pulmonary injury.

6. Body weight in rats is not a sensitive measure of illness associated with radiation damage to the lung. However, a significant decrease in body weight correlated with the induction of lethal pulmonary injury.

7. The hazard-function model for predicting death from radiation pneumonitis, which was developed from data for inhalation exposure of dogs to beta-emitting radionuclides, adequately predicted the median lethal doses for rats receiving one of several different beta dose rate patterns to the lung.

CHAPTER 1 INTRODUCTION

The main focus of the research reported here is on early and continuing effects of irradiation of the lungs and its relevance to nuclear reactor accident risk assessment. Two modes of exposure could occur in an accident at a light water nuclear power plant: (1) brief external exposure to ground-shine and cloud-shine gamma rays at high dose rates, and (2) protracted internal exposure due to inhaled and ingested radionuclides.

Large doses to the lungs from inhaled radionuclides can cause radiation pneumonitis and pulmonary fibrosis and may lead to impaired pulmonary function and death. The severity of reactions and their time course depend on total radiation dose (Collis and Steel, 1982; Phillips and Margolis, 1972), dose rate (Travis *et al.*, 1983; Depledge and Barrett, 1982), and type of radiation (Mauderly *et al.*, 1980). Although the histologic descriptions of radiation pneumonitis are based primarily on observations of man or laboratory animals exposed to external thoracic x-irradiation, similar changes have been observed with inhaled radionuclides (Slauson *et al.*, 1976; Slauson *et al.*, 1977). One major difference is the time course of the lesions, which is more delayed depending on the degree of dose protraction associated with the particular radionuclide.

In a recent evaluation of data for exposure of human lung to external x-irradiation, the onset of pneumonitis was shown to be between 1 and 7 months after irradiation, with no correlation between time of onset and radiation dose to the lung over a range of 6.5 to 12.5 Gy (650-1250 rad) (Van Dyk *et al.*, 1981).

Morbidity after inhalation exposure of the lung to nonlethal beta-radiation doses has been demonstrated using pulmonary function measurements in Beagle dogs that inhaled ^{90}Y in an insoluble form (Mauderly *et al.*, 1973). Functional measurements were performed under the stresses of treadmill exercise and added external deadspace. The smallest dose to the lung that was observed to cause alteration in lung function was approximately one-half of the estimated median lethal dose (D_{50}). Results of the studies by Mauderly and coworkers have been interpreted as indicating that the low-LET dose required to cause morbidity may be about one-half that required for lethality (Scott and Hahn, 1985).

Previously available information suggests that age at exposure can influence the effectiveness of the radiation (McClellan *et al.*, 1982). About one-half as much dose to the lungs was required for immature and aged dogs as was required for young adults to cause death from early effects. This has been interpreted as indicating that children and the aged may be more sensitive than young adults, by about a factor of two, to lethality from exposure of the lungs (Scott and Hahn, 1985).

The main objective of this document is to describe mortality and morbidity for rats that were exposed via inhalation to large doses of beta radiation to the lung. The research that produced these data represents Phase II of a two-phased project. In Phase I, a computer simulation model was developed for assessing the risk of death from early and continuing effects that could arise from radiation exposure associated with an accident at a light water nuclear power plant.

In Phase II, experiments were conducted to (1) provide data on mortality to validate the mortality model developed in Phase I and (2) provide data on morbidity for developing a morbidity model. The data are derived from studies in which rats were exposed via inhalation to ^{147}Pm , ^{90}Sr (in equilibrium with ^{90}Y), ^{90}Sr (in equilibrium with ^{90}Y) plus additional ^{90}Y , or ^{90}Y only. Each radionuclide was delivered in a relatively insoluble fused aluminosilicate particle (FAP) matrix.

Throughout the document, ^{90}Sr will refer to an equilibrium mixture of ^{90}Sr and its daughter radionuclide ^{90}Y . A data base is also being developed from rats exposed via inhalation to ^{147}Pm plus ^{238}Pu inhaled in fused aluminosilicate particles, but these data will be described in a subsequent report.

CHAPTER 2

EARLY AND CONTINUING EFFECTS OF LOW-ENERGY BETA IRRADIATION OF THE LUNG

2.1 INTRODUCTION

The purpose of the study was to determine if irradiation of organs other than lung by high-energy beta particles, such as from ^{90}Sr deposited in the lung, leads to greater mortality than would be expected if only the lung was irradiated. Of special interest was the potential for cross-organ irradiation and injury to the hematopoietic system by high-energy beta rays originating in the lung and escaping to irradiate the bone marrow of the sternum, ribs and thoracic vertebra as well as the blood passing through the lung. If injury to the hematopoietic system was significant, then it would be reflected in depressed peripheral leucocyte counts measured at various times after exposure. The hypothesis tested in this study was that low-energy beta irradiation from ^{147}Pm ($E_{\text{max}} = 0.224 \text{ MeV}$), localized in the lung, would not produce detectable injury to the hematopoietic system through irradiation of the bone marrow. However, some of the high energy beta emissions from ^{90}Sr or ^{90}Y (E_{max} of $^{90}\text{Y} = 2.27 \text{ MeV}$) would escape the lung and could cause detectable injury to the hematopoietic system via irradiation of the bone marrow. The experiments involving high energy beta emitters are discussed in Chapter 3.

It will be demonstrated that, while ^{147}Pm caused deaths from radiation pneumonitis and pulmonary fibrosis and a reduction in weight gain, no observable injury occurred to the hematopoietic system when this low-energy beta emitter was localized in the lung of rats. In addition, deaths from radiation pneumonitis and pulmonary fibrosis were observed even at the last sacrifice time, 1.5 years after inhalation exposure, a time when tumors of the lung were also observed.

2.2 METHODS

2.2.1 Animals

Equal numbers of male and female F344/Cr1 rats were obtained from the Lovelace ITRI breeding colony for use in the study. The breeding colony is free of known rat respiratory pathogens and is tested serologically every three months. The rats were 15 ± 2 weeks of age at exposure.

2.2.2 Animal Maintenance

Before exposure, members of each sex were weighed and housed separately, 2 per cage, in polycarbonate cages with aspen bedding and filter caps. The room housing the rats was maintained between 20 to 22°C and the relative humidity was maintained between 20 to 50%. A 12-hour-on, 12-hour-off light cycle was used. Rats were given food (Lab Blox, Allied Mills, Chicago, IL) and water ad libitum.

2.2.3 Biologic Measurements

Biological measurements made during the study were body weight, hematology, survival time and histologic changes at death. Body weights were taken before exposure and at monthly intervals to 6 months and again at 12 months after exposure on all rats.

Hematological examinations were performed on rats in the hematology group before exposure and at 7, 14, 30, 60, 90, 180 and 540 days after exposure. Blood was collected from the retrobulbar sinus in a capillary tube. Smears were made and the blood was diluted in Unopettes®. Hematocrit, total red blood cells, total white blood cells and white blood cell differential counts were determined. Total blood cell counts were performed with an electronic blood cell counter (Coulter S550).

The rats were observed twice per day for 1.5 years after exposure. Those moribund were euthanized and necropsied. At the end of the observation period, a representative number of rats was sacrificed, necropsied and examined for histologic changes. At necropsy, all animals were

examined for gross lesions and the likely cause of death was determined. All major organ systems were examined except for the brain. The lungs were weighed and perfused with 10% neutral buffered formalin embedded in paraffin, sectioned at 5 micrometers and stained with hematoxylin and eosin for histologic evaluation.

2.2.4 Aerosol Preparation And Generation

Polydisperse aerosols were prepared by cation exchange of ^{147}Pm and ^{169}Yb into montmorillonite clay, followed by aerosolization with a Lovelace nebulizer and heat treatment by passing through a heating column at 1150°C with a flow rate of 2 Lpm. The aerosol was then diluted with clean air and directed into an 80-port, nose-only exposure chamber. Cascade impactor, filter, and electrostatic precipitator (ESP) samples of the aerosol were taken at the beginning and near the end of each exposure; these samples were used to determine physical characteristics of the aerosols and aerosol radioactivity during inhalation exposure.

The particle size distributions were lognormal. The range for activity median aerodynamic diameters among the different inhalation exposure runs was 0.9 to 1.77 micrometers. The range of the geometric standard deviation was 1.5 to 1.8.

2.2.5 Determination of Lung and Bronchial Lymph Node Radioactivity Content

Because ^{147}Pm in fused aluminosilicate particles is relatively insoluble in body fluids, the lungs and bronchial lymph nodes (BLN) of the rats were the organs of primary interest. At death or sacrifice, whole-body, lung and BLN weights were measured. Fixed lung and lymph node tissue remaining after sampling for histopathology were reweighed, wet-ashed, sampled and counted in triplicate using liquid scintillation techniques to determine the ^{147}Pm content. Corrections were made for quench using external standards and for loss of tissue samples taken for histopathology. Results were used to obtain the content of ^{147}Pm in lungs and lymph nodes at death.

2.2.6 Estimation of Initial Lung Burdens

Initial lung burdens (ILB) of ^{147}Pm were estimated indirectly by measuring whole-body ^{169}Yb activity at early times (4 to 8 days after exposure). Shielded NaI(Tl) crystal counters were used to detect gamma radiation from the ^{169}Yb radioactive tag. The observed whole-body radioactivity in the animal at 4-8 days after exposure was assumed to represent the existing lung burden. An exponential retention relationship was derived for retention of ^{169}Yb . After it was corrected for physical decay of ^{169}Yb , a biological (total-body) clearance fraction of approximately 0.032 per day was observed. Knowing the ^{147}Pm to ^{169}Yb initial activity ratio (approximately 80 to 1 calculated from the filter samples collected at exposure) and the physical half-life of ^{147}Pm (2.62 years), the initial ^{147}Pm lung burden was estimated by extrapolating back to the time of exposure. The initial lung burden estimates obtained for each rat are given in the Appendix.

2.2.7 Estimation of Doses To Lung

Lung burden estimates derived at early times from whole-body counting of ^{169}Yb were coupled with those obtained for animals that died throughout the study whose lungs were analyzed radiochemically for ^{147}Pm content to obtain an effective lung retention function given by

$$^{147}\text{Pm lung retention} = 0.58\exp(-0.15T) + 0.42\exp(-0.0046T)$$

where T represents days after inhalation exposure. The retention function is plotted in Figure 2.1. The effective retention half-time for the long-term component was 150 days.

Cumulative radiation doses to the lung to death or doses to a specified time (e.g., 1 year after inhalation exposure) were determined by numerical integration over the dose rate pattern for each exposed individual. Instantaneous dose rates, $\text{DR}(t)$, at any given time t in the interval from 0 to 550 days after exposure were given by

2.1 Pulmonary retention pattern for inhaled ^{147}Pm in fused aluminosilicate particles.

$$DR(t) = 0.512\bar{E} \cdot A(t) \cdot f / W(t), \text{ Gy/day}$$

where

$\bar{E} = 0.062 \text{ MeV}$ for ^{147}Pm

$A(t)$ = the activity retained which equals the product of the initial activity times the lung retention function

f = fractional energy absorption in the lung; 0.97 (based on Snipes, 1980)

$W(t)$ = lung weight in g at t days after inhalation exposure

= $0.005 \cdot [\text{Initial Weight (g)} + 124 \cdot GF(t)]$ for females

= $0.0041 \cdot [\text{Initial Weight (g)} + 166 \cdot GM(t)]$ for males

where

$$GF(t) = 1 - \exp(-0.0169 \cdot t^{0.822})$$

and

$$GM(t) = 1 - \exp(-0.0133 \cdot t^{0.938}).$$

The function $W(t)$ is based on weight of the control rats in the study with 0.5% of the female body weight being due to the lung weight and 0.41% being the lung weight percentage for males (Lundgren, 1980). This function accounts for the increased size and weight of the lung as the rats mature.

2.2.8 Experimental Design

Equal numbers of both sexes were randomly assigned to exposure groups as indicated in Table 2.1. Randomizations were constrained such that the average body weights were similar among all exposure levels and groups for a given sex. The rats were divided into groups that were exposed to aerosol concentrations of ^{147}Pm -FAP that were estimated to result in one-year mortalities of between 0 and 2%, 2 and 25%, 25 and 95%, and 95 and 100%. The desired average initial lung burdens are also given in Table 2.1. These estimates were based on the hazard function model for early mortality based on data from dogs that inhaled beta emitters (Hahn, 1979).

A wide range of desired initial lung burdens was chosen to bracket the estimated D_{50} and provide rats in the high and low ranges of the dose-response curves where uncertainties are large. Animals in groups designated for hematology were bled periodically and were regarded as a separate group for analysis purposes.

Table 2.1
Experimental Design for Rats Exposed to ^{147}Pm Inhaled
In Fused Aluminosilicate Particles

Exposure	Range for Expected	Desired Initial	Number of Rats ^c	
Group	Mortality (%) ^a	Lung Burden (MBq) ^b	Mortality	Hematology
A	0	0	30	10
B	0 - 2	1.7	50	10
C	2 - 25	2.8	70	10
D	25 - 95	3.2	40	10
E	95 - 100	4.4	40	0
			230	40
			Combined Total = 270	

^aOne year mortality.

^bOne MBq = 27 μCi .

^cEqual numbers of males and females in each group.

2.3 RESULTS

2.3.1 Radiation Dose to Lung

The pulmonary dose accumulation function for inhaled ^{147}Pm in fused aluminosilicate is plotted in Figure 2.2. One MBq of ^{147}Pm /g lung initial lung burden = 46 Gy (4600 rad) at 365 days after inhalation or 53 Gy (5300 rad) at 900 days. The radioactive label ^{169}Yb contributed about 1% of the total dose to the lung. Estimates of cumulative rads to the lung at death for each rat are provided in the Appendix. Caution should be taken in using dose to death for analysis of dose-effect relationships because these doses represent random variables. To use doses to death, one must adjust for the fact that the doses are, in part, dictated by the death of the animals as well as the experimental design. Use of dose to death to form dose groups for dose-effect analysis can lead to results that are in error by several orders of magnitude when hundreds of animals are involved. In this report, cumulative doses to a specified time have been used in the analyses.

Calculated cumulative doses to 900 days (approximate median life span for controls) are provided in the Appendix along with the 30-day doses. The 30-day dose is the basis upon which an early-effects mortality model has been developed at Pacific Northwest Laboratory (Filipy *et al.*, 1980). Given an initial lung burden and lung retention function, doses to a specified time can be calculated before an individual dies and therefore are more useful for making predictions than dose to death.

2.2 Calculated pulmonary dose accumulation pattern after inhalation of ^{147}Pm in fused aluminosilicate particles.

2.3.2 Survival Distribution

Survival times for each rat were recorded to the end of the study period at 1.5 years after inhalation exposure and are plotted in Figure 2.3 and given in the Appendix. The mean survival time was about 254 days. The original protocol called for observations to 1 year after exposure. However, 15% of the rats that died of radiation pneumonitis before 1 year died between 300 and 365 days after exposure. The observation period was, therefore, extended to ascertain the potential bias in risk estimates derived from limiting the observations to one year. During the first 365 days after exposure, 55 rats died; 95% of these died of radiation pneumonitis and 5% had lung tumors. Between 365 days and 540 days after exposure, 43 rats died, 10 of radiation pneumonitis and pulmonary fibrosis and 25 of lung tumors. The survival distribution of the rats that died of radiation pneumonitis is shown in Figure 2.4.

- 2.3 Time to death from radiation pneumonitis and its relation to initial lung burden after inhalation of ^{147}Pm in fused aluminosilicate particles. Triangles represent time to death or euthanasia due to radiation pneumonitis. The horizontal bar represents survivors at the end of the study. Open circles represent lung tumors and closed circles represent other effects.

- 2.4 Distribution of survival times for rats dying of radiation pneumonitis and pulmonary fibrosis after inhalation of ^{147}Pm in fused aluminosilicate particles. Vertical ticks bracket the time intervals.

Examination of the rats that died revealed several causes of death (see Appendix). The most prevalent cause was radiation pneumonitis and pulmonary fibrosis. It was characterized by increased numbers of vacuolated alveolar macrophages and occasional neutrophils, alveolar fibrosis, alveolar hemosiderin, vasculitis and fine alveolar septal fibrosis. Thrombosis was also present occasionally. Radiation pneumonitis and pulmonary fibrosis were considered the cause of death when these characteristics were found and there was no other obvious cause of death.

Primary lung tumors were also a major cause of death. Hemangiosarcomas and squamous cell carcinomas were the major types observed. One adenocarcinoma was found. The cause of death was determined by examination of each case and evaluation of the size and presence of metastasis of the tumor. Two leukemias that involved the lung were also found. They were not considered radiation-induced but were judged to be the spontaneous granular cell leukemia commonly seen in F344 rats.

The first rat to die with radiation pneumonitis died at 161 days after exposure with a dose to death of 390 Gy (39,000 rad). Two rats died before this time, one at 6 days after exposure and a second at 131 days after exposure. Neither of these deaths was judged related to the radiation exposure and the animals were excluded from all dose-effect analyses.

The death of the first rat with a lung tumor occurred 199 days after exposure with a dose to death of 430 Gy (43,000 rad). Although this rat had two primary lung tumors, an hemangiosarcoma and a squamous cell carcinoma, radiation pneumonitis was considered the cause of death. The first rat to die with a lung tumor as the primary cause of death, died 322 days after exposure with a dose to death of 330 Gy (33,000 rad). The tumor type was hemangiosarcoma. The prevalences of tumors among all rats that died or were euthanized or sacrificed between 1 and 1.5 years after exposure that were submitted to histopathological examination are given in Table 2.2. Hemangiosarcomas were more prevalent in the higher dose groups compared to the prevalence of carcinomas.

Table 2.2
Number of Lung Tumors to 1.5 Years After Exposure in Rats Exposed by Inhalation
to ^{147}Pm in Fused Aluminosilicate Particles

Number of Rats	Dose Range (Gy) ^a	Average Dose (Gy) ^b	Squamous Carcinoma	Hemangio- Sarcoma	Adeno- Carcinoma	Other Tumors	Total Lung Tumors	Lung Tumors per Rat ^c
40	10 - 80	40	1	0	0	0	1	0.025
40	80 - 130	100	3	3	0	0	6	0.15
30	130 - 240	160	1	6	1	0	8	0.27
30	260 - 570	360	6	13	0	3	22	0.73

^aOne Gray = 100 rad.

^bOne year doses to lungs.

^cNo tumors observed among control rats.

2.3.3 Body Weight Data

In analyzing body weight data, two plausible models were considered: (1) a constant weight-gain model, and (2) a constant percentage weight-gain model. With both these models, body weight gain was negatively correlated with radiation dose and was uncorrelated with initial body weight. The data were examined to determine if percentage body weight gain or body weight gain were correlated with initial body weight. As shown in Figures 2.5 and 2.6, the percentage body weight gain for control females and males over a 10-week period after exposure was negatively correlated with the initial body weight. Similar results were obtained at all other times after exposure that body weights were recorded. The negative correlation indicates that the constant percentage weight-gain model is not a plausible model.

2.5 Percent body weight gain at 10 weeks after exposure vs initial weight for male control rats.

2.6 Percent body weight gain at 10 weeks after exposure vs initial weight for female control rats.

A similar analysis was done for the constant weight-gain model. Figures 2.7 and 2.8 demonstrate that body weight gain at 10 weeks after exposure was not correlated with initial body weight for either sex. Similar results were obtained at all other times that weights were recorded. These results suggest that the constant weight-gain model is more plausible than the constant percentage weight-gain model. Therefore, only the constant weight-gain model was used in the analysis of body weight data.

2.7 Body weight gain at 10 weeks after exposure vs initial weight for male control rats.

2.8 Body weight gain at 10 weeks after exposure vs initial weight for female control rats.

2.9 Body weight gain for male rats after inhalation exposure to ^{147}Pm in fused aluminosilicate particles. Four groups are: controls, low, medium, and high that have doses in units of D_{50} of 0, 0.003-0.44, 0.44-1.2 and 1.2-1.8, respectively.

Body weight gain vs days after exposure for males and females assigned to specific dose groupings are plotted in Figures 2.9 and 2.10. For males, the low, medium and high dose groups had initial lung burdens that ranged from 20-3100, 3100-8700, and 8900-12,900 kBq/g lung, respectively. For females, the ranges were 70-3200, 3900-8100 and 8400-18,000 kBq/g lung, respectively. For males, group-averaged initial lung burdens for the low, medium and high dose groups were 1700, 6100 and 10,300 kBq/g lung, respectively. For females, the respective averages were 1600, 6500 and 11,800 kBq/g lung. Reduced weight gains are present only for animals receiving lethal or nearly lethal doses (high and medium dose groups).

2.10 Body weight gain for female rats after inhalation exposure to ^{147}Pm in fused aluminosilicate particles. Four groups are: controls, medium, and high that have doses in units of D_{50} of 0, 0.017-0.70, 0.83-1.7 and 1.8-3.8, respectively.

2.3.4 Hematological Data

Hematological measurements were repeatedly performed on the same 20 males and 20 females assigned to the hematology group. Hematological measurements recorded before exposure and 7, 14, 30, 60, 90, 180, and 540 days after exposure included red and white blood cell concentrations, differential white cell counts, platelet concentration, hematocrit, and % hemoglobin concentration. Based on the 95% confidence interval for the correlation coefficient, none of the hematology measurements was significantly correlated with time after exposure or radiation dose to lung.

Plots of lymphocyte concentration vs time after exposure are given in Figure 2.11 for low, medium and high dose groups as well as controls. For the low dose group, initial lung burdens ranged from 20 to 1300 kBq/g lung. For the medium dose group, initial lung burdens ranged from 1600 to 6300 kBq/g lung. For the high dose group, initial lung burdens ranged from 7500 to 13,600 kBq/g lung. In these plots, no dose-related depression in lymphocyte concentration is apparent. These results indicate that low energy beta emissions from ^{147}Pm in rat lungs are insufficient to cause detectable injury to the hematopoietic system.

2.3.5 Mortality Data

Risk estimators have been developed for lethality from radiation pneumonitis during the first 1.5 years after exposure. Only individuals listed in the Appendix as having radiation pneumonitis as the major finding at death were considered as dying from radiation pneumonitis.

A maximum likelihood procedure was used in the analysis because data from individual rats, rather than groups of rats, could then be used (SAS, 1982). This eliminated the systematic error associated with forming dose groups which generally leads to underestimating the slope of the dose effect curve.

A Weibull-type risk function has been used to describe lethality. It can be characterized by the median lethal dose, D_{50} , and shape parameter, V (Scott and Hahn, 1985). With the Weibull model, the cumulative hazard H is related to the lethality risk, R , by

$$R = 1 - \exp(-H)$$

where

$$H = \ln(2) * [D/D_{50}]^V.$$

2.11 Lymphocyte concentration after inhalation exposure (males and females combined): low = D_{50} units of 0.003-0.22, moderate = D_{50} units of 0.26-1.1, high = D_{50} units of 1.3-2.3.

The variable D is the radiation dose evaluated to a specified time and D_{50} is in the same units as D . The time chosen to which the doses would be calculated was the median survival time of the control animals (900 days). This calculation yields a dose that is essentially the same as the potential infinite dose to the lungs. However, the median lethal dose in terms of kBq/g lung initially deposited in the lung (ILB's), as well as the shape parameter, was first estimated. This value was then converted to the appropriate radiation dose in Gy. This eliminated the systematic error contribution to the shape parameter estimate that arises from errors in the dose accumulation curve. The median lethal initial lung burden was 5900 ± 180 kBq/g lung. This corresponds to a 900-day dose of 310 ± 11 Gy (31,000 rad) to the lung. The shape parameter (or slope) V was estimated to be 5.4 ± 0.9 . A graphic illustration of the shape of the curve described by these parameters is shown in Figure 2.12.

2.12 Dose-response curve for death from radiation pneumonitis after inhalation of ^{147}Pm in fused aluminosilicate particles by rats.

2.4 DISCUSSION

This study demonstrates that, while low-energy beta irradiation from ^{147}Pm deposited in the lung caused deaths from radiation pneumonitis and pulmonary fibrosis, it did not cause a reduction in peripheral blood cell counts when the radioactivity was mainly localized in the lung. These results indicate that injury to the hematopoietic system due to beta radiations transversing from the lung to the bone marrow or blood was not significant enough to reduce peripheral blood counts.

Changes in body weight were evaluated as an indicator of illness or morbidity. The results show that body weight is a poor choice as an indicator of morbidity in the nonlethal dose range. Effects on body weight were observed mainly in animals within the lethal dose range.

The prevalence of lung tumors among rats that died or were euthanized or sacrificed between 1 and 1.5 years after inhalation exposure and submitted for histopathological evaluation was analyzed in terms of the calculated cumulative dose to 1 year (Table 2.2). The total prevalence of lung tumors per rat increased monotonically from 0.025 at an average dose of 40 Gy (4000 rad) to 0.73 at an average dose of 360 Gy (36,000 rad). This means that a 9-fold increase in dose was associated with an approximate 30-fold increase in tumor prevalence over the dose range considered and is indicative of a nonlinear dose-effect relationship. Because of the known inverse relationship between time to tumor occurrence and radiation dose, the observation of a nonlinear relationship for tumor-prevalence vs dose for the 1 to 1.5 year time interval does not rule out the possibility of a linear relationship for the tumor prevalence at a longer time after exposure.

2.5 SUMMARY

This chapter of the report describes data for early mortality and morbidity among rats exposed via inhalation to the low-energy beta emitter ^{147}Pm . The purpose of the ^{147}Pm experiment was to provide a reference data set to be used with the results discussed in Chapter 3 for the high-energy beta emitter ^{90}Sr to determine if significant injury to the hematopoietic system occurs from high-energy beta emitters deposited and remaining in the lung. The ^{147}Pm was delivered via inhalation of an insoluble fused aluminosilicate particle matrix that also contained a small amount of ^{169}Yb as tracer to determine retention of the particles in the lung. Changes in lung weights with time after exposure were taken into consideration in evaluating radiation doses to the lung. The lungs of irradiated rats were assumed to have the same growth curve as did the unirradiated controls.

No effects were observed on the peripheral blood of irradiated rats. This indicates that cross-organ irradiation effects are not likely to be significant after inhalation exposure of rats to ^{147}Pm when inhaled in an insoluble aerosol. Cross-organ irradiation effects in larger species would be even less.

It was demonstrated that body weight was a poor choice for indicating morbidity in the sublethal dose range. Significant effects on body weight were observed only in rats in the lethal dose range.

While no lung tumors were induced in control rats, a spectrum of primary lung tumors were produced in irradiated rats. Most prevalent were hemangiosarcomas, followed by squamous cell carcinomas. The prevalence of lung tumors among rats that died or were euthanized or sacrificed between 1 and 1.5 years after inhalation exposure increased with dose, but in a nonlinear fashion.

CHAPTER 3

THE INFLUENCE OF RADIATION DOSE RATE PATTERN ON EARLY EFFECTS IN THE LUNG

3.1 INTRODUCTION

This chapter describes morbidity and mortality data developed from rats that inhaled mixtures of ^{90}Sr and ^{90}Y in fused aluminosilicate particles. Three experiments were conducted, each with aerosols of different mixtures of ^{90}Y + ^{90}Sr that yielded different temporal beta irradiation patterns of the lung. Biological data obtained included hematology, body weight, pulmonary function, survival time and likely cause of death that can be used to develop morbidity and validate mortality models.

Exposure of rat lungs to beta radiation from mixtures of ^{90}Y + ^{90}Sr inhaled in fused aluminosilicate particles leads to a complex dose rate pattern to the lung. In Phase I, a model was developed that allows the prediction of the lethality risk for deaths from radiation pneumonitis when exposed to complex dose rate patterns. The mortality data described in this chapter will be used to test the mortality model.

3.2 METHODS

3.2.1 Animals and Animal Maintenance

Equal numbers of male and female F344/Cr1 rats were exposed by inhalation when they were approximately 15 ± 2 weeks of age. They were obtained from the breeding colony of the Lovelace Inhalation Toxicology Research Institute. Before exposure, members of each sex were weighed, ear tagged and housed separately, 2 per cage, in polycarbonate cages (25 x 48 x 20 cm high) with hardwood chip bedding and filter caps. The room housing the rats was maintained at 68 to 72°F and the relative humidity was maintained at 20 to 50%. A 12-hour-on, 12-hour-off light cycle was used. Rats were fed (Lab Blox, Allied Mills, Chicago, IL) and given water ad libitum. After inhalation exposure the animals were returned to their quarters and maintained in a similar fashion.

3.2.2 Biological Measurements

Hematological measurements were recorded before exposure and at 7, 14, 30, 60, 90, 180 and 360 days after exposure for rats in the hematology groups. Hematological determinations included the red and white blood cell concentrations, differential white blood cell counts and the hematocrit. The rats were bled from the retrobulbar sinus. Blood smears were made and the blood diluted in Unopettes®. Blood cell concentrations were performed with an electronic blood cell counter (Coulter S550).

Rats in all groups were weighed one week before exposure and on weeks 2, 4, 6, 8, 10 and then once a month thereafter to one year.

Pulmonary function measurements were made on a predesignated group of ^{90}Sr -exposed rats at 1-2 weeks before exposure and 60, 90, 180, 270, 360 and 540 days after exposure. In addition, 48 surviving rats in the mortality group exposed to ^{90}Y FAP were tested at 1.5 years after inhalation exposure. The function measurements determined were breathing patterns, dynamic mechanics, diffusion capacity, maximum expiratory flow, quasistatic compliance of lung and lung volume. Measurements were made with a 1.5-liter combination flow (volume displacement) and pressure (constant volume) plethysmograph using procedures previously published (Harkema *et al.*, 1982 and Mauderly, 1982).

3.2.3 Aerosol Preparation And Generation

The stock suspensions used for aerosol generation were prepared by cation exchange of the radionuclide or radionuclide mixture of interest into montmorillonite clay. For the ^{90}Sr aerosol generator stock solution, an equilibrium mixture of ^{90}Sr and ^{90}Y was exchanged and a 10 day period

was used to achieve equilibrium. This was necessary because of a higher exchange specificity of day for the $[Y^{+3}]$ cations versus the $[Sr^{+2}]$ cations. For the ^{90}Y generator stock solution, pure ^{90}Y was exchanged into the clay. The ^{90}Y was obtained by preparing and filtering an yttrium hydrogen phosphate colloidal suspension from ^{90}Sr , in secular equilibrium with ^{90}Y , on the day of exposure. For the combined ^{90}Sr and ^{90}Y aerosol generator stock solution, pure ^{90}Y was prepared on the day of exposure and added to ^{90}Sr (in secular equilibrium with ^{90}Y) to achieve a $^{90}Y:^{90}Sr$ radioactivity ratio of approximately 3:1. The concentration of radionuclide in the clay was adjusted by adding unlabeled clay as necessary to produce an aerosol that yielded the desired initial lung burdens.

The aerosols were generated from the stock solution using an air flow rate of 1.5 Lpm through a Lovelace nebulizer, passed through a heating column at $1100^{\circ}C$, diluted with clean air and directed into the exposure chamber using a total volume flow rate of 20 Lpm.

Nose-only exposures were done using an 80-port small animal exposure chamber. Cascade impactor, filter, and electrostatic precipitator (ESP) samples were taken at the beginning and near the end of each exposure; these samples were used to determine physical characteristics of the aerosols and the aerosol radioactivity during inhalation exposure.

The particle size distribution was lognormal with an activity median aerodynamic diameter of approximately $2\ \mu m$ and geometric standard deviation of approximately 1.5 to 2.0.

3.2.4 Whole-Body Counting Procedures

Shielded NaI(Tl) crystal counters were used to detect the Bremsstrahlung radiation from ^{90}Sr deposited in the rats. One- or two-minute whole-body counts were made immediately after inhalation exposure and on 3, 4, 5, 6, 7 and 8 days after exposure. Thereafter, rats were counted at monthly intervals. Appropriate reference standards were used including a counting phantom that simulated a typical lung burden in a rat.

3.2.5 Determination of Lung and Bronchial Lymph Node Radioactivity

The ^{90}Sr contents of the lung and bronchial lymph nodes were determined on animals that died or were euthanized during the observation period and those sacrificed at the end of 1.5 years. At necropsy, whole-body, lung and bronchial lymph node weights were taken. Fixed lung and lymph node tissue remaining after sampling for histopathology were wet-ashed, sampled in triplicate and counted using liquid scintillation techniques to determine the content of ^{90}Sr . Corrections were made for quench using external standards and for loss of tissue sampled for histopathology.

3.2.6 Estimation of Initial Lung Burdens

3.2.6.1 Rats Exposed to ^{90}Sr

Initial lung burdens of ^{90}Sr were estimated from the measurements of whole-body activity of ^{90}Sr at various times after inhalation exposure. To determine what percentage of the whole-body burden was in the lung, two rats (one male and one female) were sacrificed on the day of exposure and two (one male and one female) were sacrificed at 5 days after exposure and analyzed radiochemically. At 5 days after exposure, 79% of the body burden of ^{90}Sr was in the lung. Based on an exploratory data analysis, it was judged that the ^{90}Sr in the lung at 5 days was more representative of the counting data taken 4 to 8 days after exposure than the ^{90}Sr found in the lung of the rats sacrificed immediately after exposure. Assuming 79% of the total body burden at 4 to 8 days after exposure to be in the lungs, initial lung burdens were estimated by extrapolating back to the day of exposure using the same procedure that was used for ^{147}Pm . The initial lung burden estimates obtained for each rat in this way are given in the Appendix.

3.2.6.2 Rats Exposed to ^{90}Y

Initial lung burdens were estimated by first estimating the ^{90}Y initial lung burden based on whole-body counts at early times when ^{90}Y was still present. From radioactive decay measurements on the filters collected during exposure, it was determined that 2.3% of the

initial activity in the lung was due to ^{90}Sr carried over when the ^{90}Y stock generator solution was prepared. The fraction of the total-body activity at early times T (in days) that was due to ^{90}Y was estimated using

$$\text{Fraction} = 0.977 \exp(-0.26T) / [0.023 + 0.977 \exp(-0.26T)].$$

Multiplying the above fraction by 0.79 and multiplying the whole-body activity (determined from whole-body counting) at time T by the product gave the estimated ^{90}Y activity in the lung. Initial lung burdens of ^{90}Y were estimated by correcting for biological clearance and physical decay of ^{90}Y .

Initial lung burdens of ^{90}Sr were estimated based on 2.3% of the initial activity being due to ^{90}Sr and the remaining 97.7% due to ^{90}Y . The ^{90}Sr initial activity in the lung was estimated by multiplying the ^{90}Y initial activity by 0.023. The total activity ($^{90}\text{Y} + ^{90}\text{Sr}$) initially in the lung was approximately equal to the ^{90}Y initial activity.

3.2.6.3 Rats Exposed to $^{90}\text{Y} + ^{90}\text{Sr}$

Initial lung burdens were estimated by first estimating the ^{90}Sr initial lung burden based on whole-body counts at intermediate times when ^{90}Y decay was essentially completed. Using whole-body counting data, and correcting for biological clearance, physical decay, and percent of total activity not in lung (21%), initial lung burdens of ^{90}Sr were estimated by extrapolating back to the time of exposure.

Initial lung burdens for ^{90}Y were then estimated based on 75% of the initial activity in lung being due to ^{90}Y and 25% due to ^{90}Sr . Thus the ^{90}Y initial activity was obtained by multiplying the ^{90}Sr initial activity by 3. The estimated total activity initially in the lung was therefore 4 times that for ^{90}Sr .

3.2.7 Experimental Design

The experimental designs for the exposures to the three combinations of ^{90}Sr and ^{90}Y are presented in Tables 3.1, 3.2 and 3.3. Equal numbers of males and females were randomly assigned to each designated group. For the rats exposed to ^{90}Sr only (Table 3.1) three separate groups of rats were designated: mortality, hematology and pulmonary function. The rats in the mortality group were weighed periodically and observed twice daily for sickness or death for 1.5 years after exposure. Rats in the hematology group were bled periodically for hematology tests as well as being weighed and observed. Rats in the pulmonary function group were tested periodically for pulmonary function in addition to being weighed and observed. The hematology and pulmonary function groups were maintained as distinct groups so that any bias in the survival time or incidence introduced by the increased handling and the testing procedures could be determined.

The numbers of rats needed to yield significant results were determined from response-probability estimates shown in Table 3.4 (Crow *et al.*, 1960). For studies of hematologic changes the number per group (10) was a compromise among the number necessary for valid statistics (6 per group), the number that could be processed per day and the probability of the number decreasing with time as the rats die of early effects. For studies of pulmonary functional changes, groups of 20 were chosen based on analysis of pulmonary functional abnormalities in dogs after inhalation of ^{144}Ce in fused aluminosilicate particles (Mauderly *et al.*, 1980).

The initial lung burdens desired were chosen to give 1%, 50% and 99% chance of survival to 1.5 years after inhalation exposure. A wide range of doses was chosen for two primary reasons. First, the low and high ends of the dose-response curve are the regions of most uncertainty, thus more information is needed there. Second, with inhalation exposure of a group of animals, a range of initial lung burdens results that span the desired initial lung burden by a factor of at least two. The range of initial lung burdens is due to different pulmonary depositions and retentions in the group of animals as well as some variations in aerosol concentrations at different points in the exposure chamber.

Table 3.1
Experimental Design for Rats Exposed by Inhalation to ⁹⁰Sr
In Fused Aluminosilicate Particles

Exposure Group	Desired Initial Lung Burden (MBq) ^a	Calculated		Number of Rats ^c	
		Initial Dose Rate to Lung- Gy/Day ^b	Mortality	Hematology	Pulmonary Function
L00 (Controls)	0	0	40	10	20
L01	0.15	0.70	40	10	20
L50	0.67	3.10	40	10	20
L99	0.93	4.30	<u>40</u>	<u>10</u>	<u>20</u>
			160	40	80
Combined Total = 280					

^aOne MBq = 27 μ Ci.

^bOne Gray = 100 rad.

^cEqual numbers of males and females in each group.

Table 3.2
Experimental Design for Rats Exposed by Inhalation to ⁹⁰Y
In Fused Aluminosilicate Particles

Exposure Group	Desired Initial Lung Burden (MBq) ^a	Calculated		Number of Rats ^c	
		Initial Dose Rate to Lung- Gy/Day ^b	Mortality ^d	Hematology	
L00 (Controls)	0	0	60	10	
L01	5.6	22	60	10	
L50	6.9	27	60	10	
L99	8.3	32	<u>60</u>	<u>10</u>	
			240	40	
Combined Total = 280					

^aOne MBq = 27 μ Ci.

^bOne Gray = 100 rad.

^cEqual numbers of males and females in each group.

^dAt the end of the study, 48 survivors were subjected to pulmonary function testing.
This included 6 control males and 6 control females.

Table 3.3
Experimental Design for Rats Exposed by Inhalation to $^{90}\text{Sr} + ^{90}\text{Y}$
In Fused Aluminosilicate Particles

Exposure Group	Desired Initial Lung Burden (MBq) ^a	Calculated	Number of Rats ^c	
		Initial Dose Rate to Lung		
		Gy/Day ^b	Mortality	Hematology
L00 (Controls)	0	0	60	10
L01	0.59	2.40	60	10
L50	2.2	8.70	60	10
L99	2.7	11.0	<u>60</u>	<u>10</u>
			240	40
			Combined Total = 280	

^aOne MBq = 27 μCi .

^bOne Gray = 100 rad.

^cEqual numbers of males and females in each group.

Table 3.4
Response Probability Estimates for 20, 30 or 50 Rats Per Group

Dose	Theoretical Effect Probability	95% Confidence Range of Expected Probability for Various Group Sizes		
		20 Rats	30 Rats	50 Rats
D01	0.01	< 0.14	< 0.05	< 0.05
D50	0.50	0.29 - 0.71	0.32 - 0.68	0.35 - 0.65
D99	0.99	> 0.86	> 0.95	> 0.95

Values for D01 represent upper bounds.

Values for D99 represent lower bounds.

Because of the variability in initial lung burdens, analysis of the data with animals placed in discrete groups before exposure is difficult. Therefore, analysis was done by determining doses for each animal and regrouping into dose groups or treating each animal individual in dose-response analyses.

The experimental design for the rats exposed to ^{90}Y only is shown in Table 3.2. Only two groups of rats were designated, mortality and hematology. However, at the end of the 1.5 year observation period 48 surviving rats were subjected to pulmonary function testing. This differs from the rats exposed to ^{90}Sr since sequential data was not obtained in the ^{90}Y study.

The experimental design for the rats exposed to ^{90}Y mixed with ^{90}Sr is shown in Table 3.3. No pulmonary function testing was done on these rats.

3.3 RESULTS

3.3.1 Radiation Doses to Lung

3.3.1.1 Rats Exposed to ^{90}Sr

An exploratory data analysis revealed that for animals with initial lung burdens below that which killed 50% of those exposed ($D_{50} = 1170 \text{ kBq/g lung}$), the retention of radioactivity in lung was adequately represented by the retention function given by

$$\text{Retention, low level } ^{90}\text{Sr} = 0.58 \exp(-0.15T) + 0.42 \exp(-0.0046T)$$

where T represents days after exposure. However, animals with lung burdens equal to or greater than the D_{50} had increased retention of radioactivity in the lung (based on animals dying in the study at early times and radiochemical analysis of their lung); for these animals, retention of radioactivity in lung was adequately represented by the single exponential

$$\text{Retention, high level } ^{90}\text{Sr} = \exp(-0.006T),$$

where T represents days after exposure.

The cumulative radiation doses to the lung to death or doses to a specified time were determined by numerical integration over the dose rate pattern for each exposed individual. Instantaneous dose rates $DR(t)$ at any given time, t , were given by

$$DR(t) = 0.512\bar{E} \cdot A(t) \cdot f / W(t), \text{ Gy/day}$$

where

$\bar{E} = 1.13 \text{ MeV}$ for an equilibrium mixture of ^{90}Sr and ^{90}Y

$A(t)$ = the activity retained which equals the product of the initial activity times the lung retention function

f = fractional energy absorption in lung ≈ 0.3 (based on Snipes, 1980)

$W(t)$ = lung weight (g) at t days after inhalation exposure

= $0.005 \cdot [\text{initial lung weight (g)} + 124 \times GF(t)]$ for females

= $0.004 \cdot [\text{initial lung weight (g)} + 166 \times GM(t)]$ for males

where

$$GF(t) = 1 - \exp(-0.0169 \cdot t^{0.822})$$

and

$$GM(t) = 1 - \exp(-0.0133 \cdot t^{0.938}).$$

The function $W(t)$ was estimated by assuming that the lung weight was a fraction (males 0.5%, females 0.4%) of the body weight of the control rats in the study (Lundgren, 1980).

Lung retention and dose accumulation patterns in lung are plotted in Figures 3.1 and 3.2. Because most of the animals in the study were below the median lethal dose range, only the dose accumulation patterns for these animals are shown. One MBq of $^{90}\text{Sr/g lung}$ initial lung burden equalled 270 Gy (27,000 rad) at 365 days after inhalation or 320 Gy (32,000 rad) at 900 days.

3.1 Pulmonary retention pattern for inhaled ^{90}Sr in fused aluminosilicate particles. $D_{50} = 1170$ kBq/g lung or a 900 day dose of 370 Gy (37,000 rad).

3.2 Calculated pulmonary dose accumulation pattern after inhalation of ^{90}Sr in fused aluminosilicate particles.

3.3.1.2 Rats Exposed to ^{90}Y

The ^{90}Y activity in lung was assumed to be reduced mainly by physical decay of ^{90}Y (half-life of 64.1 hours). The ^{90}Sr contaminant was assumed to have the same retention in lung as ^{90}Sr administered singly. This led to the retention function for ^{90}Y with 2.3% ^{90}Sr contamination of

$$\text{retention } ^{90}\text{Y} + 2.3\% ^{90}\text{Sr} = 0.977\exp(-0.26T) + 0.0066\exp(-0.15T) + 0.0164\exp(-0.005T),$$

where T represents days after exposure.

To obtain cumulative rads to the lung, a computer program that accounts for growth of the animals was used. Calculated cumulative doses to the lung at 30 and 900 days, and at death are reported in the Appendix.

Lung retention and dose accumulation patterns in lung are plotted in Figures 3.3 and 3.4. One MBq of ^{90}Y /g lung initial lung burden equalled 19 Gy (1900 rad) at 365 days after exposure or 20 Gy (2000 rad) at 900 days.

3.3 Pulmonary retention pattern for inhaled ^{90}Y mixed with 2.3% ^{90}Sr in fused aluminosilicate particles.

3.4 Calculated pulmonary dose accumulation pattern after inhalation of ^{90}Y mixed with 2.3% ^{90}Sr in fused aluminosilicate particles.

3.3.1.3 Rats Exposed to ^{90}Y + ^{90}Sr

The ^{90}Sr in the mixture was assumed to have the same retention in lung as ^{90}Sr administered by itself. The ^{90}Y activity was assumed to be eliminated mainly by physical decay (half-life of 64.1 hours). This leads to a retention function for the mixture having 75% of the initial activity due to ^{90}Y and 25% due to ^{90}Sr given by

$$\text{Retention } ^{90}\text{Y} + 25\% ^{90}\text{Sr} = 0.75 \exp(-0.26T) + 0.071 \exp(-0.15T) + 0.179 \exp(-0.005T),$$

where T represents days after exposure.

To obtain cumulative doses to the lung, a computer program was used that accounts for growth of the animals. Calculated cumulative doses to the lung at 30 and 900 days, and at death are reported in the Appendix.

Lung retention and dose accumulation patterns in lung are plotted in Figures 3.5 and 3.6. One MBq of ^{90}Y + ^{90}Sr /g lung initial lung burden equalled 71 Gy (7100 rad) at 365 days after inhalation or 80 Gy (8000 rad) at 900 days.

3.5 Pulmonary retention pattern for inhaled ^{90}Y mixed with 25% ^{90}Sr in fused aluminosilicate particles.

3.6 Calculated pulmonary dose accumulation pattern after inhalation of ^{90}Y mixed with 25% ^{90}Sr in fused aluminosilicate particles.

3.3.2 Survival Distribution

The survival times for each rat were recorded to 1.5 years after inhalation exposure and are recorded in the Appendix. The survival times for those dying of radiation pneumonitis and pulmonary fibrosis are graphed in Figure 3.7 for ^{90}Sr , Figure 3.8 for $^{90}\text{Y} + 2.3\% ^{90}\text{Sr}$ and Figure 3.9 for $^{90}\text{Y} + 25\% ^{90}\text{Sr}$. The mean survival times and fractions of animals that died between 365 and 540 days after exposure are shown in Table 3.5. The mean survival time was much longer in rats receiving the protracted irradiation from the ^{90}Sr deposited in the lung. The survival times were not normally distributed, as shown in Figure 3.10. There was a bimodal distribution of deaths with one peak occurring between 60 and 180 days after exposure and a second, but smaller, peak, between 380 and 500 days after exposure.

Examination of the rats that died revealed several causes of death just as in the study with rats exposed to ^{147}Pm in fused aluminosilicate particles. The major findings at death are noted for each rat in the Appendix. The most prevalent cause of death was radiation pneumonitis and pulmonary fibrosis. It was characterized by increased numbers of vacuolated alveolar macrophages and occasional neutrophils, alveolar necrosis, alveolar hemosiderin, vasculitis and fine alveolar septal fibrosis. In rats that died at earlier times, the inflammatory component, radiation pneumonitis, was most prominent. At later times, fibrosis was more prominent. In a few cases, severe vasculitis with pulmonary thrombosis was a key feature.

3.7 Time to death from radiation pneumonitis and its relation to initial lung burden after inhalation of ^{90}Sr in fused aluminosilicate particles. A dose of 1 in units of the D_{50} equals a 50% lethality dose for death from radiation pneumonitis and corresponds to 1200 kBq/g lung or a 900 day dose of 370 Gy (37,000 rad). Includes animals in mortality, hematology and pulmonary function groups.

- 3.8 Time to death from radiation pneumonitis and its relation to dose after inhalation of ^{90}Y mixed with 2.3% ^{90}Sr in fused aluminosilicate particles. A dose of 1 in units of the D₅₀ equals a 50% lethality dose for death from radiation pneumonitis and corresponds to 10,000 kBq/g lung or a 900 day dose of 200 Gy (20,000 rad). Includes animals in mortality, hematology and pulmonary function groups.

- 3.9 Time to death from radiation pneumonitis and its relation to dose after inhalation of ^{90}Y mixed with 25% ^{90}Sr in fused aluminosilicate particles. A dose of 1 in units of the D₅₀ equals a 50% lethality dose for death from radiation pneumonitis and corresponds to 4000 kBq/g lung or a 900 day dose of 330 Gy (33,000 rad). Includes animals in mortality, hematology and pulmonary function groups.

Table 3.5
Comparison of Survival Times in Rats Exposed to
Beta-Emitting Radionuclides with Differing Half-times in the Lung

Radionuclide	Clearance Times						Mean	Died Between 365-540 dpe (%)
	Component 1		Component 2		Component 3		Survival	
	A ₁ (%)	t _{1/2} (days)	A ₂ (%)	t _{1/2} (days)	A ₃ (%)	t _{1/2} (days)	Time (days)	
⁹⁰ Sr	-	-	58	4.6	18	150	283	37
⁹⁰ Y + 25% ⁹⁰ Sr	75	2.7	7	4.6	18	140	223	20
⁹⁰ Y + 2.3 % ⁹⁰ Sr	97	2.7	1	4.6	2	140	97	5

3.10 Distribution of survival of times for rats dying of radiation pneumonitis and pulmonary fibrosis after inhalation of either ⁹⁰Sr, ⁹⁰Y + 2.3% ⁹⁰Sr or ⁹⁰Y + 25% ⁹⁰Sr in fused aluminosilicate particles.

3.3.3 Body Weight Data

A constant weight-gain model was used to analyze the body weight data for rats exposed by inhalation to each of the three combinations of ^{90}Sr and ^{90}Y . In addition to control rats, three dose groups were formed (low, medium, and high) for each study containing approximately the same number of individuals. Males and females were analyzed separately.

Body weight gain after exposure for males and females are plotted in Figures 3.11 and 3.12 for ^{90}Sr , Figures 3.13 and 3.14 for $^{90}\text{Y} + 2.3\% ^{90}\text{Sr}$ and Figures 3.15 and 3.16 for $^{90}\text{Y} + 25\% ^{90}\text{Sr}$. There was a decreased weight gain in all those groups of rats that had a lethal dose (a D_{50} unit dose of 1 or greater) Table 3.6. Another finding was a distinct flattening, or in the case of the $^{90}\text{Y} + 2.3\% ^{90}\text{Sr}$ study, an actual weight loss in the high dose group between 50 and 150 days after inhalation exposure. These decreases in weight gain corresponded with the times that the highest fraction of rats died of radiation pneumonitis (see Figure 3.10). Thus, reduction in weight gain and deaths from radiation pneumonitis were correlated as would be expected. There was not, however, a weight gain reduction in those groups where a majority of the rats survived.

3.3.4 Hematological Data

Hematological measurements were recorded just before exposure (baseline) and at 7, 14, 30, 60, 90, 180, and 360 days after exposure for 20 males and 20 females assigned to the hematology groups in each of the studies. For the analysis of the data, three dose groups (low, medium and high) containing approximately the same number of rats were formed for each of the three studies. Each of the parameters measured (red and white blood cell concentration, white blood cell differential count and hematocrit), in each dose group were compared with the respective control groups sampled at the same time.

The only values that were altered were the total lymphocyte counts as shown in Figure 3.17 for ^{90}Sr , Figure 3.18 for $^{90}\text{Y} + 2.3\% ^{90}\text{Sr}$ and Figure 3.19 for $^{90}\text{Y} + 25\% ^{90}\text{Sr}$.

3.3.5 Pulmonary Function Data

Pulmonary function was measured before exposure and at 2, 3, 6, 9, 12 and 18 months after inhalation exposure in a designated group of 20 control rats and of 60 rats exposed to ^{90}Sr in fused aluminosilicate particles. Pulmonary function was also measured in 12 control rats and 36 rats surviving 18 months after inhalation exposure to $^{90}\text{Y} + 2.3\% ^{90}\text{Sr}$ in fused aluminosilicate particles. The pulmonary function data for each of these rats are given in the Appendix. As shown in Figures 3.20, 3.21 and 3.22, for control males, the vital capacity, CO diffusing capacity, and quasistatic compliance are all strongly age dependent. However, as shown in Figures 3.23 and 3.24, the age dependence of the CO diffusing capacity can be eliminated by normalizing to the alveolar volume, and the age dependence of the vital capacity can be eliminated by dividing by the total lung capacity. Similar results were obtained for females, although the vital capacity, CO diffusing capacity, and quasistatic compliance were clearly different for males and females. The normalizations also tended to reduce the sex differences. These results demonstrate that both age and sex-related differences in these parameters are largely due to changes or differences in lung size.

To construct dose-effect relationships, a second normalization was carried out in which results were expressed as a percentage of control values taken at the same time after exposure as for test rats. With this normalization, data for males and females could then be combined. Values outside the range of $\pm 20\%$ of normal values are typically considered abnormal in human studies. In these studies of rats, values outside the range of $\pm 20\%$ of the mean control value were considered abnormal.

For the purposes of analysis of the rats exposed to ^{90}Sr , two groups were considered: (1) those with sublethal doses and lower dose rates that survived to 1.5 years after exposure and

3.11 Body weight gain for male rats after inhalation exposure to ^{90}Sr in fused aluminosilicate particles. Four dose groups are shown: controls, low, medium and high with average doses in units of the D_{50} of 0, 0.0, 0.1, 0.6 and 1.4, respectively.

3.12 Body weight gain for female rats after inhalation exposure to ^{90}Sr in fused aluminosilicate particles. Four dose groups are shown: controls, low, medium and high with average doses in units of the D_{50} of 0, 0.0, 0.2, 0.4 and 1.2, respectively.

3.13 Body weight gain for male rats after inhalation exposure to ^{90}Y + 2.3% ^{90}Sr in fused aluminosilicate particles. Low, medium and high groups have average doses in units of the D_{50} of 0.7, 1.3 and 2.0, respectively.

3.14 Body weight gain for female rats after inhalation exposure to ^{90}Y and 2.3% ^{90}Sr in fused aluminosilicate particles. Low, medium and high groups have average doses in units of the D_{50} of 0.5, 0.8 and 1.4, respectively.

3.15 Body weight gain for male rats after inhalation exposure to ^{90}Y + 25% ^{90}Sr in fused aluminosilicate particles. Low, medium and high groups have average doses in units of the D_{50} of 0.1, 0.3 and 0.9, respectively.

3.16 Body weight gain for female rats after inhalation exposure to ^{90}Y + 25% ^{90}Sr in fused aluminosilicate particles. Low, medium and high groups have average doses in units of the D_{50} of 0.1, 0.3 and 1.1, respectively.

Table 3.6
Comparison of Effect of Inhaled Beta Emitters on Body Weight Gain

Radionuclide Exposure	Dose Groups					
	High		Medium		Low	
	Males	Females	Males	Females	Males	Females
⁹⁰ Sr						
Average Dose*	1.4	1.2	0.6	0.4	0.1	0.2
in Group						
Effect on Weight	-	-	±	±	±	±
⁹⁰ Sr + 2.3% ⁹⁰ Sr						
Average Dose*	2.0	1.4	1.3	0.8	0.7	0.5
in Group						
Effect on Weight	-	-	±	-	0	0
⁹⁰ Y + 25% ⁹⁰ Sr						
Average Dose*	0.9	1.1	0.3	0.3	0.1	0.1
in Group						
Effect on Weight	±	-	0	0	0	0

* = Doses in units of the D₅₀. A dose of 1 represents a median lethal dose.

- = Decrease in body weight gain.

± = Marginal decrease in body weight gain.

0 = No effect on body weight gain.

3.17 Blood lymphocyte concentration after inhalation exposure to ⁹⁰Sr in fused aluminosilicate particles. Low, medium and high groups have average doses in units of the D₅₀ of 0.04-0.2, 0.2-1.0 and 1.7-2.4, respectively.

3.18 Blood lymphocyte concentration after inhalation exposure to ^{90}Y + 2.3% ^{90}Sr in fused aluminosilicate particles. Low, medium and high groups have average doses in units of D_{50} of 0.2-0.8, 0.8-1.2 and 1.2-2.2, respectively.

3.19 Blood lymphocyte concentration after inhalation exposure to ^{90}Y + 25% ^{90}Sr in fused aluminosilicate particles. Low and medium groups have average doses in units of D_{50} of 0.04-0.2 and 0.2-0.3, respectively.

3.20 Relationship of vital capacity to age (months after exposure from age 15 weeks) for control male rats. Linear regression line with 95% confidence region.

3.21 Relationship of CO diffusing capacity to age (months after exposure from age 15 weeks) for control male rats. Linear regression line with 95% confidence region.

3.22 Relationship of quasistatic lung compliance to age (months after exposure from age 15 weeks) for control male rats. Linear regression line with 95% confidence region.

3.23 CO diffusing capacity per alveolar volume as function of age (months after exposure from age 15 weeks). Linear regression line with 95% confidence region.

3.24 Vital capacity to total lung capacity ratio as function of age (months after exposure from age 15 weeks). Linear regression line with 95% confidence region.

(2) those with higher dose rates and lethal doses that died within 1.5 years after exposure. Lethal doses were near the median lethal dose (370 Gy or 37,000 rad) or higher.

Dose-effect relationships for CO diffusing capacity per alveolar volume are shown for rats that died within 1.5 years (Figure 3.25) and those that survived (Figure 3.26) after inhalation of ^{90}Sr . The results indicate that only individuals that are exposed at high dose rates which lead to death from radiation pneumonitis are likely to have impaired CO diffusing capacity. Individuals exposed at lower dose rates that do not lead to death are not likely to have such impairment. The results also indicate that individuals with lethal doses (i.e., high-dose rate exposure) can have impaired lung function at cumulative doses as low as about 150 Gy (15,000 rad) which is less than one-half of the estimated lethal dose. If one were able to turn off the radiation exposure at the time the cumulative dose was 150 Gy (15,000 rad), one would expect that those individuals with impaired pulmonary function would have survived to 1.5 years. This interpretation leads to the hypothesis that sublethal doses delivered at high dose rates can cause impaired lung function, which is supported by data for dogs and rats exposed via inhalation to ^{90}Y resulting in brief irradiation of the lung.

Dose-effect relationships for CO diffusing capacity per alveolar volume normalized to percent of control values (selected to demonstrate dose-effect relationships with age and sex biases removed) are given in Figure 3.27 for rats surviving 1.5 years after inhalation of ^{90}Y + 2.3% ^{90}Sr . Unlike the analysis of the pulmonary function data from the ^{90}Sr study, only one group was formed: those with sublethal doses that survived to 1.5 years after exposure. Nonlethal doses as low as about 150 Gy (15,000 rad), 65% of the median lethal dose, caused impaired pulmonary function. This is in contrast to the results of pulmonary function tests in 1.5 year survivors after inhalation of ^{90}Sr where no effect on function was noted.

The results indicate that, for high dose exposure of the lung, nonlethal doses as low as 65% of the median lethal dose can cause impaired pulmonary function that is observable as late as 1.5 years after exposure. These results agree with those obtained in dogs exposed via inhalation to ^{90}Y inhaled in fused aluminosilicate particles, where sublethal doses, roughly one-half the median lethal dose, caused impaired pulmonary function (Mauderly *et al.*, 1973). The tests used by Mauderly in dogs may have been more sensitive than those used in these studies in rats because his tests were conducted under the stress of treadmill exercise and added external respiratory dead space.

3.3.6 Mortality Data

The dose-response data for death due to radiation pneumonitis and pulmonary fibrosis included observations to 1.5 years after exposure. Using the Weibull model and a maximum likelihood procedure, the median lethal exposure dose (D_{50}) and shape parameter V for death from radiation pneumonitis were estimated in terms of initial lung burden for each exposure (Table 3.7). The errors represent asymptotic standard deviations. Because systematic errors in dose are not accounted for, the shape parameters should not be regarded as being different from one another. In addition, a judgement is that systematic errors could contribute as much as 40 Gy (4000 rad) to the error for the D_{50} .

Dose response curves for death from radiation-pneumonitis are shown in Figure 3.28.

3.4 DISCUSSION

An important consideration is whether the median lethal dose for death from radiation pneumonitis is the same for the low-energy beta emitter ^{147}Pm and the high-energy beta emitter ^{90}Sr (in secular equilibrium with its daughter ^{90}Y). For ^{147}Pm , the median lethal dose was estimated to be 310 Gy (31,000 rad) (900 day dose) as compared to 370 Gy (37,000 rad) for ^{90}Sr .

3.25 CO diffusing capacity per alveolar volume vs cumulative radiation dose to the lung from ^{90}Sr for various followup times. Rats of both sexes that died within 1.5 years after exposure are included.

3.26 CO diffusing capacity per alveolar volume vs cumulative radiation dose to the lung from ^{90}Sr for rats of both sexes that survived to and were tested at 1.5 years after exposure.

3.27 Dose-effect relationship for CO diffusing capacity per alveolar volume normalized to percent of control values based on measurements obtained from rats of both sexes. Cumulative Gy to the lung from ^{90}Y at the time measurements were taken are used as dose.

The results indicate an RBE of $310/270 = 1.1$ for low-energy beta emissions from ^{147}Pm relative to those from ^{90}Sr . The results suggest that for modeling the consequences of nuclear reactor accidents, low-energy beta emitters can be treated as being equally effective as high-energy beta emitters in producing lethal injury.

Table 3.7
Summary of Various Expressions of Median Lethal Doses (D_{50})
and Shape Parameters (V) for Death From Radiation Pneumonitis and Pulmonary Fibrosis

Radionuclide	D_{50} 's for Radiation Pneumonitis			Shape Parameter (V)
	365 Day Dose (Gy) ^a	900 Day Dose (Gy)	Initial Lung Burden (kBq/g lung) ^c	
^{147}Pm	270 ± 10^b	310 ± 11	$5,900 \pm 180$	5.4 ± 0.9
^{90}Sr	320 ± 10	370 ± 12	$1,200 \pm 40$	4.6 ± 0.8
$^{90}\text{Y} + 25\% ^{90}\text{Sr}$	290 ± 6	330 ± 7	$4,000 \pm 90$	5.6 ± 0.9
$^{90}\text{Y} + 2.3\% ^{90}\text{Sr}$	190 ± 7	200 ± 7	$10,000 \pm 360$	3.7 ± 0.7

^aOne Gray = 100 rad.

^bErrors are asymptotic standard deviations.

^cOne MBq = 27 μCi .

3.28 Dose response curves for death from radiation pneumonitis after inhalation of $^{90}\text{Y} + 2.3\% \text{ Sr}$, $^{90}\text{Y} + 25\% \text{ Sr}$ or ^{90}Sr in fused aluminosilicate particles by rats.

CHAPTER 4

IMPLICATIONS FOR MODELING OF REACTOR ACCIDENT CONSEQUENCES

4.1 INTRODUCTION

In this chapter, we examine how well the hazard-function model developed at ITRI predicts deaths from radiation pneumonitis in rats. It is assumed that Beagle dogs and F344 rats are equally sensitive to the induction of radiation pneumonitis in the lungs. We show that the rat data are fully explained by the model after a systematic error in model parameters is eliminated.

Implications of the rat data to the 30-day dose lethality model (Filipy *et al.*, 1980) are also discussed. With the 30-day dose model, the risk of death from radiation pneumonitis is estimated by the dose to the lung that accumulates in the first 30 days. With this model, it does not matter how much dose accumulates after 30 days. It is shown that the rat data for death from radiation pneumonitis do not support the 30-day dose lethality model.

4.2 HAZARD FUNCTION-MODEL TESTING AND REFINEMENTS

With the hazard-function model, one estimates the risk of death from radiation pneumonitis in the lung from information about the pattern of dose accumulation. The modeling assumptions were that 1) different mammalian species have equal radiosensitivities to pulmonary injury and 2) they will respond in the same way when the dose accumulation patterns and radiation qualities are the same. Differences in dose-effect relationships for death from radiation pneumonitis were attributed to differences in the dose accumulation patterns when the type of radiation and other variables (e.g., age category) were held constant.

For predicting the risk of lethal injury to the bone marrow, different species were assumed to have different sensitivities and the cross-species extrapolation procedure has been described (Scott and Hahn, 1985).

4.2.1 Dose-Effect Model for Predicting the Median Lethal Dose, D_{50} , for Radiation Pneumonitis and Pulmonary Fibrosis

The hazard-function model for death from radiation pneumonitis caused by internal beta and gamma irradiation of the lung as originally proposed allows one to predict the D_{50} in terms of the 1-year dose to the lung (Scott and Hahn, 1985). Model parameters are based on limited data for dogs exposed via inhalation to beta and gamma emitters in insoluble forms. Because the studies in dogs were designed to study late-occurring effects, the data on early effects were scant, resulting in model parameters that were uncertain.

To use the model to predict the D_{50} for radiation pneumonitis, one needs to know the fraction (f_1) of the 1-year dose that would occur within the first 14 days after exposure, the fraction (f_2) which would occur between 14 and 200 days, and the fraction (f_3 equal to $1-f_1-f_2$) that would accumulate between 200 and 365 days.

The predicted D_{50} is then obtained from the following relationship:

$$1/D_{50} = f_1/94 + f_2/220 + f_3/540$$

where the parameters 94, 220, and 540 (which represent doses to the lung in Gy) were determined from early effects data for dogs exposed via inhalation to ^{90}Y , ^{91}Y , and ^{144}Ce inhaled in fused aluminosilicate particles. The parameters represent estimated median lethal doses for varying degrees of dose protraction.

In the ^{90}Y , ^{91}Y , and ^{144}Ce studies in dogs, the average exposure times were about 4, 80, and 300 days, respectively. The approximately 6-fold increase in the D_{50} as the average exposure time increased from about 4 to 300 days demonstrates a dramatic dose-rate protraction effect. Such a dramatic dose-rate protraction effect cannot be explained solely in terms of an intracellular

repair. The results suggest that other factors, such as cell turnover, may be a major contributor in the overall repair process.

The equation for predicting the D_{50} is only applicable to exponentially decaying patterns of dose rates in the lung after inhalation exposure to beta- and gamma-emitting radionuclides. A fourth term is added when brief external exposure from gamma rays is a significant contributor to the total dose (Scott and Hahn, 1985) and a fifth term can be added to accommodate irradiation from inhaled alpha-emitting radionuclides. A discussion of the full model including effects in all organ systems will be provided in a subsequent NUREG document.

4.2.2 Patterns Of Dose Accumulation

To predict the D_{50} for death from radiation pneumonitis, one needs to know the pattern of dose accumulation in the lung to apply to the model equation. Patterns of dose accumulation for the four rat studies (^{147}Pm , ^{90}Sr , $^{90}\text{Y} + 2.3\% \text{ }^{90}\text{Sr}$, and $^{90}\text{Y} + 25\% \text{ }^{90}\text{Sr}$) are given in Figure 4.1. Values for f_1 , f_2 , and f_3 and the predicted and observed D_{50} 's are given in Table 4.1. It was assumed that the Beagle dog lung and F344 rat lung were equally sensitive to the induction of radiation pneumonitis.

4.2.3 Sample Calculation

It is useful to provide an example of how the D_{50} for death from radiation pneumonitis is predicted. The results from the ^{147}Pm study are used as an example. The fraction of the 1-year dose that would accumulate in the first 14 days is given in Table 4.1 as $f_1=0.158$. For the 14- to 200-day time interval, one gets $f_2=0.642$. For the 200- to 365-day time interval, one gets $f_3=0.2$. Note that f_1 plus f_2 plus f_3 equals to 1. The predicted D_{50} in Gy is obtained from

$$1/D_{50} = 0.158/94 + 0.642/220 + 0.2/540,$$

or

$$1/D_{50} = 0.001681 + 0.002918 + 0.00037 = 0.004969,$$

or

$$D_{50} = (1/0.004969) \text{ Gy} = 200 \text{ Gy}.$$

The observed D_{50} (1-year dose) was obtained by multiplying the median lethal initial lung burden (5880 kBq/g-lung) by the appropriate conversion factor (1.95 Gy/37kBq/g-lung) to obtain the potential infinite dose in Gy and multiplying the potential infinite dose by 0.856 to get the 1-year dose. The factor of 0.856 arises because 85.6% of the potential infinite dose accumulated in 1 year. The observed D_{50} as a 1-year dose to the lung was

$$\text{Observed } D_{50} = 5880 \times 1.95 \times 0.856 / 37 = 270 \text{ Gy}$$

The ratios of the observed to the predicted D_{50} was $270/200 = 1.3$.

4.2.4 Observed Vs Expected D_{50} 's

Ratios of observed to predicted D_{50} 's for death from radiation pneumonitis are shown in Table 4.1 for the four studies in rats. The observed-to-predicted ratio is greater than one indicating underprediction of the D_{50} in each case and suggesting a systematic error. A plausible explanation for the systematic error relates to the original selection of model parameters.

Re-examination of the data from dogs exposed to inhaled beta emitters from which the model was originally derived illustrates that a systematic error was present in the definition of the parameter estimates. A recalculation of the data resulted in new parameter estimates that allow more accurate prediction of the observed D_{50} doses for both dogs and rats exposed by inhalation to beta emitters.

The systematic error seems to be associated with the model parameters (94, 220, and 540) which correspond to median lethal doses (1-year doses in Gy) for dogs exposed to ^{90}Y , ^{91}Y , and ^{144}Ce inhaled in an insoluble form. The beta dose from ^{90}Y was delivered within about 14 days, the ^{91}Y dose within about 200 days and the ^{144}Ce dose over several years. We will use the ^{91}Y and ^{144}Ce studies to demonstrate a bias in the model parameter estimates.

4.1 Dose accumulation pattern after inhalation of ^{147}Pm , ^{90}Sr , $^{90}\text{Y} + 2.3\% \text{ } ^{90}\text{Sr}$, or $^{90}\text{Y} + 25\% \text{ } ^{90}\text{Sr}$ inhaled in fused aluminosilicate particles.

For the ^{91}Y study, the radioactivity in dog lung decreased exponentially with a half-time of approximately 53 days so that $f_1 = 0.169$, $f_2 = 0.765$ and $f_3 = 0.066$. The expected D_{50} was calculated using

$$1/D_{50} = 0.169/94 + 0.765/220 + 0.066/540$$

or

$$D_{50} = 190 \text{ Gy (19,000 rad)}.$$

The observed median lethal dose was approximately 220 Gy (22,000 rad). This predicted D_{50} is biased downward by a factor of $220/190 = 1.2$.

For the ^{144}Ce study, the radioactivity in dog lung decreased exponentially with a half-time of approximately 200 days so that $f_1 = 0.066$, $f_2 = 0.63$ and $f_3 = 0.304$. The expected D_{50} was calculated using

$$1/D_{50} = 0.066/94 + 0.63/220 + 0.304/540$$

or

$$D_{50} = 240 \text{ Gy (24,000 rad)}.$$

The observed median lethal dose was approximately 540 Gy (54,000 rad). This predicted D_{50} is also biased downward by a factor of $540/240 = 2.2$. We can easily correct for the bias using the average bias of $(1.2 + 2.2)/2 = 1.7$. Multiplying each of the model parameters 94, 220, and 540 by 1.7 and rounding leads to the bias-adjusted equation

$$1/D_{50} = f_1/160 + f_2/370 + f_3/920.$$

Table 4.1
Expected and Observed Median Lethal Doses for Death from Radiation Pneumonitis^a

Radionuclide	Fraction of			Normalized Fractions			Sum of	D ₅₀ (1-Year Gy) ^b		
	1-Year Dose			(Gy ⁻¹)			Normalized	Expected		Observed
	f1	f2	f3	f1/94	f2/220	f3/540	Fractions (F)	(1/F)	Observed	Expected
¹⁴⁷ Pm	0.158	0.642	0.200	0.00168	0.00292	0.00037	0.00497	200	270	1.3
⁹⁰ Sr	0.137	0.678	0.185	0.00146	0.00308	0.00034	0.00488	210	320	1.5
⁹⁰ Y + 2.3% ⁹⁰ Sr	0.758	0.188	0.054	0.00806	0.00085	0.00010	0.00901	110	190	1.7
⁹⁰ Y + 25% ⁹⁰ Sr	0.284	0.543	0.173	0.00302	0.00247	0.00032	0.00581	170	290	1.7

^aBased on model $1/D_{50} = f1/94 + f2/220 + f3/540$. See text for explanation.

^bOne Gray = 100 rad.

Table 4.2
Expected and Observed Median Lethal Doses for Death from Radiation Pneumonitis
Based on Bias Adjusted Formulae^a

Radionuclide	Fraction of			Normalized Fractions			Sum of	D ₅₀ (1-Year Gy) ^b		
	1-Year Dose			(Gy ⁻¹)			Normalized	Expected		Observed
	f1	f2	f3	f1/160	f2/370	f3/920	Fractions (F)	(1/F)	Observed	Expected
¹⁴⁷ Pm	0.158	0.642	0.200	0.00099	0.00174	0.000217	0.00295	340	270	0.80
⁹⁰ Sr	0.137	0.678	0.185	0.00086	0.00183	0.000201	0.00289	350	320	0.91
⁹⁰ Y + 2.3% ⁹⁰ Sr	0.758	0.188	0.054	0.00474	0.00051	0.000059	0.00531	190	190	1.0
⁹⁰ Y + 25% ⁹⁰ Sr	0.284	0.543	0.173	0.00178	0.00147	0.000188	0.00344	290	290	1.0

^aBased on model $1/D_{50} = f1/160 + f2/370 + f3/920$. See text for explanation.

^bOne Gray = 100 rad.

Predicted and observed D_{50} 's for death from radiation pneumonitis for the four studies in rats, based on the above modified equation are given in Table 4.2 and are in excellent agreement. Recall that none of the data for rats was used to make predictions. The agreement between observed and expected D_{50} 's suggest that the revised model should be adequate for reactor accident consequence modeling when only internal low-LET radiation is of concern.

4.2.5 30-Day Dose Lethality Model

According to the 30-day dose lethality model, the 30-day dose determines the lethality risk regardless of the pattern of dose accumulation in the lung. With this model, the D_{50} 's should be the same for all four studies, when expressed in terms of the 30-day dose to the lung. Table 4.3 provides values for the D_{50} expressed in 30-day and 1-year doses to the lung for the four rat studies. Using the 30-day dose model, one would conclude that more low-LET dose is needed to cause lethality when the average dose rates are the highest (^{90}Y study) than when they are the lowest (^{147}Pm and ^{90}Sr studies). Such a conclusion is contradicted by an overwhelming body of data on dose rate effects of low-LET radiation (NCRP 64, 1980) and the results of these studies.

4.2.6 Predicting Risks with the Hazard Function Model

To predict the risk of dying from radiation pneumonitis using the hazard function model, a second model parameter, the shape parameter V , is also needed in addition to the D_{50} . As shown in Table 3.7, values for V for the four rat studies were quite similar suggesting that for beta irradiation, the shape parameter does not depend on dose rate pattern. The average value for V from the four studies with beta radiation was approximately 5, which is slightly larger than the value of 4 previously used (Scott and Hahn, 1985). With a value of 5, fewer deaths would be expected in the lower tail region of the dose-effect curve than if a value of 4 was used. There is some evidence that the dose-effect curve may be considerably steeper for gamma radiation with V being approximately 10 (Scott *et al.*, 1986).

To calculate the predicted risk, one can first calculate the expected D_{50} using the relationship presented earlier. Once the D_{50} is known, the risk of death from radiation pneumonitis is given by

$$\text{Risk} = 1 - \exp[-H]$$

where

$$H = 0.693[D/D_{50}]^V$$

where D is the calculated 1-year dose to the lung in Gy.

Table 4.3
Comparison of Median Lethal Dose to Cause Death from Radiation Pneumonitis

Study	Initial		Calculated Dose (Gy) ^a			
	Lung Burden					
	MBq/g Lung ^b		30 Day	365 Day	540 Day	900 Day
$^{90}\text{Y} + 2.3\% \text{ } ^{90}\text{Sr}$	10		16 $\pm$ 5.5	190	200	200
$^{90}\text{Y} + 25\% \text{ } ^{90}\text{Sr}$	4.0		11 $\pm$ 2.3	290	310	330
^{90}Sr	1.2		7.9 $\pm$ 2.5	320	350	370
^{147}Pm	5.9		6.9 $\pm$ 2.1	270	290	310

^aOne Gray = 100 rad.

^bOne MBq = 27 μCi .

4.3 MORBIDITY DATA IMPLICATIONS

Three classes of morbidity data were examined: body weight, hematological parameters, and pulmonary function. The major implications of the data are discussed below.

4.3.1 Body Weight Data

Effects on body weight were mainly observed in rats receiving radiation induced lethal injury to the lung. For these rats, there was a period before development of lethal injury in which lethal doses accumulated and where their body weights increased. After receiving lethal injury and becoming sick, there was a plummeting in their body weight. This phenomenon occurred primarily at doses near the median lethal dose or higher. The implication of these results is that body weight is a measure of morbidity only for those individuals that are likely to have lethal injury.

Having both nonsurvivors and survivors in a dose group can lead to a short plateau in the average weight-gain vs time relationship, with the plateau corresponding to the time that the deaths from radiation pneumonitis occurred. Individuals with sublethal doses continued to gain weight in a similar fashion as unirradiated controls.

At doses approximately 2 times higher than the median lethal dose (supralethal doses), all rats died from early effects of irradiating the lung. For those rats, there was a transient increase in body weight over a short time period followed by a plummeting in the weights of all rats to values less than their initial weight.

4.3.2 Hematology Data

Effects on the hematopoietic system were only demonstrated for rats that inhaled the relatively high energy beta emitters ^{90}Sr , ^{90}Y , or $^{90}\text{Y} + ^{90}\text{Sr}$. The low energy betas from ^{147}Pm were apparently not energetic enough to reach critical targets suggesting that the critical targets were in the bone marrow rather than blood passing through the lung.

An important consideration in light of these data is whether or not irradiation of the bone marrow can affect lung sensitivity to induction of radiation pneumonitis. If significant injury to the bone marrow occurred so as to make the lung more sensitive (cross-organ interaction effect), then the D_{50} for lethality from radiation pneumonitis should be greater for ^{147}Pm than that for ^{90}Sr , because of the higher beta energies from ^{90}Sr . The ^{90}Sr and ^{147}Pm studies are appropriate to compare because dose-rate patterns were similar in the two studies, while ^{90}Sr has an average beta energy of 1.13 MeV (0.935 MeV from daughter ^{90}Y and 0.196 MeV from ^{90}Sr parent) as compared to the 0.062 MeV average beta energy for ^{147}Pm . Instead of the D_{50} for ^{147}Pm being greater than that for ^{90}Sr , it was about 1.2 times smaller, suggesting that a synergistic effect due to irradiation of both the lung and bone marrow did not occur in the dose range studied in the ^{90}Sr study. The results suggest that, while a temporary decrease in blood lymphocyte counts was demonstrated in rats exposure to high-energy beta radiation from the lung, the decrease had no observable effect on the induction of radiation pneumonitis.

These results do not mean that irradiation of the lung from internal emitters cannot affect sensitivity of an individual to whole-body irradiation where injury to the bone marrow may be the cause of death; current experiments at the Pacific Northwest Laboratory will clarify whether irradiation of the lung can affect the D_{50} for lethality from injury to the bone marrow. One might expect such an interaction effect could occur when exposed from both external photon radiation (total-body) and from internal inhaled radionuclides. Such an interaction could occur because of the role granulocytes play in protecting the body from infections. Irradiation of the lung could make infection more likely, so that when coupled with serious reduction in granulocyte cellularity by external radiation, could lead to a significant cross-organ interaction. If such an interaction is demonstrated to be quantifiable and significant, a term could be added to the hazard function model to account for it.

4.3.3 Pulmonary Function Data

Pulmonary function measurements were recorded in the ^{90}Sr and ^{90}Y studies. Dose-effect relationships for various followup times were constructed using the diffusing capacity per alveolar volume normalized as a percent of the control values. As in humans, individuals with less than 80% of the control value were judged to have impaired pulmonary function. The data clearly demonstrated that for short lived radionuclides, such as ^{90}Y which generate doses at relatively high dose rates, sublethal doses can cause impaired pulmonary function. The data also demonstrated that the long-lived radionuclide ^{90}Sr which generate doses at relatively lower dose rates than ^{90}Y , mainly produce impaired pulmonary function among individuals with initial dose rate high enough to produce about 150 Gy (15,000 rad) or more (cumulative dose) within about 2 months after exposure. However, these dose rates were high enough that lethal doses were eventually acquired by all individuals showing impaired pulmonary function at early times.

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APPENDIX: DATA BASES

Listing of rats exposed to aerosols of beta-emitting radionuclides in fused aluminosilicate particles (FAP).

1. Rats exposed to aerosols of ^{147}Pm FAP
2. Rats exposed to aerosols of ^{90}Sr FAP
3. Rats exposed to aerosols of ^{90}Y FAP
4. Rats exposed to aerosols of $^{90}\text{Y}/^{90}\text{Sr}$ FAP
5. Pulmonary function measurements in rats exposed to aerosols of ^{90}Sr FAP

1A. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO PM147-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
140	3230	F	HEMATOLOGY	118	0	540	0	0	0	ALIVE	NO LESIONS	
149	3230	F	HEMATOLOGY	119	0	540	0	0	0	ALIVE	NO LESIONS	
168	3230	M	HEMATOLOGY	241	0	540	0	0	0	ALIVE	ALVEOLAR HISTEO	
187	3230	M	HEMATOLOGY	225	0	540	0	0	0	ALIVE	NO LESIONS	
226	3230	M	HEMATOLOGY	188	0	540	0	0	0	ALIVE	ALVEOLAR HISTEO	
233	3230	M	HEMATOLOGY	232	0	540	0	0	0	ALIVE	NO LESIONS	
276	3230	F	HEMATOLOGY	138	0	540	0	0	0	ALIVE	ALVEOLAR HISTEO	
329	3230	F	HEMATOLOGY	121	0	540	0	0	0	ALIVE	ALVEOLAR HISTEO	
177	3230	M	HEMATOLOGY	220	20	540	0	0		ALIVE	ALVEOLAR HISTEO	
235	3230	M	HEMATOLOGY	245	120	540	1	10		ALIVE	ALVEOLAR HISTEO	
313	3230	F	HEMATOLOGY	129	760	540	9	40		ALIVE	ALVEOLAR HISTEO	SEPT_FIBROSIS
165	3230	M	HEMATOLOGY	193	800	540	9	40		ALIVE	ALVEOLAR HISTEO	
369	3230	F	HEMATOLOGY	104	840	540	10	40		ALIVE	ALVEOLAR HISTEO	
340	3230	F	HEMATOLOGY	125	890	556	10	50	40	DIED	ALVEOLAR HISTEO	
244	3230	M	HEMATOLOGY	195	930	540	11	50		ALIVE	ALVEOLAR HISTEO	
161	3230	M	HEMATOLOGY	241	1190	540	14	60		ALIVE	ALVEOLAR HISTEO	SEPT_FIBROSIS
278	3230	F	HEMATOLOGY	124	1250	540	15	70		ALIVE	ALVEOLAR HISTEO	SEPT_FIBROSIS
354	3230	M	HEMATOLOGY	206	1310	540	15	70		ALIVE	ALVEOLAR HISTEO	
116	3230	M	HEMATOLOGY	264	1550	540	18	80		ALIVE	RAD_PNEUMONITIS	SEPT_FIBROSIS, SQUAM_CELL_PAP
316	3230	F	HEMATOLOGY	120	1680	540	20	90		ALIVE	ALVEOLAR HISTEO	
122	3230	M	HEMATOLOGY	217	2140	540	25	110		ALIVE	ALVEOLAR HISTEO	SQUAM_CELL_CA
290	3230	M	HEMATOLOGY	205	2320	540	27	120		ALIVE	ALVEOLAR HISTEO	SEPT_FIBROSIS
322	3230	F	HEMATOLOGY	95	2480	540	29	130		ALIVE	ALVEOLAR HISTEO	HEMANGIOSARCOMA
205	3230	F	HEMATOLOGY	119	2570	525	30	140	120	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
107	3230	M	HEMATOLOGY	266	2730	533	32	140	150	EUTHANIZED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
195	3230	F	HEMATOLOGY	123	5260	275	62	280	210	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
338	3230	F	HEMATOLOGY	131	6110	374	72	320	280	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS, HEMORRHAGE
336	3230	F	HEMATOLOGY	110	6300	365	74	330	270	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS, HEMORRHAGE
213	3230	F	HEMATOLOGY	125	7470	385	88	390	340	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
241	3230	M	HEMATOLOGY	247	8150	262	96	430	350	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
123	3230	M	HEMATOLOGY	239	8560	242	101	450	350	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
272	3230	F	HEMATOLOGY	114	8640	254	102	460	330	DIED	RAD_PNEUMONITIS	
136	3230	F	HEMATOLOGY	140	9160	207	108	480	340	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
221	3230	M	HEMATOLOGY	200	9770	297	115	520	410	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
289	3230	M	HEMATOLOGY	207	10720	205	126	570	390	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
181	3230	M	HEMATOLOGY	236	11660	177	137	610	410	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
159	3230	F	HEMATOLOGY	117	13640	244	160	720	520	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, PULMONARY_THROMBOSIS
108	3230	M	MORTALITY	270	0	327	0	0	0	DIED	CONGESTION	
147	3230	F	MORTALITY	122	0	792	0	0	0	EUTHANIZED		
148	3230	F	MORTALITY	126	0	761	0	0	0	DIED		
150	3230	F	MORTALITY	118	0	944	0	0	0	DIED		
151	3230	F	MORTALITY	133	0	326	0	0	0	DIED	ALVEOLAR HISTEO	
166	3230	M	MORTALITY	230	0	1103	0	0	0	DIED		
172	3230	M	MORTALITY	225	0	750	0	0	0	DIED		
173	3230	M	MORTALITY	240	0	775	0	0	0	EUTHANIZED		
189	3230	M	MORTALITY	202	0	522	0	0	0	UNRESOLVED		
207	3230	F	MORTALITY	123	0	918	0	0	0	DIED		
212	3230	F	MORTALITY	140	0	947	0	0	0	DIED		
215	3230	F	MORTALITY	131	0	609	0	0	0	DIED		
240	3230	M	MORTALITY	246	0	568	0	0	0	DIED		

1B. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO PM147-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
248	3230	M	MORTALITY	224	0	830	0	0	0	DIED		
258	3230	F	MORTALITY	121	0	790	0	0	0	EUTHANIZED		
263	3230	F	MORTALITY	104	0	988	0	0	0	DIED		
264	3230	F	MORTALITY	113	0	870	0	0	0	EUTHANIZED		
269	3230	F	MORTALITY	126	0	790	0	0	0	EUTHANIZED		
271	3230	F	MORTALITY	114	0	982	0	0	0	EUTHANIZED		
275	3230	F	MORTALITY	131	0	852	0	0	0	EUTHANIZED		
281	3230	M	MORTALITY	236	0	231	0	0	0	DIED	PNEUMONIA	SEPT_FIBROSIS
285	3230	M	MORTALITY	214	0	838	0	0	0	DIED		
291	3230	M	MORTALITY	249	0	743	0	0	0	EUTHANIZED		
299	3230	M	MORTALITY	249	0	832	0	0	0	EUTHANIZED		
301	3230	M	MORTALITY	256	0	638	0	0	0	DIED		
302	3230	M	MORTALITY	257	0	760	0	0	0	DIED		
309	3230	M	MORTALITY	210	0	870	0	0	0	EUTHANIZED		
337	3230	F	MORTALITY	113	70	783	1	4	4	EUTHANIZED		
368	3230	F	MORTALITY	129	90	848	1	5	5	DIED		
246	3230	M	MORTALITY	245	100	921	1	10	10	EUTHANIZED		
255	3230	F	MORTALITY	114	100	789	1	10	5	EUTHANIZED		
190	3230	M	MORTALITY	194	100	758	1	10	10	DIED		
249	3230	M	MORTALITY	179	110	802	1	10	10	EUTHANIZED		
214	3230	F	MORTALITY	125	110	901	1	10	10	EUTHANIZED		
349	3230	M	MORTALITY	204	140	649	2	10	10	DIED		
115	3230	M	MORTALITY	259	170	679	2	10	10	EUTHANIZED		
253	3230	F	MORTALITY	120	180	832	2	10	10	DIED		
124	3230	M	MORTALITY	227	230	941	3	10	10	DIED		
335	3230	F	MORTALITY	94	290	881	3	20	10	EUTHANIZED		
265	3230	F	MORTALITY	97	300	716	3	20	10	DIED		
358	3230	F	MORTALITY	126	520	865	6	30	30	DIED		
331	3230	F	MORTALITY	104	600	1028	7	30	30	UNRESOLVED		
167	3230	M	MORTALITY	196	780	467	9	40	40	DIED	ALVEOLAR_HISTEO	
323	3230	F	MORTALITY	105	860	603	10	50	40	EUTHANIZED		
356	3230	F	MORTALITY	110	860	733	10	50	40	EUTHANIZED		
228	3230	M	MORTALITY	190	900	686	11	50	50	DIED		
314	3230	F	MORTALITY	127	920	538	11	50	50	DIED	NO_LESIONS	
274	3230	F	MORTALITY	117	980	749	12	50	50	DIED		
247	3230	M	MORTALITY	246	1040	727	12	50	60	DIED		
362	3230	F	MORTALITY	111	1050	876	12	60	50	DIED		
199	3230	F	MORTALITY	127	1050	692	12	60	50	DIED		
330	3230	F	MORTALITY	94	1080	818	13	60	50	DIED		
163	3230	M	MORTALITY	209	1080	876	13	60	60	EUTHANIZED		
344	3230	M	MORTALITY	211	1150	932	14	60	60	EUTHANIZED		
364	3230	F	MORTALITY	122	1230	881	14	60	60	EUTHANIZED		
220	3230	F	MORTALITY	106	1250	786	15	70	60	DIED		
243	3230	M	MORTALITY	218	1270	901	15	70	70	DIED		
210	3230	F	MORTALITY	120	1320	538	16	70	60	DIED	LEUKEMIA	RAD_PNEUMONITIS, SEPT_FIBROSIS
227	3230	M	MORTALITY	197	1320	805	16	70	70	DIED		
279	3230	F	MORTALITY	117	1350	812	16	70	70	DIED		
174	3230	M	MORTALITY	212	1400	901	16	70	70	EUTHANIZED		
277	3230	F	MORTALITY	117	1420	797	17	70	70	DIED		
143	3230	F	MORTALITY	112	1430	626	17	80	70	DIED		

1C. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO PM147-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITAIL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
238	3230	M	MORTALITY	250	1580	749	19	80	90	EUTHANIZED		
169	3230	M	MORTALITY	215	1600	927	19	80	90	DIED		
118	3230	M	MORTALITY	206	1600	817	19	80	80	DIED		
352	3230	M	MORTALITY	215	1630	526	19	90	80	EUTHANIZED	SQUAM_CELL_CA	RAD_PNEUMONITIS
131	3230	F	MORTALITY	124	1670	588	20	90	80	DIED		
326	3230	F	MORTALITY	137	1670	581	20	90	80	DIED		
126	3230	M	MORTALITY	243	1710	526	20	90	90	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS
128	3230	M	MORTALITY	237	1720	685	20	90	90	EUTHANIZED		
223	3230	M	MORTALITY	190	1720	723	20	90	90	EUTHANIZED		
185	3230	M	MORTALITY	210	1760	605	21	90	90	DIED		
103	3230	M	MORTALITY	249	1780	680	21	90	100	DIED		
164	3230	M	MORTALITY	206	1810	617	21	100	90	DIED		
250	3230	M	MORTALITY	216	1890	658	22	100	100	DIED		
321	3230	F	MORTALITY	105	1900	934	22	100	90	DIED		
101	3230	M	MORTALITY	284	1920	780	23	100	110	EUTHANIZED		
156	3230	F	MORTALITY	94	2000	946	24	110	90	DIED		
225	3230	M	MORTALITY	196	2010	822	24	110	100	DIED		
180	3230	M	MORTALITY	205	2030	784	24	110	110	EUTHANIZED		
319	3230	F	MORTALITY	118	2040	675	24	110	100	DIED		
234	3230	M	MORTALITY	247	2110	6	25	110	10	DIED	CONGESTION	
259	3230	F	MORTALITY	127	2110	638	25	110	110	DIED		
158	3230	F	MORTALITY	113	2120	1025	25	110	110	DIED		
176	3230	M	MORTALITY	225	2130	594	25	110	110	DIED		
211	3230	F	MORTALITY	126	2200	354	26	120	100	DIED	PULMONARY_THROMBOSIS HEMANGIOSARCOMA	ALVEOLAR_HISTEO
194	3230	F	MORTALITY	133	2210	485	26	120	110	DIED		
178	3230	M	MORTALITY	205	2220	640	26	120	110	DIED		
345	3230	M	MORTALITY	205	2290	676	27	120	120	DIED		
133	3230	F	MORTALITY	134	2310	505	27	120	110	DIED	LEUKEMIA	SQUAM_CELL_CA, SEPT_FIBROSIS
303	3230	M	MORTALITY	219	2310	610	27	120	120	DIED		
361	3230	F	MORTALITY	116	2340	710	28	120	120	DIED		
287	3230	M	MORTALITY	217	2410	718	28	130	130	DIED		
219	3230	F	MORTALITY	107	2430	489	29	130	110	DIED	NO_LESIONS	
184	3230	M	MORTALITY	234	2470	683	29	130	130	EUTHANIZED		
232	3230	M	MORTALITY	276	2480	574	29	130	130	DIED		
307	3230	M	MORTALITY	256	2500	771	29	130	140	DIED		
359	3230	F	MORTALITY	143	2510	719	30	130	130	EUTHANIZED		
318	3230	F	MORTALITY	116	2540	558	30	130	120	DIED		
112	3230	M	MORTALITY	262	2580	756	30	140	140	DIED		
230	3230	M	MORTALITY	234	2590	445	30	140	130	DIED	ALVEOLAR_HISTEO	
130	3230	M	MORTALITY	249	2650	560	31	140	140	DIED		
209	3230	F	MORTALITY	117	2760	545	33	150	130	EUTHANIZED	SQUAM_CELL_CA	
129	3230	M	MORTALITY	219	2790	838	33	150	150	DIED		
284	3230	M	MORTALITY	223	2810	689	33	150	150	EUTHANIZED		
114	3230	M	MORTALITY	234	2820	636	33	150	150	DIED		
365	3230	F	MORTALITY	105	2840	702	33	150	140	DIED		
273	3230	F	MORTALITY	108	2890	591	34	150	140	DIED		
311	3230	F	MORTALITY	116	2920	482	34	150	140	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
117	3230	M	MORTALITY	243	2970	611	35	160	160	DIED		
229	3230	M	MORTALITY	199	3080	718	36	160	160	DIED		
121	3230	M	MORTALITY	237	3090	537	36	160	160	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, HEMORRHAGE

1D. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO PM147-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
334	3230	F	MORTALITY	95	3100	779	36	160	140	DIED		
202	3230	F	MORTALITY	123	3100	577	37	160	150	DIED		
350	3230	M	MORTALITY	223	3130	629	37	160	160	DIED		
144	3230	F	MORTALITY	130	3150	603	37	170	160	DIED		
154	3230	F	MORTALITY	115	3190	703	37	170	160	DIED		
203	3230	F	MORTALITY	116	3190	587	38	170	150	DIED		
201	3230	F	MORTALITY	127	3190	683	38	170	160	DIED		
137	3230	F	MORTALITY	136	3200	439	38	170	150	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
347	3230	M	MORTALITY	216	3240	812	38	170	170	DIED		
251	3230	F	MORTALITY	113	3240	606	38	170	160	DIED		
171	3230	M	MORTALITY	207	3260	656	38	170	170	DIED		
119	3230	M	MORTALITY	215	3280	556	39	170	170	DIED		
196	3230	F	MORTALITY	137	3310	371	39	170	150	DIED	CONGESTION	
175	3230	M	MORTALITY	228	3520	558	41	190	180	DIED	HEMANGIOSARCOMA	HEMORRHAGE
293	3230	M	MORTALITY	226	3840	545	45	200	200	DIED	LEUKEMIA	
282	3230	M	MORTALITY	213	3890	569	46	210	200	DIED		
206	3230	F	MORTALITY	142	4000	548	47	210	200	DIED		
146	3230	F	MORTALITY	134	4320	490	51	230	210	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
286	3230	M	MORTALITY	219	4360	691	51	230	230	DIED		
363	3230	F	MORTALITY	105	4370	646	51	230	210	DIED		
353	3230	M	MORTALITY	208	4410	355	52	230	200	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
110	3230	M	MORTALITY	265	4420	416	52	230	220	DIED	SEPT_FIBROSIS	
300	3230	M	MORTALITY	239	4520	520	53	240	230	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SQUAM_CELL_CA, SEPT_FIBROSIS
134	3230	F	MORTALITY	134	4730	534	56	250	230	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS, HEMORRHAGE
138	3230	F	MORTALITY	130	5210	494	61	270	250	DIED	ADENO_CARCIOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
193	3230	F	MORTALITY	142	5310	553	62	280	270	DIED		
367	3230	F	MORTALITY	131	5450	312	64	290	230	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
370	3230	F	MORTALITY	140	5740	628	68	300	300	DIED		
192	3230	F	MORTALITY	135	5860	513	69	310	290	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS, SEPT_FIBROSIS
292	3230	M	MORTALITY	223	6250	556	74	330	320	DIED		
304	3230	M	MORTALITY	239	6290	487	74	330	320	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
104	3230	M	MORTALITY	262	6360	488	75	340	330	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
325	3230	F	MORTALITY	130	6400	431	75	340	300	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS
324	3230	F	MORTALITY	118	6570	456	77	350	300	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SQUAM_CELL_CA, SEPT_FIBROSIS
102	3230	M	MORTALITY	319	6760	423	80	360	360	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS, HEMORRHAGE
132	3230	F	MORTALITY	130	6810	574	80	360	340	DIED		
310	3230	M	MORTALITY	254	7060	322	83	370	330	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS, HEMORRHAGE
315	3230	F	MORTALITY	146	7080	400	83	370	340	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SQUAM_CELL_CA, SEPT_FIBROSIS
216	3230	F	MORTALITY	121	7220	375	85	380	320	DIED	RAD_PNEUMONITIS	HEMORRHAGE
106	3230	M	MORTALITY	282	7250	339	85	380	350	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
306	3230	M	MORTALITY	264	7300	207	86	390	280	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
127	3230	M	MORTALITY	240	7570	349	89	400	350	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
357	3230	F	MORTALITY	128	7570	429	89	400	360	DIED	NO LESIONS	
105	3230	M	MORTALITY	269	7580	296	89	400	340	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, HEMORRHAGE
200	3230	F	MORTALITY	142	7600	414	89	400	360	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SQUAM_CELL_PAP, SEPT_FIBROSIS
142	3230	F	MORTALITY	121	7630	435	90	400	350	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS, SEPT_FIBROSIS
157	3230	F	MORTALITY	120	7830	445	92	410	360	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS, SEPT_FIBROSIS
312	3230	F	MORTALITY	127	7870	371	93	410	350	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS, HEMORRHAGE
160	3230	F	MORTALITY	122	7900	192	93	420	280	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS, HEMORRHAGE
186	3230	M	MORTALITY	228	8050	259	95	420	330	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS

1E. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO PM147-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
152	3230	F	MORTALITY	131	8090	475	95	430	390	DIED	RAD_PNEUMONITIS	SQUAM_CELL_PAP, SEPT_FIBROSIS
327	3230	F	MORTALITY	126	8200	299	96	430	350	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
204	3230	F	MORTALITY	125	8250	367	97	440	370	DIED	RAD_PNEUMONITIS	HEMANGIOSARCOMA
351	3230	M	MORTALITY	205	8270	234	97	440	320	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
308	3230	M	MORTALITY	277	8320	230	98	440	340	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
328	3230	F	MORTALITY	135	8320	381	98	440	380	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS, HEMORRHAGE
182	3230	M	MORTALITY	210	8420	370	99	440	390	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
109	3230	M	MORTALITY	249	8480	197	100	450	320	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
217	3230	F	MORTALITY	129	8560	251	101	450	340	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, VASCULITIS
218	3230	F	MORTALITY	116	8610	407	101	450	390	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
179	3230	M	MORTALITY	214	8710	233	102	460	340	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
339	3230	F	MORTALITY	129	8740	351	103	460	390	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS, HEMORRHAGE
170	3230	M	MORTALITY	241	8880	432	104	470	440	DIED	SEPT_FIBROSIS	HEMORRHAGE
208	3230	F	MORTALITY	122	9210	368	108	490	410	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
305	3230	M	MORTALITY	231	9220	205	108	490	350	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
135	3230	F	MORTALITY	128	9340	337	110	490	410	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
183	3230	M	MORTALITY	223	9380	170	110	490	320	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
125	3230	M	MORTALITY	234	9400	237	111	500	380	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
360	3230	F	MORTALITY	126	9550	391	112	500	440	DIED	LUNG_TUMOR_GROSS	
348	3230	M	MORTALITY	209	9610	246	113	510	380	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
242	3230	M	MORTALITY	259	9970	223	117	530	400	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
120	3230	M	MORTALITY	204	10010	201	118	530	360	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
366	3230	F	MORTALITY	120	10020	222	118	530	370	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
236	3230	M	MORTALITY	241	10050	219	118	530	390	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
346	3230	M	MORTALITY	217	10060	207	118	530	370	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
355	3230	M	MORTALITY	279	10230	264	120	540	450	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
222	3230	M	MORTALITY	191	10250	682	121	540	520	DIED		
237	3230	M	MORTALITY	235	10390	197	122	550	380	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
283	3230	M	MORTALITY	223	10540	181	124	560	370	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
280	3230	F	MORTALITY	124	10550	400	124	560	480	DIED	RAD_PNEUMONITIS	HEMORRHAGE, SEPT_FIBROSIS
231	3230	M	MORTALITY	198	10560	252	124	560	420	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
139	3230	F	MORTALITY	142	10670	336	126	560	480	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, VASCULITIS
294	3230	M	MORTALITY	243	10720	210	126	570	410	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
162	3230	M	MORTALITY	245	11240	202	132	590	420	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
270	3230	F	MORTALITY	111	11380	198	134	600	390	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
298	3230	M	MORTALITY	224	11470	197	135	610	420	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
224	3230	M	MORTALITY	196	11570	257	136	610	460	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
341	3230	M	MORTALITY	255	11640	265	137	610	500	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
260	3230	F	MORTALITY	114	11650	360	137	610	500	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, HEMORRHAGE
239	3230	M	MORTALITY	238	11780	164	139	620	400	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
268	3230	F	MORTALITY	108	11920	186	140	630	400	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
245	3230	M	MORTALITY	245	11930	167	140	630	410	DIED	ALVEOLAR_HISTEO	SEPT_FIBROSIS
297	3230	M	MORTALITY	241	11930	181	140	630	430	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
141	3230	F	MORTALITY	123	11940	307	140	630	500	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, VASCULITIS, SQUAM_CELL_PAP
296	3230	M	MORTALITY	218	12070	178	142	640	420	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
198	3230	F	MORTALITY	114	12160	193	143	640	420	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
267	3230	F	MORTALITY	119	12230	161	144	650	390	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
145	3230	F	MORTALITY	125	12240	401	144	650	560	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS, HEMORRHAGE
320	3230	F	MORTALITY	113	12360	199	145	650	430	DIED	RAD_PNEUMONITIS	HEMANGIOSARCOMA, SQUAM_CELL_CA
155	3230	F	MORTALITY	114	12740	386	150	670	560	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SQUAM_CELL_CA, SEPT_FIBROSIS

1F. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO PM147-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
288	3230	M	MORTALITY	203	12880	188	152	680	450	DIED	RAD_PNEUMONITIS	
332	3230	F	MORTALITY	98	13830	131	163	730	380	UNRESOLVED		
153	3230	F	MORTALITY	111	13850	343	163	730	590	DIED	RAD_PNEUMONITIS	
254	3230	F	MORTALITY	111	15090	183	177	800	500	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
317	3230	F	MORTALITY	109	15590	197	183	820	530	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, VASCULITIS
262	3230	F	MORTALITY	97	17280	184	203	910	560	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, VASCULITIS, PULMONARY_THROMBOSIS
266	3230	F	MORTALITY	102	18370	173	216	970	580	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
256	3230	F	MORTALITY	116	18450	189	217	970	630	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, PULMONARY_THROMBOSIS

2A. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
431	3525	F	HEMATOLOGY	159	0	540	0	0	0	ALIVE		
432	3525	F	HEMATOLOGY	176	0	540	0	0	0	ALIVE		
433	3525	F	HEMATOLOGY	164	0	540	0	0	0	ALIVE		
434	3525	F	HEMATOLOGY	184	0	510	0	0	0	DIED	NO_LESION	
435	3525	F	HEMATOLOGY	201	0	540	0	0	0	ALIVE		
436	3525	M	HEMATOLOGY	268	0	259	0	0	0	DIED	NOT_SUBMITTED	
437	3525	M	HEMATOLOGY	187	0	540	0	0	0	ALIVE		
438	3525	M	HEMATOLOGY	221	0	540	0	0	0	ALIVE		
439	3525	M	HEMATOLOGY	250	0	480	0	0	0	DIED	NO_LESION	
440	3525	M	HEMATOLOGY	252	0	540	0	0	0	ALIVE		
136	3522	M	HEMATOLOGY	279	50	123	3	10	10	DIED	NO_LESION	
340	3524	M	HEMATOLOGY	243	80	540	6	30		ALIVE		
134	3522	F	HEMATOLOGY	198	90	565	6	30	30	DIED	LEUKEMIA	
351	3524	M	HEMATOLOGY	273	110	540	7	30		ALIVE		
339	3524	M	HEMATOLOGY	229	110	540	8	40		ALIVE		
133	3522	F	HEMATOLOGY	169	120	540	8	40		ALIVE		
332	3524	F	HEMATOLOGY	163	170	540	12	50		ALIVE		
331	3524	F	HEMATOLOGY	153	170	540	12	60		ALIVE		
335	3524	F	HEMATOLOGY	167	190	540	13	60		ALIVE		
334	3524	F	HEMATOLOGY	165	210	540	14	70		ALIVE		
120	3522	F	HEMATOLOGY	156	220	540	15	70		ALIVE		
234	3523	F	HEMATOLOGY	169	300	540	20	90		ALIVE		
333	3524	F	HEMATOLOGY	163	310	540	21	100		ALIVE		
138	3522	M	HEMATOLOGY	225	380	540	25	120		ALIVE		
231	3523	F	HEMATOLOGY	175	500	540	34	160		ALIVE		
338	3524	M	HEMATOLOGY	234	520	540	35	170		ALIVE		
118	3522	F	HEMATOLOGY	168	640	540	43	200		ALIVE		
119	3522	F	HEMATOLOGY	169	790	488	53	250	230	DIED	RAD_PNEUMONITIS	SQUAM_CELL_CA
337	3524	M	HEMATOLOGY	262	790	540	53	250		ALIVE		
237	3523	M	HEMATOLOGY	212	1180	540	80	370		ALIVE		
139	3522	M	HEMATOLOGY	258	1250	417	146	660	630	EUTHANIZED	SQUAM_CELL_CA	
232	3523	F	HEMATOLOGY	160	1270	507	86	400	370	DIED	SQUAM_CELL_CA	SEPT_FIBROSIS
236	3523	M	HEMATOLOGY	254	1300	499	152	690	660	DIED	SQUAM_CELL_CA	
233	3523	F	HEMATOLOGY	170	1310	331	154	690	630	EUTHANIZED	NO_LESION	
239	3523	M	HEMATOLOGY	240	1390	497	162	730	700	DIED	SQUAM_CELL_CA	HEMANGIOSARCOMA
235	3523	F	HEMATOLOGY	154	1540	330	180	820	720	EUTHANIZED	RAD_PNEUMONITIS	SEPT_FIBROSIS, HEMANGIOSARCOMA
240	3523	M	HEMATOLOGY	246	2020	154	236	1070	720	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
140	3522	M	HEMATOLOGY	224	2290	99	268	1210	630	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
238	3523	M	HEMATOLOGY	252	2300	163	269	1220	850	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
137	3522	M	HEMATOLOGY	230	2510	163	293	1320	910	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
401	3525	F	MORTALITY	154	0	540	0	0	0	ALIVE		
402	3525	F	MORTALITY	147	0	540	0	0	0	ALIVE		
403	3525	F	MORTALITY	143	0	540	0	0	0	ALIVE		
404	3525	F	MORTALITY	165	0	540	0	0	0	ALIVE		
405	3525	F	MORTALITY	147	0	540	0	0	0	ALIVE		
406	3525	F	MORTALITY	147	0	540	0	0	0	ALIVE		
407	3525	F	MORTALITY	145	0	540	0	0	0	ALIVE		
408	3525	F	MORTALITY	158	0	540	0	0	0	ALIVE		
409	3525	F	MORTALITY	151	0	540	0	0	0	ALIVE		
410	3525	F	MORTALITY	157	0	556	0	0	0	EUTHANIZED	NOT_SUBMITTED	

2B. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
411	3525	F	MORTALITY	160	0	526	0	0	0	EUTHANIZED	ALVEOLAR_HISTEO	
412	3525	F	MORTALITY	173	0	540	0	0	0	ALIVE		
413	3525	F	MORTALITY	150	0	540	0	0	0	ALIVE		
414	3525	F	MORTALITY	151	0	540	0	0	0	ALIVE		
415	3525	F	MORTALITY	156	0	540	0	0	0	ALIVE		
416	3525	F	MORTALITY	153	0	540	0	0	0	ALIVE		
417	3525	F	MORTALITY	168	0	540	0	0	0	ALIVE		
418	3525	F	MORTALITY	168	0	592	0	0	0	EUTHANIZED	NOT_SUBMITTED	
419	3525	F	MORTALITY	158	0	540	0	0	0	ALIVE		
420	3525	F	MORTALITY	166	0	540	0	0	0	ALIVE		
452	3525	M	MORTALITY	268	0	624	0	0	0	DIED	NOT_SUBMITTED	
453	3525	M	MORTALITY	258	0	540	0	0	0	ALIVE		
454	3525	M	MORTALITY	283	0	540	0	0	0	ALIVE		
455	3525	M	MORTALITY	283	0	540	0	0	0	ALIVE		
456	3525	M	MORTALITY	287	0	540	0	0	0	ALIVE		
457	3525	M	MORTALITY	259	0	540	0	0	0	ALIVE		
458	3525	M	MORTALITY	272	0	540	0	0	0	ALIVE		
459	3525	M	MORTALITY	276	0	540	0	0	0	ALIVE		
460	3525	M	MORTALITY	270	0	540	0	0	0	ALIVE		
461	3525	M	MORTALITY	275	0	540	0	0	0	ALIVE		
462	3525	M	MORTALITY	267	0	534	0	0	0	EUTHANIZED	NOT_SUBMITTED	
463	3525	M	MORTALITY	270	0	540	0	0	0	ALIVE		
464	3525	M	MORTALITY	262	0	540	0	0	0	ALIVE		
465	3525	M	MORTALITY	267	0	540	0	0	0	ALIVE		
466	3525	M	MORTALITY	283	0	540	0	0	0	ALIVE		
467	3525	M	MORTALITY	266	0	540	0	0	0	ALIVE		
468	3525	M	MORTALITY	271	0	540	0	0	0	ALIVE		
469	3525	M	MORTALITY	272	0	540	0	0	0	ALIVE		
470	3525	M	MORTALITY	262	0	384	0	0	0	DIED	CONGESTION	EDEMA
154	3522	M	MORTALITY	278	10	515	1	0	0	EUTHANIZED	NO_LESION	
160	3522	M	MORTALITY	292	10	540	1	0		ALIVE		
153	3522	M	MORTALITY	254	30	535	2	10	10	EUTHANIZED	NO_LESION	
159	3522	M	MORTALITY	272	30	540	2	10		ALIVE		
157	3522	M	MORTALITY	285	40	578	2	10	10	EUTHANIZED	NOT_SUBMITTED	
152	3522	M	MORTALITY	263	50	540	3	20		ALIVE		
164	3522	M	MORTALITY	288	50	579	3	20	20	DIED	NOT_SUBMITTED	
354	3524	M	MORTALITY	251	50	540	3	20		ALIVE		
106	3522	F	MORTALITY	159	50	540	3	20		ALIVE		
167	3522	M	MORTALITY	295	60	540	4	20		ALIVE		
367	3524	M	MORTALITY	269	70	540	5	20		ALIVE		
303	3524	F	MORTALITY	142	70	540	5	20		ALIVE		
359	3524	M	MORTALITY	276	90	540	6	30		ALIVE		
304	3524	F	MORTALITY	150	110	540	7	30		ALIVE		
116	3522	F	MORTALITY	164	150	540	10	50		ALIVE		
169	3522	M	MORTALITY	281	150	540	10	50		ALIVE		
101	3522	F	MORTALITY	116	170	325	11	50	40	DIED	NO_LESION	
268	3523	M	MORTALITY	299	170	540	11	50		ALIVE		
315	3524	F	MORTALITY	147	180	540	12	60		ALIVE		
163	3522	M	MORTALITY	283	190	624	13	60	60	DIED	NOT_SUBMITTED	
165	3522	M	MORTALITY	291	190	619	13	60	60	EUTHANIZED	NOT_SUBMITTED	

2C. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
307	3524	F	MORTALITY	161	190	540	13	60		ALIVE		
310	3524	F	MORTALITY	162	200	540	13	60		ALIVE		
306	3524	F	MORTALITY	156	200	540	13	60		ALIVE		
317	3524	F	MORTALITY	164	210	540	14	70		ALIVE		
366	3524	M	MORTALITY	279	230	540	15	70		ALIVE		
313	3524	F	MORTALITY	168	240	540	16	80		ALIVE		
312	3524	F	MORTALITY	155	250	540	17	80		ALIVE		
311	3524	F	MORTALITY	151	260	414	17	80	70	DIED	NOT_SUBMITTED	
316	3524	F	MORTALITY	174	260	540	17	80		ALIVE		
320	3524	F	MORTALITY	160	270	540	18	90		ALIVE		
314	3524	F	MORTALITY	162	280	540	19	90		ALIVE		
155	3522	M	MORTALITY	284	290	579	19	90	90	DIED	NOT_SUBMITTED	
360	3524	M	MORTALITY	289	290	540	19	90		ALIVE		
365	3524	M	MORTALITY	287	310	540	21	100		ALIVE		
207	3523	F	MORTALITY	157	310	514	21	100	90	DIED	CONGESTION	
302	3524	F	MORTALITY	142	320	540	21	100		ALIVE		
156	3522	M	MORTALITY	282	320	540	22	100		ALIVE		
252	3523	M	MORTALITY	260	320	540	22	100		ALIVE		
361	3524	M	MORTALITY	271	320	540	22	100		ALIVE		
308	3524	F	MORTALITY	147	340	540	23	110		ALIVE		
318	3524	F	MORTALITY	161	340	623	23	110	100	EUTHANIZED	NOT_SUBMITTED	
301	3524	F	MORTALITY	113	350	574	24	110	90	EUTHANIZED	NOT_SUBMITTED	
215	3523	F	MORTALITY	169	360	540	24	110		ALIVE		
114	3522	F	MORTALITY	164	380	525	26	120	110	DIED	CONGESTION	
255	3523	M	MORTALITY	279	390	611	26	120	120	DIED	NOT_SUBMITTED	
254	3523	M	MORTALITY	280	410	540	27	130		ALIVE		
355	3524	M	MORTALITY	274	420	540	28	130		ALIVE		
370	3524	M	MORTALITY	299	410	623	28	130	130	EUTHANIZED	NOT_SUBMITTED	
357	3524	M	MORTALITY	286	430	540	29	130		ALIVE		
209	3523	F	MORTALITY	153	440	540	30	140		ALIVE		
363	3524	M	MORTALITY	253	440	540	30	140		ALIVE		
258	3523	M	MORTALITY	253	440	540	30	140		ALIVE	STANDARD	
218	3523	F	MORTALITY	161	450	540	30	140		ALIVE	STANDARD	
202	3523	F	MORTALITY	140	470	540	32	150		ALIVE		
309	3524	F	MORTALITY	142	470	540	32	150		ALIVE		
112	3522	F	MORTALITY	161	490	540	33	160		ALIVE		
253	3523	M	MORTALITY	283	490	623	33	150	150	EUTHANIZED	NOT_SUBMITTED	
319	3524	F	MORTALITY	161	490	540	33	160		ALIVE		
305	3523	F	MORTALITY	144	520	540	35	170		ALIVE		
369	3524	M	MORTALITY	300	550	540	37	170		ALIVE		
201	3523	F	MORTALITY	134	550	540	37	180		ALIVE		
368	3524	M	MORTALITY	279	600	540	40	190		ALIVE		
206	3523	F	MORTALITY	153	610	540	41	190		ALIVE		
107	3522	F	MORTALITY	154	650	591	44	200	190	DIED	NOT_SUBMITTED	
220	3523	F	MORTALITY	161	660	493	45	210	190	DIED	RAD_PNEUMONITIS	
358	3524	M	MORTALITY	270	690	540	46	220		ALIVE		
108	3522	F	MORTALITY	146	710	540	48	230		ALIVE		
356	3524	M	MORTALITY	259	710	540	48	230		ALIVE		
211	3523	F	MORTALITY	148	720	540	49	230		ALIVE		
362	3524	M	MORTALITY	291	730	538	49	230	220	DIED	LUNG_TUMOR_GROSS	

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2D. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
208	3523	F	MORTALITY	150	740	540	50	230		ALIVE	STANDARD	
104	3522	F	MORTALITY	146	760	259	51	240	180	DIED	NOT_SUBMITTED	
266	3523	M	MORTALITY	283	790	540	53	250		ALIVE		
256	3523	M	MORTALITY	279	810	540	55	260		ALIVE		
217	3523	F	MORTALITY	156	830	612	56	260	250	DIED	NOT_SUBMITTED	
267	3523	M	MORTALITY	294	920	481	62	290	280	DIED	AUTOLYTIC	
262	3523	M	MORTALITY	291	930	557	62	290	290	DIED	NOT_SUBMITTED	
352	3524	M	MORTALITY	267	950	540	64	300		ALIVE		
203	3523	F	MORTALITY	151	970	425	66	310	270	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
269	3523	M	MORTALITY	283	970	474	114	510	510	DIED	AUTOLYTIC	
264	3523	M	MORTALITY	284	1000	537	117	530	530	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS
162	3522	M	MORTALITY	287	1060	290	124	560	500	DIED	SQUAM_CELL_CA	
216	3523	F	MORTALITY	163	1060	378	71	330	290	DIED	HEMANGIOSARCOMA	SEPT_FIBROSIS
261	3523	M	MORTALITY	281	1070	540	125	560		ALIVE		
260	3523	M	MORTALITY	265	1170	595	136	620	610	EUTHANIZED	NOT_SUBMITTED	
161	3522	M	MORTALITY	283	1180	586	138	620	630	DIED	NOT_SUBMITTED	
259	3523	M	MORTALITY	286	1250	436	146	660	640	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, SQUAM_CELL_PAP
270	3523	M	MORTALITY	311	1300	540	152	690		ALIVE		
219	3523	F	MORTALITY	168	1300	431	88	410	400	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, BA_HYPERPLASIA
204	3523	F	MORTALITY	150	1350	383	91	430	360	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
213	3523	F	MORTALITY	166	1360	341	159	720	650	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
151	3522	M	MORTALITY	260	1380	478	162	730	710	DIED	SQUAM_CELL_CA	SEPT_FIBROSIS
212	3523	F	MORTALITY	155	1410	354	95	450	370	DIED	HEMANGIOSARCOMA	SEPT_FIBROSIS
205	3523	F	MORTALITY	146	1430	287	97	450	350	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
257	3523	M	MORTALITY	272	1430	504	168	760	740	DIED	SQUAM_CELL_CA	HEMANGIOSARCOMA
214	3523	F	MORTALITY	150	1450	442	98	460	410	DIED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
210	3523	F	MORTALITY	171	1510	409	176	800	760	DIED	SEPT_FIBROSIS	SQUAM_CELL_CA
265	3523	M	MORTALITY	270	1540	534	180	810	800	DIED	SQUAM_CELL_CA	HEMANGIOSARCOMA
251	3523	M	MORTALITY	244	1610	391	188	850	780	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
109	3522	F	MORTALITY	152	1610	144	189	850	560	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
113	3522	F	MORTALITY	152	1700	250	199	900	740	DIED	NOT_SUBMITTED	
102	3522	F	MORTALITY	136	1720	152	201	910	590	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
103	3522	F	MORTALITY	151	1740	326	203	920	810	DIED	HEMANGIOSARCOMA	SEPT_FIBROSIS
263	3523	M	MORTALITY	273	1820	215	213	960	770	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
115	3522	F	MORTALITY	163	1830	157	214	970	670	DIED	NOT_SUBMITTED	
158	3522	M	MORTALITY	271	2060	160	241	1090	770	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
168	3522	M	MORTALITY	301	2100	283	245	1110	1000	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
166	3522	M	MORTALITY	271	2190	158	256	1160	810	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
329	3524	F	PUL_FUNCT	167	0	540	0	0	0	ALIVE		
330	3524	F	PUL_FUNCT	167	0	540	0	0	0	ALIVE		
421	3525	F	PUL_FUNCT	151	0	540	0	0	0	ALIVE		
422	3525	F	PUL_FUNCT	173	0	553	0	0	0	EUTHANIZED	NOT_SUBMITTED	
423	3525	F	PUL_FUNCT	165	0	620	0	0	0	SAC_EXAMAMINED	NO_LESION	
424	3525	F	PUL_FUNCT	165	0	620	0	0	0	SAC_EXAMAMINED	NO_LESION	
425	3525	F	PUL_FUNCT	155	0	621	0	0	0	SAC_EXAMAMINED	NO_LESION	
426	3525	F	PUL_FUNCT	162	0	621	0	0	0	SAC_EXAMAMINED	NO_LESION	
427	3525	F	PUL_FUNCT	170	0	622	0	0	0	SAC_EXAMAMINED	NO_LESION	
428	3525	F	PUL_FUNCT	162	0	540	0	0	0	ALIVE		
429	3525	F	PUL_FUNCT	165	0	540	0	0	0	ALIVE		
430	3525	F	PUL_FUNCT	158	0	540	0	0	0	ALIVE		

2E. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
442	3525	M	PUL_FUNC	236	0	622	0	0	0	SAC_EXAMAMINED	ALVEOLAR_HISTEO	
443	3525	M	PUL_FUNC	252	0	623	0	0	0	SAC_EXAMAMINED	NO_LESION	
444	3525	M	PUL_FUNC	257	0	623	0	0	0	SAC_EXAMAMINED	NO_LESION	
445	3525	M	PUL_FUNC	252	0	606	0	0	0	EUTHANIZED	NOT_SUBMITTED	
446	3525	M	PUL_FUNC	259	0	624	0	0	0	SAC_EXAMAMINED	NO_LESION	
447	3525	M	PUL_FUNC	251	0	624	0	0	0	SAC_EXAMAMINED	NO_LESION	
448	3525	M	PUL_FUNC	283	0	540	0	0	0	ALIVE		
449	3525	M	PUL_FUNC	263	0	540	0	0	0	ALIVE		
450	3525	M	PUL_FUNC	281	0	540	0	0	0	ALIVE		
451	3525	M	PUL_FUNC	242	0	540	0	0	0	ALIVE		
143	3522	M	PUL_FUNC	255	20	540	1	10		ALIVE		
347	3524	M	PUL_FUNC	257	20	540	1	10		ALIVE		
141	3522	M	PUL_FUNC	246	90	622	6	30	30	SAC_EXAMAMINED	NO_LESION	
125	3522	F	PUL_FUNC	163	110	620	7	40	30	SAC_EXAMAMINED	NO_LESION	
344	3524	M	PUL_FUNC	244	140	593	10	50	40	DIED	NOT_SUBMITTED	
142	3522	M	PUL_FUNC	251	150	623	10	50	50	SAC_EXAMAMINED	NO_LESION	
325	3524	F	PUL_FUNC	163	160	619	11	50	50	SAC_EXAMAMINED	NO_LESION	
341	3524	M	PUL_FUNC	249	160	620	11	50	50	SAC_EXAMAMINED	ALVEOLAR_HISTEO	
324	3524	F	PUL_FUNC	173	170	540	11	50		ALIVE		
327	3524	F	PUL_FUNC	170	170	620	11	50	50	SAC_EXAMAMINED	NO_LESION	
328	3524	F	PUL_FUNC	158	180	539	12	60	50	EUTHANIZED	NO_LESION	
124	3522	F	PUL_FUNC	160	200	540	14	60		ALIVE		
129	3522	F	PUL_FUNC	174	200	540	14	60		ALIVE		
250	3523	M	PUL_FUNC	270	220	540	15	70		ALIVE		
323	3524	F	PUL_FUNC	175	260	612	18	80	80	EUTHANIZED	NOT_SUBMITTED	
226	3523	F	PUL_FUNC	156	270	620	18	90	80	SAC_EXAMAMINED	ALVEOLAR_HISTEO	
342	3524	M	PUL_FUNC	246	300	488	20	90	90	EUTHANIZED	ALVEOLAR_HISTEO	
146	3522	M	PUL_FUNC	264	310	624	21	100	90	SAC_EXAMAMINED	NO_LESION	
326	3524	F	PUL_FUNC	168	320	615	21	100	100	EUTHANIZED	NOT_SUBMITTED	
321	3524	F	PUL_FUNC	157	330	623	23	110	100	SAC_EXAMAMINED	NO_LESION	
322	3524	F	PUL_FUNC	173	330	619	22	110	100	SAC_EXAMAMINED	NO_LESION	
349	3524	M	PUL_FUNC	263	360	595	24	110	110	EUTHANIZED	UNRESOLVED	
128	3522	F	PUL_FUNC	161	370	622	25	120	110	SAC_EXAMAMINED	ALVEOLAR_HISTEO	
228	3523	F	PUL_FUNC	176	390	622	26	120	120	SAC_EXAMAMINED	SQUAM_CELL_CA	
247	3523	M	PUL_FUNC	257	390	65	27	130	40	DIED	CONGESTION	
150	3522	M	PUL_FUNC	265	450	540	30	140		ALIVE		
127	3522	F	PUL_FUNC	163	450	621	31	140	140	SAC_EXAMAMINED	ALVEOLAR_HISTEO	
145	3522	M	PUL_FUNC	242	510	623	34	160	150	SAC_EXAMAMINED	BA_HYPERPLASIA	ALVEOLAR_HISTEO
350	3524	M	PUL_FUNC	249	510	623	34	160	150	SAC_EXAMAMINED	BA_HYPERPLASIA	
345	3524	M	PUL_FUNC	249	620	621	42	190	190	SAC_EXAMAMINED	ALVEOLAR_HISTEO	
225	3523	F	PUL_FUNC	157	630	619	42	200	190	SAC_EXAMAMINED	SQUAM_CELL_CA	
121	3522	F	PUL_FUNC	167	680	521	46	220	200	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
343	3524	M	PUL_FUNC	270	800	621	54	250	250	SAC_EXAMAMINED	ALVEOLAR_HISTEO	
221	3523	F	PUL_FUNC	158	820	553	55	260	240	EUTHANIZED	NOT_SUBMITTED	
248	3523	M	PUL_FUNC	253	880	501	60	280	260	DIED	SQUAM_CELL_CA	
348	3524	M	PUL_FUNC	258	910	623	61	290	280	SAC_EXAMAMINED	NO_LESION	
346	3524	M	PUL_FUNC	259	940	622	63	300	290	SAC_EXAMAMINED	BA_HYPERPLASIA	SQUAM_CELL_CA
230	3523	F	PUL_FUNC	153	970	411	66	310	270	DIED	RAD_PNEUMONITIS	HEMORRHAGE
222	3523	F	PUL_FUNC	159	1000	504	67	320	290	DIED	SQUAM_CELL_CA	
147	3522	M	PUL_FUNC	256	1020	489	69	320	300	EUTHANIZED	ALVEOLAR_HISTEO	LEUKEMIA

2F. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
227	3523	F	PUL_FUNCT	158	1100	403	74	350	300	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS, SEPT_FIBROSIS
229	3523	F	PUL_FUNCT	165	1150	458	77	360	330	DIED	HEMANGIOSARCOMA	SEPT_FIBROSIS
242	3523	M	PUL_FUNCT	229	1160	504	78	370	330	DIED	SQUAM_CELL_CA	
148	3522	M	PUL_FUNCT	255	1220	486	142	640	620	DIED	HEMANGIOSARCOMA	SEPT_FIBROSIS
246	3523	M	PUL_FUNCT	252	1370	89	160	720	360	DIED	RAD_PNEUMONITIS	
244	3523	M	PUL_FUNCT	258	1400	369	164	740	690	DIED	HEMANGIOSARCOMA	SQUAM_CELL_CA
223	3523	F	PUL_FUNCT	153	1480	503	174	780	750	DIED	SQUAM_CELL_CA	
243	3523	M	PUL_FUNCT	242	1510	306	177	800	700	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
245	3523	M	PUL_FUNCT	259	1680	437	197	890	850	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
122	3522	F	PUL_FUNCT	161	1780	125	208	940	570	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
224	3523	F	PUL_FUNCT	159	1810	179	212	960	700	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
249	3523	M	PUL_FUNCT	256	2000	149	234	1060	710	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
130	3522	F	PUL_FUNCT	165	2960	182	346	1560	1160	DIED	RAD_PNEUM_GROSS	

3A. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO Y90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
362	3535	M		292	0	540	0	0	0	SAC EXAMINED	NO_LESIONS	
208	3534	F	HEMATOLOGY	153	0	540	0	0	0	ALIVE		
210	3534	F	HEMATOLOGY	158	0	540	0	0	0	ALIVE		
211	3534	F	HEMATOLOGY	154	0	540	0	0	0	ALIVE		
266	3534	M	HEMATOLOGY	292	0	540	0	0	0	ALIVE		
268	3534	M	HEMATOLOGY	298	0	511	0	0	0	DIED	LEUKEMIA	
269	3534	M	HEMATOLOGY	314	0	540	0	0	0	ALIVE		
270	3534	M	HEMATOLOGY	309	0	540	0	0	0	ALIVE		
335	3535	F	HEMATOLOGY	169	2350	540	38	50		ALIVE		
333	3535	F	HEMATOLOGY	175	4240	540	68	100		ALIVE		
340	3535	M	HEMATOLOGY	229	4320	540	69	100		ALIVE		
331	3535	F	HEMATOLOGY	166	4680	540	75	110		ALIVE		
334	3535	F	HEMATOLOGY	166	5250	540	84	120		ALIVE		
234	3534	F	HEMATOLOGY	170	6790	540	109	160		ALIVE		
337	3535	M	HEMATOLOGY	217	7320	540	117	170		ALIVE		
134	3533	F	HEMATOLOGY	174	7420	161	119	170	130	DIED	UNRESOLVED	
336	3535	M	HEMATOLOGY	236	8070	540	129	190		ALIVE		
235	3534	F	HEMATOLOGY	173	8120	540	130	190		ALIVE		
339	3535	M	HEMATOLOGY	241	8210	602	131	190	160	DIED	NOT SUBMITTED	
132	3533	F	HEMATOLOGY	169	8300	79	133	190	140	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
332	3535	F	HEMATOLOGY	158	8700	70	139	200	140	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
232	3534	F	HEMATOLOGY	163	8930	85	143	210	150	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
137	3533	M	HEMATOLOGY	234	9360	540	150	220		ALIVE		
131	3533	F	HEMATOLOGY	168	9430	93	151	220	160	DIED	RAD_PNEUMONITIS	
236	3534	M	HEMATOLOGY	242	9720	540	155	230		ALIVE		
338	3535	M	HEMATOLOGY	228	9850	540	157	230		ALIVE		
233	3534	F	HEMATOLOGY	166	11550	94	185	270	190	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
240	3534	M	HEMATOLOGY	228	11570	71	185	270	190	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
135	3533	F	HEMATOLOGY	164	12450	55	199	290	200	DIED	RAD_PNEUMONITIS	
231	3534	F	HEMATOLOGY	164	12710	79	203	300	210	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
238	3534	M	HEMATOLOGY	217	12880	540	206	300		ALIVE		
138	3533	M	HEMATOLOGY	241	13060	540	209	300		ALIVE		
139	3533	M	HEMATOLOGY	221	13640	540	218	320		ALIVE		
133	3533	F	HEMATOLOGY	167	14150	63	226	330	230	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
239	3534	M	HEMATOLOGY	226	18010	76	288	420	300	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
136	3533	M	HEMATOLOGY	228	18500	68	296	430	300	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
140	3533	M	HEMATOLOGY	216	18720	67	299	440	300	DIED	RAD_PNEUMONITIS	
237	3534	M	HEMATOLOGY	235	21770	52	348	510	350	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
204	3534	F	MORTALITY	156	0	540	0	0	0	ALIVE		
205	3534	F	MORTALITY	160	0	540	0	0	0	ALIVE		
206	3534	F	MORTALITY	150	0	540	0	0	0	ALIVE		
260	3534	M	MORTALITY	291	0	540	0	0	0	ALIVE		
262	3534	M	MORTALITY	297	0	487	0	0	0	EUTHANIZED	NOT SUBMITTED	
263	3534	M	MORTALITY	297	0	540	0	0	0	ALIVE		
265	3534	M	MORTALITY	293	0	540	0	0	0	ALIVE		
301	3535	F	MORTALITY	168	0	540	0	0	0	ALIVE		
303	3535	F	MORTALITY	147	0	540	0	0	0	ALIVE		
305	3535	F	MORTALITY	151	0	540	0	0	0	ALIVE		
306	3535	F	MORTALITY	158	0	540	0	0	0	ALIVE		
307	3535	F	MORTALITY	156	0	540	0	0	0	ALIVE		

3B. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO Y90-FAP

ANIMAL NUMBER	EXPER- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
308	3535	F	MORTALITY	155	0	540	0	0	0	ALIVE		
309	3535	F	MORTALITY	156	0	540	0	0	0	ALIVE		
310	3535	F	MORTALITY	154	0	540	0	0	0	ALIVE		
311	3535	F	MORTALITY	151	0	540	0	0	0	ALIVE		
360	3535	M	MORTALITY	219	0	540	0	0	0	ALIVE		
361	3535	M	MORTALITY	280	0	540	0	0	0	ALIVE		
364	3535	M	MORTALITY	290	0	540	0	0	0	ALIVE		
365	3535	M	MORTALITY	307	0	540	0	0	0	ALIVE		
366	3535	M	MORTALITY	295	0	540	0	0	0	ALIVE		
367	3535	M	MORTALITY	306	0	540	0	0	0	ALIVE		
368	3535	M	MORTALITY	302	0	592	0	0	0	DIED	NOT_SUBMITTED	
369	3535	M	MORTALITY	300	0	540	0	0	0	ALIVE		
370	3535	M	MORTALITY	316	0	540	0	0	0	ALIVE		
320	3535	F	MORTALITY	155	1710	540	27	40		ALIVE		
346	3535	M	MORTALITY	256	2140	540	34	50		ALIVE		
319	3535	F	MORTALITY	156	2160	540	35	50		ALIVE		
322	3535	F	MORTALITY	152	4110	540	66	100		ALIVE		
328	3535	F	MORTALITY	160	4710	602	75	110	90	DIED	NOT_SUBMITTED	
329	3535	F	MORTALITY	169	4830	540	77	110		ALIVE		
325	3535	F	MORTALITY	165	5070	540	81	120		ALIVE		
324	3535	F	MORTALITY	158	5180	540	83	120		ALIVE		
330	3535	F	MORTALITY	168	5640	594	90	130	110	DIED	RAD_PNEUMONITIS	
347	3535	M	MORTALITY	251	5900	540	94	140		ALIVE		
314	3535	F	MORTALITY	151	6040	540	96	140		ALIVE		
327	3535	F	MORTALITY	168	6370	540	102	150		ALIVE		
323	3535	F	MORTALITY	155	6950	487	111	160	140	EUTHANIZED	BA_HYPERPLASIA	
355	3535	M	MORTALITY	257	7070	540	113	160		ALIVE		
118	3533	F	MORTALITY	159	7080	540	113	170		ALIVE		
215	3534	F	MORTALITY	153	7500	367	120	170	140	EUTHANIZED	NO_LESIONS	
111	3533	F	MORTALITY	161	7600	540	121	180		ALIVE		
226	3534	F	MORTALITY	160	7850	585	125	180	160	EUTHANIZED	RAD_PNEUMONITIS	ADENO_CARINOMA
229	3534	F	MORTALITY	166	8130	540	130	190		ALIVE		
123	3533	F	MORTALITY	162	8300	531	133	190	160	DIED	RAD_PNEUMONITIS	BA_HYPERPLASIA
112	3533	F	MORTALITY	159	8400	75	134	200	140	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
358	3535	M	MORTALITY	201	8490	540	136	200		ALIVE		
230	3534	F	MORTALITY	163	8750	96	140	200	150	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
349	3535	M	MORTALITY	261	8780	487	140	200	170	EUTHANIZED	NO_LESIONS	
104	3533	F	MORTALITY	143	8900	226	142	210	160	DIED	RAD_PNEUMONITIS	
341	3535	M	MORTALITY	241	9030	540	144	210		ALIVE		
218	3534	F	MORTALITY	155	9320	50	149	220	150	DIED	RAD_PNEUMONITIS	
321	3535	F	MORTALITY	155	9670	540	154	230		ALIVE		
159	3533	M	MORTALITY	270	9730	339	155	230	190	DIED	LEUKEMIA	
356	3535	M	MORTALITY	199	9860	540	157	230		ALIVE		
216	3534	F	MORTALITY	153	10010	57	160	230	160	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
223	3534	F	MORTALITY	161	10220	101	163	240	170	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
107	3533	F	MORTALITY	154	10510	537	168	250	210	EUTHANIZED	RAD_PNEUMONITIS	ADENO_CARINOMA
108	3533	F	MORTALITY	150	10750	88	172	250	180	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
121	3533	F	MORTALITY	163	10820	82	173	250	180	DIED	RAD_PNEUMONITIS	
110	3533	F	MORTALITY	153	11020	64	176	260	180	DIED	RAD_PNEUMONITIS	
242	3534	M	MORTALITY	276	11100	75	177	260	180	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS

3C. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO Y90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
124	3533	F	MORTALITY	155	11240	53	180	260	180	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
155	3533	M	MORTALITY	264	11240	474	180	260	220	DIED	RAD_PNEUMONITIS	
220	3534	F	MORTALITY	158	11280	68	180	260	180	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
351	3535	M	MORTALITY	251	11300	274	180	260	210	EUTHANIZED	RAD_PNEUMONITIS	
143	3533	M	MORTALITY	233	11420	435	182	270	220	DIED	RAD_PNEUMONITIS	ADENO CARCINOMA
248	3534	M	MORTALITY	247	11560	104	185	270	200	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
117	3533	F	MORTALITY	154	11590	72	185	270	190	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
114	3533	F	MORTALITY	147	11700	65	187	270	190	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
221	3534	F	MORTALITY	157	11710	540	187	270		ALIVE		
119	3533	F	MORTALITY	160	11890	88	190	280	200	DIED	RAD_PNEUMONITIS	
144	3533	M	MORTALITY	246	12070	65	193	280	200	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
357	3535	M	MORTALITY	202	12170	540	194	280		ALIVE		
222	3534	F	MORTALITY	150	12220	61	195	290	200	DIED	RAD_PNEUMONITIS	
354	3535	M	MORTALITY	258	12290	63	196	290	200	DIED	RAD_PNEUMONITIS	
145	3533	M	MORTALITY	248	12400	488	198	290	240	EUTHANIZED	SQUAM_CELL_CA	RAD_PNEUMONITIS
348	3535	M	MORTALITY	249	12420	246	198	290	230	DIED	RAD_PNEUMONITIS	
250	3534	M	MORTALITY	291	12890	63	206	300	210	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
350	3535	M	MORTALITY	250	12990	72	208	300	210	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
243	3534	M	MORTALITY	245	13060	540	209	300		ALIVE		
152	3533	M	MORTALITY	251	13170	79	210	310	220	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
103	3533	F	MORTALITY	152	13380	66	214	310	220	DIED	RAD_PNEUMONITIS	
106	3533	F	MORTALITY	145	13440	54	215	310	210	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
228	3534	F	MORTALITY	153	14130	48	226	330	220	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
164	3533	M	MORTALITY	271	14380	62	230	340	230	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
163	3533	M	MORTALITY	267	14470	74	231	340	240	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
214	3534	F	MORTALITY	140	14580	58	233	340	230	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
247	3534	M	MORTALITY	254	14590	81	233	340	240	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
168	3533	M	MORTALITY	275	15080	56	241	350	240	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
105	3533	F	MORTALITY	148	15250	54	244	360	240	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
167	3533	M	MORTALITY	272	15470	126	247	360	270	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
255	3534	M	MORTALITY	253	15620	108	250	360	270	EUTHANIZED	RAD_PNEUMONITIS	SEPT_FIBROSIS
219	3534	F	MORTALITY	137	15750	57	252	370	250	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
148	3533	M	MORTALITY	254	16000	72	256	370	260	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
150	3533	M	MORTALITY	248	16020	71	256	370	260	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
227	3534	F	MORTALITY	139	16190	65	259	380	260	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
149	3533	M	MORTALITY	253	16240	65	259	380	260	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
245	3534	M	MORTALITY	243	16530	73	264	390	270	DIED	RAD_PNEUMONITIS	
249	3534	M	MORTALITY	241	16610	59	265	390	270	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
109	3533	F	MORTALITY	150	17100	52	273	400	270	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
147	3533	M	MORTALITY	253	17260	73	276	400	280	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
162	3533	M	MORTALITY	259	17310	53	277	400	280	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
254	3534	M	MORTALITY	251	17500	57	280	410		DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
141	3533	M	MORTALITY	239	18140	59	290	420	290	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
161	3533	M	MORTALITY	265	18760	66	300	440	310	DIED	RAD_PNEUM_GROSS	
252	3534	M	MORTALITY	243	19430	58	310	450	310	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
241	3534	M	MORTALITY	234	19600	65	313	460	320	DIED	RAD_PNEUMONITIS	
224	3534	F	MORTALITY	140	19800	64	316	460		DIED	RAD_PNEUMONITIS	
217	3534	F	MORTALITY	143	20320	57	325	470	320	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
157	3533	M	MORTALITY	263	20470	68	327	480	340	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
253	3534	M	MORTALITY	236	20970	60	335	490	340	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS

3D. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO Y90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
244	3534	M	MORTALITY	216	22640	60	362	530	360	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
257	3534	M	MORTALITY	246	22770	50	364	530	360	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
153	3533	M	MORTALITY	250	23440	86	374	550		DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
213	3534	F	MORTALITY	134	23830	59	381	560	380	DIED	RAD_PNEUMONITIS	
225	3534	F	MORTALITY	112	24440	72	390	570	390	DIED	RAD_PNEUMONITIS	
258	3534	M	MORTALITY	251	25800	63	412	600		DIED	RAD_PNEUMONITIS	
251	3534	M	MORTALITY	251	26710	54	427	620	430	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
256	3534	M	MORTALITY	248	26840	54	429	630		DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
201	3534	F	PUL_FUNCT	150	0	601	0	0	0	SAC_EXAMINED	NO LESIONS	
202	3534	F	PUL_FUNCT	138	0	592	0	0	0	DIED	UREMIC_PNEUMONIA	
203	3534	F	PUL_FUNCT	146	0	601	0	0	0	SAC_EXAMINED	ALVEOLAR_HISTEO	
207	3534	F	PUL_FUNCT	156	0	601	0	0	0	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS
259	3534	M	PUL_FUNCT	286	0	540	0	0	0	ALIVE		
261	3534	M	PUL_FUNCT	282	0	540	0	0	0	ALIVE		
264	3534	M	PUL_FUNCT	297	0	540	0	0	0	ALIVE		
302	3535	F	PUL_FUNCT	141	0	540	0	0	0	ALIVE		
304	3535	F	PUL_FUNCT	156	0	540	0	0	0	ALIVE		
359	3535	M	PUL_FUNCT	214	0	601	0	0	0	SAC_EXAMINED	NO LESIONS	
362	3535	M	PUL_FUNCT	292	0	540	0	0	0	ALIVE		
363	3535	M	PUL_FUNCT	297	0	601	0	0	0	SAC_EXAMINED	ALVEOLAR_HISTEO	
344	3535	M	PUL_FUNCT	250	1680	540	27	40		ALIVE		
318	3535	F	PUL_FUNCT	156	2850	708	45	70	60	SAC_EXAMINED	ALVEOLAR_HISTEO	
315	3535	F	PUL_FUNCT	154	2890	608	46	70	60	SAC_EXAMINED	ADENO_CARCIOMA	
345	3535	M	PUL_FUNCT	248	2960	608	47	70	60	SAC_EXAMINED	SEPT_FIBROSIS	
128	3533	F	PUL_FUNCT	169	3650	609	58	90	70	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS
342	3535	M	PUL_FUNCT	240	3730	608	60	90	70	SAC_EXAMINED	NO LESIONS	
120	3533	F	PUL_FUNCT	165	3900	609	62	90	80	SAC_EXAMINED	RAD_PNEUMONITIS	
316	3535	F	PUL_FUNCT	157	4360	572	70	100	90	SAC_EXAMINED	ALVEOLAR_HISTEO	
125	3533	F	PUL_FUNCT	171	4450	609	71	100	90	SAC_EXAMINED	BA_HYPERPLASIA	
122	3533	F	PUL_FUNCT	165	4660	609	74	110	90	SAC_EXAMINED	ALVEOLAR_HISTEO	BA_HYPERPLASIA
317	3535	F	PUL_FUNCT	155	5230	608	83	120	100	SAC_EXAMINED	NO LESIONS	
113	3533	F	PUL_FUNCT	156	5740	609	92	130	110	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS
115	3533	F	PUL_FUNCT	160	5800	609	93	140	110	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS
154	3533	M	PUL_FUNCT	262	5880	609	94	140	120	SAC_EXAMINED	BA_HYPERPLASIA	
313	3535	F	PUL_FUNCT	157	5890	608	94	140	120	SAC_EXAMINED	BA_HYPERPLASIA	ALVEOLAR_HISTEO
142	3533	M	PUL_FUNCT	240	6170	609	99	140	120	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS, SQUAM_CELL_CA
326	3535	F	PUL_FUNCT	164	6650	608	106	160	130	SAC_EXAMINED	SQUAM_CELL_CA	SEPT_FIBROSIS
102	3533	F	PUL_FUNCT	140	6720	609	107	160	130	SAC_EXAMINED	SEPT_FIBROSIS	ALVEOLAR_HISTEO, ADENO_CARCIOMA
116	3533	F	PUL_FUNCT	159	7370	609	118	170	150	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS, BA_CARCIOMA
158	3533	M	PUL_FUNCT	265	7370	609	118	170	150	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS, BA_HYPERPLASIA, LEUKEMIA
127	3533	F	PUL_FUNCT	163	7550	586	121	180	150	EUTHANIZED	RAD_PNEUMONITIS	ADENO_CARCIOMA
352	3535	M	PUL_FUNCT	264	7620	608	122	180	150	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS
170	3533	M	PUL_FUNCT	293	7800	605	125	180	160	DIED	RAD_PNEUMONITIS	LEUKEMIA
353	3535	M	PUL_FUNCT	258	8000	608	128	190	160	SAC_EXAMINED	NO LESIONS	
130	3533	F	PUL_FUNCT	165	8430	574	135	200	170	EUTHANIZED	RAD_PNEUMONITIS	
129	3533	F	PUL_FUNCT	167	8870	563	142	210	180	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS
156	3533	M	PUL_FUNCT	263	8930	609	143	210	180	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS
101	3533	F	PUL_FUNCT	135	9050	609	145	210	180	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS
343	3535	M	PUL_FUNCT	236	9430	608	151	220	190	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS, BA_HYPERPLASIA
246	3534	M	PUL_FUNCT	238	9900	603	158	230	200	DIED	SQUAM_CELL_CA	LEUKEMIA

3E. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO Y90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
160	3533	M	PUL_FUNCT	266	10410	609	166	240	210	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS, VASCULITIS
166	3533	M	PUL_FUNCT	265	10970	609	175	260	220	SAC_EXAMINED	NO_LESIONS	
165	3533	M	PUL_FUNCT	272	10980	575	175	260	220	EUTHANIZED	RAD_PNEUMONITIS	BA_HYPERPLASIA
146	3533	M	PUL_FUNCT	243	11490	571	184	270	230	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS, BA_HYPERPLASIA
151	3533	M	PUL_FUNCT	263	12690	609	203	300	250	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS, BA_HYPERPLASIA
169	3533	M	PUL_FUNCT	268	14030	609	224	330	280	SAC_EXAMINED	ALVEOLAR_HISTEO	SEPT_FIBROSIS, ADENO_CARCIOMA

2 4A. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR90 AND Y90 IN FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
431	3529	F	HEMATOLOGY	176	0	540	0	0	0	ALIVE		
432	3529	F	HEMATOLOGY	175	0	540	0	0	0	ALIVE		
433	3529	F	HEMATOLOGY	178	0	540	0	0	0	ALIVE		
435	3529	F	HEMATOLOGY	183	0	565	0	0	0	EUTHANIZED	LEUKEMIA	
436	3529	M	HEMATOLOGY	230	0	540	0	0	0	ALIVE		
437	3529	M	HEMATOLOGY	247	0	540	0	0	0	ALIVE		
438	3529	M	HEMATOLOGY	246	0	540	0	0	0	ALIVE		
439	3529	M	HEMATOLOGY	259	0	540	0	0	0	ALIVE		
440	3529	M	HEMATOLOGY	261	0	629	0	0	0	SAC EXAMINED	NO_LESIONS	
332	3528	F	HEMATOLOGY	172	160	540	5	10		ALIVE		
339	3528	M	HEMATOLOGY	261	210	540	6	20		ALIVE		
338	3528	M	HEMATOLOGY	235	230	540	6	20		ALIVE		
337	3528	M	HEMATOLOGY	237	270	540	7	20		ALIVE		
333	3528	F	HEMATOLOGY	174	410	540	11	40		ALIVE		
331	3528	F	HEMATOLOGY	182	450	540	13	40		ALIVE		
335	3528	F	HEMATOLOGY	185	550	540	15	50		ALIVE		
334	3528	F	HEMATOLOGY	177	580	540	16	50		ALIVE		
233	3527	F	HEMATOLOGY	174	740	540	21	70		ALIVE		
240	3527	M	HEMATOLOGY	260	760	540	21	70		ALIVE		
235	3527	F	HEMATOLOGY	140	840	630	23	80	70	SAC EXAMINED	BA_HYPERPLASIA	SEPT_FIBROSIS
336	3528	M	HEMATOLOGY	219	900	629	25	80	80	SAC EXAMINED	BA_HYPERPLASIA	
133	3526	F	HEMATOLOGY	178	940	630	26	80	80	SAC EXAMINED	ALVEOLAR_HISTEO	
232	3527	F	HEMATOLOGY	175	1150	575	32	100	100	DIED	RAD_PNEUMONITIS	
236	3527	M	HEMATOLOGY	218	1170	540	33	110		ALIVE		
132	3526	F	HEMATOLOGY	169	1300	530	36	120	110	EUTHANIZED	SQUAM_CELL_CA	
140	3526	M	HEMATOLOGY	240	1330	540	37	120		ALIVE		
340	3528	M	HEMATOLOGY	232	1350	540	38	120		ALIVE		
238	3527	M	HEMATOLOGY	257	1450	540	40	130		ALIVE		
234	3527	F	HEMATOLOGY	180	1570	540	44	140		ALIVE		
135	3526	F	HEMATOLOGY	184	1600	540	45	140		ALIVE		
139	3526	M	HEMATOLOGY	263	2260	568	63	200	200	DIED	ADENO_CACARCINOMA	
137	3526	M	HEMATOLOGY	256	2610	575	73	240	230	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS
237	3527	M	HEMATOLOGY	250	3440	459	96	310	280	DIED	RAD_PNEUMONITIS	
131	3526	F	HEMATOLOGY	174	3650	119	102	330	190	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
231	3527	F	HEMATOLOGY	172	4330	176	121	390	270	DIED	RAD_PNEUMONITIS	
138	3526	M	HEMATOLOGY	262	5230	561	146	470	450	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS, SEPT_FIBROSIS
134	3526	F	HEMATOLOGY	175	6470	263	181	580	470	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
401	3529	F	MORTALITY	135	0	540	0	0	0	ALIVE		
402	3529	F	MORTALITY	138	0	540	0	0	0	ALIVE		
403	3529	F	MORTALITY	149	0	540	0	0	0	ALIVE		
404	3529	F	MORTALITY	157	0	540	0	0	0	ALIVE		
405	3529	F	MORTALITY	145	0	241	0	0	0	EUTHANIZED	ALVEOLAR_HISTEO	SEPT_FIBROSIS
406	3529	F	MORTALITY	151	0	540	0	0	0	ALIVE		
407	3529	F	MORTALITY	155	0	540	0	0	0	ALIVE		
408	3529	F	MORTALITY	151	0	540	0	0	0	ALIVE		
409	3529	F	MORTALITY	161	0	540	0	0	0	ALIVE		
410	3529	F	MORTALITY	157	0	540	0	0	0	ALIVE		
411	3529	F	MORTALITY	163	0	540	0	0	0	ALIVE		
412	3529	F	MORTALITY	153	0	540	0	0	0	ALIVE		
413	3529	F	MORTALITY	165	0	540	0	0	0	ALIVE		

4B. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR90 AND Y90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
414	3529	F	MORTALITY	154	0	540	0	0	0	ALIVE		
415	3529	F	MORTALITY	158	0	540	0	0	0	ALIVE		
416	3529	F	MORTALITY	167	0	540	0	0	0	ALIVE		
417	3529	F	MORTALITY	166	0	540	0	0	0	ALIVE		
418	3529	F	MORTALITY	170	0	540	0	0	0	ALIVE		
420	3529	F	MORTALITY	162	0	629	0	0	0	SAC_EXAMINED	NO_LESIONS	
421	3529	F	MORTALITY	172	0	629	0	0	0	SAC_EXAMINED	NO_LESIONS	
422	3529	F	MORTALITY	168	0	629	0	0	0	SAC_EXAMINED	NO_LESIONS	
423	3529	F	MORTALITY	158	0	540	0	0	0	ALIVE		
424	3529	F	MORTALITY	160	0	499	0	0	0	DIED	LEUKEMIA	
425	3529	F	MORTALITY	167	0	539	0	0	0	DIED	NO_LESIONS	
426	3529	F	MORTALITY	167	0	540	0	0	0	ALIVE		
427	3529	F	MORTALITY	172	0	540	0	0	0	ALIVE		
428	3529	F	MORTALITY	173	0	540	0	0	0	ALIVE		
429	3529	F	MORTALITY	173	0	208	0	0	0	DIED	CONGESTION	
430	3529	F	MORTALITY	189	0	540	0	0	0	ALIVE		
441	3529	M	MORTALITY	267	0	629	0	0	0	SAC_EXAMINED	NO_LESIONS	
442	3529	M	MORTALITY	255	0	629	0	0	0	SAC_EXAMINED	NO_LESIONS	
443	3529	M	MORTALITY	285	0	540	0	0	0	ALIVE		
444	3529	M	MORTALITY	277	0	540	0	0	0	ALIVE		
445	3529	M	MORTALITY	279	0	540	0	0	0	ALIVE		
446	3529	M	MORTALITY	256	0	540	0	0	0	ALIVE		
447	3529	M	MORTALITY	268	0	540	0	0	0	ALIVE		
448	3529	M	MORTALITY	269	0	540	0	0	0	ALIVE		
449	3529	M	MORTALITY	270	0	540	0	0	0	ALIVE		
450	3529	M	MORTALITY	254	0	540	0	0	0	ALIVE		
451	3529	M	MORTALITY	255	0	540	0	0	0	ALIVE		
452	3529	M	MORTALITY	282	0	540	0	0	0	ALIVE		
453	3529	M	MORTALITY	256	0	540	0	0	0	ALIVE		
454	3529	M	MORTALITY	283	0	540	0	0	0	ALIVE		
456	3529	M	MORTALITY	291	0	637	0	0	0	EUTHANIZED	NO_LESIONS	
457	3529	M	MORTALITY	290	0	540	0	0	0	ALIVE		
458	3529	M	MORTALITY	285	0	540	0	0	0	ALIVE		
459	3529	M	MORTALITY	268	0	540	0	0	0	ALIVE		
460	3529	M	MORTALITY	275	0	540	0	0	0	ALIVE		
461	3529	M	MORTALITY	302	0	540	0	0	0	ALIVE		
462	3529	M	MORTALITY	289	0	540	0	0	0	ALIVE		
463	3529	M	MORTALITY	260	0	540	0	0	0	ALIVE		
464	3529	M	MORTALITY	277	0	645	0	0	0	DIED	CONGESTION	
465	3529	M	MORTALITY	305	0	540	0	0	0	ALIVE		
466	3529	M	MORTALITY	306	0	540	0	0	0	ALIVE		
467	3529	M	MORTALITY	304	0	540	0	0	0	ALIVE		
468	3529	M	MORTALITY	313	0	540	0	0	0	ALIVE		
469	3529	M	MORTALITY	323	0	540	0	0	0	ALIVE		
470	3529	M	MORTALITY	298	0	640	0	0	0	DIED	LEUKEMIA	
350	3528	M	MORTALITY	292	110	540	3	10		ALIVE		
370	3528	M	MORTALITY	323	120	540	3	10		ALIVE		
310	3528	F	MORTALITY	163	120	540	3	10		ALIVE		
319	3528	F	MORTALITY	164	160	540	4	10		ALIVE		
230	3527	F	MORTALITY	173	160	540	5	10		ALIVE		

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4C. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR9C AND Y90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
342	3528	M	MORTALITY	265	180	380	5	20	10	DIED	NO_LESIONS	
328	3528	F	MORTALITY	165	200	540	6	20		ALIVE		
354	3528	M	MORTALITY	265	210	540	6	20		ALIVE		
209	3527	F	MORTALITY	160	220	540	6	20		ALIVE		
212	3527	F	MORTALITY	151	220	540	6	20		ALIVE		
258	3527	M	MORTALITY	300	230	631	6	20	20	DIED	UREMIC_PNEUMONIA	
311	3528	F	MORTALITY	154	250	307	7	20	20	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
210	3527	F	MORTALITY	166	280	540	8	20		ALIVE		
317	3528	F	MORTALITY	169	280	623	8	30	20	EUTHANIZED	RAD_PNEUMONITIS	
222	3527	F	MORTALITY	161	290	540	8	30		ALIVE		
330	3528	F	MORTALITY	177	300	600	8	30	30	DIED	CONGESTION	HEMORRHAGE
158	3526	M	MORTALITY	294	320	540	9	30		ALIVE		
318	3528	F	MORTALITY	161	310	623	9	30	30	EUTHANIZED	LEUKEMIA	
208	3527	F	MORTALITY	155	320	540	9	30		ALIVE		
154	3526	M	MORTALITY	285	320	540	9	30		ALIVE		
307	3528	F	MORTALITY	151	320	540	9	30		ALIVE		
306	3528	F	MORTALITY	153	330	540	9	30		ALIVE		
368	3528	M	MORTALITY	303	320	540	9	30		ALIVE		
114	3526	F	MORTALITY	157	330	614	9	30	30	EUTHANIZED	RAD_PNEUMONITIS	
348	3528	M	MORTALITY	269	330	540	9	30		ALIVE		
106	3526	F	MORTALITY	153	370	540	10	30		ALIVE		
304	3528	F	MORTALITY	160	390	540	11	30		ALIVE		
353	3528	M	MORTALITY	285	390	540	11	40		ALIVE		
167	3526	M	MORTALITY	286	390	643	11	40	40	SAC_EXAMINED	UNRESOLVED	
341	3528	M	MORTALITY	234	400	540	11	40		ALIVE		
267	3527	M	MORTALITY	310	400	540	11	40		ALIVE		
303	3528	F	MORTALITY	158	400	540	11	40		ALIVE		
150	3526	M	MORTALITY	264	430	624	12	40	40	EUTHANIZED	RAD_PNEUMONITIS	
262	3527	M	MORTALITY	291	440	540	12	40		ALIVE		
364	3528	M	MORTALITY	294	440	540	12	40		ALIVE		
257	3527	M	MORTALITY	302	450	540	12	40		ALIVE		
213	3527	F	MORTALITY	166	450	540	13	40		ALIVE		
323	3528	F	MORTALITY	160	480	540	13	40		ALIVE		
362	3528	M	MORTALITY	286	480	540	13	40		ALIVE		
248	3527	M	MORTALITY	247	490	641	14	40	40	DIED	RAD_PNEUMONITIS	BA_HYPERPLASIA
225	3527	F	MORTALITY	169	490	540	14	40		ALIVE		
312	3528	F	MORTALITY	157	490	540	14	40		ALIVE		
358	3528	M	MORTALITY	301	510	540	14	50		ALIVE		
270	3527	M	MORTALITY	327	510	630	14	50	50	SAC_EXAMINED	BA_HYPERPLASIA	
219	3527	F	MORTALITY	169	520	540	14	50		ALIVE		
218	3527	F	MORTALITY	168	520	540	15	50		ALIVE		
367	3528	M	MORTALITY	309	530	584	15	50	50	DIED	LEUKEMIA	
343	3528	M	MORTALITY	262	550	540	15	50		ALIVE		
314	3528	F	MORTALITY	155	560	540	16	50		ALIVE		
221	3527	F	MORTALITY	169	570	540	16	50		ALIVE		
147	3526	M	MORTALITY	252	580	540	16	50		ALIVE		
301	3528	F	MORTALITY	143	580	522	16	50	50	EUTHANIZED	UREMIC_PNEUMONIA	
360	3528	M	MORTALITY	291	580	587	16	50	50	EUTHANIZED	LEUKEMIA	
265	3527	M	MORTALITY	285	600	540	17	50		ALIVE		
206	3527	F	MORTALITY	157	610	540	17	50		ALIVE		

4D. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR90 AND Y90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS A DEATH
227	3527	F	MORTALITY	177	610	596	17	50	50	EUTHANIZED	UNRESOLVED	
327	3528	F	MORTALITY	163	610	540	17	60		ALIVE		
357	3528	M	MORTALITY	281	610	540	17	60		ALIVE		
316	3528	F	MORTALITY	156	660	602	18	60	60	EUTHANIZED	BA_HYPERPLASIA	
224	3527	F	MORTALITY	166	660	540	19	60		ALIVE		
329	3528	F	MORTALITY	175	680	540	19	60		ALIVE		
245	3527	M	MORTALITY	279	700	630	19	60	60	SAC_EXAMINED	BA_HYPERPLASIA	
207	3527	F	MORTALITY	157	710	587	20	60	60	EUTHANIZED	ALVEOLAR_HISTEO	
256	3527	M	MORTALITY	270	710	540	20	60		ALIVE		
166	3526	M	MORTALITY	307	750	580	21	70	70	DIED	RAD_PNEUMONITIS	
320	3528	F	MORTALITY	162	770	602	21	70	70	EUTHANIZED	ALVEOLAR_HISTEO	
216	3527	F	MORTALITY	171	780	540	22	70		ALIVE		
366	3528	M	MORTALITY	304	800	540	22	70		ALIVE		
315	3528	F	MORTALITY	161	810	629	23	70	70	SAC_EXAMINED	ALVEOLAR_HISTEO	
322	3528	F	MORTALITY	165	840	634	23	80	70	SAC_EXAMINED	RAD_PNEUMONITIS	
313	3528	F	MORTALITY	164	840	629	23	80	70	SAC_EXAMINED	NO_LESIONS	
203	3527	F	MORTALITY	148	840	540	24	80		ALIVE		
202	3527	F	MORTALITY	139	860	540	24	80		ALIVE		
205	3527	F	MORTALITY	160	900	540	25	80		ALIVE		
164	3526	M	MORTALITY	295	960	540	27	90		ALIVE		
214	3527	F	MORTALITY	162	960	540	27	90		ALIVE		
165	3526	M	MORTALITY	255	990	540	28	90		ALIVE		
369	3528	M	MORTALITY	294	1020	540	29	90		ALIVE		
345	3528	M	MORTALITY	275	1070	458	30	100	90	DIED	RAD_PNEUMONITIS	
356	3528	M	MORTALITY	271	1070	640	30	100	90	DIED	LEUKEMIA	SQUAM_CELL_CA
352	3528	M	MORTALITY	270	1090	540	31	100		ALIVE		
250	3527	M	MORTALITY	274	1100	638	31	100	100	SAC_EXAMINED	LEUKEMIA	BA_HYPERPLASIA
170	3526	M	MORTALITY	313	1110	540	31	100		ALIVE		
169	3526	M	MORTALITY	300	1120	540	31	100		ALIVE		
111	3526	F	MORTALITY	160	1130	600	32	100	100	EUTHANIZED	RAD_PNEUMONITIS	
324	3528	F	MORTALITY	172	1140	629	32	100	100	SAC_EXAMINED	NO_LESIONS	
157	3526	M	MORTALITY	279	1140	540	32	100		ALIVE		
363	3528	M	MORTALITY	281	1160	540	32	100		ALIVE		
204	3527	F	MORTALITY	156	1190	630	33	110	100	SAC_EXAMINED	BA_HYPERPLASIA	
249	3527	M	MORTALITY	270	1200	540	34	110		ALIVE		
359	3528	M	MORTALITY	279	1210	503	34	110	100	DIED	MESOTHELIOMA	
365	3528	M	MORTALITY	283	1250	556	35	110	110	DIED	BA_HYPERPLASIA	
344	3528	M	MORTALITY	272	1260	629	35	110	110	SAC_EXAMINED	NO_LESIONS	
152	3526	M	MORTALITY	281	1270	582	35	110	110	DIED	LEUKEMIA	
326	3528	F	MORTALITY	167	1270	540	36	110		ALIVE		
251	3527	M	MORTALITY	264	1280	630	36	120	110	SAC_EXAMINED	BA_HYPERPLASIA	
346	3528	M	MORTALITY	280	1300	629	36	120	120	SAC_EXAMINED		
308	3528	F	MORTALITY	141	1330	540	37	120		ALIVE		
255	3527	M	MORTALITY	298	1330	540	37	120		ALIVE		
355	3528	M	MORTALITY	277	1360	540	38	120		ALIVE		
155	3526	M	MORTALITY	257	1410	630	39	130	120	SAC_EXAMINED	BA_HYPERPLASIA	
217	3527	F	MORTALITY	168	1450	540	40	130		ALIVE		
148	3526	M	MORTALITY	266	1470	540	41	130		ALIVE		
242	3527	M	MORTALITY	242	1510	540	42	140		ALIVE		
347	3528	M	MORTALITY	274	1510	597	42	140	130	DIED	SQUAM_CELL_CA	

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4E. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR90 AND Y90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
305	3528	F	MORTALITY	154	1560	630	43	140	130	DIED	RAD_PNEUMONITIS	HEMORRHAGE
244	3527	M	MORTALITY	290	1610	540	45	140		ALIVE		
149	3526	M	MORTALITY	271	1620	540	45	150		ALIVE		
126	3526	F	MORTALITY	166	1660	540	46	150		ALIVE		
269	3527	M	MORTALITY	311	1670	540	47	150		ALIVE		
142	3526	M	MORTALITY	264	1670	623	47	150	150	DIED	MESOTHELIOMA	SEPT_FIBROSIS
228	3527	F	MORTALITY	170	1750	587	49	160	150	DIED	UNRESOLVED	
211	3527	F	MORTALITY	157	1760	540	49	160		ALIVE		
361	3528	M	MORTALITY	303	1880	540	53	170		ALIVE		
243	3527	M	MORTALITY	278	1930	540	54	170		ALIVE		
122	3526	F	MORTALITY	169	2020	587	56	180	180	DIED	SQUAM_CELL_CA	
260	3527	M	MORTALITY	291	2050	540	57	180		ALIVE		
253	3527	M	MORTALITY	269	2070	540	58	190		ALIVE		
229	3527	F	MORTALITY	176	2090	540	58	190		ALIVE		
220	3527	F	MORTALITY	162	2140	566	60	190	180	DIED	SQUAM_CELL_CA	BA_HYPERPLASIA
268	3527	M	MORTALITY	301	2170	603	61	200	200	EUTHANIZED	SEPT_FIBROSIS	
266	3527	M	MORTALITY	305	2260	540	63	200		ALIVE		
168	3526	M	MORTALITY	319	2410	537	67	220	220	DIED	LEUKEMIA	
247	3527	M	MORTALITY	251	2420	540	68	220		ALIVE		
246	3527	M	MORTALITY	276	2430	546	68	220	210	DIED	HEMANGIOSARCOMA	SQUAM_CELL_CA
264	3527	M	MORTALITY	263	2440	565	68	220	210	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS, SEPT_FIBROSIS
226	3527	F	MORTALITY	162	2470	449	69	220	200	DIED	CONGESTION	
351	3528	M	MORTALITY	261	2590	540	72	230		ALIVE		
325	3528	F	MORTALITY	169	2590	594	72	230	230	DIED	SQUAM_CELL_CA	
349	3528	M	MORTALITY	282	2620	540	73	240		ALIVE		
159	3526	M	MORTALITY	282	2670	540	75	240		ALIVE		
128	3526	F	MORTALITY	172	2710	529	76	240	230	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS, SEPT_FIBROSIS
201	3527	F	MORTALITY	145	2780	579	78	250	230	DIED	SQUAM_CELL_CA	SEPT_FIBROSIS
146	3526	M	MORTALITY	274	2900	641	81	260	260	EUTHANIZED	SQUAM_CELL_CA	BA_HYPERPLASIA
241	3527	M	MORTALITY	282	3090	460	86	280	260	EUTHANIZED	NO LESIONS	
118	3526	F	MORTALITY	169	3160	475	88	290	270	EUTHANIZED	HEMANGIOSARCOMA	RAD_PNEUMONITIS, SEPT_FIBROSIS
215	3527	F	MORTALITY	165	3190	551	89	290	270	DIED	ADENO_CACARCINOMA	
108	3526	F	MORTALITY	162	3220	630	90	290	280	SAC_EXAMINED	SQUAM_CELL_CA	HEMANGIOSARCOMA, RAD_PNEUMONITIS, SEPT_FIBROSIS
101	3526	F	MORTALITY	139	3340	538	93	300	270	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS
223	3527	F	MORTALITY	159	3350	470	93	300	280	DIED	SQUAM_CELL_CA	
120	3526	F	MORTALITY	166	3380	600	94	300	290	EUTHANIZED	SQUAM_CELL_CA	RAD_PNEUMONITIS
153	3526	M	MORTALITY	289	3460	630	97	310	310	SAC_EXAMINED	SQUAM_CELL_CA	
261	3527	M	MORTALITY	291	3470	529	97	310	300	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS, SEPT_FIBROSIS
151	3526	M	MORTALITY	284	3480	630	97	310	310	SAC_EXAMINED	SQUAM_CELL_CA	RAD_PNEUMONITIS
252	3527	M	MORTALITY	262	3510	630	98	320	310	SAC_EXAMINED	SQUAM_CELL_CA	SEPT_FIBROSIS, BA_HYPERPLASIA
102	3526	F	MORTALITY	169	3620	501	101	330	310	DIED	SQUAM_CELL_CA	
124	3526	F	MORTALITY	170	3670	433	102	330	300	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
162	3526	M	MORTALITY	285	3770	553	105	340	330	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS, SQUAM_CELL_CA, HEMANGIOSARCOMA
163	3526	M	MORTALITY	272	3800	630	106	340	340	SAC_EXAMINED	SQUAM_CELL_CA	SEPT_FIBROSIS, BA_HYPERPLASIA
144	3526	M	MORTALITY	261	3870	417	108	350	320	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
259	3527	M	MORTALITY	277	3970	610	111	360	350	DIED	SQUAM_CELL_CA	
103	3526	F	MORTALITY	155	4010	385	112	360	320	DIED	HEMANGIOSARCOMA	SQUAM_CELL_CA, SEPT_FIBROSIS
105	3526	F	MORTALITY	151	4110	204	115	370	260	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
125	3526	F	MORTALITY	172	4190	623	117	380	370	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS
263	3527	M	MORTALITY	291	4390	615	122	400	390	DIED	SQUAM_CELL_CA	RAD_PNEUMONITIS, SEPT_FIBROSIS

4F. PATHOLOGICAL OBSERVATIONS AND OTHER COMMENTS FOR RATS THAT DIED, WERE SACRIFICED OR EUTHANIZED AFTER INHALATION EXPOSURE TO SR90 AND Y90-FAP

ANIMAL NUMBER	EXPERI- MENT NUMBER	SEX	GROUP	INITIAL WEIGHT (g)	ILB (kBq/g LUNG)	DPE	30-DAY GRAYS	900-DAY GRAYS	GRAYS AT DEATH	MODE OF DEATH	MAJOR FINDING	OTHER FINDINGS AT DEATH
117	3526	F	MORTALITY	172	4470	472	125	400	380	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
116	3526	F	MORTALITY	171	4600	149	128	410	260	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
127	3526	F	MORTALITY	171	4600	546	128	410	400	DIED	UNDIFF CARCINOMA	
121	3526	F	MORTALITY	161	4630	363	129	420	360	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
110	3526	F	MORTALITY	160	5040	117	141	450	260	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
129	3526	F	MORTALITY	163	5280	63	148	480	200	DIED	RAD_PNEUMONITIS	
112	3526	F	MORTALITY	146	5290	229	148	480	310	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
109	3526	F	MORTALITY	165	5300	93	148	480	240	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
113	3526	F	MORTALITY	160	5520	106	154	500	270	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
145	3526	M	MORTALITY	269	5810	103	162	520	280	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
123	3526	F	MORTALITY	164	5920	252	165	530	420	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
104	3526	F	MORTALITY	140	6110	135	170	550	330	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
119	3526	F	MORTALITY	165	6570	149	183	590	380	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
141	3526	M	MORTALITY	267	6570	132	183	590	360	DIED	RAD_PNEUMONITIS	SEPT_FIBROSIS
160	3526	M	MORTALITY	294	6880	138	192	620	390	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
107	3526	F	MORTALITY	159	6960	106	194	630	340	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS
115	3526	F	MORTALITY	169	7060	130	197	640	380	DIED	RAD_PNEUMONITIS	VASCULITIS, SEPT_FIBROSIS

5A. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO SR90-FAP

ANIMAL NUMBER	EXPERIMENT NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mmHg)	DIFFUSING CAPACITY PER kg BODY WT	DIFFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE CQ10 (ml/cm-H2O)	SLOPE PHASE 3
121	3522	F	0	0	9.4	0.85	0.17	1.01	0.018	0.68	0.45
122	3522	F	0	0	8.3	0.79	0.15	0.93	0.018	0.57	0.53
124	3522	F	0	0	9.0	0.86	0.16	1.03	0.017	0.62	0.46
125	3522	F	0	0	8.2	0.83	0.15	0.93	0.018	0.48	0.46
127	3522	F	0	0	8.6	0.81	0.15	0.92	0.018	0.62	0.47
128	3522	F	0	0	8.2	0.86	0.13	0.81	0.016	0.55	0.43
129	3522	F	0	0	8.8	0.76	0.14	0.81	0.015	0.56	0.43
130	3522	F	0	0	8.1	0.83	0.17	1.06	0.021	0.53	0.53
221	3523	F	0	0	8.6	0.83	0.15	0.94	0.018	0.61	0.50
222	3523	F	0	0	9.2	0.84	0.18	1.12	0.019	0.66	0.41
223	3523	F	0	0	9.1	0.79	0.15	0.97	0.016	0.63	0.43
224	3523	F	0	0	7.8	0.75	0.15	0.98	0.018	0.52	0.76
225	3523	F	0	0	7.7	0.80	0.15	0.96	0.019	0.49	0.45
226	3523	F	0	0	7.9	0.84	0.15	0.93	0.018	0.51	0.47
227	3523	F	0	0	8.8	0.77	0.15	0.94	0.018	0.66	0.46
228	3523	F	0	0	10.4	0.85	0.17	1.02	0.018	0.79	0.36
229	3523	F	0	0	9.6	0.87	0.18	1.10	0.019	0.68	0.38
230	3523	F	0	0	8.5	0.81	0.15	0.97	0.019	0.66	0.48
321	3524	F	0	0	7.3	0.76	0.16	1.03	0.017	0.47	0.45
322	3524	F	0	0	9.4	0.80	0.17	1.00	0.018	0.70	0.48
323	3524	F	0	0	9.7	0.85	0.18	1.02	0.019	0.71	0.42
324	3524	F	0	0	9.3	0.80	0.15	0.85	0.014	0.64	0.39
325	3524	F	0	0	10.8	0.79	0.18	1.08	0.018	0.80	0.37
326	3524	F	0	0	10.0	0.85	0.17	0.98	0.016	0.74	0.43
327	3524	F	0	0	10.1	0.83	0.18	1.04	0.017	0.77	0.42
328	3524	F	0	0	10.2	0.83	0.18	1.13	0.019	0.75	0.43
421	3525	F	0	0	9.2	0.84	0.14	0.91	0.016	0.68	0.46
422	3525	F	0	0	9.6	0.81	0.17	0.96	0.017	0.71	0.41
423	3525	F	0	0	10.1	0.82	0.19	1.10	0.017	0.75	0.53
424	3525	F	0	0	10.1	0.87	0.21	1.22	0.019	0.75	0.35
425	3525	F	0	0	8.3	0.72	0.16	1.00	0.017	0.66	0.75
426	3525	F	0	0	8.8	0.86	0.11	0.66	0.014	0.64	0.42
427	3525	F	0	0	9.1	0.82	0.15	0.92	0.016	0.67	0.39
428	3525	F	0	0	10.0	0.88	0.20	1.21	0.019	0.76	0.45
429	3525	F	0	0	9.6	0.84	0.15	0.91	0.016	0.63	0.42
430	3525	F	0	0	8.7	0.80	0.14	0.90	0.015	0.59	0.33
141	3522	M	0	0	11.0	0.84	0.24	1.09	0.020	0.80	0.48
142	3522	M	0	0	10.2	0.85	0.23	1.00	0.022	0.69	0.43
143	3522	M	0	0	11.2	0.85	0.21	0.89	0.019	0.82	0.36
145	3522	M	0	0	9.6	0.87	0.18	0.81	0.019	0.67	0.43
146	3522	M	0	0	11.5	0.88	0.20	0.85	0.018	0.79	0.34
147	3522	M	0	0	11.4	0.87	0.20	0.85	0.018	0.80	0.34
148	3522	M	0	0	10.0	0.86	0.20	0.87	0.018	0.65	0.41
150	3522	M	0	0	11.3	0.86	0.19	0.81	0.018	0.81	0.32
242	3523	M	0	0	9.2	0.84	0.19	0.89	0.020	0.65	0.48
243	3523	M	0	0	10.6	0.86	0.15	0.66	0.014	0.81	0.37

5B. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO SR90-FAP

ANIMAL NUMBER	EXPERIMENT NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mmHg)	DIFFUSING CAPACITY PER kg BODY WT	DIFFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE CQ10 (ml/cm-H2O)	SLOPE PHASE 3
244	3523	M	0	0	10.4	0.84	0.21	0.93	0.020	0.71	0.38
245	3523	M	0	0	11.8	0.89	0.24	0.99	0.022	0.82	0.39
246	3523	M	0	0	12.4	0.87	0.23	0.97	0.019	0.89	0.29
247	3523	M	0	0	9.8	0.84	0.17	0.78	0.016	0.64	0.46
248	3523	M	0	0	10.2	0.88	0.16	0.72	0.015	0.64	0.45
249	3523	M	0	0	10.5	0.84	0.20	0.82	0.018	0.68	0.48
250	3523	M	0	0	11.9	0.92	0.24	1.02	0.020	0.79	0.41
341	3523	M	0	0	10.2	0.87	0.22	0.91	0.020	0.64	0.49
342	3524	M	0	0	11.5	0.90	0.18	0.81	0.015	0.80	0.38
343	3524	M	0	0	10.0	0.88	0.19	0.78	0.020	0.65	0.49
344	3524	M	0	0	9.2	0.77	0.20	0.87	0.018	0.69	0.52
345	3524	M	0	0	11.9	0.89	0.24	0.99	0.019	0.76	0.37
346	3524	M	0	0	11.0	0.84	0.23	0.90	0.021	0.74	0.41
347	3524	M	0	0	9.0	0.78	0.20	0.83	0.018	0.53	0.62
348	3524	M	0	0	11.1	0.86	0.24	0.99	0.022	0.76	0.38
349	3524	M	0	0	9.4	0.81	0.21	0.88	0.019	0.68	0.51
350	3524	M	0	0	10.9	0.86	0.20	0.87	0.019	0.81	0.48
442	3525	M	0	0	10.9	0.85	0.19	0.87	0.018	0.76	0.40
443	3525	M	0	0	11.8	0.85	0.24	0.96	0.020	0.85	0.42
444	3525	M	0	0	12.1	0.83	0.22	0.89	0.020	0.90	0.41
445	3525	M	0	0	12.2	0.87	0.24	0.99	0.020	0.79	0.43
446	3525	M	0	0	11.1	0.83	0.22	0.89	0.018	0.83	0.35
447	3525	M	0	0	12.8	0.88	0.22	0.91	0.017	0.93	0.35
448	3525	M	0	0	13.3	0.83	0.25	0.93	0.019	1.00	0.37
449	3525	M	0	0	11.6	0.87	0.23	0.95	0.019	0.81	0.33
450	3525	M	0	0	11.7	0.82	0.26	0.96	0.021	0.85	0.37
451	3525	M	0	0	10.8	0.87	0.21	0.88	0.020	0.70	0.46
421	3525	F	2	0	10.6	0.82	0.17	0.98	0.016	0.79	0.37
422	3525	F	2	0	10.9	0.79	0.19	0.97	0.017	0.82	0.35
423	3525	F	2	0	10.8	0.84	0.18	1.00	0.017	0.83	0.39
424	3525	F	2	0	10.2	0.81	0.17	0.96	0.016	0.74	0.36
425	3525	F	2	0	9.5	0.80	0.18	1.01	0.019	0.75	0.58
426	3525	F	2	0	9.8	0.80	0.18	1.00	0.017	0.78	0.48
427	3525	F	2	0	9.7	0.80	0.18	0.96	0.016	0.75	0.39
428	3525	F	2	0	10.6	0.80	0.18	1.00	0.017	0.82	0.47
429	3525	F	2	0	10.8	0.83	0.17	0.93	0.015	0.85	0.33
430	3525	F	2	0	9.8	0.85	0.15	0.85	0.014	0.72	0.40
125	3522	F	2	10	11.5	0.85	0.19	1.05	0.016	0.84	0.36
124	3522	F	2	20	9.5	0.86	0.17	0.97	0.018	0.63	0.53
129	3522	F	2	20	9.8	0.86	0.17	0.87	0.016	0.72	0.38
324	3524	F	2	20	10.0	0.80	0.18	0.92	0.016	0.74	0.36
325	3524	F	2	20	11.5	0.86	0.19	1.01	0.017	0.86	0.31
327	3524	F	2	20	10.8	0.84	0.20	1.05	0.019	0.79	0.40
328	3524	F	2	20	10.9	0.87	0.18	1.00	0.017	0.81	0.36
226	3523	F	2	30	7.7	0.84	0.14	0.80	0.016	0.49	0.56
321	3524	F	2	30	9.7	0.86	0.18	1.06	0.017	0.68	0.54

5C. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO SR90-FAP

ANIMAL NUMBER	EXPERIMENT NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mmHg)	DIFFUSING CAPACITY PER kg BODY WT	DIFFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE C010 (ml/cm-H2O)	SLOPE PHASE 3
322	3524	F	2	30	10.4	0.82	0.20	1.04	0.018	0.77	0.50
323	3524	F	2	30	10.4	0.84	0.18	0.95	0.017	0.79	0.41
326	3524	F	2	30	11.2	0.85	0.22	1.15	0.018	0.81	0.37
128	3522	F	2	40	9.5	0.86	0.19	1.07	0.018	0.69	0.41
228	3523	F	2	40	9.9	0.83	0.21	1.09	0.019	0.64	0.38
127	3522	F	2	50	9.1	0.67	0.14	0.79	0.015	0.71	0.60
225	3523	F	2	60	7.9	0.84	0.12	0.68	0.014	0.59	0.71
121	3522	F	2	70	10.7	0.85	0.16	0.86	0.015	0.77	0.36
221	3523	F	2	80	8.6	0.63	0.14	0.77	0.015	0.67	0.64
222	3523	F	2	100	8.5	0.83	0.11	0.64	0.014	0.65	0.60
230	3523	F	2	100	9.3	0.84	0.17	0.97	0.016	0.75	0.33
227	3523	F	2	110	9.1	0.84	0.14	0.81	0.015	0.66	0.37
229	3523	F	2	120	10.3	0.88	0.18	0.97	0.016	0.75	0.37
223	3523	F	2	150	8.8	0.88	0.12	0.69	0.013	0.58	0.46
122	3522	F	2	180	9.5	1.13	0.15	0.86	0.016	0.66	0.44
224	3523	F	2	200	7.8	0.82	0.09	0.56	0.011	0.56	0.64
130	3522	F	2	310	8.6	0.85	0.10	0.59	0.013	0.66	0.57
143	3522	M	2	0	11.9	0.95	0.25	0.89	0.020	0.75	0.58
347	3524	M	2	0	13.9	0.87	0.28	0.92	0.020	0.97	0.38
442	3525	M	2	0	13.8	0.83	0.23	0.80	0.015	1.04	0.28
443	3525	M	2	0	13.0	0.88	0.28	0.92	0.021	0.94	0.51
444	3525	M	2	0	14.0	0.88	0.24	0.79	0.016	1.10	0.31
445	3525	M	2	0	14.7	0.86	0.22	0.69	0.015	1.06	0.26
446	3525	M	2	0	12.9	0.88	0.23	0.75	0.017	0.96	0.33
447	3525	M	2	0	13.8	0.82	0.22	0.75	0.015	1.08	0.27
448	3525	M	2	0	15.0	0.86	0.33	1.00	0.021	1.17	0.32
449	3525	M	2	0	14.0	0.85	0.22	0.71	0.015	1.03	0.25
450	3525	M	2	0	13.9	0.83	0.26	0.81	0.020	1.00	0.37
451	3525	M	2	0	12.7	0.85	0.24	0.86	0.020	0.84	0.40
141	3522	M	2	10	12.6	0.77	0.28	0.98	0.021	0.90	0.49
142	3522	M	2	20	12.5	0.88	0.27	0.96	0.021	0.91	0.37
341	3523	M	2	20	14.0	0.82	0.27	0.90	0.019	1.08	0.36
344	3524	M	2	20	13.0	0.85	0.21	0.76	0.016	0.91	0.36
250	3523	M	2	30	14.4	0.87	0.25	0.79	0.017	1.11	0.43
342	3524	M	2	30	13.6	0.91	0.22	0.78	0.017	0.99	0.42
146	3522	M	2	40	12.7	0.86	0.27	0.94	0.022	0.88	0.34
349	3524	M	2	40	14.0	0.83	0.25	0.81	0.017	1.03	0.37
150	3522	M	2	50	13.4	0.86	0.24	0.75	0.016	0.96	0.51
247	3523	M	2	50	12.2	0.89	0.25	0.85	0.019	0.95	0.67
145	3522	M	2	60	7.3	0.80	0.17	0.64	0.015	0.48	0.69
350	3524	M	2	60	11.6	0.88	0.20	0.70	0.017	0.77	0.45
345	3524	M	2	70	13.7	0.82	0.25	0.85	0.017	1.01	0.45
343	3524	M	2	90	13.1	0.81	0.27	0.85	0.020	0.93	0.44
346	3524	M	2	100	12.7	0.78	0.24	0.79	0.018	0.97	0.40
348	3524	M	2	100	13.6	0.81	0.22	0.73	0.015	1.06	0.43
248	3523	M	2	110	12.7	0.85	0.21	0.74	0.015	0.98	0.39

5D. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO SR90-FAP

ANIMAL NUMBER	EXPERIMENT NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mmHg)	DIFFUSING CAPACITY PER kg BODY WT	DIFFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE CQ10 (ml/cm-H2O)	SLOPE PHASE 3
147	3522	M	2	120	12.6	0.87	0.22	0.78	0.016	0.91	0.51
242	3523	M	2	130	10.6	0.85	0.15	0.60	0.013	0.78	0.32
148	3522	M	2	140	11.9	0.92	0.17	0.60	0.014	0.79	0.50
246	3523	M	2	160	13.4	0.84	0.20	0.70	0.015	1.02	0.52
243	3523	M	2	170	11.5	0.88	0.18	0.64	0.015	0.85	0.34
244	3523	M	2	170	12.3	0.82	0.15	0.52	0.012	0.99	0.40
245	3523	M	2	190	11.7	0.88	0.19	0.63	0.017	0.95	0.45
249	3523	M	2	220	13.3	0.85	0.21	0.77	0.014	1.02	0.43
421	3525	F	3	0	10.5	0.85	0.18	1.01	0.017	0.80	0.40
422	3525	F	3	0	11.5	0.89	0.23	1.14	0.018	0.86	0.37
423	3525	F	3	0	11.3	0.89	0.18	0.99	0.017	0.84	0.38
424	3525	F	3	0	11.0	0.87	0.21	1.14	0.017	0.84	0.34
425	3525	F	3	0	9.4	0.85	0.18	1.06	0.019	0.67	0.50
426	3525	F	3	0	10.2	0.86	0.16	0.86	0.015	0.77	0.40
427	3525	F	3	0	9.9	0.85	0.19	0.96	0.017	0.69	0.45
428	3525	F	3	0	10.8	0.89	0.20	1.08	0.016	0.78	0.45
429	3525	F	3	0	11.0	0.83	0.20	1.12	0.019	0.81	0.41
430	3525	F	3	0	10.3	0.88	0.15	0.83	0.014	0.76	0.37
125	3522	F	3	20	12.0	0.93	0.20	1.05	0.017	0.83	0.38
324	3524	F	3	20	11.8	0.88	0.20	1.05	0.017	0.83	0.43
325	3524	F	3	20	11.5	0.86	0.20	1.08	0.017	0.83	0.43
327	3524	F	3	20	10.8	0.81	0.20	1.01	0.017	0.86	0.38
328	3524	F	3	20	10.9	0.83	0.19	1.02	0.017	0.81	0.37
124	3522	F	3	30	10.7	0.86	0.18	1.00	0.017	0.80	0.40
129	3522	F	3	30	10.8	0.87	0.16	0.80	0.015	0.78	0.36
226	3523	F	3	40	9.7	0.85	0.15	0.85	0.016	0.68	0.46
323	3524	F	3	40	11.5	0.83	0.20	1.02	0.017	0.86	0.17
326	3524	F	3	40	11.7	0.89	0.20	1.01	0.017	0.86	0.36
128	3522	F	3	50	10.9	0.84	0.14	0.80	0.013	0.76	0.46
321	3524	F	3	50	10.8	0.87	0.16	0.92	0.013	0.79	0.37
322	3524	F	3	50	10.8	0.82	0.23	1.19	0.019	0.83	0.48
127	3522	F	3	60	10.8	0.86	0.18	1.01	0.017	0.77	0.39
228	3523	F	3	60	12.2	0.92	0.22	1.07	0.019	0.87	0.34
121	3522	F	3	90	10.9	0.88	0.18	0.95	0.017	0.79	0.50
225	3523	F	3	90	9.6	0.87	0.15	0.85	0.016	0.71	0.49
221	3523	F	3	110	10.0	0.85	0.17	0.92	0.017	0.75	0.39
230	3523	F	3	130	9.9	0.87	0.15	0.86	0.014	0.73	0.47
222	3523	F	3	140	10.3	0.85	0.16	0.92	0.016	0.78	0.38
227	3523	F	3	150	9.7	0.87	0.16	0.91	0.015	0.69	0.45
229	3523	F	3	160	10.2	0.83	0.15	0.80	0.015	0.76	0.63
223	3523	F	3	200	10.4	0.85	0.14	0.76	0.012	0.79	0.36
122	3522	F	3	240	9.2	0.85	0.11	0.60	0.011	0.68	0.45
224	3523	F	3	260	6.6	0.78	0.07	0.44	0.010	0.44	0.68
130	3522	F	3	420	8.8	0.84	0.13	0.73	0.013	0.63	0.54
143	3522	M	3	0	13.1	0.88	0.26	0.86	0.019	0.96	0.36
347	3524	M	3	0	14.0	0.87	0.27	0.86	0.019	1.00	0.29

5E. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO SR90-FAP

ANIMAL NUMBER	EXPERIMENT NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mmHg)	DIFFUSING CAPACITY PER kg BODY WT	DIFFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE CQ10 (ml/cm-H2O)	SLOPE PHASE 3
442	3525	M	3	0	13.3	0.89	0.27	0.92	0.020	0.96	0.35
443	3525	M	3	0	13.3	0.87	0.26	0.81	0.018	0.99	0.32
444	3525	M	3	0	14.1	0.88	0.25	0.78	0.017	1.04	0.30
445	3525	M	3	0	14.0	0.86	0.30	0.91	0.018	1.04	0.41
446	3525	M	3	0	12.1	0.84	0.25	0.77	0.019	0.93	0.37
447	3525	M	3	0	14.2	0.89	0.23	0.77	0.015	1.08	0.22
448	3525	M	3	0	15.6	0.88	0.30	0.92	0.017	1.15	0.27
449	3525	M	3	0	14.5	0.85	0.24	0.72	0.015	1.07	0.23
450	3525	M	3	0	14.4	0.89	0.30	0.86	0.019	1.06	0.38
451	3525	M	3	0	12.7	0.84	0.26	0.85	0.019	0.98	0.33
141	3522	M	3	10	13.0	0.91	0.30	0.98	0.022	0.91	0.40
142	3522	M	3	20	13.2	0.90	0.28	0.93	0.020	0.92	0.42
341	3523	M	3	20	14.2	0.88	0.29	0.87	0.019	1.01	0.33
344	3524	M	3	20	12.8	0.87	0.24	0.81	0.017	0.87	0.36
250	3523	M	3	40	14.6	0.90	0.28	0.85	0.018	0.97	0.35
146	3522	M	3	50	12.8	0.89	0.27	0.90	0.020	0.89	0.35
342	3524	M	3	50	13.6	0.88	0.26	0.87	0.019	0.98	0.41
349	3524	M	3	60	14.7	0.88	0.28	0.87	0.019	1.12	0.31
150	3522	M	3	70	13.4	0.84	0.25	0.82	0.017	0.96	0.28
145	3522	M	3	80	10.9	0.93	0.19	0.71	0.016	0.72	0.33
350	3524	M	3	80	12.6	0.84	0.22	0.74	0.017	0.97	0.33
345	3524	M	3	90	15.0	0.89	0.33	1.05	0.020	1.15	
343	3524	M	3	120	13.9	0.88	0.23	0.66	0.015	1.01	0.26
346	3524	M	3	130	13.6	0.83	0.26	0.79	0.018	1.00	0.32
248	3523	M	3	140	13.2	0.85	0.21	0.71	0.016	1.02	0.29
348	3524	M	3	140	14.3	0.85	0.23	0.73	0.016	1.11	0.31
147	3522	M	3	160	10.6	0.90	0.21	0.69	0.017	0.62	0.48
242	3523	M	3	170	11.3	0.90	0.25	0.94	0.021	0.81	0.38
148	3522	M	3	190	11.8	0.90	0.22	0.73	0.018	0.84	0.39
244	3523	M	3	220	11.1	0.80	0.17	0.55	0.014	0.76	0.43
243	3523	M	3	230	11.7	0.91	0.19	0.67	0.016	0.84	0.44
245	3523	M	3	250	10.8	0.87	0.17	0.54	0.015	0.73	0.38
249	3523	M	3	300	11.6	0.89	0.16	0.54	0.012	0.83	0.46
421	3525	F	6	0	11.7	0.87	0.17	0.92	0.014	0.87	
422	3525	F	6	0	11.8	0.86	0.24	1.15	0.020	0.85	
423	3525	F	6	0	11.4	0.83	0.18	0.88	0.015	0.87	
424	3525	F	6	0	11.2	0.80	0.21	1.11	0.017	0.85	
425	3525	F	6	0	10.8	0.82	0.14	0.77	0.013	0.82	
426	3525	F	6	0	10.6	0.81	0.20	1.01	0.019	0.79	
427	3525	F	6	0	10.9	0.84	0.21	1.02	0.017	0.81	
428	3525	F	6	0	12.0	0.82	0.21	1.10	0.018	0.94	
429	3525	F	6	0	10.7	0.78	0.17	0.93	0.016	0.82	
430	3525	F	6	0	10.5	0.85	0.16	0.83	0.015	0.80	
125	3522	F	6	20	12.4	0.84	0.20	1.05	0.016	0.94	
324	3524	F	6	30	12.1	0.86	0.23	1.06	0.017	0.81	
325	3524	F	6	30	12.4	0.81	0.17	0.89	0.013	0.96	

5F. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO SR90-FAP

ANIMAL NUMBER	EXPERIMENT NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mmHg)	DIFFUSING CAPACITY PER kg BODY WT	DIFFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE CQ10 (ml/cm-H2O)	SLOPE PHASE 3
327	3524	F	6	30	12.2	0.85	0.21	1.00	0.017	0.93	
124	3522	F	6	40	11.4	0.82	0.17	0.89	0.015	0.87	
129	3522	F	6	40	11.0	0.82	0.21	1.02	0.018	0.84	
328	3524	F	6	40	11.2	0.80	0.24	1.26	0.019	0.79	
323	3524	F	6	50	11.0	0.81	0.21	1.00	0.017	0.83	
226	3523	F	6	60	10.1	0.85	0.19	0.96	0.017	0.73	
326	3524	F	6	60	12.1	0.84	0.22	1.11	0.016	0.92	
321	3524	F	6	70	10.5	0.79	0.17	0.92	0.016	0.78	
322	3524	F	6	70	10.9	0.85	0.20	1.01	0.018	0.77	
128	3522	F	6	80	10.6	0.76	0.21	1.09	0.017	0.80	
228	3523	F	6	80	13.1	0.86	0.23	1.06	0.017	0.96	
127	3522	F	6	90	11.3	0.79	0.17	0.87	0.014	0.86	
225	3523	F	6	130	10.3	0.81	0.16	0.87	0.015	0.76	
121	3522	F	6	140	11.5	0.82	0.13	0.68	0.011	0.84	
221	3523	F	6	170	10.0	0.81	0.16	0.79	0.015	0.73	
230	3523	F	6	190	9.7	0.79	0.18	0.99	0.017	0.73	
222	3523	F	6	200	10.2	0.83	0.13	0.71	0.012	0.77	
227	3523	F	6	230	9.6	0.80	0.14	0.74	0.013	0.69	
229	3523	F	6	230	10.9	0.86	0.16	0.80	0.015	0.76	
223	3523	F	6	290	10.1	0.82	0.14	0.75	0.013	0.75	
130	3522	F	6	610	2.5	0.52	0.02	0.15	0.005	0.16	
143	3522	M	6	0	15.3	0.84	0.26	0.79	0.016	1.13	
347	3524	M	6	0	15.1	0.88	0.28	0.81	0.017	1.07	
442	3525	M	6	0	15.8	0.87	0.21	0.68	0.013	1.18	
443	3525	M	6	0	14.0	0.79	0.22	0.62	0.015	1.02	
444	3525	M	6	0	15.9	0.85	0.28	0.83	0.018	1.17	
445	3525	M	6	0	16.6	0.91	0.28	0.75	0.016	1.24	
446	3525	M	6	0	14.4	0.85	0.26	0.72	0.016	1.14	
447	3525	M	6	0	15.7	0.89	0.26	0.77	0.016	1.18	
448	3525	M	6	0	17.2	0.79	0.33	0.86	0.017	1.32	
449	3525	M	6	0	15.7	0.80	0.27	0.75	0.017	1.12	
450	3525	M	6	0	15.0	0.87	0.30	0.78	0.019	1.09	
451	3525	M	6	0	14.6	0.78	0.26	0.75	0.016	1.14	
141	3522	M	6	20	14.4	0.84	0.25	0.74	0.017	1.10	
142	3522	M	6	30	15.0	0.85	0.29	0.99	0.019	1.14	
341	3523	M	6	30	16.3	0.90	0.31	0.85	0.020	1.23	
344	3524	M	6	30	14.3	0.79	0.23	0.74	0.015	1.01	
250	3523	M	6	50	15.1	0.83	0.30	0.83	0.019	1.08	
146	3522	M	6	70	14.8	0.83	0.29	0.89	0.018	1.05	
342	3524	M	6	70	15.3	0.84	0.27	0.80	0.017	1.10	
349	3524	M	6	80	15.3	0.85	0.31	0.90	0.019	1.20	
150	3522	M	6	100	15.9	0.87	0.30	0.84	0.018	1.14	
350	3524	M	6	110	13.3	0.86	0.23	0.75	0.016	0.98	
145	3522	M	6	120	12.8	0.86	0.19	0.61	0.014	0.91	
345	3524	M	6	140	15.6	0.82	0.27	0.79	0.017	1.16	
343	3524	M	6	180	15.2	0.83	0.27	0.70	0.017	1.13	

5G. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO SR90-FAP

ANIMAL NUMBER	EXPERIMENT NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mm)	DIFFUSING CAPACITY PER kg BODY WT	DIFFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE CQ10 (ml/cm-H2O)	SLOPE PHASE 3
346	3524	M	6	200	14.3	0.85	0.26	0.70	0.016	1.04	
348	3524	M	6	200	15.7	0.85	0.31	0.92	0.019	1.22	
248	3523	M	6	210	13.9	0.82	0.24	0.77	0.017	1.03	
147	3522	M	6	240	16.1	0.89	0.24	0.72	0.014	1.10	
242	3523	M	6	260	11.7	0.87	0.18	0.59	0.015	0.82	
148	3522	M	6	280	12.6	0.78	0.24	0.74	0.018	0.96	
243	3523	M	6	330	11.4	0.82	0.16	0.52	0.013	0.80	
244	3523	M	6	330	12.1	0.83	0.16	0.45	0.013	0.83	
245	3523	M	6	370	11.5	0.87	0.17	0.47	0.014	0.77	
421	3525	F	9	0	11.3	0.83	0.20	0.98	0.018	0.85	0.45
422	3525	F	9	0	12.4	0.74	0.21	0.86	0.017	0.98	0.42
423	3525	F	9	0	11.7	0.87	0.20	0.97	0.015	0.84	0.53
424	3525	F	9	0	11.5	0.83	0.19	0.94	0.016	0.91	0.48
425	3525	F	9	0	10.2	0.86	0.20	1.01	0.018	0.71	0.78
426	3525	F	9	0	11.1	0.87	0.20	0.97	0.018	0.81	0.64
427	3525	F	9	0	10.3	0.79	0.20	0.87	0.017	0.81	0.52
428	3525	F	9	0	12.2	0.86	0.23	1.12	0.018	0.92	0.50
429	3525	F	9	0	11.6	0.87	0.19	0.95	0.016	0.81	0.48
430	3525	F	9	0	10.6	0.82	0.17	0.85	0.016	0.73	0.57
125	3522	F	9	30	12.8	0.74	0.23	1.15	0.018	1.01	0.40
324	3524	F	9	40	13.1	0.87	0.21	0.93	0.016	0.99	0.44
325	3524	F	9	40	13.1	0.83	0.24	1.18	0.019	0.96	0.42
327	3524	F	9	40	11.6	0.82	0.17	0.77	0.014	0.88	0.54
328	3524	F	9	40	12.4	0.87	0.25	1.23	0.019	0.97	0.59
124	3522	F	9	50	11.4	0.85	0.23	0.57	0.020	0.83	0.57
129	3522	F	9	50	12.0	0.83	0.21	0.92	0.017	0.90	0.40
226	3523	F	9	60	11.0	0.85	0.20	1.01	0.018	0.84	0.63
323	3524	F	9	60	11.8	0.84	0.25	1.03	0.019	0.91	0.40
326	3524	F	9	70	12.6	0.83	0.22	0.98	0.017	1.01	0.45
321	3524	F	9	80	11.9	0.88	0.20	0.93	0.016	0.89	0.41
322	3524	F	9	80	12.4	0.91	0.20	0.99	0.016	0.88	0.38
128	3522	F	9	90	9.8	0.79	0.28	1.39	0.025	0.70	0.94
228	3523	F	9	100	12.4	0.81	0.22	0.97	0.019	0.99	0.48
127	3522	F	9	110	11.7	0.80	0.19	0.93	0.016	0.89	0.40
225	3523	F	9	150	10.2	0.81	0.21	1.09	0.019	0.79	0.80
121	3522	F	9	160	11.1	0.87	0.23	1.08	0.019	0.79	0.33
221	3523	F	9	190	10.7	0.83	0.18	0.87	0.017	0.81	0.48
230	3523	F	9	230	9.5	0.86	0.14	0.68	0.015	0.68	0.62
222	3523	F	9	240	10.0	0.79	0.13	0.68	0.012	0.77	0.66
227	3523	F	9	260	9.3	0.81	0.15	0.74	0.016	0.70	0.79
229	3523	F	9	270	10.2	0.85	0.15	0.71	0.014	0.75	0.58
223	3523	F	9	340	9.9	0.79	0.14	0.68	0.014	0.71	0.58
143	3522	M	9	0	15.5	0.84	0.27	0.76	0.017	1.19	0.31
347	3524	M	9	0	16.3	0.91	0.38	1.05	0.023	1.15	0.24
442	3525	M	9	0	15.4	0.87	0.30	0.89	0.019	1.16	0.45
443	3525	M	9	0	15.6	0.84	0.31	0.80	0.018	1.24	0.32

5H. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO SR90-FAP

ANIMAL NUMBER	EXPERIMENT NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mmHg)	DIFFUSING CAPACITY PER kg BODY WT	DIFFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE CQ10 (ml/cm-H2O)	SLOPE PHASE 3
444	3525	M	9	0	16.0	0.83	0.29	0.77	0.017	1.25	0.35
445	3525	M	9	0	16.8	0.86	0.39	1.03	0.021	1.26	0.36
446	3525	M	9	0	14.1	0.86	0.31	0.78	0.020	1.02	0.42
447	3525	M	9	0	15.3	0.84	0.36	0.99	0.020	1.04	0.36
448	3525	M	9	0	17.3	0.86	0.37	0.92	0.020	1.28	0.29
449	3525	M	9	0	15.3	0.84	0.27	0.67	0.020	1.20	0.45
450	3525	M	9	0	14.8	0.87	0.27	0.64	0.019	1.05	0.51
451	3525	M	9	0	14.6	0.83	0.30	0.79	0.019	1.09	0.37
141	3522	M	9	20	14.8	0.82	0.34	0.90	0.021	1.11	0.32
142	3522	M	9	40	15.4	0.85	0.30	0.84	0.019	1.10	0.34
341	3523	M	9	40	16.1	0.90	0.29	0.75	0.018	1.16	0.18
344	3524	M	9	40	14.2	0.85	0.31	0.89	0.019	1.03	0.06
250	3523	M	9	60	17.4	0.87	0.33	0.85	0.018	1.32	0.35
146	3522	M	9	80	14.1	0.82	0.32	0.89	0.021	1.06	0.22
342	3524	M	9	80	15.6	0.88	0.30	0.84	0.018	1.15	0.26
349	3524	M	9	100	16.3	0.85	0.35	0.91	0.020	1.28	0.34
150	3522	M	9	120	16.8	0.85	0.37	0.97	0.019	1.31	0.38
350	3524	M	9	130	14.2	0.86	0.29	0.84	0.019	1.10	0.38
145	3522	M	9	140	12.8	0.87	0.22	0.66	0.017	0.90	0.36
345	3524	M	9	160	16.0	0.85	0.30	0.82	0.018	1.16	0.36
343	3524	M	9	210	15.5	0.87	0.30	0.72	0.020	1.16	0.32
346	3524	M	9	230	15.1	0.87	0.39	1.00	0.024	1.14	0.00
248	3523	M	9	240	13.6	0.85	0.25	0.72	0.017	1.01	0.47
348	3524	M	9	240	16.3	0.87	0.33	0.86	0.020	1.22	0.36
147	3522	M	9	280	17.2	0.87	0.28	0.77	0.014	1.28	0.18
242	3523	M	9	300	11.4	0.88	0.20	0.61	0.016	0.81	0.67
148	3522	M	9	330	9.9	0.76	0.19	0.53	0.015	0.67	0.75
243	3523	M	9	390	9.9	0.85	0.14	0.42	0.013	0.66	0.62
244	3523	M	9	390	11.3	0.83	0.14	0.38	0.012	0.77	0.41
245	3523	M	9	440	10.4	0.83	0.14	0.38	0.013	0.69	0.27
421	3525	F	12	0	12.3	0.83	0.15	0.68	0.013	0.93	0.51
422	3525	F	12	0	12.9	0.81	0.24	0.92	0.019	1.04	0.82
423	3525	F	12	0	12.2	0.84	0.20	0.91	0.017	0.95	0.70
424	3525	F	12	0	12.2	0.81	0.20	1.01	0.016	0.91	0.66
425	3525	F	12	0	10.3	0.78	0.20	1.02	0.018	0.76	1.00
426	3525	F	12	0	10.8	0.79	0.15	0.68	0.013	0.78	0.62
427	3525	F	12	0	11.6	0.79	0.18	0.78	0.015	0.87	0.46
428	3525	F	12	0	13.0	0.81	0.26	1.23	0.019	1.01	0.67
429	3525	F	12	0	11.8	0.85	0.19	0.89	0.015	0.88	0.47
430	3525	F	12	0	9.0	0.79	0.12	0.61	0.012	0.53	1.09
125	3522	F	12	30	13.3	0.89	0.24	1.17	0.017	1.00	0.53
324	3524	F	12	40	12.5	0.86	0.22	0.88	0.017	0.92	
325	3524	F	12	40	13.2	0.78	0.19	0.87	0.014	0.98	
327	3524	F	12	40	12.6	0.88	0.23	0.96	0.019	0.94	0.70
124	3522	F	12	50	12.3	0.89	0.21	0.97	0.015	0.94	0.53
328	3524	F	12	50	12.6	0.86	0.22	1.05	0.017	0.92	0.74

51. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO SR90-FAP

ANIMAL NUMBER	EXPERIMENT NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mmHg)	DIFFUSING CAPACITY PER kg BODY WT	DIFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE CQ10 (ml/cm-H2O)	SLOPE PHASE 3
129	3522	F	12	60	12.6	0.82	0.17	0.78	0.014	0.92	0.43
226	3523	F	12	70	10.4	0.76	0.22	1.03	0.020	0.78	0.79
323	3524	F	12	70	11.8	0.85	0.24	0.92	0.018	0.87	0.67
326	3524	F	12	80	13.1	0.82	0.22	0.91	0.017	1.02	
321	3524	F	12	90	11.0	0.83	0.22	1.00	0.018	0.77	0.51
322	3524	F	12	90	11.9	0.80	0.24	1.16	0.019	0.88	0.62
128	3522	F	12	100	11.2	0.87	0.23	1.04	0.021	0.84	0.77
228	3523	F	12	110	13.1	0.86	0.24	0.99	0.019	1.03	0.62
127	3522	F	12	120	11.6	0.87	0.20	0.89	0.017	0.85	0.72
225	3523	F	12	170	9.4	0.86	0.21	1.03	0.019	0.60	1.04
121	3522	F	12	180	12.3	0.87	0.21	0.95	0.015	0.92	0.52
221	3523	F	12	220	10.6	0.75	0.22	1.02	0.020	0.79	0.53
230	3523	F	12	260	6.6	0.71	0.16	0.72	0.011	0.47	0.98
222	3523	F	12	270	8.1	0.81	0.13	0.61	0.015	0.63	0.84
227	3523	F	12	300	8.4	0.88	0.10	0.45	0.011	0.64	0.50
229	3523	F	12	310	8.8	0.81	0.13	0.59	0.013	0.59	0.94
223	3523	F	12	390	9.0	0.81	0.13	0.57	0.013	0.67	0.68
442	3525	M	12	0	16.1	0.86	0.33	0.92	0.020	1.23	0.58
443	3525	M	12	0	16.6	0.83	0.29	0.69	0.017	1.26	0.55
444	3525	M	12	0	15.9	0.86	0.35	0.87	0.019	1.16	0.56
445	3525	M	12	0	17.6	0.87	0.30	0.75	0.016	1.31	0.52
446	3525	M	12	0	15.8	0.84	0.30	0.71	0.018	1.28	0.40
447	3525	M	12	0	14.8	0.89	0.30	0.78	0.018	0.95	0.50
448	3525	M	12	0	19.0	0.95	0.35	0.81	0.018	1.38	0.43
449	3525	M	12	0	16.8	0.77	0.32	0.79	0.017	1.32	
450	3525	M	12	0	14.6	0.84	0.30	0.71	0.021	1.02	0.44
451	3525	M	12	0	16.0	0.80	0.26	0.67	0.016	1.25	0.46
143	3522	M	12	10	16.5	0.85	0.33	0.92	0.018	1.28	0.58
347	3524	M	12	10	16.4	0.76	0.32	0.86	0.018	1.24	0.36
141	3522	M	12	30	15.7	0.83	0.38	0.97	0.022	1.24	
344	3524	M	12	40	14.3	0.80	0.31	0.84	0.018	1.00	0.48
142	3522	M	12	50	15.4	0.87	0.36	1.02	0.021	1.15	0.42
341	3523	M	12	50	17.1	0.87	0.34	0.82	0.019	1.15	0.44
250	3523	M	12	70	18.1	0.87	0.38	0.92	0.020	1.43	
342	3524	M	12	90	16.4	0.86	0.28	0.75	0.015	1.15	0.45
146	3522	M	12	100	16.7	0.85	0.30	0.81	0.016	1.32	0.47
349	3524	M	12	110	16.8	0.90	0.31	0.78	0.017	1.27	0.46
150	3522	M	12	140	17.8	0.90	0.30	0.77	0.016	1.25	0.39
145	3522	M	12	150	13.7	0.82	0.23	0.65	0.015	1.06	0.38
350	3524	M	12	150	14.8	0.90	0.26	0.74	0.017	1.08	0.55
345	3524	M	12	180	16.4	0.85	0.35	0.92	0.020	1.22	0.44
343	3524	M	12	240	16.2	0.82	0.28	0.63	0.016	1.23	0.51
346	3524	M	12	260	13.6	0.78	0.30	0.73	0.020	0.97	0.50
348	3524	M	12	270	15.3	0.79	0.31	0.79	0.019	1.08	0.54
248	3523	M	12	280	14.5	0.77	0.26	0.69	0.017	1.13	0.49
147	3522	M	12	310	18.0	0.84	0.25	0.66	0.013	1.21	0.43

5J. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO SR90-FAP

ANIMAL NUMBER	EXPERIMENT NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mmHg)	DIFFUSING CAPACITY PER kg BODY WT	DIFFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE CQ10 (ml/cm-H2O)	SLOPE PHASE 3
242	3523	M	12	340	10.9	0.69	0.15	0.45	0.012	0.79	0.92
148	3522	M	12	380	11.5	0.85	0.21	0.57	0.016	0.78	0.92
245	3523	M	12	500	8.6	0.84	0.12	0.33	0.012	0.48	2.01
421	3525	F	18	0	11.9	0.86	0.23	0.92	0.017	0.85	0.70
423	3525	F	18	0	12.7	0.78	0.20	0.77	0.014	1.03	0.37
424	3525	F	18	0	13.0	0.86	0.22	1.01	0.017	0.97	0.54
425	3525	F	18	0	11.6	0.84	0.22	0.96	0.018	0.80	0.87
426	3525	F	18	0	12.4	0.87	0.23	0.90	0.018	0.88	0.78
427	3525	F	18	0	12.3	0.84	0.22	0.83	0.017	0.88	0.55
428	3525	F	18	0	12.5	0.82	0.21	0.86	0.017	0.93	0.68
429	3525	F	18	0	12.5	0.79	0.24	0.99	0.018	1.03	0.61
430	3525	F	18	0	11.3	0.84	0.22	0.88	0.019	0.82	0.82
125	3522	F	18	30	13.1	0.82	0.23	1.02	0.017	1.00	0.47
324	3524	F	18	50	12.8	0.83	0.23	0.89	0.016	0.92	0.51
325	3524	F	18	50	14.6	0.92	0.22	0.88	0.015	1.06	0.55
327	3524	F	18	50	13.3	0.85	0.27	0.97	0.019	0.98	0.65
124	3522	F	18	60	12.1	0.88	0.20	0.79	0.015	0.84	0.75
129	3522	F	18	60	12.8	0.90	0.18	0.72	0.014	0.86	0.42
226	3523	F	18	80	11.4	0.82	0.26	1.03	0.020	0.89	0.83
323	3524	F	18	80	12.2	0.79	0.22	0.76	0.017	0.94	0.25
321	3524	F	18	100	11.8	0.82	0.21	0.83	0.016	0.85	0.56
322	3524	F	18	100	12.5	0.88	0.22	0.95	0.018	0.82	0.69
128	3522	F	18	110	12.4	0.88	0.20	0.90	0.016	0.89	0.60
228	3523	F	18	120	11.8	0.83	0.24	0.88	0.019	0.77	0.48
127	3522	F	18	140	11.8	0.86	0.20	0.80	0.016	0.88	0.57
225	3523	F	18	190	9.9	0.83	0.18	0.79	0.017	0.73	1.19
221	3523	F	18	240	4.5	0.53	0.07	0.35	0.010	0.36	0.64
442	3525	M	18	0	15.9	0.82	0.32	0.87	0.019	1.24	0.48
443	3525	M	18	0	17.2	0.87	0.35	0.82	0.018	1.29	0.36
444	3525	M	18	0	16.2	0.83	0.32	0.81	0.018	1.25	0.40
445	3525	M	18	0	18.1	0.85	0.32	0.81	0.017	1.36	0.25
446	3525	M	18	0	15.5	0.84	0.28	0.66	0.018	1.17	0.33
447	3525	M	18	0	16.9	0.85	0.30	0.79	0.017	1.30	0.34
448	3525	M	18	0	19.5	0.87	0.41	0.91	0.020	1.51	0.33
449	3525	M	18	0	16.7	0.83	0.33	0.83	0.018	1.25	0.16
450	3525	M	18	0	16.6	0.86	0.33	0.78	0.020	1.24	0.36
451	3525	M	18	0	16.5	0.86	0.25	0.63	0.014	1.27	0.32
143	3522	M	18	10	17.3	0.87	0.28	0.72	0.017	1.34	0.25
347	3524	M	18	10	17.3	0.82	0.28	0.78	0.016	1.31	0.35
141	3522	M	18	30	16.6	0.84	0.34	0.84	0.019	1.30	0.32
142	3522	M	18	50	16.8	0.88	0.29	0.81	0.018	1.26	0.24
341	3523	M	18	50	17.4	0.85	0.40	0.99	0.021	1.31	0.26
344	3524	M	18	50	17.3	0.82	0.21	0.53	0.012	1.41	0.24
250	3523	M	18	80	15.7	0.81	0.39	0.97	0.022	1.14	0.43
146	3522	M	18	110	17.1	0.85	0.27	0.72	0.016	1.29	0.28
349	3524	M	18	120	16.6	0.85	0.32	0.81	0.018	1.27	0.24

5K. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO SR90-FAP

ANIMAL NUMBER	EXPERIMENT NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mmHg)	DIFFUSING CAPACITY PER kg BODY WT	DIFFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE CQ10 (ml/cm-H ₂ O)	SLOPE PHASE 3
150	3522	M	18	150	17.3	0.83	0.26	0.66	0.015	1.30	0.44
350	3524	M	18	160	14.4	0.84	0.28	0.75	0.018	1.11	0.29
145	3522	M	18	170	14.2	0.82	0.26	0.73	0.018	1.02	0.56
345	3524	M	18	200	16.8	0.84	0.33	0.88	0.018	1.22	0.42
343	3524	M	18	270	17.4	0.86	0.31	0.73	0.018	1.29	0.30
346	3524	M	18	290	14.8	0.82	0.29	0.70	0.018	0.98	0.42
348	3524	M	18	290	17.2	0.86	0.32	0.83	0.018	1.37	0.33

6. PULMONARY FUNCTION MEASUREMENTS FOR RATS EXPOSED VIA INHALATION TO Y90-FAP

ANIMAL NUMBER	SEX	MONTHS AFTER EXPOSURE	CUMULATIVE DOSE (Gy)	VITAL CAPACITY (ml)	VITAL TO TOTAL CAPACITY RATIO	CO DIFFUSING CAPACITY (ml/min/mm)	DIFFUSING CAPACITY PER kg BODY WT	DIFFUSING CAPACITY PER ml ALVEOLAR VOLUME	QUASISTATIC COMPLIANCE CQ10 (ml/cm-H2O)	SLOPE PHASE 3
201	F	18	0	10.2	0.85	0.20	0.86	0.019	0.80	0.33
202	F	18	0	10.3	0.88	0.19	0.92	0.018	0.78	0.37
203	F	18	0	10.3	0.88	0.20	0.86	0.016	0.73	0.40
207	F	18	0	9.4	0.86	0.15	0.74	0.014	0.72	0.80
259	M	18	0	15.8	0.90	0.33	0.81	0.019	1.19	0.31
261	M	18	0	14.9	0.88	0.37	0.91	0.022	1.09	0.24
264	M	18	0	14.0	0.79	0.34	0.77	0.021	0.97	0.17
302	F	18	0	10.2	0.91	0.20	0.90	0.017	0.76	0.36
304	F	18	0	11.8	0.93	0.19	0.76	0.014	0.88	0.46
359	M	18	0	14.6	0.94	0.32	0.78	0.021	1.06	0.18
362	M	18	0	16.3	0.89	0.34	0.76	0.019	1.27	0.22
363	M	18	0	16.9	0.91	0.40	0.95	0.020	1.28	0.48
344	M	18	30	16.5	0.94	0.37	0.91	0.020	1.24	0.18
318	F	18	60	11.5	0.89	0.23	0.97	0.019	0.87	0.32
315	F	18	60	10.4	0.88	0.19	0.85	0.017	0.72	0.47
345	M	18	60	16.0	0.93	0.35	0.93	0.021	1.24	0.31
128	F	18	70	12.4	0.87	0.25	0.99	0.019	0.98	0.30
342	M	18	80	13.8	0.90	0.29	0.76	0.017	1.01	0.31
120	F	18	80	11.8	0.89	0.24	0.92	0.018	0.84	0.65
316	F	18	90	10.5	0.88	0.21	0.96	0.018	0.76	0.38
125	F	18	90	11.6	0.87	0.25	0.96	0.020	0.87	0.65
122	F	18	90	11.0	0.90	0.24	1.00	0.021	0.79	0.25
317	F	18	100	10.2	0.88	0.19	0.81	0.017	0.72	0.32
113	F	18	110	11.1	0.85	0.20	0.74	0.016	0.79	0.32
115	F	18	110	11.3	0.92	0.24	1.06	0.019	0.78	0.62
313	F	18	120	10.4	0.89	0.21	0.85	0.019	0.70	0.65
154	M	18	120	15.6	0.92	0.30	0.77	0.017	1.11	0.23
142	M	18	120	14.6	0.93	0.30	0.87	0.018	0.98	0.17
326	F	18	130	9.8	0.88	0.15	0.57	0.013	0.75	0.44
102	F	18	130	7.1	0.83	0.11	0.48	0.014	0.53	1.03
116	F	18	150	9.5	0.89	0.18	0.73	0.017	0.71	0.56
127	F	18	150	7.4	0.94	0.11	0.51	0.013	0.50	1.08
158	M	18	150	7.4	0.82	0.24	0.61	0.015	0.50	1.08
352	M	18	150	14.1	0.87	0.29	0.73	0.019	1.03	0.44
170	M	18	160	16.2	0.90	0.33	0.71	0.019	1.14	0.12
353	M	18	160	15.6	0.89	0.30	0.74	0.018	1.25	0.20
130	F	18	170	11.5	0.86	0.10	0.41	0.008	0.79	0.36
129	F	18	180	6.5	0.86	0.10	0.43	0.012	0.44	2.78
101	F	18	180	12.8	0.90	0.18	1.04	0.013	0.81	0.44
156	M	18	180	15.5	0.86	0.26	0.63	0.014	1.26	0.34
343	M	18	190	13.8	0.92	0.36	0.96	0.023	0.99	0.36
246	M	18	200	11.9	0.84	0.15	0.44	0.011	0.82	0.34
160	M	18	210	15.9	0.98	0.24	0.81	0.015	0.96	0.29
166	M	18	220	14.1	0.86	0.29	0.78	0.018	0.99	0.43
165	M	18	220	16.6	0.88	0.35	0.80	0.019	1.31	0.15
146	M	18	230	14.9	0.94	0.31	0.76	0.018	1.03	0.32
151	M	18	260	13.2	0.91	0.25	0.64	0.017	0.92	0.29
169	M	18	280	12.8	0.95	0.24	0.56	0.017	0.84	0.50

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13. ABSTRACT (200 words or less) This report summarizes a series of experiments concerning the effect of linear energy transfer and temporal radiation dose pattern to the lung from inhaled beta-emitting radionuclides. The results were used to test the validity of a hazard-function mathematical model for predicting death from radiation pneumonitis. Both morbidity and mortality within 18 months after exposure were examined in rats exposed to beta emitting radionuclides, giving brief or protracted irradiation of the lung or having weak or strong beta emissions. Protraction of the radiation dose to the lung from a lung half time of less than 3 days to a lung half time of 150 days has a sparing effect with a factor of 1.7. Low energy beta emissions have a similar effectiveness in producing lethal injury as high energy beta emissions. The hazard function model for predicting death adequately predicted the median lethal doses for rats.			
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