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ACUTE MORTALITY OF MICE AND RATS EXPOSED TO MIXED GAMMA-NEUTRON RADIATIONS OR TO X RAYS

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FOREWORD
(Nontechnical Summary)

Mortality data are reported for CF#1 BL mice and Sprague-Dawley rats exposed to either mixed gamma-neutron radiations from the AFRRI-TRIGA reactor or 250 kVp x rays. These data were collected as a part of the program to characterize the biological effects of the reactor radiations and to provide reference information for future studies.

Groups of rats and mice were exposed to radiation doses over a range estimated to produce 0 to 100 percent mortality during the first 30 days following irradiation. Deaths were counted daily, and at the end of the 30-day observation period the percent mortality was calculated for each group of mice and rats.

When these kinds of data are plotted as percent mortality versus dose, one ordinarily obtains a sigmoid (S-shaped) curve. Such a curve can be converted to a straight line by a mathematical transformation called probit analysis. The mathematical transformation simplifies the analysis of the data.

Many investigators summarize their mortality results by reporting a single value, the median lethal dose (LD_{50}). The LD_{50} serves as an estimate of the sensitivity of the animal species to the set of exposure conditions used. The LD_{50} is that dose required to produce mortality, within a specified time period, in 50 percent of the individuals in a large group of exposed animals. The first 30-day postirradiation period is used by many investigators and the results reported as an $LD_{50/30}$.

In this study, the $LD_{50/30}$ midline tissue doses for mice exposed to either x rays or reactor radiations were found to be 589 and 432 rads, respectively. The

corresponding values for the rat exposures were 740 and 434 rads. With the $LD_{50/30}$ values as the end points for comparison, the reactor radiations were 1.4 and 1.7 times more effective in mice and rats, respectively, than were x rays. In addition, analysis of the survival times indicates the mice and rats exposed to reactor radiations died significantly earlier than those exposed to similar doses of x rays.

ABSTRACT

Mortality data for C57BL mice and Sprague-Dawley rats were collected as a part of the program to biologically characterize AFRRI TRIGA reactor radiations and to provide reference information for future studies. Unilateral whole body exposures to mixed gamma-neutron radiations from the reactor or to 250 kVp x rays were carried out over a range of midline tissue doses from 370 to 875 rads. The 30-day median lethal doses were calculated to be 589 and 432 rads for mice exposed to the x rays and to the reactor radiations, respectively. The corresponding values for the rat exposures were 740 and 434 rads. Using the $LD_{50/30}$ values as the end points for comparison, the reactor radiations were 1.4 and 1.7 times more effective in mice and rats, respectively, than were the x rays. The survival times of the mice and rats exposed to reactor radiations were significantly less than those of the animals exposed to similar doses of x rays.

I. INTRODUCTION

Median lethality studies were initiated in different mammalian species in order to accumulate base line data and to assess the biological effectiveness of the mixed gamma-neutron radiations from the AFRRI-TRIGA reactor. Mammals with body masses ranging from that of the mouse to that of miniature swine are being investigated.

Comparable exposures were made using a 250 kVp x-ray unit as a reference source, to facilitate calculation of the biological effectiveness of the reactor radiations and to permit interlaboratory comparisons of results. The results of rodent exposures to these radiation sources as well as the techniques utilized are the subjects of this report

II. MATERIALS AND METHODS

Biological Considerations

Male and female C57BL mice* (18-22 grams) and Sprague-Dawley rats† (250-350 grams), 8-10 weeks of age, were obtained commercially, housed as pairs of the same sex, and acclimatized for 2 weeks prior to exposure. During this period they were weighed twice weekly and those animals which failed to gain weight or otherwise appeared unhealthy were excluded from the study. Throughout the experiment, all animals had free access to a commercial pathogen-free baked diet‡ and to tap water.

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* Microbiological Associates, Inc., Bethesda, Maryland

† Simonsen Laboratories, Inc., White Bear Lake, Minnesota

‡ C L. Baking Co., Frederick, Maryland. D & G Research Animal Laboratory Diet for Rats and Mice -- Specific Pathogen Free

Groups of mice and rats were exposed to one of a series of graded doses from either radiation source. Individual animals were randomly assigned to dose groups which were selected for x or mixed gamma-neutron (reactor) irradiations. There were equal numbers of each sex for each dose group and type of radiation. The number exposed at each dose and with each type of radiation is given in Tables I and II. A concomitant objective of the study was to check the biological response to the radiations from two different reactor cores. The doses listed in bold print in these tables denote groups exposed to radiations from the original reactor core (aluminum clad fuel elements) and their x irradiated counterparts. The corresponding exposures made after installation of the new reactor core (stainless steel clad fuel elements) are italicized. Three rat x-ray doses were repeated twice at the time the exposures were made using the new reactor core to obtain an indication of the degree of biological variability between similar exposures at different times. Control animals were sham irradiated in the appropriate exposure facility.

Deaths were recorded daily for 30 days following irradiation. Probit analysis was used to obtain the best fitting dose-mortality regression line for each species and each type of radiation. The estimated $LD_{50/30}$ value was obtained from each regression line. Since identical doses of x ray and mixed gamma-neutron radiations were not used, the survival times after these irradiations were not compared directly. The mean survival time for the decedents of each group was plotted as the logarithm of the dose and a "least squares" method employed to determine the best fit regression line for each type of radiation. Confidence bands (95 percent) for the lines

as a whole were calculated. Comparison of the regression lines indirectly compared the mean survival times.

No significant difference was found when the homogeneity of the regression lines of the exposures made with the original reactor core was tested against the counterpart from the exposures made with the new core, nor was there any significant difference between the radiosensitivity of males and females. The results of the rat exposures conducted on the same day were not significantly different. Since the results of the exposures made with the original and new reactor cores were not found to differ, the data were combined for probit analysis.

Physical Considerations

All animals were subjected to unilateral, whole-body exposures conducted under minimal scatter conditions. Exposure containers consisted of transparent Plexiglas* rectangular boxes. The rat boxes were fabricated from 1/8" thick Plexiglas sheets and measured 2-7/8" wide x 6-5/8" long x 3-1/8" high. For mouse irradiations, partitions were added to the rat exposure boxes so that four mice could be positioned in each box.

X-ray exposures (Figures 1 and 2) were accomplished with the 360° radial beam from a 250 kVp generator operated at 30 milliamperes. The filtration used, inherent (1.2 mm beryllium) and added (0.95 mm copper), resulted in a half value layer (HVL) of 1.9 mm of copper. Exposure boxes were positioned so that the midline

* Acrylic plastic (polymer of methyl methacrylate; composition by weight: 60 percent carbon, 8 percent hydrogen and 32 percent oxygen). Rohm and Haas Co., Philadelphia, Pennsylvania.

of each animal was 1 meter from the x-ray source. The absorbed dose at the center of the animal was calculated from three factors. First, the exposure, free-in-air, was determined at the position to be occupied by the center line of the animal.

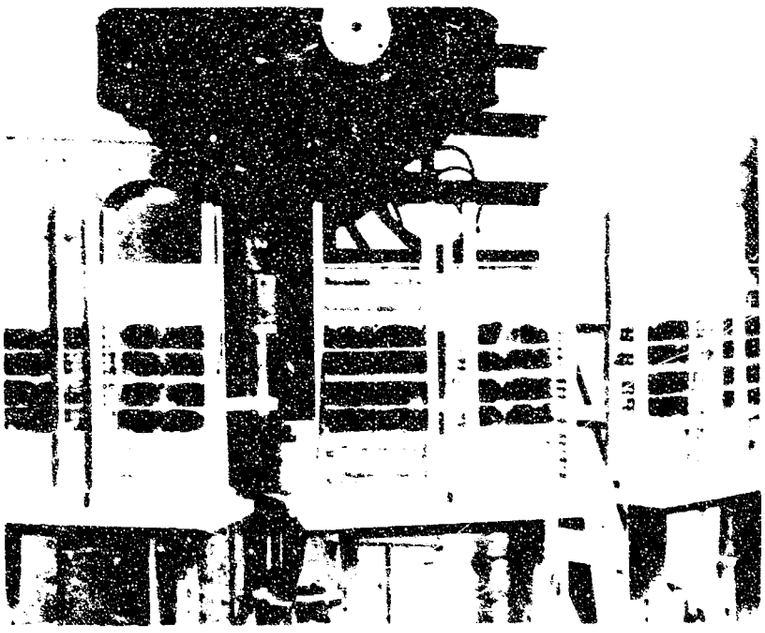

Figure 1. X-ray exposure array for mice

Figure 2. X-ray exposure array for rats

Positions were selected so that the variation in this quantity was less than 4 percent from the mean. Second, the ratio of the dose in a Plexiglas phantom (simulating each animal in the irradiation position) to the exposure, free-in-air, was obtained using miniature ionization chambers.[4] Third, the conversion factor, ($\bar{f}$), of 0.95 for soft tissue and for this quality of radiation was obtained from ICRU Report 10b.[9] The product of these factors gave the absorbed dose at the center of the animal. The absorbed dose rate in all exposures was approximately 21 rads per minute. The exposure rate was monitored continuously during each irradiation by a Victoreen rate meter to detect any changes in the output of the x-ray unit.

The mouse and rat arrays used for the mixed gamma-neutron (reactor) exposures are shown in Figures 3 and 4. Arrays were positioned so that the midline of each animal was on an arc 292 centimeters from the vertical center line of the reactor core. This arc, located in the middle of the exposure room, formed an exposure field in which the tissue kerma, free-in-air, did not vary by more than 4 percent from the mean. The absorbed dose at the midline of the animal was calculated from two factors. First, the tissue kerma, free-in-air, was obtained from measurement with a 50 cm^3 cavity tissue equivalent plastic* walled ionization chamber. Second, the ratio of the dose in the center of a Plexiglas phantom (simulating the animal in the irradiation position) to the tissue kerma, free-in-air, was obtained. The product of these two quantities gave the absorbed dose at the center line of the animal. The absorbed dose rate for all exposures was approximately 20 rads per minute.

* Plastic supplied by Dr. F. R. Shonka, St. Procopius College, Lisle, Illinois. (Composition by weight: 76.1 percent carbon, 10.1 percent hydrogen, 5.2 percent oxygen, 3.5 percent nitrogen, 1.0 percent silicon, 2.0 percent calcium and 2.0 percent fluorine.)

Figure 3. Reactor exposure array for mice

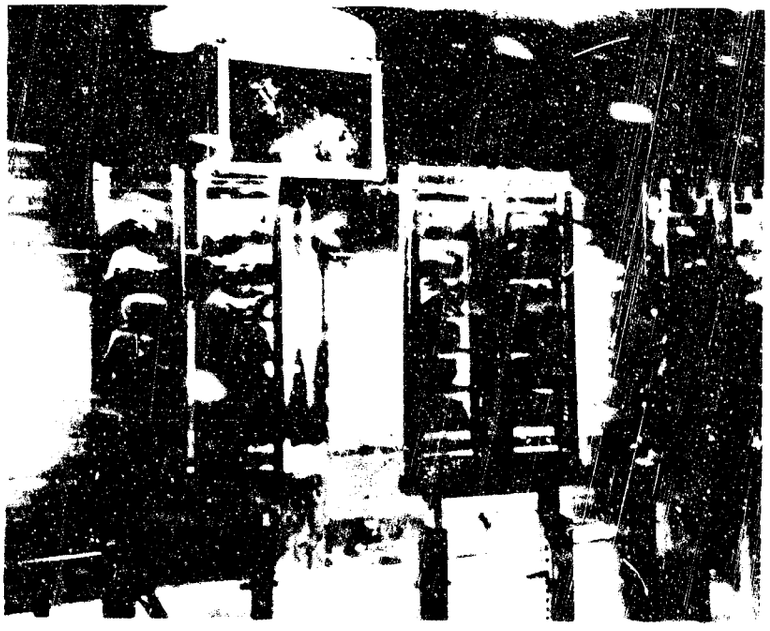

Figure 4. Reactor exposure array for rats

Approximately 60 percent of the tissue kerma, free-in-air, was attributed to gamma rays, and 40 percent to neutrons. The effective energy* of the gamma component was between 1 and 2 MeV. About 75 percent of the neutron dose was attributed to fast neutrons (greater than 10 keV). The remaining 25 percent was from neutrons of lower energies. Details of the reactor characteristics and methods of dosimetry in this mixed radiation field have been previously described.[6, 16]

The cylindrical, homogeneous Plexiglas phantoms used to make depth dose measurements are shown in Figure 5. The rat phantom weighed about 280 grams and the mouse phantom about 26 grams. A 3/16" diameter hole was made through the long

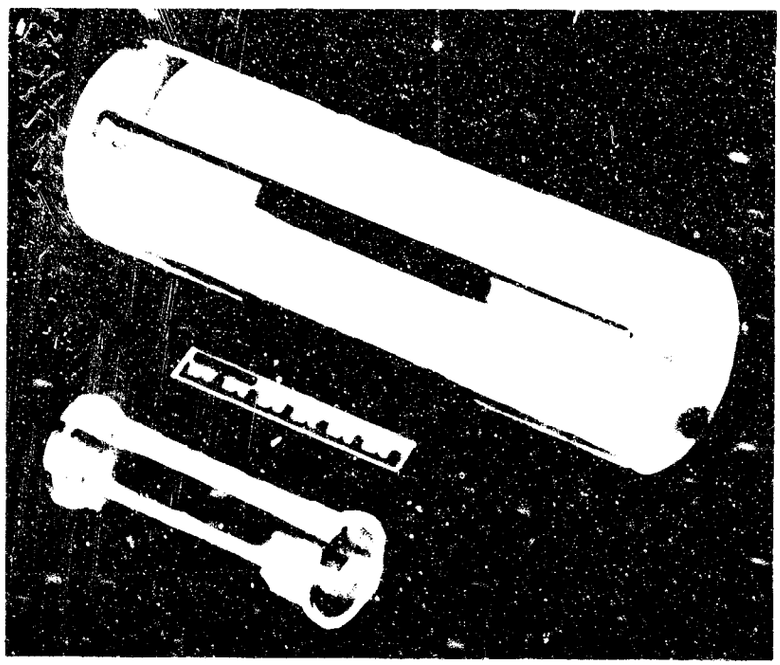

Figure 5. Mouse and rat phantoms with miniature tissue equivalent ionization chambers in place

* Depth dose studies, using Plexiglas rat phantoms, indicated that the deposition of energy by the gamma component of the reactor radiations was similar to that seen with ^{60}Co gamma rays.

axis of both phantoms and two grooves were longitudinally centered on the surface of each cylinder, diametrically opposing each other. Miniature tissue equivalent ionization chambers were placed in each surface groove to measure the entrance and exit doses. The midline tissue dose was determined from the readings of the chambers positioned at the longitudinal axes of the two phantoms.

According to the criteria set forth by the recommendations of the International Commission on Radiological Units and Measurements for the classification of irradiations,[10] the radiation sources utilized in this study produced Class A exposures in mice and Class B moderately uniform exposures in rats.

III. RESULTS

Tables I and II summarize the mortality data for mice and rats. The raw data used for probit analysis and the resultant dose-response regression lines are displayed graphically in Figures 6 and 7. The results of probit analysis and the calculated relative biological effectiveness (RBE) for the mixed gamma-neutron radiations are shown in Table III. The mean survival time regression lines and their 95 percent confidence bands for mice and rats are shown in Figures 8 and 9, respectively.

Table I. Mouse Mortality Data

MIDLINE TISSUE DOSE (RADS)*	*DIED / *EXPOSED	POSTIRRADIATION DAY OF DEATH **																							PERCENT MORTALITY (30 DAYS)	SURVIVAL TIME (DAYS)	
		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26 - 30		MEAN	MEDIAN
											X RAYS																
0	0 48																								0		
437	0 47																								0		
[illegible]	6 50			1						1					1		1	1					1		12	16.8	18.0
492	18 48				2	2	1		7	2	2				2										38	11.1	11.0
546	14 48			2		3	1	4	2	1						1									29	9.8	10.0
[illegible]	19 50						2	6	1	1	1		1	1	2	1		1	1	1					38	12.7	12.0
601	31 48		2	3	6	6	3	2	2	1	1				1					1					65	9.0	8.0
655	20 48				2	6	2	3	2	1	3	1													41	9.9	9.5
[illegible]	26 49			4	1	5	1	3	1		3	1	1	1		1	2	1					1		53	11.5	10.0
710	41 48		2	14	8	9	3	1		3	1														85	7.8	7.0
765	42 48		3	16	7	3	1	3		3	4	1		2										1	88	8.7	7.0
[illegible]	49 50		6	16	6	3	5	1	1	1	1	3	2	3		1									98	8.5	7.0
819	46 48	1	11	21	7		1			1	2	1	1												96	6.7	6.0
874	48 48		9	9	3	4		2	3	9	4		2	3				1							100	9.3	8.0
[illegible]	50 50	4	28	9	1	3			4	2															100	6.0	5.0
											MIXED GAMMA-NEUTRON RADIATIONS																
0	0 48																								0		
369	7 48					2		2	2	1															15	10.0	10.0
[illegible]	21 50		3	1	3	4	2	1	2	2			1												42	8.4	8.0
463	28 48		1	10		3	2	3	1	1	1	1			1		1	1	1		1				58	10.3	8.5
[illegible]	38 50	1	19	4	2	4	2	1		2	1									1		1			76	7.4	5.0
509	46 48	2	10	17	1	3	1	1	1	1		2		2	3										96	7.8	6.0
[illegible]	49 50	8	19	7	2	3	1	1		1	2		2		1		1	1			1				98	7.4	5.0
[illegible]	50 50	14	16	8	3	3	3			1	1		1												100	5.9	5.0
[illegible]	50 50	34	19	1	5	1																			100	4.8	5.0
629	48 48	19	24	5																					100	4.7	5.0
729	48 48	28	19	1																					100	4.4	4.0

*BOLD TYPE DENOTES "OLD" CORE AND ASSOCIATED X-RAY EXPOSURES, ITALIC, "NEW" CORE AND ASSOCIATED X-RAY EXPOSURES.
**FIGURES IN POSTIRRADIATION DAY OF DEATH COLUMNS INDICATE NUMBER OF DEATHS ON THAT DAY

Table II. Rat Mortality Data

MIDLINE TISSUE DOSE (RADS)*	#DIED / #EXPOSED	POSTIRRADIATION DAY OF DEATH**																						PERCENT MORTALITY (30 DAYS)	SURVIVAL TIME (DAYS)	
		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26-30		MEAN	MEDIAN
		X RAYS																									
0	0/48																								0		
410	0/48																								0		
462	0/48																								0		
513	2/48																					1		1	4	25.0	25.0
513	0/48																								0		
564	1/48																			1					2	22.0	22.0
616	3/48																	1	1					1	6	22.3	21.0
616	4/48					1	1								1	1									8	13.0	13.0
616***	2/48						1										1								4	14.0	14.0
667	5/48												2					1				1		1	10	20.2	20.0
718	19/48				1			3	3	2	4	1	2	1				1						1	40	13.4	13.0
718	20/48			3	3	5	1	1	1	2					1									3	42	11.4	8.0
718***	20/48			1	2	3	1	4		2	2	1		1			1		1		1				42	11.8	10.0
770	30/48							2	2	6	3	2	4	1	2		2		2	2			1	1	63	13.6	14.5
821	34/48		1	1	3	1	5	1	8	6	2	2						1	1				2		71	11.8	11.0
821	36/48			8	3	9	3	5	3	1		1			1	1									75	8.9	8.0
821***	43/48	1	2	1	8	7	6	6	6	1	1	1	2						1						90	9.3	9.0
872	45/48		3	4	2	3	3	10	7	10	2	1					1								94	10.0	10.0
955	47/47			13	14	16	1	3	1	1															100	6.8	7.0
MIXED GAMMA-NEUTRON RADIATIONS																											
0	0/48																								0		
106	0/48																								0		
145	3/48			1	1			1																	6	7.7	7.0
171	5/48				1	1	1		2																10	9.2	9.0
402	6/48														2		2	1						1	13	19.8	19.0
422	16/48			4	2	2		1		1	1		2		1					1					33	10.5	8.0
462	31/48			3	3	3	7	5	3		3		2												65	9.5	9.0
483	45/48		5	13	4	6	3	3	5	1	2			1											94	8.1	8.0
548	48/48	2	3	18	9	3	4	4	3	1				1											100	7.4	7.0
649	48/48	16	28	2																					100	4.7	5.0
734	48/48	34	14																						100	4.5	4.5

*BOLD TYPE DENOTES "OLD" CORE AND ASSOCIATED X-RAY EXPOSURES; ITALIC, "NEW" CORE AND ASSOCIATED X-RAY EXPOSURES
**FIGURES IN POSTIRRADIATION DAY OF DEATH COLUMNS INDICATE NUMBER OF DEATHS ON THAT DAY
***DUPLICATE "NEW" CORE EXPOSURE GROUPS

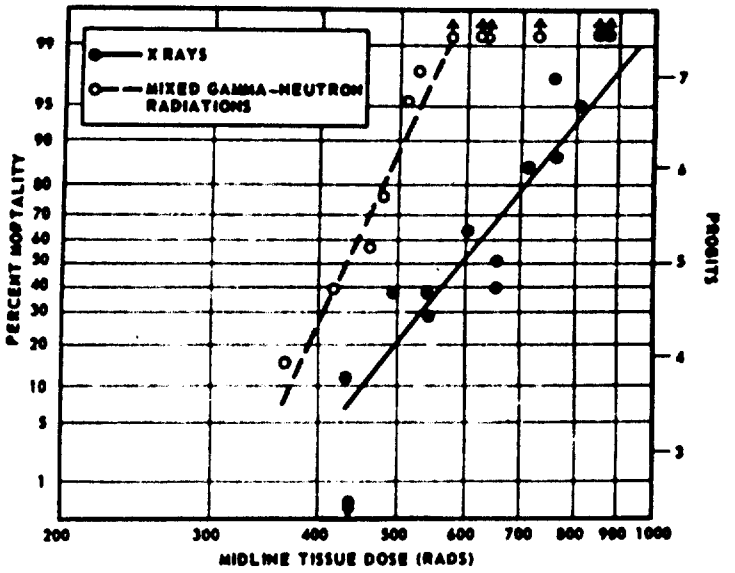

Figure 6. Dose-response regression lines for the mouse as calculated by probit analysis. Plotted points represent raw data and arrows indicate the doses associated with 0 or 100 percent mortality

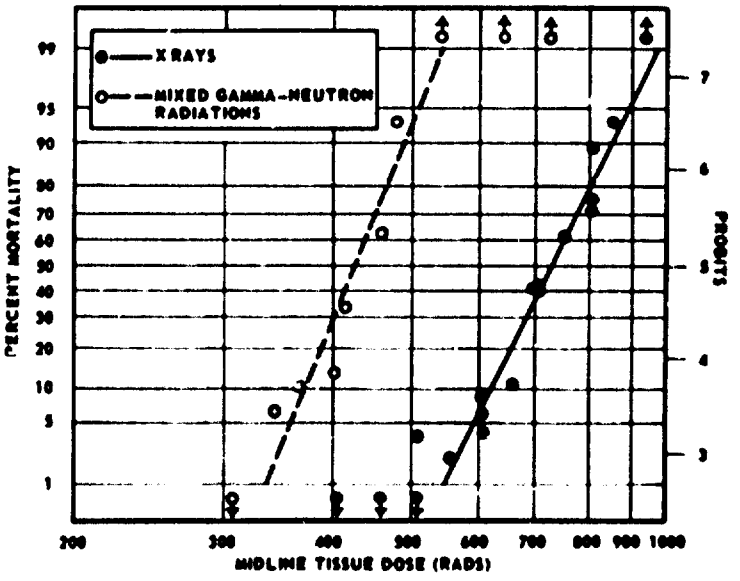

Figure 7. Dose-response regression lines for the rat as calculated by probit analysis. Plotted points represent raw data and arrows indicate the doses associated with 0 or 100 percent mortality

Table III. Probit Analysis of 30-day Mortality Data

Species	Radiation source	Calculated lethal dose values*					Slope of regression line	RBE† for $LD_{50/30}$'s
		LD_{10}	LD_{30}	LD_{50}	LD_{70}	LD_{90}		
mouse	x ray	451 (370-501)‡	528 (467-570)	589 (541-633)	657 (612-719)	769 (706-897)	11.1	
mouse	reactor	371 (355-387)	406 (394-418)	432 (422-442)	460 (450-469)	503 (489-517)	19.3	1.4
rat	x ray	631 (597-655)	693 (670-713)	740 (720-761)	791 (768-820)	869 (835-921)	18.4	
rat	reactor	379 (354-395)	411 (394-424)	434 (420-450)	459 (444-482)	498 (477-537)	21.5	1.7

* Midline tissue dose (rads)
† 250 kVp x rays used as standard reference source
‡ 95 percent confidence limits shown in parentheses

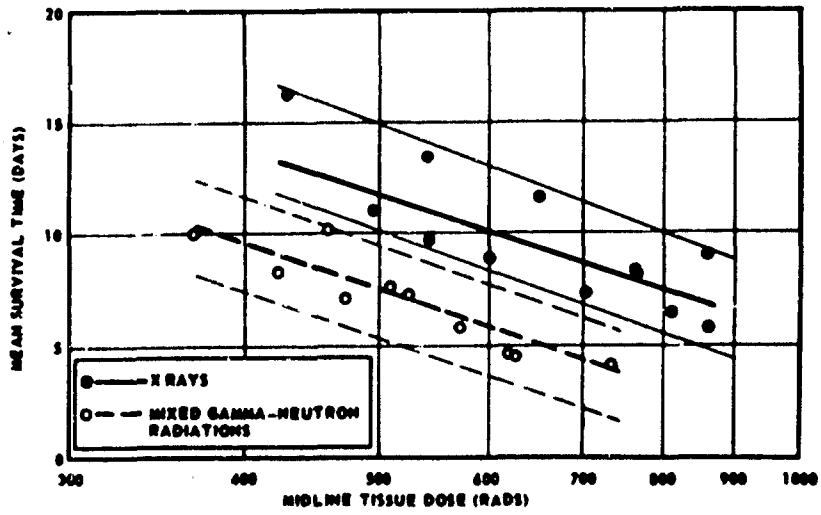

Figure 8. Survival time regression lines and associated 95 percent confidence bands for mice

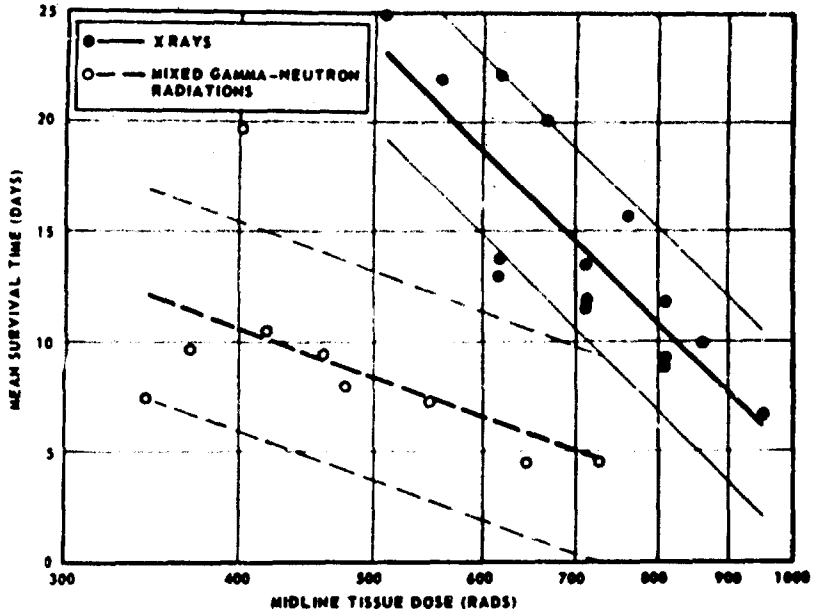

Figure 9. Survival time regression lines and associated 95 percent confidence bands for rats

IV. DISCUSSION

It has long been recognized that the results obtained from mortality studies conducted on various species of mammals are dependent upon the biological (age, weight, diet, vendor, etc.) and physical (exposure geometry, source characteristics, methods of dosimetry, etc.) factors of each individual study. The variation which exists in reported results is evident even in the same strain of animals, as can be seen in Tables IV and V. These tables list the reported $LD_{50/30}$ values for C57BL mice and Sprague-Dawley rats, as well as some of the reported exposure conditions of each study.

In order to make valid interlaboratory comparisons of results it is necessary that identical conditions be utilized or enough information given so that the proper correction factors can be applied to express the results in terms common to different studies. Identical exposure conditions, although theoretically possible, appear

Table IV. Reported $LD_{50/30}$ Values for C57BL Mice and Associated Physical and Biological Factors

Physical and biological factors	X ray					Mixed gamma-neutron radiations	
	Reinhard et al.[15]	Kaplan and Brown[11]	Kohn and Kallman[12]	Grahn and Hamilton[7]	Present study	Mewissen[14]**	Present study
$LD_{50/30}$ dose	~550 R*	486 R	618 R‡	630 R	585 rads	423 rads	432 rads
kVp or gamma-neutron ratio		120, 120†	250	200	250	~1:9	~3:2
HVL (mm Cu)	0.9	0.33, 0.37	1.6	1.1	1.9		
TMD* (cm)	30	30, 30	98-107**	89	100		292††
Dose rate	150 R/min	25 R, 32 R/min	33-39 R/min	21-23 R/min	21 rads/min	17 rads/min	20 rads/min
Exposure geometry	unilateral	unilateral	unilateral		unilateral		unilateral
Dose reported as	midline air	measured in air	average tissue	measured in air	midline tissue	surface	midline tissue
Sex	♂ + ♀	♂ + ♀	♂ + ♀	♂ + ♀	♂ + ♀	♂ + ♀	♂ + ♀
Age (weeks)	8-15	4-5	15-23	8-12	10-12	6	10-12
Weight (grams)					18-22		18-22

* Distance from target to animal's midline
‡ $LD_{50/12}$ days
† Two different x-ray sources were used and the results combined
§ $LD_{50/28}$ days
** Distance from target to skin
** Pathogen free C57BL/6 mice
†† Distance from reactor core center to animal's midline

Table V. Reported $LD_{50/30}$ Values for Sprague-Dawley Rats and Associated Physical and Biological Factors

Physical and biological factors	X ray			Mixed gamma-neutron radiations	
	Hagen and Simmons[8]	Swift and Takeda[19]	Present study	Swift and Takeda[19]	Present study
$LD_{50/30}$ days	600 R	714 rads	740 rads	256 rads	434 rads
kVp or gamma-neutron ratio	200	250	250	~1:9	~3:2
HVL (mm Cu)	0.98	0.1	1.9		
TMD* (cm)	84	102	100		292†
Dose rate	12 R/min	55 R/min	21 rads/min		20 rads/min
Exposure geometry	bilateral	bilateral	unilateral	bilateral	unilateral
Dose reported as	midline air	midline tissue	midline tissue	midline tissue	midline tissue
Sex	♂ + ♀	♂	♂ + ♀	♂	♂ + ♀
Age (weeks)		8.5-10	10-12	8.5-10	10-12
Weight (grams)	180-220	250-350	250-350	250-350	250-350

* Distance from target to animal's midline
† Distance from reactor core center to animal's midline

limited to the individual laboratories from which the initial work was reported. Experimental and dosimetric details needed to determine the necessary correction factors have been omitted or inadequately described in many reports. The inter-laboratory comparison of results, in these cases, depends upon the interpretation of available information. Because of these problems, no exhaustive attempt was made to compare the results of this study with those of similar studies reported in the literature. In general, it can be stated that the results are consistent with the range of values reported by other investigators for the same rodent species and strains (Tables IV and V).

The temporal distribution of death for mice (Table I) and rats (Table II) indicates that the mice and rats exposed to reactor radiations have shorter survival times than their x-ray exposed counterparts. Valid comparison of survival times for animals exposed to different sources requires that the results from equal doses of these radiations be used. Since equal doses of the two radiations were not used in this study, the survival time regression lines for both radiations were compared for the two rodent species. Figures 8 and 9 show that the mice and rats exposed to reactor radiations have significantly shorter survival times than their x-ray exposed counterparts over the dose range that was used in this study. Similar results were previously reported by some investigators[2,3,21] but not by all.[17] The earlier mortality of mice and rats irradiated with neutrons as compared with x- or gamma-irradiated mice and rats has been attributed to greater gastrointestinal damage and earlier onset of bacteremia.

Under the conditions of this study, the reactor radiations were 1.4 and 1.7 times more effective than the x rays in causing mortalities in mice and rats, respectively.

These values are consistent with the RBE values reported for other rodent strains (Table VI).

Table VI. Reported RBE Values* for Fast Neutron Radiations Relative to 250 kVp x rays

RBE	Strain	Radiation source	Gamma contamination	Reference #
	MICE			
1.8+	CF #1	General Atomic TRIGA Mark F Reactor	10%	1
1.6	CF #1	Crocker Radiation Laboratory 60-inch Cyclotron	<10%	3
1.7	CF #1	Brookhaven Reactor using U^{235} "converter plate"	7%	5
1.8	CF #1	Los Alamos "Godiva" Reactor	<5%	18
2.0‡	CF #1	Argonne National Laboratory Cp-3' Heavy Water Reactor	~7%	21
2.3	C3H	Crocker Radiation Laboratory 60-inch Cyclotron	<10%	13
2.7	RF	Los Alamos "Godiva" Reactor	12%	17
1.5	RF	Oak Ridge National Laboratory 86-inch Cyclotron	small amount	20
1.3+	C57BL/6§	ITAL Reactor	1.2%	14
1.4	C57BL/6	AFRRI-TRIGA Reactor	~60%	present study
	RATS			
2.8	Sprague-Dawley	Crocker Radiation Laboratory 60-inch Cyclotron	9%	19
1.7	Sprague-Dawley	AFRRI-TRIGA Reactor	~60%	present study

* $LD_{50/30}$ values compared

+ Reported RBE value obtained by comparison with ^{60}Co results. Authors divided by 1.4 to normalize to an RBE value having 250 kVp x rays as the standard.

‡ Recalculated on basis of improved neutron dosimetry

§ Pathogen free

V. SUMMARY

C57BL mice and Sprague-Dawley rats were exposed to whole-body doses of mixed gamma-neutron radiations or 250 kVp x rays. Radiations were delivered at the rate of approximately 20 rads/min. All animals were irradiated unilaterally:

However, using the ICRU classification, exposures were Class A for mice and Class B moderately uniform for rats. The $LD_{50/30's}$ (midline tissue doses) were calculated to be 589 and 432 rads for mice exposed to x rays and reactor radiations, respectively. For the rat exposures, corresponding values were 740 and 434 rads. From these results, the RBE's calculated for the mixed gamma-neutron radiations were 1.4 for mice and 1.7 for rats. Mice and rats exposed to reactor radiations survived a shorter time than those mice and rats exposed to similar doses of x rays.

REFERENCES

1. Ainsworth, E. J., Leong, G. F., Kendall, K., and Alpen, E. L. The lethal effects of pulsed neutron or gamma irradiation in mice. Radiation Res. 21: 75-85, 1964.

2. Bond, V. P. Comparison of the mortality response of different mammalian species to X-rays and fast neutrons. In: Biological Effects of Neutron and Proton Irradiations, Vol. II, pp. 365-377. Vienna, International Atomic Energy Agency, 1964.

3. Carter, R. E., Bond, V. P., and Seymour, P. H. The relative biological effectiveness of fast neutrons in mice. Radiation Res. 4:413-423, 1956.

4. Chambers, F. W., Jr. Miniature tissue equivalent ionization chambers and their use. Aerospace Med. 34:193-196, 1963.

5. Delihas, N. and Curtis, H. J. The relative biological effectiveness of fission neutrons for the production of acute mortality in mice. Radiation Res. 8:166-180, 1958.

6. Dowling, J. H. Experimental determination of dose for the monkey in a reactor pulse environment. Bethesda, Maryland Armed Forces Radiobiology Research Institute Scientific Report SR66-3, 1966.

7. Grahn, D. and Hamilton, K. F. Genetic variation in the acute lethal response of four inbred mouse strains to whole body X-irradiation. Genetics 42:185-198, 1957.

8. Hagen, C. W., Jr. and Simmons, E. L. Effects of total-body X irradiation on rats. I. Lethal action of single, paired and periodic exposures. In: Biological Effects of External X and Gamma Radiation, Part 2, Zirkle, R. E., editor, Chapter 14, pp. 281-299. Oak Ridge, Tennessee, United States Atomic Energy Commission, Technical Information Service Extension Report TID-5220, 1956.

9. International Commission on Radiological Units and Measurements (ICRU) Report 10b, 1962. Physical aspects of irradiation. National Bureau of Standards Handbook No. 85. Washington, D. C., U. S. Government Printing Office, 1964.

10. International Commission on Radiological Units and Measurements (ICRU) Report 10c, 1962. Radiobiological Dosimetry. National Bureau of Standards Handbook No. 88. Washington, D. C., U. S. Government Printing Office, 1963.

11. Kaplan, H. S. and Brown, M. B. Mortality of mice after total-body irradiation as influenced by alterations in total dose, fractionation and periodicity of treatment. J. Natl. Cancer Inst. 12:765-775, 1952.

12. Kohn, E. I. and Kallman, R. F. The influence of strain on acute X-ray lethality in the mouse. I. LD_{50} and death rate studies. Radiation Res. 5:309-317, 1956.

13. Krebs, J. S. and Brauer, R. W. Residual injury caused by irradiation with fast neutrons. Radiation Res. 17:855-863, 1962.

14. Mewissen, D. J. Efficacité biologique relative des neutrons de fission dans l'irradiation corporelle totale de la Souris. Compt. Rend. Soc. de Biol. (Paris) 160:873-875, 1966.

15. Reinhard, M. C., Mirand, E. A., Goltz, H. L., and Hoffman, J. G. Mouse-strain differences in response to radiation. Proc. Soc. Exptl. Biol. and Med. 85:367-370, 1954.

16. Sayeg, J. A., compiler. Neutron and gamma dosimetry measurements at the AFRRI-DASA TRIGA Reactor. Bethesda, Maryland, Armed Forces Radiobiology Research Institute Contract Report CR 65-6, 1965 (originally issued as Edgerton, Germeshausen and Grier, Inc. Report S-260-R, Santa Barbara, California, 1964).

17. Spalding, J. F. and Trujillo, T. T. Survival time of mice exposed to fission neutrons and 250 KVP X rays, pp. 9-93. Los Alamos, New Mexico: Los Alamos Scientific Laboratory Report LAMS 2780, 1962.

18. Storer, J. B., Harris, P. S., Furchner, J. E., and Langham, W. H. The relative biological effectiveness of various ionizing radiations in mammalian systems. Radiation Res. 6:188-288, 1957.

19. Swift, M. N. and Taketa, S. T. Comparative mortality following partial and whole body irradiation of rats with fast neutrons and X-rays. San Francisco, California, U. S. Naval Radiological Defense Laboratory Report TR-456, 1960.

20. Upton, A. C., Conte, F. P., Hurst, G. S., and Mills, W. A. The relative biological effectiveness of fast neutrons, X-rays and γ-rays for acute lethality in mice. Radiation Res. 4:117-131, 1956.

21. Vogel, H. H., Jr., Clark, J. W., and Jordan, D. L. Comparative mortality following single whole-body exposures of mice to fission neutrons and Co^{60} gamma rays. Radiology 68:386-398, 1957.

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13 ABSTRACT

Mortality data for C57BL mice and Sprague-Dawley rats were collected as a part of the program to biologically characterize AFRRI-TRIGA reactor radiations and to provide reference information for future studies. Unilateral whole body exposures to mixed gamma-neutron radiations from the reactor or to 250 kVp x rays were carried out over a range of midline tissue doses from 370 to 875 rads. The 30-day median lethal doses were calculated to be 589 and 432 rads for mice exposed to the x rays and to the reactor radiations, respectively. The corresponding values for the rat exposures were 740 and 434 rads. Using the $LD_{50/30}$ values as the end points for comparison, the reactor radiations were 1.4 and 1.7 times more effective in mice and rats, respectively, than were the x rays. The survival times of the mice and rats exposed to reactor radiations were significantly less than those of the animals exposed to similar doses of x rays.

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