Table I: Summary Statistics for Mortality Among Oak Ridge Workers 1942–1984 By Race and Gender for Selected Causes of Death

Causes	Males						Females					
	White			Non-White			White			Non-White		
(ICDA-8)	SMR[a]	(OBS)	FTR[b]	SMR	(OBS)	FTR	SMR	(OBS)	FTR	SMR	(OBS)	FTR
All Causes	1.00	(22724)	-0.7	.96	(1121)	-1.4	.89	(3595)	-7.5	.76	(542)	-6.8
All Cancer	.98	(4679)	-1.1	.98	(202)	-0.3	.86	(1124)	-5.1	.78	(109)	-2.8
Buccal cavity (140-149)	.79	(117)	-2.6	1.13	(9)	0.4	1.44	(26)	1.7	2.36	(5)	1.6
Digestive (150-159)	.79	(1041)	-8.0	.98	(64)	-0.2	.71	(202)	-5.4	.64	(24)	-2.4
Esophagus (150)	.82	(93)	-2.0	.94	(12)	-0.1	1.23	(13)	0.8	.60	(2)	-0.6
Stomach (151)	.73	(176)	-4.5	.72	(12)	-1.2	.75	(26)	-1.6	.58	(4)	-1.1
Large intestine (153)	.81	(347)	-4.2	1.73	(23)	2.3	.71	(89)	-3.4	.73	(9)	-1.0
Rectum (154)	.55	(78)	-6.1	.91	(4)	-0.1	.39	(11)	-3.8	.90	(3)	-0.0
Liver (155-156)	.78	(78)	-2.3	.16	(1)	-2.7	.53	(14)	-2.7	1.49	(5)	0.9
Pancreas (157)	.95	(241)	-0.9	1.01	(11)	0.1	.88	(46)	-0.9	.14	(1)	-2.9
Respiratory (160-163)	1.16	(1919)	6.4	.97	(65)	-0.2	1.01	(181)	0.1	.92	(13)	-0.2
Larynx (161)	.88	(62)	-1.1	1.34	(5)	0.7	1.69	(7)	1.3	1.64	(1)	0.6
Lung (162-163)	1.18	(1849)	7.0	.94	(59)	-0.4	1.00	(172)	-0.0	.92	(12)	-0.2
Bone (170)	1.19	(25)	0.9	1.15	(1)	0.3	.89	(4)	-0.1	.00	(0)	-0.8
Skin (172-173)	.95	(80)	-0.4	1.70	(2)	0.8	1.17	(22)	0.8	1.28	(1)	0.4
Breast (174)	-	(-)	-	-	(-)	-	.86	(263)	-2.6	.55	(14)	-2.5
Cervis Uteri (180)	-	(-)	-	-	(-)	-	1.10	(70)	0.8	.88	(13)	-0.4
Corpus Uteri (181-182)	-	(-)	-	-	(-)	-	.68	(27)	-2.3	.66	(5)	-0.9
All Uterus (180-182)	-	(-)	-	-	(-)	-	.95	(106)	-0.5	.80	(20)	-1.0
Other Genital (183-184)	-	(-)	-	-	(-)	-	.79	(80)	-2.2	.38	(3)	-2.0
All Genital Organs (180-184)	-	(-)	-	-	(-)	-	.87	(186)	-2.0	.70	(23)	-2.0
Prostate (185)	1.01	(319)	0.1	.94	(20)	-0.2	-	(-)	-	-	(-)	-
Testes (186-187)	.72	(18)	-1.4	.00	(0)	-1.2	-	(-)	-	-	(-)	-
Bladder (188)	.76	(105)	-3.0	.98	(4)	0.1	.76	(9)	-0.8	.43	(1)	-1.0
Kidney (189)	.92	(109)	-0.9	.31	(1)	-1.3	.95	(18)	-2.2	2.69	(4)	1.6
Eye (190)	.99	(4)	0.1	.00	(0)	-0.1	1.80	(2)	0.8	.00	(0)	-0.0
Brain (191-192)	1.09	(151)	1.0	.37	(1)	-1.0	.80	(30)	-1.2	.66	(1)	-0.2
Thyroid (193)	.33	(3)	-2.4	.00	(0)	-0.5	.52	(2)	-0.9	.00	(0)	-0.7
Lymphosarcoma & RCS (200)	.91	(82)	-0.8	.93	(2)	0.0	1.15	(25)	0.7	.00	(0)	-1.4
Hodgkin's disease (201)	.77	(40)	-1.7	.62	(1)	-0.3	.41	(5)	-2.3	1.43	(1)	0.5
Leukemia, aleukemia (204-207)	.98	(180)	-0.2	1.11	(6)	0.3	.82	(34)	-1.2	.57	(2)	-0.7
Other lymphatic (202-3, 208)	.84	(105)	-1.8	1.28	(7)	0.7	1.26	(41)	1.4	1.33	(5)	0.7
All lymphatic (200-209)	.93	(420)	-1.6	1.10	(16)	0.4	1.00	(109)	0.1	.87	(8)	-0.3
Benign (210)	.94	(60)	-0.5	2.01	(6)	1.5	.87	(21)	-0.6	.39	(2)	-1.5
Disease of blood (280-289)	.52	(29)	-4.1	1.19	(5)	0.4	.63	(10)	-1.5	.69	(2)	-0.4
Nervous system (320-329)	.70	(148)	-4.7	.66	(8)	-1.2	.37	(22)	-5.9	.74	(5)	-0.6
Circulatory system (390-458)	.95	(11076)	-5.6	.88	(438)	-2.8	.84	(1323)	-6.7	.70	(235)	-6.1
Respiratory system (460-519)	1.12	(1568)	4.2	.81	(54)	-1.6	1.00	(193)	0.0	.57	(16)	-2.5
Digestive system (520-577)	.80	(865)	-6.9	.73	(40)	-2.1	.85	(178)	-2.2	.52	(16)	-3.0
Genitourinary system(580-629)	.83	(270)	-3.2	.78	(26)	-1.3	.64	(46)	-3.3	.63	(17)	-2.1
External causes (800-998)	1.05	(2140)	2.3	1.02	(171)	0.3	1.02	(281)	0.3	.95	(34)	-0.2

[a] Standardized mortality ratios (SMR) = Observed death/expected deaths. The expected deaths were computed using age-calendar year specific rates for the U.S. population.

[b] Freeman-Tuckey residuals = $\sqrt{Obs} + \sqrt{Obs+1} - \sqrt{4\,exp+1}$ are approximately normally distributed with mean zero and variance one under the null hypothesis that the SMR is one.

Table II: Alternative Representations of All Causes Mortality Among White Males (N = 67,197) Who Worked in Oak Ridge Between 1943 and 1984

	Birth Cohort				
	<1900	**1905**	**1915**	**1925**	**1930+**
	A - Maximim Likelihood Estimates [a] **(α_{jk})**				
X10	2.07	2.06	1.77	1.54	1.03
TEC	2.26	2.24	2.23	2.23	
Y12	2.03	2.16	2.06	1.90	1.37
K25	2.30	2.36	2.25	2.04	1.31
MUL	2.24	2.21	2.12	1.90	0.98
	B - Estimated Death Rate (per 1000) at Age 50				
X10	7.92	7.84	5.85	4.69	2.79
TEC	9.57	9.37	9.31	9.26	.
Y12	7.61	8.65	7.88	6.68	3.92
K25	10.00	10.59	9.48	7.71	3.71
MUL	9.37	9.15	8.37	6.67	2.67
	C - Estimated Median Survival Time at Age 50				
X10	26.11	26.22	29.49	32.04	38.17
TEC	24.04	24.28	24.34	24.40	.
Y12	26.55	25.14	26.16	28.00	34.12
K25	23.57	22.97	24.15	26.39	34.78
MUL	24.27	24.52	25.49	28.01	38.71
	D - SMR (L% Units) [b]				
X10	-19.6	-15.3	-36.7	-47.6	-83.9
TEC	-1.3	2.0	8.7	19.0	.
Y12	-22.4	-5.4	-7.3	-11.6	-50.5
K25	2.9	14.1	10.8	1.4	-55.7
MUL	-3.1	-0.2	-1.5	-13.3	-87.6
	E - SMR				
X10	0.82	0.86	0.69	0.62	0.43
TEC	0.99	1.02	1.09	1.21	.
Y12	0.80	0.95	0.93	0.89	0.60
K25	1.03	1.15	1.11	1.01	0.57
MUL	0.97	1.00	0.99	0.88	0.42

[a] Based on the regression model $\lambda_{ijk} = exp\ [\alpha_{jk} + \theta\ (\text{age} - 50)]$; $\hat{\theta} = 0.0794$ (SE = 0.00069).

[b] Based on the regression model $\lambda_{ijk} = \lambda^*_{ij}\ exp\ (\alpha^*_{jk})$, where α^*_{jk} represents the log SMR for each birth cohort/facility group.

Table III: Parameter Estimates for the Main Effects Model for Mortality from Selected Causes of Death Among White Males (N = 67,197) and Females (N = 27,377) Who Worked in Oak Ridge Between 1943 and 1984

MALES

Cause of Death (ICDA-8)	Observed Number	SMR	Facilities[a] X10	TEC	Y12	K25	MUL	LRT[b]	SES[c] (Monthly)	Length of Employment[c] (<1 Year)	Period Trend[d] (% per Year)
All Causes (001-999)	22,590	1.00	-26.8	-5.9	-17.1	-1.0	-6.0	101.0	-41.5 (2.9)[c]	19.2 (1.4)	0.49(0.07)
All Cancer (140-209)	4,673	.99	-18.9	-8.8	-6.0	-5.3	-4.2	6.5	-38.1 (6.2)	16.3 (3.1)	0.58 (.16)
Non Cancer (Omit 140-209)	17,917	1.00	29.2	-5.2	-20.5	0.0	-6.7	106.0	-42.5 (3.3)	20.0 (1.6)	0.48 (.08)
Circulatory System (390-458)	11,043	0.95	-26.5	-7.5	-18.5	-1.8	-14.6	50.9	-34.4 (4.1)	9.9 (2.0)	0.59 (.10)
Respiratory System (460-519)	1,565	1.12	-43.0	1.6	-29.4	6.6	6.3	24.4	-78.6 (13.6)	26.1 (5.3)	0.97 (.28)
Emphysema (492)	362	1.16	18.6	25.7	-2.3	30.6	26.9	1.6	-175.4 (41.4)	7.3 (11.0)	-1.48 (.71)
All Except Emphysema	1,203	1.11	-62.4	-5.6	-37.0	-0.6	0.2	26.2	-59.3 (14.3)	31.8 (6.0)	1.45 (.32)
All External Causes (800-998)	2,073	1.06	-33.7	-3.1	-24.1	-3.5	-1.9	18.5	-55.6 (9.8)	42.2 (4.6)	0.26(0.21)

FEMALES

Cause of Death (ICDA-8)	Observed Number	SMR	Facilities X10	TEC	Y12	K25	MUL	LRT[b]	SES (Monthly)	Length of Employment (<1 Year)	Period Trend (% per Year)
All Causes (001-999)	3,581	0.89	-55.6	-31.0	-78.6	-14.6	-15.3	45.4	-41.4 (19.7)	13.4 (3.5)	1.60 (0.19)
All Cancer (140-209)	1,124	0.87	-61.5	-30.5	-47.3	-13.2	-19.6	13.0	-19.2 (33.2)	4.2 (6.2)	1.78 (0.35)
Non Cancer (Omit 140-209)	2,457	0.90	-53.1	-31.5	-100.3	-15.5	-13.4	35.5	-52.3 (24.5)	17.7 (4.2)	1.54 (0.22)
Circulatory System (390-458)	1,320	0.84	-70.1	-45.8	-92.3	-27.8	-42.5	14.8	-72.6 (36.4)	15.7 (5.7)	2.29 (0.35)
Respiratory System (460-519)	192	1.00	-97.9	-18.4	.	-7.1	2.4	11.4	15.1 (75.0)	9.7 (15.0)	1.86 (0.85)
Emphysema (492)	23	0.96	-10.6	-38.5	.	46.1	-11.8	4.0	.	13.9 (43.6)	.
All Except Emphysema	69	1.01	-112.7	-15.0	.	-15.3	4.9	11.0	35.3 (75.5)	9.2 (16.0)	2.00 (0.88)
All External Causes (800-998)	277	1.02	-22.2	-15.9	-138.6	-6.1	36.9	13.2	-807.1(1776)	25.9 (12.8)	0.01 (0.57)

[a] The “facility” factor is used as the reference category so that the first five parameter estimates (colmun 4-8) are the natural logarithms of the SMRs in logarithmic percent (L%) units at the reference level of SES and length of employment at the midpoint (1965) of period of follow-up.

[b] LRT statistic is chi-square (with 4 degrees of freedom) for the null hypothesis of no difference in the facility effects adjusted for SES, length of employment, and period trend (values that exceed 9.49 are significant at .05 level).

[c] The reference category for SES is the non-monthly (vs. monthly) workers, and the reference level for length of employment is greater than one year. The parameter estimates for SES, and length of employment are log relative risks in L% units. These estimates can be compared with the null value zero using the SEs given in parentheses, or converted into estimates of relative risk, e.g. for all cause mortality for white males the relative risk for nonmonthly workers is exp (-.415) = 0.66.

[d] The period trend describes the change in the SMR (percent per year) over the forty years of follow-up.

Table IV: Parameter Estimates for the Main Effects Model for Mortality from Selected Causes of Death Among Non-White Males (N = 3,909) and Females (N = 2,826) Who Worked in Oak Ridge Between 1943 and 1984

MALES

Cause of Death (ICDA-8)	Observed Number	SMR	Facilities[a] X10	TEC	Y12	K25	MUL	LRT[b]	SES[c] (Monthly)	Length of Employment[c] (<1 Year)	Period Trend[d] (% per Year)
All Causes (001-999)	1,106	0.97	-26.8	-5.3	-34.3	-11.7	-12.3	7.4	-166.0 (40.9)[c]	19.3 (6.6)	0.67 (0.29)
All Cancer (140-209)	201	0.98	-32.3	-9.6	-6.7	11.7	8.9	4.3	-92.9 (71.7)	-8.0 (15.3)	0.29 (0.76)
Non Cancer (Omit 140-209)	905	0.96	-26.2	-8.6	40.1	-16.9	-17.4	5.3	-188.9 (50.6)	25.4 (7.3)	0.76 (0.32)
Lung Cancer (162)	59	0.95	-139.9	-33.4	-122.3	15.5	6.2	11.6	.	29.1 (29.1)	0.83 (1.62)

FEMALES

Cause of Death (ICDA-8)	Observed Number	SMR	Facilities X10	TEC	Y12	K25	MUL	LRT[b]	SES (Monthly)	Length of Employment (<1 Year)	Period Trend (% per Year)
All Causes (001-999)	542	0.77	-41.8	-38.3	-132.7	-24.2	-25.9	5.8	.	5.1 (9.3)	2.64 (0.43)
All Cancer (140-209)	109	0.78	14.5	-33.8	-68.9	-10.0	21.2	5.0	.	-17.8 (20.5)	1.64 (1.01)
Non Cancer (Omit 140-209)	433	0.77	-60.0	-39.7	-154.6	-27.7	-40.7	5.5	.	11.3 (10.5)	2.88 (0.48)

[a] The "facility" factor is used as the reference category so that the first five parameter estimates (colmun 4-8) are the natural logarithms of the SMRs in logarithmic percent (L%) units at the reference level of SES and length of employment at the midpoint (1965) of period of follow-up.

[b] LRT statistic is chi-square (with 4 degrees of freedom) for the null hypothesis of no difference in the facility effects adjusted for SES, length of employment, and period trend (values that exceed 9.49 are significant at .05 level).

[c] The reference category for SES is the non-monthly (vs. monthly) workers, and the reference level for length of employment is greater than one year. The parameter estimates for SES, and length of employment are log relative risks in L% units. These estimates can be compared with the null value zero using the SEs given in parentheses, or converted into estimates of relative risk.

[d] The period trend describes the change in the SMR (percent per year) over the forty years of follow-up.

Table V: Parameter Estimates for the Main Effects Model for Mortality from Selected Cancer Causes of Death Among White Males (N = 67,197) Who Worked in Oak Ridge Between 1943 and 1984

Cause of Death (ICDA-8)	Observed Number	SMR	Facilities[a] X10	TEC	Y12	K25	MUL	LRT[b]	SES[c] (Monthly)	Length of Employment[c] (<1 Year)	Period Trend[d] (% per Year)
All Cancer	4,673	0.99	-18.9	-8.80	-6.0	-5.2	-4.2	6.5	-38.1 (6.2)[c]	16.3 (3.1)	0.58 (0.16)
Mouth and Pharynx (140-149)	117	0.80	-32.7	-29.7	-161.2	-28.4	-3.3	6.9	.	31.7 (19.4)	0.50 (0.99)
Digestive (150-159)	1,038	0.79	-17.8	-33.6	-31.7	-20.2	-36.4	5.2	-20.5 (12.1)	9.8 (6.5)	0.55 (0.32)
Esophagus (150)	93	0.83	-6.2	-30.9	-53.3	-3.3	-40.4	2.4	-97.9 (53.2)	26.6 (21.6)	-0.91 (1.08)
Stomach (151)	176	0.74	5.9	-23.9	-52.3	-22.0	-29.3	2.0	-88.2 (37.7)	-5.3 (15.9)	-0.22 (0.72)
Large Intestine (153)	344	0.80	-14.5	-38.0	-40.5	-19.1	-34.7	3.1	-0.7 (19.0)	2.3 (11.4)	1.01 (0.60)
Rectum (154)	78	0.55	-88.0	-74.0	-23.0	-50.8	-89.8	2.6	20.6 (40.4)	12.3 (23.7)	-0.96 (1.12)
Liver (155-156)	78	0.78	-108.6	-59.2	-39.0	-51.2	-58.0	1.8	63.2 (36.4)	47.4 (24.0)	1.46 (1.14)
Pancrease (157)	241	0.95	8.0	-21.4	-2.0	-14.5	-22.9	1.9	-51.6 (27.3)	22.2 (13.6)	0.92 (0.73)
Larynx (161)	62	0.88	-4.5	-82.7	6.3	-0.4	-52.4	8.6	-207.1 (99.6)	59.6 (27.0)	-0.18 (1.35)
Lung (162-163)	1,848	1.19	-34.8	10.5	15.4	9.4	13.1	21.6	-62.3 (11.1)	21.7 (4.9)	0.85 (0.28)
Bone (170)	25	1.22	-80.5	-4.5	.	45.6	3.0	5.3	7.6 (77.8)	11.3 (41.4)	-2.51 (1.94)
Skin (172-173)	80	0.96	-3.7	-0.3	-31.6	-18.6	22.0	2.1	-18.8 (39.0)	-35.0 (25.6)	2.80(1.29)
Prostate (185)	319	1.01	0.8	-8.8	1.0	-10.1	16.9	2.6	-21.5 (22.7)	17.1 (11.8)	-0.08 (0.67)
Testes (186-187)	18	0.75	-10.3	22.0	.	3.9	-105.0	5.4	-74.8 (110.2)	-32.1 (49.0)	-0.46 (2.20)
Bladder (188)	105	0.76	-108.0	-9.0	-56.7	-47.0	-8.9	6.6	-21.5 (44.0)	9.9 (20.6)	-0.07 (1.05)
Kidney (189)	109	0.92	-41.7	-23.0	17.8	-21.3	-20.0	1.8	34.5 (31.3)	7.6 (20.6)	1.007 (1.08)
Brain, CNS (191-192)	51	1.10	15.4	-16.3	55.8	13.3	4.2	6.1	-43.9 (32.7)	20.2 (17.3)	-1.61 (0.79)
All Lymphatic (200-209)	418	0.93	9.7	4.2	-4.2	-3.6	0.6	0.8	4.4 (16.9)	-19.3 (10.6)	-0.52 (0.50)
Lympho/Reticulosarcoma (200)	82	0.92	-23.7	-14.8	50.3	20.1	-12.9	3.5	43.4 (33.6)	-35.0 (24.4)	1.15 (1.27)
Hodgkin's Disease (201)	39	0.77	-13.4	-5.5	-32.9	-28.9	-57.1	1.0	34.6 (51.1)	-22.2 (34.6)	0.04 (1.59)
Leukemia (204-207)	180	0.99	61.7	4.8	-64.5	0.7	13.3	10.7	-39.7 (27.9)	-10.1 (15.9)	-0.46 (0.74)
Other Lymphatic (202, 203, 208)	105	0.84	-92.8	8.2	71.9	-15.4	7.9	12.3	23.0 (34.3)	-27.0 (22.2)	-1.48 (1.16)

[a]The "facility" factor is used as the reference category so that the first five parameter estimates (colmun 4-8) are the natural logarithms of the SMRs in logarithmic percent (L%) units at the reference level of SES and length of employment at the midpoint (1965) of period of follow-up.

[b]LRT statistic is chi-square (with 4 degrees of freedom) for the null hypothesis of no difference in the facility effects adjusted for SES, length of employment, and period trend (values that exceed 9.49 are significant at .05 level).

[c]The reference category for SES is the non-monthly (vs. monthly) workers, and the reference level for length of employment is greater than one year. The parameter estimates for SES, and length of employment are log relative risks in L% units. These estimates can be compared with the null value zero using the SEs given in parentheses, or converted into estimates of relative risk.

[d]The period trend describes the change in the SMR (percent per year) over the forty years of follow-up.

Table VI: Parameter Estimates for Selected Causes of Death for X-10/Y-12 Subcohort (N = 28,347) Using Main Effects ERR Model with External Rates and Unadjusted Cumulative Dose with Ten Year Lag

		All Causes		All Cancer		Circulatory System		External Causes	
	Term	**Est**	**SE**	**Est**	**SE**	**Est**	**SE**	**Est**	**SE**
A[a]	(Age - 52.5)/100	.35	.17	-.27	.38	-0.1	.26	.83	.51
	<1900	-28.8	6.2	-9.2	13.4	-19.5	8.7	-56.4	25.2
	1900 - 09	-17.0	4.8	-4.3	10.4	-9.3	6.9	-20.2	16.1
B[b] -	1910 - 19	-20.9	4.5	-10.1	9.4	-20.2	6.5	-27.8	14.1
	1920 - 29	-30.2	5.0	-25.0	10.3	-31.8	7.5	-18.9	14.5
	1930+	-63.1	7.8	-66.2	17.9	-71.3	14.4	-47.3	17.3
S[c] –	Nonmonthly	0	.	0	.	0	.	0	.
	Monthly vs Non	-42.6	4.1	-41.4	8.3	-37.6	5.8	-55.5	12.82
L[c] -	At Least 1 Year	0	.	0	.	0	.	0	.
	Less than 1 Year	9.9	4.3	11.3	9.1	1.3	6.3	24.9	12.3
IG[c,d] -	EN	0	.	0	.	0	.	0	.
	EM	-2.4	3.7	4.3	7.5	-5.3	5.3	-1.5	12.5
	NE	7.3	4.1	2.9	8.7	7.9	5.8	34.5	13.0
F[c] -	X-10	0	.	0	.	0	.	0	.
	Y-12 vs X-10	12.4	4.2	15.3	8.7	10.8	6.2	12.2	12.3
	Multiple vs X-10	8.4	3.8	5.9	7.8	3.1	5.4	8.5	12.4
D[e] -	Dose	.31		1.45		0[f]		0[f]	.
	95% CI[g]	(-0.16, 1.01)		(0.15, 3.48)		(<0, 0.86)		(<0, 1.99)	.

[a]This term describes (and adjusts for) any systematic age-related difference in the external rates (U.S. White Males) and the study cohort in percent per year units — see Eq. 3 and the Appendix for further discussion.

[b]The estimates for each birth cohort are SMRs (in L% units) for the reference level of each of the other terms in the model, e.g. for the 1910-19 cohort the estimated all cause SMR = exp (-.208) = .81. The reference group is nonmonthly workers employed at least 1 year at X-10 and who were eligible but not monitored for internal radiation exposure.

[c]For S, L, IG, and F the estimates are of relative risks in L% units, i.e. for all cancer the relative risk for monthly vs. nonmonthly workers is exp (-.414) = 0.66.

[d]IG-Internal Radiation: EN - eligible and not monitored, EM = eligible and monitored, and NE = not eligible for monitoring.

[e]Dose-response for the ERR per Sv (see Eq. 4) which is equivalent to percent per 10 mSv (rem).

[f]Likelihood maximized at value that would lead to negative relative risk estimate.

[g]Likelihood ratio based confidence interval for ERR.

Table VII: Parameter Estimates for Selected Cancer Causes of Death for X-10/Y-12 Subcohort (N = 28,347) Using Main Effects ERR Model with External Rates and Unadjusted Cumulative Dose with Ten Year Lag (Two Year Lag for Leukemia)

		Digestive		**Lung**		**Prostate**		**Leukemia**	
	Term	**Est**	**SE**	**Est**	**SE**	**Est**	**SE**	**Est**	**SE**
A[a]	(Age - 52.5)/100	2.50	.83	-1.17	.69	-1.78	1.68	-2.55	1.5
	<1900	-64.7	27.7	-11.6	25.3	71.9	50.3	68.9	59.7
	1900 - 09	-30.5	21.6	-6.9	18.2	27.5	45.0	85.3	44.8
B[b] -	1910 - 19	-17.7	19.3	-5.5	16.1	8.9	41.7	47.6	43.1
	1920 - 29	-26.9	21.9	-36.4	17.4	54.6	43.2	39.2	45.7
	1930+	-34.8	41.4	-104.5	34.9	.	.	-105.1	82.4
S[c] –	Nonmonthly	0	.	0	.	0	.	0	.
	Monthly vs Non	-21.7	16.2	-84.0	16.1	-18.2	30.3	-9.3	33.4
L[c] -	At Least 1 Year	0	.	0	.	0	.	0	.
	Less than 1 Year	-9.6	18.9	19.7	15.5	37.1	34.1	8.4	39.9
IG[c,d] -	EN	0	.	0	.	0	.	0	.
	EM	-14.3	15.8	11.2	11.9	-15.3	29.1	20.0	36.2
	NE	-5.7	17.6	0.5	15.4	-42.0	32.1	3.3	39.2
F[c] -	X-10	0	.	0	.	0	.	0	.
	Y-12 vs X-10	-14.2	18.4	46.0	14.6	-5.3	36.0	-113.9	48.2
	Multiple vs X-10	-23.0	15.8	33.4	13.5	20.7	28.9	-64.4	35.0
D[e] -	Dose (10 mSv)	1.42	.	1.68	.	2.06	.	0[f]	.
	95% CI[g]	(<0, 6.79)		(0.03, 4.94)		(<0, 24.6)		(<0, 6.5)	

[a]This term describes (and adjusts for) any systematic age-related difference in the external rates (U.S. White Males) and the study cohort in percent per year units — see Eq. 3 and the Appendix for further discussion.

[b]The estimates for each birth cohort are SMRs (in L% units) for the reference level of each of the other terms in the model, e.g. for the 1910-19 cohort the estimated lung cancer SMR = exp (-0.055) = 0.95. The reference group is nonmonthly workers employed at least 1 year at X-10 and who were eligible but not monitored for internal radiation exposure.

[c]For S, L, IG, and F the estimates are of relative risks in L% units, i.e. lung cancer the relative risk for monthly vs. nonmonthly workers is exp (-.84) = 0.43.

[d]IG-Internal Radiation: EN - eligible and not monitored, EM = eligible and monitored, and NE = not eligible for monitoring.

[e]Dose-response for the ERR per Sv (see Eq 4) which is equivalent to percent per 10 mSv (rem).

[f]Likelihood maximized at value that would lead to negative relative risk estimate.

[g]Likelihood ratio based confidence interval for ERR.

Table VIII: Dose Response Estimates for X-10/Y-12 Succohort (N = 28,347). Multiplicative Relative Risk for Selected Causes of Death Based on Main Effects Model Using Unadjusted Doses with Ten Year Lag (Two Year Lag for Leukemia)

			SMR[a]			Low Dose β[c]		
	Obs	**%**	**L%**	**SE**	**Score**[b]	**Est**	**SE**	**LRT**[d]
All Causes	4,786	79.84	-22.52	1.45	1.10	0.56	0.50	1.19
All Cancer Causes (140-209)	1,134	87.31	-13.576	2.97	2.46	1.59	0.83	3.23
Digestive (150-159)	258	76.10	-27.32	6.22	.53	2.90	1.46	3.12
Lung (162-163)	424	94.40	-5.76	4.83	2.91	0.97	1.39	0.43
Skin (172-173)	29	109.60	9.16	18.52	-0.42	-7.33	10.44	0.71
Prostate (185)	77	105.33	5.19	11.26	0.13	2.67	2.98	0.62
Kidney (189)	35	104.81	4.70	16.86	0.13	2.61	4.22	0.30
Brain (191-192)	46	108.50	8.16	14.73	-0.62	-15.97	14.15	2.13
Leukemia (204-207)	50	99.51	-0.50	14.12	-0.65	-3.93	6.83	0.42
Other Lymphatic (202-3, 208)	34	92.16	-8.16	17.12	0.47	5.67	3.50	1.62
All Lymphatic (200-9)	123	95.72	-4.38	8.96	0.08	1.71	2.48	0.42
Non-Cancer	3,652	77.77	-25.14	1.65	-0.22	0.06	0.63	0.01
Circulatory System (390-458)	2,281	78.03	-24.81	2.09	-0.30	0.45	0.74	0.35
Arteriosclerotic Disease (410-413)	1,658	78.85	-23.76	2.45	0.09	0.81	0.83	0.87
Cerebrovascular Disease (430-438)	292	88.53	-12.18	5.85	-0.35	0.25	2.26	0.01
Respiratory (460-519)	275	78.41	-24.33	5.98	0.01	2.17	1.73	1.30
Emphysema (492)	73	95.97	-4.11	11.64	1.25	6.91	1.86	7.93
Digestive (420-577)	165	54.80	-60.15	7.78	-0.21	0.35	2.78	0.02
Ill-defined (790-799)	185	264.64	97.32	7.35	1.59	-2.77	3.06	0.98
All External Causes (800-998)	485	75.40	-28.24	4.51	-0.69	-1.82	2.41	0.65
All Accidents (800-949)	298	70.25	-35.31	5.79	-0.86	-6.27	4.66	2.54
Motor Vehicle (810-827)	147	72.37	-32.33	8.24	-0.90	-19.53	11.38	5.23
Suicide (950-959)	146	93.81	-6.39	8.25	0.03	1.53	2.64	0.30

[a]Marginal SMRs for the X-10/Y-12 ever subcohort.

[b]Scores test statistic using all data (see methods)

[c]Relative risk is represented as $exp\ (\beta D)$, where D is cumulative dose in Sv, so β represents the change in the log relative risk per sievert (which is equivalent to L% per 10mSv). Data in the highest dose group (greater than 640 mSv) were excluded.

[d]Likelihood ratio test statistic for null hypothesis $\beta = 0$.

Table IX: White Males Ever Employed at X-10 or Y-12 Between 1943 and 1984 (N = 28,347) Dose Response Estimates for Multiplicative Relative Risk for Selected Causes of Death Based on Main Effects Model Using Adjusted Doses with Ten Year Lag

		Low Dose β[b]		
	Score[a]	**Est**	**SE**	**LRT**[c]
All Causes	0.85	0.55	0.46	1.37
All Cancer Causes (140-209)	1.95	1.26	0.80	2.26
Digestive (150-159)	0.27	2.48	1.41	2.48
Lung (162-163)	2.48	0.48	1.39	0.12
Skin (173-173)	-0.40	-7.33	9.43	0.86
Prostate (185)	0.10	2.67	2.75	0.75
Kidney (189)	0.02	1.97	4.31	0.18
Brain (191-192)	-0.42	-6.37	8.37	0.81
Leukemia (204-207)	-0.20	-0.63	4.62	0.02
Other Lymphatic (202-3, 208)	0.21	4.76	3.75	1.10
All Lymphatic (200-9)	-0.02	1.45	2.39	0.33
Non-Cancer	0.21	0.23	0.56	0.16
Circulatory System (390-458)	-0.45	0.50	0.68	0.51
Arteriosclerotic Disease (410-413)	-0.93	0.84	0.76	1.14
Cerebrovascular Disease (430-438)	-0.31	0.57	1.96	0.08
Respiratory (460-519)	-0.10	1.82	1.66	1.05
Emphysema (492)	0.88	6.27	1.91	6.57
Digestive (420-577)	-0.23	0.33	2.57	0.02
Ill-defined (790-799)	2.07	0.66	2.27	0.09
All External Causes (800-998)	-0.71	-2.20	2.28	1.07
All Accidents (800-949)	-0.75	-5.25	3.84	2.40
Motor Vehicle (810-827)	-0.73	-12.67	7.99	3.94
Suicide (950-959)	-0.13	0.88	2.64	0.10

[a]Score test statistic base on all data (see Methods).

[b]Relative risk is represented as $exp(\beta D)$, where D is cumulative dose in Sv, so β represents the change in the log relative risk per sievert (which is equivalent to L% per 10mSv). Data in the highest dose group (greater than 640 mSv) were excluded.

[c]Likelihood ratio test statistic for null hypothesis $\beta = 0$.

Table X: Estimates[a] of Linear Excess Relative Risk (per Sv) (and Likelihood Ratio Test Statistics) for all Cancer Causes By Facility and Lag Interval Using Unadjusted and Adjusted Cumulative Doses For the X-10/Y-12 Ever Subcohort (N = 28,347)

A. RESULTS USING UNADJUSTED DOSES

	Lag Interval (Years)		
Facility	**Two**	**Ten**	**Twenty**
Combined	0.79	1.45	1.27
LRT[b]	(2.42)	(5.30)	(1.05)
X-10	1.87	3.59	6.27
Y-12	1.23	1.75	-0.33
Multiple	0.16	0.36	-0.24
LRT[c]	(1.41)	(3.32)	(7.87)

B. RESULTS USING ADJUSTED DOSES

	Lag Interval (Years)		
Facility	**Two**	**Ten**	**Twenty**
Combined	0.48	0.93	0.84
LRT[b]	(1.53)	(3.65)	(0.62)
X-10	1.43	2.80	4.68
Y-12	0.72	0.91	-0.17
Multiple	0.00	0.21	-0.17
LRT[c]	(1.62)	(2.89)	(7.81)

[a]Using main effects model with external rates for baseline risk.
[b]Likelihood ratio test for slope equal to zero has chi-square distribution with 1 df.
[c]Likelihood ratio test for common slope, has chi-square distribution with 2 df.

Table XI: Summary Statistics For Relative Risk Models For All Cancer Using Unadjusted Doses and Ten Year Lag For X-10/Y-12 Ever Subcohort

Relative Risk Function[a]	**m**[b]	**Deviance**	**AIC**[c]	$\hat{\beta}_1$	$\hat{\beta}_2$
1	12	2020.05	2044.05	.	.
$exp\,(\beta_1 D)$	13	2016.50	2042.50	0.49	.
$exp\,(\beta_1 D + \beta_2 D^2)$	14	2013.69	2041.69	1.65	-0.42
$1 + \beta_1 D$	13	2014.75	2040.75	1.45	.
$1 + \beta_1 D + \beta_2 D^2$	14	2013.73	2041.73	2.48	-0.63
$1 + \beta_1 D^{\beta 2}$	14	2014.40	2042.40	1.39	0.81
Dose Groups[d]	21	2012.08	2054.10	.	.

[a]Using main effects model with external rates for baseline.
[b]m is the number of parameters in the model.
[c]AIC = Deviance + 2m (smaller is better).
[d]Separate parameter for each dose group (see Fig. 2-A).