Online supplementary - Table S1: Disease group definitions used in the analysis

Cause of death	ICD-6 and 7	ICD-8	ICD-9	ICD-10
All non-cancers	1-138, 240-293, 295-E999	0-136, 240-E999 (x 275.5)	1-139, 240-E999 (x 273.3)	A00-B99, D50- Y89
Infectious diseases	001-138	000-007,010-136	001-007,010-139	A00-A07, A15-B99
Endocrine diseases	240,242-289	240-279 (x 275.5)	240-279 (x 273.3)	E00-E90
Diabetes	260	250	250	E10-E14
Blood diseases	290-293,295-299	280-289	280-289	D50-D89
Mental disorders	300-326	290-315	290-319	F00-F99
Nervous system	340-398	320-389	320-389	G00-H95
Circulatory diseases (CD)	330-334,400-468	390-458	390-459	I00-I99
Hypertensive diseases	440-447	400-404	401-405	I10-I15
IHD	420-422	410-414	410-414	I20-I25
Myocardial infarction	420.1	410	410	I21
Chronic IHD	-	412	414	I25
Other IHD	420.0, 420.2-422	411, 413-414	411-413	I20, I22-I24
Other heart diseases	430-434, 465	420-429	415-429	I26-I52
Cerebrovascular disease (CeVD)	330-334	430-438	430-438	I60-I69
Haemorrhagic stroke	330-331	430-431	430-432	I60-I62
Ischemic stroke	332-333	432-435	433-435	I63, I65-I66
Ill-defined stroke	334	436-438	436-438	I64, I67-I69
Other circulatory diseases	400-416,450-464, 466-468	390-398, 440-448, 451-458	390-398, 440-459	I00-I09, I70-I99
CD excluding CeVD	400-468	390-429, 440-458	390-429, 440-459	I00-I52, I70-I99
Respiratory diseases	241,470-527	460-519	460-519	J00-J99
Pneumonia	490-493	480-486	480-486	J12-J18
COPD[a]	241, 500-502, 527.1	490-493	490-493,496	J40-J46
Other respiratory	470-483,510-527.0, 527.2	460-474,500-519	460-478, 487, 494-495,500-519	J00-J11, J20-J39, J47-J99
Digestive diseases	530-587	008-009,520-577	008-009,520-579	A08-A09, K00-K93
Cirrhosis	581	571	571	K70, K73-K74
Other digestive	530-580, 582-587	008-009,520-570, 572-577	008-009,520-570, 572-579	A08-A09, K00-K67, K71-K72, K75-K93
Genito-urinary diseases	590-637	580-629	580-629	N00-N99
Skin diseases[b]	690-716	680-709	680-709	L00-L99
Musulcoskeletal disease	720-749	710-738	710-739	M00-M99
Congenital malformations[b]	750-759	740-759	740-759	Q00-Q99
Other diseases[b]	640-689,760-776	630-678,760-779	630-676,760-779	O00-O99, P00-P99
Ill-defined diseases	780-795	780-796	780-799	R00-R99
External causes	E800-E999	E800-E999	E800-E999	V01-Y89
Smoking related non-cancers (SRNC)	420-422,330-334,450-456,480-502.1	410-414,426-448,470-492	410-414,428-448,480-492,496	I20-I25, I50-I79, J12-J44
Non-cancer diseases not strongly related to smoking[c]	1-138, 240-293, 295-326, 340-416, 430-447, 460-475, 510-E999	0-136, 240-275.4, 275.9-404, 420-425, 450-466, 493-E999	1-139, 240-273.2, 273.8-405, 415-427, 451-478, 493-495, 500-E999	A00-B99, D50-I15, I26-I49, I80-J11, J45-Y89

[a] the COPD grouping also includes bronchitis, emphysema and asthma causes of death, [b] no results are reported for these diseases because the number of deaths was too small (<100 deaths) [c] this grouping represents all non-cancer causes of death not in the SRNC grouping and therefore consists of a number of diseases not strongly related to smoking.

Online supplementary - Table S2: Definition of variables used in the analysis

Variable	Categories
Factors included in the background model:	
Birth cohort	7 categories : <1905, 1905-14, 1915-24,……,1945-54, ≥1955
Attained age (years)	15 categories: 15-19, 20-24, …,75-79, 80-84, ≥85
Gender	2 categories: Male, Female
Socio-economic status	5 categories: professional and technical/non-industrial, administrative staff, skilled workers/industrial, unskilled workers, unknown/uncertain
Facility/employer group	15 categories: CEA, AREVA, EDF, AWE, BNFL other, Sellafield/Chapelcross, UKAEA other, Doureay, BEGME, MOD, PNS, ORNL, Hanford, SRS, INL
Duration of employment (years)	4 categories: <10, 10-20, 20-30, ≥30
Exposure variable for regression analyses:	
Cumulative external radiation Hp(10) dose (mSv)	11 categories: [0-4), [5-9), [10-19), [20-49), [50-99), [100-149), [150-199), [200-299), [300-399), [400-499), ≥500
Additional factors used in sensitivity analysis:	
Country	3 categories: France, UK, US
Main employer	13 categories: CEA, AREVA, EDF, AWE, BNFL, UKAEA, Magnox, MOD, PNS, ORNL, Hanford, SRS, INL
Calendar Period	12 categories: 1944-50, 1951-55, 1956-60,…,1996-2000, 2001-05
Socio-economic grouping	2 broad categories: white collar (professional/technical/non-industrial/administrative staff), blue collar (skilled/industrial/unskilled workers)
Employment status	2 categories: serving staff, ex-worker
Neutron monitoring status	3 categories: no record of positive neutron monitoring, positive recorded neutron dose, neutron dose > 10% of recorded total external dose
Neutron exposure status	2 categories: no evidence of significant neutron dose, recorded neutron dose >10% total external dose
Internal monitoring status	2 categories: external radiation worker, worker monitored for internal radiation
Time since exposure	3 windows: dose received 10-20, 20-30, ≥30 year ago 11 dose categories for each of the time since exposure windows: [0-4), [5-9), [10-19), [20-49), [50-99), [100-149), [150-199), [200-299), [300-399), [400-499), ≥500 mSv
Age at exposure	3 windows: dose received at ages <35, 35-50, ≥50 years 11 dose categories for each of the age at exposure windows: [0-4), [5-9), [10-19), [20-49), [50-99), [100-149), [150-199), [200-299), [300-399), [400-499), ≥500 mSv

Online supplementary - Table S3: Mortality from circulatory diseases in relation to external radiation dose: ERR/Sv estimates, observed and expected number[c] of deaths from the Poisson regression analysis

Cause of death	Observed deaths [expected deaths] by cumulative external dose (mSv), 10 y lag													
	<5	5-10	10-20	20-50	50-100	100-150	150-200	200-300	300-400	400-500	>500	Total	ERR/Sv[b] (90% CI)	p-value[a]
Circulatory diseases	13185	3006	3261	3627	1961	944	509	606	356	171	222	27848	0.22 (0.08,0.37)	0.004
	[13176.7]	[3007.0]	[3266.6]	[3597.6]	[1944.8]	[900.9]	[511.6]	[558.4]	[300.3]	[164.8]	[201.4]	[27630.0]		
Hypertensive diseases	304	60	63	67	39	20	12	7	8	1	3	584	-0.05 (<-0.96,1.15)	0.532
	[300.0]	[61.9]	[67.3]	[69.6]	[36.5]	[17.1]	[10.1]	[10.6]	[5.5]	[3.0]	[3.1]	[584.9]		
IHD	8241	1888	2080	2232	1213	627	315	388	221	117	141	17463	0.18 (0.00,0.36)	0.046
	[8220.5]	[1877.8]	[2037.5]	[2275.2]	[1242.5]	[576.1]	[328.7]	[362.2]	[193.6]	[106.3]	[131.7]	[17352.1]		
- Myocardial infarction	5393	1177	1259	1351	769	402	196	245	137	59	88	11076	0.26 (0.03,0.51)	0.029
	[5360.2]	[1165.4]	[1249.5]	[1407.6]	[767.9]	[352.1]	[200.2]	[219.6]	[115.4]	[62.1]	[76.5]	[10976.3]		
- Chronic IHD	2763	698	806	864	436	220	117	142	83	56	53	6238	0.07 (-0.19,0.36)	0.332
	[2777.0]	[697.7]	[773.3]	[849.9]	[464.1]	[219.1]	[125.6]	[139.5]	[76.5]	[43.5]	[54.7]	[6220.8]		
- Other IHD	85	13	15	17	8	5	2	1	1	2	0	149	-0.16 (<0,2.84)	0.547
	[84.0]	[14.1]	[14.5]	[16.8]	[9.2]	[4.3]	[2.5]	[2.3]	[1.1]	[0.4]	[0.4]	[149.6]		
Other heart diseases	1686	376	385	460	209	96	41	69	35	16	25	3398	0.21 (-0.18,0.67)	0.199
	[1695.6]	[368.5]	[397.2]	[410.1]	[217.2]	[103.2]	[58.2]	[61.5]	[31.9]	[16.3]	[16.4]	[3375.9]		
Cerebrovascular disease (CeVD)	2014	477	530	614	336	147	102	97	62	28	37	4444	0.50 (0.12,0.94)	0.014
	[2046.3]	[484.7]	[532.4]	[583.4]	[308.2]	[139.8]	[77.8]	[84.8]	[47.7]	[26.5]	[34.1]	[4365.7]		
- Haemorrhagic stroke	602	107	114	129	87	36	18	20	10	1	6	1130	0.42 (-0.39,1.51)	0.217
	[618.5]	[109.4]	[114.1]	[125.5]	[67.5]	[30.2]	[16.8]	[17.3]	[8.3]	[4.4]	[5.2]	[1117.2]		
- Ischemic stroke	290	80	55	84	36	16	18	11	10	2	5	607	0.44 (-0.48,1.79)	0.241
	[289.3]	[68.5]	[73.0]	[76.3]	[39.0]	[17.3]	[9.8]	[11.0]	[6.0]	[3.4]	[4.4]	[598.1]		
- Ill-defined stroke	1122	290	361	401	213	95	66	66	42	25	26	2707	0.52 (0.07,1.06)	0.027
	[1138.8]	[306.6]	[345.1]	[381.7]	[202.1]	[92.5]	[51.4]	[56.6]	[33.6]	[18.7]	[24.4]	[2651.5]		
Other circulatory diseases	940	205	203	254	164	54	39	45	30	9	16	1959	0.16 (-0.32,0.76)	0.305
	[917.2]	[212.9]	[230.0]	[257.5]	[140.0]	[64.4]	[36.7]	[39.1]	[21.4]	[12.6]	[15.7]	[1947.5]		
Circulatory excluding (CeVD)	11171	2529	2731	3013	1625	797	407	509	294	143	185	23404	0.17 (0.02,0.33)	0.027
	[11130.1]	[2522.2]	[2733.6]	[3012.8]	[1635.8]	[760.7]	[433.6]	[473.4]	[252.2]	[138.1]	[166.8]	[23259.4]		

[a] p-value represents a 1-sided test of the linear ERR/Sv parameter, [b]ERR/Sv estimates are calculated from a linear ERR model that contains background adjustments for age, birth-cohort, gender, socio-economic status, duration of employment and facility of employment. [c]The expected number of deaths is the estimated number of background deaths using the Poisson regression model in the absence of occupational radiation exposure.

Online supplementary - Table S4: Mortality from respiratory, digestive and endocrinal diseases: ERR/Sv estimates, observed and expected number of deaths from the Poisson regression analysis

Cause of death	Observed deaths [expected deaths] by cumulative external dose (mSv), 10 y lag												$P(H_0$:	
	<5	5-10	10-20	20-50	50-100	100-150	150-200	200-300	300-400	400-500	>500	Total	ERR>0)	ERR/Sv (90% CI)
Respiratory diseases	2381 [2394.4]	572 [596.9]	666 [656.5]	737 [716.8]	398 [382.1]	177 [176.1]	109 [100.4]	115 [108.8]	58 [60.6]	33 [33.4]	45 [39.4]	5291 [5265.5]	0.243	0.13 (-0.17,0.47)
- Pneumonia	721 [696.4]	172 [190.8]	207 [207.9]	226 [224.9]	115 [117.0]	55 [52.3]	29 [28.5]	38 [30.2]	12 [17.1]	8 [8.9]	19 [11.5]	1602 [1585.4]	0.198	0.29 (-0.24,0.96)
- COPD	1244 [1272.5]	312 [307.9]	344 [341.2]	389 [374.4]	202 [200.3]	92 [93.1]	60 [54.1]	55 [59.9]	35 [33.4]	19 [19.4]	19 [22.0]	2771 [2778.1]	0.605	-0.07 (-0.45,0.38)
- Other respiratory	416 [426.1]	88 [98.5]	115 [107.4]	122 [116.5]	81 [64.6]	30 [30.4]	20 [17.8]	22 [18.8]	11 [10.2]	6 [5.2]	7 [5.9]	918 [901.3]	0.147	0.52 (-0.26,1.53)
Digestive diseases	1145 [1155.7]	215 [219.5]	243 [230.6]	280 [252.9]	129 [138.4]	45 [63.8]	44 [35.5]	38 [37.3]	16 [18.6]	11 [9.5]	14 [10.7]	2180 [2172.7]	0.358	0.11 (-0.36,0.69)
- Cirrhosis	329 [332.2]	54 [51.6]	52 [53.2]	66 [60.7]	30 [34.2]	17 [15.4]	12 [8.5]	7 [8.3]	3 [3.6]	3 [1.6]	1 [1.4]	574 [570.7]	0.375	0.23 (<-0.85,1.75)
- Other digestive	816 [823.2]	161 [168.0]	191 [177.3]	214 [191.8]	99 [103.9]	28 [48.1]	32 [26.8]	31 [28.8]	13 [14.8]	8 [7.8]	13 [9.0]	1606 [1599.5]	0.355	0.13 (-0.39,0.79)
Endocrine diseases	642 [614.3]	118 [125.5]	128 [131.5]	131 [136.2]	62 [75.4]	43 [36.8]	26 [21.1]	25 [23.1]	10 [11.9]	3 [6.4]	14 [6.8]	1202 [1188.8]	0.196	0.34 (-0.28,1.13)
- Diabetes	490 [471.8]	85 [97.5]	106 [103.4]	111 [108.7]	48 [60.3]	37 [29.7]	22 [17.0]	24 [18.7]	8 [9.8]	3 [5.3]	12 [5.8]	946 [928.0]	0.108	0.58 (-0.16,1.53)

[a] p-value represents a 1-sided test of the linear ERR/Sv parameter, [b]ERR/Sv estimates are calculated from a linear ERR model that contains background adjustments for age, birth-cohort, gender, socio-economic status, duration of employment and facility of employment. [c]The expected number of deaths is the estimated number of background deaths using the Poisson regression model in the absence of occupational radiation exposure.

Online supplementary - Table S5: Mortality from circulatory disease, ischemic heart disease and cerebrovascular disease: linear ERR/Sv estimates and dose category specific ERR estimates

	Circulatory diseases		Ischemic heart diseases		Cerebrovascular diseases	
	N	ERR/Sv (90% CI)	N	ERR/Sv (90% CI)	N	ERR/Sv (90% CI)
Overall[b]	27570	0.22 (0.08; 0.37)	17279	0.17 (0.002; 0.36)	4399	0.49 (0.11; 0.92)
Dose category specific risks:		ERR (90% CI)		ERR (90% CI)		ERR (90% CI)
<5[a]	12984	0	8111	0	1984	0
5-10	2995	0.00 (-0.03; 0.04)	1882	0.00 (-0.04; 0.05)	475	0.01 (-0.08; 0.10)
10-20	3237	-0.00 (-0.04; 0.03)	2065	0.01 (-0.03; 0.06)	524	0.02 (-0.07; 0.11)
20-50	3604	0.00 (-0.03; 0.04)	2214	-0.03 (-0.07; 0.01)	610	0.09 (-0.00; 0.18)
50-100	1951	0.00 (-0.04; 0.05)	1205	-0.03 (-0.09; 0.02)	334	0.13 (0.01; 0.25)
100-150	940	0.05 (-0.01; 0.11)	623	0.08 (0.00; 0.16)	147	0.10 (-0.06; 0.26)
150-200	505	-0.01 (-0.08; 0.07)	312	-0.05 (-0.15; 0.04)	102	0.38 (0.14; 0.62)
200-300	606	0.09 (0.01; 0.17)	388	0.06 (-0.03; 0.16)	97	0.20 (-0.02; 0.42)
300-400	355	0.18 (0.08; 0.30)	221	0.13 (-0.00; 0.27)	61	0.34 (0.04; 0.64)
400-500	171	0.04 (-0.09; 0.18)	117	0.09 (-0.08; 0.26)	28	0.11 (-0.25; 0.47)
500+	222	0.10 (-0.02; 0.24)	141	0.06 (-0.10; 0.22)	37	0.14 (-0.19; 0.47)

[a] – ERR estimates expressed relative to baseline category < 5mSv,). [b]For the overall results the ERR/Sv estimates are calculated from a linear ERR model that contains background adjustments for age, birth-cohort, gender, socio-economic status, duration of employment and facility of employment.

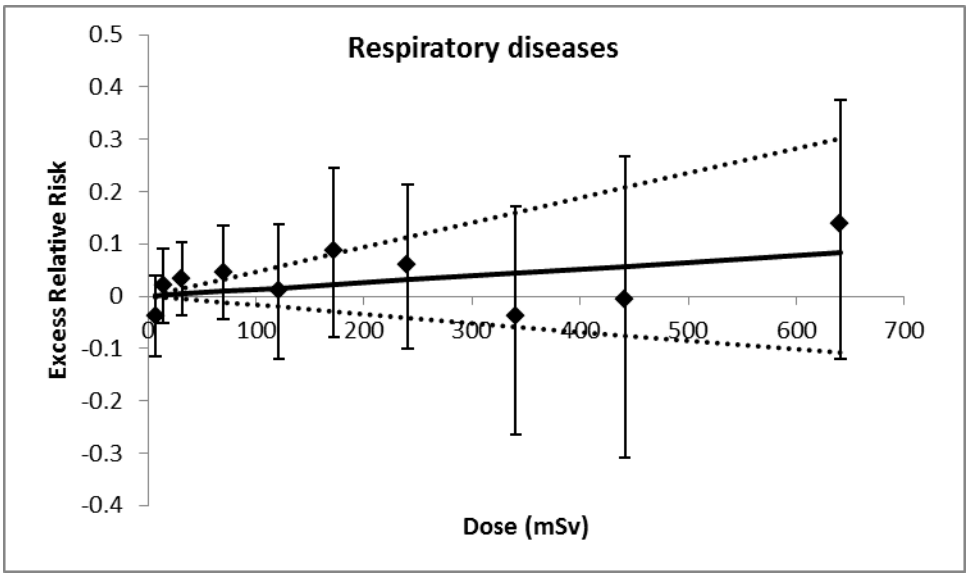
Online supplementary - Table S6: Country and employer/facility specific linear ERR/Sv estimates for circulatory diseases, ischemic heart diseases and cerebrovascular diseases

Country -cohort	Circulatory diseases		Ischemic heart diseases		Cerebrovascular diseases	
	N	ERR/Sv (90% CI)	N	ERR/Sv (90% CI)	N	ERR/Sv (90% CI)
Overall[a]	27570	0.22 (0.08; 0.37)	17279	0.17 (0.00; 0.36)	4399	0.49 (0.11; 0.92)
France	1467	-0.16 (-1.06; 0.93)	579	0.36 (<0; 2.23)	376	-0.60 (<0; 2.07)
UK – AWE	1342	1.92 (0.11; 4.20)	886	2.47 (0.24; 5.38)	212	1.58 (<0; 8.36)
UK – Sel/Chx[b]	2135	0.53 (0.28; 0.82)	1471	0.49 (0.19; 0.83)	393	0.62 (0.07; 1.33)
UK – BNFL[c]	2227	1.27 (0.22; 2.49)	1467	0.29 (-0.77; 1.65)	439	4.77 (1.85; 8.53)
UK – Dounreay	713	0.36 (-0.32; 1.21)	503	0.53 (-0.33; 1.62)	128	-0.45 (<0; 1.30)
UK – UKAEA[d]	2382	-0.27 (-0.61; 0.14)	1562	-0.27 (<0; 0.24)	445	-0.60 (<0; 0.58)
UK – BEGME	1069	-0.48 (<0; 0.90)	730	-0.52 (<0; 1.24)	174	1.06 (<0; 5.37)
UK – MOD	1690	0.53 (-0.33; 1.61)	1204	0.22 (<0; 1.47)	231	0.28 (<0; 4.03)
UK	11558	0.38 (0.19; 0.60)	7823	0.33 (0.10; 0.59)	2022	0.51 (0.04; 1.07)
US – PNS	2097	-1.09 (<0; -0.41)	1385	-1.07 (<0; -0.21)	259	-1.58 (<0; 0.85)
US – ORNL	2217	0.30 (-0.28; 0.99)	1317	0.64 (-0.15; 1.61)	348	-0.73 (<0; 1.17)
US – Hanford	5603	0.25 (-0.03; 0.57)	3395	0.16 (-0.19; 0.56)	843	0.74 (-0.07; 1.72)
US – SRS	2249	0.17 (-0.38; 0.78)	1378	-0.48 (<0; 0.24)	290	2.68 (0.80; 5.13)
US – INL	2379	-0.47 (-0.87; 0.01)	1402	-0.39 (<0; 0.25)	301	-0.36 (<0; 1.35)
US	14545	0.02 (-0.18, 0.24)	8877	-0.05 (-0.30; 0.21)	2041	0.52 (-0.09; 1.22)
Test for homogeneity by facility[e]		p=0.006		p=0.087		p=0.116
Test for homogeneity by country[e]		p=0.089		p=0.183		p>0.50

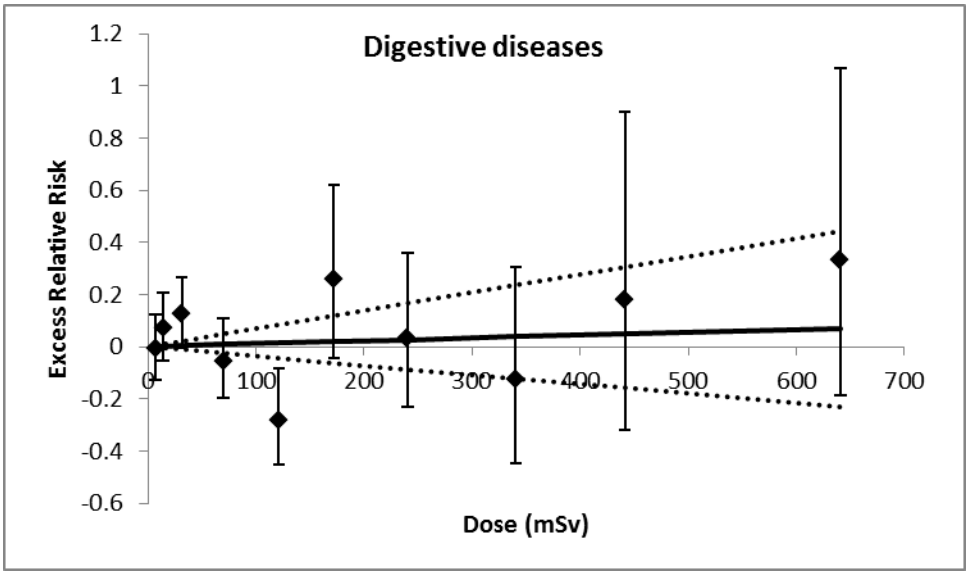
[a]For the overall results the ERR/Sv estimates are calculated from a linear ERR model that contains background adjustments for age, birth-cohort, gender, socio-economic status, duration of employment and facility of employment, [b]for analyses purposes the Sel/Chx figures represent combined figures for the Chapelcross and Sellafield sites, [c]the BNFL figure represents the combined figures for the BNFL sites excluding Sellafield/Chapelcross, [d]the UKAEA figure represents the combined figures for the UKAEA sites excluding Dounreay, [e]test for homogeneity based on the likelihood ratio test comparing overall model with a model that allows the ERR to vary by country or employer/facility.

Online supplementary - Table S7: Female circulatory disease ERR/Sv estimates by dose category

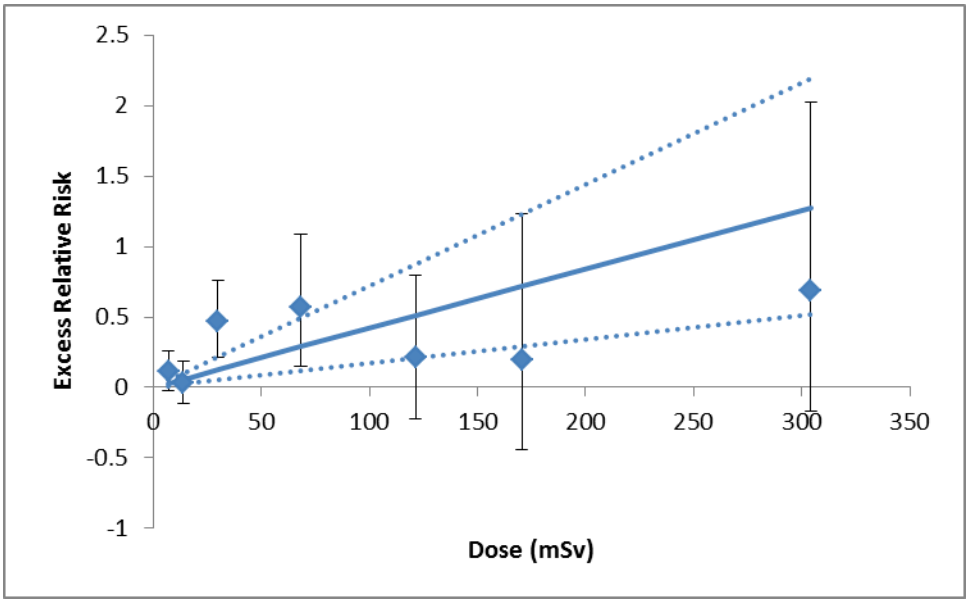
Dose (mSv)	Deaths	ERR	90% CI	
			Lower	Upper
<5	1159	0	.	.
5-10	213	0.11	-0.02	0.26
10-20	170	0.03	-0.11	0.19
20-50	102	0.46	0.21	0.76
50-100	34	0.57	0.15	1.09
100-150	17	0.21	-0.22	0.80
150-200	6	0.20	-0.44	1.23
200+	7	0.69	-0.17	2.02
All		4.22	1.72	7.21



Online supplementary - Figure S1: Mortality from respiratory diseases – ERR estimates and 90% CI by 10 year lagged external dose category with linear ERR/Sv estimate and associated 90% CI reference lines



Online supplementary - Figure S2: Mortality from digestive diseases – ERR estimates and 90% CI by 10 year lagged external dose category with linear ERR/Sv estimate and associated 90% CI reference lines



Online supplementary - Figure S3: Female mortality from circulatory diseases - ERR estimates and 90% CI by external dose category with linear ERR/Sv estimate and associated 90% CI reference lines also shown