CUMULATIVE RADIATION EXPOSURE AT BNFL SELLAFIELD: A HISTORICAL PERSPECTIVE

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ABSTRACT

The temporal distribution of the average cumulative whole body annual recorded external radiation doses of 15,182 monitored male Sellafield employees is presented. Results are given for successive pairs of years of first monitoring, from 1949-50 to 1985-86, and for successive single years of follow up for each of these cohorts. The results show: there is a reduction in average cumulative dose with later years of first monitoring at any length of follow up; a marginal reduction in the increase in the average cumulative dose for any given cohort with longer length of follow up; and the pattern of average dose in the first year of follow up is similar to that previously reported, in [1].

INTRODUCTION

Historical annual recorded whole body dose data for Sellafield employees were computerised as a special exercise by a dedicated team of British Nuclear Fuels plc (BNFL) Sellafield staff in the This computerised annual dose database has had the late 1970's. annual dose data for all Sellafield employees added to it up to These dose data together with personnel and tracing return data form part of the BNFL Company Epidemiology database and are held on computer in the Company Medical Office at the Sellafield site. Extracts from the Epidemiology database have been supplied to researchers for use in a range of studies, published and forthcoming eg. [1,2,3,4]. The Sellafield employee data have been combined with equivalent data for the Atomic Energy Authority (AEA) and the Atomic Weapons Establishment (AWE) by Harwell staff to form the Nuclear Industry Combined Epidemiological Analysis (NICEA) database. These data, which will be analysed by epidemiologists at the London School of Hygiene and Tropical Medicine (LSHTM), have been transferred to the International Agency for Research on Cancer (IARC) for combining with American and Canadian data, for analysis by IARC staff.

THE DISTRIBUTION OF ANNUAL EXTERNAL DOSE DATA

The Sellafield whole body annual dose data are, as with other such data [5], in their own right of considerable epidemiological interest. There are 15,182 male radiation workers on this database who have been occupationally exposed to 1307 Sv during 112,582 person years of employment. Only the first episode of continuous employment as a monitored worker and those annual external doses recorded during that employment period are used for the results of this paper.

AVERAGE CUMULATIVE ANNUAL EXTERNAL WHOLE BODY DOSES IN mSv (UPPER SUCCESSIVE PAIRS OF YEARS OF FIRST MONITORING, STARTING IN 1949-50, OF ALL AGES WHILE CONTINUOUSLY MONITORED DURING THEIR FIRST EMPLOYMENT

Year of first			Υe	ears of	follo	ow-up			
monitoring	1	2	3	4	5	6	7	8	9
49-50	2.3	7.3	30.8	59.5	83.8	109.7	143.9	178.8	200.7
51-52	6.9	26.7	45.7	62.9				141.1	
53-54	10.1	24.8	42.9	64.0	81.2			134.5	
55 - 56	8.9	28.4	44.9	60.6	78.3			125.1	
57 - 58	8.8	24.4	43.8	61.7	78.9			125.2	
59 - 60	8.8	23.0	35.9	47.6	56.8	68.2		102.4	
61-62	5.6	14.8	22.4	32.3	46.5	63.6		100.1	
	3.4				39.1			73.5	83.0
63-64		10.1	18.1	26.7		49.2	61.0		
65-66	5.1	15.0	26.5	40.1	53.8	70.1		100.9	
67 ~ 68	7.0	20.5	35.0	52.2	71.9			119.2	109.1
69 - 70	5.0		31.5	46.1	58.2	73.2	87.0	109.0	
71-72	7.6	22.1	37.1	52.5	69.8	83.8			
73-74	7.6	23.3	41.3	56.8	71.0	84.4		112.2	
75-76	8.1	22.3	36.9	51.0	65.7	81.4		105.5	
77-78	5.3	15.0	25.4	35.4	44.4	52.9	61.5	69.5	73.4
79-80	4.9	12.6	20.6	28.9	37.0	44.2	48.7	59.7	
81-82	3.0	7.2	12.6	19.3	23.4	29.8			-J 45
83-84	1.9	7.3	10.4	12.2				100	113
85 - 86	2.3	5.8			39 لــ	62	69	78	85
			_ا 36	88	110	143	165	177	197
49-50	0	20	24	32	38	43	45	48	58
Years of	38	37	36	35	34	33	32	31	30
follow-up									
·									
			-						
Year of first				Years		llow-u			
Year of first monitoring	20	21	22	Years 23	of fo	llow-u _] 25	p 26	27	28
monitoring				23	24	25	26		
monitoring 49-50	428.6	450.8	467.7	23 484.8	24 501.5	25 524.3	26 553.0	568.8	586.9
monitoring 49-50 51-52	428.6 344.3	450.8 353.5	467.7 367.6	23 484.8 382.9	24 501.5 400.0	25 524.3 417.5	26 553.0 422.3	568.8 431.9	586.9 432.8
monitoring 49-50 51-52 53-54	428.6 344.3 317.3	450.8 353.5 335.1	467.7 367.6 347.3	23 484.8 382.9 362.7	24 501.5 400.0 362.8	25 524.3 417.5 375.9	553.0 422.3 395.1	568.8 431.9 414.4	586.9 432.8 422.1
monitoring 49-50 51-52 53-54 55-56	428.6 344.3 317.3 306.2	450.8 353.5 335.1 316.2	467.7 367.6 347.3 326.6	23 484.8 382.9 362.7 336.1	501.5 400.0 362.8 346.1	25 524.3 417.5 375.9 357.3	26 553.0 422.3 395.1 370.3	568.8 431.9 414.4 375.6	586.9 432.8 422.1 387.9
monitoring 49-50 51-52 53-54 55-56 57-58	428.6 344.3 317.3 306.2 323.2	450.8 353.5 335.1 316.2 332.3	467.7 367.6 347.3 326.6 346.4	23 484.8 382.9 362.7 336.1 364.7	501.5 400.0 362.8 346.1 380.7	25 524.3 417.5 375.9 357.3 387.1	553.0 422.3 395.1 370.3 399.2	568.8 431.9 414.4 375.6 408.4	586.9 432.8 422.1 387.9 430.4
monitoring 49-50 51-52 53-54 55-56 57-58 59-60	428.6 344.3 317.3 306.2 323.2 263.4	450.8 353.5 335.1 316.2 332.3 278.0	467.7 367.6 347.3 326.6 346.4 288.0	23 484.8 382.9 362.7 336.1 364.7 293.8	24 501.5 400.0 362.8 346.1 380.7 292.9	25 524.3 417.5 375.9 357.3 387.1 296.2	26 553.0 422.3 395.1 370.3 399.2 300.6	568.8 431.9 414.4 375.6 408.4 296.0	586.9 432.8 422.1 387.9 430.4
monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62	428.6 344.3 317.3 306.2 323.2 263.4 242.5	450.8 353.5 335.1 316.2 332.3 278.0 250.7	467.7 367.6 347.3 326.6 346.4 288.0 259.2	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6	26 553.0 422.3 395.1 370.3 399.2 300.6	568.8 431.9 414.4 375.6 408.4 296.0	586.9 432.8 422.1 387.9 430.4 309.2
monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2	568.8 431.9 414.4 375.6 408.4 296.0	586.9 432.8 422.1 387.9 430.4 309.2
monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4	450.8 353.5 335.1 316.2 332.3 278.0 250.7	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2	568.8 431.9 414.4 375.6 408.4 296.0	586.9 432.8 422.1 387.9 430.4 309.2
monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 86 172	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 222 174	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 86 172 101	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 222 174 103	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 86 172 101 98	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 222 174 103 99	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68 67-68 65-66	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92 61	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96 64	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 172 101 98 67	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 222 174 103 99 74	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103 76	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106 79
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68 67-68 65-66 63-64	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5 94 90 59 50	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92 61 50	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96 64 53	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 172 101 98 67 55	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 222 174 103 99 74 57	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103 76 62	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106 79 67
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68 67-68 67-68 65-66 63-64 61-62	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3 83 55 46 132	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3 26 88 56 49 139	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5 94 90 59 50 152	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92 61 50 154	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96 64 53 161	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 172 101 98 67 55 171	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 174 103 99 74 57 178	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103 76 62 187	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106 79 67 195
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68 67-68 67-68 65-66 63-64 61-62 59-60	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3 83 55 46 132 229	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3 26 88 56 49 139 241	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5 94 90 59 50 152 249	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92 61 50 154 264	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96 64 53 161 277	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 172 101 98 67 55 171 288	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 174 103 99 74 57 178 296	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103 76 62 187 313	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106 79 67 195 326
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68 67-68 67-68 65-66 63-64 61-62 59-60 57-58	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3 83 55 46 132 229 248	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3 26 88 56 49 139 241 252	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5 94 90 59 50 152 249 258	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92 61 50 154 264 262	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96 64 53 161 277 269	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 172 101 98 67 55 171 288 283	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 174 103 99 74 57 178 296 303	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103 76 62 187 313 315	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106 79 67 195 326 333
monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68 67-68 67-68 65-66 63-64 61-62 59-60 57-58 55-56	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3 83 55 46 132 229 248 207	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3 26 88 56 49 139 241 252 207	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5 94 90 59 50 152 249 258 213	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92 61 50 154 264 262 225	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96 64 53 161 277 269 240	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 172 101 98 67 55 171 288 283 247	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 174 103 99 74 57 178 296 303 260	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103 76 62 187 313 315 281	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106 79 67 195 326 333 303
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68 67-68 65-66 63-64 61-62 59-60 57-58 55-56 53-54	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3 83 55 46 132 229 248 207 163	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3 26 88 56 49 139 241 252 207 172	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5 94 90 59 50 152 249 258 213 176	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92 61 50 154 264 262 225 185	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96 64 53 161 277 269 240 200	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 172 101 98 67 55 171 288 283 247 216	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 174 103 99 74 57 178 296 303 260 227	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103 76 62 187 313 315 281 246	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106 79 67 195 326 333 303 262
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68 67-68 65-66 63-64 61-62 59-60 57-58 55-56 53-54 51-52	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3 83 55 46 132 229 248 207 163 431	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3 26 88 56 49 139 241 252 207 172 459	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5 94 90 59 50 152 249 258 213 176 482	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92 61 50 154 264 262 225 185 508	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96 64 53 161 277 269 240 200 529	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 172 101 98 67 55 171 288 283 247 216 560	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 174 103 99 74 57 178 296 303 260 227 578	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103 76 62 187 313 315 281 246 612	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106 79 67 195 326 333 303 262 654
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68 67-68 65-66 63-64 61-62 59-60 57-58 55-56 53-54	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3 83 55 46 132 229 248 207 163	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3 26 88 56 49 139 241 252 207 172	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5 94 90 59 50 152 249 258 213 176	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92 61 50 154 264 262 225 185	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96 64 53 161 277 269 240 200	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 172 101 98 67 55 171 288 283 247 216	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 174 103 99 74 57 178 296 303 260 227	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103 76 62 187 313 315 281 246	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106 79 67 195 326 333 303 262
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68 67-68 65-66 63-64 61-62 59-60 57-58 55-56 53-54 51-52 49-50	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3 83 55 46 132 229 248 207 163 431 110	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3 26 88 56 49 139 241 252 207 172 459 114	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5 94 90 59 50 152 249 258 213 176 482 117	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92 61 50 154 264 262 225 185 508 120	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96 64 53 161 277 269 240 200 529 123	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 172 101 98 67 55 171 288 247 216 560 129	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 174 103 99 74 57 178 296 303 260 227 578 133	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103 76 62 187 313 315 281 246 612 142	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106 79 67 195 326 333 303 262 654 145
## Monitoring 49-50 51-52 53-54 55-56 57-58 59-60 61-62 63-64 65-66 67-68 67-68 65-66 63-64 61-62 59-60 57-58 55-56 53-54 51-52	428.6 344.3 317.3 306.2 323.2 263.4 242.5 194.2 228.4 225.3 83 55 46 132 229 248 207 163 431	450.8 353.5 335.1 316.2 332.3 278.0 250.7 198.6 234.3 26 88 56 49 139 241 252 207 172 459	467.7 367.6 347.3 326.6 346.4 288.0 259.2 212.4 276.5 94 90 59 50 152 249 258 213 176 482	23 484.8 382.9 362.7 336.1 364.7 293.8 265.8 215.2 93 98 92 61 50 154 264 262 225 185 508	24 501.5 400.0 362.8 346.1 380.7 292.9 279.7 199.8 166 100 96 64 53 161 277 269 240 200 529	25 524.3 417.5 375.9 357.3 387.1 296.2 287.6 172 101 98 67 55 171 288 283 247 216 560	26 553.0 422.3 395.1 370.3 399.2 300.6 329.2 174 103 99 74 57 178 296 303 260 227 578	568.8 431.9 414.4 375.6 408.4 296.0 255 231 179 106 103 76 62 187 313 315 281 246 612	586.9 432.8 422.1 387.9 430.4 309.2 548 238 183 111 106 79 67 195 326 333 303 262 654

TRIANGULAR PART) AND NUMBERS OF EMPLOYEES (LOWER TRIANGULAR PART) BY BY YEARS OF FOLLOW-UP TO 1986 FOR MALE SELLAFIELD RADIATION WORKERS EPISODE

Year of f	irst			Year	rs of i	follow-	-up			
monitorin		11	12	13	14	15	16	17	18	19
49-50	219.6	245.4	266.3	288.1	300.2	319.3	334.5	358.8	379.0	403.9
51-52	177.7	194.9	211.1	223.7	236.9	256.4	275.8	294.0	311.6	330.4
53-54									285.2	
55-56									282.8	
57-58									302.1	
59-60									247.1	
61-62									228.6	
63-64	93.9								180.5	
65-66									217.3	
67 - 68									213.2	
69-70								179.2		200:1
71-72			153.5						147.1	26
73-74			157.0				102.4	22	52	54
75 - 76			160.1		140.0	6	40	42	45	45
77 - 78	76.1		100.1	55	97	102	108	114	118	123
	70.1	i	1/2	154	166	176	184	188	201	221
E7 E0	107	69	143							
57 - 58	127 127	144	154	163	171	183	191	206	225	236
55 - 56		136	146	149	153	165	172	178	187	194
53-54	92	98	102	110	122	126	142	148	156	159
51-52	217	232	249	271	297	321	350	364	383	409
49-50	60	66	72	75	79	81	89	94	99	106
Years of	29	28	27	26	25	24	23	22	21	20
follow-up										
Year of f	irst			Years	of fo	llow-u	ρ			
Year of f monitorin		30	31	Years 32	of fo	llow-u _] 34	p 35	36	37	38
	g 29			32	33	34	35		37 750.7	
monitorin	g 29 622.0	631.5		32 666.5	33 673.0	34 685.7	35 704.0	721.3	750.7	
monitorin 49-50	g 29 622.0 437.3	631.5 443.1	665.3	32 666.5 443.1	33 673.0 427.8	34 685.7 463.2	35 704.0 483.9	721.3	750.7	
monitorin 49-50 51-52	g 29 622.0 437.3 425.8	631.5 443.1 440.5	665.3 444.5	32 666.5 443.1 462.1	33 673.0 427.8 466.9	34 685.7 463.2	35 704.0 483.9	721.3	750.7	750.0
monitorin 49-50 51-52 53-54	g 29 622.0 437.3 425.8 394.5	631.5 443.1 440.5	665.3 444.5 446.9 395.5	32 666.5 443.1 462.1	33 673.0 427.8 466.9	34 685.7 463.2	704.0 483.9	721.3 463.1	750.7 495	750.0
monitorin 49-50 51-52 53-54 55-56	g 29 622.0 437.3 425.8 394.5	631.5 443.1 440.5 393.8	665.3 444.5 446.9 395.5	32 666.5 443.1 462.1	33 673.0 427.8 466.9	34 685.7 463.2 472.3	704.0 483.9	721.3 463.1 539	750.7 495 609	750.0 1210 668
monitorin 49-50 51-52 53-54 55-56	g 29 622.0 437.3 425.8 394.5	631.5 443.1 440.5 393.8	665.3 444.5 446.9 395.5	32 666.5 443.1 462.1 365.0	33 673.0 427.8 466.9	34 685.7 463.2 472.3	35 704.0 483.9 213 449	721.3 463.1 539 537	750.7 495 609 690	750.0 1210 668 798
49-50 51-52 53-54 55-56 57-58	g 29 622.0 437.3 425.8 394.5 443.0	631.5 443.1 440.5 393.8 460.0	665.3 444.5 446.9 395.5	32 666.5 443.1 462.1 365.0	33 673.0 427.8 466.9 208 868	34 685.7 463.2 472.3 408 900	35 704.0 483.9 213 449 944	721.3 463.1 539 537 1011	750.7 495 609 690 1090	750.0 1210 668 798 1191
monitorin 49-50 51-52 53-54 55-56 57-58	g 29 622.0 437.3 425.8 394.5 443.0	631.5 443.1 440.5 393.8 460.0	665.3 444.5 446.9 395.5 389 785	32 666.5 443.1 462.1 365.0 815 814	33 673.0 427.8 466.9 208 868 850	34 685.7 463.2 472.3 408 900 891	35 704.0 483.9 213 449 944 937	721.3 463.1 539 537 1011 1032	750.7 495 609 690 1090 1185	750.0 1210 668 798 1191 1387
## Monitorin 49-50 51-52 53-54 55-56 57-58 77-78 75-76	g 29 622.0 437.3 425.8 394.5 443.0 322 562	631.5 443.1 440.5 393.8 460.0	665.3 444.5 446.9 395.5 389 785 599	32 666.5 443.1 462.1 365.0 815 814 607	33 673.0 427.8 466.9 208 868 850 643	34 685.7 463.2 472.3 408 900 891 720	35 704.0 483.9 213 449 944 937 817	721.3 463.1 539 537 1011 1032 935	750.7 495 609 690 1090 1185 1083	750.0 1210 668 798 1191 1387 1248
## Monitorin 49-50 51-52 53-54 55-56 57-58 77-78 75-76 73-74	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246	631.5 443.1 440.5 393.8 460.0 757 581 254	665.3 444.5 446.9 395.5 389 785 599 265	32 666.5 443.1 462.1 365.0 815 814 607 282	33 673.0 427.8 466.9 208 868 850 643 311	34 685.7 463.2 472.3 408 900 891 720 340	35 704.0 483.9 213 449 944 937 817 371	721.3 463.1 539 537 1011 1032 935 399	750.7 495 609 690 1090 1185 1083 466	750.0 1210 668 798 1191 1387 1248 549
monitorin 49-50 51-52 53-54 55-56 57-58 77-78 75-76 73-74 71-72	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186	631.5 443.1 440.5 393.8 460.0 757 581 254 197	665.3 444.5 446.9 395.5 389 785 599 265 207	32 666.5 443.1 462.1 365.0 815 814 607 282 220	33 673.0 427.8 466.9 208 868 850 643 311 234 174	34 685.7 463.2 472.3 408 900 891 720 340 247	35 704.0 483.9 213 449 944 937 817 371 277	721.3 463.1 539 537 1011 1032 935 399 318 232	750.7 495 609 690 1090 1185 1083 466 368 282	750.0 1210 668 798 1191 1387 1248 549 438 343
## Monitorin 49-50 51-52 53-54 55-56 57-58 77-78 75-76 73-74 71-72 69-70	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186 126	631.5 443.1 440.5 393.8 460.0 757 581 254 197 135 110	665.3 444.5 446.9 395.5 389 785 599 265 207 154	32 666.5 443.1 462.1 365.0 815 814 607 282 220 158 139	33 673.0 427.8 466.9 208 868 850 643 311 234 174 151	34 685.7 463.2 472.3 408 900 891 720 340 247 195 157	35 704.0 483.9 213 449 944 937 817 371 277 214 176	721.3 463.1 539 537 1011 1032 935 399 318 232 213	750.7 495 609 690 1090 1185 1083 466 368 282 242	750.0 1210 668 798 1191 1387 1248 549 438 343 294
77-78 75-76 71-72 69-70 67-68 65-66	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186 126 108 83	631.5 443.1 440.5 393.8 460.0 757 581 254 197 135 110 88	665.3 444.5 446.9 395.5 389 785 599 265 207 154 119 96	32 666.5 443.1 462.1 365.0 815 814 607 282 220 158 139 105	33 673.0 427.8 466.9 208 868 850 643 311 234 174 151 112	34 685.7 463.2 472.3 408 900 891 720 340 247 195 157 125	35 704.0 483.9 213 449 944 937 817 371 277 214 176 143	721.3 463.1 539 537 1011 1032 935 399 318 232 213 180	750.7 495 609 690 1090 1185 1083 466 368 282 242 223	750.0 1210 668 798 1191 1387 1248 549 438 343 294 299
77-78 75-76 73-74 71-72 69-70 67-68 65-66 63-64	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186 126 108 83 73	631.5 443.1 440.5 393.8 460.0 757 581 254 197 135 110 88 76	665.3 444.5 446.9 395.5 389 785 599 265 207 154 119 96 81	32 666.5 443.1 462.1 365.0 815 814 607 282 220 158 139 105 89	33 673.0 427.8 466.9 208 868 850 643 311 234 174 151 112 98	34 685.7 463.2 472.3 408 900 891 720 340 247 195 157 125	35 704.0 483.9 213 449 944 937 817 371 277 214 176 143 134	721.3 463.1 539 537 1011 1032 935 399 318 232 213 180 173	750.7 495 609 690 1090 1185 1083 466 368 282 242 223 208	750.0 1210 668 798 1191 1387 1248 549 438 343 294 299 259
77-78 75-76 73-74 71-72 69-70 67-68 65-66 63-64 61-62	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186 126 108 83 73 210	631.5 443.1 440.5 393.8 460.0 757 581 254 197 135 110 88 76 223	665.3 444.5 446.9 395.5 389 785 599 265 207 154 119 96 81 238	32 666.5 443.1 462.1 365.0 815 814 607 282 220 158 139 105 89 256	33 673.0 427.8 466.9 208 868 850 643 311 234 174 151 112 98 303	34 685.7 463.2 472.3 408 900 891 720 340 247 195 157 125 105 379	35 704.0 483.9 213 449 944 937 817 371 277 214 176 143 134 443	721.3 463.1 539 537 1011 1032 935 399 318 232 213 180 173 537	750.7 495 609 690 1090 1185 1083 466 368 282 242 223 208 660	750.0 1210 668 798 1191 1387 1248 549 438 343 294 299 259 842
77-78 75-76 73-74 71-72 69-70 67-68 65-66 63-64 61-62 59-60	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186 126 108 83 73 210 337	631.5 443.1 440.5 393.8 460.0 757 581 254 197 135 110 88 76 223 361	665.3 444.5 446.9 395.5 389 785 599 265 207 154 119 96 81 238 403	32 666.5 443.1 462.1 365.0 815 814 607 282 220 158 139 105 89 256 465	33 673.0 427.8 466.9 208 868 850 643 311 234 174 151 112 98 303 534	34 685.7 463.2 472.3 408 900 891 720 340 247 195 157 125 105 379 618	35 704.0 483.9 213 449 944 937 817 371 277 214 176 143 134 443 717	721.3 463.1 539 537 1011 1032 935 399 318 232 213 180 173 537 851	750.7 495 609 690 1090 1185 1083 466 368 282 242 223 208 660 1052	750.0 1210 668 798 1191 1387 1248 549 438 343 294 299 259 842 1189
77-78 75-76 73-74 71-72 69-70 67-68 65-66 63-64 61-62 59-60 57-58	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186 126 108 83 73 210 337 365	631.5 443.1 440.5 393.8 460.0 757 581 254 197 135 110 88 76 223 361 414	665.3 444.5 446.9 395.5 389 785 599 265 207 154 119 96 81 238 403 467	32 666.5 443.1 462.1 365.0 815 814 607 282 220 158 139 105 89 256 465 505	33 673.0 427.8 466.9 208 868 850 643 311 234 174 151 112 98 303 534 559	34 685.7 463.2 472.3 408 900 891 720 340 247 195 157 125 105 379 618 627	35 704.0 483.9 213 449 944 937 817 371 277 214 176 143 134 443 717 737	721.3 463.1 539 537 1011 1032 935 399 318 232 213 180 173 537 851 804	750.7 495 609 690 1090 1185 1083 466 368 282 242 223 208 660 1052 893	750.0 1210 668 798 1191 1387 1248 549 438 343 294 299 259 842 1189 995
77-78 75-76 73-74 71-72 69-70 67-68 65-66 63-64 61-62 59-60 57-58 55-56	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186 126 108 83 73 210 337 365 329	631.5 443.1 440.5 393.8 460.0 757 581 254 197 135 110 88 76 223 361 414 353	665.3 444.5 446.9 395.5 389 785 599 265 207 154 119 96 81 238 403 467 380	32 666.5 443.1 462.1 365.0 815 814 607 282 220 158 139 105 89 256 465 505 404	33 673.0 427.8 466.9 208 868 850 643 311 234 174 151 112 98 303 534 559 441	34 685.7 463.2 472.3 408 900 891 720 340 247 195 157 125 105 379 618 627 478	35 704.0 483.9 213 449 944 937 817 277 214 176 143 134 443 717 737 514	721.3 463.1 539 537 1011 1032 935 399 318 232 213 180 173 537 851 804 586	750.7 495 609 690 1090 1185 1083 466 368 282 242 223 208 660 1052 893 700	750.0 1210 668 798 1191 1387 1248 549 438 343 294 299 259 842 1189 995 768
77-78 75-76 73-74 71-72 69-70 67-68 65-66 63-64 61-62 59-60 57-58 55-56 53-54	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186 126 108 83 73 210 337 365 329 280	631.5 443.1 440.5 393.8 460.0 757 581 254 197 135 110 88 76 223 361 414 353 290	665.3 444.5 446.9 395.5 389 785 599 265 207 154 119 96 81 238 403 467 380 301	32 666.5 443.1 462.1 365.0 815 814 607 282 220 158 139 105 89 256 465 505 404 314	33 673.0 427.8 466.9 208 868 850 643 311 234 174 151 112 98 303 534 559 441 337	34 685.7 463.2 472.3 408 900 891 720 340 247 195 157 125 105 379 618 627 478 375	35 704.0 483.9 213 449 944 937 817 277 214 176 143 134 443 717 737 514 416	721.3 463.1 539 537 1011 1032 935 399 318 232 213 180 173 537 851 804 586 496	750.7 495 609 690 1090 1185 1083 466 368 282 242 223 208 660 1052 893 700 635	750.0 1210 668 798 1191 1387 1248 549 438 343 294 299 259 842 1189 995 768 731
77-78 75-76 73-74 71-72 69-70 67-68 65-66 63-64 61-62 59-60 57-58 55-56	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186 126 108 83 73 210 337 365 329	631.5 443.1 440.5 393.8 460.0 757 581 254 197 135 110 88 76 223 361 414 353	665.3 444.5 446.9 395.5 389 785 599 265 207 154 119 96 81 238 403 467 380	32 666.5 443.1 462.1 365.0 815 814 607 282 220 158 139 105 89 256 465 505 404	33 673.0 427.8 466.9 208 868 850 643 311 234 174 151 112 98 303 534 559 441	34 685.7 463.2 472.3 408 900 891 720 340 247 195 157 125 105 379 618 627 478 375 1014	35 704.0 483.9 213 449 944 937 817 277 214 176 143 134 443 717 737 514	721.3 463.1 539 537 1011 1032 935 399 318 232 213 180 173 537 851 804 586	750.7 495 609 690 1090 1185 1083 466 368 282 242 223 208 660 1052 893 700	750.0 1210 668 798 1191 1387 1248 549 438 343 294 299 259 842 1189 995 768 731 1610
monitorin 49-50 51-52 53-54 55-56 57-58 77-78 75-76 73-74 71-72 69-70 67-68 65-66 63-64 61-62 59-60 57-58 55-56 53-54 51-52 49-50	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186 126 108 83 73 210 337 365 329 280 687 151	631.5 443.1 440.5 393.8 460.0 757 581 254 197 135 110 88 76 223 361 414 353 290 719 159	665.3 444.5 446.9 395.5 389 785 599 265 207 154 119 96 81 238 403 467 380 301 756 167	32 666.5 443.1 462.1 365.0 815 814 607 282 220 158 139 105 89 256 465 505 404 314 799 185	33 673.0 427.8 466.9 208 868 850 643 311 234 174 151 112 98 303 534 559 441 337 876 223	34 685.7 463.2 472.3 408 900 891 720 340 247 195 157 125 105 379 618 627 478 375 1014 254	35 704.0 483.9 213 449 944 937 817 371 277 214 176 143 134 443 717 737 514 416 1164 279	721.3 463.1 539 537 1011 1032 935 399 318 232 213 180 173 537 851 851 804 586 496 1319 307	750.7 495 609 690 1090 1185 1083 466 368 282 242 223 208 660 1052 893 700 635 1478 336	750.0 1210 668 798 1191 1387 1248 549 438 343 294 299 259 842 1189 995 768 731 1610 363
monitorin 49-50 51-52 53-54 55-56 57-58 77-78 75-76 73-74 71-72 69-70 67-68 65-66 63-64 61-62 59-60 57-58 55-56 53-54 51-52	g 29 622.0 437.3 425.8 394.5 443.0 322 562 246 186 126 108 83 73 210 337 365 329 280 687 151	631.5 443.1 440.5 393.8 460.0 757 581 254 197 135 110 88 76 223 361 414 353 290 719	665.3 444.5 446.9 395.5 389 785 599 265 207 154 119 96 81 238 403 467 380 301 756	32 666.5 443.1 462.1 365.0 815 814 607 282 220 158 139 105 89 256 465 505 404 314 799	33 673.0 427.8 466.9 208 868 850 643 311 234 174 151 112 98 303 534 559 441 337 876	34 685.7 463.2 472.3 408 900 891 720 340 247 195 157 125 105 379 618 627 478 375 1014	35 704.0 483.9 213 449 944 937 817 277 214 176 143 134 443 717 737 514 416 1164	721.3 463.1 539 537 1011 1032 935 399 318 232 213 180 173 537 851 804 586 496 1319	750.7 495 609 690 1090 1185 1083 466 368 282 242 223 208 660 1052 893 700 635 1478	750.0 1210 668 798 1191 1387 1248 549 438 343 294 299 259 842 1189 995 768 731 1610

The distribution of average cumulative whole body annual recorded doses for these male Sellafield employees (all ages) is given in the table. The upper triangular part of the table gives the average cumulative dose by successive pairs of calendar years of first year of monitoring and for successive years of follow-up through to 1986. The lower triangular part of the table gives the respective numbers of workers.

Comparison of the average doses in the first year of follow up for these cohorts with those of figure 3 of [1], shows that the average dose patterns are similar when it is noted that a worker will not normally contribute a full year of dose during his first year of employment.

Examination of the pattern of average cumulative dose for each successive pairs of years of first monitoring suggests an initially constant annual rate of accumulation of dose, with this rate reducing in later years of follow up. This dose accumulation rate is higher in earlier cohorts. An examination of the data for those workers continuously employed through to 1985 (eg. 20 for the 1949-50 cohort, 94 for the 1969-70 cohort, etc) supports this notion of a genuine reduction in individual average annual dose with increasing length of follow up.

CONCLUSIONS

This preliminary analysis draws out some features of these data, but further work is needed to better understand these data, particularly with respect to age at exposure and occupation. These results are consistent with a reduction in annual external whole body doses received by Sellafield workers over the follow up period.

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