

TEN YEARS EXPERIENCE OF OCCUPATIONAL EXPOSURE AT SWEDISH LWRs

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1 INTRODUCTION

The Swedish light-water reactor (LWR) program contains twelve units, see Table 1, distributed on four coast-situated sites. Up to 1983, ten of them have been in production and during 1982 not less than 39 per cent of the electrical energy produced in Sweden originated from the LWRs.

To follow the occupational exposure, each power station performs its own dosimetry service. All the nuclear power stations use the same type of thermoluminescent dosimeters and registered doses are transferred and kept in one joint central dose register for the industry. Furthermore, all the stations are equipped with whole-body counters for internal contamination measurements. The experience is, however, that the dose-equivalents from internal contamination have been insignificant compared with the dose-equivalents from external exposure.

2 COLLECTIVE DOSE-EQUIVALENT DISTRIBUTIONS

Figure 1 shows that since 1977, with 6 or more units in operation, the annual collective doses have been in the interval 8 to 13 manSv. The distributions of the annual collective doses have been such that the contractors' personnel on average received about 75 per cent of these doses.

The major portions of the radiation exposure have occurred, as was expected, during the annual routine outage periods and have then mostly amounted to from 70 to 80 per cent of the annual collective dose-equivalents.

On average, as can be seen in Table 2, the annual collective dose-equivalents per unit have been below 2 manSv.

In comparison with internationally accepted recommendations for the limitation of exposures to the individual, there are no recommendations or guidelines to restrict the occupational collective dose-equivalents for different practices. To establish a tentative guideline for such a restriction of the occupational exposure at the Swedish LWRs, the National Institute of Radiation Protection have suggested 2 mmanSv per installed MW electrical capacity and year as a level of ambition to which the

TABLE 1 SWEDISH LWRs PROGRAM

Station unit and type	Electric power (MW _e)	First start-up
Barsebeck		
B1 BWR	570	1975
B2 BWR	570	1977
Forsmark		
F1 BWR	900	1980
F2 BWR	900	1980
F3 BWR	1060	1984
Oskarshamn		
O1 BWR	440	1971
O2 BWR	570	1974
O3 BWR	1060	1985
Ringhals		
R1 BWR	750	1974
R2 PWR	800	1974
R3 PWR	915	1980 a)
R4 PWR	915	1982 b)

Not in production before a) 1981, b) 1983

BWR-Boiling Water Reactor
PWR-Pressurized Water Reactor

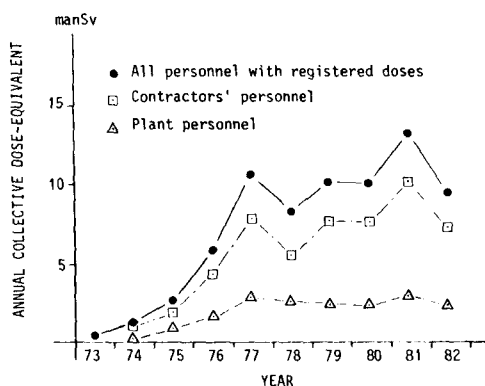


Figure 1. Annual collective dose-equivalents for the Swedish LWRs, total and divided between plant personnel and contractors' personnel, 1973-1982

collective dose-equivalent on average ought to be limited. As can be seen from Table 2, column 5, this value has been exceeded for some individual years, but not for the time period as a whole. The collective doses per unit energy generated, column 4, have been in the range 2-6 mmanSv per MW(e)·a, which is below reported values for most countries with LWRs. Among these countries, the United States have reported average values in the range 8-25 mmanSv per MW(e)·a.

TABLE 2 ANNUAL NORMALIZED COLLECTIVE DOSES
AT SWEDISH LWRs

Year	Number of reactors	Average manSv per unit	a) mmanSv per MW(e)·a	b) mmanSv per MW(e) and year
1973	1	0.30	1.3	0.7
1974	4 c)	0.35	6.3	0.5
1975	5	0.53	2.0	0.9
1976	5	1.18	3.4	1.9
1977	6	1.77	4.9	2.9
1978	6	1.37	3.2	2.2
1979	6	1.69	4.2	2.7
1980	7	1.43	3.5	2.2
1981	9	1.46	3.2	2.1
1982	9	1.06	2.3	1.5

Collective dose-equivalent per unit:

a) energy generated,

b) installed capacity and year

c) Units O2, R1 and R2 were commissioned during
the last three months of 1974

3 INDIVIDUAL DOSE-EQUIVALENT DISTRIBUTIONS

In Figure 2, the individual annual dose-equivalent distributions for workers at Swedish LWRs are shown for the years 1981 and 1982. These graphs, which can be regarded as representative for the whole period of time considered, show that about 85 per cent of the workers received an annual individual dose of less than one tenth of the 50 mSv annual dose limit and that on average only about 3 per cent of the exposed workers each year received annual doses above 15 mSv. As can be seen from Figure 3, the number of contractors' personnel has been three times the number of plant personnel. However, the annual average doses

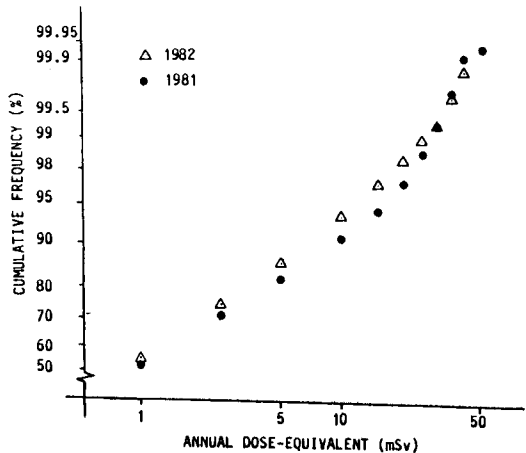


Figure 2. Log-probability plot of annual dose-equivalents to workers at Swedish LWRs for 1981 and 1982.

since 1975 have been in the range 2.3-3.3 mSv for both these groups.

Some attempts have also been made to divide up the collective dose-equivalents between occupational groups. The figures in Table 3 can, with the exception of those for the Insulation Personnel, be regarded as representative for the last six years.

The group Mechanical Repair Personnel, which have received about half the collective dose, contains smaller sub-groups such as steam generator workers and specialists performing control rod drive service and these sub-groups have received higher average doses than the total for the whole group.

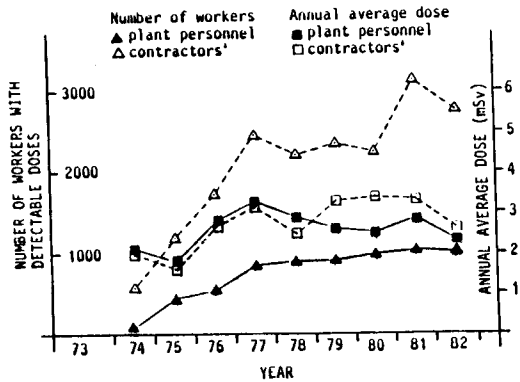


Figure 3. The number of workers with detectable doses and the annual average dose-equivalents for plant personnel and contractors' personnel at Swedish LWRs, 1974-1982.

TABLE 3 DOSE DISTRIBUTIONS FOR OCCUPATIONAL GROUPS AT SWEDISH LWRs 1982

Occupational group	Number 1) of persons	Proportion of total collective dose (%)	Average dose (mSv)	DRT 2)
Health physicists	131	8.3	6.0	1.9
Service personnel	578	11.7	1.9	0.9
Insulation personnel	138	6.4	4.4	0.4
Material testers	186	3.6	1.8	0.6
Operations personnel	483	6.5	1.3	0
Mechanical repair personnel	1323	53.1	3.8	1.9
Electrical and instrument technicians	413	6.1	1.4	0
Chemists	57	0.5	0.9	0
Others	457	3.8	0.8	0
Totals:	3766	100.0	2.5	1.3

1) Number of persons with detectable doses

2) DRT=Distribution Ratio Term, is the ratio of the fraction of the collective dose above 15 mSv for the observed group to the same fraction for the reference distribution defined in the 1982 UNSCEAR report, normalized to one for the reference distribution.

4 PREDICTION OF LIFETIME DOSE-EQUIVALENTS

An attempt to predict the lifetime dose-equivalents for workers who have received the highest individual doses at the LWRs during 1975-1982 is summarized in Table 4. The dose data are taken from the central dose register, which at the end of 1982 contained 10 037 workers with detected doses during that period. However, it should be noted that this prediction only includes those workers who received accumulated dose-equivalents of at least 50 mSv during the years 1975-1982 with the received dose distributed over 5 or more years during this period. This means that registered dose-equivalents to 158 individuals or about 1.5 per cent of all workers with registered doses have been considered. Excluded from this prediction were 47 individuals who have registered dose-equivalents exceeding 50 mSv for the period considered, but with the dose accumulation time less than 5 years. Of these 47 individuals four were Health Physicists, 30 Mechanical Workers, eight Service Personnel and five Insulation Personnel. To calculate the cumulative lifetime dose-equivalents the following mathematical extrapolation formula has been used:

$$H_{40} = \frac{40}{n} \sum_{i=1}^n \bar{H}_i$$

\bar{H}_i = average annual dose-equivalent for each of the
 n years for which doses were registered
 H_{40} = predicted dose-equivalent for a 40-year
 employment period

TABLE 4 PREDICTED LIFETIME DOSE-EQUIVALENTS FOR THE MOST EXPOSED WORKERS IN VARIOUS OCCUPATIONAL GROUPS

Occupational group	Number in the group	Dose-equivalents predicted over 40 years (Sv)			
		Average H_{40}	Maximum H_{40}	Median H_{40}	75-procentile H_{40}
Health physicists	23 (171) ¹⁾	0.58	1.00	0.53	0.70
Mechanical workers	105(4628)	0.48	1.02	0.45	0.55
Service personnel	5(1126)	0.63	0.80	0.68	-
Insulation personnel	8 (302)	0.55	1.24	0.46	-
Operation personnel	4 (787)	0.42	0.52	-	-
Material testers	3 (409)	0.42	0.51	-	-
Electrical and instrument technicians	5 (961)	0.32	0.35	0.33	-
Others	5(1653)	0.46	0.71	0.50	-

1) Number of workers with registered doses within the group.

As can be seen in Table 4, the predicted lifetime dose-equivalents on average range from 0.32 to 0.63 Sv and with a highest value of 1.24 Sv for the group Insulation Personnel. Of the groups Health Physicists and Mechanical Workers about 32 individuals, which corresponds to about 0.3 per cent of all workers with registered doses, have predicted lifetime dose-equivalents of 0.55 Sv or more.

The use of 40 years as an extrapolation time means that the lifetime dose-equivalents so predicted can probably be regarded as conservative values corresponding to the circumstances at present prevailing at the Swedish LWRs.