General Distribution

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ISOE INFORMATION SHEET

ANNUAL INDIVIDUAL DOSES DISTRIBUTIONS: DATA AVAILABLE AND STATISTICAL BIASES

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This information sheet is not a report; its aim is only to provide readers with some remarks concerning individual doses distributions.

When speaking of individual doses distribution, one has to keep in mind that different types of information are available, from the doses distribution at the level of a job to the actual annual doses distribution corresponding to individuals.

The individual doses distribution at the level of a specific job is often characterised by the average, maximum and minimum individual doses (source: NEA 3 reports, literature, …). Together with the collective dose and the number of workers involved, individual doses distribution is a good indicator of the radiological risk corresponding to the job and a criterion for the decision of implementing radiological protection actions.

The actual annual distribution of individual doses allows the assessment of the annual radiological risk among individuals in different countries and to check the situation with regards to the dose limit. These data are usually provided by the National Authorities statistics based upon legal dosimetry (for the residents in the country).

Other types of individual doses distributions correspond either to Nuclear Power Plants (NPP) outages (source: outage reports), or to the annual individual doses distribution at the plant level (source: NEA 1 Questionnaire).

1. Knowing individual doses distributions at the level of NPP, is it possible to obtain the annual individual doses distribution at the level of a country?

A distribution of annual external doses is reported by utilities in the NEA1 questionnaire. This information is usually available at the site level. It is not possible to sum these annual doses distributions reported by the sites in order to obtain distribution for a country because a significant number of workers work at more than one site during a year. These workers are called transient workers. Statistical biases corresponding to the way they are taken into account will be first illustrated for two countries: the United States of America and France.

These two countries are characterised by the existence of a national computerised database system allowing the aggregation of individual occupational exposures of any worker working at more than one site.

These computerised databases are respectively:
- in the USA, the computerised Radiation Exposure Information Reporting System (REIRS). The US Nuclear Regulatory Commission (NRC) requires licensees to submit annually individual radiation exposure records under 10 CFR 2.2206 (Form 5) for each individual (utility employee and contractor personnel) working at US NPPs. All the information is manually coded and entered into REIRS.
- in France, the computerised system called DOSINAT (national dosimetry). This system, developed by the French utility EDF, fully automated and directly connected to the site computerised system, collects doses received by each worker (EDF employee or contractor) at all French NPPs[1].

The analyse of these two databases show that the summation of annual doses distributions reported by each nuclear power plants will result in:

· an overestimation of the total number of exposed workers at the national level and correlatively an underestimation of the average annual individual dose, due to the multiple reporting of individuals.

· an important underestimation of the frequencies of individuals belonging to high dose intervals.

1.1. *First bias: overestimation of the total number of workers at the national level*

Table 1 presents the annual external individual doses distribution in the United States of America in 1995 corresponding to the summation of annual doses distribution of all NPP sites and the corrected annual doses distribution taking care of multiple reporting of transient workers. Table 2 gives the same type of information for France.

The overestimation of the total number of exposed workers due to the existence of multiple reporting for transient workers represents about one fourth of the total number of workers with measurable dose (24% in the USA and 26% in France). This overestimation leads to a correlative underestimation of the annual average dose.

[1] : *In France, EDF is the one and unique utility which operates nuclear power plants.*

Table 1. Impact of multiple reporting for transient workers: the case of the United States of America in 1995

Dose Interval (mSv)	Summation of annual individual doses distributions of all NPP sites *number of individuals*	Annual individual doses distribution corrected to take care of multiple reporting *number of individuals*
No measurable exposure	81 032	62 080
< 1	38 575	29 681
1 - 2.5	20 245	15 152
2.5 - 5	15 279	12 083
5 - 7.5	6 884	6 146
7.5 - 10	3 336	3 306
10 - 20	3 077	3 905
20 - 30	125	590
30 - 40	5	121
40 - 50	0	2
> 50	0	0
Total	168 558	133 066
Total with measurable dose	87 526	70 986

Source: US NRC computerised Radiation Exposure Information Reporting System (REIRS)

Table 2. Impact of multiple reporting for transient workers: the case of France in 1996

Dose Interval (mSv)	Summation of annual individual doses distributions of all NPP sites *number of individuals*	Annual individual doses distribution corrected to take care of multiple reporting *number of individuals*
0.01 - 0.5	18 933	13 662
0.51 - 1	6 302	2 873
1.01 - 2	10 160	3 130
2.01 - 5	10 720	4 357
5.01 - 10	2 738	2 992
10.01 - 15	557	1 278
15.01 - 20	130	705
20.01 - 30	90	526
30.01 - 40	9	53
> 40	0	2
Total	49 369	29 578

Source: DOSINAT (EDF)

1.2. *Second bias: underestimation of the frequencies of individuals belonging to high dose intervals*

Figures 1 and 2 illustrate, for doses greater than 10 mSv, 20 mSv and 30 mSv, the gap between the number of workers as it would appear in a summation of the annual individual doses distribution submitted by each NPP site and the actual (corrected) number of workers - in the USA (Figure 1) and in France (Figure 2).

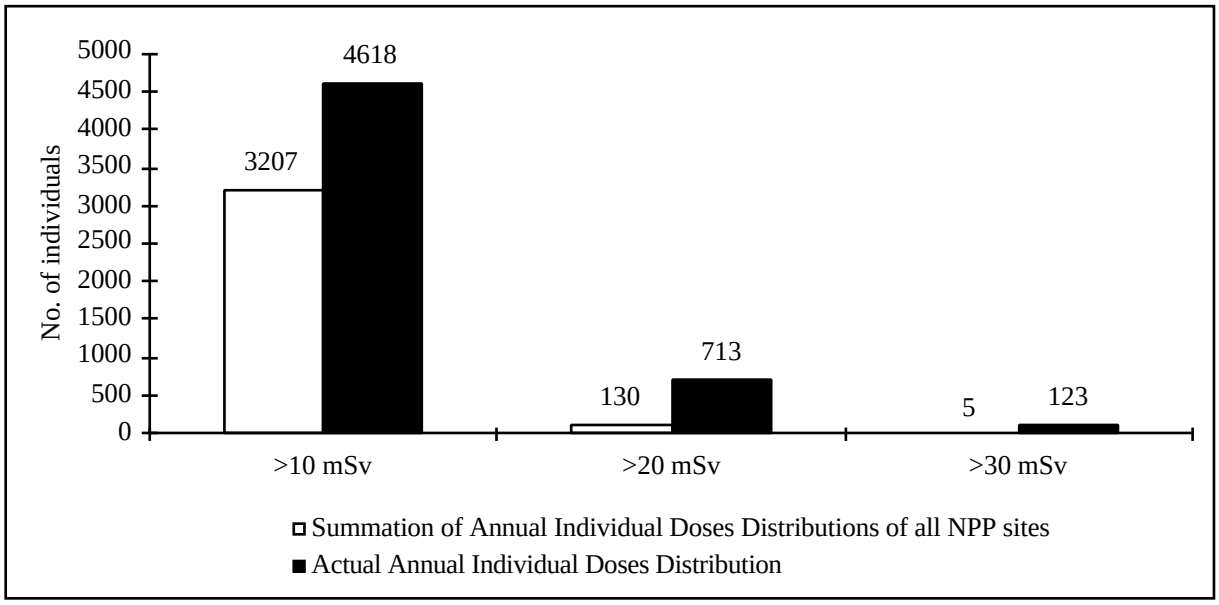

Figure 1. Number of workers who received doses greater than 10 mSv, 20 mSv and 30 mSv at US Nuclear Power Plants in 1995

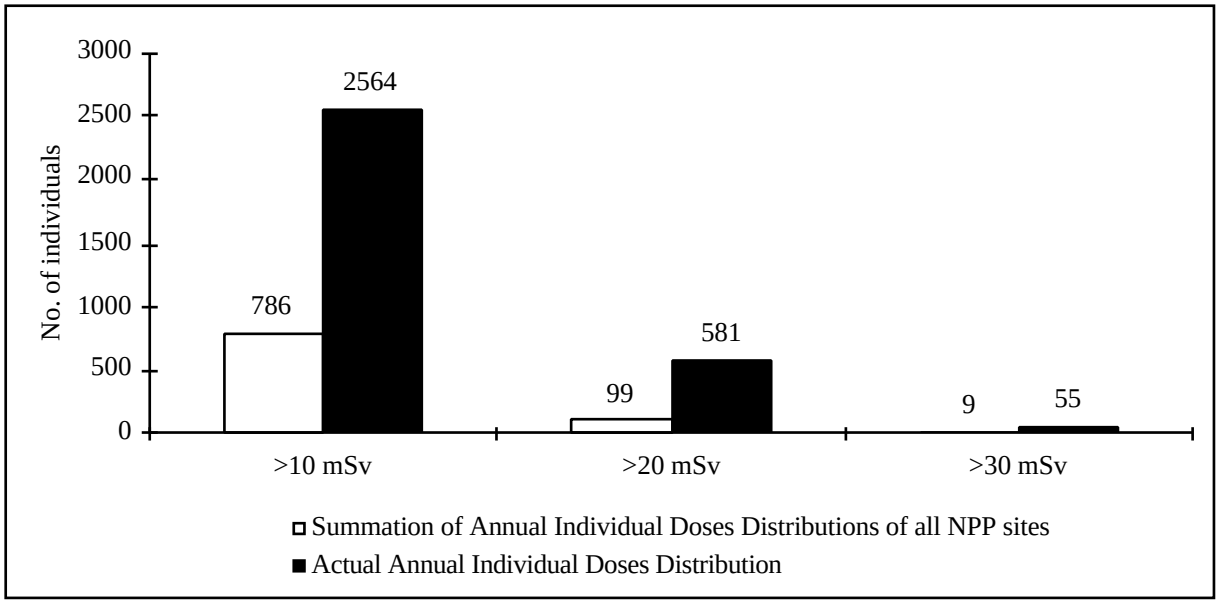

Figure 2. Number of workers who received doses greater than 10 mSv, 20 mSv and 30 mSv at French Nuclear Power Plants in 1996

The underestimation of the frequencies of individuals is obvious for these three categories of doses when using the sum of dose distributions available at NPP sites. **As far as the number of individual exceeding 20 mSv (ICRP 60 average annual dose on a five years basis) is concerned, the actual number is between 5 and 6 times higher than the one that should be obtained in summing NPP sites doses distributions for both countries**. It is therefore clear that the single summation of NPP sites dose distributions will give a totally distorted picture of the occupational exposure situation within a country.

1.3. *Biases concern mainly contractor personnel*

It should be expected that biases concern mainly contractors personnel as transient workers belong much more to these contractors than to utilities. This may be clearly demonstrated in France, where the information contained in DOSINAT allows to distinguish EDF personnel and contractors personnel (see Table 3). The overestimation of the number of contractor workers corresponds to a multiplication factor higher than 2 (35290 individuals instead of 17129). That means that in France the average number of sites where a contractor worker works is greater than 2 per year. This may be compared with the overestimation of EDF personnel which is about 15%.

Figure 3 presents the number of EDF and contractor personnel receiving doses greater than 10 mSv, 20 mSv and 30 mSv at French Nuclear Power Plants in 1996. As can be seen, the Figure shows that 573 individuals belonging to contractors actually received doses greater than 20 mSv in 1996 while the sum of NPP site statistics would have accounted only 93.

Table 3. Number of workers in various dose intervals for all French NPPs for the year 1996 by type of personnel

Dose Intervals (mSv)	EDF personnel		Contractor personnel	
	Summation of indiv. dose distributions of all NPP sites	Actual indiv. dose distribution taking care of multiple reporting	Summation of indiv. dose distributions of all NPP sites	Actual indiv. dose distribution taking care of multiple reporting
0.01 - 0.5	7 530	6 418	11 403	7 244
0.51 - 1	1 950	1 581	4 352	1 292
1.01 - 2	2 177	1 588	7 983	1 542
2.01 - 5	1 860	1 894	8 860	2 463
5.01 - 10	694	802	2 044	2 190
10.01 - 15	105	124	452	1 154
15.01 - 20	27	34	103	671
20.01 - 30	5	7	85	519
30.01 - 40	1	1	8	52
> 40	0	0	0	2
total	14 349	12 449	35 290	17 129

Source: DOSINAT (EDF)

Remark: France is characterised by the fact that there is only one utility with 55 units. Therefore in the other countries with several utilities owning each a few units, the transient workers belonging to utilities should be less numerous than in France and a summation of individual dose distribution of all plants for utilities workers should be a quite good indicator of national individual dose distribution for all workers belonging to utilities.

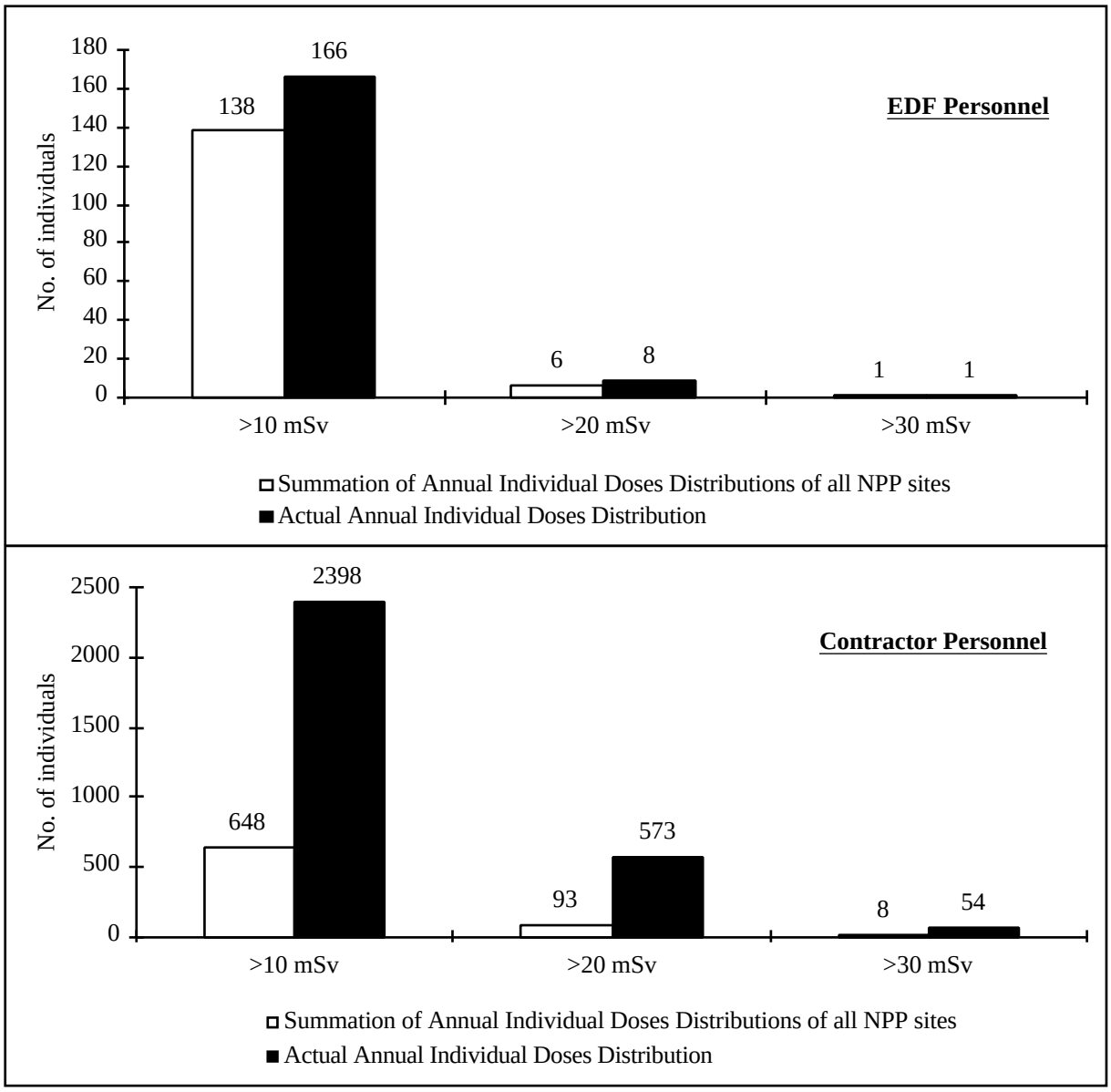

Figure 3. Number of EDF and contractor personnel receiving doses greater than 10 mSv, 20 mSv and 30 mSv at French Nuclear Power Plants in 1996

2. Statistics published at the national level

The above detailed analysis performed with French and American data showed that it is not possible to sum the annual external doses distributions reported by each site in order to obtain the annual external doses distribution for a country. This can be confirmed using Swedish data. Sweden has also a national computerised database allowing to avoid double counting of transient workers. SSI report for 1993 data shows that the overestimation of the number of workers followed up in Sweden should have been 15% in counting several times transient workers: 7589 instead of 6574; the gap corresponds essentially to contractor workers (about an extra of 1000 workers). So Swedish national statistics do not present any dose distribution at the level of the plants but only at a national level.

In order to obtain real annual individual doses distribution it is therefore necessary to produce them directly at a national level. This is generally performed by the National Authorities. This second chapter will briefly describe the situation in different countries, and describe some limits of such statistics. The authors do not pretend that the following description is exhaustive neither in terms of countries nor of data sources in different countries. Furthermore it may be pointed out that data analysed are already published, and that other data may be available but not published.

2.1 *Individual doses distribution published at the national level*

The Table 4 shows that the situation seems to be very different from one country to another. Some countries are still providing national statistics summing plant statistics, while others publish statistics coming from national databases. In a few countries national databases allow to distinguish utility and contractor personnels.

Table 4. National statistics published in some countries

Country	Data source	Individual doses distributions at NPP site level	Individual doses distribution at national level	
			summation of site distributions	actual doses distribution
France	EDF			U/C
Germany	BfS*			U
Japan	NUPEC	U/C	U/C	
United States of America	NRC	A		A
Spain	CSN			U/C
Sweden	SSI			A
Switzerland	HSK	U/C		U/C
United Kingdom	HSE/NRPB			A

**: on request*
U= individual doses distribution for utility personnel
C= individual doses distribution for contractor personnel
A= individual doses distribution with no breakdown between utility and contractor personnel

2.2 *Impact of international transient workers*

Due to the differences previously described, comparisons of statistics at an international level are not really obvious. Furthermore one has to keep in mind that some contractor personnel, especially "specialised workers", are going to work in neighbouring countries. As an example, Figure 4 shows the number of Finnish and Swedish workers working respectively in Swedish and Finnish nuclear power plants from 1992 to 1996. The number of these workers even if not so important is significant: for example, in 1993, 3 % of the workers at Swedish NPPs were coming from Finland. However, this figure should be more important when completed by the number of individuals coming from other countries such as Germany, France or even USA.

Nevertheless this problem is surely more important in countries where there is a small number of reactors than in USA, France or Japan. **It will only be solved with the creation of an international central dose register, at regional level (Europe, America…).**

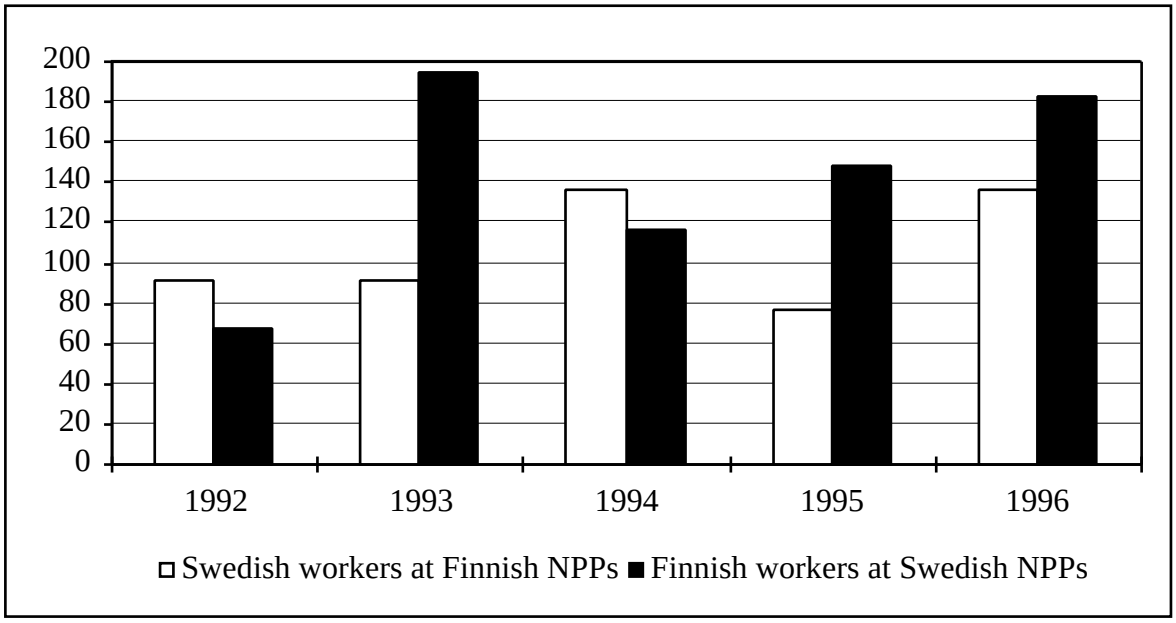

Figure 4. Numbers of Finnish and Swedish workers working respectively in Swedish and Finnish NPPs from 1992 to 1996
source: Central Dose Register in Finland

3. Some possible analyses with national data

The following tables show that national data on individual dose distributions are good index, complementary to the collective dose, to describe the trends in occupational exposure in each country. Moreover when data are available with the same level of details they also allow to describe differences between national contexts.

3.1 *Evolution of annual doses distributions for all NPP site workers in the USA and the UK*

In the USA (see Table 5), the total number of workers with measurable dose reached a maximum of 100 000 in 1989 and decreased after that to about 70 000. From 1977 to 1995, there has been a continuous improvement in the structure of the individual doses distribution: the number of individual exceeding 5 mSv going from more than 40% to less than 20%; the number of individual exceeding 20 mSv going from more than 10% to 1%. It is interesting to point out that since 1983 the total annual collective dose for operating reactors is decreasing in the USA (see ISOE Annual Reports), which **proves that it is possible to reduce both collective dose and highest individual doses without any increase of the total number of workers**.

In the UK the same type of evolution is noticeable. However the percentage of high doses is, by far, lower and the number of individuals exceeding 20 or even 10 mSv is now nil; while the number of individuals exceeding 5 mSv is now approximately 6%.

It is therefore obvious that the types of the operating reactors in a country, mainly GCR in the UK and LWR in USA, have an important impact not only on the collective doses but also on the individual dose distributions.

Table 5. Evolution of annual doses distribution for all NPP site workers in USA (1977 to 1995)

	No. of workers with measurable dose	> 5 mSv	> 10 mSv	> 20 mSv
1977	38 858	40.96%	27.81%	13.27%
1978	42 674	38.04%	25.54%	11.49%
1979	60 119	35.19%	21.79%	9.20%
1980	74 503	37.61%	24.58%	10.26%
1981	76 654	38.17%	24.43%	9.85%
1982	79 223	35.83%	22.38%	9.48%
1983	79 604	37.63%	24.91%	10.66%
1984	90 310	33.56%	21.23%	8.74%
1985	86 828	29.88%	17.02%	5.45%
1986	93 905	27.72%	15.25%	4.34%
1987	96 162	27.32%	13.88%	2.85%
1988	95 944	27.78%	13.85%	3.10%
1989	100 060	23.72%	10.65%	2.02%
1990	98 558	24.58%	10.90%	2.18%
1991	91 065	20.35%	7.85%	1.29%
1992	94 160	20.84%	7.41%	0.95%
1993	86 147	20.64%	6.98%	0.83%
1994	73 780	19.71%	6.14%	0.59%
1995	70 986	19.82%	6.51%	1.00%

Table 6. Evolution of annual doses distribution for all NPP site workers in the UK (1986 to 1994)

	No. of workers with measurable dose	> 5 mSv	> 10 mSv	> 20 mSv
1986	12 642	18.40%	8.80%	2.86%
1987	13 250	13.83%	6.88%	2.41%
1988	13 704	13.23%	5.87%	1.01%
1989	14 017	13.49%	5.85%	1.22%
1990	13 918	12.56%	4.72%	0.55%
1991	12 518	9.27%	1.37%	0.02%
1992	12 862	8.04%	0.85%	0.01%
1993	11 384	7.31%	0.56%	0.06%
1994	10 025	5.87%	0.21%	0.00%

3.2 *Comparison of annual individual dose distribution of utility personnel in France Spain and Germany in 1994*

In some countries (see Table 4) doses distributions allow to distinguish utility and contractor personnels. The comparison of individual doses distributions of utility personnel (Table 7) in three European countries show, that for these countries the figures are quite similar: **less than 1% of utility workers with measurable dose exceed 20 mSv and about 10% exceed 5 mSv.**

Table 7. Individual dose distribution of utility personnel in France Spain and Germany in 1994

Country	No. of workers with measurable dose	> 5 mSv	> 10 mSv	> 20 mSv
France	12175	9.63%	2.45%	0.16%
Germany	9968	12.87%	5.16%	0.92%
Spain	1145	9.17%	1.66%	0.44%

4. Conclusion

The analyses performed show that the summation of annual doses distributions reported by each nuclear power plants will result in:

- an overestimation of about one fourth (France and USA) of the total number of exposed workers at the national level and correlatively an underestimation of the average annual individual dose, due to the multiple reporting of individuals.
- an important underestimation of the frequencies of individuals belonging to high dose intervals. As far as the number of individual exceeding 20 mSv is concerned, the actual number is between 5 and 6 times higher than the one that should be obtained in summing NPP sites doses distributions for both countries.

It is therefore clear that the single summation of NPP sites doses distributions will give a totally distorted picture of the occupational exposure situation within a country. As expected these biases concern mainly contractors personnel as transient workers belong much more to these contractors than to utilities.

In order to perform analysis at a national level it is therefore necessary to use national statistics that take care of these biases. Most countries provide such statistics.

Another possible use of individual doses distributions should be comparisons between plants or jobs: problems to be solved in such cases as well as examples will be described in a later information sheet.