Introduction to occupational radiation exposure trends in Europe and problems to be solved

European Studies on Occupational Radiation Exposures - ESOREX

Gerhard Frasch, BfS, Germany

Karla Petrová, SÚJB, Czech Republic

Abstract

The ESOREX project was initiated in 1997 by the EC DG TREN and is executed by the BfS/Germany in close co-operation with the State Office for Nuclear Safety/Czech Republic). It consists of surveys carried out in the 30 European states. The study provides comparable descriptions of the national administrative structures used to monitor and register individual occupational radiation exposure and the national dose statistics. The analysis of time series about the occupational radiation exposure in different work sectors allows the evaluation of changes and trends after the transposure of the COUNCIL DIRECTIVE 96/29/EURATOM.

During 1996 and 2000 occupational radiation protection led to partly substantial dose reductions, primarily in the nuclear sector. General industry performs less successful in the reduction of radiation exposure. Work sectors with traditionally low doses like the medical sector or research and education reduced less but show that even at levels of low exposures there is still room for improvement.

Purpose and objectives of the ESOREX project

National monitoring of occupational radiation exposure in Europe faces several new challenges. Occupational radiation protection was considerably intensified as well as extended by the adoption of the new basic safety standards in the Council Directive 96/29 EURATOM. This resulted in a substantial reduction of the annual dose limit. Furthermore, natural radiation exposure at the work place is now considered as occupational radiation exposure and thus has to be regulated. The Council Directive is not only an obligation for the current EU-Member States but also for the assessed and future Member States. Therefore, all concerned European states have to take actions in order to implement the Council Directive into adequate national regulations.

The expanding common European Market with it's open borders leads to an increasing exchange of labour-force between Member States. The new dose limits must also be kept for migrating labour-force and outside workers. Therefore the updating of the individual dose history must likewise be guaranteed for transnational migrating outside-workers. These challenges meet with different national practices of occupational radiation monitoring. The European Commission has both to support the process of adaptation and to evaluate the effectiveness of the new Council Directive. It is the purpose of the ESOREX project to provide information and international transparency for these tasks. The acronym ESOREX stands for “European Studies of Occupational Radiation Exposure”. It was initiated and financed by the European Commission/DG TREN and contains data surveys and workshops.

ESOREX consists of several separated data survey projects: in 1997, the German Federal Office for Radiation Protection (BfS) started ESOREX West with data surveys executed in those former 15 Member States of the European Union plus Iceland, Norway and Switzerland. One year later the BfS continued these surveys with ESOREX East, focussing on ten central and eastern European countries, most of them are in the meanwhile members of the European Union. At that time, a very fruitful and effective co-operation started between the German BfS and the Czech State Office for Nuclear Safety (SUJB). Updates of these surveys were done under ESOREX 2000. The latest project, ESOREX 2005 is presently executed by both organisations and under the responsibility of the SONS. Presently ESOREX covers thirty European States. Each project contains always a qualitative information survey (Part I) and a quantitative data survey (Part II).

In part I, the structure of national systems applied to monitor and register individual occupational radiation exposures in each country are surveyed (legislative framework of occupational radiation protection (Acts, Ordinances, Guidelines) surveillance structures, administrative and scientific support dose quantities, dose levels , dose limits, monitoring of individual occupational exposure (external, internal, natural radiation), dosimetric services, accreditation, quality assurance, approved dosemeters, methods in internal dosimetry, dose reporting and information flow, central registration of radiation doses, registration of outside workers, radiation passbooks, medical surveillance. The survey results are presented in country specific files, following as much as possible the same structure.

The surveys of part II provide the data for a comparable overview over the present exposure situation of radiation workers in the European countries. In order to gain a maximum of comparability between the countries, a common structure of work sectors and subclasses has been derived from the classification systems used in every country[1]. On this base the total number of occupational radiation exposed persons and the distribution of doses in the shortest and best comparable dose bands, broken down by work sectors and its sub-classes are surveyed. Statistical parameters and collective doses are calculated for each country. It is the aim to cover a ten-years time series of the calendar years 1995 to 2004.

The purpose of ESOREX shall not only be data collection and analysis. We are ambitious to create a vital network between the persons and institutions responsible for the official monitoring of occupational radiation exposure in each European country. For that purpose, three common workshops had been held and an internet web-site with a discussion forum for rapid questioning and answering and for the collection of information was installed.

ALARA and the proof of evidence

The optimisation principles of ICRP focuses on the following reduction targets

- individual doses,
- likelihood of exposure,

- number of people exposed.

The reductions shall be achieved by following the ALARA-principle, i.e. on reasonable considerations by taking economical and social factors into account. It is plausible to concentrate on the above three targets when seeking optimisation. To evaluate optimisation achievements in e.g. a controlled area of a single site may be comparatively easy: more or less homogenous groups of radiation workers, standardised dose monitoring, exposure conditions that are good to describe, well measurable cost-benefit-relations (e.g. saved collective dose per monetary unit), etc.. Here, the difficulties are primarily to come to a rational choice between different optimisation options and interests. Therefore, ICRP offers here a series of decision aiding tools in its new recommendations.

In contrast, it is not trivial to prove evidence of optimisation from an international perspective. How is the ALARA-principle accepted in the different work sectors in Europe? To figure out where we are, what changes in occupational radiation exposure we have gained until now and if there is still room for improvement, we need to look at exposure statistics calculated from aggregated data of the official dose monitoring in the Member States. At this level we have to pay the price for aggregating data from various countries: workers categories that are less distinguished or comparable, dose monitoring standards vary as well as the dose recording and reporting practices. The likelihood of exposure for a group of workers (e.g. as the ratio of number of people exposed by number of people monitored) is very unsharp and may be more influenced by varying monitoring practices between the countries than by exposure conditions at the workplaces. In order to measure or better to describe optimisation with statistics it is necessary to provide a combined overview by defining and use several statistical parameters.

Reduction of the average dose

The average dose is a value easy to calculate and useful to give a first rough overview. The number of workers who are included in official dose monitoring differs considerably between the European countries. Some focus only on workers of category A, other countries, such as Germany, include also most of category B-workers. Therefore it is reasonable to calculate average dose not for all monitored workers, but only for those who received measurable doses.

Reduction of the collective dose

When analysing exposure changes it is insufficient to look only at the mean value. Changes of average doses are not only caused by changes of exposure, they may also result form changed monitoring practices, i.e. from changes in the number of monitored workers. Thus, it is wise to look also to changes of the collective doses.

Reduction of dose limit exceeds

Not all changes can be attributed solely to the ALARA-principle: the reduction of the dose limit from 50 mSv to 20 mSv by the Council Directive 96/29 EURATOM had lead in some work sectors to a decrease in the number of cases with exposures above the new threshold.

Shift of dose distributions

Normally, practical radiation protection concentrates primarily on workers with notoriously higher exposures than on those with small dose values. Therefore, a shift in the dose distribution towards smaller dose values can be expected.

Included in the analyses are those countries, which provide sufficiently detailed dose data in each work sector for the years 1996 to 2000. Most of the detailed work categories for which the countries provide annual dose distributions can be are clearly assigned to the respective work sector (e.g. NPP own staff, fuel enrichment to "nuclear sector", diagnostic radiology, nuclear medicine to "medical sector", radiochemical manufacture, industrial radiography to "general industry", higher education, radiation research to "research and education"). The situation is somewhat different in the new work sector "natural sources" and implies limitations of the interpretation of the results (see below). To provide a better overview only the data points of 1996, 1998, 2000 are presented.

Exposure trends in Europe

In year 2000 there were about 1 Mio. workers in Europe, classified as occupationally radiation exposed of category A or B and monitored. This does not mean that they were all de facto radiation exposed. Only about 35 % of all monitored workers received measurable doses. For these workers a collective dose of about 450 Person-Sv can be accumulated for the year 2000. The average annual dose of all measurably exposed workers in Europe was 1.3 mSv. But the values differ considerably between the various countries and the different work sectors.

Table 1: Dose monitoring and exposure statistics in different work sectors in Europe in 2000

	Nuclear sector	Medical sector	General industry	Research education	Natural sources	Total
Number of European countries with dose data	16	20	21	17	9	
Number of monitored workers	155.816	672.299	103.345	71.444	17.039	1.021.747
Mean annual dose of exposed workers [mSv]	1,5	0,9	1,8	0,7	3,0	1,3
Collective dose [Pers-Sv]	162,6	171,3	69,1	10,5	39,0	453,5
N of cases per 10,000 monitored workers with doses greater than 20mSv/a	101	208	95	5	88	497

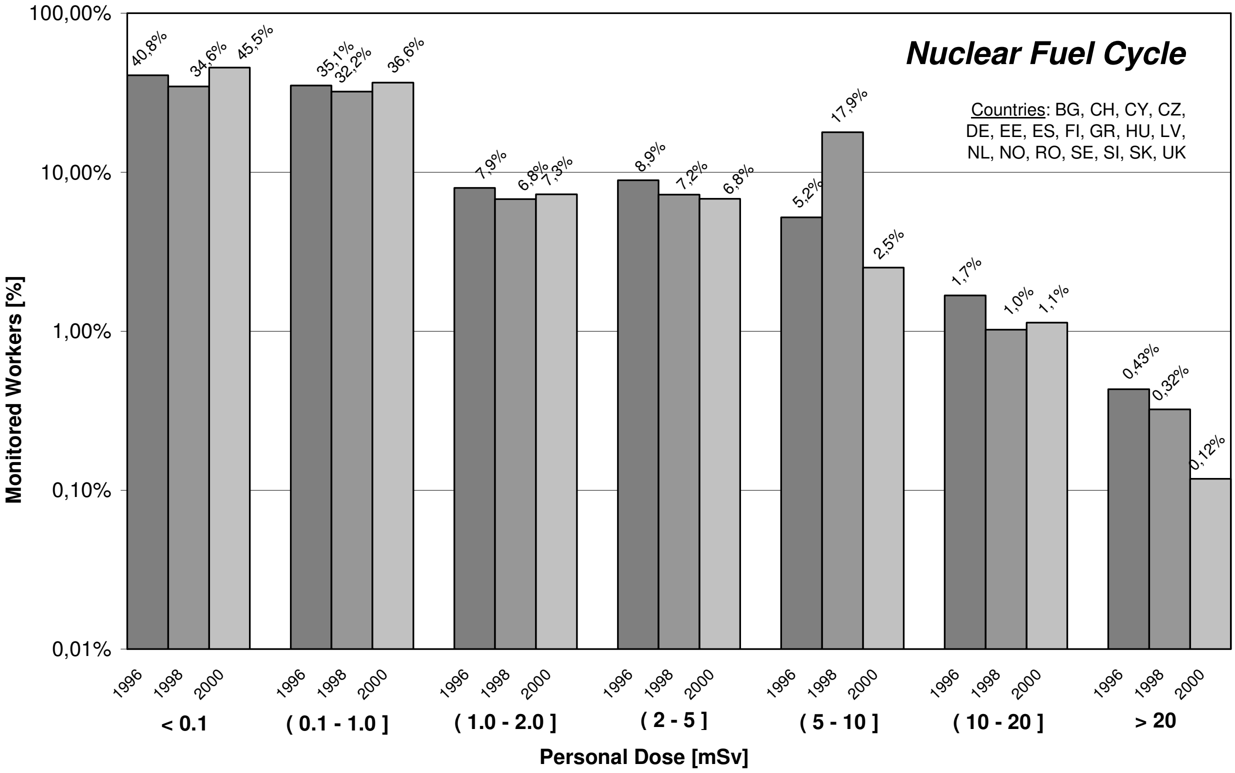
Nuclear fuel circle

Between 1996 and 2000 an overall reduction of radiation exposure in the nuclear work sector is evident. The average annual dose decreased from 2.2 mSv/a to 1.5 mSv/a and the collective dose was reduced in the same proportion to 163 person-Sv. The number of cases with annual doses higher than 20 mSv reduced from 40 to 11 per 10,000 monitored workers. The dose distributions show a left-shifted towards the smaller values.

Table 2: Dose trends in the nuclear fuel cycle in 16 European countries

Year Nuclear Fuel Cycle	1996	1998	2000
Mean annual dose of exposed workers [mSv]	2,23	1,82	1,51
Collective dose [Pers-Sv]	224,9	172,7	162,6
N of cases per 10,000 monitored workers with doses greater than 20mSv/a	40,3	34,3	11,3

Figure 1: Distribution of personal doses from occupational radiation exposure in Europe from 1996 – 2000 in work sector nuclear fuel cycle



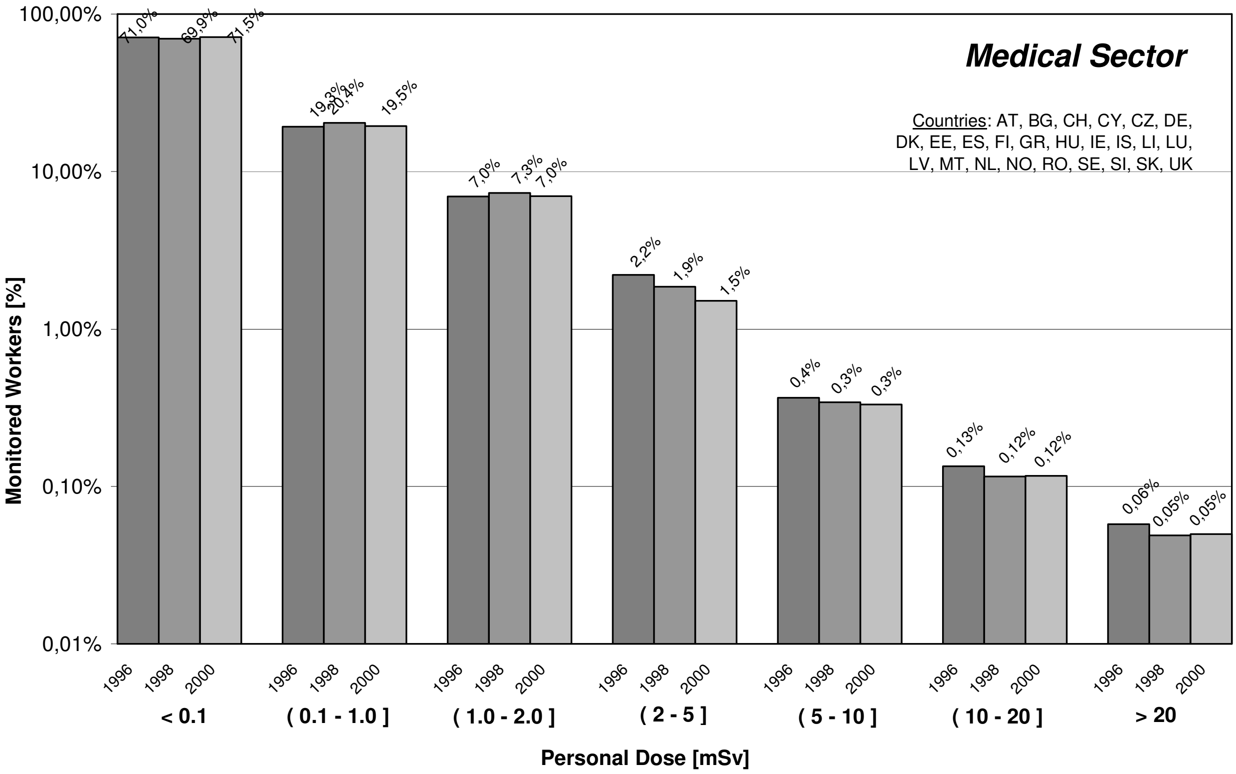
Medical sector

The situation appears different in the medical sector. The radiation exposure in the medical sector is already at a low level compared to nuclear or industrial work sectors and thus, the changes are as well comparatively small. The average annual dose remained with about 0,9 mSv almost constant. The collective dose shows only a small reduction of 3.4 %. The number of cases with annual doses higher than 20 mSv decreased slightly from 5.2 to 4.4 per 10,000 monitored workers. Also the left-shift of the dose distributions appears very small.

Table 3: Dose trends in the medical sector in 20 European countries

Medical Sector / Year	1996	1998	2000
Mean annual dose of exposed workers [mSv]	1,00	1,00	0,90
Collective dose [Pers-Sv]	176,9	173,8	171,3
N of cases per 10,000 monitored workers with doses greater than 20mSv/a	5,2	4,4	4,4

Figure 2: Distribution of personal doses from occupational radiation exposure in Europe from 1996 – 2000 in the medical sector



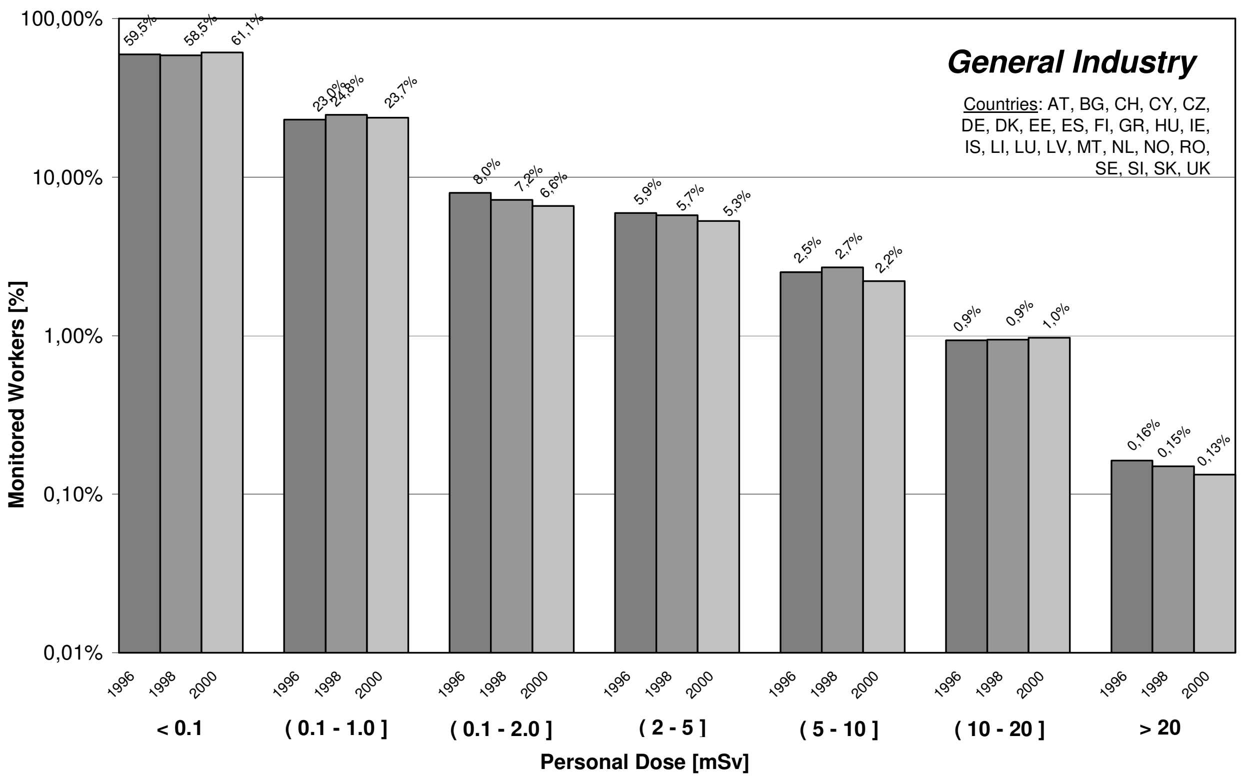
General industry

The level of individual radiation exposure in general industry shows more similarity with the exposures in the nuclear fuel circle than with those the medical sector. Nevertheless, only small dose reductions can be stated. The average annual dose decreased only about 10 % to 1.8 mSv. The decrease of the collective dose to 69 person-Sv lies with 9 % in the same proportion. The reduction of the number of cases with annual doses higher than 20 mSv is with values from 15.3 to 12,6 per 10,000 monitored workers also comparatively small. There is only a very little change in the dose distributions towards smaller doses.

Table 4: Dose trends in general industry in 21 European countries

Year General Industry	1996	1998	2000
Mean annual dose of exposed workers [mSv]	1,96	1,90	1,83
Collective dose [Pers-Sv]	75,6	73,2	69,1
N of cases per 10,000 monitored workers with doses greater than 20mSv/a	15,3	14,0	12,6

Figure 3: Distribution of personal doses from occupational radiation exposure in Europe from 1996 – 2000 in work sector general industry



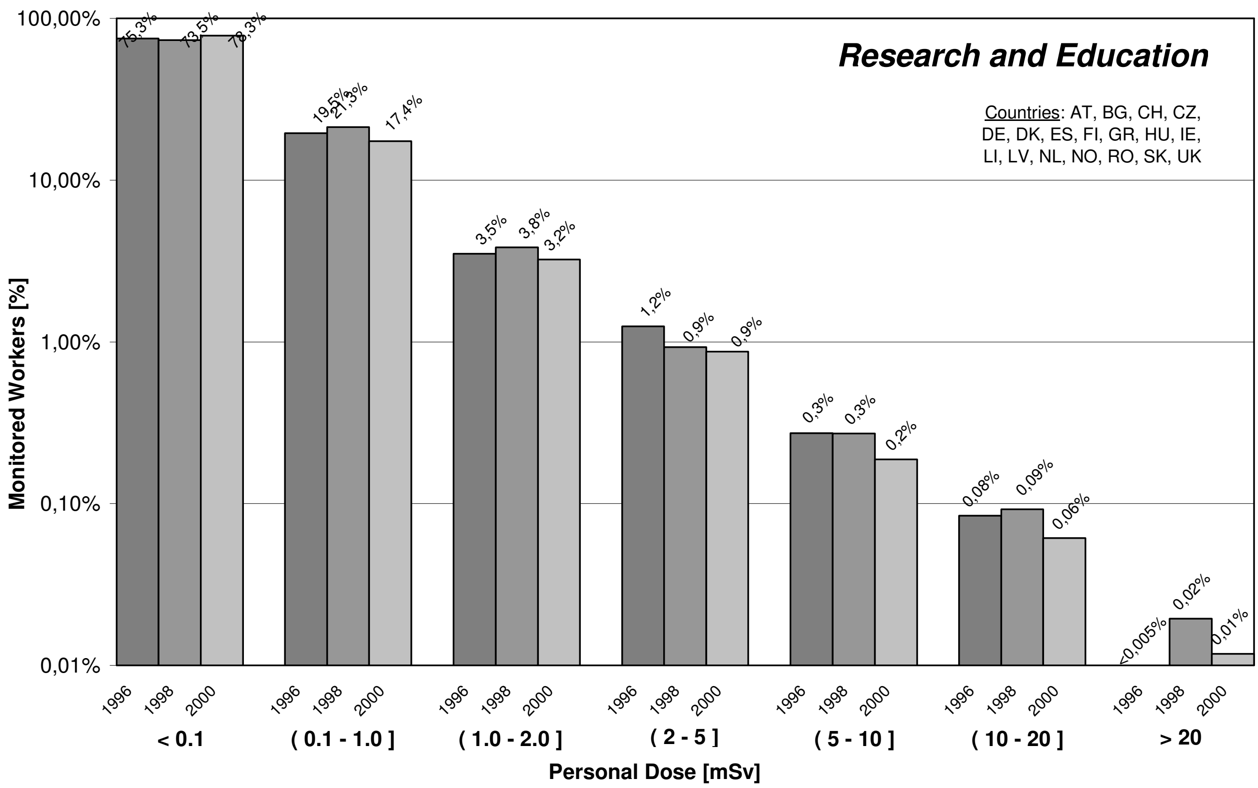
Research and education

Radiation exposure in the work sector research and education is at a very low level and below those in medicine. Yet, there is a little reduction of the average annual dose to 0.7 mSv and a 15 %-decline of the collective dose. Cases with exposures higher than 20 mSv are very seldom and occur stochastically. A little left-shift of the dose distributions is visible in dose bands below the 20 mSv-threshold.

Table 5: Dose trends in research and education in 17 European countries

Year Research and Education	1996	1998	2000
Mean annual dose of exposed workers [mSv]	0,79	0,77	0,67
Collective dose [Pers-Sv]	12,3	11,9	10,5
N of cases per 10,000 monitored workers with doses greater than 20mSv/a	0,4	1,6	0,9

Figure 4: Distribution of personal doses from occupational radiation exposure in Europe from 1996 – 2000 in work sector research and education



Natural sources

In the work sector natural sources the picture appears completely different. Here, we see the highest exposures and also the most changes. But for some reason the interpretation of the exposure level and it's changes has to be done very reserved: There are substantial monitoring differences between the countries in which exposures from natural sources matter. The registered doses are from uranium miners as well as from non-uranium miners and workers in show caves or drinking water facilities, i.e. they include external exposures as well as doses from ^{222}Rn-inhalation. The recommendations of ICRP 65 in 1993[2] for dose calculation changed the dose calculation for ^{222}Rn substantially by introducing conversion factors and detriment coefficients; in the consequence the calculated doses reduced at about 60 %. Germany implemented the ICRP 65 recommendation in 2000, but we have not yet sufficient information if or when other countries adopted these recommendations. Therefore, we are reluctant to attribute these calculated exposure changes completely to improvements of radiation protection.

The average dose declined to 3 mSv/a, i.e. more than 50 %. The collective dose decreased with 44 % to 39 Person-Sv, therefore the mean value may - apart from the nuisances mentioned above - also be influenced by a increasing number of monitored workers. The reduction of the number of workers that exceed annual doses of 20 mSv is 71 % and the highest in all work sectors. A decline to this extent can hardly be regarded as a mere result of dose calculation. We can also see a substantial change of the dose distributions towards the lower values in almost all dose bands. Yet, the shape of the distribution is considerably different from those in all other work sectors

Table 6: Dose trends in work sector natural sources in 9 European countries

Year Natural Sources	1996	1998	2000
Mean annual dose of exposed workers [mSv]	6,32	4,14	3,01
Collective dose [Pers-Sv]	70,2	44,5	39,0
N of cases per 10,000 monitored workers with doses greater than 20mSv/a	346,0	234,2	99,9

Conclusion

When we regard the changes in occupational radiation exposure around the years before and after the implementation of the Council Directive 96/29 we can state partly considerably reductions of exposures. The statistical results of dose monitoring suggest that radiation protection appears in full compliance with the ALARA-principle: radiation protection seems to operate efficiently, i.e. the higher the level of exposure, the stronger is the dose reduction. But this is only true for work sectors that are under strict observation such as the nuclear sector or new monitoring areas like natural sources. An inhomogeneous work sector like the general industry performs less successful in the reduction of radiation exposure. Work sectors with traditionally low doses like the medical sector or research and education reduced less. Yet, the dose reductions in the sector research and education show that even at levels of low exposures there is still room for improvement and dose reduction.

Figure 5: Distribution of personal doses from occupational radiation exposure in Europe from 1996 – 2000 in work sector natural sources

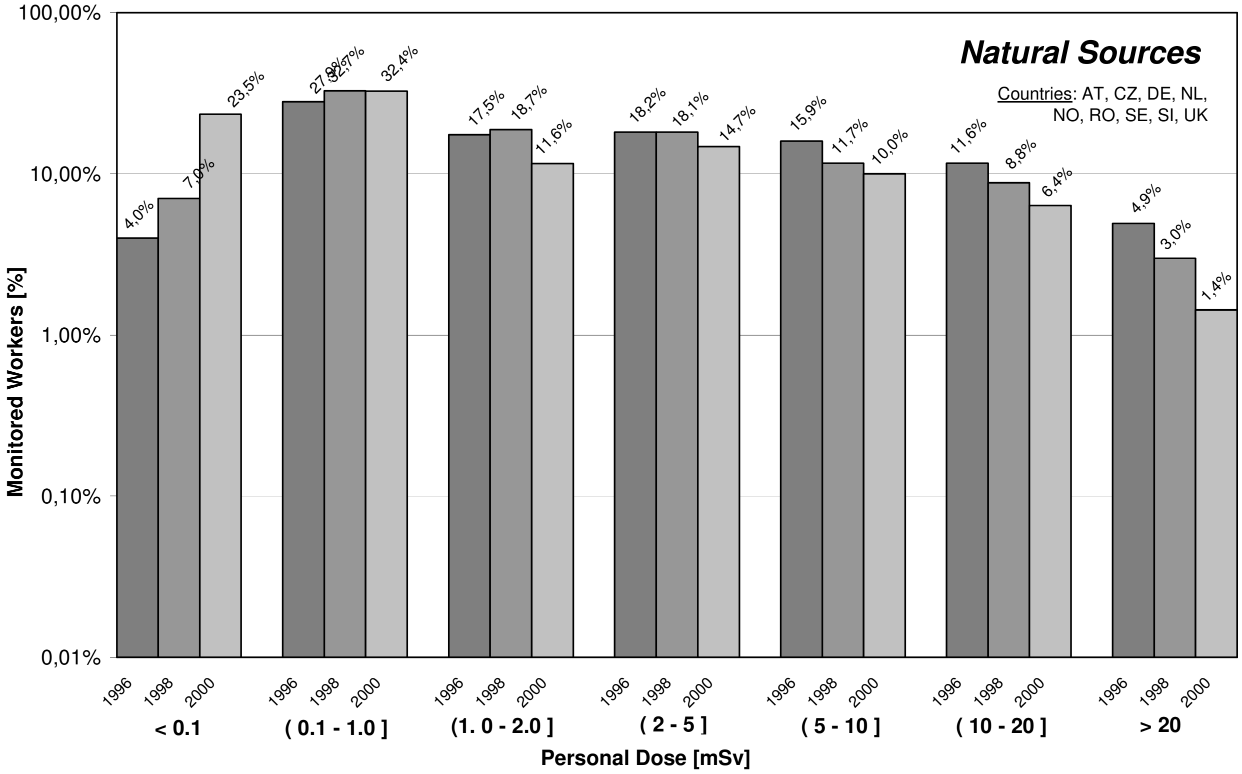


Table 7: Dose trends in different work sectors in Europe

↔ no ↘ little ↘ moderate ↘ **strong**	Nuclear sector	Medical sector	General industry	Research education	Natural sources
Countries	16	20	21	17	8
Mean dose	↘	↔	↘	↔	↘
Collective dose	↘	↘	↘	↘	↘
Cases with high doses	↘	↔	↘	↔	↘
Dose distribution shift	←	←	←	←	←

Authors

Dr. Gerhard Frasch:
Bundesamt für Strahlenschutz
Strahlenschutzregister
85762 Oberschleissheim
GERMANY
Phone: +49 (0)1888 333 2410
Fax: +49 (0)1888 333 2415
e-mail: GFrasch@BfS.de

Dipl.-Ing. Karla Petrová
State Office for Nuclear Savety
Senovazne namesti Nr. 9
110000 Praha 1
CZECH REPUBLIC
Phone: +420 2 21624556
Fax: +420 2 21624710
e-mail: karla.petrova@sujb.cz

---

[1] G. Frasch, K. Petrova, E. Anatschkowa: Dose registry in Europe - national data bases and international statistics, Rad. Prot. Dosim. 96 (1-3) 273-275 (2001)

[2] ICRP Publication 65: Protection against Radon-222 at Home and at Work; Pergamon Press 1993