Occupational exposure to ionising radiation 1990-1996

Analysis of doses reported to the Health and Safety Executive's Central Index of Dose Information

First published 1998

FOREWORD

The Central Index of Dose Information (CIDI) is the Health and Safety Executive's (HSE's) national database of occupational exposure to ionising radiation. It is operated under contract by the National Radiological Protection Board (NRPB). CIDI receives annually from Approved Dosimetry Services (ADS) summaries of radiation doses recorded for employees designated as classified persons in the United Kingdom. This is the second analysis of dose summary information to be published.

All the data provided to HSE by ADS for the purposes of CIDI are treated as confidential in respect of individual persons and employers. The computer files are protected by various safeguards (Registration No C0607047). The style of data presentation here maintains this confidentiality.

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INTRODUCTION

1 The Ionising Radiations Regulations 1985 (IRR85)[1] apply to a large range of work with artificial radioactive substances and electrical equipment emitting ionising radiation. They also apply to work with naturally occurring radionuclides, including work in which persons are exposed to the naturally occurring gas radon and its decay products. Any employer who undertakes work with ionising radiations must ensure specified dose limits are not exceeded and work-related exposure is restricted as far as reasonably practicable.

2 The system of control established by these regulations requires employers to designate employees as 'classified persons' if their exposure is likely to exceed three-tenths of any dose limit. All significant radiation doses likely to be received by these individuals must be assessed and recorded by dosimetry services approved by the Health and Safety Executive (HSE). These approved dosimetry services (ADS) are required to send HSE annual summaries of the doses recorded for each classified person.

3 This publication analyses the dose summary information reported to HSE for the years 1990-1996. It is the second such report published by HSE; the first such report[2] covered the period 1986-1991.

BACKGROUND

Legislation

4 IRR85 largely implement the Basic Safety Standards (BSS) Directive 80/836/Euratom[3] (as amended by Council Directive 84/467/Euratom[4]). A revised BSS Directive[5] was adopted on 13 May 1996 and has to be implemented by 13 May 2000; this will require changes to IRR85.

5 IRR85 establish dose limits for exposure at work to ionising radiation. For adult employees the dose limit for whole-body exposure is currently 50 millisieverts (mSv) per year. HSE must be informed if an exposure in excess of a dose limit is suspected and the employer must carry out a thorough investigation. In practice, almost all doses recorded for employees are well below dose limits.

6 The employer who is responsible for the work must restrict exposure so far as reasonably practicable. The employer is obliged to restrict exposure by means of engineering controls such as shielding, physical separation, containment, ventilation (for unsealed sources) and warning devices where these are reasonably practicable, rather than relying on systems of work or personal protective equipment.

7 Parts 1 to 3 of the Approved Code of Practice (ACOP)[6,7] supporting IRR85 provide practical guidance on the means required to meet this legal requirement for various work activities. HSE has also published advice on establishing management procedures to restrict exposure[8].

8 In most cases the employer is required to appoint a radiation protection adviser (RPA) under IRR85 to provide expert advice on measures to restrict exposure and related matters.

Investigations

9 If an employee has a recorded whole-body dose greater than 15mSv for the year (three-tenths of the principal dose limit) the employer must carry out an investigation (IRR85 regulation 28); usually this investigation will be done in conjunction with the RPA. The purpose of this investigation is to establish whether or not sufficient is being done to restrict exposure.

10 In 1991 a fourth part to the Approved Code of Practice (ACOP Part 4)[9] was published in response to new evidence that the risks from exposure to ionising radiation were two or three times as great as previously thought. It introduced an investigation (centred on the past and future work of the individual) which is triggered if an employee has a recorded dose of 75mSv or more in any period of 5 calendar years starting from 1 January 1988.

Dose monitoring and record-keeping

11 If an employee is likely to receive a radiation dose greater than three-tenths of a relevant dose limit in a year (15mSv in the case of whole-body exposure) the employer has to designate that employee as a classified person. The employer then has to arrange for any significant doses likely to be received by that person to be assessed by a dosimetry service approved by HSE for the measurement and assessment of doses for the relevant type of radiation. Such services are referred to in this report as ADS(assessment). HSE also approves dosimetry services to co-ordinate individual doses received from different ADS (assessment) and to produce and maintain dose records for classified persons. These services are referred to as ADS(records)

12 Doses may need to be assessed by one or more ADS(assessment) for exposure to external radiation and/or internal radiation from inhaled or ingested radionuclides. An ADS (records) appointed by the employer has to record all the assessed doses and maintain a formal dose record for each classified person.

13 To help the employer assess the effectiveness of the dose control measures, the ADS (records) provides a written summary of the doses recorded for each classified employee at least once every three months; many ADS(records) provide monthly dose summaries. By the end of March each year the ADS(records) must also send HSE summaries of all recorded doses relating to classified persons for the previous year.

Central Index of Dose Information

14 On 1 January 1987, HSE established a computerised Central Index of Dose Information (CIDI) in order to receive and process these annual dose summaries. The operation of CIDI is described in NRPB-M92[10] and NRPB-M176[11].

15 CIDI is operated for HSE under contract by NRPB. All the dose summary and personal data provided to HSE by ADS under IRR85 are treated as confidential. The computer files are protected by various safeguards and the database is registered under the Data Protection Act (Registration Number C0607047). The information presented in this report maintains that confidentiality.

16 One of the purposes of CIDI is to generate statistical information from the dose summaries provided to HSE by ADS(records). Detailed information relating to annual dose statistics has been published for each year from 1986 to 1996[12-22].

17 This report focuses on annual whole-body doses reported for classified persons in Great Britain for 1990-1996 and presents figures which indicate trends in occupational doses over that period. Annex 1 lists the occupational groupings used in this report. Annex 2 gives relevant data in tabular form. Whole-body doses shown in this report comprise the sum of effective dose equivalent (from external exposure to ionising radiation) and, where assessed, committed effective dose equivalent (from exposure to radionuclides in the body).

18 Data are presented on collective dose, mean doses and numbers of persons who had a reported dose in excess of 5mSv, 10mSv, 15mSv or 20mSv a year. The revised BSS Directive[5] requires that employees and self-employed persons are designated as category A (classified persons) if they are liable to receive a dose in excess of 6 mSv a year. Employers will have to take account of potential exposure to ionising radiation resulting from incidents or occurrences as well as historical information about doses actually received. Nevertheless, it is of interest to see how doses greater than this value have changed since 1990 - these data are also included in annex 2.

NATURE OF CIDI DATA

Comparison with published statistical summaries

19 There are some differences between the data reported in the published annual summaries of statistics and the data used in this report. The differences arise from amendments reported to CIDI by ADS since the statistical summaries were prepared; in general they have no significant effect on the overall conclusions of this report. However, revised data on whole body doses from neutrons does differ significantly from published data in that one ADS omitted to report neutron doses for a number of classified persons in the period. These doses were generally very low. In view of this error, the corrected neutron data are given in annex 3 of this report.

20 The data used in this report are those held on CIDI in September 1997.

Number of classified persons

21 CIDI includes doses for classified persons who were monitored for only part of the year; they may not have been designated as classified persons until part-way through the year or they may have changed employment (15-20% of records only cover part of the year). If a classified person changes employment in radiation work, CIDI normally receives dose

summaries from each ADS who had responsibility for that person's dose record at some stage in the year; but the last ADS for the year would normally have reported the total annual dose.

22 The CIDI statistical programmes treat each of the reported dose summaries as belonging to a different classified person. Therefore, in 1993 a special check was introduced to minimise the possibility of double counting records for individuals. This special check was applied to all the dose data used in this report.

23 The total number of classified persons for whom annual dose summaries were reported will have been affected by the Ionising Radiations (Outside Workers) Regulations 1993[23]. These regulations apply to classified persons carrying out activities in a controlled area of another employer. The introduction of the regulations caused some employers to look critically at the continuing need to designate certain employees as classified persons. Figure 1 gives the variation between 1990 and 1996 in the total number and in the number with non-zero reported doses.

Reported doses of zero

24 This report shows that most classified persons receive an annual dose much less than 15mSv per year; in 1996 over 95% of reported doses were less than 5mSv. This might suggest that employers are designating more employees than strictly required by IRR85. However, ACOP Part 1 advises that it is not sufficient to rely solely on past avoidance of such a dose in deciding whether or not an employee should be designated as a classified person. Therefore, employers must take into account the possibility that employees might receive a significant dose as a result of an accidental exposure. Also, employers may designate employees for other reasons, eg to obtain good dosimetric information to help restrict exposure - especially in controlled areas - and reassurance.

25 Employers in some non-nuclear sectors, most notably the medical sector, tend not to classify staff unless they are likely to exceed three-tenths of a relevant dose limit. It is important to recognise these differences in practice between sectors.

26 In any year during the period, between 20-30% of the persons for whom annual dose summaries were submitted had a reported dose of zero. A zero dose may have been reported for these persons because:

- they were not subject to routine dose assessment that year, eg they did no work with ionising radiation; or

- a dosemeter was worn but recorded no measurable dose (less than 0.1mSv) since exposure was very low.

27 The effect of including these individuals in any analyses of reported dose is to lower the mean dose for the group being considered, which might be misleading. Therefore, for the purposes of this report, only those persons with a non-zero reported dose have been included in the Figures. However, mean doses for all the classified persons are shown in brackets in the Tables at annex 2.

Notional doses

28 The data in this report have also been adjusted to remove notional doses. Notional doses are entered into a dose record for a period when no dose assessment could be made, for example when a dosemeter has been damaged or lost, and it is not possible to estimate the dose received from available information. Notional doses are intended to be used as a last resort and should be fairly rare. Usually, the employer's investigation required under regulation 13(7)IRR85 should enable the employer, with the assistance of the RPA, to provide the ADS with an adequate estimation of the dose received.

29 The proportion of notional doses in dose summaries sent to CIDI by ADS(records) varies from year to year, and tends to increase as collective dose falls. However, in 1996 nearly 16% of the collective dose on CIDI was accounted for by notional doses, which seems unreasonably high. This tended to obscure trends in the raw data for higher doses - over 30% of those reported as receiving a dose in excess of 15 mSv in 1996 had notional doses for at least one recording period of the year.

30 Notional doses are used in these circumstances as a precautionary measure to try to ensure that dose limits are not exceeded. They are calculated on the basis of the proportion of the relevant dose limit for the period concerned. However, they are rarely representative of the likely dose received by the employee. For that reason, a dose estimate for the relevant period has been substituted for each notional dose by the CIDI statistics programmes when compiling the data used for this report. Each substitute dose estimate is based on the doses assessed for that person during the rest of the year concerned. This is a well established convention in the presentation of dose data and it gives a more realistic value for the purposes of analysis.

31 The substitution of notional doses is only applied to the data when they are undergoing statistical analysis. The annual dose summaries reported by ADS(records) and kept on CIDI remain unchanged. These raw data are presented in Table A1 of each CIDI annual statistical summary[12-22].

Uncertainties in reported dose

32 Most of the classified persons with records on CIDI were monitored for exposure to external photon radiation (gamma rays and X-rays). Some, for example employees who work in nuclear fuel fabrication/reprocessing and non-coal miners, were monitored for radionuclides which could be inhaled or ingested into the body. Also, dose assessments were made for certain individuals who were likely to receive exposure to neutrons.

33 Dose assessment is subject to some uncertainties. The aim is to avoid underestimates while making sure that large overestimates do not occur. Dosimetry services approved by HSE for assessing exposure to photon radiation (gamma radiation and X-rays) have to undergo regular performance tests for which pass/fail criteria have been established[24,25]. A review of performance test results for 1985-1990 by Clark and others[26] showed that for batches of dosemeters irradiated to doses in the range 1-30 mSv over 90% of ADS obtained results within +15% of the nominally true dose (for doses of less than 1mSv the figure was +25%). HSE analysis of more recent performance test data shows that 95% of

results reported between 1992 and 1996 were within ± 20% of the nominally true dose. These results are for single dosemeters and exposure at normal incidence in simple radiation fields. However, uncertainties in measurements made with dosemeters in practical radiation fields are likely to be greater than this: workplace exposures usually cover a range of energies and classified persons move around in radiation fields, so their dosemeters are likely to be exposed at a range of different angles to the field.

34 Except for the measurement of tritium in urine, there are no comparable performance tests for assessing dose from intakes of radionuclides; the methods of assessment are generally more complex and the corresponding uncertainties in assessed dose are higher.

35 Occasionally, employees accidentally expose their dosemeters to radiation when they are not being worn; and sometimes employees forget to wear their dosemeters during particular operations. In these circumstances, provided that the problem is reported immediately to senior management, arrangements can be made with the ADS(assessment) and the RPA to estimate the dose the person actually received, rather than recording the dose indicated by the dosemeter. If the employer does not arrange for a dose estimate to be made in these circumstances an incorrect dose will be recorded by ADS(records) for that assessment period in the dose record. IRR85 make special provision for HSE to approve a special entry in the dose record in these cases. The employer is required to carry out an investigation of the circumstances and seek approval for a special entry in the record from HSE.

36 ADS(records) do not always advise CIDI of the amended annual dose after a special entry certificate has been issued. Also, some employers fail to apply for special entries despite the requirement to do so under regulation 13(8) IRR85. Therefore, it is likely that a few of the relatively high doses recorded on CIDI each year are gross over-estimates of the actual dose received. It is also possible that some annual doses recorded on CIDI are underestimates of the doses actually received, if dosemeters are not worn during work with ionising radiation. Although HSE inspectors rarely come across this situation, an exceptional case heard at a fatal accident enquiry in 1992 showed that this does sometimes occur. In that disturbing case[27], an industrial radiographer was found to have a lifetime dose many times greater the cumulative dose recorded in his dose record. There have also been a few cases where HSE inspectors have found that employers have not made arrangements with ADS (records) to maintain dose records for certain employees who are classified persons. Doses for these individuals would not have been reported to CIDI.

Occupational categories

37 Dose summaries reported to CIDI include information about the main type of work undertaken by the individual in that year (occupational category). Classified persons, who might undertake a range of work on different sites in the year, should be assigned to the occupational category which accounts for the largest proportion of dose received during the year. However, it is generally impracticable to distinguish between practices such as site radiography done at nuclear sites (where contractors may receive some exposure from the facility itself) and similar work undertaken at chemical plants.

38 For the purposes of this report the occupational categories used on CIDI have been combined into larger related groups (annex 1). This makes the presentation of dose information more straightforward and, to a large extent, overcomes the difficulties seen in some of the annual statistical summaries of misclassification by employers or ADS(records). Nevertheless, it is important to avoid over interpretation of the data.

ANALYSIS OF CIDI DATA

Numbers of classified persons

39 Figure 1 shows the total number of classified persons over the period 1990-1996. Data are given for all those with reported doses to CIDI in the relevant year and those with a reported dose ≥0.1 mSv (after adjustment for notional doses).

Breakdown by occupational category

40 Figures 2A and 2B give a breakdown of classified persons with a reported dose ≥0.1 mSv by occupational group for 1990 and 1996. Annex 2 Table 2 includes a breakdown for all years in the period 1990 - 1996.

Analysis of mean and collective dose

41 Mean doses and collective doses referred to in the text have been rounded to the nearest 0.1 milliSievert (mSv) and 1 manSievert (manSv) respectively. Information is given for classified workers with a recorded dose ≥0.1 mSv (after adjustment for notional doses). Collective dose in this case is the sum of all the reported doses for classified persons in that group. Assuming a linear dose-response relationship between dose and risk, collective dose can be taken as an indication of the total risk to that group.

42 Collective dose in a particular occupational group may decrease without any improvement in dose restriction because the number employed in that group has reduced over the period. Conversely, mean dose may decrease because more employees are designated as classified persons in that group with no overall improvement in the control of exposure. Therefore the combination of mean dose and collective dose in the same figure is a good way of examining the overall effect of efforts by employers to restrict exposure over the period 1990-1996.

43 Figures 3A and 3B, 5A to 9A and Annex 2 Tables 3 to 15 present mean dose and collective dose information for different occupational groupings based on reports to CIDI for each of the years 1990-1996, corrected for notional doses. Figure 3A gives data for all classified persons while figure 3B excludes non-coal miners. The latter data give a clearer picture about likely future exposures since the non-coal mine in England which accounted for most recorded doses over 15 mSv in 1996 (resulting from exposure to radon) closed in March 1998. Figure 3B can be seen as representative of exposure to artificial sources since no other occupational grouping on CIDI includes significant exposure to natural radiation sources.

Reported doses greater than 5 msv

44 Figures 4A to 9B (and annex 2 Tables 3 to 15) show how reported doses for the most exposed individuals have altered over the same period, after adjustment for notional doses. It is presented in terms of the percentage of classified persons in that occupational group who had reported doses exceeding 5mSv, 10mSv, 15mSv or 20mSv.

45 The figures could have shown the numbers of persons with reported doses above certain levels (see Tables) but that might have been misleading for some groups where the number of individuals employed decreased significantly over the period. By looking at the percentage of individuals in the group, rather than at absolute numbers, the effect on dose trends of any downturn in economic activity (and thus a reducing labour force) can be minimised.

46. Figures 14A and 14B show how particular occupational groups accounted for those classified persons with reported doses exceeding 10 mSv in 1990 and 1996.

Other data

47 Figure 13 and Tables 16 and 17 give summaries of neutron doses reported to CIDI and numbers of individuals who exceeded 6 mSv a year.

RESULTS

Numbers of classified persons

48 Figure 1 shows that, overall, there was a reduction of about 20% in the number of all classified persons from 59 563 to 43 805. It also shows that the number of classified persons with reported dose of at least 0.1 mSv fell over the period 1990-1996 by 35% from 43 805 to 28 385, with the most significant change taking place between 1993 and 1996 (24%). This reduction probably resulted from a decrease in employment in certain occupational groupings and a re-assessment by employers of the need for classification after the introduction of the Ionising Radiations (Outside Workers) Regulations 1993.

Breakdown by occupational category

49 There were no major changes in the balance of the different groupings over the period. Overall, the nuclear sector continued to account for more than 50% of the total number of classified persons over the period. The proportion of classified persons from the nuclear power grouping contracted while the proportion working in nuclear fuel fabrication and reprocessing increased. The smaller sectors, eg medical/dental and academic research and teaching continued to shrink as fewer employees in these sectors were classified by 1996.

Doses for all classified persons

50 The distribution of reported doses for classified persons for each year of the period was heavily skewed towards the low dose end. Therefore, it was not surprising that, in general, mean doses were low: the mean reported dose for all classified persons with a non-zero reported dose in 1996 was 1.3 mSv (0.8 mSv)[1], less than 70% of the 1990 figure.

51 Figure 3A shows a continuing downwards trend in both reported mean and collective dose for classified persons over the whole period, even taking account of uncertainties in dose assessment. Collective dose fell faster than mean dose which was unchanged between 1995 and 1996. There was a step change in collective and mean doses between 1990 and 1991 (around 30% reduction). The reduction in collective dose from 1991-1996 was 38% with a corresponding 13% decrease in mean dose.

52 Figure 3B excludes non-coal miners, for the reason given in paragraph 43. It shows that for those exposed to artificial sources there was a 44% reduction in collective dose over the period 1991 to 1996 and mean dose decreased by 20% over the same period.

53 Figures 4A and 4B show a substantial reduction in the number of classified persons who had a reported annual dose in excess of 15mSv (the principal investigation level) over the seven year period. Again, there was a step change in the year 1990-1991. However, the exclusion of non-coal miners reveals a decrease of about 85% in the numbers exceeding this level between 1991-1996 compared with a 20% increase when non-coal miners are included. Figure 4B shows that the downwards trend in those with doses above the investigation level continued throughout the whole seven year period when non-coal miners are excluded from the figures - a 95% reduction of the whole period. The number reported as having received more than 20mSv in a year also fell by about the same proportion to 10 individuals, if non-coal miners are excluded, after correction for notional doses.

54 There were also significant reductions in the proportion of classified persons with a recorded dose which exceeded either 10 mSv or 5 mSv.

55 Taken together, these figures show clearly that the most highly exposed groups of workers now form a very small proportion of the total number of classified persons with a reported dose of at least 0.1 mSv, except for non-coal miners.

56 There was no particular pattern to the numbers of classified persons reported as having a recorded dose in excess of the annual whole-body dose limit of 50mSv in a year. Typically there are now around six persons a year with a recorded dose in excess of the dose limit, most being industrial radiographers. As explained in paragraph 33, a few of these reported doses may be over-estimates of the dose actually received. HSE investigations suggest that individuals who did have recorded doses of this magnitude were almost always involved in incidents or occurrences and did not receive these doses as a result of any planned exposure.

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[1] The figure in brackets includes classified persons with a reported dose less than 0.1 mSv

Neutron doses

57 Neutron doses were reported to CIDI for groups other than those in the nuclear sector, eg site radiography, radiation protection, offshore work and research and teaching. It is likely in the first two examples that most of the exposure to neutrons arose from work on nuclear licensed sites. Although updated neutron data on CIDI has been given in this report because previously published CIDI data was incomplete (see paragraph 19) there still seems to be a disparity between the data for 1990 and that for 1991. Figure 13 reveals a substantial reduction in collective and mean doses from neutrons and annex 2 shows a 20% reduction in the numbers of persons being monitored for neutrons over that period. Overall, the numbers of classified persons being monitored for neutrons appears to have fallen by 60% from 29 619 to 12 053 over the whole seven year period. It is not clear why this change had occurred, although mean doses from neutrons were fairly low at around 0.5 mSv from 1991-1996. Also, few persons had reported neutron doses in excess of 5 mSv a year in any year of the period (see Table 13).

Doses for classified persons in particular groups

58 In terms of collective dose, it is clear that the two nuclear groupings accounted for the largest proportion (over 50%). Also, the greatest number of classified persons with doses above 5 mSv a year came from these groups. The next largest group comprised those in the general industrial grouping; this group together with the industrial radiography group and non-coal miners also had significant collective doses. Figure 14 shows the relative success of employers from particular industrial groups in reducing the numbers of persons with recorded doses > 10 mSv a year over the period 1990-1996. In 1990 the nuclear sector as a whole accounted for over 70% of these persons. By 1996 this sector was responsible for only 25% of such persons; the non-coal mining group accounted for 60% of the total in that year. Industrial radiographers were the only other important group with a significant number of classified persons receiving > 10 mSv a year.

59 In general, classified persons in the different occupational groups tended to follow the overall trends for classified persons as a whole, although the mean dose for nuclear power tended to increase slightly in the later years of the period. As in the first Trends Report, which covered the period 1986-1991, the two key exceptions were industrial radiography and non-coal mining. In the case of the first group, many classified employees had recorded doses of less than 0.1 mSv and over the seven year period there was a noticeable reduction in collective dose. But, the mean dose for industrial radiography hardly altered over the period 1990-1996. A few individuals still had recorded doses in excess of the investigation level (nine in 1996 after corrections for notional doses). Further improvement should be possible. Nevertheless, it is the non-coal mining group that stands out, dominating trends in mean dose and doses in the higher dose bands (Figures 9A and 9B). The closure of the non-coal mine which accounted for most doses over 15 mSv should have a dramatic effect on dose trends for this group in future years (see paragraph 43).

60 The number of classified persons employed in some groupings is now so small that it is difficult to identify any meaningful trends. However, it was notable that the mean doses for transport workers showed a noticeable blip for 1993-1995. One reason for this was the

consistently poor performance of one company involved with the handling and transport of radioactive materials at an airport; HSE took enforcement action in that case.

CONCLUSIONS

61 For classified persons as a whole the data on CIDI suggest that, in general, employers have continued with the successful reduction of exposures reported in the first CIDI Trends Report, which covered the period 1986-1991. The improvements in the nuclear sector are particularly noticeable. When the special case of non-coal miners was excluded, the number of classified persons exceeding the investigation level by 1996 fell to a modest 17 (after correction for notional doses), compared with the 1986 figure of 1 911 (the first operational year of IRR85). The corresponding number exceeding 20 mSv a year, the average dose limit established under the revised Basic Safety Standards Directive[5], was 10 in the last year of the period.

62 The principal exception to this improving picture was the non-coal mining group. However, the closure of the non-coal mine which accounted for most of those with doses in excess of 15 mSv a year is expected to have a major impact on the adverse dose trends seen for 1990-1996 for this group. Although significant improvements in the industrial radiography group were recorded for collective dose and numbers of persons above the IRR85 investigation level there is still work to do to improve the control of exposure; the enhanced HSE enforcement strategy for this sector, which was mentioned in the first dose trends report, remains relevant.

63 Problems with interpretation of CIDI occupational categories - and the difficulty of determining whether or not doses in certain occupational groups were associated with a particular type of site - suggest that the grouping and definition of these categories should be improved in any future upgrading of CIDI.

Acknowledgement

64 HSE wishes to acknowledge to the work of Mrs K Buckley, of the HSE CIDI office at NRPB, for the preparation of the statistics on which this report is based.

REFERENCES

1 Statutory Instrument SI No 1333, 1985. *The Ionising Radiations Regulations 1985* HMSO.

2 Occupational Exposure to Ionising Radiation 1986-1991. *Analysis of doses reported to HSE's Central Index of Dose Information.* HSE London 1993.

3 European Communities Council Directive of 15 July 1980, 80/836/Euratom, laying down the basic safety standards for the health protection of the general public and workers against the dangers of ionising radiation.

4 European Communities Council Directive of 3 September 1984, 84/467/Euratom, amending Directive 80/836/Euratom as regards the basic safety standards for the health protection of the general public and workers against the dangers of ionising radiation.

5 European Union Council Directive of 29 June 1996, 96/29/Euratom, laying down the basic safety standards for the health protection of the general public and workers against the dangers of ionising radiation.

6 HSC *Protection of persons against ionising radiation arising from any work activity, Approved Code of Practice, Parts 1 and 2* COP 16 ISBN 0-7176-0508-6.

7 HSC *Exposure to Radon, Approved Code of Practice, Part 3* COP 23 ISBN 0-11-883978-0.

8 HSE *A Framework for the restriction of occupational exposure to ionising radiation* HS(G) 91 ISBN 0-11-886324-X.

9 HSC *Dose limitation - restriction of exposure: Additional guidance on regulation 6 of the Ionising Radiations Regulations 1985 Approved Code of Practice*, Part 4 L7 ISBN 0-11-885605-7.

10 Kendall, G M, Greenslade, E, and Young, T O. *Report of the Working Party on the Central Index of Dose Information.* Chilton NRPB-M92 (1983)

11 Greenslade E, Kendall G M, Iles W J, Gardner P H and Young, T O. *Reference manual for data transfer to the Central Index of Dose Information.* NRPB-M176 (1989)

12 *Central Index of Dose Information, Summary of Statistics for 1986.* Chilton, NRPB 1991.

13 *Central Index of Dose Information, Summary of Statistics for 1987.* Chilton, NRPB 1992.

14 *Central Index of Dose Information, Summary of Statistics for 1988.* Chilton, NRPB 1993.

15 *Central Index of Dose Information, Summary of Statistics for 1989.* HSE 1993.

16 *Central Index of Dose Information, Summary of Statistics for 1990.* HSE 1993.

17 *Central Index of Dose Information, Summary of Statistics for 1991.* HSE 1993.

18 *Central Index of Dose Information, Summary of Statistics for 1992.* HSE 1994.

19 *Central Index of Dose Information, Summary of Statistics for 1993.* HSE 1995.

20 *Central Index of Dose Information, Summary of Statistics for 1994.* HSE 1996.

21 *Central Index of Dose Information, Summary of Statistics for 1995.* HSE 1997.

22 *Central Index of Dose Information, Summary of Statistics for 1996.* HSE 1997.

23 Statutory Instrument SI No 2379, 1993. *The Ionising Radiations (Outside Workers) Regulations 1993* HMSO.

24 HSE *Guidance on the Approval of Dosimetry Services under the Ionising Radiations Regulations 1985.* London 1985.

25 HSE *Requirements for the Approval of Dosimetry Services under the Ionising Radiations Regulations 1985, Part 3 - Co-ordination and Record-keeping.* London revised 1996.

26 Clark M J, Burgess P H ,Young T O and Gray R C *Performance tests on dosimetry services in Great Britain*. Journal of Radiological Protection 1991 Vol. 11 No2 117-126.

27 Lloyd D C et al *Death of a classified worker probably caused by overexposure to gamma radiation* 1994. Occupational and Environmental Medicine, Vol.51 713-718.

Fig 1 - Numbers of classified persons on CIDI

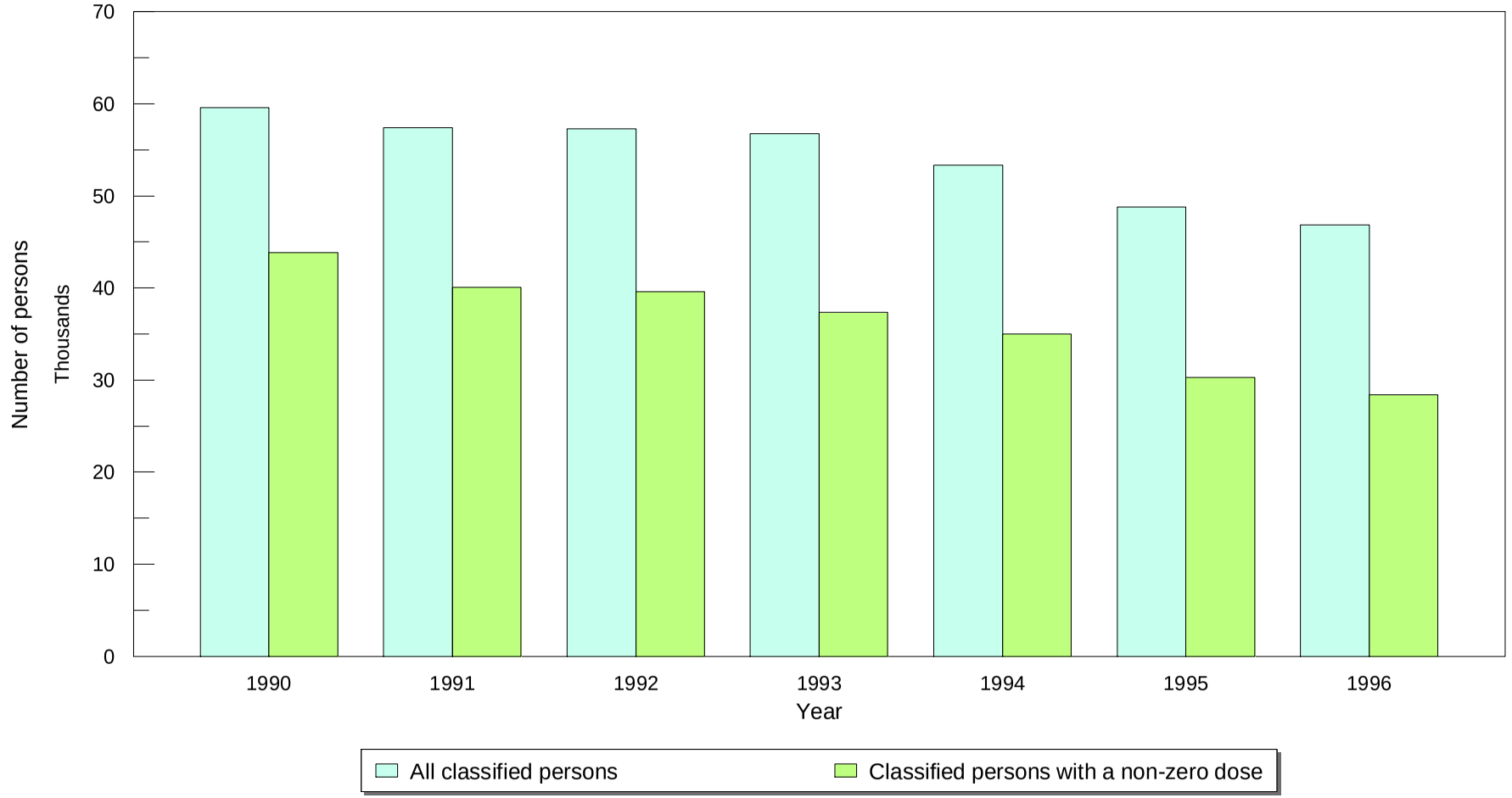


Fig 2A Classified persons by category - 1990

(excluding classified persons with a recorded dose less than 0.1 mSv)

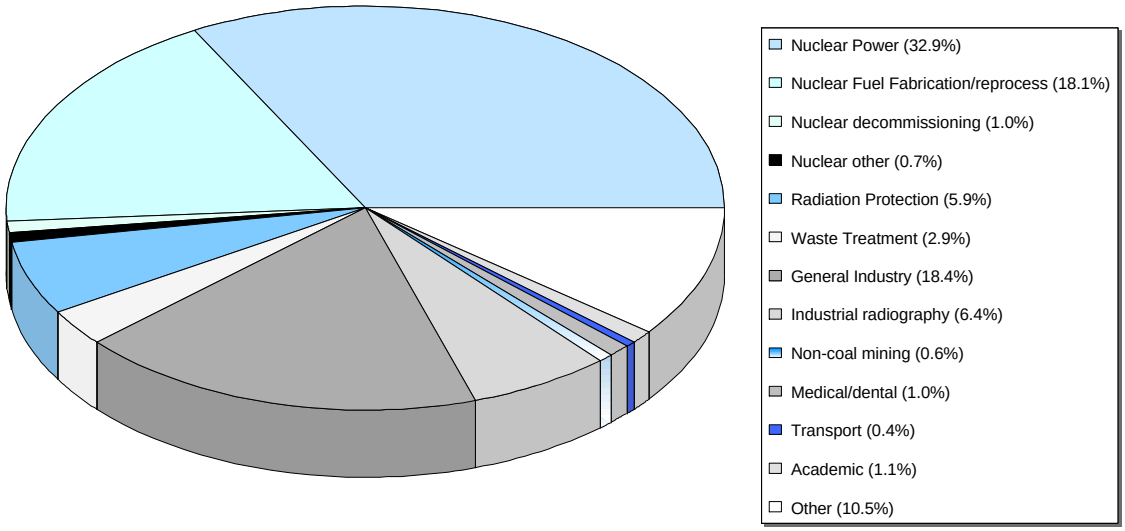


Fig 2B Classified persons by category - 1996

(excluding classified persons with a recorded dose less than 0.1 mSv)

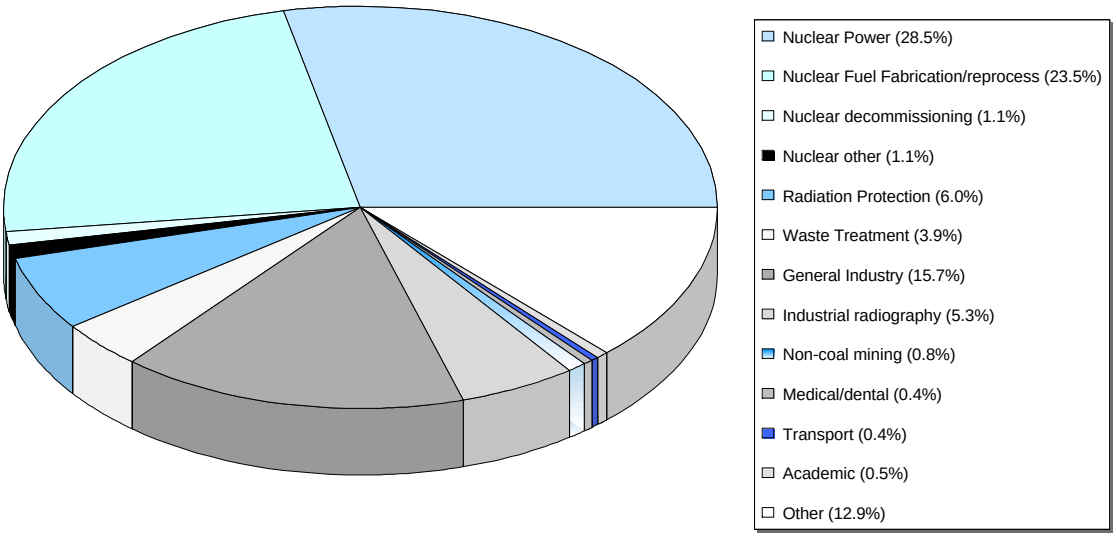


Fig 3A Collective and Mean Doses for classified persons

(excluding classified persons with a recorded dose less than 0.1 mSv)

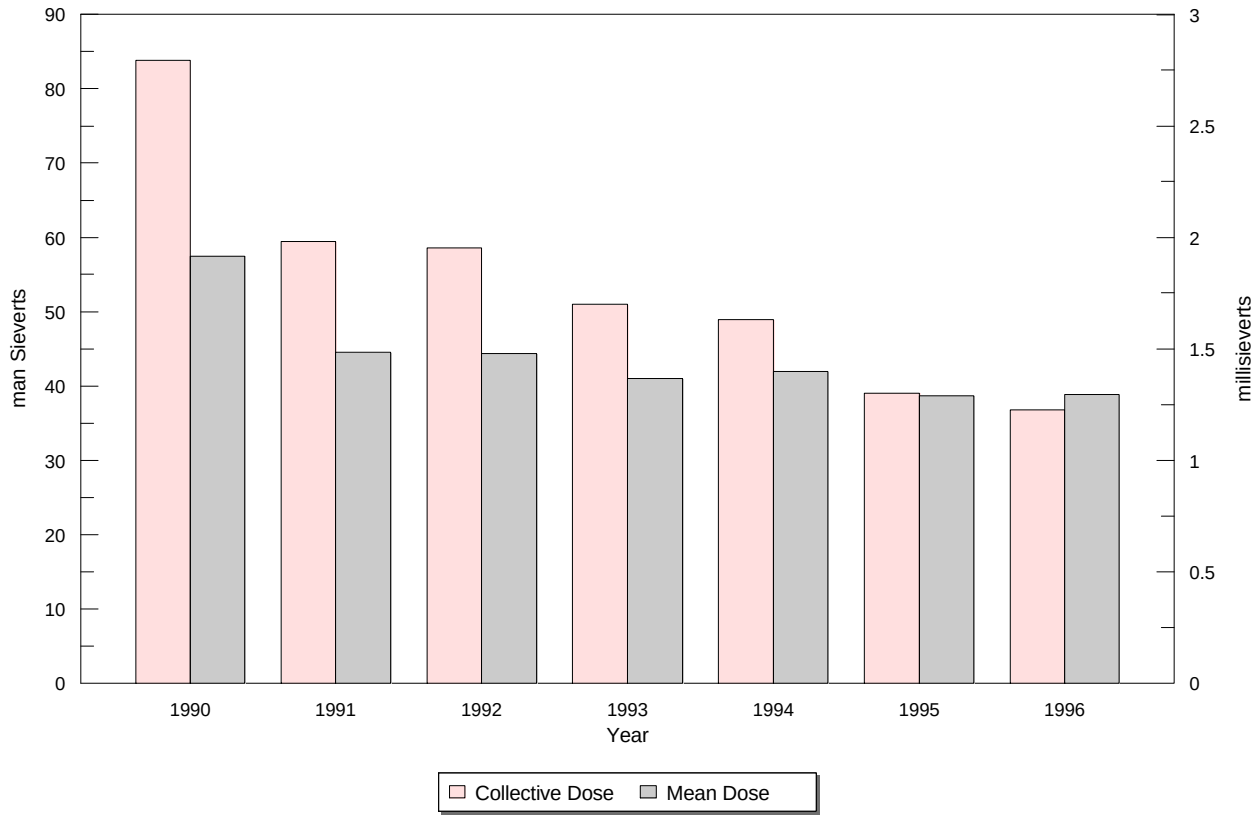


Fig 3B Collective and Mean Doses for classified persons

(excluding non-coal miners and classified persons with a recorded dose less than 0.1 mSv))

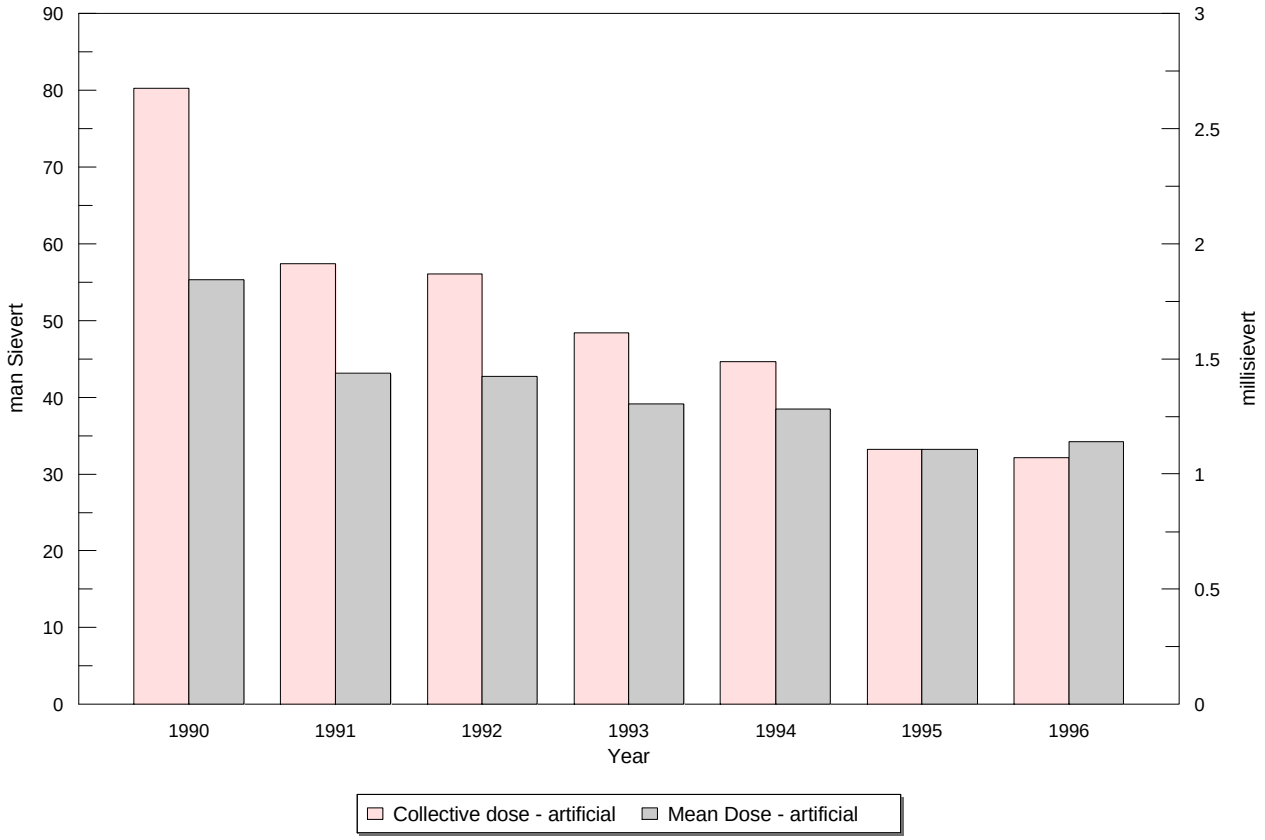


Figure 4A Number of classified persons exceeding certain levels of dose

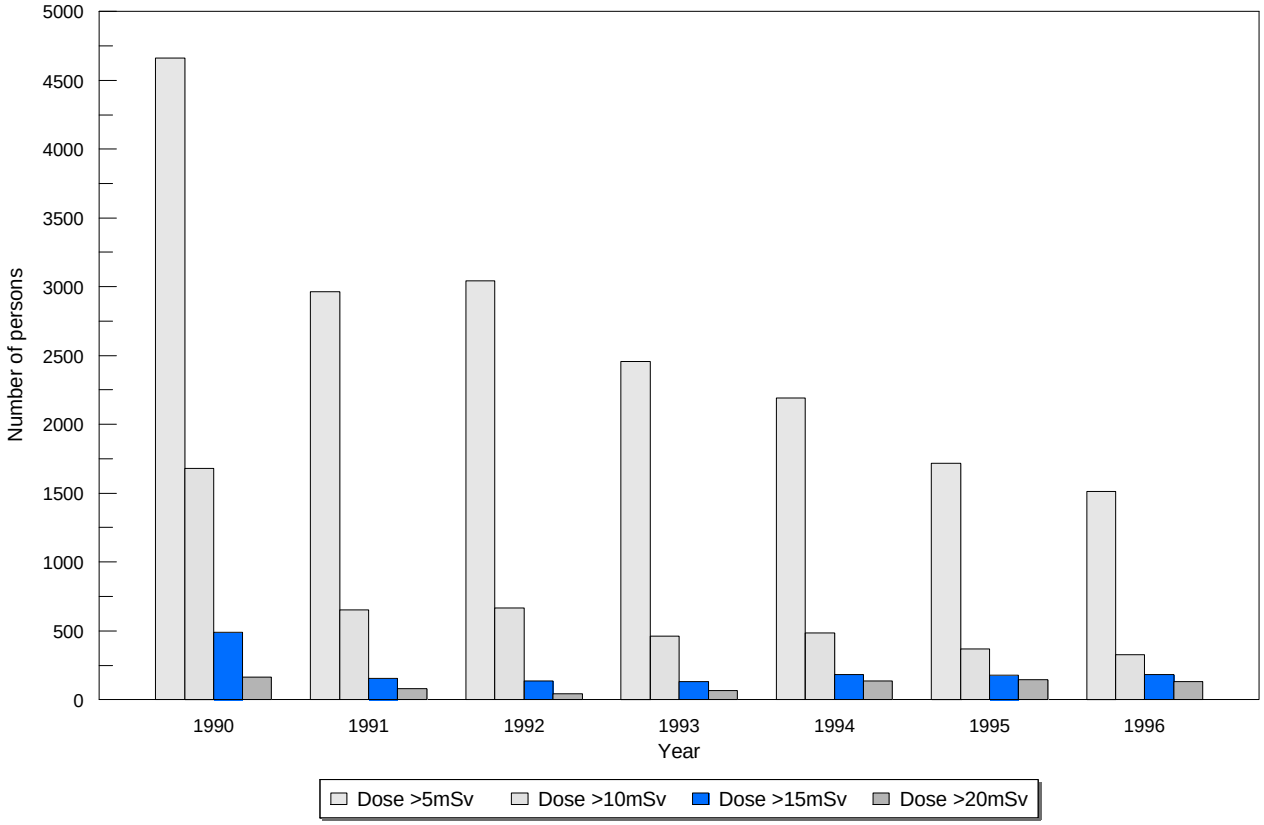
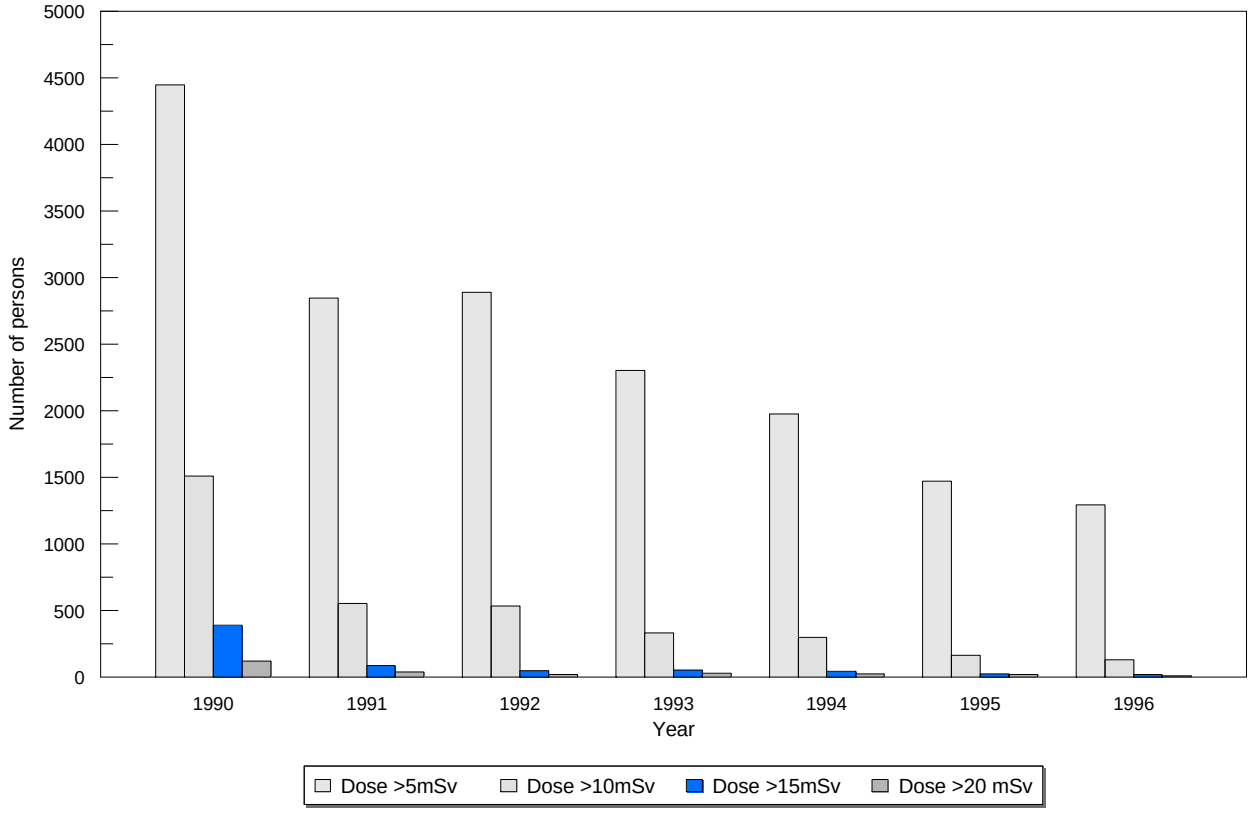


Fig 4B Number of classified persons exceeding certain levels of dose

(excluding non-coal miners)



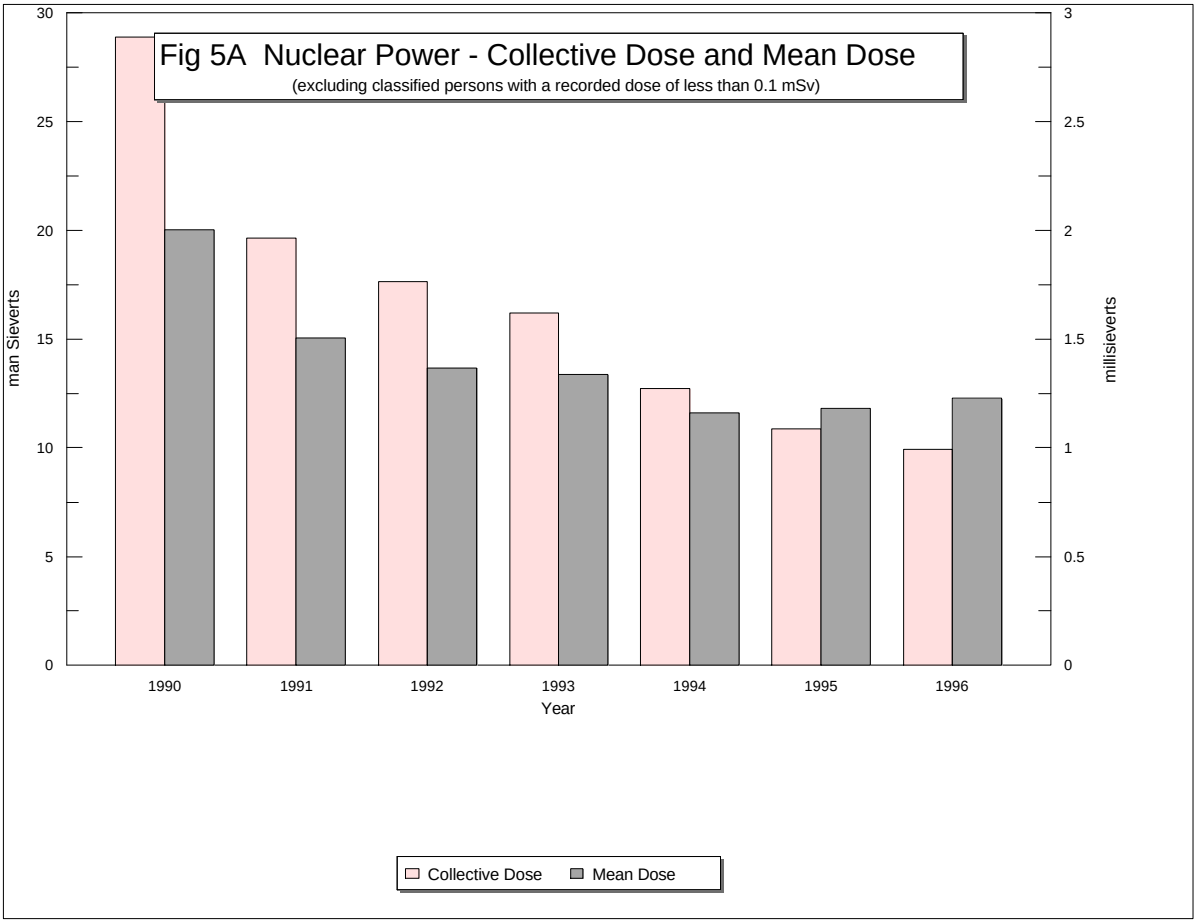


Fig 5A Nuclear Power - Collective Dose and Mean Dose
(excluding classified persons with a recorded dose of less than 0.1 mSv)
man Sieverts
millisieverts
Year
1990
1991
1992
1993
1994
1995
1996
Collective Dose
Mean Dose

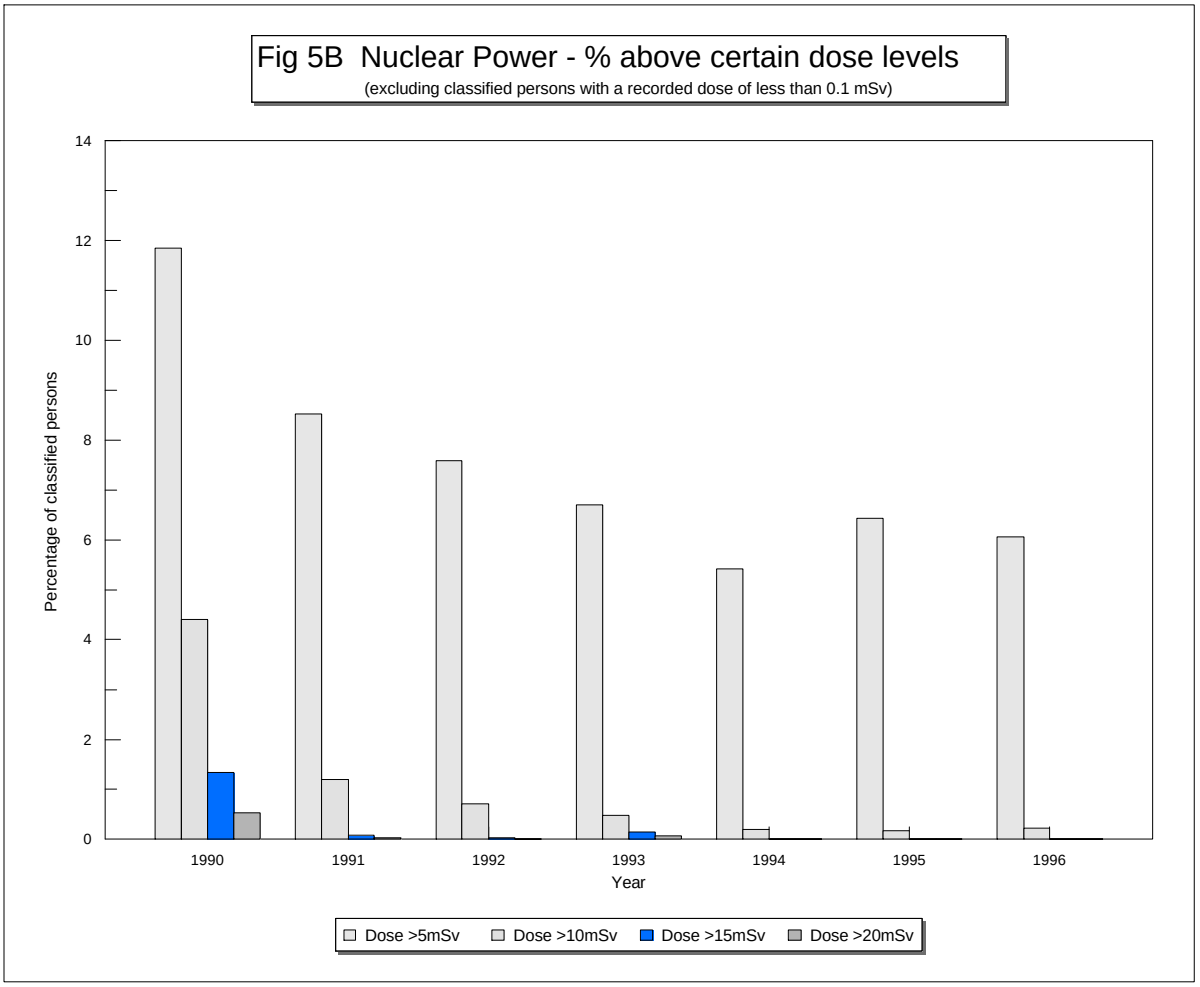


Fig 5B Nuclear Power - % above certain dose levels
(excluding classified persons with a recorded dose of less than 0.1 mSv)
Percentage of classified persons
Year
1990
1991
1992
1993
1994
1995
1996
Dose >5mSv
Dose >10mSv
Dose >15mSv
Dose >20mSv

Fig 6A Nuclear Fuel fabrication/reprocessing - Collective Dose and Mean Dose

(excluding classified persons with a recorded dose of less than 0.1 mSv)

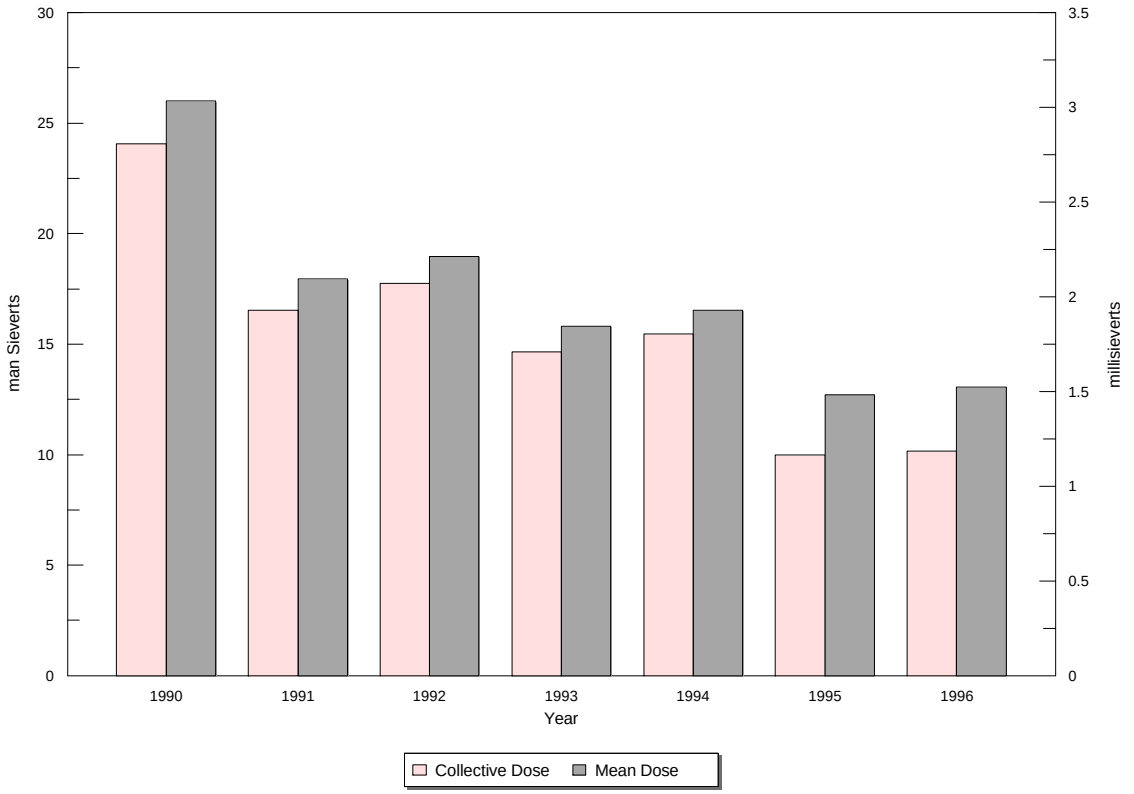


Fig 6B Nuclear Fuel fabrication/Reprocessing - % above certain dose levels

(excluding classified persons with a recorded dose of less than 0.1 mSv)

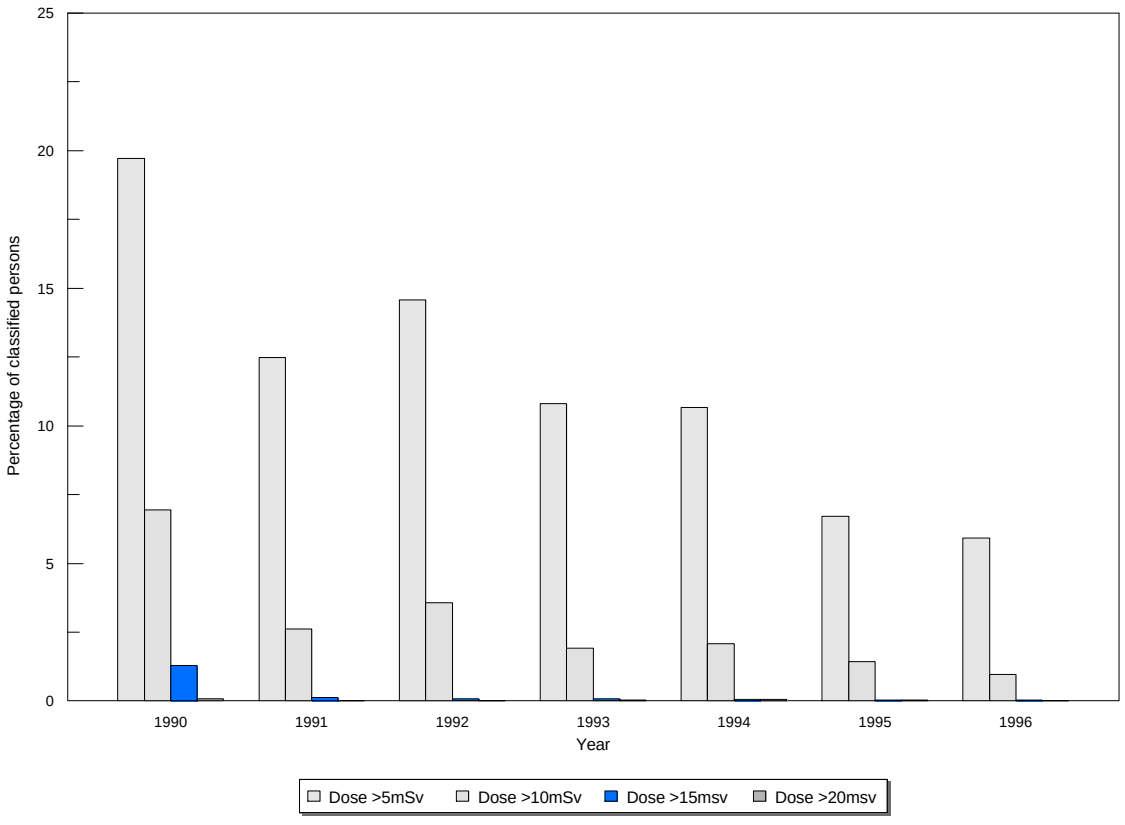


Figure 7A General Industrial Activities - Collective Dose and Mean Dose

(excluding industrial radiographers and classified persons with a recorded dose less than 0.1 mSv)

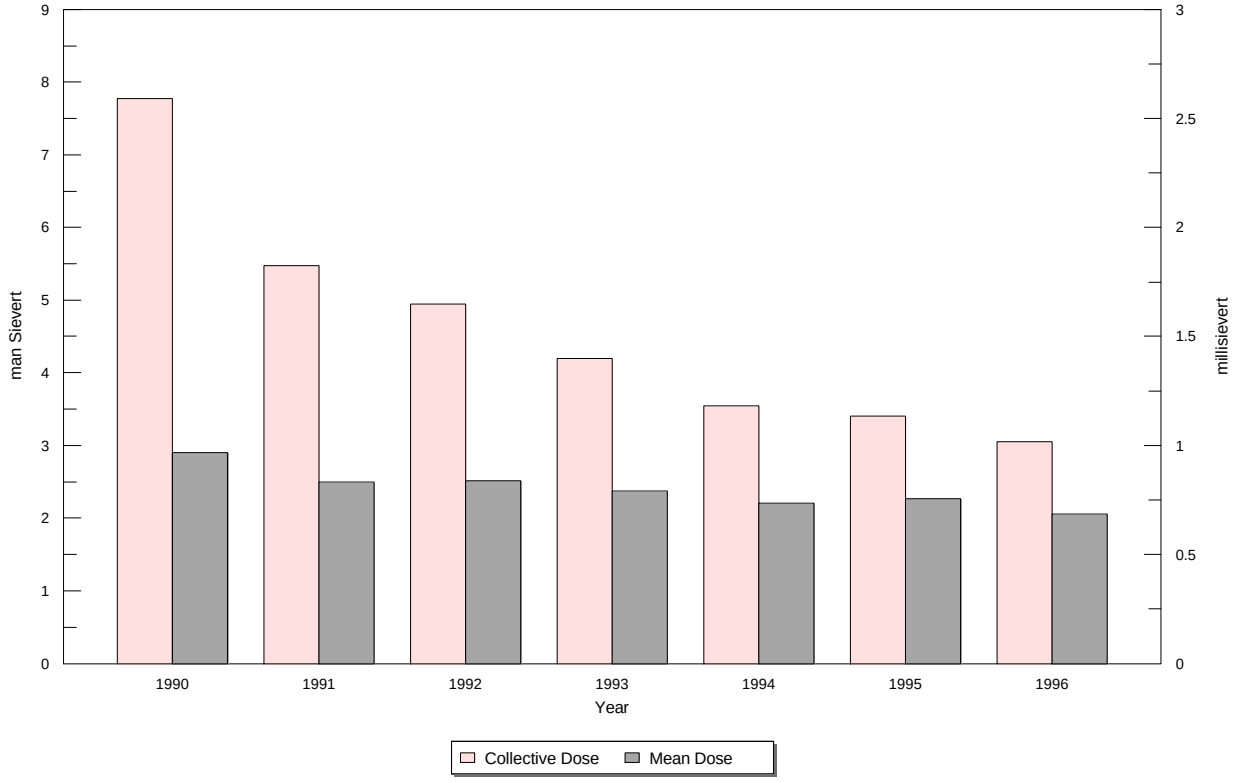


Fig 7B General Industrial Activities - % above certain dose levels

(excluding industrial radiogarphers and classified persons with a recorded dose below 0.1 mSv)

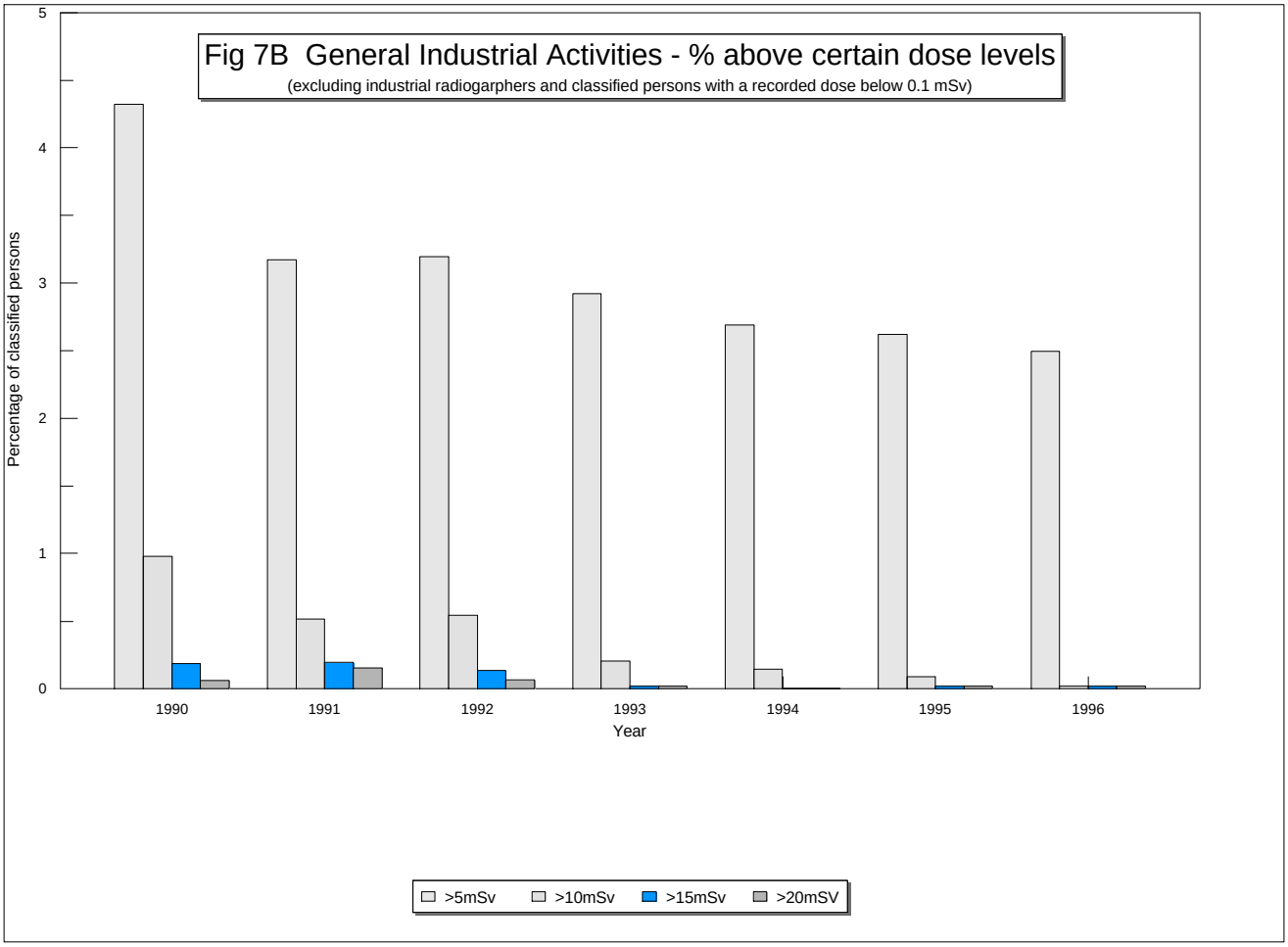


Fig 8A Industrial Radiography - Collective Dose and Mean Dose

(excluding classified persons with a recorded dose of less than 0.1 mSv)

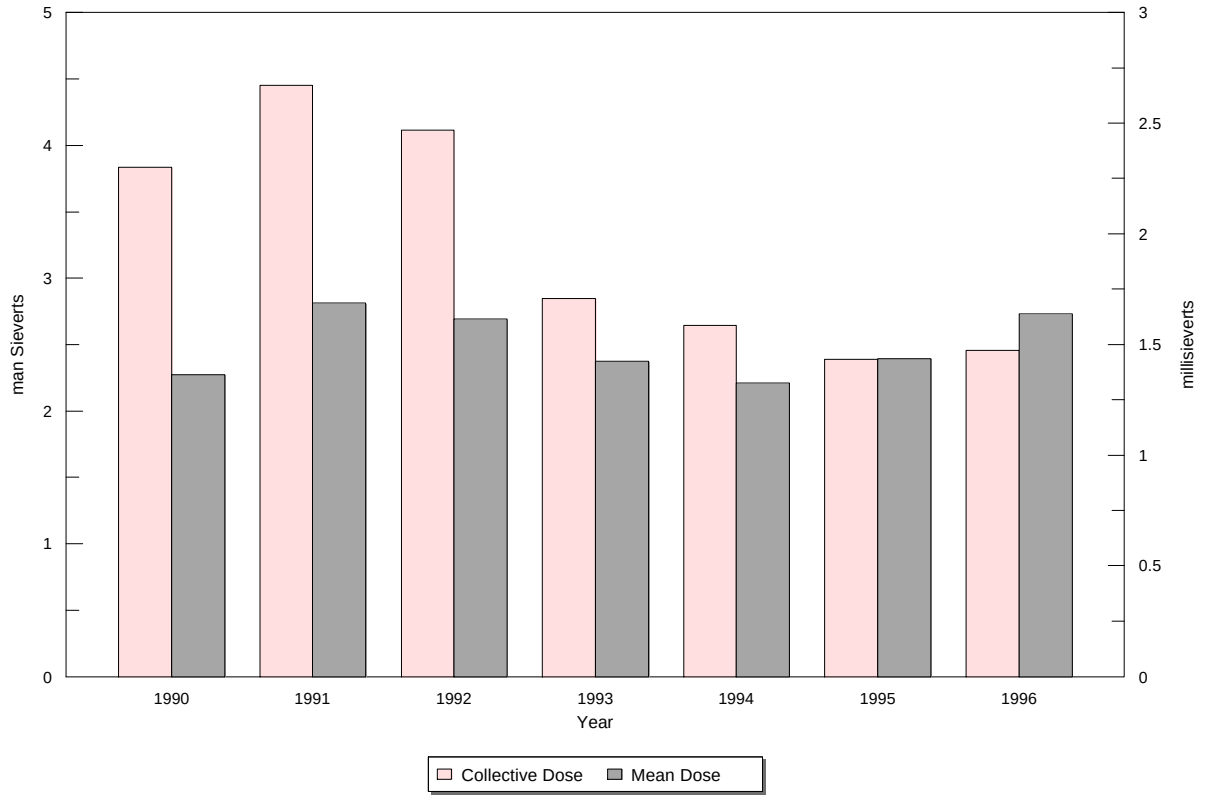


Fig 8B Industrial Radiography - % above certain dose levels

(excluding classified persons with a recorded dose less than 0.1 mSv)

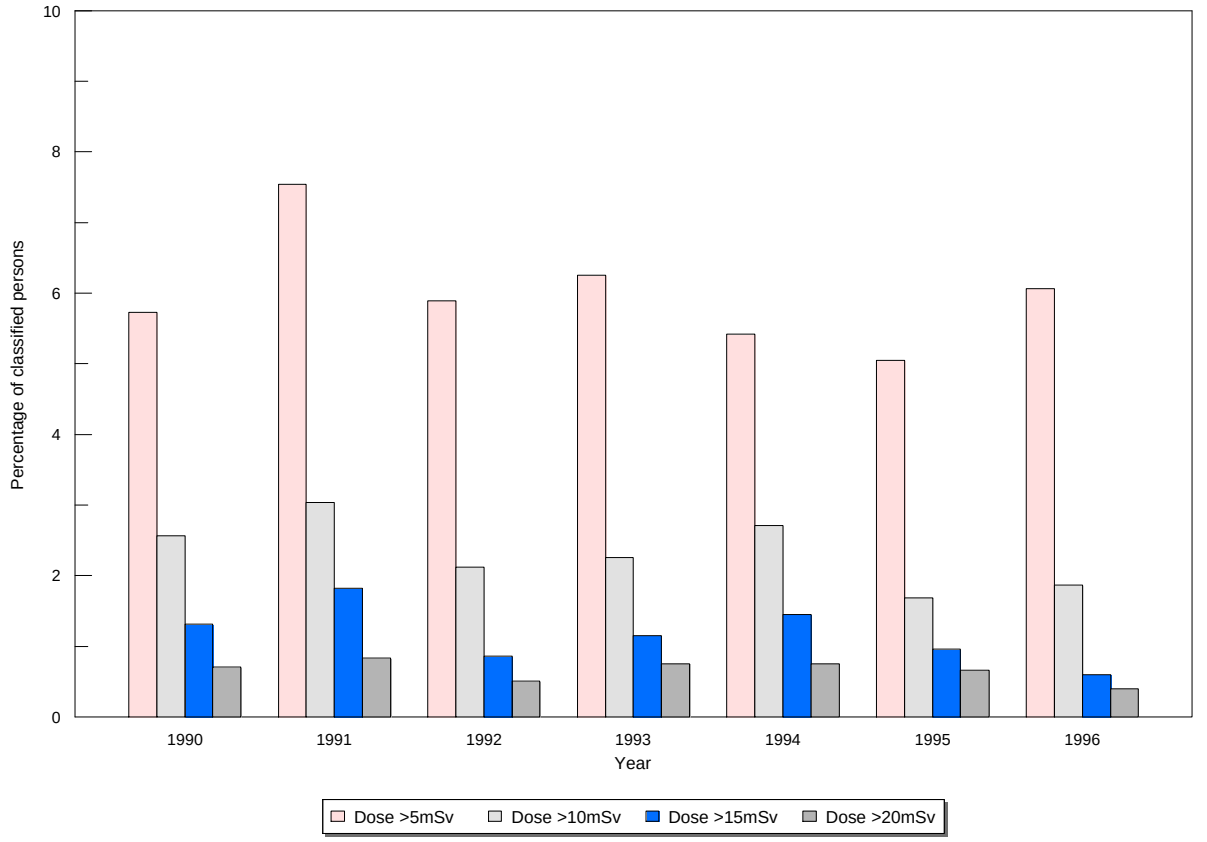


Fig 9A Non-coal mining - Collective and Mean Dose

(excluding classified persons with a recorded dose of less than 0.1 mSv)

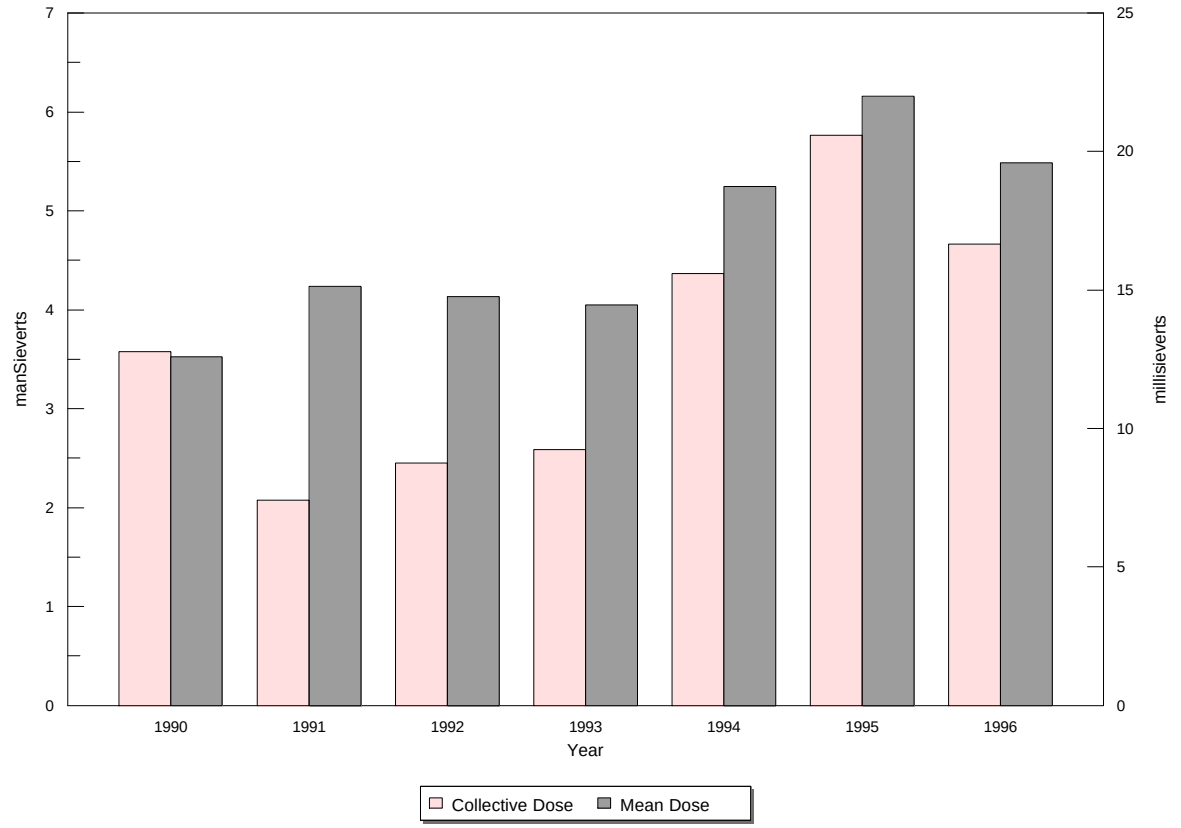


Fig 9B Non-coal mining - % above certain dose levels

(excluding classified persons with a recorded dose less than 0.1 mSv)

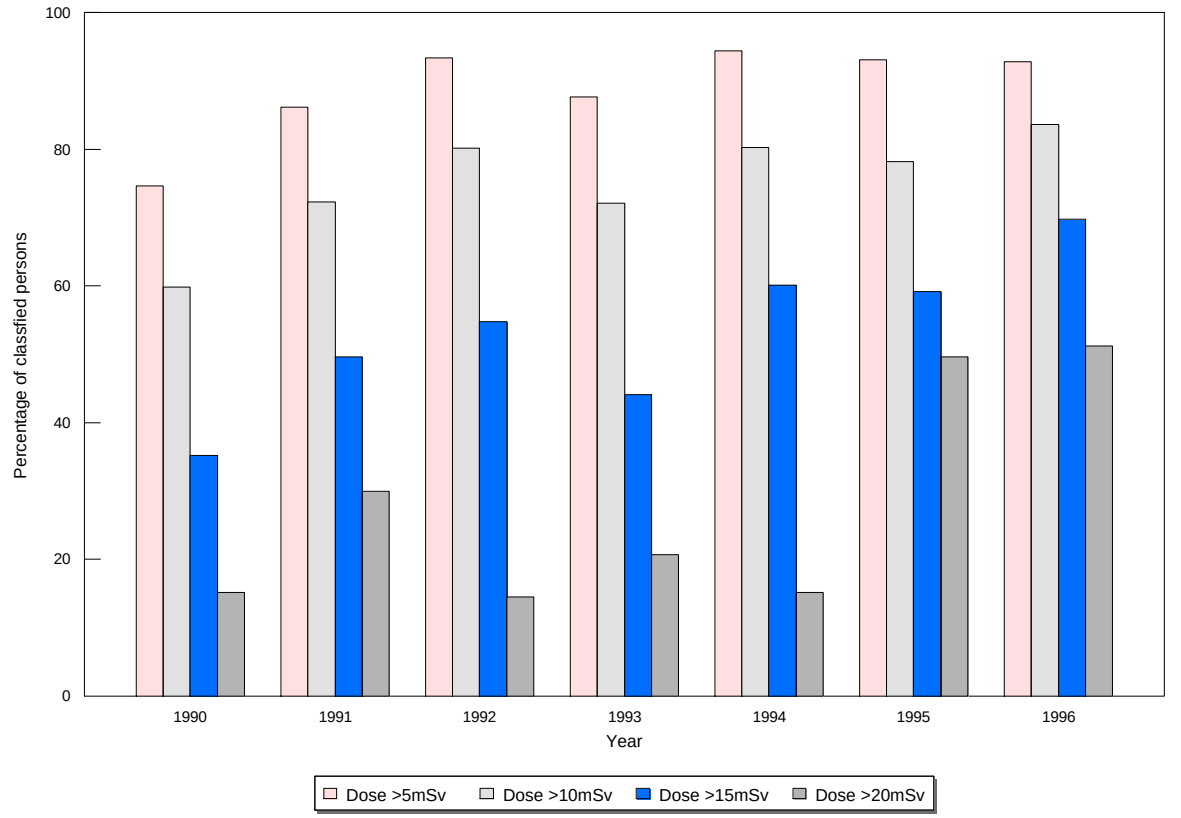


Fig 10 Medical and Dental - Collective Dose and Mean Dose

(excluding classified persons with a recorded dose less than 0.1 mSv)

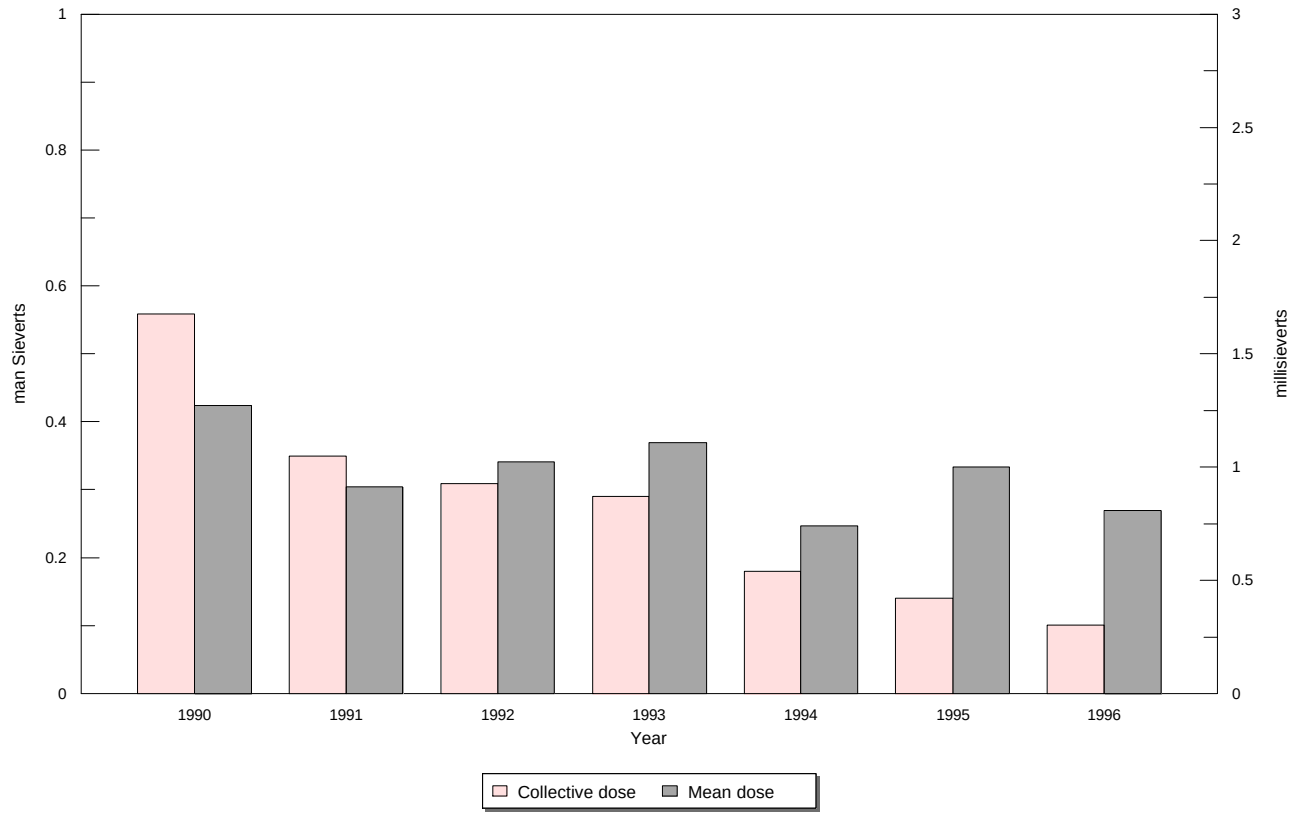


Fig 11 Transport - Collective Dose and Mean Dose

(excluding classified persons with a recorded dose less than 0.1 mSv)

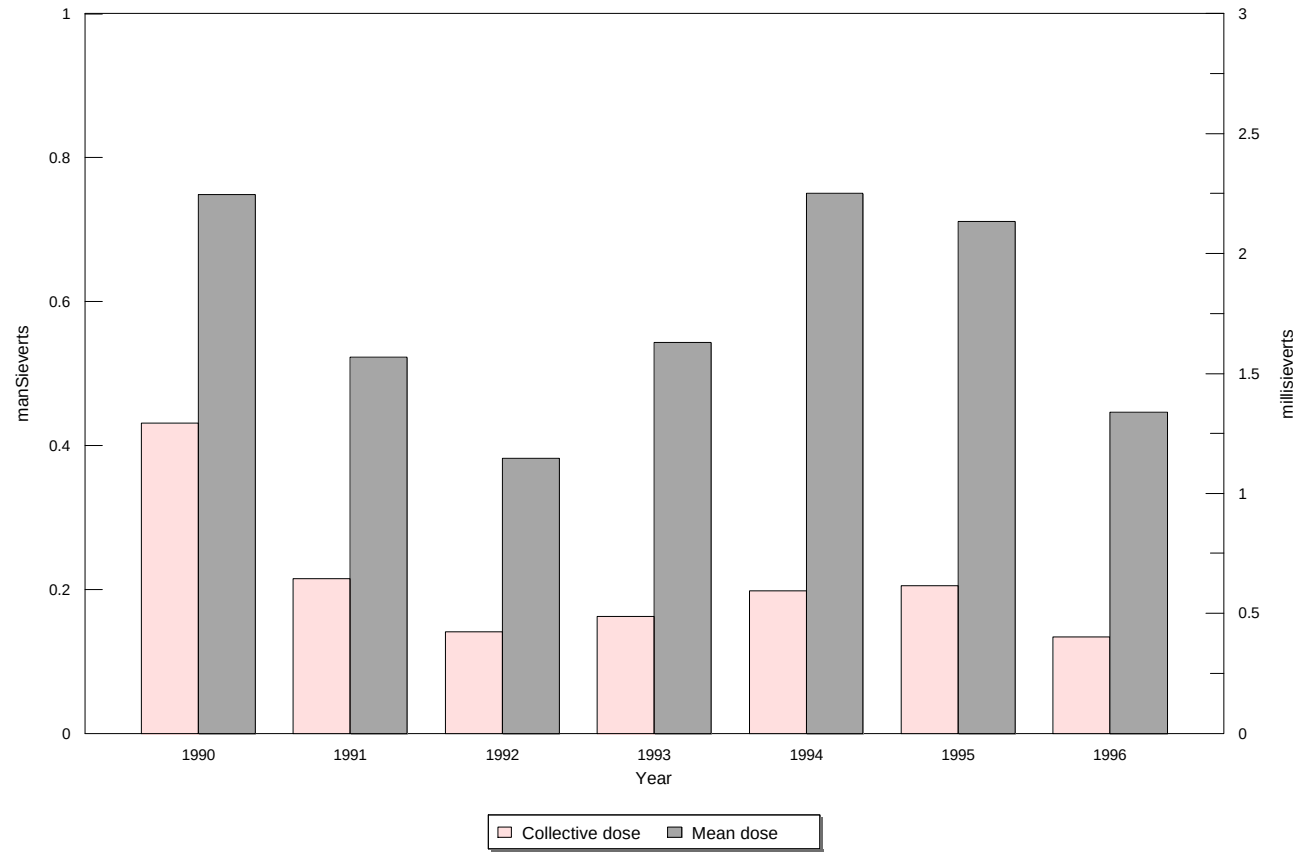


Fig 12 Academic research and teaching - Collective Dose and Mean Dose

(excluding classified persons with a recorded dose less than 0.1 mSv)

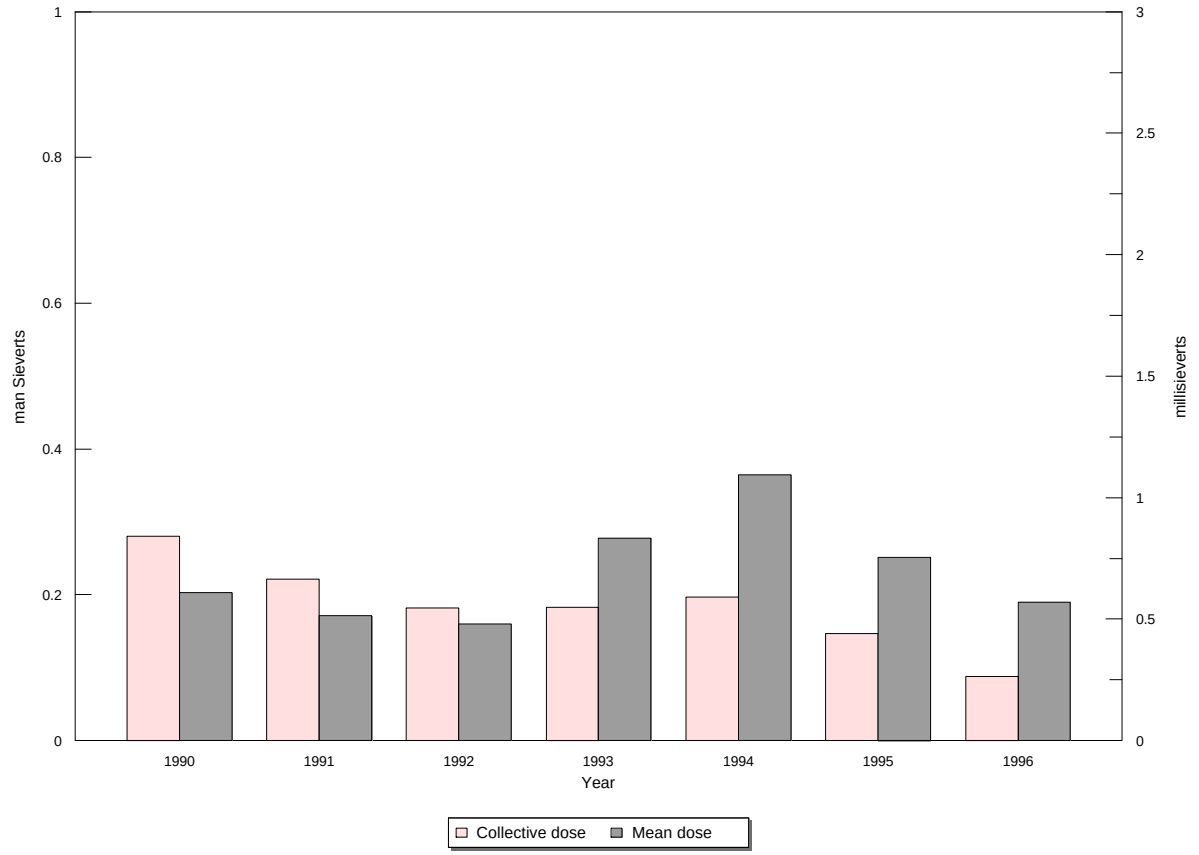


Fig 13 Exposure to neutrons - Collective Dose and Mean Doses

(excluding classified persons with a reported neutron dose of less than 0.1 mSv)

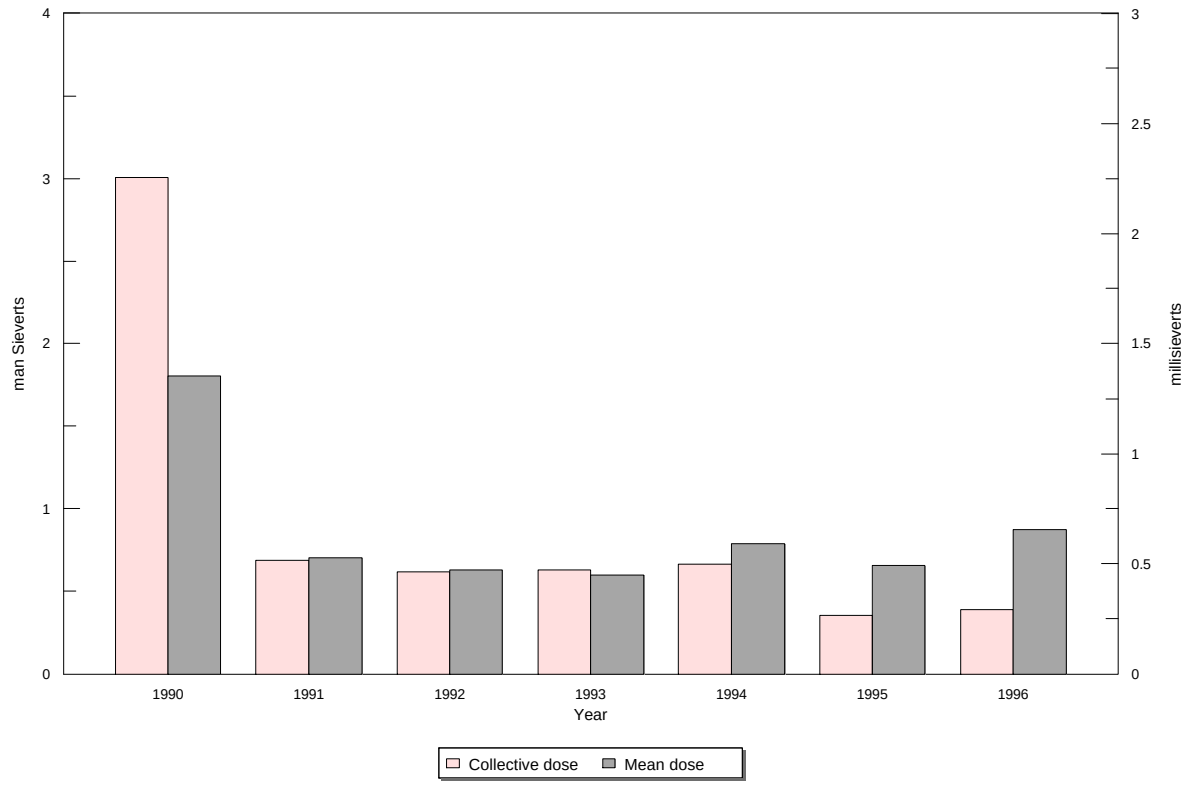


Fig 14A Reported doses > 10 mSv by occupational grouping - 1990

(Total number with reported doses > 10 mSv + 1681)

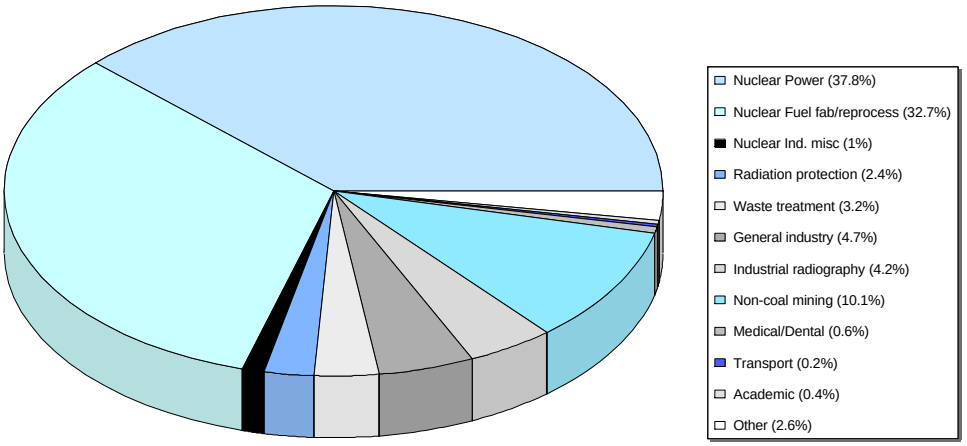
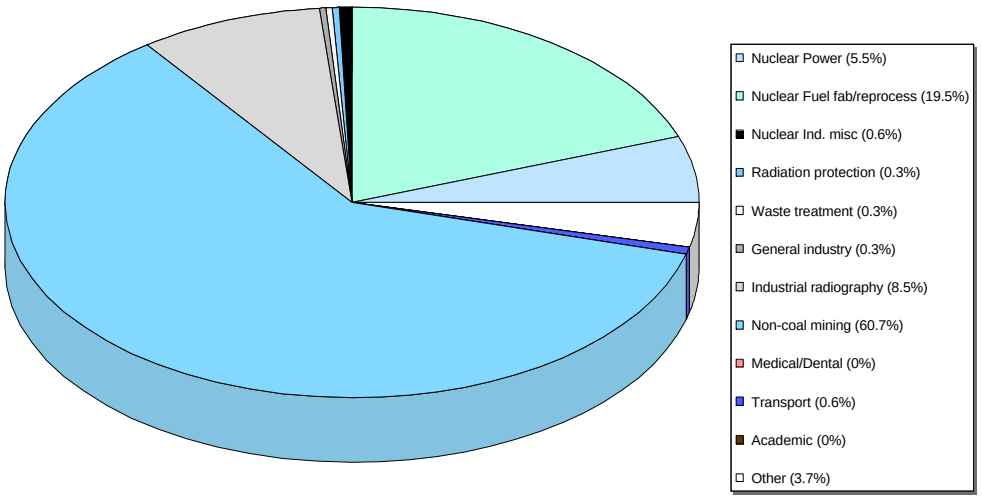


Fig 14B Reported doses > 10mSv by occupational grouping - 1996

(Total number of classified persons with doses > 10 mSv = 328)



Annex 1

OCCUPATIONAL GROUPINGS PRESENTED IN THIS REPORT	
Occupational grouping	**CIDI occupational category**
All classified persons	All occupational categories
Nuclear power	Nuclear reactor operations Nuclear reactor maintenance
Nuclear fuel	Nuclear fuel fabrication Nuclear fuel reprocessing
General industrial	Application and servicing activities of machines producing ionising radiation Application and manipulation of radioactive substances Luminising Industrial research/teaching Other industrial applications
Industrial radiography	Industrial radiography using permanent installations Industrial Radiography on site or works of engineering construction
Non-coal mining	Mining minerals other than coal - underground workers
Medical	Medical application-doctors Medical application-nurses Medical application-radiographers Medical application-physicists and technicians Medical application -other Dental work
Transport	Transport of radioactive sources
Academic	Academic research and teaching
Radiation Protection	Radiation Protection
Waste management	Waste management
Nuclear Industry Misc.	Nuclear decommissioning Nuclear other
Other	Mining coal - surface and underground Offshore work activities Onshore drilling Quarrying Veterinary work Not assigned elsewhere

Annex 2

Tables covering whole body doses for the period 1990-1996

Table 1
Number of classified persons for whom doses were reported

	1990	1991	1992	1993	1994	1995	1996
Total	59563	57393	57276	56776	53340	48791	46806
Total with dose of 0.1 mSv or more	43805	40033	39577	37338	34995	30289	28385

Table 2
Numbers of classified persons (except those with a recorded dose less than 0.1 mSv) - breakdown by occupational grouping

	1990	1991	1992	1993	1994	1995	1996
Nuclear Power	14424	13063	12929	12134	10978	9220	8085
Nuclear Fuel Fabrication/reprocess	7931	7898	8019	7950	8015	6729	6662
General Industry	8053	6586	5911	5307	4829	4500	4448
Industrial radiography	2811	2638	2547	1999	1994	1666	1500
Non-coal mining	284	137	166	179	233	262	238
Medical/dental	439	384	302	262	243	140	125
Transport	192	137	123	100	88	96	100
Academic	460	433	379	220	180	195	155
Radiation Protection	2588	2445	2335	2183	2093	1740	1702
Waste Treatment	1292	1195	1270	1302	1243	1001	1109
Nuclear Industry Misc.	734	744	756	726	560	742	607
Other	4597	4373	4840	4976	4539	3998	3654

Table 3
Dose information for classified persons - excluding those with a recorded dose less than 0.1 mSv

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	83.8	59.5	58.6	51.0	49.0	39.0	36.8
Mean dose in mSv	1.9(1.4)	1.5(1.0)	1.5(1.0)	1.4(0.9)	1.4(0.9)	1.3(0.8)	1.3(0.8)
No. with doses >5 mSv	4660	2965	3042	2458	2193	1715	1511
No. with doses >10 mSv	1681	651	666	461	485	369	328
No. with doses >15 mSv	488	154	138	132	184	179	183
No. with doses >20 mSv	162	77	44	64	134	147	132

Figure in brackets is mean dose for all classified persons * Doses rounded to one decimal place

Table 4
Dose information for classified persons - excluding non-coal miners and classified persons with a recorded dose less than 0.1 mSv

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	80.3	57.4	56.1	48.4	44.6	33.2	32.1
Mean dose in mSv	1.8(1.4)	1.4(1.0)	1.4(1.0)	1.3(0.9)	1.3(0.8)	1.1(0.7)	1.1(0.7)
No. with doses >5 mSv	4448	2847	2887	2301	1973	1471	1290
No. with doses >10 mSv	1511	552	533	332	298	164	129
No. with doses >15 mSv	388	86	47	53	44	24	17
No. with doses >20 mSv	119	36	20	27	24	17	10

Figure in brackets is mean dose for all classified persons * Doses rounded to one decimal place

Table 5
Dose information for classified persons (except those with a recorded dose less than 0.1mSv) - nuclear power

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	28.9	19.6	17.7	16.2	12.7	10.9	9.9
Mean dose in mSv	2.0(1.6)	1.5(1.2)	1.4(1.1)	1.3(1.0)	1.2(0.9)	1.2(0.8)	1.2(0.8)
No. with doses >5 mSv	1708	1114	981	822	592	593	490
No. with doses >10 mSv	636	157	92	66	21	16	18
No. with doses >15 mSv	194	10	4	17	0	1	1
No. with doses >20 mSv	76	3	1	8	0	1	0

Figure in brackets is mean dose for all classified persons * Doses rounded to one decimal place

Table 6
Dose information for classified persons (except those with a recorded dose less than 0.1 mSv) - nuclear fuel/fabrication

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	24.1	16.5	17.8	14.7	15.5	10.0	10.2
Mean dose in mSv	3.0(2.9)	2.1(1.9)	2.2(2.0)	1.8(1.6)	1.9(1.7)	1.5(1.2)	1.5(1.3)
No. with doses >5 mSv	1564	985	1168	858	855	452	395
No. with doses >10 mSv	550	206	287	152	167	96	64
No. with doses >15 mSv	103	11	7	6	5	3	2
No. with doses >20 mSv	7	0	0	2	4	2	1

Figure in brackets is mean dose for all classified persons * Doses rounded to one decimal place

Table 7 Revised October 1998

Dose information for classified persons (except those with a recorded dose less than 0.1 mSv) - General Industrial Activities

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	7.8	5.5	5.0	4.2	3.5	3.4	3.1
Mean dose in mSv	1.0(0.6)	0.8(0.4)	0.8(0.4)	0.8(0.4)	0.7(0.3)	0.8(0.4)	0.7(0.4)
No. with doses >5 mSv	348	209	189	155	130	118	111
No. with doses >10 mSv	79	34	32	11	7	4	16
No. with doses >15 mSv	102	13	8	1	0	1	2
No. with doses >20 mSv	21	10	4	1	0	1	2
Figure in brackets is mean dose for all classified persons	* Doses rounded to one decimal place						

Table 8

Dose information for classified persons (except those with a recorded dose less than 0.1 mSv) - Industrial radiography

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	3.8	4.5	4.1	2.8	2.6	2.4	2.5
Mean dose in mSv	1.4(0.7)	1.7(0.9)	1.6(0.8)	1.4(0.6)	1.3(0.6)	1.4(0.6)	1.6(0.6)
No. with doses >5 mSv	161	199	150	125	108	84	91
No. with doses >10 mSv	72	80	54	45	54	28	28
No. with doses >15 mSv	37	48	22	23	29	16	9
No. with doses >20 mSv	20	22	13	15	15	11	6
Figure in brackets is mean dose for all classified persons	* Doses rounded to one decimal place						

Table 9

Dose information for classified persons (except those with a recorded dose less than 0.1 mSv) - Non-coal mining

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	3.6	2.1	2.4	2.6	4.4	5.8	4.7
Mean dose in mSv	12.6(12.6)	15.1(15.1)	14.8(14.8)	14.5(14.4)	18.7(17.7)	22.0(21.9)	19.5(19.5)
No. with doses >5 mSv	212	118	155	157	220	244	221
No. with doses >10 mSv	170	99	133	129	187	205	199
No. with doses >15 mSv	100	68	91	79	140	155	166
No. with doses >20 mSv	43	41	24	37	110	130	122
Figure in brackets is mean dose for all classified persons	* Doses rounded to one decimal place						

Table 10

Dose information for classified persons (except those with a recorded dose less than 0.1 mSv) - Medical and Dental

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	0.6	0.4	0.3	0.3	0.2	0.1	0.1
Mean dose in mSv	1.3(0.7)	0.9(0.5)	1.0(0.5)	1.1(0.6)	0.7(0.4)	1.0(0.5)	0.8(0.4)
No. with doses >5 mSv	28	8	11	11	6	5	4
No. with doses >10 mSv	10	3	2	5	1	2	0
No. with doses >15 mSv	3	1	1	1	0	0	0
No. with doses >20 mSv	2	0	1	0	0	0	0
Figure in brackets is mean dose for all classified persons	* Doses rounded to one decimal place						

Table 11

Dose information for classified persons (except those with a recorded dose less than 0.1 mSv) - Transport

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	0.4	0.2	0.1	0.2	0.2	0.2	0.1
Mean dose in mSv	2.2(1.9)	1.6(1.1)	1.1(0.8)	1.6(1.0)	2.3(1.4)	2.1(1.4)	1.3(0.9)
No. with doses >5 mSv	36	8	7	9	9	19	10
No. with doses >10 mSv	3	1	3	3	5	7	2
No. with doses >15 mSv	1	0	0	2	3	0	0
No. with doses >20 mSv	1	0	0	1	3	0	0
Figure in brackets is mean dose for all classified persons	* Doses rounded to one decimal place						

Table 12

Dose information for classified persons (except those with a recorded dose less than 0.1 mSv) - Academic research and teaching

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	0.3	0.2	0.2	0.2	0.2	0.1	0.1
Mean dose in mSv	0.6(0.2)	0.5(0.2)	0.5(0.1)	0.8(0.2)	1.1(0.2)	0.8(0.2)	0.6(0.1)
No. with doses >5 mSv	7	4	6	9	7	8	4
No. with doses >10 mSv	6	4	1	3	7	3	0
No. with doses >15 mSv	5	1	0	1	4	0	0
No. with doses >20 mSv	2	1	0	0	1	0	0
Figure in brackets is mean dose for all classified persons	* Doses rounded to one decimal place						

Table 13
Dose information for classified persons (except those with a recorded dose less than 0.1 mSv) - Radiation Protection

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	4.2	3	2.8	2.7	2.8	1.9	1.9
Mean dose in mSv	1.6(1.3)	1.2(1.0)	1.2(1.0)	1.3(1.0)	1.3(1.1)	1.1(0.8)	1.1(0.8)
No. with doses >5 mSv	189	102	116	108	109	74	67
No. with doses >10 mSv	41	17	22	12	12	2	1
No. with doses >15 mSv	8	1	0	1	0	1	1
No. with doses >20 mSv	1	0	0	0	0	1	1
Figure in brackets is mean dose for all classified persons * Doses rounded to one decimal place							

Table 14
Dose information for classified persons (except those with a recorded dose less than 0.1 mSv) - Waste Treatment

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	3.1	1.9	1.6	1.3	1.5	0.8	0.8
Mean dose in mSv	2.4(2.1)	1.6(1.3)	1.2(1.0)	1.0(0.9)	1.2(1.0)	0.8(0.6)	0.7(0.6)
No. with doses >5 mSv	154	76	44	31	20	14	6
No. with doses >10 mSv	53	16	7	8	6	1	1
No. with doses >15 mSv	16	0	0	0	3	0	0
No. with doses >20 mSv	5	0	0	0	1	0	0
Figure in brackets is mean dose for all classified persons * Doses rounded to one decimal place							

Table 15
Dose information for classified persons (except those with a recorded dose less than 0.1 mSv) - Nuclear Industry Misc.

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	1.4	1.2	1.0	0.9	0.6	0.7	0.6
Mean dose in mSv	1.9(1.6)	1.6(1.3)	1.4(1.0)	1.2(0.8)	1.0(0.5)	0.9(0.5)	1.0(0.4)
No. with doses >5 mSv	72	34	36	23	21	26	22
No. with doses >10 mSv	18	7	1	6	5	3	2
No. with doses >15 mSv	3	0	1	0	0	1	2
No. with doses >20 mSv	0	0	0	0	0	1	0
Figure in brackets is mean dose for all classified persons * Doses rounded to one decimal place							

Table 16
Neutron doses (except for those with a recorded dose less than 0.1 mSv)

	1990	1991	1992	1993	1994	1995	1996
Collective Dose in man Sv	3	0.7	0.6	0.6	0.7	0.4	0.4
Mean Dose in mSv	1.4	0.5	0.5	0.4	0.6	0.5	0.7

Table 17
Dose information for classified persons - number with doses > 6 mSv a year

	1990	1991	1992	1993	1994	1995	1996
Number > 6 mSv	0	0	0	0	0	0	0

Annex 3

Tables covering neutron doses for the period 1990-1996

Distribution of EDE + CEDE by dose interval plus collective and mean dose for year 1990
(pro-rata substitution for notional doses)

	0	0.1	1.1	5.1	10.1	15.1	20.1	30.1	50.1	Total	Coll	Mean
	0	1	5	10	15	20	30	50		workers	dose	dose
Indust radiog perm.	1273	974	156	42	12	6	4	1	2	2470	1488	0.6
Indust radiog site	1166	1264	256	47	23	11	9	3	1	2780	2345	0.8
Reactor operations	784	3640	1460	403	190	36	33	1	0	6547	11563	1.8
Reactor maintenance	2484	5457	2159	669	252	82	42	0	0	11145	17307	1.6
Fuel fabrication	137	1177	1609	413	91	1	0	0	0	3428	8511	2.5
Fuel reprocessing	264	2126	1455	601	356	95	6	0	1	4904	15558	3.2
Waste treatment	190	644	494	101	37	11	3	1	1	1482	3084	2.1
Radiation protection	762	1464	935	148	33	7	1	0	0	3350	4234	1.3
Applic + servicing	1727	1039	39	6	7	0	0	0	0	2818	453	0.2
Applic + manip.	1446	1291	398	173	47	4	2	0	0	3361	3216	1
Transport work	33	117	39	33	2	0	1	0	0	225	431	1.9
Offshore work	222	244	13	0	1	0	0	0	0	480	109	0.2
Onshore drilling	17	16	0	0	0	0	0	0	0	33	4	0.1
Coal mining surface	6	1	0	0	0	0	0	0	0	7	0	0
Other mining undgrd.	2	13	59	42	70	57	34	7	2	286	3577	12.5
Dental work	10	39	1	0	0	0	0	0	0	50	15	0.3
Veterinary work	206	131	2	0	0	0	0	0	0	339	34	0.1
Medical - doctors	17	35	21	6	3	0	1	0	0	83	153	1.8
Medical - nurses	6	9	18	6	1	1	0	0	0	41	117	2.9
Medical radiography	61	128	16	3	0	0	0	0	0	208	106	0.5
Medical physics	48	27	8	0	0	0	0	0	0	83	32	0.4
Medical - other	167	105	4	3	3	0	0	1	0	283	136	0.5
Quarrying	4	4	0	0	0	0	0	0	0	8	1	0.1
Academic res + tchg	922	427	26	1	1	3	2	0	0	1382	280	0.2
Industr res + tchg.	1191	2782	593	56	7	6	3	0	0	4638	2792	0.6
Nuclear ind - other	59	156	147	7	3	1	0	0	0	373	416	1.1
Other industrial	842	1240	323	34	3	0	0	0	0	2442	1316	0.5
Others	1626	2629	1376	138	39	3	0	0	0	5811	5560	1
Nuclear decommission	86	180	179	47	12	2	0	0	0	506	1006	2
Total workers	15758	27359	11786	2979	1193	326	141	14	7	59563	83843	1.4
% in each dose interval	26.5	45.9	19.8	5	2	0.5	0.2	0	0			

Distribution of EDE + CEDE by dose interval plus collective and mean dose for year 1991
(pro-rata substitution for notional doses)

	0	0.1	1.1	5.1	10.1	15.1	20.1	30.1	50.1	Total	Coll	Mean
	0	1	5	10	15	20	30	50		workers	dose	dose
Indust radiog perm.	1247	826	173	34	11	13	3	2	4	2313	1743	0.8
Indust radiog site	1313	1174	266	85	21	13	7	4	2	2885	2708	0.9
Reactor operations	871	3738	1211	378	71	6	2	0	0	6277	8186	1.3
Reactor maintenance	3094	5074	1926	579	76	1	0	0	1	10751	11459	1.1
Fuel fabrication	189	1787	1429	224	26	1	0	0	0	3656	6306	1.7
Fuel reprocessing	688	2456	1241	555	169	10	0	0	0	5119	10234	2
Waste treatment	266	711	408	60	16	0	0	0	0	1461	1874	1.3
Radiation protection	661	1655	688	85	16	1	0	0	0	3106	3048	1
Applic + servicing	1776	854	45	6	5	0	0	0	0	2686	403	0.2
Applic + manip.	1328	1215	357	123	10	2	10	0	0	3045	2534	0.8
Transport work	66	77	52	7	1	0	0	0	0	203	215	1.1
Offshore work	329	238	14	1	0	0	0	0	0	582	92	0.2
Onshore drilling	25	12	1	0	0	0	0	0	0	38	3	0.1
Coal mining surface	5	1	0	0	0	0	0	0	0	6	0	0
Other mining undgrd.	4	3	16	19	31	27	38	3	0	141	2074	14.7
Dental work	14	38	4	0	0	0	0	0	0	56	20	0.3
Veterinary work	234	98	2	0	0	0	0	0	0	334	21	0.1
Medical - doctors	21	54	13	1	2	1	0	0	0	92	107	1.2
Medical - nurses	3	11	24	3	0	0	0	0	0	41	89	2.2
Medical radiography	81	122	11	1	0	0	0	0	0	215	74	0.3
Medical physics	45	23	7	0	0	0	0	0	0	75	19	0.3
Medical - other	112	57	12	0	0	0	0	0	0	181	41	0.2
Quarrying	4	4	0	0	0	0	0	0	0	8	1	0.2
Academic res + tchg	973	402	27	0	3	0	1	0	0	1406	222	0.2
Industr res + tchg.	1576	2133	311	29	3	0	0	0	0	4052	1565	0.4
Nuclear ind - other	85	162	150	3	1	0	0	0	0	401	400	1
Other industrial	967	1301	161	17	3	1	0	0	0	2450	970	0.4
Others	1295	2862	1033	80	26	1	0	0	0	5297	4275	0.8
Nuclear decommission	88	229	169	24	6	0	0	0	0	516	780	1.5
Total workers	17360	27317	9751	2314	497	77	61	9	7	57393	59463	1
% in each dose interval	30.2	47.6	17	4	0.9	0.1	0.1	0	0			

Distribution of EDE + CEDE by dose interval plus collective and mean dose for year 1992
(pro-rata substitution for notional doses)

	0	0.1	1.1	5.1	10.1	15.1	20.1	30.1	50.1	Total	Coll	Mean
	0	1	5	10	15	20	30	50		workers	dose	dose
Indust radiog perm.	1091	732	168	31	11	5	5	1	2	2046	1721	0.8
Indust radiog site	1350	1208	289	65	21	4	1	3	1	2942	2391	0.8
Reactor operations	827	3947	1084	291	37	0	0	0	0	6186	6540	1.1
Reactor maintenance	2698	5101	1816	598	51	3	0	1	0	10268	11112	1.1
Fuel fabrication	245	1898	1274	307	50	0	0	0	0	3774	6714	1.8
Fuel reprocessing	733	2487	1192	574	230	7	0	0	0	5223	11042	2.1
Waste treatment	257	829	397	37	7	0	0	0	0	1527	1566	1
Radiation protection	685	1613	606	94	22	0	0	0	0	3020	2870	1
Applic + servicing	1641	743	39	10	9	0	0	0	0	2442	429	0.2
Applic + manip.	1263	1090	329	94	11	4	1	3	0	2795	2213	0.8
Transport work	54	102	14	4	3	0	0	0	0	177	141	0.8
Offshore work	385	269	11	0	1	0	0	0	0	666	96	0.1
Onshore drilling	21	10	0	0	0	0	0	0	0	31	1	0
Coal mining surface	5	1	0	0	0	0	0	0	0	6	0	0
Other mining undgrd.	0	1	10	22	42	67	24	0	0	166	2449	14.8
Dental work	17	28	2	1	0	0	0	0	0	48	18	0.4
Veterinary work	221	85	1	0	0	0	0	0	0	307	16	0.1
Medical - doctors	27	45	13	3	1	0	1	0	0	90	111	1.2
Medical - nurses	5	12	21	4	0	0	0	0	0	42	92	2.2
Medical radiography	68	79	7	0	0	0	0	0	0	154	37	0.2
Medical physics	44	21	1	0	0	0	0	0	0	66	11	0.2
Medical - other	99	53	9	1	0	0	0	0	0	162	40	0.2
Quarrying	2	3	0	0	0	0	0	0	0	5	1	0.1
Academic res + tchg	992	351	22	5	1	0	0	0	0	1371	182	0.1
Industr res + tchg.	2107	1752	252	35	3	0	0	0	0	4149	1298	0.3
Nuclear ind - other	93	184	159	11	0	0	0	0	0	447	427	1
Other industrial	1170	1337	180	18	1	0	0	0	0	2706	1010	0.4
Others	1453	3005	1276	147	27	3	0	0	1	5912	5426	0.9
Nuclear decommission	146	219	158	24	0	1	0	0	0	548	598	1.1
Total workers	17699	27205	9330	2376	528	94	32	8	4	57276	58550	1
% in each dose interval	30.9	47.5	16.3	4.1	0.9	0.2	0.1	0	0			

Distribution of EDE + CEDE by dose interval plus collective and mean dose for year 1993
(pro-rata substitution for notional doses)

	0	0.1	1.1	5.1	10.1	15.1	20.1	30.1	50.1	Total	Coll	Mean
	0	1	5	10	15	20	30	50		workers	dose	dose
Indust radiog perm.	1223	469	115	26	7	1	4	1	1	1847	1040	0.6
Indust radiog site	1468	1066	224	54	15	7	6	3	0	2843	1804	0.6
Reactor operations	1109	3492	982	347	5	0	0	0	0	5935	6056	1
Reactor maintenance	2630	5021	1817	409	44	9	8	0	0	9938	10152	1
Fuel fabrication	531	1876	1134	170	3	0	0	0	0	3714	4682	1.3
Fuel reprocessing	783	2903	1179	536	143	4	1	1	0	5550	9976	1.8
Waste treatment	242	917	354	23	8	0	0	0	0	1544	1340	0.9
Radiation protection	644	1444	631	96	11	1	0	0	0	2827	2745	1
Applic + servicing	1725	376	62	16	0	0	0	0	0	2179	381	0.2
Applic + manip.	1346	1010	299	96	10	0	0	0	0	2761	1914	0.7
Transport work	60	68	23	6	1	1	1	0	0	160	163	1
Offshore work	488	185	5	0	0	0	0	0	0	678	59	0.1
Onshore drilling	39	11	0	0	0	0	0	0	0	50	3	0.1
Coal mining surface	8	0	0	0	0	0	0	0	0	8	0	0
Other mining undgrd.	1	7	15	28	50	42	29	8	0	180	2588	14.4
Dental work	8	35	4	0	0	0	0	0	0	47	25	0.5
Veterinary work	246	31	0	0	0	0	0	0	0	277	6	0
Medical - doctors	24	41	17	1	3	1	0	0	0	87	111	1.3
Medical - nurses	4	9	19	3	1	0	0	0	0	36	83	2.3
Medical radiography	67	62	5	0	0	0	0	0	0	134	33	0.2
Medical physics	39	14	2	0	0	0	0	0	0	55	10	0.2
Medical - other	114	39	4	2	0	0	0	0	0	159	28	0.2
Quarrying	2	0	1	0	0	0	0	0	0	3	1	0.4
Academic res + tchg	916	194	17	6	2	1	0	0	0	1136	183	0.2
Industr res + tchg.	1895	1824	189	19	0	0	1	0	0	3928	1087	0.3
Nuclear ind - other	119	216	130	2	1	0	0	0	0	468	333	0.7
Other industrial	1325	1241	151	13	0	0	0	0	0	2730	811	0.3
Others	2186	3438	1155	129	20	1	0	0	0	6929	4848	0.7
Nuclear decommission	196	217	140	15	5	0	0	0	0	573	541	0.9
Total workers	19438	26206	8674	1997	329	68	50	13	1	56776	51004	0.9
% in each dose interval	34.2	46.2	15.3	3.5	0.6	0.1	0.1	0	0			

Distribution of EDE + CEDE by dose interval plus collective and mean dose for year 1994
(pro-rata substitution for notional doses)

	0	0.1	1.1	5.1	10.1	15.1	20.1	30.1	50.1	Total	Coll	Mean
	0	1	5	10	15	20	30	50		workers	dose	dose
Indust radiog perm.	1045	517	123	18	6	4	4	1	1	1719	918	0.5
Indust radiog site	1350	1025	221	36	19	10	6	3	0	2670	1725	0.6
Reactor operations	947	3317	920	268	7	0	0	0	0	5459	5480	1
Reactor maintenance	2782	4820	1329	303	14	0	0	0	0	9248	7246	0.8
Fuel fabrication	446	1895	1074	102	1	0	0	0	0	3518	3906	1.1
Fuel reprocessing	548	2399	1792	586	161	1	1	3	0	5491	11566	2.1
Waste treatment	293	717	506	14	3	2	1	0	0	1536	1515	1
Radiation protection	546	1318	666	97	12	0	0	0	0	2639	2789	1.1
Applic + servicing	1352	427	41	18	0	0	0	0	0	1838	372	0.2
Applic + manip.	1081	907	255	90	7	0	0	0	0	2340	1682	0.7
Transport work	49	63	16	4	2	0	2	1	0	137	198	1.4
Offshore work	367	166	31	23	4	0	0	0	0	591	345	0.6
Onshore drilling	41	12	3	1	0	0	0	0	0	57	22	0.4
Coal mining surface	4	4	0	0	0	0	0	0	0	8	1	0.1
Other mining undgrd.	13	0	13	33	47	30	85	25	0	246	4365	17.7
Dental work	11	43	2	0	0	0	0	0	0	56	22	0.4
Veterinary work	202	41	0	0	0	0	0	0	0	243	6	0
Medical - doctors	27	45	8	2	1	0	0	0	0	83	57	0.7
Medical - nurses	2	7	10	1	0	0	0	0	0	20	31	1.6
Medical radiography	60	62	7	0	0	0	0	0	0	129	34	0.3
Medical physics	25	12	2	0	0	0	0	0	0	39	9	0.2
Medical - other	98	37	2	2	0	0	0	0	0	139	27	0.2
Quarrying	2	4	0	0	0	0	0	0	0	6	1	0.2
Academic res + tchg	879	149	24	0	3	3	1	0	0	1059	197	0.2
Industr res + tchg.	1828	1627	124	10	0	0	0	0	0	3589	784	0.2
Nuclear ind - other	302	225	35	1	0	0	0	0	0	563	159	0.3
Other industrial	1306	1189	129	5	0	0	0	0	0	2629	710	0.3
Others	2439	2727	1435	79	9	0	0	0	0	6689	4340	0.6
Nuclear decommission	310	183	96	15	5	0	0	0	0	599	452	0.8
Total workers	18345	23938	8864	1708	301	50	100	33	1	53340	48958	0.9
% in each dose interval	34.4	44.9	16.6	3.2	0.6	0.1	0.2	0.1	0			

Distribution of EDE + CEDE by dose interval plus collective and mean dose for year 1995
(pro-rata substitution for notional doses)

	0	0.1	1.1	5.1	10.1	15.1	20.1	30.1	50.1	Total	Coll	Mean
	0	1	5	10	15	20	30	50		workers	dose	dose
Indust radiog perm.	1006	401	90	17	5	1	1	0	2	1523	789	0.5
Indust radiog site	1446	837	254	39	7	4	4	2	2	2595	1601	0.6
Reactor operations	957	2518	684	237	4	0	0	0	0	4400	4159	0.9
Reactor maintenance	3012	4214	1211	340	11	0	1	0	0	8789	6724	0.8
Fuel fabrication	489	1793	848	33	0	0	0	0	0	3163	2794	0.9
Fuel reprocessing	1180	2593	1043	323	93	1	0	0	2	5235	7189	1.4
Waste treatment	441	783	204	13	1	0	0	0	0	1442	802	0.6
Radiation protection	616	1290	376	72	1	0	0	0	1	2356	1866	0.8
Applic + servicing	1259	269	27	14	0	0	0	1	0	1570	289	0.2
Applic + manip.	859	651	248	84	3	0	0	0	0	1845	1518	0.8
Transport work	46	69	8	12	7	0	0	0	0	142	205	1.4
Offshore work	355	277	41	0	0	0	0	0	0	673	186	0.3
Onshore drilling	52	12	2	0	1	0	0	0	0	67	21	0.3
Coal mining surface	2	0	0	0	0	0	0	0	0	2	0	0
Other mining undgrd.	1	1	17	39	50	25	55	75	0	263	5759	21.9
Dental work	8	2	2	0	0	0	0	0	0	12	4	0.3
Veterinary work	190	43	1	0	0	0	0	0	0	234	9	0
Medical - doctors	31	30	7	2	1	0	0	0	0	71	51	0.7
Medical - nurses	0	5	8	0	1	0	0	0	0	14	30	2.1
Medical radiography	28	23	4	1	0	0	0	0	0	56	20	0.4
Medical physics	13	19	3	0	0	0	0	0	0	35	14	0.4
Medical - other	81	28	4	0	0	0	0	0	0	113	21	0.2
Quarrying	3	3	0	0	0	0	0	0	0	6	1	0.1
Academic res + tchg	723	171	16	5	3	0	0	0	0	918	147	0.2
Industr res + tchg.	1428	1754	173	8	0	0	0	0	0	3363	950	0.3
Nuclear ind - other	237	364	48	5	0	0	1	0	0	655	245	0.4
Other industrial	1274	1144	116	8	0	0	0	0	0	2542	646	0.3
Others	2469	3105	436	76	0	1	0	0	0	6087	2530	0.4
Nuclear decommission	296	220	84	18	2	0	0	0	0	620	434	0.7
Total workers	18502	22619	5955	1346	190	32	62	78	7	48791	39001	0.8
% in each dose interval	37.9	46.4	12.2	2.8	0.4	0.1	0.1	0.2	0			

Distribution of EDE + CEDE by dose interval plus collective and mean dose for year 1996
(pro-rata substitution for notional doses)

	0	0.1	1.1	5.1	10.1	15.1	20.1	30.1	50.1	Total	Coll	Mean
	0	1	5	10	15	20	30	50		workers	dose	dose
Indust radiog perm.	969	356	84	20	5	0	1	0	3	1438	931	0.6
Indust radiog site	1485	701	268	43	14	3	0	0	2	2516	1526	0.6
Reactor operations	981	2225	654	193	6	1	0	0	0	4060	3837	0.9
Reactor maintenance	3546	3523	1193	279	11	0	0	0	0	8552	6092	0.7
Fuel fabrication	606	1556	767	20	0	0	0	0	0	2949	2396	0.8
Fuel reprocessing	759	2711	1233	311	62	1	0	0	1	5078	7756	1.5
Waste treatment	260	884	219	5	1	0	0	0	0	1369	798	0.6
Radiation protection	501	1226	409	66	0	0	0	1	0	2203	1855	0.8
Applic + servicing	1255	190	27	15	0	0	0	0	0	1487	219	0.1
Applic + manip.	810	681	218	72	0	0	0	1	0	1782	1280	0.7
Transport work	46	80	10	8	2	0	0	0	0	146	134	0.9
Offshore work	337	204	173	4	0	0	0	1	0	719	533	0.7
Onshore drilling	60	5	1	0	0	0	0	0	0	66	3	0.1
Coal mining surface	0	1	0	0	0	0	0	0	0	1	0	0.2
Other mining undgrd.	1	5	14	22	33	44	101	21	0	239	4664	19.5
Dental work	7	1	1	0	0	0	0	0	0	9	2	0.2
Veterinary work	204	20	1	0	0	0	0	0	0	225	6	0
Medical - doctors	15	37	1	2	0	0	0	0	0	55	31	0.6
Medical - nurses	7	3	3	1	0	0	0	0	0	14	17	1.2
Medical radiography	23	22	3	0	0	0	0	0	0	48	16	0.3
Medical physics	10	21	2	0	0	0	0	0	0	33	14	0.4
Medical - other	70	24	3	1	0	0	0	0	0	98	21	0.2
Quarrying	4	4	0	0	0	0	0	0	0	8	1	0.2
Academic res + tchg	747	140	11	4	0	0	0	0	0	902	88	0.1
Industr res + tchg.	895	1847	154	6	0	0	0	0	0	2902	852	0.3
Nuclear ind - other	507	267	35	4	1	0	0	0	0	814	201	0.2
Other industrial	1154	1097	123	17	0	0	0	0	0	2391	704	0.3
Others	2797	2795	358	74	9	2	0	0	0	6035	2389	0.4
Nuclear decommissioni	365	201	82	16	1	0	0	0	0	665	400	0.6
Total workers	18421	20827	6047	1183	145	51	102	24	6	46806	36763	0.8
% in each dose interval	39.4	44.5	12.9	2.5	0.3	0.1	0.2	0.1	0			