Health and Safety Executive

Occupational exposure to ionising radiation

Exposures among classified UK workers as reported to the Central index of Dose Information (CIDI), 2015

Contents

Summary

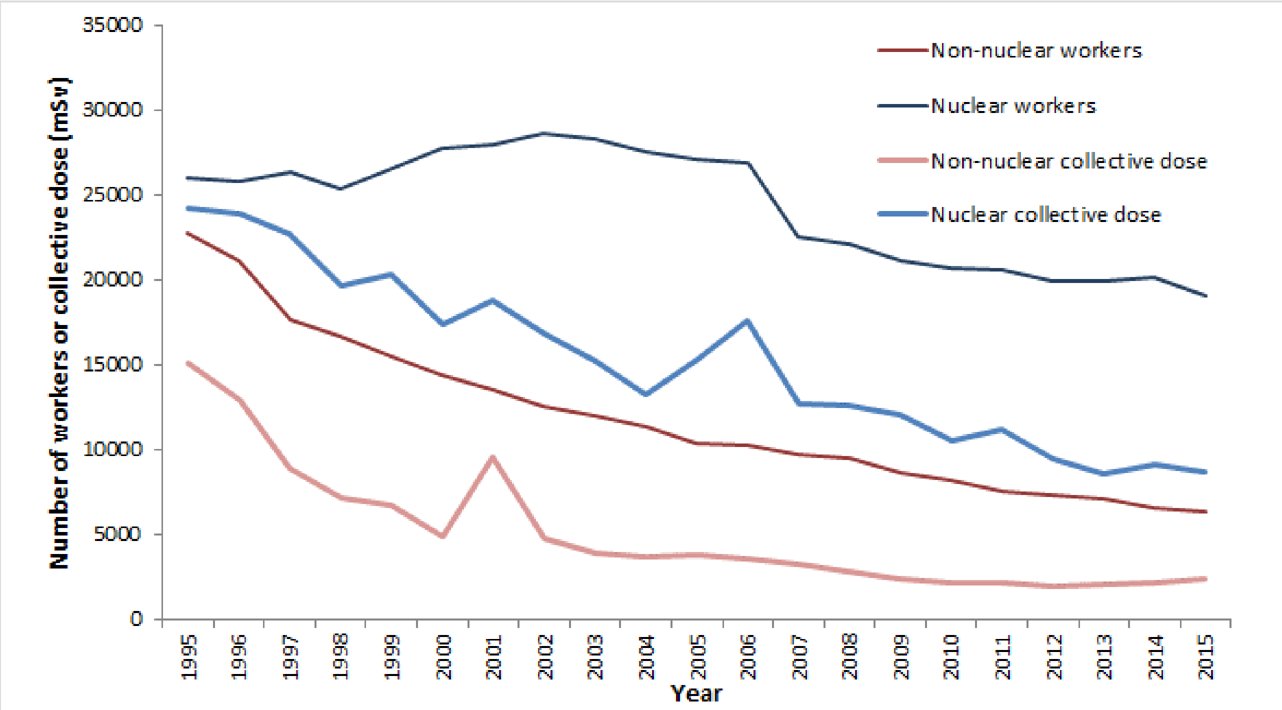
The information in this document relates to Health and Safety statistics for 2015/16. The document can be found at: www.hse.gov.uk/statistics/ionising-radiation/

- Here we publish data on classified workers exposed to ionising radiation for the period 2005-2015, the last such data was published for 2004.

The latest information shows in 2015:

- There were 7879 classified nuclear workers with a zero dose and 11219 with a non-zero dose, the figures for non-nuclear workers were 4118 and 2259 respectively.
- Non-nuclear covers six broad industrial categories: Dental, Medical and Veterinary; Research and teaching; Mining/drilling/quarrying; General Industrial; Non-Destructive testing (NDT) and Other.
- The mean annual dose was 0.4 millisieverts (mSv); 0.5 mSv for nuclear and 0.4 mSv for non-nuclear with the mean non-zero annual doses being 0.8 mSv for nuclear and increasing to 1.0 mSv for non-nuclear.
- The annual number of classified workers has declined; since 2005 from around 27200 to 19900 for nuclear and from 10500 to 6400 for non-nuclear.
- The numbers reporting zero dose have remained broadly similar since 2005, the decline in overall numbers means that they form an increasing proportion, in particular for non-nuclear where now they account for two thirds of classified workers.

Figure 1: Number of classified workers and collective dose (mSv), 1995-2015



Introduction and background

The Health and Safety Executive (HSE) and the Office for Nuclear Regulation (ONR) enforce health and safety law on an employer's responsibility to control exposure of their workers, and other people who might be affected by their work, to ionising radiation that arises from its use of radioactive materials and radiation generators in its work activities – this includes work in the nuclear industry where ONR is the enforcing authority; medical and dental practice; manufacturing; construction; engineering; offshore drilling; education and non-destructive testing where HSE is the enforcing authority.

Strict control measures for any work with radiation are required by the Ionising Radiations Regulations 1999 (IRR99), which include the need for workers who are at risk of significant exposure to be designated as "classified persons" who are then subject to formal radiation exposure monitoring arrangements.

The Central Index of Dose Information (CIDI) is the HSE's database of occupational exposure of classified workers to ionising radiation in the United Kingdom. The purpose of CIDI is to maintain a life-long radiation exposure history for all UK classified workers and to facilitate statistical analyses of occupational radiation exposure.

This document summarises the latest statistical information about radiation doses of UK workers based on data from CIDI. The emphasis here is on the newly published data for the period 2005-2015 and on whole body doses

Arrangements for monitoring radiation doses

The Ionising Radiations Regulations require employers to make arrangements for radiation dose monitoring of their classified workers and to make arrangements with an HSE Approved Dosimetry Service (ADS) for obtaining such data and storing it securely. These arrangements must include the provision by the employer's ADS of annual radiation exposure summaries to CIDI.

Exposure of the human body to ionising radiation can occur different ways, for example, uniform external irradiation of the whole body or irradiation of specific organs or tissue as a result of either external or internal radiations sources.

The most common form of dose assessment is from measurements made by external body dosimeters (usually thermoluminescent (TLD) or an electronic device) worn by workers during their work with radiation. However, an ADS may be approved for other kinds of measurement, such as bio-assay, whole or partial body monitoring for internal radionuclides and personal or static air monitoring.

Measurement and assessment of radiation dose

The fundamental quantity in the measurement of ionising radiation is the radiation absorbed dose which is defined as the energy deposited in matter per unit mass. The quantity is measured in gray (Gy) and is defined as the absorption of 1 Joule of energy by 1 Kilogramme of matter.

However, for the purposes of radiological protection, radiation doses are typically estimated using a related unit known as the Sievert (Sv). This takes into the account the biological effect of different kinds of radiation absorbed by different types of human tissue, and relates to the probability of cancer induction such that a dose of 1Sv confers a lifetime risk of cancer of approximately 5% (International Commission on Radiological Protection ICRP 103).

The overall measure for the purposes of radiological protection is the Whole Body Dose (shown in Table CIDI01, and the main focus of this commentary) which incorporates radiation absorbed externally by different parts of the body and any radiation absorbed internally. Tables CIDI02-CIDI11 show certain components of the whole body dose for particular body sites where these were separately assessed for workers. More details of the various summary measures of a worker's radiation dose that are used in the context of radiological protection and are relevant to the statistics in this report is given at the beginning of the Appendix.

Overview of statistical information and tables

This document summarises information about radiation doses among classified workers based on annual extracts of information from the CIDI database for the years 2005 to 2015. Data are summarised visually in charts, the detailed tabulated data that are also available in Excel format are listed in table 1.

A simplified set of eleven tables has been developed to summarise the data for each year during the period 2005 to 2015. A wider set of tables summarising data for earlier years from 1997 to 2004 are also available at http://www.hse.gov.uk/radiation/ionising/doses/cidi.htm. Details of the latest tables and how these relate to the tables for earlier years are shown in Table 1 below.

The tables show the number of classified persons in each year broken down by dose band and occupation within the following industrial sectors:

- Nuclear (Including contractors)
- Dental, Medical and Veterinary
- Research and teaching
- Mining/drilling/quarrying
- General Industrial
- Non-Destructive testing (NDT)
- Other

Whilst the main purpose of CIDI is to monitor the lifetime history of ionising radiation exposure to classified workers, occupational categorisation is a secondary consideration and can be quite variable. Additionally some workers whilst classified in non-nuclear sector may do some work in the nuclear sector where their greatest exposures may lie. Later on we analyse classified workers by nuclear and non-nuclear categorisation and so it should be borne in mind that such categorisations are not always accurate.

The data within the various dose ranges of the tables are expressed in millisieverts (mSv). Mean and collective dose are rounded to the nearest 0.1 mSv and the nearest mSv respectively. Values given as a percentage are rounded to the nearest 0.1%.

The zero dose category is based on doses reported to CIDI after rounding to the nearest tenth of a millisievert, which means that non-zero doses less than 0.05 mSv are recorded as zero along with no-exposure at all. The use of summary data means that there is no way of telling what proportion low risk exposure jobs form of those reported as having a zero dose.

Table 1: summary of available statistical tables for the period 2005-2015

Table number	Table number for pre 2005 data summaries*	Description
CIDI01	A2	Distribution of Whole Body Dose (EDE+CEDE) by dose interval
CIDI02	A3	Distribution of Effective Dose Equivalent (EDE) from neutron by dose interval
CIDI03	A4	Distribution of Committed Effective Dose Equivalent (CEDE) from radon by dose interval
CIDI04	A5	Distribution of Committed Effective Dose Equivalent (CEDE) by dose interval
CIDI05	C1	Distribution of Equivalent Dose (DE) to skin (whole body) by dose interval
CIDI06	C2	Distribution of Equivalent Dose (DE) to lens of the eye by dose interval
CIDI07		Distribution of maximum of
	C3	Equivalent Dose (DE) to left hand/forearm by dose interval
	C4	Equivalent Dose (DE) to right hand/forearm by dose interval
	C5	Equivalent Dose (DE) to left foot/ankle by dose interval
	C6	Equivalent Dose (DE) to right foot/ankle by dose interval
CIDI08	C7	Distribution of DE + CDE to lung by dose interval plus collective and mean dose
CIDI09	C8	Distribution of DE + CDE to bone surface by dose interval
CIDI10	C9	Distribution of DE + CDE to liver by dose interval
CIDI11	C10	Distribution of DE + CDE to thyroid by dose interval

*See http://www.hse.gov.uk/radiation/ionising/doses/cidi.htm for details of earlier tables.

In 2015 there were 3017 new classified workers, 6916 who stopped being classified workers, which included 731 of the newly classified workers. (Corresponding figures for 2014 were 3751, 4471, and 706 respectively.)

As a guide to the scale of the number of workers included in the 11 tables CIDI01-CIDI11 each year, Table 2 shows the number of nuclear and non-nuclear workers included for 2015, along with the mean dose (where calculated).

Table 2: Summary of the number of workers with zero and non-zero recorded annual radiation dose and mean dose for nuclear and non-nuclear workers in 2015

2015	Nuclear classified worker numbers				Non-Nuclear classified worker numbers			
Table	Zero	Non-zero	Mean dose	Mean non-zero dose	Zero	Non-zero	Mean dose	Mean non-zero dose
CIDI01	7879	11219	0.5	0.8	4118	2259	0.4	1.0
CIDI02	653	118	0.0	0.3	1051	55	0.0	0.8
CIDI03	0	0			0	69	6.3	6.3
CIDI04	995	358	0.1	0.3	636	9	0.0	0.3
CIDI05	5559	11061	0.8	1.1	2930	1699	2.7	7.2
CIDI06	1268	7178	0.8	0.9	21	44	3.9	5.8
CIDI07	123	1828	3.1	3.3	243	327	11.7	20.3
CIDI08	Zero in 2015, and zero or small numbers for earlier years.							
CIDI09								
CIDI10								
CIDI11								

Overall number of classified workers

The overall number of classified workers each year during the 20-year period 1995-2015 and their annual collective dose in mSv is shown for nuclear and non-nuclear workers in Figure 1 below. The overall number of workers and their collective radiation dose in each year has tended to decline for both nuclear and non-nuclear during this period.

Over recent years non-nuclear has shown a greater decline in the numbers of workers compared to the collective dose i.e. the average annual dose has increased.

Figure 1 is shown for the years 1995-2015 rather than 1986-2015, to illustrate the trends more clearly. (The latter range would start with a 1986 nuclear collective dose of about three times the 1995 figure, two times for the non-nuclear collective dose.)

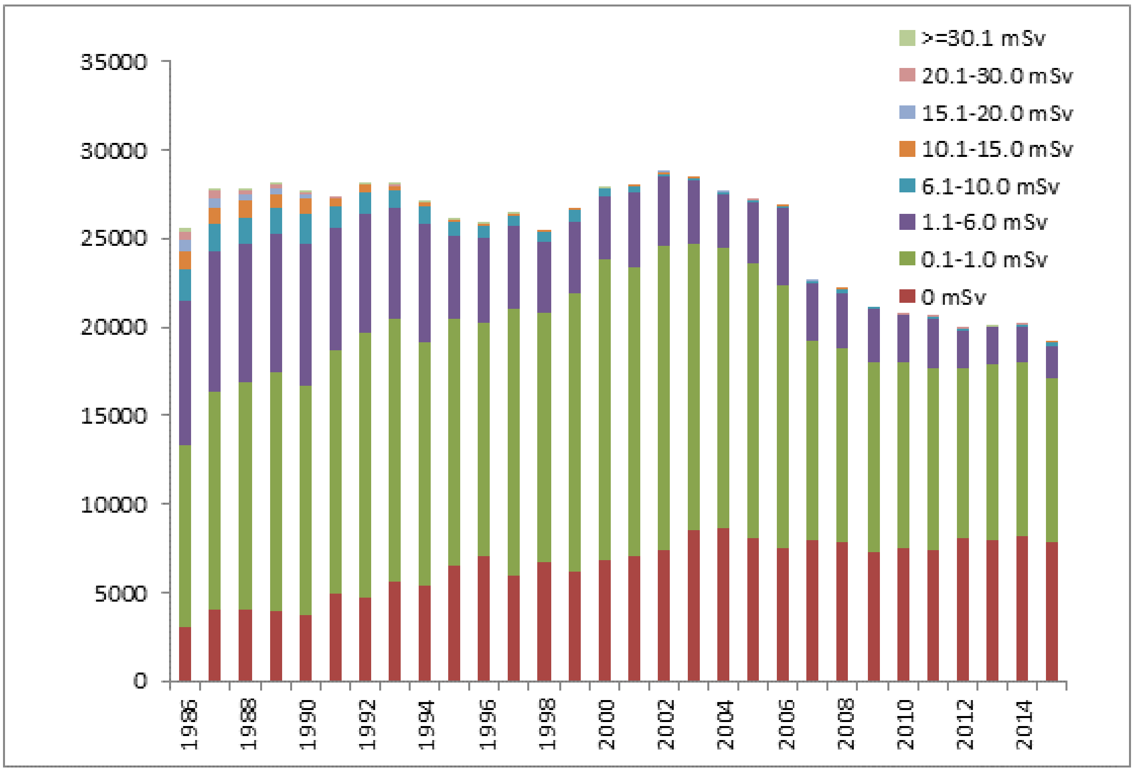
Classified Nuclear workers

In 2015 there were 19,098 classified nuclear workers of which 7879 had a zero dose and 11,219 a non-zero dose. Figure 2 shows the decline in overall numbers since 1986, in particular note the decline in numbers in the higher exposure bands. The numbers in the zero exposure band have increased since 1986, but have remained at around or up to 10% below the current level since 2005.

The overall nuclear figures give the best indication of trends. Occupational classifications cannot be wholly relied upon, in particular this applies to the nuclear sub-sectors. In 2015 the number of classified workers were split amongst these nuclear occupational category sub-sectors as follows:

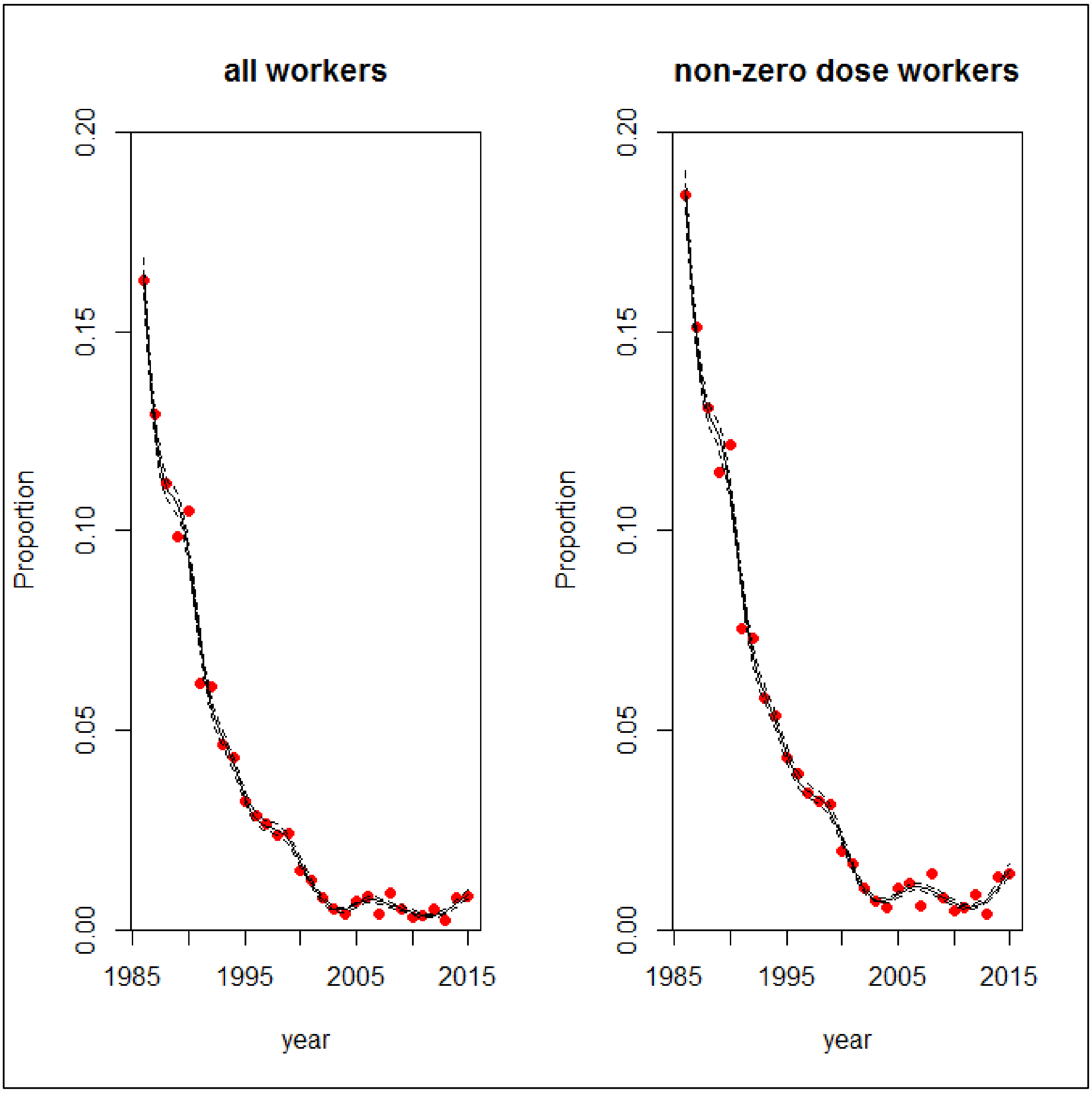
- Nuclear site radiography: 106
- Nuclear reactor operations: 4374
- Nuclear reactor maintenance: 1705
- Nuclear fuel fabrication: 860
- Nuclear fuel reprocessing: 3084
- Other nuclear industry work: 5184
- Nuclear decommissioning: 3785.

Figure 2: Classified Nuclear workers by dose band 1986-2015



The decline in the collective dose from 25 Sv in 1986 to 8.7 Sv in 2015 is shown in Figure 1.

Figure 3: Proportion of classified nuclear workers with doses above 6 mSv (30% of the current dose limit), 1986-2015



The smoothing models shown as black lines in Figure 3 (with dashed 95% confidence intervals) show the decline in the annual proportion of workers having a dose above 6mSv, which is 30% of the dose limit. The first shows the overall proportion and the second the proportion of such non-zero dose workers. The proportion has declined considerably since 1986 from over 15%, and is currently around 1% but has been quite variable since 2005.

The second model was used to see if there was a non-proportional effect when excluding those with a zero dose, some of whom could have had a persistently low exposure risk. There is no evidence here of such an effect.

Classified non-nuclear workers

Annual numbers of classified non-nuclear workers have declined from 10450 in 2005 to 6377 in 2015, and the collective dose declined from 3842mSv in 2005 to 1987mSv in 2012 but increased to 2355mSv in 2015 – see Figure 1.

Of the 6377 classified non-nuclear workers in 2015, 4118 had a zero dose and 2259 a non-zero dose.

These numbers were split amongst non-nuclear industrial categories as follows:

- Dental, Medical and Veterinary: 145 (37%) with zero dose out of a total of 385 workers;
- Mining/Drilling/Quarrying: 484 (65%) with zero dose out of a total of 739 workers;
- Non-destructive testing: 1689 (72%) with zero dose out of a total of 2249 workers;
- General Industrial: 707 (75%) with zero dose out of a total of 988 workers;
- Research and teaching: 307 (58%) with zero dose out of a total of 533 workers;
- Other: 847 (55%) with zero dose out of a total of 1545 workers.

Figure 4a: Number of classified non-nuclear workers, 2005-2015

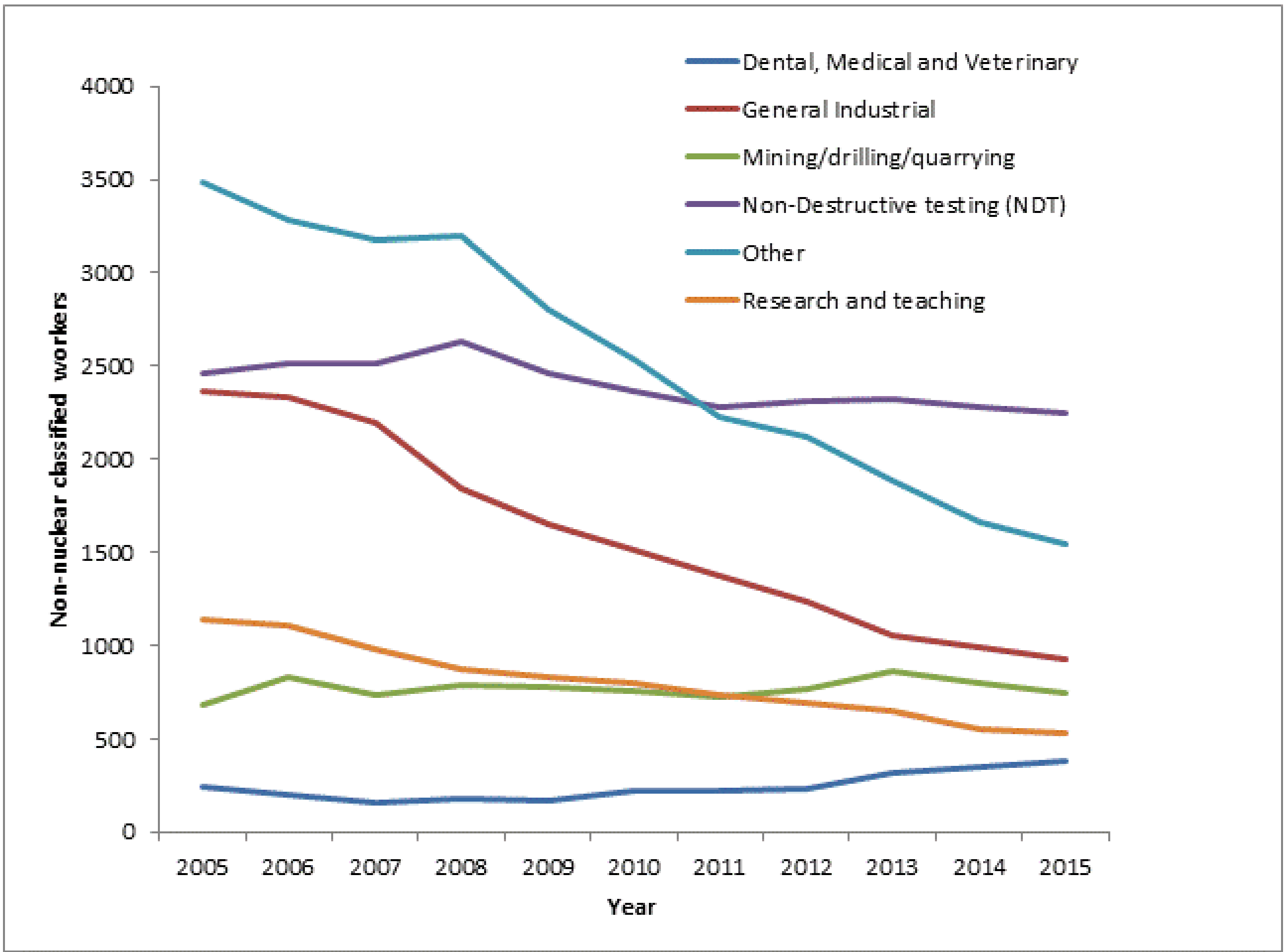
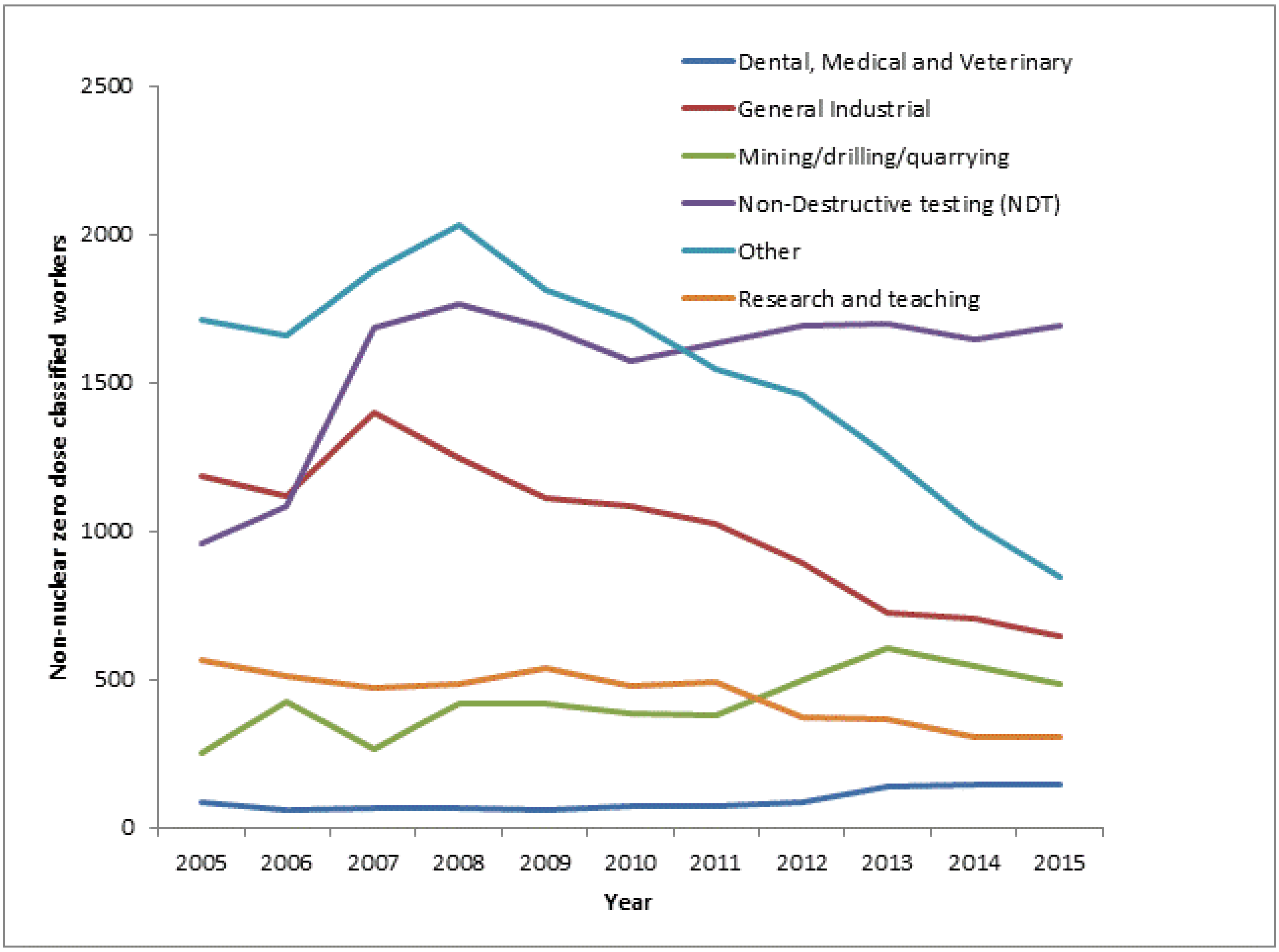


Figure 4b: Number of classified non-nuclear workers with a zero dose, 2005-2015



Figures 4a and 4b show the decline in the numbers of classified workers since 2005 and figure 5 since 1986, with the proportion of zero doses increasing to the current figure of around two thirds.

Figure 5: Number of classified non-nuclear workers by dose band, 1986-2015

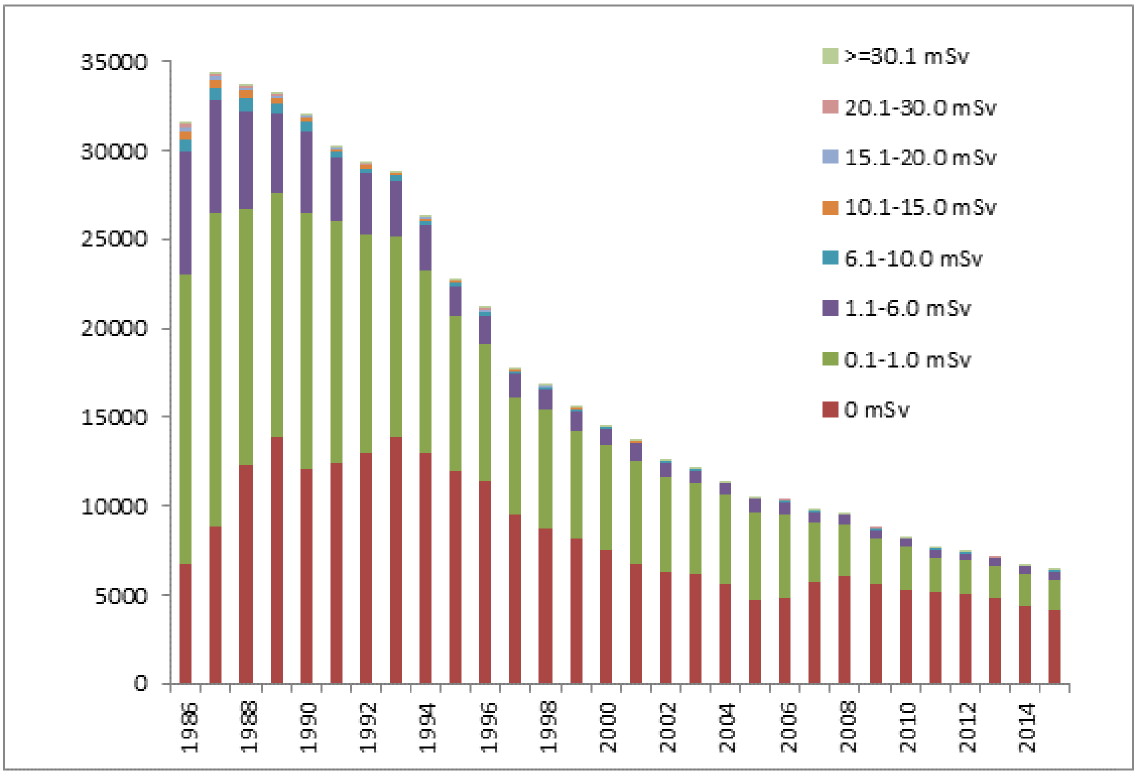
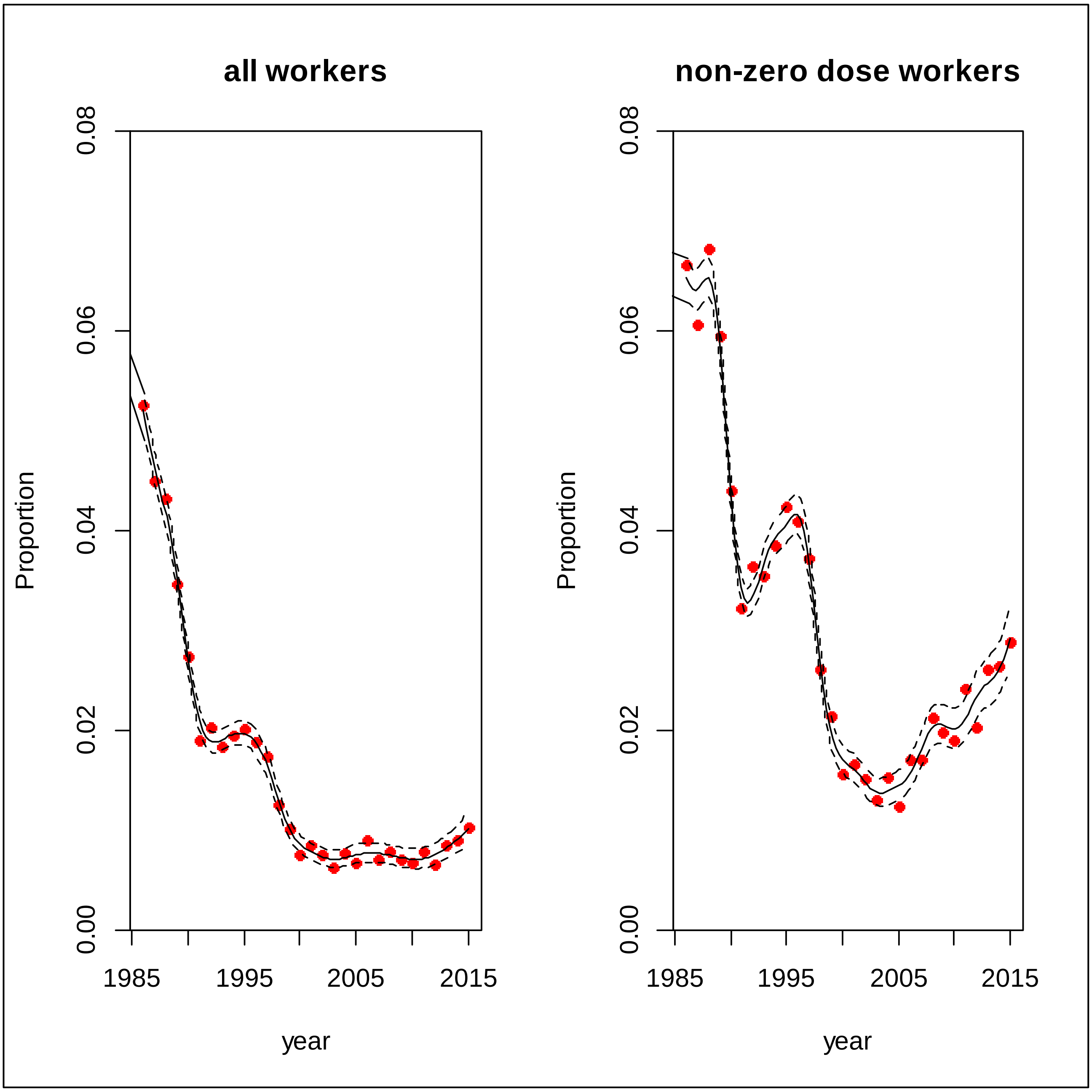


Figure 6: Proportion of classified non-nuclear workers with dose above 6 mSv (30% of the current dose limit), 1986-2015



The smoothing models shown in black lines in Figure 6 (with dashed 95% confidence intervals) show the decline in the proportion of all and non-zero dose classified workers having a dose above 6mSv, which is 30% of the normal limit. The overall proportion has declined from over 5% in 1986, but remained broadly static since 2000 at around 1%.

The second model was used to see if there was a non-proportional effect when ignoring those with a zero dose, some of whom could have had a persistently low exposure risk. The proportion of non-zero dose classified workers has shown an increasing trend since 2000 to just over 2%. It provides some evidence that the rate amongst exposed workers might be increasing since 2000.

Appendix

SUMMARY RADIATION DOSE MEASUREMENTS

Equivalent dose (DE): the radiation absorbed dose to a particular organ/tissue adjusted by the application of a radiation weighting factor to take account of the effect of radiation type on tissue damage efficacy. This quantity is normally given as the summation of the adjusted radiation absorbed doses arising from all the radiation types to which an organ or tissue has been exposed. This quantity may be used for both external and internal radiation exposure assessment.

Committed Equivalent Dose (CDE): For intakes of radioactive substances, for example from inhalation or ingestion of radioactive contamination, internal organ/tissue dose may accrue over long periods of time and so this quantity allows this effect to be taken into account. It is defined as the equivalent dose integrated over a period of 50 years from the date of assessment. This quantity is therefore only used for internal radiation exposure assessment.

Effective Dose Equivalent (EDE also called E_{ext}**)**: This quantity is essentially the equivalent dose adjusted by the application of a tissue weighting factor for the organ/tissue in question and is normally given as the summation of the so adjusted equivalent doses to all the organs/tissues that have been exposed. This quantity may be used for both external and internal radiation exposure assessment.

Committed Effective Dose Equivalent (CEDE also called E_{int}**)**: This quantity is similar to CDE but the quantity that is integrated over 50 years is that of EDE rather than DE. As with CDE, this quantity is only used for internal radiation exposure assessment.

Whole Body Dose (EDE+CEDE): This is an overall measure for radiological protection purposes and is the sum of the Effective Dose Equivalent and the Committed Effective Dose Equivalent.

The current annual whole body dose limit for a worker is 20 millisieverts (mSv), based on the dose received in a calendar year, hereafter in this report a year will be taken to mean calendar year.

DOSE ESTIMATES AND NOTIONAL ENTRIES

Where no assessment of dose is available for any period of work as a classified person, an estimation of the dose for that period must be made by the employer and entered in the record in lieu of an assessed dose. No distinction is made in the data between assessed and estimated doses. If there is insufficient information upon which to make a dose estimate, the employer must authorise the ADS to enter a notional dose in the record for that period.

The data in this summary include doses for classified persons who were monitored for only part of a year or who changed their employment in radiation work during a given year. For persons who change employer within ayear, there will be more than one dose summary on CIDI. A special check for such ‘double’ entries is therefore made during the preparation of the data presented in this summary.

The data submitted by ADS contain a relatively small fraction of notional doses. Notional doses are substitute dose values in the record of a person for a period when no dose assessment was available; they are based on the proportion of the relevant annual dose limit for that period. (The previously published Table A1 included notional doses.) However, such values are rarely representative of the likely doses to persons. For that reason a pro-rata dose estimate for the period of each notional dose has been calculated by the CIDI statistics programme; these data are presented in Table CIDI01 (previously Table A2). The pro-rata dose estimate is based on the doses assessed for the person during the rest of the year. This is a well-established convention in the presentation of dose record data and one which gives a more realistic substitute dose value for dose analysis and epidemiological purposes. This substitution applies only to the data during statistical analysis by CIDI and is not applied to the basic data on the CIDI database or to the source data kept by the ADS: these remain unchanged.

DOSES ARISING FROM INTAKES OF RADIONUCLIDES

The CIDI protocol does not require submission of organ/tissue dose data if doses are less than 10% of the pro-rata dose limit. N.B. Nevertheless, some ADS have reported doses below this level and these have been included in the tables. This means that there may appear to be discrepancies between certain tables (e.g. Tables CIDI04 (formerly A5) and CIDI08-CIDI10 (formerly C7-C9)).

Zero dose categories shown in the Tables, include both monitored classified persons, for whom no measurable dose was recorded in the year, and persons who were not monitored but who were reported as having received no measurable dose as classified persons.

In Table CIDI02 (formerly Table A3), which shows neutron doses, the zero dose category also includes zero neutron doses reported to CIDI by ADS for individuals who were not monitored for neutron dose.

.

TECHNICAL NOTE ABOUT STATISTICAL MODELLING IN THIS REPORT

The statistical modelling used a smoothing procedure carried out separately for nuclear and non-nuclear datasets containing summary data from 1986 to 2015. This methodology uses binomial Generalized Additive Models (GAM) with a logit link, and the models contained a smoothed term for the year. This was implemented in R using Professor Simon Wood's mgcv library (cran.r-project.org/web/packages/mgcv/index.html).

References

1. International Commission on Radiological Protection [ICRP 103]

Statistician: Andrew Darnton

Contact: andrew.darnton@hse.gov.uk

Last updated: March 2017

© *Crown copyright* If you wish to reuse this information visit www.hse.gov.uk/copyright.htm for details.
First published 03/17.