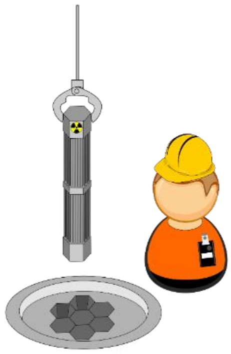
UK Health Security Agency

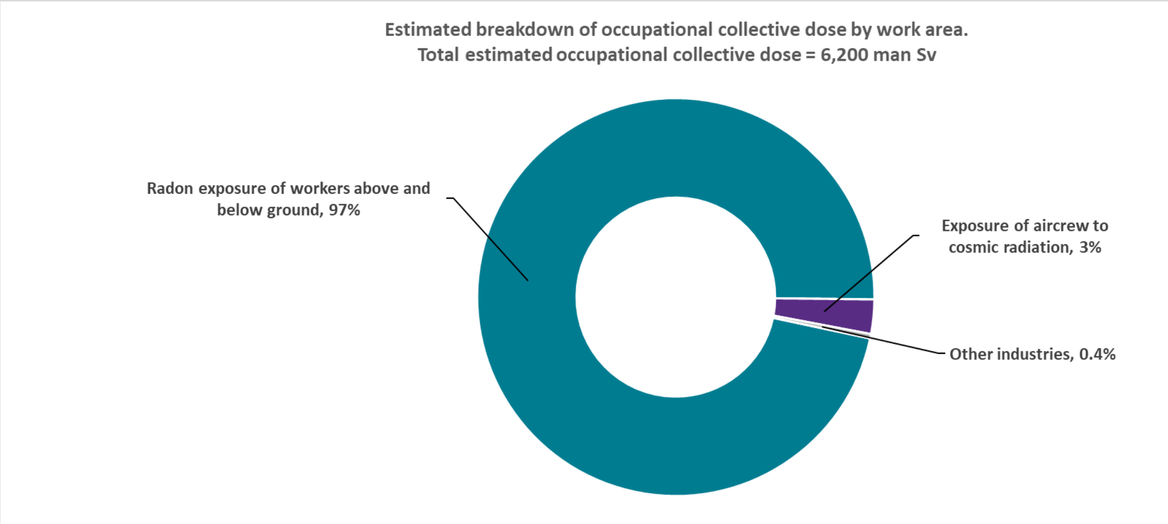
Occupational Exposure to Radiation

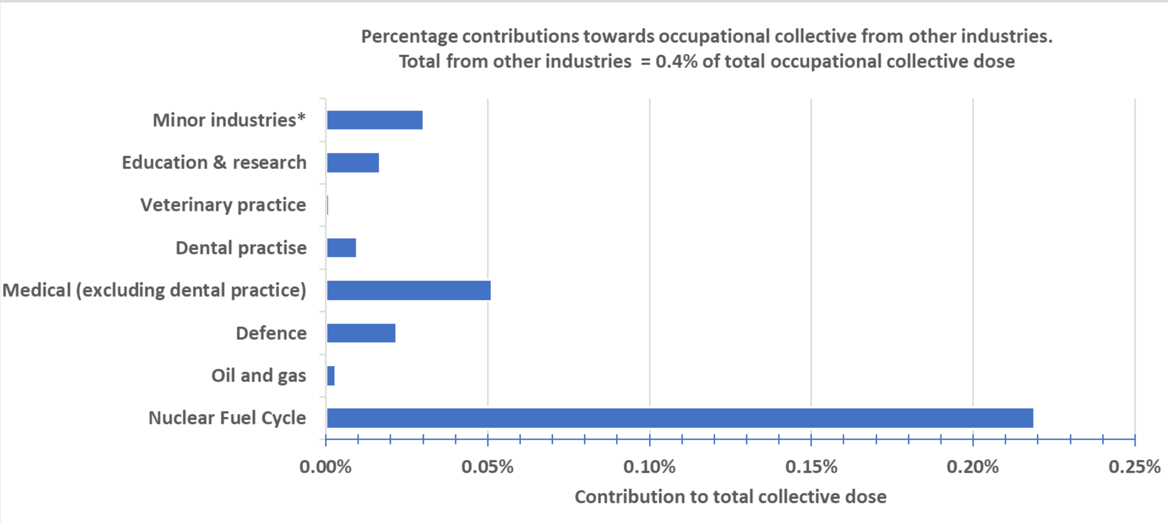


In this, and other, tables in this report, values are shown rounded to 2 significant figures. Therefore, the total may not equal the sum of all rows.

Source of occupational exposure	**Average annual worker dose, mSv y^{-1}**	**Annual collective dose to workers, man Sv y^{-1}**
Radon exposure of workers above and below ground	0.20	6,000
Exposure of aircrew to cosmic radiation	3.6	170
Other industries: oil and gas	0.4	0.19
Other industries: nuclear fuel cycle	0.4	14
Other industries: defence	0.1	1.4
Other industries: medical (excluding dental)	0.07	3.2
Other industries: dental practice	0.005	0.6
Other industries: veterinary practice	0.004	0.06
Other industries: education and research	0.1	1.0
Other industries: minor industries[1]	0.08	1.9
Total exposure within other industries[2]	0.08	22
Total occupational[2]	**0.20**	**6,200**

[1] minor industries = radioisotope production, mining minerals, industrial research, industrial or site radiography, use and servicing of machines producing ionising radiation, other manipulation of radioactive substances, radiation protection, radioactive waste treatment, safety and inspections, transport and other/unknown.
[2] Total collective dose = sum of collective doses to each sector. Total average dose = total collective dose divided by the total number of people included in each sector, not the sum of the average doses for each sector.





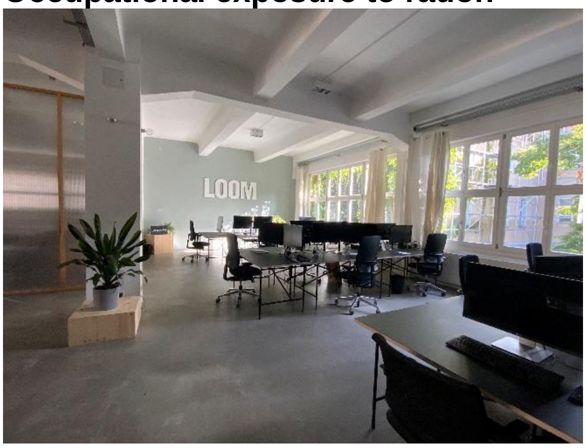
* radioisotope production, mining minerals, industrial research, industrial or site radiography, use and servicing of machines producing ionising radiation, other manipulation of radioactive substances, radiation protection, radioactive waste treatment, safety and inspections, transport and other/unknown

Workers are exposed to ionising radiation in a wide range of situations. This includes workers exposed to natural and artificial sources of radiation. Natural sources of radiation that cause occupational exposures include inhalation of radon gas by workers in offices and other buildings, aircrew being subjected to cosmic radiation while working at altitude, and workers in the oil and gas industry receiving doses due to naturally occurring radioactive materials. Artificial sources of radiation can expose workers in the nuclear power industry as well as a wide range of other industries including medicine, manufacturing and service industries, areas of defence, universities and other educational establishments.

In the UK, occupational exposure to radiation is controlled by the Ionising Radiations Regulations 2017 (UK Parliament, 2017), which sets limits of exposure that must not be exceeded. Occupational exposures are commonly monitored using small dosimeters worn by workers, such as those pictured below. Workers who are considered likely to exceed a specified fraction of those limits must be designated as classified workers. Requirements for monitoring of classified workers are more stringent, resulting in much more complete records on exposure of these workers. There are also many occupationally exposed workers who are not designated as classified workers but are monitored for reassurance purposes. Exposure data for these workers is more difficult to collate as it is not a legal requirement.

Occupational exposure from natural sources of radiation

Occupational exposure to radon



Workers are exposed to natural radiation in workplaces such as offices, schools, shops, factories, as they are in their homes. It is impracticable to expect employers to control “normal” levels of exposure to natural radiation but there are some situations where the level of exposure does justify control. Wrixon et al (1988), estimated that the average occupational dose from inhaling radon in above ground workplaces is about 0.2 mSv per year. Data from the Office for National Statistics (2022) indicates that the working population in the UK is roughly 30 million, which suggests a collective dose over all workers of 6,000 man Sv. This is lower than the estimated collective dose in the previous review (Oatway et al, 2016), which applied the average dose in above-ground workplaces to the whole population rather than the working one.

Workers in underground spaces, such as mines will also be exposed to radon occupationally. There is no more recent data available for these workers than that used in the previous review (Oatway et al, 2016). For small mines, the enclosed atmosphere may lead to higher individual doses, potentially around 5 mSv per year. However, the number of such workers is very low so the contribution to the total collective dose is insignificant. There are more workers in larger mines, but this is still a relatively small population, and the average annual dose tends to be very low at around 0.06 mSv. Overall, the exposure to radon in mines leads to extremely low doses due to low dose rates in larger mines and decreasing numbers of workers.

Occupational exposure to cosmic radiation

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While cosmic radiation is a natural radiation source, exposure of aircrew from cosmic radiation during their time at work is considered as occupational. It is difficult to determine how many hours these workers spend in flight. The limit of 900 hours flying time for flight crew and cabin attendants in any calendar year (Civil Aviation Authority, 2024), when combined with an average dose rate of 0.004 mSv h^{-1} (European Commission, 2004), suggests a maximum individual annual dose of around 3.6 mSv. This is higher than the individual annual dose estimated in the previous review (Oatway et al, 2016), which assumed a lower annual flying time.

Data from the UK Department for Transport and Civil Aviation Authority (2022) reports that around 48,000 aircrew worked as flight crew or cabin attendants for UK registered airlines in 2019. This year was chosen to avoid any changes in air travel resulting from the COVID pandemic. If it is assumed that all of these workers receive the estimated maximum individual annual dose, this implies an annual collective dose of around 170 man Sv. This represents the upper limit of estimates, and the actual values of individual and collective doses may be lower. This assumed annual collective dose of 170 man Sv is higher than the estimate in the previous review (Oatway et al, 2016), as a result of the higher individual dose and an increased number of aircrew in this review.

Note that the previous review of the ionising radiation exposure of the UK population (Oatway et al, 2016) included occupational exposure to radon and cosmic radiation, within the sections about exposure to radon and cosmic radiation.

Occupational exposure to materials with enhanced levels of natural radioactivity

Offshore production of oil and gas mobilises some natural radionuclides such as radium-226 (^{226}Ra), radium-228 (^{228}Ra) and lead-210 (^{210}Pb). These can then build up as scale in pipes. production vessels and other equipment, leading to exposure of workers operating or decommissioning drilling platforms. Data on classified workers in the offshore oil and gas industry, obtained from the Central Index of Dose Information (CIDI) (HSE, 2017) indicates that in 2015 the collective dose to around 480 classified workers was 0.19 man Sv, equivalent to an average dose of about 0.4 mSv to each worker.

There are other cases where workers are occupationally exposed to enhanced levels of naturally occurring radioactive material, but these exposures tend to be very small. The number of workers in these industries is not known, but the collective dose to these workers is likely to be very low. Examples are:

- Workers maintaining equipment at facilities which burn coal – such as changing air filters at coal-fired power stations or at blast furnaces, may be exposed to radionuclides in ash. The maximum annual doses to workers at a coal-fired power station and a steel production plant were estimated to be approximately 0.01 mSv and 0.09 mSv, respectively (Crockett et al, 2003; Smith et al, 2001). The last coal-fired power station, and one of the two sites in the UK with blast furnaces for steel production, closed in 2024.
- Workers who process imported mineral sands, a class of ore deposit which are an important source of various elements such as zirconium, titanium, thorium and tungsten, may be exposed to radionuclides of the uranium and thorium radioactive decay series, usually in relatively high activity concentrations in the ores. A conservative estimate puts the maximum annual dose to workers processing mineral sands is higher at 2 mSv, but the majority of workers in this industry were estimated to receive annual doses below 1 mSv (Oatway et al, 2004; Shaw, 2012).

Occupational exposure from artificial sources of radiation

Occupational exposure in UK civil nuclear sector

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The UK civil nuclear fuel sector is composed of several processes. The main areas are fuel enrichment, fuel fabrication, reactor operations, reprocessing of fuel[1], and decommissioning. As well as employers keeping records of occupational exposures, data for many workers in the UK nuclear fuel sector are collected by the National Registry of Radiation Workers (NRRW). Data supplied by employers for the year 2014 was used in conjunction with NRRW data for years 2016 to 2019 to give estimated doses in the last few years preceding 2020. As well as the five main areas of the nuclear fuel cycle, there are workers doing other tasks, or where the work area was not included in the data. These workers are included as other/unspecified in the table below.

Estimated annual average individual and collective doses to workers in the UK civil nuclear fuel sector

Area of nuclear fuel cycle	Average annual worker dose, mSv y^{-1}	Annual collective dose to workers, man Sv y^{-1}
Fuel enrichment	0.3	0.09
Fuel fabrication	0.3	0.35
Reactor operations	0.1	1.6
Fuel reprocessing	0.6	4.8
Decommissioning	1.0	2.1
Other activities	0.8	4.7
Total nuclear fuel cycle[1]		**14**

[1] Total collective dose = sum of collective doses to each sector. Total average dose = total collective dose divided by the total number of people included in each sector, not the sum of the average doses for each sector.

Exposure of workers in the UK civil nuclear sector makes the largest contribution of the “other industries”, and the third largest contribution overall, to total occupational exposure. This is a contribution of 14 man Sv collective dose, around 0.2% contribution to the total collective dose from occupational exposure in the UK. The average worker dose associated with this is 0.4 mSv per year.

Other than reactor operations, the areas of fuel reprocessing and other activities showed the highest reported numbers of workers. The highest collective doses were reported for reprocessing and other activities, possibly because of the larger numbers of workers in those areas. Decommissioning and reactor operations gave the next highest reported values of collective dose. The highest reported average individual worker dose was for decommissioning, followed by other activities and reprocessing. Workers in reactor operations received the lowest average individual

[1] Reprocessing of fuel stopped in 2022. However, as dose information was collected for the period 2014-2019, this part of the nuclear fuel cycle is included in this report.

worker dose. Fuel enrichment and fuel fabrication only contributed small amounts of collective dose, but as the reported number of workers was lower than other areas, the average individual worker dose in these areas was higher than for reactor operations.

The areas of fuel enrichment, fabrication, and reprocessing show a decrease in both collective dose and average worker dose over time. In the case of fuel fabrication, it is likely that a decrease in the number of workers is linked to the decrease in doses. However decreasing doses are seen in fuel enrichment and reprocessing despite the number of workers either remaining stable or increasing. Such decreases in dose may be linked to better working practices. Reactor operations and decommissioning show increases in collective dose over time, linked to an increase in the number of workers in these areas. In these areas the average worker dose has remained stable, as expected.

Occupational exposure in the defence industry

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In the UK, military uses of radiation include weapons fabrication, nuclear powered submarines, and other activities. Occupational dose data has been supplied by the Atomic Weapons Establishment (AWE), the Defence Science and Technology Laboratory (DSTL), and Rolls Royce (RR). The most recent data for workers involved in weapons fabrication is from 2014, but estimates have been made for 2018 for staff who manufacture and maintain nuclear submarines and other activities.

Reported estimates of annual average individual and collective doses to workers in the UK defence industry

Area of defence industry	Average annual worker dose, $mSv\ y^{-1}$	Annual collective dose to workers, man $Sv\ y^{-1}$
Weapons fabrication	0.06	0.23
Nuclear submarines	0.1	0.50
Other	0.2	0.62
Total[1]	0.1	1.4

[1] Total collective dose = sum of collective doses to each sector. Total average dose = total collective dose divided by the total number of people included in each sector, not the sum of the average doses for each sector.

Overall, the activities in the defence industry contribute 1.4 man Sv collective dose, just 0.02% of the total occupational collective dose. This is a little lower than the total collective dose from the defence industry reported in the previous review (Oatway et al, 2016).

From the reported data, other activities make the largest contribution to collective doses from defence activities, even though the reported number of workers is greater in the areas of weapons fabrication or nuclear submarines. Weapons fabrication gives the lowest average and collective worker doses from the areas within the defence industry.

Occupational exposure from the medical use of radiation (excluding dental practice)

Medical staff in diagnostic radiology, radiotherapy, and nuclear medicine may receive a dose from working with sources of radiation. With the development of better techniques, exposure of medical staff has tended to decrease with time. Historically, few medical staff were classified workers because of the low doses received. In more recent years, in areas such as nuclear medicine and Positron Emission Therapy (PET), many of the workers work with unsealed sources of radioactivity, often at close proximity to the sources. These workers may therefore receive higher exposures and be classified workers. In other areas many workers remain unclassified but still wear personal dosemeters to provide reassurance that doses remain low and to monitor work procedures. However, if all individual doses have remained at or below limits of detection for long periods of time, monitoring of all individual staff tends not to be carried out routinely.

It is recognised that the COVID pandemic has had an impact on clinical practice. For this review, data was collected for 2019, to avoid any such influence. At that point in time there were few classified medical staff, so that data from the Central Index of

Dose Information (CIDI), which holds data for classified workers, was of limited use. Therefore, a sample of information on radiation exposure of medical staff was obtained directly from Approved Dosimetry Services (ADSs), to collect information on exposures of both classified and unclassified workers.

Sample of ADS estimates of annual average individual and collective doses for UK medical workers

Area of medicine	Average annual worker dose, mSv y^{-1}	Annual collective dose to workers, man Sv y^{-1}
Diagnostic radiology	0.01	0.0082
Interventional cardiology	0.03	0.0068
Interventional radiology	0.28	0.022
Radiotherapy	0.01	0.0016
Nuclear medicine	0.53	0.039
Other	0.07	1.1
Total[1]	**0.06**	**1.1**

[1] Total collective dose = sum of collective doses to each sector. Total average dose = total collective dose divided by the total number of people included in each sector, not the sum of the average doses for each sector.

Much of the data reported from the ADSs did not specify which work area the dose should be attributed to. Therefore, it is seen in the table above that the majority of the reported collective dose is in the “other” category. For the five named areas, it is seen that the average annual doses reported for nuclear medicine and interventional radiology are much higher than for the other areas. This was also seen in the previous review and is expected as these are the areas where staff must spend more time at closer proximity to sources of ionising radiation then is seen in the other work areas.

The total occupational annual collective dose from medicine reported in the survey is around 1 man Sv, with an average annual worker dose of 0.06 mSv. It is recognised however, that the data returned from the ADS survey represents only a fraction of the total workforce in the medical field that were monitored for, or may have received, exposure from ionising radiation. It is very difficult to estimate the number of medical workers that were occupationally exposed to ionising radiation. It is estimated that there could be several hundred thousand hospital workers overall in the UK, though it is impossible to know how many of these will be occupationally exposed to ionising radiation. In a recent survey by UNSCEAR (2021), it was estimated that there were around 50,000 exposed staff working in diagnostic and interventional radiology, nuclear medicine and radiotherapy in the UK in 2016. If the average annual worker dose of 0.06 mSv, as estimated from the sample of ADS data for non-dental medical workers, is applied to an assumed 50,000 workers, this implies an annual collective dose of 3.2 man Sv. Both the assumed annual average and collective doses are less than the estimates made in the previous review (Oatway et al, 2016).

Occupational exposure in dental practice

Similarly to medical workers, there are very few classified workers in dental practice because doses are usually very low. Despite almost every dental clinic in the UK routinely performing diagnostic X-ray imaging, there were only 4 classified dental workers in 2015, the last year for which CIDI data is available. A limited amount of data was obtained from the ADS survey, which provided data for around 1,000 dental workers. The annual collective dose for this sample was 0.006 man Sv, leading to an average annual individual dose of 0.005 mSv. It was reported by the General Dental Council (2023) that in 2019 there were around 119,000 dental professionals registered with them in the UK. Assuming that all of these workers are exposed to ionising radiation, and receive the average individual dose of 0.005 mSv, as estimated in the sample of data provided by the ADS survey, the estimated annual collective dose to UK dental workers is 0.6 man Sv. This collective dose is greater than the estimate in the previous review, because a larger number of dental workers was assumed.

Occupational exposure in veterinary medicine

The use of radiation in veterinary practice has become commonplace. Diagnostic radiology is probably the most used specialism, but nuclear medicine and radiotherapy procedures are also known to be performed. The ADS survey provided information on around 2,000 veterinary workers. This sample had an annual collective dose of 0.009 man Sv, with an annual average individual dose of 0.004 mSv. As with medicine and dentistry, it is known that this sample is only a fraction of the number of veterinary workers that are exposed to radiation. The Royal College of Veterinary Surgeons (2020) reported that there were around 52,800 veterinary surgeons and veterinary nurses on their register in 2020. Based on the number of practicing veterinary surgeons and the fraction of practicing staff that perform diagnostic imaging (Robertson-Smith et al, 2010), it is estimated that around 13,000 veterinary workers are exposed to ionising radiation. Assuming each of these receives the estimated average annual dose of 0.004 mSv, this suggests an annual collective dose of 0.06 man Sv. This collective dose is lower than estimated in the previous review (Oatway et al, 2016), due to a lower estimate of average annual dose.

Occupational exposure in tertiary education and research

A number of university laboratories and research establishments use radioactive materials or X-ray sources in research work. Although many workers may be issued with dosemeters, most will only wear them for intermittent periods – for example, when carrying out particular experiments. For this review a survey was conducted by the Association of University Radiation Protection Officers (AURPO) of universities and research establishments. The survey provided information on doses to workers for 25 establishments across the UK, including around 1,000 workers with an annual collective dose of 0.1 man Sv, giving an annual average individual dose of around 0.1 mSv. It has previously been estimated (Oatway et al, 2016) that there are around 10,000 workers in research and education in the UK who are occupationally exposed to ionising radiation. With no more recent data, this value has been used with the estimated 0.1 mSv average individual dose to give an estimated total collective dose of around 1 man Sv. This is twice the annual collective dose estimated in the previous review, because the average individual dose estimated from the AURPO survey was twice the estimated value in the previous review (Oatway et al, 2016).

Occupational exposure in minor industries

The use of the term "minor industries" refers to the fact that these industries each contribute a very minor part of the annual occupational collective dose. The industries included in this section are radioisotope production, mining minerals, industrial research, industrial or site radiography, use and servicing of machines producing ionising radiation, other manipulation of radioactive substances, radiation protection, radioactive waste treatment, safety and inspections, transport and other/unknown uses of ionising radiation.

The total annual collective dose from these minor industries is 1.9 man Sv, approximately 0.03% of the total annual occupational collective dose. This is higher than the collective dose estimated in the previous review (Oatway et al, 2016) because that estimation of collective dose was based on a smaller number of workers. The use and servicing of machines producing ionising radiation (0.6 man Sv), followed by industrial or site radiography (0.2 man Sv) make the largest contributions to this category. The average annual individual dose from the minor industries is 0.08 mSv.

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