Minor Exposures

The six main sources of exposure described in other sections make up over 99% of the total collective dose to the UK population from ionising radiation. Additionally, there are six minor sources of exposure that contribute just under 0.3% of the total collective dose. These minor sources are described below.

Source of exposure	Collective dose[1], man Sv	Average dose to UK population[2], mSv
Minor sources of exposure		
Occupational exposure, non-natural sources. This includes the civil nuclear fuel cycle, the oil and gas industry, the defence sector, education and research, and medical, dental, veterinary and industrial use	22	0.0004
Discharges of radioactive material into the environment	62	0.001
Nuclear weapons fallout	340	0.005
Accidental releases of radioactive material	0	0.0
Consumer products containing radioactive material	1	0.00002
Exposure of the public from transport of radioactive materials	0	0.0
Total of minor sources	**430**	**0.01**
1 Due to the uncertainties involved in the estimations of collective dose, rounded values are shown. Therefore, the total shown may not appear to equal the sum of the parts. 2 Dividing the collective dose evenly across an assumed population size of 67 million (Office for National Statistics 2022)		

Occupational exposure, non-natural sources

This minor source of exposure is discussed under Occupational Exposures

Exposure to radionuclides discharged into the environment

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Type of facility	Average individual annual dose, mSv y^{-1}	Annual collective dose to UK population, man Sv y^{-1}
UK civil nuclear sites	<0.001	6
Overseas civil nuclear sites	<0.001	6
Oil and gas industry	<0.001	50
Other industries	Insignificant	Insignificant
Total	**<0.001**	**62**

Exposure to radionuclides discharged by the civil nuclear industry

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Estimated collective and average individual doses to the UK population in 2020 due to atmospheric and liquid discharges from UK civil nuclear sites

	Collective dose, man Sv			Average dose to member of UK population, mSv		
Type of site	**Atmos-pheric**	**Liquid**	**Total**	**Atmos-pheric**	**Liquid**	**Total**
Nuclear power sites	3.1	0.002	3.1	<0.001	<0.001	<0.001
Fuel fabrication	0.001	0.03	0.03	<0.001	<0.001	<0.001
Fuel reprocessing*,†	0.2	2.6	2.8	<0.001	<0.001	<0.001
Research & radiochemical production	0.043	0.005	0.048	<0.001	<0.001	<0.001
Total	**3.3**	**2.6**	**6.0**	<0.001	<0.001	<0.001

* This includes discharges from the Low Level Waste Repository (LLWR), which could not be distinguished from discharges made by the nearby Sellafield site (Environment Agency et al, 2011).
† Fuel reprocessing ceased in 2022

The civil nuclear industry in the UK includes nuclear power stations, nuclear fuel cycle facilities, and research and development facilities. As of 2024, the nuclear power generation industry in the UK consists of nine operating nuclear power stations, eight operating advanced gas-cooled reactors (AGR) and one operating pressurised water reactor (PWR). Additionally there are 13 reactors that are non-operational, in the defueling or decommissioning stage. Fuel cycle facilities are located at Capenhurst, Springfields and Sellafield where uranium enrichment, fuel fabrication, fuel reprocessing (until 2022) and spent fuel storage are carried out. There are also come research and radiochemical production facilities which release minor discharges.

The collective dose in 2020 to the UK population from exposure to discharges of radionuclides by the civil nuclear industry was assessed using the computer model PC CREAM 08® (Smith et al, 2009; Smith and Simmonds, 2009). For radionuclides released to the atmosphere, PC CREAM 08® assesses doses due to external irradiation from, and intake by inhalation of, radionuclides in the air, external irradiation following deposition of radionuclides, and ingestion of deposited radionuclides in terrestrial food. For exposure to radionuclides released to the marine environment, PC CREAM 08® assesses doses due to external irradiation from radionuclides in beach sediment and from the consumption of radionuclides in marine foods. Collective and average individual doses to a member of the UK population are shown in the table above.

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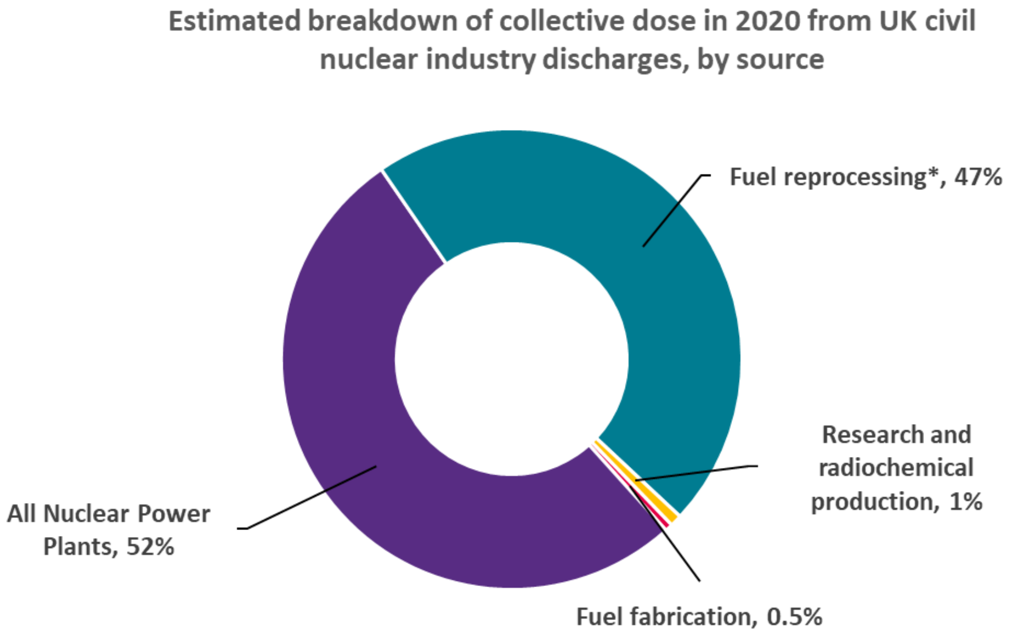

* Fuel reprocessing ceased in 2022

Radionuclides discharged to atmospheric and liquid environments accounted for about 60% and 40% respectively, of the total dose received. Nuclear power production sites were the most significant source of radionuclides with respect to the UK population dose in 2020, for both releases to atmosphere, and total releases. The most significant radionuclide released to atmosphere was carbon-14 (^{14}C) incorporated in terrestrial foods, particularly grain. Although fuel reprocessing ceased in 2022, it accounted for most of the dose from liquid discharges in 2020, with the most significant doses arising from americium-241 (^{241}Am), carbon-14 (^{14}C) and plutonium-239 (^{239}Pu) in molluscs, and caesium-134 (^{134}Cs), caesium-137 (^{137}Cs) and carbon-14 (^{14}C) in fish. The most important contribution to dose from facilities undertaking research and radiochemical production was exposure to carbon-14 (^{14}C) discharged to atmosphere.

Radionuclides discharged from nuclear facilities located in other countries also contribute to the UK population dose. Whilst no specific assessment of the dose to the UK population in 2020 from such discharges has been made, an assessment by the European Commission (Jones et al, 2013) implied such discharges would most likely result in a similar level of exposure as discharges made by UK civil nuclear facilities. Between 80 and 90% of the estimated collective dose to the EU population from European discharges come from atmospheric discharges. Power production sites contributed almost 70% of the dose from atmospheric discharges, with reprocessing sites accounting for the rest of the atmospheric discharges and 95% of the dose from liquid discharges.

Exposure to radionuclides discharged by non-nuclear industries

Oil and gas industry

Water produced during extraction of oil and gas, termed produced water, includes low levels of radium isotopes and their radioactive decay progeny. From offshore installations this water is discharged into the marine environment as a waste product. The collective and per caput doses to the UK population in 2010 due to these discharges, estimated using PC CREAM 08® (Smith et al, 2009; Smith and Simmonds, 2009), together with the annual discharges reported by Harvey et al (2010), were approximately 50 man Sv and 6 10^{-5} mSv, respectively.

Other industries

- The defence industry discharges radioactivity to the environment as a result of its work designing, testing, maintaining and decommissioning nuclear reactors for the UK nuclear submarine fleet.
- Hospitals discharge radioactivity during and after nuclear medicine procedures.
- Radiopharmaceutical production in the UK has significantly declined compared to previous years.
- Other facilities release radioactivity into the environment as a byproduct of industrial processes. For example, coal contains low levels of radionuclides and when it is burnt, such as in coal-fired power stations or steel production facilities, some of these radionuclides are released into the environment as ash.
- Until 2001, there was an industry in the UK manufacturing phosphoric acid from imported phosphate ore. Naturally occurring radionuclides in the source material were subsequently found in liquid discharges to the environment. Those discharges ceased in 2001, and by 2010 it was difficult to distinguish radionuclides previously discharged by the phosphate industry from those naturally present in the environment (Environment Agency et al, 2011). It is therefore assumed that the dose to the UK population in 2020 arising from phosphate industry discharges was effectively zero.

For many of these organisations, the radioactivity annually released into the environment is not routinely recorded due to its low level; an assessment of the contribution to the collective dose to the UK population in 2020 from such discharges could therefore not be made. However, for those organisations where annual discharges were available, the amount of radioactivity released into the environment was several orders of magnitude lower than discharges made by civil nuclear sites (Environment Agency et al, 2011). As a result, the contribution to the collective dose to the UK population in 2020 from discharges made by non-nuclear industries, excluding the oil and gas industry, is expected to be insignificant compared to that arising from exposure to radioactivity discharged by the civil nuclear industry.

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Exposure to radionuclides produced during nuclear weapons testing

	Average individual annual dose[1], mSv y^{-1}	Annual collective dose to UK population, man Sv y^{-1}
Annual dose from exposure to radionuclides produced by nuclear weapons testing	0.005	340
1 Worldwide average individual annual dose from UNSCEAR (2010)		

The first nuclear device was detonated as a test on July 16, 1945. After this several tests occurred at various locations around the world through the rest of the 1940s, the 1950s and the early years of the 1960s. Signing of the Limited Test Ban Treaty in 1963 significantly reduced the number of atmospheric tests being conducted. Between 1963 and 1996, nuclear tests were carried out underground, releasing significantly less radioactivity into the atmosphere. In 1996, the Soviet Union, the UK, the USA, France and China also stopped underground testing.

An atmospheric nuclear detonation draws dust and debris from the explosion, together with radioactive materials high into the atmosphere to form a cloud. Particles then fall back to earth as they cool, with larger particles tending to fall closer to the detonation due to gravity, with around 50% of larger particles deposited in the immediate vicinity of the test site. The remaining particles are carried high into the atmosphere and can travel much further, spreading globally.

Exposure to radionuclides released during weapons testing is mostly due to radioactivity released by weapon tests carried out before the mid-1960s. It has decreased since, though residual levels of some radionuclides (mainly carbon-14 (^{14}C), strontium-90 (^{90}Sr) and caesium-137 (^{137}Cs)) in the environment continue to make a small contribution to exposure.

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Accidental and unintentional exposures

Exposure	Collective dose to the UK population in 2024
To radioactivity released during the Windscale fire in 1957	Negligible
To radioactivity released during the Chornobyl accident in 1986	Negligible
To radioactivity released during the Fukushima accident in 2011	Negligible

The use of radiation or radioactive material is generally very well controlled and subject to many safety requirements. However, there is still the potential for accidents to occur; over the last 60 years over 600 events are known to have occurred worldwide that caused significant radiation exposure (Nénot, 2009). Most of these incidents only affected a limited number of people, with no widespread exposure of the UK public. However, two accidents did result in the release of significant amounts of radioactivity which affected large areas of the UK at the time of the accident. Three major incidents are discussed.

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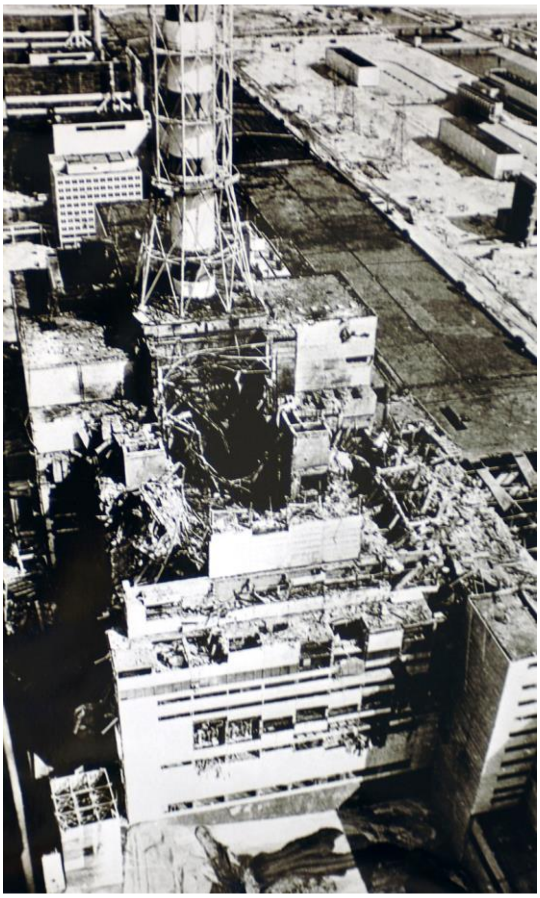
Windscale fire, 1957

In 1957, an accident occurred at the Windscale nuclear reactor facility and plutonium-production plant in Cumbria, at the site now occupied by the Sellafield site. During this accident, uranium cartridges ruptured and oxidised, causing a fire that burned for 16 hours and released sizable amounts of radioactive iodine to the atmosphere. The sale of milk produced in a 500 km^2 area around the reactor site was banned for several weeks. Environmental monitoring around the Sellafield site in 2021 (Environment Agency et al, 2022) showed that the concentrations of iodine isotopes were below the level of detection. The contribution of radionuclides released during the Windscale fire to the collective dose to the UK population in 2020 was estimated to be negligible.

Chornobyl accident, 1986



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In 1986, an uncontained rise in the core temperature of one of the reactors at the Chornobyl nuclear site in Ukraine caused a steam explosion which partially removed the concrete reactor lid. After the explosion the reactor's graphite caught fire and radionuclides were released to the atmosphere for at least 10 days. Radioactivity was then carried by the wind over most of northern Europe, including the UK, depositing radioactive material onto the ground. In the UK, the principal effect of this was ingestion of contaminated grass by sheep, bringing deposited radionuclides into the human food chain. Restrictions were placed on the movement and marketing of sheep from 9,800 farms, mainly in Cumbria, north Wales, and southern Scotland. These restrictions successfully limited the ingestion of contaminated food. Over time, monitoring showed that the levels of radioactivity in sheep meat had decreased to levels where the restrictions could be lifted, though the last restrictions were not lifted until 2012. In April 2020, several wildfires were reported in the Chornobyl exclusion zone. The potential for the UK to be impacted by these fires was examined as a precautionary measure and it was concluded that no action was required. The contribution of radionuclides released during the Chornobyl accident, and by subsequent wildfires, to the collective dose to the UK population in 2020 was estimated to be insignificant.

Fukushima accident, 2011

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In March 2011, an earthquake occurred near Japan, which led to a tsunami that caused releases of radioactive material into the environment from the Tokyo Electric Power Company's Fukushima Daiichi nuclear power station. Traces of iodine-131, associated with the release, were subsequently detected in the UK. Early measurements indicated that doses to the UK population from inhaling this radionuclide would be very much less than the annual background radiation dose. Later estimates of radiation exposures in 2021 in parts of Japan other than the affected Fukushima prefecture and its neighbouring prefectures, ranged between <0.001 and 0.028 mSv (UNSCEAR, 2021), suggesting that exposure in the UK in 2020 was estimated to be negligible.

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Radioactivity in Consumer Products

	Average annual individual dose, mSv y^{-1}	**Annual collective dose to UK population, man Sv y^{-1}**
Annual dose to UK population from exposure to two ionisation chamber smoke detectors in the home	0.00002	1.3
Annual dose to UK population from exposure to other consumer products containing radioactivity	Insignificant	Insignificant
Total dose to the UK population from exposure to consumer products containing radioactivity	0.00002	1.3

There are a range of consumer products that contain minor sources of radioactivity. Not all of these have widespread use and the use of some items is largely historic. Although individual doses from using some of these items could exceed 0.1 mSv, in many cases individual doses are much smaller. For most products, it is hard to know the number of individuals who regularly use these items and it is therefore difficult to estimate the collective dose to the UK population. With low individual doses and probable low numbers of users, the collective dose from most products is considered to be insignificant. The most used product is thought to be ionising chamber smoke detectors. With an estimated annual collective dose of 1.3 man Sv, this is still trivial compared to other types of exposure.

Further reading on radioactive consumer products is available from [Radioactive Consumer Products | Museum of Radiation and Radioactivity (orau.org)]

Ionising Chamber Smoke Detectors (ICSDs)

A commonplace use of a small radiation source is seen in many domestic smoke detectors. While not all smoke detectors contain radioactive sources, many contain a small foil of americium-241 (^{241}Am). The radiation dose from such detectors to the occupants of a house is extremely small and does not pose a health risk under all normal conditions, including during a fire. It is estimated that one ICSD in a home will give a dose of less than 0.00001 mSv of radiation each year (US NRC, 2001). With an estimated 94% of UK households having a working smoke alarm (Home Office, 2022), and allowing for two detectors per home, the estimated annual collective dose to the UK population is around 1.3 man Sv per year.

Lamps containing radioactivity

A small number of lamps – about 2% - contain low levels of hydrogen-3 (^{3}H, known as tritium), krypton-85 (^{85}Kr) or isotopes of thorium, which aid starting the lamp or are used as a component of the electrode. They are predominantly used for professional lighting such as in shops and cinemas. The maximum annual dose from the transport and disposal of these lamps was estimated to be less than 0.01 mSv (Harvey et al, 2010; Jones et al, 2011). Given that this exposure is based on recycling workers who will come into contact with many lamps, it is reasonable to assume that exposure to a few lamps during the normal use will result in much lower doses. Although the number of people who are regularly exposed to these lamps is not known, the contribution to the collective dose to the UK population will be insignificant.

Radioactivity in antiques

Radioactive materials were used in a range of products over the years, including watches, dials, ceramics and glassware.

Radio-luminescent materials, including radium-226 (^{226}Ra), hydrogen-3 (^{3}H, known as tritium), and promethium-147 (^{147}Pm), have historically been used on watches, dials and other timepieces. It is estimated that the maximum annual dose to someone wearing a watch contataining radioactivity would be no more than a few tens of microsieverts (NRPB, 1992). The number of people who regularly wear or handle such an item is unknown. However the contribution to the collective dose to the UK population is considered to be insignificant.

Natural uranium compounds have been historically used in Vaseline glass, or in glazes on the surface of tiles or tableware to produce a variety of colours. It is likely that a collector handling items of Vaseline glass will receive a trivial annual dose (Watson and Hughes, 2010). The number of people who regularly wear or handle such items is thought to be low and therefore the contribution to the collective dose to the UK population is considered to be insignificant.

For more information see Radioactivity in Antiques | US EPA.

Irradiated gemstones

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It has been known for many years that the colour of gemstones may be intensified or altered by irradiation. This process can happen naturally over a long period of time but using artificial irradiation to enhance colour, and therefore commercial value, is standard practice. The images above show a natural topaz and one that has been irradiated.

It is generally assumed that gems treated in this way are stored for a predetermined length of time to eliminate short-lived activation products prior to the gems being released on to the open market. It is estimated that the annual effective dose to a member of the public would range from <0.01 up to 1.7 microsieverts, depending on the stones used and whether an item is worn occasionally or continuously. (Shaw et al, 2007). The number of people who regularly wear or handle such items is thought to be low and therefore the contribution to the collective dose to the UK population is considered to be insignificant.

Electronic components

Image attributed to Oak Ridge Associated Universities (ORAU)

Radioactive electronic valves are used in radar and telecommunications equipment. Such items may contain radioactive material in gaseous form, in which case exposure is only likely in the case of breakage with the dose from a single broken component estimated at a maximum of 2 microsieverts. Some components containing solid radioactive material may give a very small external dose rate of less than 1 microsievert per hour (Ministry of Defence, 2020). However, the number of people who regularly handle such items is thought to be low and therefore the contribution to the collective dose to the UK population is considered to be insignificant.

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Thoriated products

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Thoriated gas mantles use thorium compounds impregnated into the mesh to provide an incandescent property. In the UK they are mostly used by campers in tents and caravans. Thorium may also be used in TIG welding electrodes or some camera lenses. Conservative assessments of such products estimate that annual doses of up to a few tens of mSv may arise (Gäfvert et al, 2003; NRPB, 1992; Taylor et al, 1983). However, the number of people who regularly wear or handle such items is thought to be low and therefore the contribution to the collective dose to the UK population is considered to be insignificant.

Geological specimens

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Geological specimens can contain significant amounts of radioactivity. Estimated doses from handling of specimens are very small, and doses from being a metre or more away from specimens are likely to be negligible (Price et al, 2013). The number of people who regularly wear or handle such items is thought to be low and therefore the contribution to the collective dose of the UK population is considered to be insignificant.

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Exposure from transport of radioactive materials

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Average annual doses to members of UK population from transport of radioactive material

Mode of transport	Estimated number of packages	Estimated annual dose to member of the public, mSv y^{-1}	Data source
Road	110,000	Negligible	Jones and Cabianca (2017)
Rail	1,500	Negligible	Jones and Cabianca (2017)
Air	46,500	Negligible	Harvey et al (2014a)
Sea	30,000	Negligible	Hughes and Harvey (2009)

Radioactive materials are routinely transported into, out of, and around the UK. Most of the transported packages are for medical procedures to diagnose and treat diseases but also for the nuclear, research and industrial sectors eg nuclear fuel flasks, tracers for experiments, industrial radiography. These materials may be transported by road, rail, air, or sea.

UKHSA have carried out studies to estimate the exposure from these transports to workers and members of the public. These studies gathered and analysed information on the types of radioactive materials transported and assessed the radiation exposures arising from the normal transport of these materials.

Transport by Road
By far the greatest number of packages containing radioactive material are transported by road in the UK, and the transport of medical radiopharmaceuticals is a large proportion (76%) of those transports. The number of packages given in the

data source is an estimate, as not all manufacturers or companies involved in transport of radiopharmaceuticals or transport of radioactive materials in the general industry sector were consulted. The actual number will therefore be higher. In 2003, a European Commission study estimated that 200,000 packages were consigned by road in the UK (EC, 2003). Despite the large volume of packages transported by road, doses to the public are negligible.

Transport by Rail

There is very little transport of radioactive material by rail, and this transport mode is only by the civil nuclear industry. Although an individual dose to a member of the public walking close to an area where high activity flasks of nuclear fuel are being handled could potentially reach 1 microsievert, it is very unlikely that more than a few people will be exposed in this way. Overall doses to members of the public are therefore considered as negligible.

Transport by Air

Most packages containing radioactive material transported by air are for the manufacture of medical radioisotopes and industrial sources. The estimated number of packages given in the table above are from 4,400 flights leaving the UK and 650 coming into the UK. The highest dose estimated (Harvey et al, 2014b) is to a frequent-flyer passenger travelling weekly on long-haul flight. Based on this, the annual dose to a passenger who travels 2 or 3 times a year will be negligible.

Transport by Sea

The radiological consequences of the shipment of radioactive material to and from the UK by sea to members of the public was found to be very low. There was no evidence found of any significant exposure of members of the public. Shipments carrying radioactive material for medical use could be carried on passenger ferries incidentally exposing members of the public in a private vehicle. However, the maximum dose was found to be less than one microsievert and therefore trivial.

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