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Assessing the risk to people's health from radioactive objects on beaches around the Sellafield site

Summary report

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Assessing the risk to people's health from radioactive objects on beaches around the Sellafield site

Summary report

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Executive summary

Past activity on the Sellafield site has led to radioactive objects being present in the environment. Public Health England (PHE) has assessed the health risk those objects may pose now and in the future to those people who use beaches or eat seafood caught off the Cumbrian coast.

In this report, we give an overview of the methods we used in the assessment and discuss our main conclusions. We have also produced a supporting technical report that describes in detail the approach we used.

The main risks to members of the public are from accidentally swallowing, or prolonged skin contact with, radioactive particles that are about the size of a grain of sand or smaller. We estimated that the risk to people developing terminal cancer during their lifetime from accidentally swallowing a particle when using a beach close to the Sellafield site or when eating seafood caught off the Cumbrian coast during a year is less than a one in a hundred billion (10^{-11}). This level of risk is at least 10,000 times less than other risks people face when using beaches for leisure, such as developing skin cancer from sun exposure or of accidentally drowning. The level of radioactivity measured on particles detected to date is also not enough to pose a significant risk of causing skin blistering.

Based on this risk assessment, we concluded that the risks from radioactive objects in the environment near to the Sellafield site are very low, and we advise that measures to control those risks to protect the public's health are not needed. We, therefore, suggest that the scope of the current beach monitoring programme could be reduced to a smaller programme that has the aim of collecting information to provide reassurance that risks to health remain extremely low.

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This report from the PHE Centre for Radiation, Chemical and Environmental Hazards reflects understanding and evaluation of the current scientific evidence as presented and referenced in this document.

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1 Introduction

Radioactivity has been discharged from the Sellafield site into the sea since the 1950s. Although most of the radioactivity discharged to the sea was in the form of a liquid, some solid matter, including small radioactive objects, were also discharged up until the mid-1980s. All current releases of radioactivity into the environment are controlled by an environmental permit enforced by the Environment Agency. Under this permit, operators of nuclear licensed sites must use 'best available techniques' to reduce or, if possible, avoid discharging radioactivity into the environment. As a result, today no radioactive objects are being released into the marine environment from the Sellafield site. Radioactive objects are, however, still present in the environment despite not being discharged for many years.

Radioactivity discharged to the sea as a liquid is quickly diluted in the marine environment and so anyone using beaches near to the Sellafield site or eating seafood caught off the Cumbrian coast will only receive a very low level of radiation dose from it. Doses received today from radioactivity in the environment due to the discharge of liquid waste from the Sellafield site are well below the public dose limit. You can find more information on the levels and impacts of radioactivity in the environment caused by the discharge of liquid radioactive waste in the 'Radioactivity in Food and the Environment' (RIFE) reports published each year by the UK environment agencies and the Food Standards Agency (Environment Agency et al, 2018).

Radioactivity attached to an object presents a different risk compared to radioactivity discharged as liquid waste. This is because radioactive objects can contain high amounts of radioactivity but, as there are relatively few of them, the chance that anyone will encounter one is very low. As a result, even if someone uses a beach for long periods of time over many years or regularly eats seafood throughout the year, they most probably will not encounter a radioactive object. However, there is a very small chance that an individual may accidentally consume one of these objects or have one of them become attached to their skin. If this were to occur, then that individual would receive a dose of radiation. Assessing risks to health from radioactive objects in the environment means considering both the chance that someone could encounter an object as well as the risks to them if this happens.

This report, which is intended for a non-technical audience, provides a summary of the latest assessment Public Health England (PHE) carried out into the risk to people's health posed by radioactive objects. An accompanying technical report provides details of the methods and approach we used in that assessment (Oatway et al, 2020).

Section 2 describes the methods we used to estimate the risk to health, with the results being discussed in section 3. The conclusions of the assessment and advice on future monitoring are presented in section 4.

2 Approach taken in the risk assessment

We have regularly assessed the health risk from radioactive objects in the environment near Sellafield to people that use beaches or eat seafood in the nearby area. Those assessments are described in reports HPA-CRCE-018, HPA-CRCE-038, and PHE-CRCE-021 (Brown and Etherington, 2011; Etherington et al, 2012; Oatway and Brown, 2015). Since those reports

were published, the ongoing monitoring programme has continued to detect radioactive objects on beaches near to the Sellafield site. We have also gathered more information about how people use Cumbrian beaches and how much seafood they eat. A meeting of the Sellafield Particles Working Group¹ decided, therefore, to update the PHE risk assessments with all information available up to the end of 2017.

The methods we used in this updated risk assessment are similar to those we used in previous assessments. However, improvements have been possible due to more data being available, and from experience gained in earlier assessments. For example, this assessment used a revised approach to estimate how many objects may be present on beaches based on a report published in 2016, which considered how effectively the tide mixed sand on Cumbrian beaches (CH2M Hill, 2016).

In previous assessments, we estimated risks to people using beaches at one of five locations: St Bees, Braystones, Sellafield, Seascale and Drigg. However, these assessments showed that the estimated risks to people using beaches were similar at either St Bees or Braystones or at either Seascale or Drigg. This assessment, therefore, used a simplified approach where we estimated the risks to those who used one of three areas of beach as shown in Figure 1: Northern beaches, representing beaches between St Bees and Braystones; Sellafield beach; and Southern beaches, representing beaches between Seascale and Drigg.

The size of an object affects how easily someone may encounter it. Sellafield Ltd has, therefore, classified objects according to their physical size to provide a practical scheme for evaluating risks to health. Under this scheme, objects with an average diameter of 2 mm or greater are classed as 'larger objects', while objects smaller than 2 mm are classed as 'particles'. This classification system is based on a widely used grain size classification scheme (Wentworth, 1922).

¹ The Sellafield Particles Working Group is made up of regulators (Environment Agency, Food Standards Agency), Public Health England, Sellafield Ltd and the Nuclear Decommissioning Authority. It aims to review findings from the beach monitoring programme and to help share information between relevant stakeholders.



Figure 1 Map illustrating the approximate extent of beaches included in the assessment (Contains Ordnance Survey data © Crown copyright and database right 2019)

2.1 Radionuclides present on objects

The dose of radiation someone may receive on encountering an object is determined by the radionuclides present and their level of radioactivity. Radioactive objects recovered from beaches near the Sellafield site contain a range of radionuclides, the main ones being caesium-137 (^{137}Cs), strontium-90 (^{90}Sr), americium-241 (^{241}Am), and isotopes of plutonium including plutonium-238 (^{238}Pu), plutonium-239 (^{239}Pu), plutonium-240 (^{240}Pu), and plutonium-241 (^{241}Pu). The main types of radiation emitted are alpha particles from ^{241}Am and isotopes of Pu except ^{241}Pu , and beta particles from Cs, Sr and ^{241}Pu .

Alpha particles travel only short distances in air and body tissues. They penetrate only through the outer layers of the skin and so radionuclides that emit alpha particles mainly present a risk if they are swallowed or inhaled. Beta particles are less damaging to tissue but they can generally travel much further, including through the skin. Beta particles can cause harm if they are emitted by radionuclides located outside the body, for example on the skin, as well as inside the body.

The level of radioactivity is measured in becquerels (Bq), where 1 Bq is equal to the radioactive decay of one atomic nucleus per second. As a Bq represents a very small level of radioactivity, the level of radioactivity on an object is expressed in terms of a kilobecquerel (kBq), where 1 kBq is equal to 1,000 Bq. On average, an object present in the environment near the Sellafield site may have up to 20 kBq of activity. However, there are some objects in the environment that have higher levels of activity, in some cases over 100 kBq. In this risk assessment, we consider both the type of radionuclides that may be present on an object and the range in their level of radioactivity.

2.2 Health effects from exposure to radiation

The International Commission on Radiological Protection (ICRP)² classifies health effects from exposure to radiation as either 'deterministic' or 'stochastic' (ICRP, 2007). In general, 'deterministic' effects occur at higher doses of radiation above a certain level (threshold dose). Below this level, there are no effects. For exposure to radioactive objects, the most important 'deterministic' effect is localised skin damage that may occur within days and weeks of the exposure occurring. To assess the risk of 'deterministic' damage to skin, we need to estimate what the chance is that someone using the beach may receive a dose of radiation above the threshold dose of the skin.

The main 'stochastic' effects are different types of cancer that may occur many years after being exposed. For 'stochastic' effects, it is assumed that there is no dose threshold, and the risk of cancer occurring is proportional to the dose received. Cancer risks are assessed and controlled for radiological protection purposes using a quantity called 'effective dose'. The effective dose is a whole-body average dose that takes account of different doses to the various organs and their different sensitivities to radiation-induced cancer. For radioactive objects, the most important 'stochastic' effect is the risk of developing cancer following the accidental swallowing of a particle. The risk of cancer developing was estimated by multiplying together the chance that cancer may develop if a particle with some level of activity was swallowed with the chance of that particle being swallowed by someone using a beach or eating seafood.

2.3 Chance of encountering an object

The chance that a member of the public may encounter a radioactive object when using a beach depends both on how many objects are present on that beach and what individuals use that beach for. With respect to someone eating seafood, the chance that they may eat a particle depends on whether a particle is present inside an animal at the time it is eaten. In this

² The ICRP is the main international body providing advice and recommendations on protection against the risks associated with ionising radiation.

assessment, only the chance that a particle could be ingested when a mollusc or crustacean was eaten was estimated. The probability that a particle could be swallowed when eating fish was not assessed as there are no routes by which particles which had been eaten by a fish caught off the Cumbrian coast could then be eaten by humans.

2.3.1 Number of objects present in the environment

An intensive large-area beach monitoring programme was started in 2006 to evaluate how many radioactive objects may be present on beaches along the Cumbrian coast. The focus of that monitoring programme was on beaches between Drigg in the south and St Bees in the north as shown in Figure 1. The monitoring programme focused on those particular beaches, as most objects were thought to be located there given how they may move once in the environment (Atkins Limited, 2018). In addition, monitoring has occasionally been carried out on beaches further away from the Sellafield site such as at Whitehaven and Allonby, as well as offshore. Up until the end of 2017, this monitoring programme had detected nearly 3,000 radioactive objects. All objects that are detected are removed from the environment, and those of higher activity are subjected to laboratory analysis.

The number of objects detected per hectare of beach monitored is called the 'find rate'. Not all objects are detected because some with low levels of radioactivity, as well as those that are buried, are much harder to detect than higher activity objects on the surface of the beach. An estimate of the actual number of objects present on a beach is required for the risk assessment. We estimated this by scaling the find rate by a factor that accounted for the chance that objects with different levels of radioactivity and located at different depths would be detected. We assumed that the number of objects present on a beach did not vary with time as the monitoring programme showed that the find rate has not increased significantly between 2009 and 2017.

It was not possible to estimate the number of objects that may be present in areas where molluscs or crustaceans live as very little offshore monitoring has taken place. In addition, as crustaceans are caught along much of the coast they may be obtained from areas where the number of radioactive objects present can vary considerably. For this assessment, we cautiously assumed that the number of objects per hectare where molluscs and crustaceans were collected was equal to the number of objects present on northern beaches or Sellafield beach respectively.

2.3.2 People's habits

Surveys into people's habits are regularly carried out around all nuclear licensed sites in the UK to collect information about the local population. This information is then used in risk assessments associated with the regulation of routine releases of radioactivity. The surveys carried out around the Sellafield site collect information on how long people spend on different pursuits when using beaches, as well as how much seafood they eat. We used information collected during habits surveys carried out around the Sellafield site between 2003 and 2017 in this risk assessment. We assumed this data would apply to people using the beach and eating seafood now and in the future.

Habits surveys deliberately focus on those individuals who spend the most time on a beach or who eat the most seafood. For example, the surveys reported that the maximum amount of

time someone spent on a beach was over 1,000 hours a year, or around three hours every day. The habits surveys also reported that some people ate over 50 kg of molluscs or crustaceans a year, implying they ate seafood on most days.

The second source of information we used in the risk assessment came from scientific literature and included how much material an individual may accidentally ingest when in different environments, including beaches. The final source of information was from ICRP or PHE publications that provide reference values which can be used in radiological assessments. This information includes breathing rates associated with different levels of physical activity such as walking or relaxing on a beach.

Although we could find a substantial amount of information in the literature, we had to use our judgement to estimate certain values including how much clothing people would wear in different weather conditions. Where we had to do this, we used values from the upper end of the possible range to avoid underestimating possible radiation doses and risks to health.

2.3.2.1 What people do when using a beach

The habits surveys showed that people used Cumbrian beaches for one of three general activities: leisure, walking and angling. Leisure activities included sunbathing and playing on sand. We therefore assumed that use of a beach for leisure activities took place mainly during the summer months and mainly involved people wearing swimwear or shorts and T-shirts. Walking included dog walking and beach combing, while we assumed anglers spent some of their time standing on the beach when angling but also some time digging in the sand for bait. As both walking and angling on beaches could occur throughout the year, we assumed individuals involved in either activity would wear a range of clothing.

We assessed the risk to health separately for those using beaches for either leisure, walking or angling activities. We then selected the highest of these risks as a maximum value. This approach provides a conservative estimate of the risk to health to those who use a beach for a range of activities, such as walking in the winter and sunbathing in the summer.

2.3.2.2 Age groups considered in the assessment

For radiological protection, ICRP recommends that the risks to a population is assessed by estimating the effective dose to representative individuals of different ages, usually consisting of 1 year old infants, 10 year old children and 20 year old adults (ICRP, 2006). Using different age groups allows the effect of age-specific habits and differences with age in doses per exposure to be considered.

Ingesting certain radionuclides, including isotopes of Pu, Am and Sr can lead to a small amount of radioactivity being absorbed into the blood and retained in internal organs, including the skeleton, for long periods of time. The dose per Bq ingested depends on the person's age, because of the smaller masses of organs in younger people, and because loss of activity from the body is generally more rapid the younger the person is. To account for exposure occurring over many years following the ingestion of activity, the 'effective dose' an individual receives is the total dose they receive up to the age of 70.

2.3.3 Exposure pathways

In this assessment, we established that the most important exposure pathways (the way in which someone comes into contact with radioactive objects) were skin contact or ingestion of particles. We also looked at inhalation of particles, although this exposure pathway is limited to only the very smallest of particles.

2.3.3.1 Objects coming into contact with the skin

When using a beach, sand and other similarly sized objects, including radioactive particles, can attach themselves to the skin or clothing. The radiation dose received from a particle will depend on the distance between the particle and the skin, with the maximum dose occurring when the particle is in direct contact with the skin. Radioactive particles held further away from the skin, for example if the particle was trapped in clothing, will cause substantially lower doses. For this assessment, we cautiously assumed that any particle that was either on the skin or trapped in clothing was in direct contact with the skin.

We assumed larger objects were too large to become trapped against the skin or in clothing for any length of time. This is because, due to their size, they would quickly fall away from the skin or be removed from clothing or shoes as they would be uncomfortable. As a result, we only assumed larger objects would come into contact with the skin if they were deliberately picked up and held.

2.3.3.2 Accidentally ingesting objects

In this assessment, we assumed that people on a beach could accidentally ingest radioactive particles. For example, grains of sand and other similarly sized objects may get onto food and may be swallowed despite being detected in the mouth. Larger objects are too large to be accidentally ingested as, due to their size, they are likely to be hard to swallow for most people. However, a very small number of people have a medical condition which means that they eat material such as sand and larger objects. In addition, young children often put material into their mouths as part of learning about the world around them. We, therefore, also estimated the risks to someone who had swallowed a larger object, recognising that this will only happen in very rare circumstances.

Molluscs and crustaceans may ingest particles that, in turn, people eating shellfish may also ingest. We cautiously assumed in this assessment that shellfish can eat any of the particles that are present in the environment although the radioactive particles detected so far are generally too large for these animals to eat. We have also assumed that people eat at least some of the animal's gut which may not always occur when someone eats a crustacean.

2.3.3.3 Inhaling particles

An individual may inhale very small particles if those particles are suspended to the height of someone's head, for example by the wind, and then enter either the mouth or nose. Only a few particles that enter the mouth or nose will reach the lungs as most will either be exhaled rapidly or deposited along the throat or windpipe and then swallowed. If a particle does manage to get to the lungs, then the body may take up some of the activity.

Only particles smaller than about one-hundredth of a millimetre can enter the lungs. The approach we took in this assessment was to very cautiously assume that all particles present on a beach could be inhaled, even though all particles detected so far are too large to reach the lungs. We did not consider inhalation of larger objects possible due to their size.

3 Results of the assessment

3.1 Risk of tissue damage from exposure to radioactive objects

The main concern regarding short-term organ and tissue damage is the possibility of radioactive particles that remain in stationary contact with the skin causing localised ulceration. If levels of radioactivity were high enough, damage could occur after about two weeks, presenting as a small blister that would heal to perhaps leave a small scar. None of the particles found up to the end of 2017, of which there are about 2,300, have enough activity to pose a significant risk of causing skin damage.

A secondary consideration is that ingested particles will expose the intestinal wall, particularly the colon wall, to radiation as the particles travel through the alimentary tract. However, the threshold dose for causing damage to the colon wall is substantially higher than for skin damage, and so this risk can be discounted for the radioactive particles identified up to the end of 2017.

3.2 Lifetime risk of cancer from exposure to radioactive objects

We estimated that someone who uses beaches close to the Sellafield site or who eats seafood caught off the Cumbrian coast for a year has a risk of developing terminal cancer in their lifetime due to radioactive objects in the environment of no more than one in a hundred billion (10^{-11} y^{-1}). The greatest risk is from ingesting particles whilst using a beach. We estimated other risks, including eating shellfish containing particles and inhaling very small particles, to be substantially lower. For particles in contact with skin, there is a small risk of skin cancer as well as the possibility of localised skin damage, which we discussed in section 3.1. However, the estimated risk of skin cancer was substantially lower than the risk of cancer following the ingestion of a particle.

When estimating the risk of cancer, we made many cautious assumptions. For example, we assumed someone spent many hundreds of hours a year on a beach or that they ate seafood many times a week throughout the year. The risk to those who make infrequent visits to the beach, such as day trippers or holiday makers, or who only eat shellfish caught locally from the Cumbrian coast a couple of times a year, will, therefore, be much less than that estimated in this assessment. For example, even if someone spent as many hours as possible over their two-week holiday on a beach, their lifetime risk would be at least 10 times lower than the risk estimated in this assessment. Likewise, even if someone walked on a beach every day of the year for an hour, such as a dog walker, their lifetime risk would be no higher than that estimated in this assessment. Similarly, we assumed someone ate seafood on most days of the year. Therefore, if someone only ate seafood once a week, their risk would be at least 5 times lower than the risk estimated in this assessment.

3.2.1 Risk to the health of those using beaches far away from the Sellafield site

A review of the habits of people using beaches in Cumbria showed that they used similar types of beaches, for example sand or pebble beaches, in much the same way regardless of where those beaches were. Given that all radioactive objects originated from the same source, we assumed that the range in the level of radioactivity present on objects does not depend on the beach where those objects are located. The level of risk people face when using different beaches, therefore, mainly depends on how many objects are present. While radioactive objects have been found on beaches beyond St Bees and Drigg, for example at Whitehaven and Allonby, they are present in lower numbers when compared to beaches closer to the Sellafield site. We therefore consider that the risk to the health of people who use beaches beyond St Bees or Drigg would be lower than the risks estimated in this assessment.

3.2.2 Risk to the health of those using beaches or eating seafood in the future

We used information from the beach monitoring programme between 2009 and 2017 and habits surveys carried out between 2003 and 2017 to estimate the risk to the health of people using beaches or who eat seafood. Between those dates, there was very little change in the number of objects present on any beach, in how people use those beaches, or in how much seafood they ate. It appears reasonable to assume, therefore, that this stable situation will continue over the coming years. Over longer timescales, we anticipate that risks to people using beaches or eating seafood will decrease as objects become more dispersed in the environment.

3.2.3 Putting the estimated risk to health into context

The estimated risk from the presence of radioactive objects on beaches near to the Sellafield site are significantly less than other risks members of the public face when they use beaches around the UK. For example, the risk of developing terminal cancer from a possible encounter with a radioactive particle is at least 10,000 times less than the risk of developing terminal skin cancer from sun exposure or of drowning in UK coastal waters. The risks posed by other hazards are also much higher than that posed by radioactive objects. For example, the 'excellent' quality band in the EC water quality directive (European Commission, 2006) is awarded to beaches where the concentration of bacteria in the water is sufficiently low that less than one in a hundred individuals (10^{-2}) may acquire gastroenteritis (Kay et al, 2004).

The risks posed by radioactive objects are also more than 100,000 times less than for situations where regulatory control of a hazard may typically be required. For example, the following extract from Health and Safety Executive (HSE) guidance (HSE, 2001) states that for a risk of death of one in a million per year (10^{-6} y^{-1}) for both workers and the public:

'Risks falling into this region are generally regarded as insignificant and adequately controlled. We, as regulators, would not usually require further action to reduce risks unless reasonably practicable measures are available. The levels of risk characterising this region are comparable to those that people regard as insignificant or trivial in their daily lives. They are typical of the risk from activities that are inherently not very hazardous or from hazardous activities that can be, and are, readily controlled to produce very low risks. Nonetheless, we

would take into account that duty holders must reduce risks wherever it is reasonably practicable to do so or where the law so requires it.'

An annual risk of death of one in a million (10^{-6} y^{-1}) is also used as the level of risk at which the Environment Agency applies regulatory control to manage the disposal of radioactive waste.

3.3 The Environment Agency's intervention plan

The Environment Agency has developed an intervention plan with the other organisations involved in protecting the public from radioactive objects (Environment Agency, 2017). That plan sets out how new objects found by the monitoring programme will be assessed, and how the different organisations will respond if a change in the find rate were to occur or if an object is detected with unusually high levels of radioactivity. To help identify when steps within the intervention plan should be followed, trigger levels are specified that relate to estimated risks of 10^{-6} y^{-1} . This is the level of risk above which regulatory control of workplace hazards or of disposal of radioactive wastes occurs.

The trigger levels in the intervention plan were reviewed with respect to the results of this risk assessment. Based on that review, we have suggested revised trigger levels that are expressed in terms of the ^{241}Am activity on a particle, the contact dose rate from a particle, and the find rate of particles in the environment. These trigger levels are discussed in the technical report.

4 Conclusions

Based on the outcome of this assessment, which used information collected by the beach monitoring programme between 2009 and 2017 and habits surveys carried out between 2003 and 2017, we conclude that the risks posed by radioactive objects on the beaches near the Sellafield site are very low. This assessment supports the conclusions reached in previous assessments.

The current beach monitoring programme was designed to detect and recover objects so that we could assess more accurately the potential hazards they pose. As it is unlikely that any new information obtained from the monitoring programme would change the outcome of this risk assessment, we suggest that there is little justification to continue with the current beach monitoring programme on public health grounds. We therefore suggest that the scope of the current beach monitoring programme could be reduced to a smaller programme that has the aim of collecting information to provide reassurance that risks to health remain extremely low.

The Environment Agency has developed an intervention plan that sets out how new objects found by the monitoring programme will be assessed, and how different organisations involved in protecting public health will respond to a change in the particle find rate or if an object with unusually high levels of radioactivity was detected. The trigger levels in the intervention plan have been reviewed with respect to the results of this risk assessment. Based on that review, alternative trigger levels for use in that plan have been suggested.

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