

Sellafield Radioactive Particles in the Environment

Environment Agency Strategy for Responding to Particle Finds

1. Introduction

Since 2006 an intensive programme of monitoring for radioactive particles has been carried out on beaches close to Sellafield site. To the end of September 2009, this programme had identified and removed 700 radioactive items comprising particles (<2mm diameter), contaminated pebbles and stones.

The programme will continue over the coming years, principally to better characterise the nature and distribution of particles in the environment around Sellafield, to in turn enable a definitive risk assessment to be developed. This risk assessment will use information on the particles that have been detected and removed by the on-going monitoring programme, to estimate the distribution and properties of the residual particle population that remains in the environment. This will enable the likelihood and consequences of members of the public encountering such particles in the future to be estimated.

It is on the basis of this definitive risk assessment that a decision will ultimately be taken on what, if any, interventions are necessary to deal with the residual particle population in the environment around Sellafield. However, undertaking this assessment, and making the associated decisions on final intervention measures, is likely to take several years to complete.

In the meantime, advice on public protection measures is needed, to cover both the current situation based on historical find information, and the future situation based on the emerging 'find' information as and when each new particle is detected. This advice should be based on a best estimate of what the available information means in terms of risks to the public.

This note sets out the Environment Agency's (EA) approach to carrying out the assessment of emerging particle find information, in order to ensure that appropriate advice and information on public and environmental protection issues is provided to the relevant decision making authorities in a timely manner.

It should be noted that development of a definitive risk assessment is a longer-term objective within the on-going programme of work on Sellafield radioactive particles in the environment¹.

¹ Sellafield Radioactive Particles in the Environment – Programme of Work, February 2008, at <http://www.environment-agency.gov.uk>

2. Basis for decision making

There are a number of key considerations and principles that underpin the EA's approach to assessing and responding to the emerging particle find information.

- i. We will consult with partner organisations and agencies, including the Health Protection Agency (HPA), the Food Standards Agency (FSA), and relevant local authorities, in developing our strategy for responding to the detection of radioactive items on Cumbrian beaches, and on any intervention advice that we provide to local authorities and to other decision making bodies.
- ii. Our advice will take into account relevant published criteria for identifying risks associated with radioactive contamination of land, and also published guidance on hazards and risk associated with heterogeneous (solid/particulate) forms of radioactive contaminants.
- iii. Any interventions that we recommend will be justified so as to provide more good than harm, and optimised such that maximum net benefit is achieved.
- iv. Decisions on placing warning signs and on restricting access to public areas are for the relevant local authorities or landowners to make. The EA will provide appropriate information and advice to enable them to consider such actions.
- v. Any consideration of the status of land under the Radioactively Contaminated Land Regulations 2006 will be made by the appropriate regulatory authority based on the specific guidance supporting these regulations.
- vi. We will adopt a precautionary approach where there is scientific uncertainty and a potential threat to human health. Any actions taken in line with this approach will accord with the principles of good regulation, i.e.:
 - actions should be proportionate to the required level of protection, consistent with other forms of action, and targeted to the risk; and
 - actions should be invoked in a process that is transparent, and accountable to stakeholders and ultimately to the political process.

3. Information to support the assessment

The beach survey work is carried out using a vehicle-mounted large area gamma radiation detection array, operated by a contractor working on behalf of Sellafield Ltd (SL)². SL is required under the terms of its Radioactive Substances Act authorisation to carry out a specified amount of beach monitoring each year.

Initial results from this work generate information on radioactive 'finds' as follows.

- Location (GPS position and depth in sand)
- Find type (particle, pebble or stone)
- Contact beta and beta+gamma dose-rates
- Early estimate of gamma-emitting radionuclide composition, and activities of these components

All of the finds are removed from the beaches following their detection. The information generated by this survey programme can be used to provide an early indication of:

- particle hazard (dose rate for deterministic effects, and potential committed effective dose for stochastic effects, were particles to be ingested or inhaled);
- particle distribution (but only by inference, based on the distribution of particles detected and removed).

Supported by information on beach user habits, the estimate of residual particle distribution can then be used to indicate the probability of a member of the public encountering (touching, inhaling or ingesting) a particle.

It should be noted that any estimates of hazard, distribution and consequently risks based on this initial information will be subject to large uncertainties, particularly given the limitations of the beach survey detection method (the detection instruments have limited sensitivity to low energy gamma emitters e.g. Am-241 or pure beta emitters e.g. Sr-90). A more rigorous assessment of encounter probability requires the development of specific models to estimate residual particle distribution, and the probability of a member of the public encountering such particles on relevant Cumbrian beaches. Work to develop this assessment is being undertaken on behalf of the EA by the HPA, as part of the on-going programme of work on Sellafield radioactive particles in the environment.

² For details of the beach monitoring technique, see the Sellafield Ltd Summary Report, Detection and Recovery of Radioactive Particulate from Beaches Associated with Sellafield Nuclear Licensed Site, at <http://www.sellafieldsites.com>

4. Intervention options

Interventions in the context of this note are actions that might prove necessary to protect the public and the environment from exposure to radioactive particles which are present on beach areas around Sellafield site.

Potential options for intervention are presented in Appendix 1. These options essentially group into three categories:

- Options 2 and 3 continuation of monitoring and find removal without further protection interventions;
- Options 4, 5 and 6 implementation of interim/temporary protection measures (e.g. warning signs; restrictions on access; restrictions on food consumption) while hazard removal and risk reduction continues;
- Options 1 and 7 achievement of a final 'end state', whereby continued monitoring, retrieval and analysis is no longer considered necessary (reached either by a definitive assessment of risks that concludes that no remediation is necessary, or by remediation).

Decisions on whether or not to implement interventions will be taken on the basis of assessed risks to members of the public and the environment, taking into account the principles set out in section 2 of this note.

Essentially it will not be appropriate to consider options 1 and 7 (leading as they do to an 'end state') until a definitive picture of particle distributions and properties, and consequently risks to the public, has been developed. This is expected to take several years to develop, and these options will not be considered further in the context of this note.

Options 2 and 3 essentially reflect the current position, in support of the forward beach monitoring programme, and these approaches will continue to be pursued, at least until such time as the available information allows measures to achieve an 'end state' to be developed.

It is therefore in relation to the implementation of options 4, 5 and 6 that we are principally concerned in this note, in terms of actions in response to the emerging find information. Given the absence of a definitive risk assessment for the particle population in the environment, a framework is needed whereby the significance of each particle detected and removed is assessed, with this information then being used to form a view on potential hazards and risks associated with residual particle populations (i.e. those remaining in the environment).

5. Establishing intervention assessment thresholds

Working thresholds for significance for hazard and risk are used elsewhere in the field of radiation protection, and provide a suitable framework for decision making in relation to emerging find information from the Sellafield beach particles survey work. However, various values for these thresholds are used depending on the context. Some are highly precautionary and form the basis of regulatory limits and constraints. Others relate to levels of exposure at which physiological effects have been observed. Appendix 2 to this note presents a summary of some relevant sources of guidance on such thresholds.

From these references, suitable thresholds for the assessment of possible intervention actions for Sellafield radioactive particle finds have been derived as follows, covering both the hazards and the risks that the particles present.

It should be noted that these thresholds do not imply that action is necessary above them, nor that below the proposed values the situation is acceptable either in terms of risk or regulatory compliance. The values are intended purely to aid decision making on the need for immediate public protection measures as new radioactive particle finds are made on beaches.

5.1 Stochastic hazard

***Proposed working threshold for assessment, stochastic hazard:
1Sv lifetime committed effective dose, and/or 10MBq actinide activity***

The 1Sv lifetime dose value proposed by the International Commission on Radiological Protection (ICRP) and the National Radiological Protection Board (NRPB, now the Radiation Protection Division of HPA) is considered to provide an appropriate threshold of 'significance' for the beach particle encounter scenario - despite the fact that conventionally the 1Sv value has been used in situations where doses are certain to occur, rather than for potential doses such as are associated with exposure to heterogeneous contaminants. This dose would correspond to a lifetime increase in the risk of contracting a fatal cancer of 1 in 20, or 5%. The 1Sv lifetime dose is more precautionary than the 50mSv/yr threshold for radioactively contaminated land, and is consistent with ICRP guidance on the level of detriment at which some degree of intervention is almost always justified.

This approach could be used to work back to a particle activity, which was in broad terms the approach adopted in the HPA's advice to the EA in September 2007, which recommended that detection of a particle having 10MBq or more actinide content should prompt an urgent review of health effects.

5.2 Deterministic hazard

***Proposed working threshold for assessment, deterministic hazard:
300mSv/h contact dose rate***

In order to arrive at a hazard 'threshold' for deterministic effects, some account does need to be taken of the way in which the exposure is likely to occur, and in particular how and for how long a particle is likely to establish contact with the skin or other tissue.

Skin dose

ICRP and HPA have recommended 50mSv/y as an appropriate regulatory limit for skin exposure of members of the public. Below these levels of exposure, no deterministic effects are expected to occur. Above this level, and up to around 2Sv, only minor effects appear likely.

For very small radioactive particles, delivery of sufficiently significant skin doses will require the particle to stay in a precise, fixed position on tissue for an extended period; even relatively small displacement of the particle will significantly reduce the likelihood of deterministic effects. Although the stationary contact time for a sand-sized particle on open skin is unlikely to be prolonged, certain encounter situations could result in longer stationary contact, e.g. sand under fingernails. Using a working upper limit of 7 hours, a particle would need to exhibit a contact dose rate of around 300mSv/h in order to deliver a dose in excess of 2Sv (the threshold for acute ulceration).

However, the maximum reasonably foreseeable contact time is uncertain. The use of a figure of 7hr appears reasonable as a working assumption, but it should be noted that this is not supported by definitive empirical or predictive data.

Eye dose

HPA guidance states that serious deterministic effects are 'very unlikely' to occur at an equivalent dose to the lens of the eye of 15mSv/y.

The Dounreay Particles Advisory Group (DPAG) suggests in its 3rd report that protection of the cornea should be considered on the same dose criteria as protection of the skin.

It is proposed to adopt the same 300mSv/h dose rate criterion as used for skin exposure as a convenient indicator of 'high hazard' particles in relation to eye exposure. If a particle triggers the criterion of 300mSv/h, HPA will be asked to provide advice on protection against deterministic effects, including any implications for protection of the eye.

5.3 Risk

***Proposed working threshold for assessment, stochastic risk:
3mSv/y (lifetime committed effective dose x annual probability of
encounter)***
***Proposed working threshold for assessment, deterministic risk:
annual probability of $>1 \times 10^{-5}$ of either skin dose $>50\text{mSv}$ or eye dose
 $>15\text{mSv}$***

For potential exposures, such as those associated with heterogeneous radioactive contaminants, HPA's existing guidance on the assessment of radioactively contaminated land³ employs the multiple of potential committed effective dose and probability of encounter to arrive at a risk-based threshold of significance, above which some intervention action may need to be considered.

It is proposed that, as a measure of risk, the HPA value of 3mSv/y for committed effective dose x probability of encounter that is contained in this guidance is an appropriate threshold to use in the context of defining thresholds for response to emerging information on Sellafield beach particles.

However, estimation of probability of encounter will be subject to significant uncertainties, given that:

- i. knowledge of the distribution of particles is currently based on particles removed, rather than particles remaining;
- ii. an encounter probability calculation methodology has yet to be developed for specific application in the Sellafield context; and
- iii. specific information on Sellafield beach user habits and occupancies is still being generated.

For deterministic effects it is not appropriate to use the multiple of hazard and probability of encounter as an indicator of risk for the full range of possible doses, as deterministic effects will only result above a certain dose threshold, irrespective of encounter time and likelihood. Therefore, it is proposed that where the high deterministic hazard threshold (section 5.2) is exceeded, further assessment should be considered where there is probability in excess of $1 \times 10^{-5}/\text{y}$ of an equivalent dose to the skin or eye exceeding relevant guidance values of 50mSv and 15mSv respectively^{3,4}.

³ Dose Criteria for the Designation of Radioactively Contaminated Land – Documents of the Health Protection Agency, Radiation Chemical and Environmental Hazards, March 2006

⁴ Value taken from ICRP Publication 64 for the optimisation of doses from justified practices, where some radiation effects are deterministic

6. Process of assessment

The process of assessment against the criteria detailed in section 5 is set out in the flow-chart at appendix 3. The approach entails considering the necessity for interventions using a stepwise approach, as follows:

- i. for each find, assess whether, on the basis purely of the hazard that it presents, specific intervention measures appear to be warranted, irrespective of the likelihood that such a find may be encountered;
- ii. where this is not the case, consider the overall risk of encountering such a find, taking into account the magnitude of the hazard and, using best available information from the population of similar finds identified to that time, the probability of encounter, and on this basis consider interventions.

Note that, for ii., until 'bespoke' models are developed for the Sellafield particles context (see section 3), the assessment of the probability of encounter will be based on:

- a. the distribution of similar particles detected and removed during the monitoring programme to date, as a surrogate for the distribution of particles remaining in the environment;
- b. the encounter assessment methodology will be based on that developed by HPA for the Scottish Environment Protection Agency (SEPA) for use in its Sandside Bay study⁵, but using beach user habit data reported by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) for Sellafield beach users as part of the Sellafield particles programme of work⁶.

7. Withdrawal of intervention measures

On the basis of particle finds to date (September 2009), no intervention measures have been considered necessary to protect the public from exposure to radioactive particles on Sellafield beaches. However, in the future the need to consider employing interventions cannot be discounted if, for example, particles are found with higher activities, and/or in increased numbers, than those that have been detected to date.

Interventions such as access and food restrictions, and the placing of warning signs, themselves carry a potential detriment, for example in relation to potentially introducing economic blight by impacting adversely on the amenity value of areas, or affecting the livelihoods of those associated with food production. Decisions to take these actions will be for the local authorities and

⁵ Public Health Implications of Fragments of Irradiated Fuel. Module 3: The likelihood of encountering a fuel fragment on Sandside beach. HPA report reference RPD-EA-9-2005

⁶ Radiological Habits Survey: Sellafield beach Occupancy, 2007. CEFAS report reference C3015

the FSA respectively to take, but informed by advice and information provided by the EA (and other organisations) in line with the process set out in this note.

In implementing such intervention measures, relevant organisations will need to have a clear vision of the circumstances under which withdrawal of the interventions should be considered, and the criteria that will need to be met to support any such withdrawals of measures.

A decision to implement intervention measures will therefore need to be supported by:

- specification of conditions that, when met, will enable the measures to be removed; and
- the development of an approach to achieving these conditions.

The EA will continue to interpret emerging particle find information as set out in this note. Where this demonstrates that the criteria on which interventions were originally based are no longer being met (for example, due to reducing particle numbers, or changes in the types of particles remaining in the environment), then we will present appropriate advice, information and recommendations to the relevant organisations as necessary.

It should be noted that the on-going programme of work on Sellafield radioactive particles in the environment will, in time, yield additional information on particle hazards and risks as a result of detailed particle analysis and risk assessment work. The outcomes of this work, in addition to the information that will continue to be routinely generated by the on-going beach monitoring programme, will be kept under review, and we will update any advice that we have prepared in line with any such emerging information from this programme of work.

8. Conclusions

There is a need to document a strategy for action in relation to emerging information on the presence of heterogeneous radioactive contaminants along the west Cumbrian coastline. This note sets out a decision making process for the Environment Agency to follow as and when individual finds are identified, based on our best assessment of hazard and risk associated with the emerging information.

It should be noted that this strategy relates to the assessment of hazard and risk on a find-by-find basis. A wider review of the overall risks associated with residual particles in the environment will be undertaken as part of the on-going Sellafield Radioactive Particles in the Environment Programme of Work.

Appendix 1

Intervention options

Option	Comments
1. Cease monitoring	Will require the completion of a definitive risk assessment on residual (rather than removed) particle populations. This is not considered to be a tenable option which could be invoked in response to the emerging find information from the on-going beach monitoring programmes, in the absence of a definitive risk assessment.
2. Continue detect-and-remove as part of the process of further assessment	This is the current position.
3. Continue detect-and-remove as part of a mitigation/remediation strategy	This is a beneficial consequence, but not a direct objective, of the current monitoring programme. This position may change as the characterisation of particle distributions becomes clearer.
4. Place warning signs on beaches	These measures will be for the relevant Local Authorities to implement, based on advice from the EA and other organisations (e.g. HPA). Not considered necessary based on find information to date.
5. Implement access restrictions to affected areas	
6. Implement food consumption restrictions	This measure will be for the FSA to implement, based on advice from the EA and other organisations (e.g. HPA). Not considered necessary based on find information to date.
7. Undertake large-scale remediation and/or protection measures	Options such as large-scale removal, and/or immobilisation of sources, will be informed by a reliable risk assessment, and by further monitoring, including off-shore monitoring, to characterise distributions of radioactive particles in the environment. Determining whether such measures are necessary will be tasked to Sellafield Ltd in the form of a Best Practicable Environmental Option (BPEO) assessment.

Appendix 2

Sources of guidance on radiation dose thresholds

Existing authoritative sources of radiation protection information have been reviewed in order to identify the most appropriate criteria for judging the significance of radioactive particle finds on beaches around Sellafield. The principal aim has been to identify appropriate dose thresholds, relating to both stochastic and deterministic effects, which can be used to trigger consideration of interventions on a find-by-find basis.

The principal sources of information on this subject have been taken to be the International Commission on Radiological Protection (ICRP), and the UK's Radiation Protection Division of the Health Protection Agency (HPA).

Recent work by the Scottish Environment Protection Agency (SEPA) on defining intervention criteria for beach particle finds has also been reviewed.

1. ICRP Guidance

The ICRP is an international advisory body providing recommendations and guidance on radiation protection. This guidance and advice is reflected in national and international regulations, including the European Union's 'Basic Safety Standards' Directive 1996.

In its Publication 59 Guidance⁷, ICRP indicates a threshold of 1 Sievert (Sv) for acute transient ulceration of the skin from what it terms 'hot' particles, and 5Sv for acute deep ulceration.

In Publication 60⁸, exposure limits for skin dose of 500mSv/y and 50mSv/y are recommended for workers and members of the public respectively. For eye exposures, the recommended limits are 150 and 15mSv/y respectively. Both sets of recommended limits apply to continuous, year-on-year exposure.

In its Publication 64 Guidance⁹, ICRP identifies that:

- i. at doses below 0.1Sv, only stochastic effects are expected to occur;
- ii. at doses of 0.5Gy and above, deterministic effects can occur; and
- iii. at doses of 6Gy and above, if delivered over a short time period, almost all individuals will suffer severe adverse health effects.

In Publication 64 ICRP also sets out a series of probability values against which decisions can be made on acceptability, or otherwise. From this guidance, the following thresholds can be interpreted:

- 1×10^{-6} for doses which could result in death;
- 1×10^{-5} for doses which could give rise principally to deterministic effects.

⁷ ICRP Publication 59 – The Biological Basis for Dose Limitation in the Skin

⁸ ICRP Publication 60 – 1990 Recommendations of the ICRP

⁹ ICRP Publication 64 – Protection from Potential Exposure – A Conceptual Framework

ICRP has also published guidance on protection against prolonged exposure¹⁰, which identifies guidance on relevant dose thresholds for intervention (implementing protective measures) in the context of emergency response. This identifies that intervention is almost always justifiable where there is an on-going annual effective dose of between 10–100mSv (equated to ca. 1-10Sv lifetime dose). A total annual effective dose of 10mSv or less can be used as a reference level for safe living (in this context “safe” means that population group will not receive a total annual dose leading to identifiable adverse health effects; it does not however mean zero risk).

2. HPA guidance on dose criteria for radioactively contaminated land.

The Health Protection Agency has published guidance on radioactively contaminated land (NRPB 1998), and more recently on dose criteria for assessing radioactively contaminated land.

The former states that, in relation to intervention situations, if the projected lifetime effective dose from the contamination is expected to exceed 1Sv then measures to reduce this dose would almost certainly be justified (corresponding to a lifetime accumulation of annual doses of 10-20mSv/y).

The latter guidance is intended to support the process of formal designation of land under the Radioactively Contaminated Land Regulations. The guidance addresses situations where there will be ‘lasting’ exposure, i.e. ‘exposures that occur at a reasonably constant rate over a significant fraction of an individual’s lifetime, i.e. some tens of years’. Within this context, the guidance does include consideration of situations where exposures are not *likely* to occur, but rather represent *potential* exposures, and in relation to these circumstances sets out the criteria summarised in table 1 below.

¹⁰ ICRP Publication 82 – Protection against Prolonged Exposure – Application in Accident Situations

Table 1

Annual dose (mSv)	Status	
Effective dose ≤50 and Equivalent dose to lens ≤15 Equivalent dose to skin ≤50	Effective dose × probability ≤3mSv/y	Not radioactively contaminated land.
	Effective dose × probability >3mSv/y	Radioactively contaminated land
Effective dose >50 and/or Equivalent dose to lens >15 and/or Equivalent dose to skin >50	Decisions on whether land is radioactively contaminated land or not will need to be taken on a case by case basis with consideration of: possibility and severity of deterministic effects, the potential non-linearity of the dose-response relationship for stochastic effects (for doses above 100mSv), the probability of doses being received, practical issues related to detectability and remediation	

3. SEPA strategy for radioactive particles on beaches along the north Solway coastline

SEPA has a published strategy¹¹ relating to beach monitoring work carried out along the north Solway coastline in December 2007. This work was specifically carried out to identify whether Sellafield radioactive particles were present, and used the same beach monitoring equipment and methodology as employed by Sellafield Ltd's monitoring contractors along the west Cumbrian coastline.

The criteria employed are summarised in table 2 below, and apply where particles have been identified and activities assessed.

Table 2

Dose	Action
effective dose ≥100mSv, and/or skin dose rate ≥10Sv/hr	Consider suitability of signage, with a view to recommending that signs are erected. Consider if other interventions are appropriate.
dose x probability of encounter ≥3mSv (effective) or ≥50mSv (skin)	Consider signs and any further interventions
dose x probability of encounter <3mSv (effective) and <50mSv (skin)	No action on radiological protection grounds. Provide information to stakeholders.

The SEPA 10Gy/hr skin dose rate threshold is based on Dounreay Particles Advisory Group (DPAG) information¹² and assumes a fixed location contact time of 1hr. The value is an ED50 (i.e. the dose level at which deterministic effects are observed in 50% of cases); the corresponding threshold for acute

¹¹ SEPA - Strategy for the Assessment of the Potential Impact of Sellafield Radioactive Particles on South-west Scotland – December 2007

¹² Dounreay Particles Advisory Group Third Report September 2006

ulceration is 2Gy. It is worth also noting the observation reported by the National Council on Radiation Protection and Measurement (NCRP) that, at doses between 50mSv and 2Sv, such effects as might occur are likely to be innocuous¹³.

4. HPA specific advice on Sellafield beach particles

On the basis of the properties of specific actinide-rich particles which have been recovered as part of the beach monitoring programme to date, HPA has provided advice to the Environment Agency¹⁴ as follows:

The finding of particles with actinide activities greater than 10 MBq (10^7 Bq) should prompt an urgent review of the health risks from public occupancy of the beaches. This activity level is at least two orders of magnitude below that at which serious deterministic effects would be expected and thus provides a considerable margin for safety in this respect. Ingestion of such a particle would, however, pose a risk of stochastic effects that could not be ignored. Using this activity level as a benchmark, an initial screening of areas of potential public exposure should be undertaken with the objective of detecting actinide-bearing particles with activity levels down to at least 1 MBq (10^6 Bq).

¹³ NCRP Report No. 106 – Limit for Exposure to Hot Particles on the Skin, 1989

¹⁴ Letter from HPA to EA dated 21 September 2007

Appendix 3

Particle finds assessment protocol

