

## **SELLAFIELD RADIOACTIVE PARTICLES IN THE ENVIRONMENT**

### **REVIEW OF PROGRESS, MARCH 2009**

#### **Executive Summary**

In February 2008 the Environment Agency (EA) put in place a formal programme of work for the assessment of contamination by radioactive particles on and around the west Cumbrian coastline. The assessment is focussed on public protection from high activity discrete radioactive particles that have been released to the environment from activities at Sellafield site.

This report presents a review of the status of the work programme, in the context of delivery against the original objectives, and the focus and direction that are needed to take the work forward, ultimately to a point of completion.

#### **Conclusions**

1. Good progress has been made to date, and the nature, extent and significance of the contamination of local beaches is now clearer than was the case at the outset of the programme.
2. There are a number of significant areas where uncertainty remains high, notably:
  - the true distribution on beaches of particles that contain high proportions of actinides (termed 'alpha-rich');
  - the distribution and behaviour of particles in offshore sediments;
  - the uptake into the body of actinides in alpha-rich particles if ingested (and associated doses if particles are encountered);
  - the likelihood of a member of the public encountering a radioactive particle.
3. Advice provided by the Health Protection Agency (HPA) and the Food Standards Agency (FSA) is that no special measures are necessary to protect the public at this time. This advisory position takes into account these uncertainties, but emphasises that priority must be given to reducing them so that a more realistic assessment of risk can be undertaken.

4. To address the areas of uncertainty, a programme of monitoring, retrieval and analysis will need to continue at current levels, supported by additional focus and priority on the matters identified in point 2. above.
5. The high level objectives of the work programme are considered to remain appropriate.
6. Current arrangements for communicating with and providing information to partner agencies and stakeholders are considered to remain appropriate.
7. The existing regulatory approach, to ensure that the potential for radioactive particles to be released from on-going activities at Sellafield site is minimised by application of Best Practicable Means (BPM), is considered to remain appropriate, but will need to be kept under continuous review as new information emerges.
8. There is a need to develop an 'end state' for the programme of work, and criteria to define when this position has been reached.

## **Recommendations**

1. For year 2009/2010 the Environment Agency (EA) will continue to specify requirements for Sellafield Ltd (SL) to undertake beach monitoring, monitoring method development and particle analysis via the Compilation of Environment Agency Requirements (CEAR) supporting the operator's Radioactive Substances Act certificate of authorisation.
2. EA will specify a further requirement to SL, possibly within the CEAR, or within schedule 9 of the authorisation, for SL to develop and implement a co-ordinated long-term programme of work by 31/3/10. This work programme will be objective-based, and will cover
  - beach monitoring and monitoring method development
  - offshore characterisation
  - particle analysis and analytical strategy development
  - source identification
  - source-term exclusion measures
  - assessment of pathways and environmental transport
  - 'end state' development – to be informed by BPEO assessment and to be implemented to BPM
  - research and development to ensure that techniques used remain best available
3. EA will retain a primary role for facilitating provision of supporting information on specific technical questions such as beach occupancies, particles encounter probabilities, food chain implications and advice on hazard & risk, from relevant expert organisations.
4. EA to maintain regulatory oversight of SL's implementation of the CEAR requirements, and the development and implementation of the long-term work programme. This will include, where appropriate, expert peer review and independent assurance.
5. EA to continue to co-ordinate engagement with key stakeholders, providing them with independent information, communications and advice (including advice on interventions to protect the public).

## **SELLAFIELD RADIOACTIVE PARTICLES IN THE ENVIRONMENT**

### **REVIEW OF PROGRESS, MARCH 2009**

#### **1. Introduction**

In February 2008 the Environment Agency (EA) published its programme of work for the assessment and regulation of contamination by radioactive particles on and around the west Cumbrian coastline<sup>1</sup>.

This document presents a review of the progress made in carrying out this programme of work, and identifies an approach for continuing with this work over the coming years.

The review is presented in the format of the original programme of work, covering the following elements:

- the high level objectives of the work programme;
- the structure of the work programme and the work stream elements themselves;
- the objectives for each work stream
- organisational interactions and responsibilities;
- status of completion of the work programme schedules of work.

This document takes into account the outcomes of the multi-agency meeting on Sellafield radioactive particles in the environment, held at Penrith on 25 November 2008<sup>2,3</sup>.

#### **2. Overall status of the work programme**

An overview of the status of the programme of work, as of March 2009, is presented in appendix 1 to this note.

#### **3. Review of the High Level Objectives of the Programme of Work**

Six high level objectives were established in the original programme of work document. These are reproduced in the following section, together with a summary of the progress made in meeting these objectives.

Progress in achieving the individual work-stream objectives that follow from these high-level objectives is summarised in section 6, with more detail on the completion of the work-stream tasks presented in appendix 2.

Following discussion at the multi-agency meeting in November 2008, it was agreed that these high level objectives remain broadly fit for purpose, and will be retained in the forward work programme, subject to the recommendations for further work/focus identified below.

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<sup>1</sup> Sellafield Radioactive Particles in the Environment – Programme of Work, February 2008  
[http://www.environment-agency.gov.uk/commonddata/acrobat/programme\\_of\\_work\\_2004785.pdf](http://www.environment-agency.gov.uk/commonddata/acrobat/programme_of_work_2004785.pdf)

<sup>2</sup> Discussion paper for a multi-agency meeting on Sellafield radioactive particles in the environment - 25 November 2008, Ghyll Mount, Penrith

<sup>3</sup> Summary note for the Record, Multi-Agency Meeting on Sellafield Radioactive Particles in the Environment. Environment Agency, Penrith, 25 November 2008

### 3.1 Objective 1

**To facilitate the characterisation of the population of particles in terms of their locations, the hazards that they pose, potential exposure pathways, and the associated risks to humans and the wider environment.**

#### **Progress**

Programmes of monitoring and analysis have improved understanding of the extent, nature and significance of the particle contamination issue. Areas of uncertainty remain, notably associated with offshore populations, and the extent of contamination by alpha-emitting and 'pure' beta emitting radionuclides. Work to address these uncertainties is on-going, principally in the form of the development of improved detection techniques, and construction of a statistical model for describing distributions of radioactive particles in the environment.

It is recognised that further development of analytical strategies will be necessary in order to fully understand particle distributions and properties that are of relevance to ecosystem transport behaviours and biological uptake.

Work to understand beach user habits and potential transport dynamics has been helpful in addressing this objective, but again is limited by uncertainties. Habit data will benefit from further assessment, and further habit survey work is recommended. Further work to develop predictive transport models requires further data on particle properties, and particularly distributions of particles off-shore. It is recommended that further development of quantitative transport models should be considered at a later stage in the programme, when such data are available. However, a limited focus on further transport modelling development to support the targeting of monitoring, and in particular offshore monitoring, may be justified in the short term.

The focus to date has been and necessarily will remain one of addressing risks to human health. There remains a paucity of information on the sensitivities of other environmental receptors to radiation exposure, and this remains an area of on-going scientific investigation and development internationally. The forward programme of work should maintain a watching brief on developments in this area, and apply any learning accordingly.

#### **Recommendations**

- Continue with programmes of monitoring, analysis, and risk assessment.
- Improve beach detection capability.
- Consider improved analytical techniques to support particle source identification, environmental mobility, and biological uptake.
- Develop and implement an approach for characterising the presence of particles in offshore areas.
- Consider further habit surveys to support the risk assessment work.
- Consider further investigations into transport mechanisms to support future monitoring targeting.
- Keep international developments on radioactive particle impacts on environmental receptors (flora and fauna) under review.

### 3.2 Objective 2

**Using a precautionary approach, to establish the levels of and natures of any interventions necessary to provide adequate protection of human health and the environment.**

### **Progress**

Clearer understandings of particle hazards and distributions have enabled precautionary assessments to be made on risks to the public associated with beach use. On this basis, using both existing and newly drafted strategies for responding to particle 'finds', HPA advice to date has remained that no direct interventions, other than continuing the 'detect and remove' monitoring programme, are necessary to protect the public.

As outlined earlier, uncertainties attach to many of the assumptions made to arrive at this position, and the forward work programme will need to be tailored to address these areas of uncertainty/information gaps.

Existing guidance on dose assessment for heterogeneous radioactive contaminants in the environment exists<sup>4</sup>, but there is a need to review and tailor this guidance to the specific situation of Sellafield beach particles. Stakeholder expectation is that such guidance should be published.

### **Recommendation**

- Working with partner agencies, develop and publish a strategy for action/intervention.

## **3.3 Objective 3**

**To identify the origins, sources and release routes to the environment of the particle populations that are identified.**

### **Progress**

Given the relatively early stage of the work programme, and the consequently limited amount of detailed particle characterisation carried out to date, progress in this area is itself limited. Specific arrangements are in place to review emerging data on find locations and characteristics in light of possible operational or environmental sources, and historical events have been reviewed and documented to support this process – enabling some tentative early conclusions on potential source terms to be drawn. However, the work to achieve this objective is on-going, and is likely to remain so for some time.

### **Recommendations**

- Ensure that sufficient resourcing and focus are maintained in attempting to link emerging particle find data with potential sources.
- Ensure that forward analytical and monitoring programmes are informed by source identification requirements.

## **3.4 Objective 4**

**Where necessary and practicable, take appropriate regulatory actions to ensure that future releases of particles from site are prevented or mitigated.**

### **Progress**

A co-ordinated regulatory programme is in place, comprising plant-specific assessments and inspections of the operator's arrangements to prevent or minimise the release of radioactive particles to the environment, against the authorisation requirement to ensure the Best Practicable Means (BPM) to

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<sup>4</sup> Dose Criteria for the Designation of Radioactively Contaminated Land – Documents of the Health Protection Agency, Radiation Chemical and Environmental Hazards, March 2006

minimise radioactive discharges. A number of requirements relating to optimising operational arrangements have been established as conditions of authorisation BX9838. Based on our current understanding of activities and standards at Sellafield site, the existing authorisation is considered to remain fit-for-purpose, and no additional specification of requirements in relation to particle release prevention/abatement is considered necessary at this time. Work to achieve this objective is on-going, and the situation will be kept under review (noting that the Sellafield Ltd RSA93 authorisation is subject to annual review).

#### **Recommendation**

- Maintain and keep under review the programme of regulatory scrutiny to ensure that BPM continues to be employed for preventing or minimising particle releases into the environment.

### **3.5 Objective 5**

**To develop and maintain an effective programme of communication to ensure that any actions taken by stakeholders are informed by an objective assessment of risk.**

#### **Progress**

A communications strategy is in place, and information is being provided to stakeholders via a number of routes. Feedback to date suggests that these arrangements are meeting stakeholder needs and expectations. These arrangements will be subject to on-going review to ensure that this objective continues to be met.

#### **Recommendation**

- Maintain communications arrangements and keep under review.

### **3.6 Objective 6**

**To build, in so far as is possible, application of sound science bringing a consistent approach to the characterisation and management of radioactive particles in the environment.**

#### **Progress**

Relevant national and international experts and expert organisations have been engaged as part of the work programme. There is considered to be greater scope to undertake benchmarking of approaches to similar situations internationally.

#### **Recommendation**

- Pursue increased engagement with the international community, and in particular relevant experts and regulators, on the particles work.

#### **4. Review of the Structure of the Programme of Work**

The structure of the work programme is as set out in the February 2008 Programme of Work document, and comprises the following work-streams:

- Environmental Monitoring Programme.
- Particle Analysis and Characterisation.
- Transport and Dispersion Model Development.
- Hazard and Risk Assessment.
- Intervention Strategy.
- Regulation and Enforcement.
- Communications Strategy.
- Research and Development.

The consensus developed at the November 2008 multi-agency meeting is that this structure remains broadly fit for purpose.

Discussions during this meeting, and subsequently with partner agencies and stakeholders, emphasised that the area of regulation and enforcement, and within this identification of potential or actual sources and pathways for particle release into the environment (both historical and on-going), is of particular interest and importance.

To build confidence that current site operations do not present an unacceptable on-going risk of discharging active particles into the environment, the bulk of the work-stream identified as Regulation and Enforcement has recently been established as a stand-alone work package, with its own set of objectives and work schedules.

The management of this work-stream now falls to Sellafield Ltd, with regulatory oversight provided by the Environment Agency. This arrangement entails increased resource allocation by both organisations.

It is intended that separate, but co-ordinated, initiatives should be maintained for the on-site and off-site particles issues. There is considered to be opportunity, and justification, for securing greater ownership by Sellafield Ltd of the latter area (see section 5 below).

## **5. Review of Roles and Organisational Interactions**

### **5.1 The Environment Agency's role**

The EA's role as stated in the February 2008 work programme is to:

- oversee delivery of each of the work streams in the context of meeting the high level objectives of the work programme;
- ensure open and transparent communication with key stakeholders;
- ensure that the project approach employs best practice, and takes full account of evolving techniques and scientific understanding, including relevant national and international developments

This wide programme management role recognised the need at that time to draw together a disparate number of pre-existing work streams, and to supplement these with additional areas of focus. 12-months on, and the structure and arrangements for delivery of the work programme tasks are now considered to be well established.

Much of the original work programme falls to the site operator, Sellafield Ltd, to deliver, and this will certainly remain true for much of the forward programme of work (which, it is recognised, is likely to extend over several years), including the areas of:

- beach monitoring and monitoring method development
- offshore characterisation
- particle analysis
- source identification
- source-term exclusion measures
- assessment of pathways and environmental transport
- 'end state' development – to be informed by BPEO assessment and to be implemented to BPM
- research and development to ensure that techniques used remain best available

The EA's current assessment is that the site operator has the capability to take on a broader role in the definition and management of this forward work programme on work. Moreover, it is considered desirable to task greater management of these work streams collectively to Sellafield Ltd for planning, co-ordination and delivery, for the following reasons:

- I. to maximises the efficiency, effectiveness and risk-based targeting of use of resource;
- II. to facilitate EA to move away from a programme management role and instead to adopt a more familiar 'business as usual' regulatory role;
- III. using objective-based specifications for delivery of the work programme, to provide the operator with greater flexibility to respond to emerging information;
- IV. to reflect a more appropriate ownership of the particles challenge.

It is EA's view that this revision to arrangements is supported the good track record of partnership working that has been achieved between the site operator, EA and the various other organisations involved in this programme of work over the past 12 months, backed by a good record of programme delivery over this time.

The intention is that the aspects of the work programme identified above will be tasked to the site operator to manage by establishing a high level, objective-based requirement in Sellafield Ltd's RSA93 authorisation for Sellafield site.

The requirement would entail Sellafield Ltd defining, implementing, reporting upon and keeping under review a programme of work to meet the specified objectives. This would, in due course, replace the existing CEAR specification on Sellafield beach monitoring, but with the key difference that the requirements on Sellafield will become objective-based rather than prescriptive in terms of the regulator defining tasks to be completed. The delivery of this requirement would be subject to the normal regulatory process in terms of compliance assessment, supported by a framework of regular reviews with EA and partner agencies, publication of information to stakeholders, and formal periodic reporting.

It is recognised that some aspects of the work programme should, however, remain with the EA, notably commission and management of the work on risk assessment, and the co-ordination and provision of advice and information to stakeholders and members of the public. Furthermore, EA's role should continue to include aspects of best practice assessment and wider liaison with relevant national and international experts.

### **Recommendations**

- Sellafield Ltd to develop and implement a co-ordinated long-term programme of work. This work programme to be objective-based, and to cover beach monitoring and offshore characterisation, particle analysis, on-site source characterisation, environmental transport aspects, the development of an 'end state' for the programme, and supporting research and development activities.
- EA to retain a lead role in obtaining advice on hazard & risk to man and the environment from relevant expert organisations, and in co-ordinating the provision of information and advice to stakeholders<sup>5</sup>.
- EA to maintain regulatory oversight of SL's implementation of the CEAR requirements, and the development and implementation of the long-term work programme. This will include, where appropriate, expert peer review and assurance.

## **5.2 Peer review**

Independent scrutiny and peer review is provided by a specifically-convened sub-group of the Committee on Medical Aspects of Radiation in the Environment (COMARE). This COMARE Sellafield Working Group meets periodically, and receives quarterly update reports from EA.

EA has also put in place an independent expert group to provide support for the technical assessment of emerging developments and arrangements. The group comprises a number of individuals with previous experience of the science, regulation and management of radioactive particles in the environment. The facility is established on a commercial contract basis.

These arrangements are considered to remain fit for purpose, and it is intended that they are retained for the forward work programme.

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<sup>5</sup> It should be noted that a programme of work was put in place in January 2009 by EA for HPA to provide support on hazard and risk assessment. This programme extends to March 2010.

### **5.3 Interactions with key partners**

EA has committed to work with key partner organisations, agencies and stakeholders to develop a methodology that is broadly applicable for the characterisation and management of radioactive particles not just at Sellafield, but also in other relevant situations.

It is believed that the approach taken, and that proposed for the forward programme, satisfies this commitment, but again this situation will be kept under continuous review as work proceeds over the coming years.

## **6. Review of Individual Work-Stream Objectives and Tasks**

Progress against the specific tasks in the original work programme schedules of work is presented in the tables in appendix 2 of this note. To what extent this meets the original work stream objectives is detailed in the following sub-sections.

### **6.1 Environmental Monitoring Programme**

<b>Objective</b>	<b>Progress</b>
<p>To ensure that best practice is employed to measure radioactive particle distributions on beaches, in offshore sediments and on land, based on the use of appropriate, defined performance criteria.</p>	<p>Objective met for medium/high energy gamma emitters such as <sup>137</sup>Cs and <sup>60</sup>Co. Technique employed to date has limited capability for detecting low energy gamma emitters (such as <sup>241</sup>Am and Pu isotopes) and 'pure' beta emitters (via Bremstrahlung radiation). Improved monitoring methods for these components have been identified as part of a BPM study and are to be implemented in 2009/10. Implementation of these new techniques will be supported by a representative field calibration study to quantify the response efficiency, again in 2009.</p> <p>On-going review and development of alternative/enhanced techniques will be required to ensure that the approach to monitoring remains consistent with BPM.</p> <p>Assessment of the distributions of particles that are below current limits of detection may need to be considered in the future programme of distribution characterisation.</p> <p>Substantive work to deploy suitable techniques on land, and to develop and deploy techniques for monitoring seabed areas has not yet been carried out. These aspects will constitute important elements of the forward work programme.</p>
<p>To generate, in so far as is reasonably practicable, a comprehensive picture of those distributions and densities, and how they may change over time.</p>	<p>A total of 440 Ha of beach area surveyed to March 2009 has yielded a considerable amount of information on particle distributions on the shore areas around Sellafield.</p> <p>The forward monitoring programme is expected to retain exclusive use of a survey vehicle for 2009/10 and beyond, corresponding to annual survey areas of around 250 Ha.</p> <p>As this is a dynamic environment, the 'picture' of beach finds distribution is and will continue to evolve with time.</p> <p>On-going interpretation of the data is enabling this picture of the broader distribution, the distribution of different particle types within this, and changes in particle distribution with time and following particular weather events to be built up.</p> <p>Although the geographical extent of the monitoring carried out to date stretches from the north Solway coastline down to the Esk estuary, there are arguments for extending this further, particularly south, and/or supplementing monitoring at the outer range of the existing monitoring area with additional surveys.</p>
<p>To ensure adequate quality assurance arrangements for the monitoring programme in</p>	<p>Formal QA arrangements have been put in place and are subject to independent audit. Errors and uncertainties associated with measurement techniques have largely</p>

<p>order to demonstrate the reliability of the data that is generated, and to establish the errors and limitations that attach to the data.</p>	<p>been established, with fully representative 'field' calibrations of the beach monitoring detection system to be completed by mid-2009.</p>
<p>To remove particles from the environment, to reduce the potential for the exposure of the public and other species and habitats, and to provide reassurance to stakeholders.</p>	<p>All 'finds' have been removed from beaches. Consideration is currently being given to directing increased beach monitoring to areas of higher occupancy.</p>
<p>To obtain sufficient number of particles to ensure screening that allows more effective and representative detailed analysis of populations with similar characteristics and origins.</p>	<p>As of February 2009 around 600 particles have been removed from beaches. 67 of these have been committed for destructive testing; the remainder are available for further analysis.</p>
<p>To inform the process of hazard and risk assessment.</p>	<p>Results from the beach monitoring and particle analysis work have been considered by HPA in reviewing its advice to EA on hazard and risk. Further monitoring and analysis will be tailored to ensure that remaining uncertainties in risk assessments are addressed, in so far as it is reasonably practicable to do so. Key areas here are the development of improved beach and offshore monitoring techniques, and quantification of the detection efficiencies of these and preceding techniques.</p>

6.2 Particle Analysis and Characterisation

Objective	Progress
<p>To establish a definition for the radioactive particles of relevance to this programme.</p>	<p>A working definition based purely on an upper bound on mean diameter (&lt;2mm) has been put in place. HPA is due to provide an initial view on the definition of a particle by April 09 and this will be updated as more information becomes available</p>
<p>To ensure that best practice is used to characterise the particles that are recovered, in order to establish the physico-chemical behaviour of the particles in the environment, and their associated transport properties, for example:</p> <ul style="list-style-type: none"> <li>i) the longevity of the particles in their actual and potential environmental settings;</li> <li>ii) the radiobiological characteristics of the particles in terms of their potential to cause harm to humans and biota; and</li> <li>iii) the technical requirements for providing efficient monitoring arrangements.</li> </ul>	<p>A programme of radiological, physical and chemical testing has been carried out to BPM on a sub-set of particles. This has provided valuable, but not yet definitive, information on which to interpret these behaviours.</p> <p>Further testing, focused on specific objectives, is to be put in place for a further sub-set of particles and carried out in 2009.</p> <p>The use of new analytical techniques will be kept under review to ensure that, where reasonably practicable, improved information is obtained in the future.</p>
<p>To generate relevant data on particle properties at a sufficient rate and with sufficient reliability to satisfy work streams 3, 4 and 6 (described later).</p>	<p>Meeting this objective is an on-going process.</p> <p>Testing to the end of March 09 has enabled views on particle transport, hazard &amp; risk, and source identification, to be developed, but uncertainties remain high.</p> <p>There have been some reliability issues with the testing carried out (density analysis; SEM image quality) which will need to be addressed in further analytical programmes.</p> <p>The scope of testing required has not enabled much in the way of useful data to be considered as part of the transport and dispersion modelling work. Further data requirements, identified as part of this latter work-stream, will be incorporated into the next tranche of particle analysis work.</p>
<p>To ensure adherence to an appropriate quality assurance plan for the analysis programme in order to demonstrate the reliability of the data that is generated, and to establish the errors and limitations that attach to the data.</p>	<p>Formal QA arrangements have been put in place and are subject to independent audit. Errors and uncertainties associated with measurement techniques are established.</p>

### 6.3 Transport and Dispersion Model Development

Objective	Progress
<p>To develop a modelling capability to predict the dispersion and transport of Sellafield radioactive particles in the littoral and marine environment, taking into account both normal and extreme weather events, to:</p> <ul style="list-style-type: none"> <li>i) facilitate the targeting of monitoring effort;</li> <li>ii) inform our understanding of the significance of potential exposure routes;</li> <li>iii) contribute towards the development of our understanding of risk;</li> <li>iv) assist in the identification of the original sources of the particles, and pathways into the environment.</li> </ul>	<p>Some indicative transport trends have been identified by the development (by CEFAS) of a conceptual model for the west Cumbrian marine and littoral environments. However, without further model development, this will remain indicative only, and insufficient for predicting particle transport direction and rates with adequate certainty.</p> <p>Further environmental data, including new offshore and beach observations of sediment processes (e.g. sediment mixing depth), will be needed to improve the set-up and validation of any models selected for further work.</p>
<p>To understand the potential for further movement of existing particle populations with time, including beach repopulation and the implications of on-going beach sediment removal and deposition.</p>	<p>The timescales relating to the provision of further particle and environmental data to support the development of more accurate models mean that further refinement of the model is not practicable at this stage in the programme of work.</p>
<p>To ensure that a good understanding of likely transport mechanisms is developed and maintained throughout the project, based on up-to-date research and published material.</p>	
<p>To identify other data requirements that will be necessary to support our understanding of Sellafield particle transport.</p>	<p>Particle measurement parameters have been identified that will facilitate the future development of potentially quantitative predictive models for particle transport.</p> <p>Future analytical strategies will take into account these measurements, including, where appropriate, weathering/degradation and remobilisation processes.</p>

### 6.4 Hazard and Risk Assessment

Objective	Progress
<p>To develop an understanding of risks associated with exposure of both human (priority) and non-human species to the full range of particles that are identified, specifically addressing;</p> <ul style="list-style-type: none"> <li>i) external doses;</li> <li>ii) internal doses; and</li> <li>iii) stochastic and deterministic effects.</li> </ul>	<p>The picture is becoming clearer, with committed effective dose estimates for ingestion supported by a limited number of in-vivo test results – which tend to show very low systemic uptake factors.</p> <p>Contact dose rates appear to be insufficient to cause deterministic effects in realistic contact scenarios.</p> <p>Little progress has been made in characterising the potential pathways and exposures relating to environmental receptors, in part due to the absence of accepted methodologies and dose-response criteria. This is an evolving area of R&amp;D internationally, and a watching brief should be maintained within the programme.</p>

<p>To reduce uncertainties associated with existing dosimetric assumptions on hazard, and as far as possible to quantify such uncertainties as remain.</p>	<p>Given apparent inconsistencies between in-vitro and in-vivo test data, retention of a precautionary gut update factor for actinides of <math>10^{-4}</math> has been recommended for the purpose of estimating ingestion doses. Further in-vivo and in-vitro testing will be undertaken in 2009 and 2010 to further refine this assumption and to reduce uncertainties.</p> <p>Uncertainties over the potential for <math>^{90}\text{Sr}</math> in the particles are being reduced by further radiochemical testing, which is revealing generally low levels of <math>^{90}\text{Sr}</math> content. <math>^{137}\text{Cs}</math>-bearing particles with higher levels of <math>^{90}\text{Sr}</math> appear to be readily identifiable based on their beta:beta+gamma contact dose rates.</p>
<p>To develop a comprehensive picture of potential exposure pathways (human habits surveys; environmental receptors; behaviour and habits of biota).</p>	<p>Data are available for beach use, but limited to the beach areas extending N to St Bees and S to Drigg Point. The beach occupancy survey carried out within this programme of work was of limited duration. A further beach user habit survey is scheduled for 2009, entailing additional beach areas and a focus on periods of high occupancy.</p> <p>Non-human species: comments as earlier in this table.</p>
<p>To develop a representative mechanism for estimating the likelihood of exposure occurring (human and non-human species).</p>	<p>Encounter probability calculation models have been developed to estimate the likelihood of human exposure occurring. These have not yet been verified as fit-for-purpose for the Sellafield situation. HPA has been tasked with developing a bespoke encounter probability calculation methodology for the Sellafield context. This work is to be completed early in FY 10/11.</p> <p>Non-human species: comments as earlier in this table.</p>
<p>To apply the resulting risk assessment methodology to actual and predicted particle populations, to facilitate informed and proportionate decision-making on the need for interventions and our communications with stakeholders.</p>	<p>Indicative data from the existing models are being generated to inform this process. Given the hazards associated with the particles recovered to date, this is considered to be adequate for decision making in the short term.</p>

### 6.5 Intervention Strategy

<b>Objective</b>	<b>Progress</b>
<p>To develop a protocol based on clear, risk-based, proportionate but precautionary criteria for intervening to manage the risks of harm that are predicted to arise as a result of exposure to particles.</p>	<p>EA continues to rely principally on the protocol set out in HPA's Guidance on dose criteria for the Designation of Radioactively Contaminated Land.</p>
<p>Within the protocol, to use quantitative risk thresholds for advising on or recommending, to the decision makers, the following general levels of intervention:</p> <ul style="list-style-type: none"> <li>i) no action;</li> <li>ii) scope for proactive information giving (could include information notices or advice to the public);</li> <li>iii) access restrictions, restrictions on foods from affected areas (advice to partner organisations), etc</li> <li>iv) targeted remediation; and</li> <li>v) large-scale area remediation and other possible interventions.</li> </ul> <p>The strategy should take into account the practicabilities of proposed interventions, the views of stakeholders, the levels of uncertainty, and should be informed by the guidance of relevant national and international expert bodies.</p>	<p>EA has drafted a more specific response strategy which sets out action thresholds that are representative of the hazards and encounter scenarios of relevance to Sellafield beach particles. This strategy needs to be developed further in conjunction with partner agencies in order to be fully fit-for-purpose in relation to stakeholder expectations and requirements.</p>

### 6.6 Regulation and Enforcement

<b>Objective</b>	<b>Progress</b>
<p>To endeavour to correlate particle finds with operational activities, both past and present, at Sellafield site in order to establish:</p> <ul style="list-style-type: none"> <li>i) whether activities have been in compliance with the relevant provisions of the RSA authorisation;</li> <li>ii) if no, whether any enforcement response is required;</li> <li>iii) to ensure that Best Practicable Means are being employed by the site operator to prevent and mitigate further particle releases to the environment.</li> </ul> <p>and in so doing ensure protection of the public and the environment, and provide stakeholder confidence.</p>	<p>Arrangements are in place to assess emerging particle find and analysis data against likely source terms. A model for source terms (historical and current) has been developed to support this capability.</p> <p>Analytical strategies are to be developed to enable forensic evaluation of finds against possible sources to be undertaken with greater confidence.</p> <p>There is continued regulatory focus on authorisation compliance performance and on the continued use of Best Practicable Means. As part of this the enforcement position will be kept under continuous review.</p>

## 6.7 Communications Strategy

Objective	Progress
To ensure that clear and timely information is provided on this issue, and that, where necessary, participation of stakeholders in seeking solutions to the issues is facilitated.	The indication is that these objectives are being met by the combination of EA and SL published documents (available on the respective web-sites), meetings and workshops. The nature, extent and frequency of communications appear to be in line with stakeholder expectations.  There are a number of reports documenting the outcome of supporting work that have yet to be published, such as CEFAS reports on habit surveys and transport modelling. We will look to see whether web access can be provided for these and further supporting documents as and when they are published.
To provide appropriate information to facilitate informed, risk-based decision making by appropriate agencies and stakeholders.	
To encourage and take into account stakeholder views and expectations in our overall approach to the investigation and regulation of the Sellafield particles issue.	

## 6.8 R&D

Objective	Progress
To maintain awareness of national and international developments of relevance to monitoring, analysis and risk assessment associated with radioactive particles in the environment.	Some progress has been made in reviewing national and international developments, but this work has been resource constrained to date. More EA resource will be allocated in 2009/2010. EA Science is also supporting the HPA risk assessment project discussed in 6.3.
To provide information and support to relevant national and international expert bodies such as IAEA Co-ordinated Research Programmes.	EA has provided an input into the National Dose Assessment Working Group (NDAWG) subgroup on heterogeneous particles in the environment. We are also actively participating in the ICRP and IAEA developments on non-human species risk assessment and the developing frameworks for environmental protection which links to our watching brief for non-human species risk assessment. EA will look to forge links with the IAEA CRPs on particle characterisation and impact from particles.
To identify those aspects of the project where there are important gaps in our knowledge, high levels of uncertainty, or where we are aware of potential innovations that might improve our understanding of the issues, that warrant the commissioning of specific research and development work.	This work is ongoing. Identified gaps of concern (e.g. monitoring for alpha rich particles) are being addressed in the work programme. More resource will be allocated to this objective in 2009/10.

## **7. Other considerations**

It is recognised that the nature of the continuing challenge presented by Sellafield radioactive particles in the environment means that fully meeting the original objectives will entail a long-term work programme - of the order of several years duration.

Taking this work programme through to a point of completion will itself require the development of an 'end state' specification for the particles contamination issue. This specification has yet to be defined. The February 08 programme of work document set out the following position on this point:

*The approach set out in this programme will lead to a position where existing Sellafield particle populations in the environment have been comprehensively characterised, and any resulting risks to the public and the environment have been addressed. This is considered to be the 'end point' of the programme. Beyond this, any potential for on-going site operations to release particles will be addressed as part of the Environment Agency's day-to-day regulation of the site under the Radioactive Substances Act.*

*Formal indicators for the criteria that will be used to identify the programme 'end point' will be developed as the programme progresses. We will strive to complete the programme and reach the 'end point' as quickly as possible.*

These formal indicators have yet to be established. Work to clarify the end state and its indicators shall form a part of the forward work programme, and clearly there will be advantages in completing this work as early as possible.

## **8. Conclusions**

Good progress has been made to date, and the nature, extent and significance of the contamination issue is now significantly clearer than was the case at the outset of the work programme.

There are, however, a number of significant areas where uncertainty is high, notably:

- the true distribution on beaches of particles that contain high proportions of actinides (termed 'alpha-rich');
- the distribution and behaviour of particles in offshore sediments;
- the uptake into the body of actinides in alpha-rich particles if ingested (and associated doses if particles are encountered);
- the likelihood of a member of the public encountering a radioactive particle.

Advice provided by the Health Protection Agency (HPA) and the Food Standards Agency (FSA) is that no special measures are necessary to protect the public at this time. This advisory position takes into account these uncertainties, but emphasises that priority must be given to reducing them.

To address the areas of uncertainty, a programme of monitoring, retrieval and analysis will need to continue at current levels, supported by additional focus and priority on the matters identified in point 2. above.

The high level objectives of the work programme are considered to remain fit for purpose.

Current arrangements for communicating with and providing information to partner agencies and stakeholders are considered to remain fit for purpose.

The existing regulatory focus and arrangements, to ensure that the potential for radioactive particles to be released from on-going activities at Sellafield site, are considered to remain fit for purpose, but will need to be kept under continuous review as new information emerges.

There is a need to develop an 'end state' for the programme of work, and criteria to define when this position has been reached.

## **9. Recommendations**

For year 2009/2010 the Environment Agency (EA) will continue to specify requirements for Sellafield Ltd (SL) to undertake beach monitoring, monitoring method development and particle analysis via the Compilation of Environment Agency Requirements (CEAR) supporting the operator's Radioactive Substances Act certificate of authorisation.

EA will implement a further requirement within the operator's certificate of authorisation in 2009, for Sellafield Ltd to develop and implement a co-ordinated long-term programme of work by 31/3/10. This work programme will be objective-based, and will cover

- beach monitoring and monitoring method development
- offshore characterisation
- particle analysis and analytical strategy development
- source identification
- source exclusion
- 'end state' development – to informed by BPEO assessment and to be implemented to BPM
- research and development to ensure that techniques used remain best available

EA will retain a primary role for obtaining advice on hazard & risk from relevant expert organisations, and this will include obtaining supporting information on issues such as beach occupancies, encounter probabilities, food chain issues.

EA to maintain regulatory oversight of SL's implementation of the CEAR requirements and the development and implementation of the long-term work programme. This will include, where appropriate, expert peer review and independent assurance.

EA to continue to co-ordinate engagement with key stakeholders, providing them with independent information, communications and advice (including advice on interventions to protect the public).

## APPENDIX 1

### Update on Sellafield Radioactive Particles March 2009

#### Progress with beach monitoring

Since vehicle-mounted beach survey work began in November 2006, a total of around 570 Ha of beach area has been surveyed, stretching from the north Solway coastline (at the request of SEPA), down to Drigg point. The survey equipment used to date is the Groundhog evolution system which was developed for Dounreay, and has specific capability in relation to the detection of medium/high energy gamma emitting radionuclides.

The finds that have been identified since Nov 2006 using this system comprise 609 stones, pebbles and particles, with around 40% being less than 2mm in diameter. All have been removed from the beaches. The vast majority of the finds are concentrated on the 3km stretch of beach running NW from Sellafield site.

Overall find rates (numbers per hectare surveyed) in 08/09 are in most areas significantly lower than seen in the previous survey year (07/08), although it should be noted that directly comparable areas of resurvey are limited within the total areas used to arrive at the figures in the following table.

Area	finds per hectare surveyed			
	Stones		Particles	
	2007/2008	2008/2009 <sup>1</sup>	2007/2008	2008/2009 <sup>1</sup>
St Bees	0	0	0.2	0.05
Braystones	0	0	0.16	0.12
Sellafield	2.5	1.3	1.6	0.7
Seascale	0	0.04	0.21	0.15
Drigg	0	0	0.25	0.05

Note 1 Data to 01 March 2009

Starting in 2009/10 an enhanced large area beach monitoring capability will be deployed, comprising additional thin crystal NaI detectors in addition to the existing large volume NaI crystal detectors. The additional detectors will provide a better capability for low energy gamma emitters (Am and Pu isotopes) and 'pure' beta emitters such as <sup>90</sup>Sr/<sup>90</sup>Y (via Bremstrahlung radiation). The implementation of this improved detection system will be supported by an in-situ calibration exercise to determine the response of both detector systems to a number of <sup>90</sup>Sr, <sup>241</sup>Am, <sup>60</sup>Co and <sup>137</sup>Cs calibration sources buried at varying depths in sand.

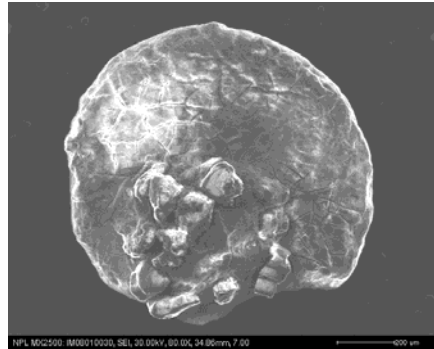
#### Particle analysis

Each 'find' (particle, pebble or stone) is analysed initially by beta and beta+gamma dose rate, and by gamma spectrometry. On the basis of this data, finds continue to be broadly classifiable as either:

- beta-rich: finds predominantly containing or contaminated with <sup>137</sup>Cs are most prevalent, with activities up to  $9 \times 10^5$  Bq. One particle recovered in 2003 contains just <sup>90</sup>Sr/<sup>90</sup>Y; no further particles of this sort have been recovered since; or
- alpha-rich: over 100 finds have been identified as containing significant levels of actinides, including isotopes of Pu, and <sup>241</sup>Am. The highest <sup>241</sup>Am inventory particle has been confirmed by fully quantitative gamma spectrometry as  $7.3 \pm 0.3 \times 10^5$  Bq.

Detailed analysis of a representative sub-set of 51 of the alpha- and beta-rich particles has now been completed.

Results for the alpha-rich particles indicate a wide range of elemental compositions, with some containing high proportions of silica and iron; others significant carbon components. None have significant quantities (by mass) of uranium, suggesting that these are not fuel fragments. Scanning electron microscopy (SEM) indicates a range of features, but overall these particles appear more homogeneous physically than is the case for the beta-rich particles.



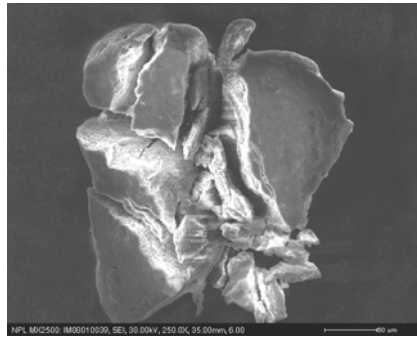
particle IMO8010030 (alpha rich; highest <sup>241</sup>Am activity)

Although in-vitro dissolution studies show that the actinide contents of the alpha-rich particles can be highly soluble in simulated gut fluids (some to over 90%), in-vivo rat ingestion studies suggest low systemic uptake of the actinides, with fractional absorption values in the range  $10^{-5}$ – $10^{-8}$  having been obtained. Non-destructive testing of a further 10 alpha-rich particles is currently underway, principally with the intention of improving mass and density data for this class of particle. However these particles will also be submitted for additional in-vivo testing early in 09/10 to improve understanding of the systemic uptake of actinides from these particles upon ingestion.

For the beta-rich particles, SEM images reveal a wide range of particle shapes and sizes; some apparently contaminated minerals, others suggesting process residues (possible pipeline/vessel scales; one metal turning, two particles appearing to be zirconium based).



Particle IMO8010023 (beta rich; high Fe component)



Particle IMO8010039 (beta rich; high Zr component)

Sellafield Ltd has completed additional radiochemical studies to evaluate  $^{137}\text{Cs}$ : $^{90}\text{Sr}$  ratios in 'beta rich' particles – a key issue in establishing the deterministic hazard of the beta-rich particles. Of the 16 particles representing 'high beta', 'medium beta', 'low beta', and 'potentially Sr rich' groupings, all except the latter show high Cs: Sr ratios. The potentially Sr rich particles have Cs: Sr ratios of up to 1:2. All such particles recovered to date are readily detectable by field ion chamber instruments, and further work will now be carried out to calibrate instrument response, to provide a reliable early indication of equivalent skin dose as part of the routine detect-and-remove programme.

Sellafield Ltd is now working up its proposals for the next full tranche of particles analysis.

#### **Potential hazards and risks from particles**

Advice from HPA is that, using a gut transfer fraction ( $f_1$ ) of  $10^{-4}$ , doses to adults upon ingestion can be estimated as around 5mSv for a  $10^5$  Bq  $^{241}\text{Am}$  particle. The most significant alpha-rich particle recovered to date, with an  $^{241}\text{Am}$  activity of  $7.3 \times 10^5$  Bq (and associated Pu isotopes) would, on this basis, correspond to an adult dose of 65mSv (doses to 1 year-old and 3-month-old children being around 2 and 20 times this figure respectively). Results of in-vivo studies suggest that using this value for  $f_1$  of  $10^{-4}$  in dose calculation is precautionary.

The likelihood of a beach user encountering radioactive particles has been assessed by EA using methodology originally developed by HPA for Dounreay, and in conjunction with a specific CEFAS beach habit survey. Although there remain uncertainties on the actual density of actinide-rich particles on west Cumbrian beaches (numbers of particles per hectare), using the highest find rate that has been encountered in the monitoring programme so far, the indication is that the probability of ingestion or inhalation is very small (less than one in a million per year).

Using this methodology, the calculated probability of skin contact is greater, potentially in the range one in one thousand to one in one hundred per year for the highest find rate area. A maximum contact dose of around 20mSv/hr (equivalent skin dose) has been measured for the most significant of the beta-rich particles. At these dose rates, unrealistically long stationary contact times would be necessary in order to result in deterministic effects if contact with members of the public occurs.

Although significant uncertainties attach to these estimates<sup>6</sup>, HPA has restated its advice originally offered in 2007, that no special precautionary measures are necessary regarding access to or use of beaches in the area. HPA has advised that if a particle with an <sup>241</sup>Am activity greater than 10 MBq is discovered, then this should prompt an urgent review of health risks (maximum to date is 0.7MBq).

It is recognised there are limitations in applying the Dounreay methodology to Sellafield. The Environment Agency has put in place a formal programme of work with HPA to support the assessment of hazards and risks presented by Sellafield radioactive beach particles. This will include the development of a bespoke encounter probability calculation methodology, the definition of 'particle' in terms of potential for ingestion, inhalation or lodging in/on tissue, and the quantification of risks to members of the public.

HPA and the University of Birmingham are continuing to advise on risks in relation to stochastic and deterministic effects. Currently, the Food Standards Agency (FSA) has not imposed a FEPA order (as imposed at Dounreay). The Environment Agency is continuing to seek advice from the FSA as new information arises.

### **Offshore monitoring**

Investigation of seabed areas is considered a high priority area of work. However, Sellafield Ltd has not been able to undertake seabed monitoring in 2008/09. Following a multi-agency workshop held at Penrith in November 2008 on Sellafield particles, it was agreed that a technical sub-group would be established to develop the technical requirements for this aspect of the work programme. A first meeting of this group, involving representatives from Sellafield Ltd, Environment Agency, HPA and FSA, has been held. The objective of the group is to identify optimal arrangements for seabed assessment to inform the process of risk assessment.

Some additional information has been obtained from past mollusc sampling (FSA/CEFAS surveys), which shows that of the samples collected and tested over the past 10 years, none show anomalies in terms of activity measurements that might indicate the incorporation of a significantly active radioactive particle. Further assessment of historical data of this sort will be undertaken to improve our understanding of the potential presence of radioactive particles offshore, as an interim measure pending identification and deployment of an appropriate seabed survey arrangement.

### **Identification of particle sources**

Sellafield Ltd's Particles Sources and Pathways Working Group is now routinely assessing the nature of the finds in light of past and current practices on site.

The conclusions to date are that the majority of alpha material fall into two groups. The first is representative of low burn Magnox fuel from 25 - 40 years old, and the second low burn oxide fuel from 25 - 35 years old. The particles are not identified as direct from the fuel but more representative of material post reprocessing operations, suggesting the origins of the alpha material to be historic B204 and B205 operations.

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<sup>6</sup> Existing methods of detection have limited capabilities, particularly for <sup>90</sup>Sr, <sup>241</sup>Am and Pu-rich particles

The presence of iron in many of the particles could suggest links to the iron flocculation effluent treatment processes on the Sellafield site (although pipeline and environmental sources of iron cannot be discounted). Iron flocculation is still carried out as part of B205 chemical separation plant operations and EARP effluent treatment.

Two beta-rich particles display high levels of zirconium, suggesting LWR fuel reprocessing as a source. Other beta-rich particles again have characteristics suggestive of aged Magnox and AGR fuel residues.

Outlying results are mainly americium based particles rather than plutonium which are thought to originate from historic processes on site which recovered plutonium from effluent and also used iron as part of a flocculation process.

Overall, there is no evidence based on existing finds to suggest that there is a current significant source of particle release into the environment. However, emerging particle find and analysis data will continue to be kept under review with the aim of identifying sources. Additionally, continued significant effort is being focused on on-site particle exclusion measures, with a programme of source term characterisation, and review of exclusion/abatement measures against Best Practicable Means (BPM) requirements now well underway.

### **Modelling and other activities**

CEFAS has presented EA with a final report on its work to develop a particle transport model. The report presents a number of recommendations relating to the targeting of future monitoring efforts, and validating a number of environmental descriptors and transport assumptions. These recommendations are being considered as part of the current review of the Sellafield particles programme of work.

EA is continuing to develop a response strategy. The strategy will set out a decision-making process in terms of providing local authorities and FSA with advice and recommendations on, for example, placing information notices or beach access restrictions. It is intended to undertake further development of this strategy in conjunction with HPA, FSA and the relevant local authorities, and to strive to achieve consistency with existing guidance on dose criteria for radioactively contaminated land, and developing output from the National Dose Assessment Working Group (NDAWG) sub-group on heterogeneous radioactive contamination.

An independent QA/QC audit of Sellafield Ltd's arrangements (and those of their contractors) for beach monitoring and particle analysis has been carried out on EA's behalf by UKAEA. The findings were overall positive, and no non-conformances were noted.

### **Working with others**

EA continues to co-ordinate its efforts with those of other agencies. A programme of work is in place (currently subject to review), setting out the key elements of work to be delivered, indicative timescales for delivery, and identifying the organisation(s) responsible for their delivery.

### **Communication with stakeholders**

Fortnightly updates on monitoring results are placed on the Sellafield Ltd web-site at

<http://www.sellafieldsites.com/what-we-do/featured-projects/beach-monitoring>

Reports are provided by EA to the West Cumbria Sites Stakeholder Group as part of routine engagement.

EA publishes information relating to the particles work on its web-site at

<http://www.environment-agency.gov.uk/homeandleisure/110563.aspx>

This includes a regularly updated briefing note on the work programme to date, a copy of the work programme itself, and a copy of the report on the 2007 workshop on Sellafield particles.

A multi-agency workshop was held at Penrith in November 2008 to review with stakeholders and partner organisations progress with the programme of work. Further meetings of this sort will be scheduled at suitable stages in the programme in the future.

**APPENDIX 2**

**PROGRESS AGAINST WORK STREAM TASKS SPECIFIED IN THE PROGRAMME OF WORK**

**WORK STREAM 1**  
**ENVIRONMENTAL MONITORING PROGRAMME**

Task	Details		Organisation responsible	Status
1.1 Development of improved monitoring techniques	Specification of detection capability for the full range of likely beach finds	a) test bed calibration	Sellafield Ltd	Test bed calibration has been completed and reported.
		b) in-situ (beach) response characterisation	Sellafield Ltd	Developing a specification for calibration representative of on-beach conditions has been specified as a requirement in Sellafield Ltd's authorisation (EAR requirement 13f). It is anticipated that this calibration work will be carried out in FY 09/10.
	Identification, evaluation and selection of suitable techniques to optimise the detection of Am-241, Sr-90 and other relevant radionuclides in discrete radioactive particles (to include an assessment of, and where appropriate a programme for R&D for suitable large area beach survey monitoring systems and equipment)	Sellafield Ltd	Candidate techniques have been reviewed, selected and reported by Sellafield Ltd (report reference SERCO/TAS/002301/002 Issue 1).  Further commitment to assessing the potential of other techniques, e.g. aerial survey, have been established by Sellafield Ltd.	
Report on the initial assessment of the Best Practicable Means for monitoring of beaches for particles (EAR requirement)	Sellafield Ltd	Proposals have been reported for the application of enhanced beach monitoring starting April 2009 (Sellafield Ltd report reference SSEM/2008/121 Issue 2). The enhanced technique entails use of thin crystal NaI detectors in parallel with the existing large volume NaI crystals. This provides increased capability for detecting low energy gamma and Bremsstrahlung radiation associated with <sup>241</sup> Am, Pu		

			isotopes and <sup>90</sup> Sr/ <sup>90</sup> Y.
1.2 Large area beach monitoring programme	Monitoring of 147 Ha of beach between Ravenglass and Kirkcudbright	Sellafield Ltd	Complete (Sellafield Ltd report reference SSEM/2008/64)
	Monitoring of specified beaches on the north Solway coastline	Sellafield Ltd	
	Development and implementation of post-March 2008 onshore monitoring requirements in EAR specification	Environment Agency	Complete – 250Ha specified for 08/09 (CEAR requirement 1-19-004 Para 13) .
	Develop a specification for the collation, presentation and reporting of monitoring data	Environment Agency	Outline specification developed. Work to refine the approaches to data collation and presentation is on-going.
1.3 Area monitoring – offshore	Collation and review of existing offshore monitoring data from past exercises (e.g. Sealine Removal Project)	Sellafield Ltd	Data is being collated for review by the end of March 2009. Additional data has been sourced from HPA relating to radionuclides in molluscs originating from the Sellafield area (CEFAS contract report reference C2706).
	Review and selection of suitable large area monitoring techniques for offshore survey work.	Sellafield Ltd	A review of options was carried out and reported by Sellafield Ltd, identifying use of a remotely operated vehicle-based detector system originally developed for Dounreay as the favoured approach (Sellafield Ltd report reference SSEM/2008/47). However, logistical and commercial obstacles have been encountered which mean that opportunistic evaluation at Sellafield of the systems intended for use at Dounreay will not now take place in FY 08/09. Further assessment of technical requirements for seabed monitoring at Sellafield needs to be carried out to ensure that fit-for-purpose techniques are employed. A technical forum comprising SL, HPA, FSA and EA has been established to take this process forward.
	Development and implementation of offshore monitoring requirements in EAR specification for	Environment Agency	A requirement for seabed monitoring was established in the 08/09 CEAR document. A report on the

	08/09.		completion of this work is due to be submitted by Sellafield Ltd by 31/3/09.
	Completion of agreed offshore monitoring programme	Sellafield Ltd	See above.
1.4 Area monitoring – terrestrial	Trial deployment of Groundhog unit inland.	Sellafield Ltd	Still intended for trial deployment in FY 09/10.
1.5 Quality Assurance and Quality Control	Identification of critical aspects of monitoring protocols and arrangements, and implementation of associated control arrangements to ensure that major uncertainties are minimised.	Sellafield Ltd	Complete (Sellafield Ltd report reference SSEM/2008/26)
	Development of a QA/QC plan for particle monitoring, to include the implementation of formal management arrangements, and the specification of formal data quality objectives and controls.	Sellafield Ltd	Complete (Sellafield Ltd quality plan reference SSF 5.04_02)
	Full implementation of the plan	Sellafield Ltd	Complete
	Employ peer review and audit	Environment Agency (contractor)	To be completed by 31/3/09. The majority of the independent audit work is complete, with just the external analytical contractor yet to be audited. Findings to date confirm that QA/QC arrangements supporting monitoring and analytical programmes are adequate.

**WORK STREAM 2**  
**PARTICLE ANALYSIS AND CHARACTERISATION**

Task	Details	Organisation responsible	Status
2.1 Definition of 'particle'	Refine and agree a definition for radioactive particles for the Sellafield situation, in order to ensure that subsequent stages of the work programme are focused on addressing the particular hazards and risks presented by the Sellafield particles.	Environment Agency / Health Protection Agency / Sellafield Ltd	This work has been formally tasked to HPA as part of a programme of work in support of the hazard & risk aspects of Sellafield radioactive particles. Due for completion by April 2009.
2.2 Development of analytical schedule and methodology	Establish programme of analysis and selection of contractor	Sellafield Ltd / Environment Agency	Complete for 'tranche 1' of particle analysis.
	Establish protocol for particle classification, prioritisation and selection for analysis	Sellafield Ltd	Complete for 'tranche 1' of particle analysis
	Characterisation of particle radiological, physical and chemical properties against agreed programme of analysis, including dissolution studies in simulated environmental and organism fluids.	Sellafield Ltd (contractor)	Complete. The first tranche of 51 particles has undergone the agreed programme of analysis, and the final report on this is expected by the end of March 2009. While in the main successfully completed, the analyses did not enable information on bulk composition of the particles, nor accurate data on mass and density (for the beta-rich particles) to be obtained.
	Particle dosimetric studies, including in-vivo experimental work.	Sellafield Ltd (contractor)	Complete for the first tranche of 51 particles. In-vivo studies on systemic uptake for the actinide components of the alpha-rich particles did not show any relationship with actinide solubilities established by in-vitro studies.  Use of TLD techniques for skin dose estimation proved to be unreliable, and better data were obtained by ionisation chamber instruments.
	Identify options for peer review of method	Environment Agency	Complete. An expert group, co-ordinated by Enviro

	development and hazard evaluation		Ltd, is in place to advise on these matters. The recommendations of this group will be taken into account in the development of the forward particles programme of work.
	Develop a forward programme for particle analysis for 2008/2009 and beyond.	Sellafield Ltd / Environment Agency	The analytical specification for tranche 2 is now under development. An intermediate tranche of non-destructive testing for a further selection of alpha-rich particles has also been agreed, principally to provide better data on mass and density. Recommendations from peer review will be considered in developing this and future analytical programmes.
2.3 Quality Assurance and Quality Control	Identification of critical aspects of analytical protocols and arrangements, and implementation of associated control arrangements to ensure that major uncertainties are minimised.	Sellafield Ltd	Complete – report submitted by SL.
	Development of a QA/QC plan for particle analysis, to include the implementation of formal management arrangements, and the specification of formal data quality objectives and controls.	Sellafield Ltd	Complete – formal QA/QC plan developed by SL, supported by monitoring and analytical contractor's arrangements (Sellafield Ltd quality plan reference SSF 5.04_02)
	Full implementation of the plan	Sellafield Ltd	Complete
	Employ peer review and audit	Environment Agency (contractor)	To be completed by 31/3/09. The majority of the independent audit work is complete, with just the external analytical contractor yet to be audited. Findings to date confirm that QA/QC arrangements supporting monitoring and analytical programmes are adequate.
2.4 Control of particles transported off-site for analysis	Review of arrangements, in particular assessing analytical facility for the storage and handling of particles, and the transfer or disposal of particles and their residues.	Environment Agency	EA regulatory audits of NPL facilities carried out. No issues of concern identified in relation to Sellafield beach particle management.

**WORK STREAM 3**  
**TRANSPORT AND DISPERSION MODEL DEVELOPMENT**

Task	Details	Organisation responsible	Status
3.1 Modelling of particle transport	Identification of candidate organisations to provide support and expertise on dispersion and transport modelling.	Environment Agency	Complete. CEFAS contracted to undertake the development of a conceptual model for particle transport in the marine and littoral environments around Sellafield. The findings have been formally reported by CEFAS at <a href="http://www.cefass.co.uk/publications/miscellaneous-publications/sellafield-particle-work-programme.aspx">http://www.cefass.co.uk/publications/miscellaneous-publications/sellafield-particle-work-programme.aspx</a>
	Development of a conceptual model for the transport of particles in the North Irish Sea / Solway Firth areas, principally based on existing published data.	Environment Agency (contractor)	
	Review of the need for and options for developing more refined and representative models.	Environment Agency	Options for better, quantitative transport modelling have been set out, but source-term data requirements are such that the ability to carry out this type of modelling at this stage is limited.
	On-going refinement of the model using particle monitoring and analysis data as generated.	Environment Agency (contractor)	Emerging information was incorporated into the CEFAS work package while this was underway.
	Review the need to incorporate field data collection and model validation requirements into on-going SL monitoring programme	Environment Agency (contractor)	On-going; source term data requirements (above) are being used to develop future monitoring and analytical programmes.

**WORK STREAM 4**  
**HAZARD AND RISK ASSESSMENT**

Task	Details	Organisation responsible	Status
4.1 Hazard assessment	Implementation of arrangements for collating and reporting analysis data to HPA for hazard assessment.	Sellafield Ltd	Complete.
	On-going review of data and provision of advice on particle hazard, based on available information	Health Protection Agency /Environment Agency	On-going – updated advice sought and provided in writing (HPA written communications to EA dated 12/07/07, 21/09/07 and 28/01/09).
4.2 Habit and consumption patterns	Review and collation of habit data relating to external exposure pathways for particle contamination	Environment Agency (contractor)	Initial assessment of beach user habits completed by CEFAS (CEFAS report reference C3015).
	Review and collation of habit data relating to internal (consumption) exposure pathways <ul style="list-style-type: none"> <li>- seafood catch data</li> <li>- consumption patterns (local and wider-range)</li> <li>- food exposure routes</li> </ul>	Environment Agency (contractor) and Food Standards Agency (contractor)	<p>Advice has been provided by FSA (FSA written communication to EA dated 05/01/09). A methodology is available (FSA spreadsheet) for estimating the likelihood of human ingestion of a radioactive particle following its incorporation into seafood. This is supported by data on consumption and seafood landings relevant to the Sellafield area. However, the ability to translate this into a risk assessment is limited by the current absence of reliable data on the presence or otherwise of radioactive particles on the seabed.</p> <p>A review of information on historical mollusc sampling has not indicated the presence of radioactive particles in any samples collected to date. However this cannot on its own be considered to be a definitive indicator of the absence of significantly active radioactive particles in offshore areas around Sellafield.</p>

	<p>Identify, review and refine methodologies for assessing encounter probabilities for non-food exposure routes</p>	<p>Environment Agency / Health Protection Agency</p>	<p>The encounter probability model developed by HPA for SEPA in support of the Sandside Bay study (HPA report reference RPD-EA-9-2005) has been used, with caveats, as an interim method to provide an indication of encounter probabilities in the Sellafield context.</p> <p>Sellafield Ltd has developed its own encounter probability estimation tool (PROPE v1, NNL report reference NNL (08) 9777).</p> <p>Development of a tailored model for Sellafield has been formally tasked to HPA as part of a programme of work in support of the hazard &amp; risk aspects of Sellafield radioactive particles. This work due for completion early in FY 10/11.</p>
<p>4.3 Risk quantification and context</p>	<p>Development and application of a quantified risk assessment protocol, including on-going provision of advice as further monitoring/analysis/encounter probability information becomes available.</p>	<p>Health Protection Agency</p>	<p>Ad-hoc advice continues to be provided, on request, by HPA. A formalised risk assessment will be undertaken and reported by HPA as part of a programme of work in support of the hazard &amp; risk aspects of Sellafield radioactive particles.</p>
	<p>Extension of the approach to non-human species.</p>	<p>Environment Agency (review with EA Science group)</p>	<p>Developing area internationally; links established with ICRP Committee 5 and IAEA ongoing work programmes. Still too early to develop quantitative risk estimators for non-human species, and likely to be many years before reliable assessments are available. Conceptual model to be developed in 2009/2010.</p>
	<p>Presentation of risk data in context of wide societal risks</p>	<p>Environment Agency / Health Protection Agency</p>	<p>This work has been tasked to HPA as part of a programme of work in support of the hazard &amp; risk aspects of Sellafield radioactive particles. Due for completion Q3 09/10.</p>

**WORK STREAM 5**  
**INTERVENTION STRATEGY**

<b>Task</b>	<b>Details</b>	<b>Organisation responsible</b>	<b>Status</b>
5.1 Contaminated Land status	Review the applicability of the Contaminated Land Regs to the Sellafield particles situation, and in particular the degree to which offshore particle caches might fall within the jurisdiction of the Regs.	Environment Agency	On the basis of existing information on Sellafield beach particles, none of the criteria for designation as radioactively contaminated land have been met. The situation will be kept under review as new information on the presence and nature of beach and offshore particles emerges.
5.2 Protocol and criteria for other interventions	Develop criteria for intervention, including suitable critical group dose thresholds, on which to base the need for either recommending more detailed and specific health risk assessments, or for recommending direct interventions such as access restriction, signage, communications and other interventions.	Environment Agency / Health Protection Agency	Draft intervention/response strategy in place to inform EA decision making. Further work is needed to take into account the position of stakeholders and partner agencies in relation to the criteria and structure proposed within this document.
5.3 Common intervention philosophy for UK regulators	Develop Sellafield particles intervention strategy, where possible building consensus and buy-in from fellow regulators (SEPA, NIE&HS, EA Wales, etc...), local stakeholders (e.g. WCSSG) and national bodies (e.g. HPA, FSA)	Environment Agency	

**WORK STREAM 6**  
**REGULATION AND ENFORCEMENT**

Task	Details	Organisation responsible	Status
6.1 Identification of particle sources	Review of historical events at SL with associated potential / actual release of particles	Environment Agency (contractor)	Review completed and reported by RMC Consulting Ltd (document reference R08-020(C))
	Provision of resource and arrangements to review emerging particle analysis data against past and current operational knowledge	Sellafield Ltd	Sellafield Ltd has established a Particle Source and Pathway Working Group (PSPWG).
6.2 Use of BPM to exclude solid matter from effluent streams	Compliance with existing Authorisation and Agency 'specification of requirements'.	Sellafield Ltd	Compliance assessment is an on-going process and part of EA's routine regulatory role. Specific compliance assessments (inspections and audits) have been carried out in relation to particle exclusion measures on-site. This topic has also featured in other more general regulatory engagements (e.g. plant and facility BPM baseline inspections).
	Compliance with Enforcement Notice May 2007 – application of BPM for the removal of entrained solids from the system, including drains, source plants, treatment plants and final discharge.	Sellafield Ltd	<p>Sellafield Ltd has submitted a response to the May 2007 Enforcement Notice, and this has been assessed by EA. The notice response sets out a programme of further assessment of individual plants and facilities against BPM, with each BPM assessment potentially leading to a programme of work to carry out any recommendations arising.</p> <p>A number of BPM assessments for individual plants and facilities have been produced and updated.</p> <p>Sellafield Ltd work programmes to implement recommendations arising from the BPM assessments have been established and are subject to defined timescales.</p>

	<p>Particle exclusion audit and BPM assessment.</p>	<p>Environment Agency</p>	<p>EA is in the process of carrying out a co-ordinated assessment of the BPM documents, with this process to be complete and feedback provided to site in quarter 1 09/10.</p> <p>EA has and continues to assess the site's progress against the work programmes to implement the BPM recommendations as part of its on-going regulatory engagement with Sellafield Ltd.</p>
	<p>Further review of arrangements re. BPM, and consideration of further regulatory measures as might be necessary following completion of the above.</p>	<p>Environment Agency</p>	<p>EA has established arrangements for co-ordinating its regulatory engagement with Sellafield Ltd on on-site particle exclusion, with a single lead Nuclear Regulator having been appointed to manage the approach.</p> <p>Sellafield Ltd has put in place a single on-site particles exclusion programme manager to co-ordinate the operator's actions across the various operating units and facilities that constitute Sellafield site operations. A formal programme has been developed and put in place by Sellafield Ltd for this work.</p>

**WORK STREAM 7**  
**COMMUNICATION STRATEGY**

Task	Details	Organisation responsible	Status
7.1 Development of a co-ordinated communications strategy	Produce an updated communications plan, including a publication strategy	Environment Agency	EA communications plan in place from February 2008.
	Co-ordinate work-stream delivery with relevant partner regulators and other relevant agencies.	Environment Agency	Dialogue established between EA communications function, and press/communications offices within other relevant agencies.
	Develop a schedule of project and stakeholder meetings, and multi-agency workshops.	Environment Agency	Regular technical and programme management meetings held with key organisations involved; some to an outline schedule, others on an 'as needs' basis. Meetings held with relevant local authorities and with COMARE. Multi-agency meeting (workshop) held in November 2008. Engagement with the public and other local stakeholders via reports for and discussion at scheduled West Cumbria Site Stakeholders Group meetings.
	Implement communications and briefings for peer review (COMARE)	Environment Agency	Quarterly web briefings produced and published to EA web-site. Quarterly update reports for COMARE produced. COMARE Sellafield Working Group now in place and undertaking regular reviews of progress with the programme of work.

**WORK STREAM 8**  
**RESEARCH AND DEVELOPMENT**

Task	Details	Organisation responsible	Status
8.1 Research and Development	Establish working arrangements, based on the relevant key workstream objectives, with the Agency's science group.	Environment Agency	EA Science Group represented as part of the particles project board and technical team.
	With partner agencies identify and engage with suitable national 'centres of excellence' in relation to potential developments in monitoring, modelling and analysis.	Environment Agency	Ongoing. Awareness of key centres has been raised but limited dialogue with partner agencies and the centres themselves as yet. Resource has been allocated in 2009/10 to facilitate these tasks.
	With partner agencies forge communications links with key international organisations.	Environment Agency	