Dounreay
Review of Beach Monitoring Programme for Fragments of Irradiated Nuclear Fuel (Particles)

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ABSTRACT

Fragments of irradiated nuclear fuel have been detected on the Dounreay site coastal strip since 1983 and on the beach at Sandside Bay since 1984.

The Dounreay site operator monitors local public beaches for fuel fragments as a requirement of its authorisation for the disposal of liquid radioactive waste.

The Dounreay site operator is voluntarily undertaking an offshore monitoring and recovery programme to remove particles in the marine environment. The offshore monitoring and recovery programme is being undertaken to determine the full extent of the particle plume on the seabed and to deplete the plume through recovery of particles where it is practicable to do so.

The current beach monitoring programme has been in force since 2002. At this time SEPA is reviewing the monitoring programme to ensure it remains fit for purpose.

Whilst at this juncture SEPA is not undertaking a radioactive contaminated land assessment, the upper dose limits within the Radioactive Contaminated Land Regulations Statutory Guidance are being used to underpin the beach monitoring in terms of protection of public health.

The upper dose limits, which need to be reached in order to meet the definition of “significant harm” to human health are where:

a) The potential total effective dose is greater than 100mSv; or
b) Contact with contamination would result in a dose to the skin greater than 10 Gray in 1 hour.

For Sandside Beach estimates have been made of the total probability of anyone visiting the beach encountering a particle of significance. The annual total probability of anybody ingesting a particle which would have an unacceptable hazard (if one existed) at Sandside Beach is far less than 1 in a million. For skin contact again the probability is far below 1 in a million. Hence the probability of anyone visiting the beach encountering a particle of significance is very low.

The outcome of this review is that SEPA has concluded that the continued monitoring of some beaches is not warranted and that for others the frequency of monitoring could be reduced, resulting in an overall reduction in the beach monitoring programme.

1 Introduction

Fragments of irradiated nuclear fuel have been detected on the Dounreay site coastal strip since 1983 and on the beach at Sandside Bay since 1984. They were first detected on the seabed offshore from Dounreay in 1997. They are typically small fragments of radioactive metal about the size of a grain of sand. They were defined and quantified by the United Kingdom Atomic Energy Authority (UKAEA[1]) according to the quantity of the easily detectable radionuclide caesium-137. The quantity of caesium-137, that is its activity, is expressed in SI units – Becquerels (Bq). The caesium-137 is found in association with other radionuclides such as strontium-90 and uranium. In the Dounreay context, UKAEA called these "particles", a terminology that also encompasses other discrete occurrences of radioactivity in the local environment.

In May 2000, the Dounreay Particles Advisory Group (DPAG) was set up by UKAEA and SEPA to provide independent scientific advice to UKAEA and SEPA on particles of irradiated nuclear fuel found in the marine environment around Dounreay. DPAG reported extensively on the fuel fragments and produced 4 reports[2]. DPAG completed its work programme following the production of its Fourth Report in 2008.

In 2008 Dounreay Site Restoration Limited (DSRL) commenced a more comprehensive offshore monitoring and recovery programme to remove the finite number of particles in the marine environment. In 2009 SEPA formed the Particles Retrieval Advisory Group (Dounreay), PRAG(D), to provide independent scrutiny of the information generated from the offshore monitoring and recovery programme.

The site operator continues to monitor local public beaches for fuel fragments as a requirement of its authorisation for the disposal of liquid radioactive waste. The current specified monitoring programme has been in force since 2002 and is being reviewed as part of SEPA's determination of the application by Dounreay Site Restoration Limited (DSRL) for a revised authorisation for the disposal of radioactive waste. This report is a review of the beach monitoring for fragments of fuel.

2 Background

Fragments of irradiated nuclear fuel were generated during the preparation of irradiated nuclear fuel for reprocessing at Dounreay. Reprocessing involves the dissolution of irradiated nuclear fuel and the separation, by solvent extraction, of uranium and plutonium (for re-use) from the other radionuclides present. Two types of nuclear fuel have been reprocessed at Dounreay, Material Test Reactor (MTR) fuel and Dounreay Fast Reactor Fuel (DFR). The first step in reprocessing MTR fuel was to dismantle the fuel element underwater. Part of this involved a milling process to remove the aluminium cladding of the MTR fuel. This process generated swarf (including particulate matter) from the fuel element casing and from time to time some of the underlying uranium fuel. This process was carried out between 1958 and 1972. From 1973 to 1996 the fuel was crushed and cut into small pieces, which produced slivers of aluminium and irradiated fuel. During the reprocessing of Dounreay Fast Reactor (DFR) fuel using a leach dissolver combustion of the fuel in the dissolver periodically occurred which created particles of irradiated fuel which had fused with the niobium cladding. This reprocessing was carried out between 1969 and 1979.

Both types of fragments of irradiated nuclear fuel and similar particulate matter entered the site's drainage system, particularly the system for the discharge of radioactive liquid

[1] UKAEA held the authorisation for the disposal of radioactive waste from 1958 to 2008 when it was transferred to Dounreay Site Restoration Limited.
[2] Dounreay Particles Advisory Group Reports 1-4. www.SEPA.org.uk

waste. A final filter on the system for the discharge of radioactive liquid waste was installed by the site operator in 2005.

Various types of “particles” have been found on Dounreay beaches. The majority probably originate from operations at Dounreay in preparing Material Test Reactor (MTR) and Dounreay Fast Reactor (DFR) irradiated fuel for reprocessing. In 1983 black waxy agglomerates were detected at Sandside Bay and attributed to the process of combusting solid low level radioactive waste in a facility on the UKAEA site, these particles had a differing radionuclide composition (dominated by Ru-106). This process was modified and has since been discontinued. A small number of stainless steel particles with activity due to cobalt-60 have been detected and removed. Recently, a particle dominated by the radionuclide strontium-90 was recovered from the beach at Sandside Bay.

3 History of beach monitoring

Following the 1983 detection and recovery of a fragment of irradiated nuclear fuel from the Dounreay foreshore, UKAEA introduced an improved monitoring system. The system consisted of beta/gamma probes which, in the case of foreshore monitoring were mounted on a trolley. From 1983 UKAEA routinely detected and removed particles from the Dounreay Foreshore. This system was still being utilised when SEPA became responsible (in 1996) for regulation under the Radioactive Substances Act 1993.

At the nearby Sandside Beach, the first particle was detected and recovered in 1984 but no further fragments of irradiated nuclear fuel were detected until 1997 when two fragments of irradiated nuclear fuel at Sandside Bay were removed. In response UKAEA improved their monitoring strategy for Sandside Bay. UKAEA increased the frequency of limited strandline monitoring from once a month to twice a month. UKAEA also introduced monitoring with a hand held instrument capable of recording both the count rate and position. SEPA regularly expressed the view to UKAEA and publicly that the monitoring strategy required further urgent improvement. In particular SEPA believed that more frequent and extensive monitoring of Sandside Bay was warranted to ensure that any fragments of irradiated nuclear fuel finding their way to Sandside Bay were promptly detected and removed. In addition, given the absence of information on the nature and extent of the issue, SEPA was of the opinion more comprehensive monitoring of the beaches at Cross Kirk, Brims Ness and Thurso Bay should be undertaken as soon as practicable by UKAEA. In specifying the beach monitoring programme the overall view of SEPA was that more frequent monitoring should be undertaken for the fragments which have the potential to cause significant harm. However, SEPA understood that this would be limited by the capability of the instrumentation available at the time and what was reasonably practicable coupled with the limited information available on the potential hazard posed by the particles. This principle was taken forward by SEPA when the 1999 authorisation was granted to UKAEA. At that time SEPA was aware that UKAEA was yet to fully implement an improved monitoring strategy, but noted that UKAEA was seeking contractors to undertake improved monitoring. SEPA required Sandside Bay to be monitored each month for fragments of irradiated nuclear fuel to a detection limit of 10^7 Bq of Cs-137 and twice per year to a detection limit of 10^5 Bq of Cs-137. Other public beaches were monitored on a less frequent basis to the same detection criteria. UKAEA implemented a vehicle mounted detection system and demonstrated that the system could be used routinely for the detection of fragments of irradiated nuclear fuel at the lower activity specified by SEPA (10^5 Bq of Cs-137). SEPA subsequently (in 2002) required all monitoring to be carried out at this lower level. UKAEA employed contractors to undertake the beach surveys. The contractors used a vehicle based system, known as Groundhog 1, that employed four cylindrical sodium iodide scintillation detectors (76mm in diameter) in combination with a Global Positioning System. The detectors were mounted vertically on the front of the vehicle on a bar (they were mounted horizontally up to January 2000). The detectors are sensitive to gamma radiation emanating from the caesium-137 radionuclide which is present in the fragments of irradiated nuclear fuel routinely being detected and removed from the local environment. During 2002 an improved monitoring system was introduced, known as Groundhog 2, which employed five cylindrical sodium iodide scintillation detectors (76mm in diameter) in combination with a Global Positioning System. Following a software upgrade the system was referred to as Groundhog Evolution. Further enhancements were carried out during 2007 and monitoring has been carried out since that time using Groundhog Evolution 2. In order to simplify the demonstration of compliance SEPA (in 2007) specified the equipment to be used for the monitoring of public beaches and its mode of operation. This requirement remains and is given below in Table 1.

The Authorisation Holder shall carry out the programme of beach monitoring at the locations and at the frequencies specified in Table 13.2 using the Groundhog Evolution equipment configured as described in report NS13332/MD/1 Dounreay Beach Survey Contract, Demonstration of Compliance and Contract Terms – Limit of Detection, RWE Nukem, and operated at an average velocity of not greater than 1 m/s, or using a system achieving an equivalent or higher overall performance.

Monitoring Type	*Sampling Location*	*Area to be Monitored*	*Frequency of Monitoring*
Large area gamma survey using Groundhog Evolution equipment or a system of equivalent or higher overall performance	*Sandside Bay*	*All of the sandy areas between National Grid Reference 295700, 966280 and 296690, 965780 that can be accessed by a vehicle from mean high water springs to as near as reasonably practicable to mean low water springs, but at least to neap low water.*	*Monthly*
	Sandside Bay	*Accessible sandy areas between National Grid Reference 295700, 966280 and 296690, 965780 which do not permit vehicle access including north beach, harbour, sandy areas below Fresgoe House, bands of sand north east of the beach below the public lavatories and the sandy areas north of Isauld Burn,*	*Monthly*
	Sandside Bay	*Strandline that can be accessed by vehicle between National Grid Reference 295700, 966280 and 296690, 965780*	*Fortnightly*
	Thurso Bay	*All of the sandy areas between National Grid Reference 311360, 968960 & 312070, 968850 that can be accessed by a vehicle from mean high water springs to as near as reasonably practicable to mean low water springs, but at least to neap low water*	*Three times per year*

	Scrabster Bay	*All of the sandy areas between National Grid Reference 310040, 970180 & 310605, 969170 that can be accessed by a vehicle from mean high water springs to as near as reasonably practicable to mean low water springs, but at least to neap low water*	*Three times per year*
	Crosskirk Bay	*All accessible sandy areas between National Grid Reference 302860, 969900 & 302970, 970250 from mean high water springs to as near as reasonably practicable to mean low water springs, but at least to neap low water*	*Six times per year*
	Brims Ness	*All accessible sandy areas between National Grid Reference 304250, 971270 & 304410, 971030 from mean high water springs to as near as reasonably practicable to mean low water springs, but at least to neap low water*	*Six times per year*
	Dounreay East Foreshore	*All accessible sandy areas between National Grid Reference 298650, 967410 & 299020, 967670 from mean high water springs to as near as reasonably practicable to mean low water springs, but at least to neap low water*	*Fortnightly except during the period 1 May to 31 August*
	Dounreay West Foreshore	*All accessible sandy areas between National Grid Reference 298190, 967029 & 298340, 967095 from mean high water springs to as near as reasonably practicable to mean low water springs, but at least to neap low water*	*Fortnightly except during the period 1 May to 31 August*

Table 1

4 Information on finds to date

The numbers of fuel fragments recovered are detailed in Table 2 below.

Location of particle finds	Number of particles recovered	Maximum Cs-137 activity of a single particle find (Bq)
Dounreay site foreshore (to 21 March 2012)	282	2.0 E8
Sandside Bay (to 20 August 2012)	216	5.0 E5*
Dunnet Beach (to date)	1	8.9 E3
Murkle Beach (to date)	2	1.3 E4
Offshore seabed (upto 8 July 2012)	2058	2.3 E8

Table 2

* On 14 February 2012 a particle with an unusual radionuclide composition was detected and recovered on Sandside Bay. Initial analysis indicates the particle has a Sr-90 activity in the region of 1.3 E6 Bq

The mean activity and summation of activity of particles recovered from Sandside Beach each year are presented in Appendix 1.

5 Hazard

Fragments of irradiated nuclear fuel (particles) pose a hazard if encountered as the radioactive emissions from the particles have the potential to cause deterministic (skin burns) and stochastic (cancer) effects. The potential magnitude of these effects is directly related to many factors including: the radionuclide; activity of the source; the pathway of exposure and residence time. Consideration of these factors has allowed classification of particles according to the potential to cause human harm.

Estimates of doses were assessed for SEPA[3] by the Health Protection Agency as follows:

Ingestion of fuel fragments would give rise to a committed effective dose of the order of $8.90\ 10^{-10}$ Sv Bq^{-1} for an adult and $3.95\ 10^{-09}$ Sv Bq^{-1} for a 1 year old child.

During the work carried out for SEPA, a fragment of fuel that was highly soluble was encountered. It was estimated that ingestion of this (or similar fragments) would give rise to a committed effective dose of the order of $2.14\ 10^{-08}$ Sv Bq^{-1} for an adult and $9.5\ 10^{-08}$ Sv Bq^{-1} for a 1 year old child.

For typical adult skin thicknesses[4] skin dose rates were estimated to be of the order of $2.5\ 10^{-6}$ Gy h^{-1} Bq^{-1} (1 cm^2 , 7 mg cm^{-2}).

Following the Health Protection Agency undertaking research into the potential health hazard of different particles, the Dounreay Particles Advisory Group (DPAG) identified three categories for classifying particles according to their potential health effects:

Significant
Radioactivity greater than 10^6 becquerels of caesium 137 and for which v*isible effects within a few hours if kept in stationary contact with skin; serious ulceration after 1-2 weeks would occur*. The health effects of a fragment of irradiated nuclear fuel of 10^6 becquerels of caesium 137 are given in table 3 below.

	1year old child	Adult
Effective Dose mSv	3.95	0.89
Effective dose (highly soluble) mSv	95	21.4
Skin dose Gy h^{-1}	2.5	2.5

Table 3

[3] Heath implications of Dounreay fuel fragments: estimates of doses and risks. www.sepa.org.uk
[4] International Commission on Radiological Protection (ICRP) Publication 89.

Relevant
Radioactivity of 10^5 to10^6 becquerels of caesium 137 and for which d*iscernible effects after seven hours if kept in stationary contact with skin; reddening after 1-2 days* would occur. Using the data from section 5 the health effects of a fragment of irradiated nuclear fuel of 10^5 becquerels of caesium 137 are given in table 4 below.

	1year old child	Adult
Effective Dose mSv	0.4	0. 09
Effective dose (highly soluble) mSv	9.5	2.1
Skin dose Gy h^{-1}	0.25	0.25

Table 4

Minor
Radioactivity of less than 10^5 becquerels of caesium 137
No discernable health effects if kept in stationary contact with skin

The group concluded that only those particles in the significant category pose a realistic potential of causing harm to members of the public.

In order for any hazard to have any potential effect on health there is a need for contact either directly e.g. skin contact or ingestion or indirectly e.g. being close to the source. The potential effects of being on a beach and in proximity to a particle are negligible as described by DPAG in its third report. Thus, the only risks which are needed to be assessed for Dounreay particles are via skin contact and ingestion.

6 Risks

Risk is a relative term and the acceptability of a risk or otherwise is an individual decision. The risk is often expressed as a product of hazard and probability of that hazard being realised. The threshold for acceptability has been debated by many authors including the HSE which in Tolerability of Risk (TOR) for Nuclear Power Stations[5] has suggested that a 1 in a million risk of death is broadly acceptable, although it must be stressed that this is the upper level and should be significantly reduced where practicable, below this value. The TOR document specifically states that "*Tolerability' does not mean 'acceptability'. It refers to a willingness to live with a risk so as to secure certain benefits and in the confidence that it is being properly controlled. To **tolerate** a risk means that we do not regard it as negligible or something we might ignore, but rather as something we need to keep under review and reduce still further if and as we can*". The 1 in a million value in this context also only refers to deterministic effects in the form of death, other deterministic effects such as skin burns and stochastic effects are not specifically considered.

Thus for Dounreay, particles encountered which could result in deterministic effects on the skin and known effects on health should be avoided. Therefore for users of Dounreay beaches, the individual risk of encountering a particle which could give rise to

[5] The Tolerability of Risk from Nuclear Power Stations, Health and Safety Executive, 1992.

doses of greater than 10 gray per hour or 100 mSv CED should be significantly lower than 1 in a million.

Normal practice in radiation protection systems is to determine individual risk which for authorised releases where the possibly of exposure is assumed to be certain. The annual committed effective dose limit for authorised releases is one millsievert which represents an approximate 1 in 20,000 chance of death from that exposure. The effects of authorised releases from Dounreay are far below that value and in 2011[6] it was estimated that the individual dose to a representative member of the public was 0.018 mSv, which is well within the 1 mSv limit.

Collective dose represents a manner of assessing the population effect of a release and can be informative in making management decisions on a range of possible options. Collective dose is a function of a large number of small exposures to a large population and can result in a total collective dose measured in ManSv. This assessment does not correspond to a number of deaths from the exposure as the doses to individuals are low, however it can be informative.

Risks from fuel fragments are not best assessed by either of these techniques as the individual exposures can be high whilst the probability of encounter can be relatively low. Society is often willing to accept low consequence high probability events such as the risk of large numbers of people crossing a suburban road when the speed restriction means that the probability of extreme events such as death is low. However, we are not willing to accept the probability of low numbers of people being exposed to extreme events e.g. plane crashes, even if the risk of a person being hit by a car in the airport car park is higher than that from flying. Hence, as the consequence of the hazard becomes increasingly life threatening, disproportionately more actions are required to make these acceptable to the public. The Tolerability Of Risk for Nuclear Power Stations report distinguishes between these two types of risk: individual and societal risk, and suggests that "*it could be represented, for example, by the chance of a large accident causing a defined number of deaths or injuries. More broadly, societal risk can be represented as a 'detriment', viz the product of the total amount of damage caused by a major accident and the probability of this happening during some defined period of time".* In 2011 the House of Commons Select Committee for Science and Technology[7] suggested that the TOR does not quantify societal total 'detriment' of multiple deaths, disaster management, public shame and outrage, land rendered unproductive and so on.

Therefore, the beach monitoring programme needs to be based both on the magnitude of the hazard and the potential for that to be realised by any user of the beach to address both individual and societal risks.

For individual risks at Sandside Bay the probability of any individual encountering a particle which could deliver a dose of greater than 10 Gray per hour or 100 mSv CED is impossible to determine as no such particle has been recovered from the beach to date. However, if one such particle were present on the beach the probability of encounter would be one in many millions. Thus, the 1 in a million probability[8] is at present

[6] Radioactivity in Food and the Environment (RIFE 17) Report which reported doses for 2011
[7] House of Commons Select Committee for Science and Technology 12th December 2011
[8] Where a particle could deliver a dose of 10 Gray per hour or 100 mSv CED then this is considered to represent significant harm regardless of the probability under the contaminated land regime.

satisfied. Only when the number of such particles exceeds 50 does the probability of any single individual using the beach near a chance of 1 in million.

For societal risk if this is defined as the probability that anybody using the beach would have the potential to encounter an unacceptable hazard it becomes a function of the hazard posed and the total occupancy of the beach per unit time. In approach this is similar to a collective dose approach but in this situation the detriment rather than being a small potential detriment over a large population, all of the detriment is associated with a single individual. This type of approach is consistent with the recommendations from the House of Commons Select Committee for Science and Technology 12th December 2011 which considered risk perception.

For Sandside Beach, using the latest habits survey data[9] estimates have been made of the total probability of anybody visiting the beach encountering a particle of significance. These societal risk estimates are reported in Appendix 3 and the annual total probability of anybody ingesting a particle which would have an unacceptable hazard (if one existed) at Sandside Beach is far less than 1 in a million. For skin contact again the probability is far below 1 in a million.

7 Longevity

Fuel fragments have been detected at Sandside and other publicly accessible beaches around Dounreay since 1984.

Although an offshore recovery programme has recovered particles as the total number released is unknown, even if it were capable of removing all particles it would not be known when such a programme was complete. Thus, it is reasonable to expect that the contamination of Sandside and other public beaches may continue for years to come.

It is expected that in the longer term the numbers and activities of particles will fall as:

- the source is finite;
- the recovery programme has depleted those which may migrate to local beaches;
- sources physically break down;
- the sources undergo radioactive decay.

Although the current assessment of the annual risk of exposure to a source that could give rise to significant harm is well within the HSE criteria it is prudent to ensure that the monitoring programme continues to allow this assessment to be made until the contamination level falls to a level below any concern and where there is confidence that this value has been met.

[9] Dounreay Radiological Habits Survey 2008. www.sepa.org.uk

8 Purpose of monitoring

All monitoring programmes need to define their objectives which will allow subsequent reviews to be undertaken satisfactorily. The objectives for the beach monitoring programme for fuel fragments are:

8.1 Protection of the environment and public health:

SEPA has a duty to ensure protection of the environment and protection of public health.

Protection of public health from radioactive contamination is addressed within the Radioactive Contaminated Land Regulations (Scotland)[10] and statutory guidance[11] to SEPA for these regulations.

The statutory guidance provide upper dose limits, which need to be reached in order to meet the definition of "significant harm" to human health, for the purposes of the radioactive contaminated land regime. These are:

Where

c) The potential total effective dose is greater than 100mSv; or
d) Contact with contamination would result in a dose to the skin greater than 10 Gy in 1 hour.

Whilst at this juncture SEPA is not undertaking a radioactive contaminated land assessment, the upper limits within the Radioactive Contaminated Land Regulations are being used to underpin the beach monitoring in terms of protection of public health.

Hence one of the main purposes of the monitoring programme is to establish whether particles exist and if so to remove particles on the publically accessible beaches which could deliver doses which would exceed the criteria for significant harm to health. Particles which could deliver a potential total effective dose of greater than 100mSv or dose to the skin of greater than 10 Gy per hour are considered to present significant harm to health, irrespective of the probability of radiation dose being received.

As outlined above fragments of fuel classified by DPAG as "**significant**" would cause significant harm.

8.2 To ensure doses are As Low As Reasonably Achievable (ALARA):

SEPA is required to ensure ionising radiation exposures to any members of the public and the population as a whole from the disposal of radioactive waste are kept As Low As Reasonably Achievable (ALARA), social and economic costs being taken into account.[12] The concept of the ALARA requirement is that radiation doses should be minimised as far as reasonably achievable.

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[10] Radioactive Contaminated Land (Scotland) Regulations 2007 (as amended)

[11] Environmental Protection Act 1990: Part IIA, Contaminated Land Radioactive Contaminated Land (Scotland) Regulations 2007 Statutory Guidance

[12] EURATOM Basic Safety Standards Directive (BSSD), 96/29/Euratom

The ALARA concept involves ensuring the benefits associated with undertaking work to minimise radiation doses are considered in the context of the costs and detriments associated with undertaking the work.

In the context of beach monitoring, it is recognised that there are upper limits in terms of monitoring frequency and lower limits in terms of particle detection capability, beyond which the additional benefits gained from the monitoring would not justify the additional costs involved.

8.3 Time trends

The programme for monitoring and recovering fuel fragments from the beaches reduces the numbers of fuel fragments in the environment and contributes to reducing the probability of encountering a fuel fragment. It also provides information regarding the numbers of particles present on the beaches and assesses whether preferential accumulation of particles is occurring on the beaches, to allow the probability of encountering a particle to be kept under review. A consistent monitoring programme allows temporal comparisons to be drawn which can provide additional insight into whether the numbers and activities of particles are changing over time.

8.4 Public Reassurance:

The issue of fuel fragments around Dounreay has gained significant local interest and this has maintained during the recent beach and offshore monitoring and recovery programmes. A purpose of the beach monitoring is to provide reassurance to the public that it is adequately protected against harm from the presence of fuel fragments on the publically accessible beaches. In particular the beach monitoring programme allows, for any fuel fragments on the beach, the probability of encounter to be derived to reassure the public that the probability of encounter remains low. The programme also requires the flexibility to identify any changes in occurrence in a timely manner and if necessary make changes in the programme.

8.5 Site Decommissioning Work:

A 50 micron final filter was fitted on the radioactive liquid waste discharge system in 2005, hence is unlikely that fuel fragments which could pose a realistic hazard to health would be released into the marine environment from this system. Not all of the sites' surface water drains are discharged through filtered systems. As the site decommissioning work is undertaken, there is a small chance that a fuel fragment could be released into the environment through the surface water discharge system, hence there is a requirement for beach monitoring to continue during the site decommissioning work. Additionally, there is a possibility that the offshore monitoring and recovery work being undertaken by the site operator could cause disturbance of the sea bed and lead to migration of in-situ particles from the sea bed to the surrounding beaches. Hence there is a requirement for beach monitoring to continue during and beyond the completion of the offshore monitoring and recovery work, to allow the detection of any affects of this work.

9 Reason for undertaking review of beach monitoring

The original beach monitoring programme was introduced in 1999 and was reviewed by SEPA in 2004. Significant research and monitoring has been undertaken in the intervening time.

A series of technical assessments have been undertaken, which includes work carried out by the Health Protection Agency (previously the National Radiological Protection Board) and by Dounreay Site Restoration Limited.

The Dounreay Particles Advisory Group (DPAG) was set up by UKAEA and SEPA in May 2000 to provide independent scientific advice to UKAEA and SEPA on the fuel fragments found in the marine environment around Dounreay. DPAG reported extensively on the fuel fragment information and technical assessments and produced 4 reports[13]. DPAG completed its work programme following the production of its Forth Report in 2008.

Following the Dounreay site's development of a "Particles Best Practicable Environmental Option (BPEO)", the site operator commenced (in 2008) an offshore monitoring and recovery programme to remove particles in the marine environment and has subsequently undertaken monitoring and recovery work each summer. The offshore monitoring and recovery programme has been undertaken to determine the full extent of the particle plume on the seabed and to deplete the plume through recovery of particles where it is practicable to do so.

In 2009 SEPA formed the Particles Retrieval Advisory Group (Dounreay), PRAG(D), to provide independent scrutiny of the information generated from the offshore monitoring and recovery programme and independent review of the progress of the BPEO implementation. PRAG(D) publish annual reports to SEPA and DSRL.

At Sandside beach, there have been occasions when monitoring has not been possible due to access issues. However, in September 2011, twelve continuous months of monitoring were completed for the first time. This full year of monitoring data is allowing PRAG(D) to make comparisons to earlier monitoring data and also allows a baseline to be determined on the potential number of particles present.

The offshore recovery work has been targeted to recover those particles in the marine environment which are the most hazardous and numerous, which will in time, reduce the finite numbers of particles arriving onshore. There is now sufficient data to allow comparisons to be drawn between the current levels of contamination and any future changes in the rate of arrivals.

In light of the above developments SEPA consider it appropriate to review the beach monitoring programme to ensure it remains fit for purpose, prior to its inclusion within a future revised authorisation for the disposal of radioactive waste from the Dounreay site.

[13] Dounreay Particles Advisory Group Reports 1-4. www.SEPA.org.uk

10 DSRL's monitoring capability

Monitoring of local beaches is undertaken using five cylindrical sodium iodide scintillation detectors mounted on a vehicle and called Groundhog Evolution. The system detects gamma rays associated with the caesium-137 present in the fragments of irradiated nuclear fuel. It also has the capability of detecting the gamma ray emissions from cobalt-60. The detection capability of the equipment has been assessed by way of trials and is fully reported in the Dounreay Particle Advisory Group's 4th report. It was found that Groundhog Evolution 2 system could readily detect a fragment of irradiated nuclear fuel with a caesium-137 activity of 10^6 Bq to at least 400mm depth, 10^5 Bq to around 300mm depth and,10^4 Bq to between 50 and 100mm depth. The report also highlighted that "*Importantly, the results also show that should a large abundance of 10^3 Bq and 10^2 Bq particles exist, it is likely that a small proportion (between 9 and 4% respectively) would have been detected"*.

Regarding the detection of cobalt-60 DPAG reported that "*In addition, tests were carried out with 10^5 Bq ^{60}Co sources at a depth of 300 mm. Using only the ^{60}Co window alarm, the detection probability was 66%. Using all alarm conditions, this probability increased to 96%".*

On the 14 February 2012 a fragment of irradiated nuclear fuel with an unusual radionuclide composition[14] was detected and recovered from Sandside Bay. The ratio of the easily detected gamma emitting radionuclide caesium-137 to the beta emitting radionuclide strontium-90[15] is usually 1:1. The recovered fragment had a ratio of 1:4062. It was detected at shallow depth by observation of the counting equipment by an experienced operator of the equipment. Groundhog Evolution is not specifically equipped or configured for the detection of strontium-90. As this fragment is completely different to other fragments found at Sandside, this find requires separate consideration. Hence, SEPA is minded to include within a future authorisation a requirement for DSRL to assess and quantify the occurrence of fragments of fuel with non typical radionuclide composition. After this work has been completed, SEPA will consider the implications on the beach monitoring programme.

11 Proposed / revised monitoring programme

SEPA has considered its current requirements for beach monitoring and the information on the health effects should a fragment be encountered, the probability of encountering a fragment and the performance of the Groundhog Evolution monitoring equipment.

SEPA has concluded that the monitoring equipment employed by DSRL and operated at the speed specified in the current authorisation will detect fragments of irradiated nuclear fuel that have the potential to cause significant harm. Additionally the use of the monitoring equipment should provide public reassurance and will allow the probability of encountering a fragment of fuel where they have previously been found to be kept under review.

[14] DSRL believes it may have recovered up to 9 such fragments from the seabed however they have been consigned as waste and are not available for further examination.
[15] The radiation harm is dominated by the strontium-90 present in a fragment of irradiated nuclear fuel.

Given this SEPA has considered the beaches which it requires to be monitored and the frequency of this monitoring against the range of data and advice included in this review. SEPA has concluded that the continued monitoring of some beaches is not warranted and that for others the frequency of monitoring could be reduced. This is discussed further below. This has been considered against the seabed remediation work being carried out by DSRL to remove the source of fragments of irradiated nuclear fuel, mitigating against their transport to public beaches.

Sandside

Noting that DPAG has not ruled out the occurrence of a significant particle at Sandside Bay but given the activity of fuel fragments found to date and the probability of encountering a fuel fragment, the current level of monitoring should be relaxed to a quarterly monitoring programme, using Groundhog Evolution 2 detection system, with the existing detection capability (as outlined in section 10). The current monitoring regime allows the detection of particles containing 10^6 Bq of Cs-137 down to a depth of at least 400mm.

Utilising the same detection criteria (with a reduced frequency of monitoring) will allow direct like-for-like comparisons to be drawn, to allow trends in data to be determined.

Other beaches

Dounreay Foreshore

Whilst the Dounreay Foreshore is relatively inaccessible to the public and signs are also in place to warn people of the danger in accessing that area, fragments of irradiated nuclear fuel which could cause significant harm have been detected and recovered on a number of occasions. Additionally the foreshore is the closest “beach” location to the plume of radioactive particles in the marine environment and monitoring of this area will provide meaningful data on potential long term trends of particle repopulation. It will also give an early indication of the efficacy of DSRL’s seabed remediation. Monitoring and removal of sources from the Dounreay Foreshore also reduces the potential that sources present on these areas will be removed before shore currents move the sources to other local beaches.

It is therefore proposed that the current fortnightly monitoring programme is retained.

Murkle

Since 1999 a total of 6 beach surveys have been undertaken at Murkle. Two particles have been found at Murkle beach categorised as minor by DPAG.

For the purposes of protection of public health, SEPA does not believe that there is a need to undertake further monitoring of this beach, as there is no indication that particles containing10^6 Bq of Cs-137 are likely to arrive at the beach. However, this should be kept under review not least for public reassurance purposes and it is proposed that annual monitoring, utilising the Groundhog Evolution 2 detection system, is undertaken.

Crosskirk

Since 1999 a total of 58 beach surveys have been undertaken at Crosskirk. No particles have been found to date at this beach. However, fragments of fuel have been found in offshore sediments in the area around Crosskirk. SEPA is of the opinion that although to date no particles have been found on the beach at Crosskirk, it would be prudent to undertake annual monitoring of this beach, utilising the Groundhog Evolution 2 detection system.

Dunnet

Since 1999 a total of 4 complete surveys of the beach have been undertaken at Dunnet. Additional targeted area monitoring at the main access points and strandline monitoring has also been undertaken 14 times to date.

One particle categorised as minor and two other contaminated items (which are outwith consideration in this review) have been found at Dunnet beach.

For the purposes of protection of public health, SEPA does not believe that there is a need to undertake further monitoring of this beach, as there is no indication that particles containing 10^6 Bq of Cs-137 are likely to arrive at the beach. Hence, SEPA is of the view that the beach does not require routine monitoring. However, this should be kept under review not least for public reassurance purposes and it is proposed that if further finds occur at the nearby Murkle beach the requirement for Dunnet beach to be monitored is reviewed.

Melvich

Since 1999 at total of 4 beach surveys have been undertaken at Melvich. No particles have been found to date at this beach. Models of particle movement to the west of Dounreay have indicated that some particles may move past Red Point. As there are no other beaches monitored further to the West of Sandside Beach in order to provide public reassurance and information on particle dispersion over time, it is recommended that the beach at Melvich is monitored, utilising the Groundhog Evolution 2 detection system, once every five years. However, in the event of a change in the number or activity of particles found at this beach or Sandside, this should be reviewed.

Brims Ness, Scrabster, Thurso & Peedie

Since 1999 the following beach surveys have been undertaken: 57 surveys at Brims Ness; 37 surveys at Scrabster, 43 surveys at Thurso and 6 surveys at Peedie. Additional strandline surveys have been undertaken 18 times at Scrabster and 18 times at Thurso.
No particles have been found to date at these beaches and modelling work has not indicated that they are being transported to these beaches. It is proposed that no monitoring is undertaken on these beaches.

SEPA proposes to include a revised beach monitoring programme within any future authorisation it is minded to grant. The proposed beach monitoring frequency is summarised below in Table 5:

Beach	Frequency of monitoring
Sandside	Quarterly
Dounreay Foreshore	Fortnightly
Murkle	Annual
Crosskirk	Annual
Dunnet	No monitoring
Melvich	Once every 5 years
Brims Ness	No monitoring
Scrabster	No monitoring
Thurso	No monitoring
Peedie	No monitoring

Table 5

12 Future changes to monitoring programme

The monitoring programme will establish if there is any step change in particle numbers being detected or increased hazard, which would necessitate additional monitoring being carried out. This would be specified by SEPA

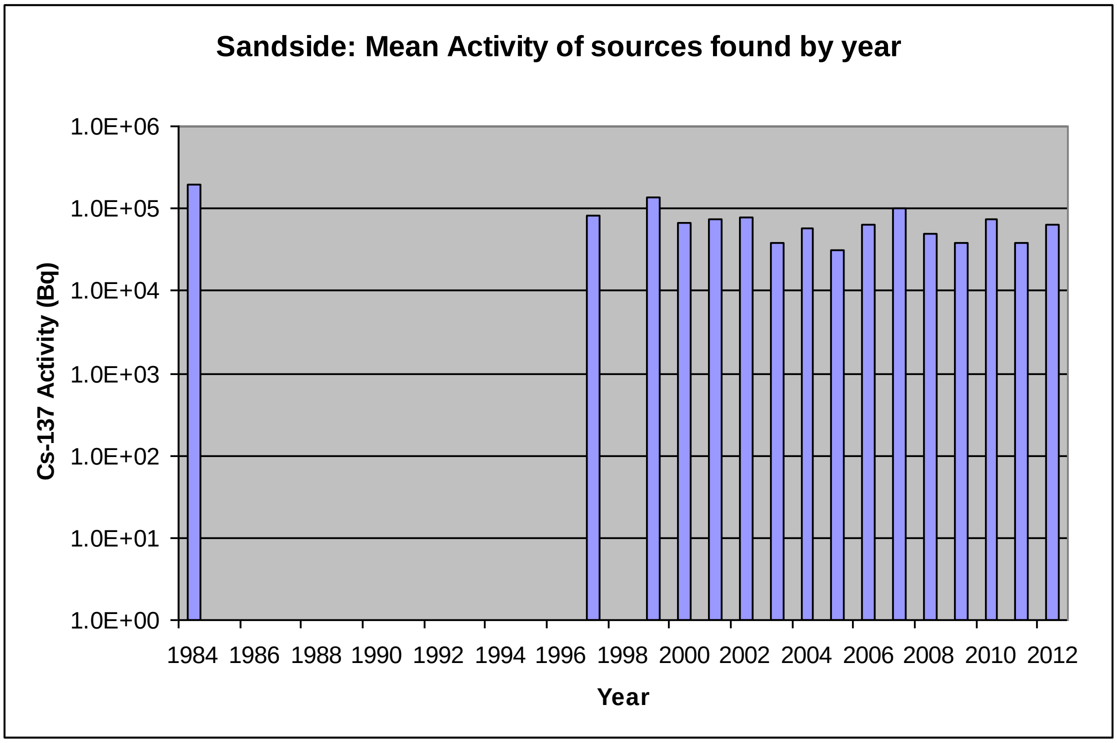
Following the specification of the revised beach monitoring programme, it is SEPA's intention to undertake a future review of the programme to establish if it is appropriate for the monitoring to be further reduced. SEPA currently envisage that a staged approach would be appropriate to reducing the frequency and scope of the monitoring programme. The basis for reduction in the monitoring programme would be judged against the results of the monitoring programme.

Appendix 2 provides an example of the type of staged monitoring programme that could be appropriate for implementation at Sandside Bay.

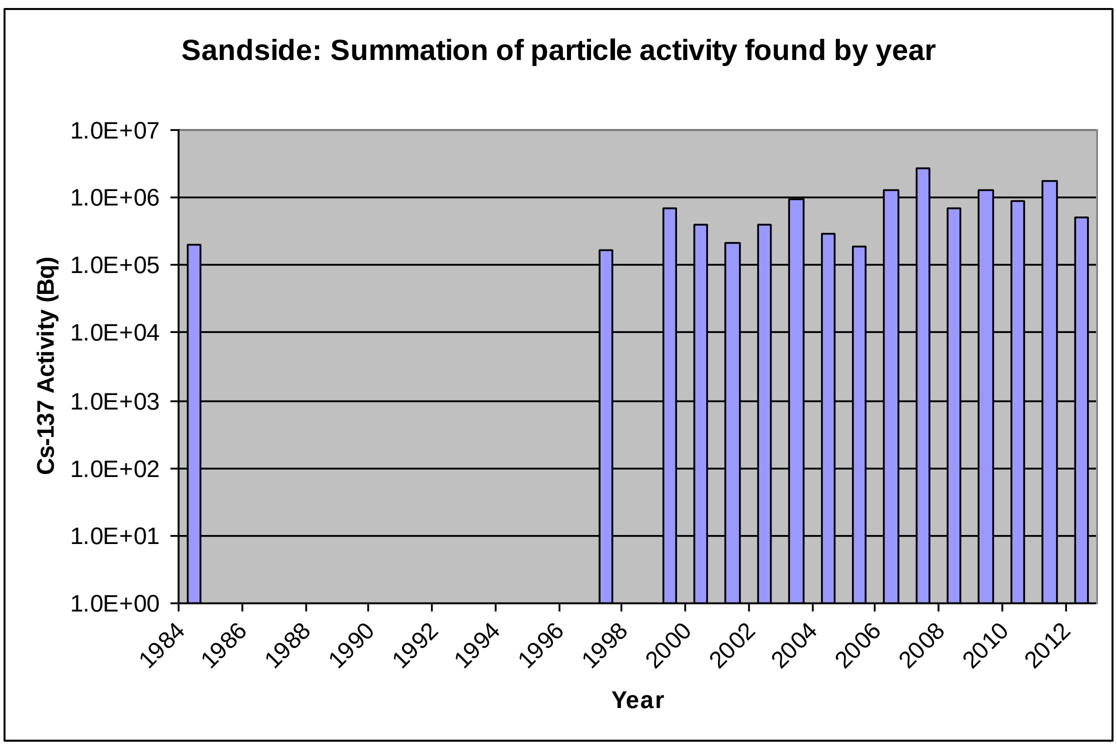
The mechanism for SEPA to implement a further reduction in the monitoring programme would be by SEPA undertaking a variation to Dounreay's authorisation for the disposal of radioactive waste.

The overall long term objective is that monitoring of local public beaches will no longer be necessary and this will be considered periodically by reviewing the monitoring requirements.

APPENDIX 1



Mean activity of particles found at Sandside



Summation of particle activity found at Sandside each year

* In 1984 only 1 particle was recovered at Sandside

APPENDIX 2

Sandside

Stage 1 (As per proposed programme, detailed in Section 11)
Quarterly monitoring programme, using Groundhog Evolution 2 detection system, with the existing detection capability, for a period of not less than 3 years.

In the event of:

- a)A source is detected with an activity that could deliver doses of >100 mSv committed effective dose or 10 Gray per hour skin dose or;
- b) A large number of particle finds (greater than 50 in any one monitoring period).

The operator must inform SEPA and consequently implement a revised monitoring programme as specified by SEPA.

A formal review of the particle finds to be undertaken, and in the event that a and b have not been met, then move to stage 2.

Stage 2
Half yearly monitoring programme, using Groundhog Evolution 2 detection system, with the existing detection capability for a period of not less than 5 years.

In the event of:

- a)A source is detected with an activity that could deliver doses of >100 mSv committed effective dose or 10 Gray per hour skin dose or;
- b) A large number of particle finds (greater than 50 in any one monitoring period).

The operator must inform SEPA and consequently implement a revised monitoring programme as specified by SEPA.

A formal review of the finds to be undertaken, and in the event that a and b have not been met, then move to stage 3.

It should be noted that at this stage, any affects of the offshore recovery programme should be detectable at Sandside beach.

Stage 3
Yearly monitoring programme, using Groundhog Evolution 2 detection system, with the existing detection capability for a period of not less than 7 years.

In the event of:

- a)A source is detected with an activity that could deliver doses of >100 mSv committed effective dose or 10 Gray per hour skin dose or;
- b) A large number of particle finds (greater than 100 in a single year or on average greater than 50 in any two consecutive years) or;
- c) A large number of particle finds (greater than 50 in any one monitoring period)

The operator must inform SEPA and consequently implement a revised monitoring programme as specified by SEPA.

A formal review of the particle finds to be undertaken.

Cessation of monitoring

For public protection matters, if any of the criteria in stage 3 have not been satisfied over 7 years, it is likely that the monitoring programme can be ended as the rate of contamination will have been either constant or declining since the monthly monitoring programme for particles was ended. This will especially be the case if there is an obvious step change in the rate of particle arrivals between stages 2 and 3. Regarding the decision to cease beach monitoring, the need for public reassurance will also be taken into account.

APPENDIX 3

Probability of encounter at Sandside

Number of Particles		1	10	50	100
Inhalation of an item	per year	6.95E-12	6.75E-11	3.38E-10	6.77E-10
Inadvertent Ingestion	per year	7.37E-11	7.36E-10	3.68E-09	7.36E-09
Direct Skin Contact					
dry sand	per year	8.53E-09	8.53E-08	4.27E-07	8.53E-07
wet sand	per year	4.27E-07	4.27E-06	2.13E-05	4.27E-05
dry and wet sand	per year	4.35E-07	4.35E-06	2.18E-05	4.35E-05
Fragment under fingernails	per year	6.32E-09	6.32E-08	3.16E-07	6.32E-07
Fragment on clothes	per year	5.59E-08	5.59E-07	2.80E-06	5.59E-06
Fragment in a shoe	per year	1.47E-07	1.47E-06	7.36E-06	1.47E-05
Total probability (all pathways)	per year	6.45E-07	6.45E-06	3.22E-05	6.45E-05