Re-assessment of Overall Health Risks to Beach Users from Ingestion of Alpha-rich Objects Using Results from the Groundhog Synergy Beach Monitoring Programme: Supporting Data

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ABSTRACT

Since 2006 an intensive programme of monitoring for radioactive objects has been carried out on beaches in the vicinity of the Sellafield site in West Cumbria. Until August 2009, the Groundhog Evolution2™ beach monitoring system was used. At that time, a new beach monitoring system, Groundhog Synergy, was brought into operation as a replacement for the Groundhog Evolution2™ system. This system has better detection capabilities for "alpha-rich" objects that contain alpha-emitting radionuclides such as americium-241 (^{241}Am). The Environment Agency (EA) first sought the advice of the Health Protection Agency (HPA) on the health implications of the findings of this beach monitoring in 2007. At the request of the Environment Agency (EA), HPA undertook an assessment of the health risks to people using the beaches, and this was published in early 2011. That assessment used only the results of the Groundhog Evolution2™ beach monitoring programme. A study has now been carried out to evaluate the performance of the Synergy system for detection of alpha-rich objects and to assess the implications of the results of the Synergy monitoring programme for the health risk assessment carried out by HPA in 2011. The purpose of this technical report is to present the supporting data and results used in the re-evaluation of the health risks from ingestion of alpha-rich particles on the beaches. This report should be read in conjunction with the main report.

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1 INTRODUCTION

Since 2006 an intensive programme of monitoring for radioactive objects has been carried out on beaches in the vicinity of the Sellafield site in West Cumbria. These objects comprise particles with sizes smaller than or similar to grains of sand (less than 2 mm) and contaminated pebbles and stones. Until August 2009, the Groundhog Evolution2™ beach monitoring system was used, and by the end of the summer of 2009, over 650 radioactive objects had been identified and removed. In August 2009 a new beach monitoring system, Groundhog Synergy, was brought into operation as a replacement for the Groundhog Evolution2™ system. This system has better detection capabilities for "alpha-rich" objects that contain alpha-emitting radionuclides which emit low energy photons, such as americium-241 (^{241}Am). By the end of March 2012, the total number of objects detected had increased to approximately 1500. Of these, approximately 650 are alpha-rich objects detected between August 2009 and March 2012 using the Synergy system.

At the request of the Environment Agency (EA), HPA undertook an assessment of the health risks to people using the beaches, and this was published in early 2011 (Brown and Etherington, 2011; Oatway *et al*., 2011). That assessment used only the results of the Groundhog Evolution2™ beach monitoring programme. A study has now been carried out to evaluate the performance of the Synergy system and to assess the implications of the results of the Synergy beach monitoring programme for the health risk assessment (Etherington, Youngman, Brown and Oatway, 2012.)

The populations of alpha-rich particles estimated from the results of the Synergy monitoring programme, particularly in the 3-30 kBq activity band, are higher than those estimated from the Groundhog Evolution2^{TM} monitoring data, except for Drigg beach. However, the increase in the estimated object populations for these particles is not reflected in a corresponding increase in the overall risk of fatal cancer from ingestion of alpha-rich particles. The reason was explained in Etherington, Youngman, Brown and Oatway (2012), but a full justification requires presentation of a large amount of data on the probabilities of ingestion and the overall risks to health for adults and young children, for each of the three object activity bands considered, and for each of the five beaches considered. Inclusion of all of this information was considered to be beyond the scope of the main report on the study, which is intended for dissemination to a wide range of stakeholders. The purpose of this technical report is to present these data, and it is intended that it should be read in conjunction with the published report on the study.

2 TABULATED DATA ON PROBABILITIES OF INGESTION OF AN ALPHA-RICH PARTICLE AND OVERALL RISKS TO HEALTH

The overall risk of fatal cancer for a beach user takes into account both the probability that a particle may be encountered by the person and the risk of fatal cancer in the

unlikely event that the person does encounter such a particle. Both factors depend on the activity of the particle, so overall health risks were determined separately for each of the activity bands used in Etherington, Youngman, Brown and Oatway (2012), and then summed to give the total overall risk. The Tables presented below show, for each activity band, the highest alpha-rich particle activity found, the effective dose that would result if a beach user ingested the particle, the corresponding lifetime risk of cancer, the highest annual probability of ingesting an alpha-rich particle in that activity band, and the overall risk of fatal cancer, obtained by multiplying the lifetime risk by the annual probability of ingestion. The annual probability of ingesting a particle used was the 97.5^{th} percentile of the distribution of calculated probabilities. The Tables present probabilities of ingestion of an alpha-rich particle and overall risk corresponding to the use of a beach during a period of one year.

Data for adult beach users are presented in Section 2.1 and data for young children (1 year old) are presented in Section 2.2. In each of these sections, data are presented separately for each beach, based on both the Evolution2^{TM} and Synergy monitoring data.

2.1 Adult beach users

2.1.1 St Bees Beach

Table 1. Estimated overall risks of fatal cancer, based on the results of the Synergy monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	132	-
Effective dose, mSv[b]	0.8	4.0	-
Lifetime risk of cancer if particle ingested, %[c]	0.007	0.036	-
Highest annual probability of ingesting a particle[d]	$6\ 10^{-9}$	$7\ 10^{-11}$	-
Overall risk of fatal cancer	$4\ 10^{-13}$	$3\ 10^{-14}$	-
Total overall risk of fatal cancer	**$5\ 10^{-13}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

Table 2. Estimated overall risks of fatal cancer, based on the results of the Groundhog Evolution2^{TM} monitoring programme

Activity band, kBq	10	100	1000[(e)]
Highest activity particle in activity band, kBq[(a)]	17.2	72.7	-
Effective dose, mSv[(b)]	0.4	2.2	-
Lifetime risk of cancer if particle ingested, %[(c)]	0.004	0.020	-
Highest annual probability of ingesting a particle[(d)]	$2\ 10^{-9}$	$6\ 10^{-11}$	-
Overall risk of fatal cancer	$7\ 10^{-14}$	$1\ 10^{-14}$	-
Total overall risk of fatal cancer	**$8\ 10^{-14}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

2.1.2 Braystones Beach

Table 3. Estimated overall risks of fatal cancer, based on the results of the Synergy monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	177	-
Effective dose, mSv[b]	0.8	5.4	-
Lifetime risk of cancer if particle ingested, %[c]	0.007	0.049	-
Highest annual probability of ingesting a particle[d]	$7\ 10^{-9}$	$1\ 10^{-10}$	-
Overall risk of fatal cancer	$5\ 10^{-13}$	$6\ 10^{-14}$	-
Total overall risk of fatal cancer	**$5\ 10^{-13}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

Table 4. Estimated overall risks of fatal cancer, based on the results of the Groundhog Evolution2^{TM} monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	128	-
Effective dose, mSv[b]	0.8	3.9	-
Lifetime risk of cancer if particle ingested, %[c]	0.007	0.035	-
Highest annual probability of ingesting a particle[d]	$1\ 10^{-9}$	$2\ 10^{-10}$	-
Overall risk of fatal cancer	$9\ 10^{-14}$	$6\ 10^{-14}$	-
Total overall risk of fatal cancer	**$1\ 10^{-13}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

2.1.3 Sellafield Beach

Table 5. Estimated overall risks of fatal cancer, based on the results of the Synergy monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	252	-
Effective dose, mSv[b]	0.8	7.7	-
Lifetime risk of cancer if particle ingested, %[c]	0.007	0.069	-
Highest annual probability of ingesting a particle[d]	$2\ 10^{-8}$	$8\ 10^{-10}$	-
Overall risk of fatal cancer	$1\ 10^{-12}$	$6\ 10^{-13}$	-
Total overall risk of fatal cancer	**$2\ 10^{-12}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

Table 6. Estimated overall risks of fatal cancer, based on the results of the Groundhog Evolution2^{TM} monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	200	634
Effective dose, mSv[b]	0.8	6.1	19.3
Lifetime risk of cancer if particle ingested, %[c]	0.007	0.055	0.174
Highest annual probability of ingesting a particle[d]	$6\ 10^{-10}$	$4\ 10^{-10}$	$4\ 10^{-12}$
Overall risk of fatal cancer	$4\ 10^{-14}$	$2\ 10^{-13}$	$6\ 10^{-15}$
Total overall risk of fatal cancer	**$2\ 10^{-13}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

2.1.4 Seascale Beach

Table 7. Estimated overall risks of fatal cancer, based on the results of the Synergy monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	51.7	-
Effective dose, mSv[b]	0.8	1.6	-
Lifetime risk of cancer if particle ingested, %[c]	0.007	0.014	-
Highest annual probability of ingesting a particle[d]	$2\ 10^{-9}$	$7\ 10^{-11}$	-
Overall risk of fatal cancer	$2\ 10^{-13}$	$1\ 10^{-14}$	-
Total overall risk of fatal cancer	**$2\ 10^{-13}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

Table 8. Estimated overall risks of fatal cancer, based on the results of the Groundhog Evolution2^{TM} monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	28.6	98	-
Effective dose, mSv[b]	0.7	3.0	-
Lifetime risk of cancer if particle ingested, %[c]	0.007	0.027	-
Highest annual probability of ingesting a particle[d]	$8\ 10^{-11}$	$6\ 10^{-11}$	-
Overall risk of fatal cancer	$5\ 10^{-15}$	$2\ 10^{-14}$	-
Total overall risk of fatal cancer	**$2\ 10^{-14}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

2.1.5 Drigg Beach

Table 9. Estimated overall risks of fatal cancer, based on the results of the Synergy monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	51.2	-
Effective dose, mSv[b]	0.8	1.6	-
Lifetime risk of cancer if particle ingested, %[c]	0.007	0.014	-
Highest annual probability of ingesting a particle[d]	$5\ 10^{-9}$	$8\ 10^{-11}$	-
Overall risk of fatal cancer	$3\ 10^{-13}$	$1\ 10^{-14}$	-
Total overall risk of fatal cancer	**$3\ 10^{-13}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

Table 10. Estimated overall risks of fatal cancer, based on the results of the Groundhog Evolution2^{TM} monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	26.5	57.5	-
Effective dose, mSv[b]	0.7	1.8	-
Lifetime risk of cancer if particle ingested, %[c]	0.006	0.016	-
Highest annual probability of ingesting a particle[d]	$1\ 10^{-8}$	$2\ 10^{-10}$	-
Overall risk of fatal cancer	$7\ 10^{-13}$	$3\ 10^{-14}$	-
Total overall risk of fatal cancer	**$7\ 10^{-13}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

2.2 Child beach users

2.2.1 St Bees Beach

Table 11. Estimated overall risks of fatal cancer, based on the results of the Synergy monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	132	-
Effective dose, mSv[b]	2.2	11.2	-
Lifetime risk of cancer if particle ingested, %[c]	0.035	0.180	-
Highest annual probability of ingesting a particle[d]	$2\ 10^{-8}$	$2\ 10^{-10}$	-
Overall risk of fatal cancer	$6\ 10^{-12}$	$4\ 10^{-13}$	-
Total overall risk of fatal cancer	**$7\ 10^{-12}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

Table 12. Estimated overall risks of fatal cancer, based on the results of the Groundhog Evolution2^{TM} monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	17.2	72.7	-
Effective dose, mSv[(b)]	1.3	6.2	-
Lifetime risk of cancer if particle ingested, %[c]	0.020	0.099	-
Highest annual probability of ingesting a particle[d]	$5\ 10^{-9}$	$2\ 10^{-10}$	-
Overall risk of fatal cancer	$1\ 10^{-12}$	$2\ 10^{-13}$	-
Total overall risk of fatal cancer	**$1\ 10^{-12}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

2.2.2 Braystones Beach

Table 13. Estimated overall risks of fatal cancer, based on the results of the Synergy monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	177	-
Effective dose, mSv[b]	2.2	15.0	-
Lifetime risk of cancer if particle ingested, %[c]	0.035	0.241	-
Highest annual probability of ingesting a particle[d]	$2\ 10^{-8}$	$4\ 10^{-10}$	-
Overall risk of fatal cancer	$7\ 10^{-12}$	$9\ 10^{-13}$	-
Total overall risk of fatal cancer	**$8\ 10^{-12}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

Table 14. Estimated overall risks of fatal cancer, based on the results of the Groundhog Evolution2™ monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	128	-
Effective dose, mSv[b]	2.2	10.9	-
Lifetime risk of cancer if particle ingested, %[c]	0.035	0.174	-
Highest annual probability of ingesting a particle[d]	$4\ 10^{-9}$	$5\ 10^{-10}$	-
Overall risk of fatal cancer	$1\ 10^{-12}$	$8\ 10^{-13}$	-
Total overall risk of fatal cancer	**$2\ 10^{-12}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

2.2.3 Sellafield Beach

No results are given for Sellafield beach, because there is no evidence from the habit surveys undertaken that young children spend time on this beach (Brown and Etherington, 2011).

2.2.4 Seascale Beach

Table 15. Estimated overall risks of fatal cancer, based on the results of the Synergy monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	51.7	-
Effective dose, mSv[b]	2.2	4.4	-
Lifetime risk of cancer if particle ingested, %[c]	0.035	0.070	-
Highest annual probability of ingesting a particle[d]	$7\ 10^{-9}$	$2\ 10^{-10}$	-
Overall risk of fatal cancer	$2\ 10^{-12}$	$1\ 10^{-13}$	-
Total overall risk of fatal cancer	**$3\ 10^{-12}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

Table 16. Estimated overall risks of fatal cancer, based on the results of the Groundhog Evolution2^{TM} monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	28.6	98	-
Effective dose, mSv[b]	2.1	8.3	-
Lifetime risk of cancer if particle ingested, %[c]	0.034	0.133	-
Highest annual probability of ingesting a particle[d]	$2\ 10^{-10}$	$2\ 10^{-10}$	-
Overall risk of fatal cancer	$8\ 10^{-14}$	$3\ 10^{-13}$	-
Total overall risk of fatal cancer	**$3\ 10^{-13}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

2.2.5 Drigg Beach

Table 17. Estimated overall risks of fatal cancer, based on the results of the Synergy monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	30	51.2	-
Effective dose, mSv[b]	2.2	4.4	-
Lifetime risk of cancer if particle ingested, %[c]	0.035	0.070	-
Highest annual probability of ingesting a particle[d]	$1\ 10^{-8}$	$2\ 10^{-10}$	-
Risk of fatal cancer	$5\ 10^{-12}$	$2\ 10^{-13}$	-
Overall risk of fatal cancer	**$5\ 10^{-12}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

Table 18. Estimated overall risks of fatal cancer, based on the results of the Groundhog Evolution2^{TM} monitoring programme

Activity band, kBq	10	100	1000[e]
Highest activity particle in activity band, kBq[a]	26.5	57.5	-
Effective dose, mSv[b]	1.9	4.9	-
Lifetime risk of cancer if particle ingested, %[c]	0.031	0.078	-
Highest annual probability of ingesting a particle[d]	$3\ 10^{-8}$	$6\ 10^{-10}$	-
Risk of fatal cancer	$1\ 10^{-11}$	$5\ 10^{-13}$	-
Overall risk of fatal cancer	**$1\ 10^{-11}$**		

[a] This activity corresponds to the activity of the detected radionuclide; ^{241}Am for alpha-rich objects.

[b] Calculated doses take account of other radionuclides measured in the particles that will contribute significantly to the dose. For this assessment these additional radionuclides are assumed to be the same as for the assessment described in Brown and Etherington (2011), and comprise ^{241}Am, ^{238}Pu and ^{239}Pu.

[c] Lifetime risk is calculated for the highest activity particle in each activity band.

[d] Value is the 97.5th percentile of the distribution for the group of beach users with the highest probability of ingesting a particle.

[e] No alpha-rich particles have been found in this activity band by the Synergy system.

3 DISCUSSION AND CONCLUSIONS

The object populations estimated from the Synergy system monitoring data, particularly in the 3-30 kBq activity band, are higher than those estimated from the Groundhog Evolution2^{TM} monitoring data except for Drigg beach, as shown in Table 10 of Etherington, Youngman, Brown and Oatway (2012). The Tables presented in Section 2 show that it is the particles in this activity band that dominate the overall risk from ingestion of alpha-rich particles. However, a comparison between the overall risks estimated from the Groundhog Evolution2^{TM} and Synergy monitoring data (Tables 13 and 14 of Etherington, Youngman, Brown and Oatway (2012)) shows that the increases in the estimated object populations for these particles are not reflected in a corresponding increase in overall risk.

The reason is that the beach giving rise to the highest estimated object population for particles has changed, for both adults and young children. For adults, based on the Evolution2^{TM} monitoring data, Drigg beach was associated with the highest annual probability of ingesting a particle ($1\ 10^{-8}$); the probability is lower for Drigg beach when based on the Synergy monitoring data ($5\ 10^{-9}$). For Sellafield beach, moving from the Evolution2^{TM} to the Synergy monitoring systems has resulted in an increase in this probability from $6\ 10^{-10}$ to $2\ 10^{-8}$, and as a result Sellafield has become the beach giving rise to the highest annual probability for ingesting a particle, with the highest probability across all the beaches increasing from $1\ 10^{-8}$ to $2\ 10^{-8}$.

A similar effect is found for young children. Based on the Evolution2^{TM} monitoring data, Drigg beach was associated with the highest annual probability for ingesting a particle ($3\ 10^{-8}$), while the probability based on the Synergy monitoring data is lower ($1\ 10^{-8}$). For Braystones beach, moving from the Evolution2^{TM} to the Synergy monitoring systems has resulted in an increase in this probability from $4\ 10^{-9}$ to $2\ 10^{-8}$, and as a result Braystones has become the beach giving rise to the highest annual probability for ingesting a particle, with the highest probability across all the beaches decreasing from $3\ 10^{-8}$ to $2\ 10^{-8}$.

Given the uncertainties associated with assessments of this type, it is judged that these small changes in the estimated annual probability for ingesting an alpha-rich particle are not significant, and that therefore the corresponding changes in estimated overall risk to beach users from ingestion of alpha-rich objects are also not significant.

4 REFERENCES

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