

Radiological Habits Survey: Sellafield Review, 2009

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Final report

Radiological Habits Survey: Sellafield Review, 2009

Shellfish consumption and intertidal occupancy review

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1. INTRODUCTION

This report describes a review of the public's shellfish consumption and intertidal occupancy relating to liquid radioactive waste discharges from the Sellafield Ltd nuclear site in Cumbria. It is also relevant to liquid discharges from the Low Level Waste Repository (LLWR) site near Drigg. The data is for use in radiological dose assessments as reported in the Radioactivity in Food and the Environment (RIFE) series. The study was funded by the Environment Agency (EA), the Food Standards Agency (FSA) and the Health and Safety Executive (HSE), to support their roles in protecting the public from the effects of radiation.

The Sellafield review specifically investigated the consumption of crustaceans and molluscs, and occupancy over intertidal substrates by members of the Sellafield Fishing Community. Reviews are conducted annually, except in years when full surveys are undertaken, because of the importance of the shellfish consumption and intertidal occupancy pathways in the Sellafield area. Additionally, consumption and occupancy rates have been known to vary from year to year with some people ceasing shellfish consumption, collection or fishing, and new individuals being identified. The last full habits survey (encompassing aquatic, terrestrial and direct radiation pathways) in the vicinity of Sellafield was conducted by the Centre for Environment, Fisheries & Aquaculture Science (Cefas) in 2008 (Clyne *et al.*, 2009).

The consumption of fish was not subject to extensive review because fish are of generally lower radiological significance around Sellafield than shellfish and external occupancy, and this would have needed a greater coverage of interviewees. However, those people interviewed in relation to shellfish consumption and intertidal occupancy were asked about their fish consumption and this has been used to improve the total dose assessment of additive exposure (see Section 7.3). For the 2009 Sellafield aquatic dose assessments, the mean consumption rate for the high-rate group for fish will be retained from the 2008 full habits survey. Handling of sediment and fishing gear were not targeted in the 2009 Sellafield review, therefore, for assessments purposes, the mean for the high-rate groups will be retained from the 2008 full habits survey.

During 2009, in addition to the review, several of the higher rate consumers of shellfish kept a diary of their seafood consumption and intertidal occupancy for a two week period every three months. These data were used to check the validity of the interview data.

2. SURVEY AREA

The survey area, shown in Figure 1, extended from Parton to Tarn Bay. This included all intertidal areas and extended up to 11 km offshore.



Figure 1. The Sellafield review aquatic survey area

3. CONDUCT OF THE SURVEY

Prior to the fieldwork, individuals identified as having high rates of crustacean and mollusc consumption and/or intertidal occupancy in previous Sellafeld full habits surveys and annual reviews were contacted and where possible interview times were arranged.

The fieldwork was carried out from 9th – 13th November 2009, by a team of two people. During the fieldwork, individuals were interviewed and asked to estimate crustacean and mollusc consumption rates, and occupancy rates over intertidal areas, for themselves and members of their families. Interviewees were also asked to provide consumption rates for fish in order to determine valid combinations of pathways and improve the total dose assessment. Information was also obtained about the origins of the seafood being consumed and locations of intertidal occupancy.

There were several interviewees who were not available during the November fieldwork. These interviewees were contacted at a later date and interviews were conducted by the Cefas team at Whitehaven or by the Cefas team at Lowestoft by telephone.

Observations for 28 adults and 7 children were recorded for the 2009 Sellafeld review.

4. METHODS OF DATA ANALYSIS

4.1 Data recording

Consumption and occupancy data collected during interviews were recorded in logbooks. These data were examined and any notably high rates were double-checked, by means of a follow-up phone call or against the diary data provided by some interviewees. The raw data were entered into a purpose-built database where each individual for whom information was obtained was given a unique identifier (the observation number) to assist in maintaining data quality.

The consumption and occupancy data in the text of this report are rounded to two significant figures, except for values less than 1.0, which are rounded to one decimal place. This method of presentation reflects the authors' judgement on the accuracy of the methods used. In the tables and annexes, the consumption rate data are usually presented to one decimal place. Occasionally, this rounding process causes the computed values (row totals, mean rates and 97.5th percentiles), which are based on un-rounded data, to appear slightly erroneous. External exposure data are quoted as integer number of hours per year.

The habits data are structured into age groups because different dose coefficients (i.e. the factors which convert intakes of radioactivity into dose) can apply to different ages. The age groups and their relevant age ranges are based on the recommendations in ICRP 72 (ICRP, 1996), and are listed below:

Age group	Age range in group
3-month-old	Under 1-year-old
1-year-old	1-year-old
5-year-old	2-year-old to 6-year-old
10-year-old	7-year-old to 11-year-old
15-year-old	12-year-old to 16-year-old
Adult	17-year-old and over

4.2 Data analysis

The results of the Sellafield review are the individuals' consumption and occupancy rates given in Annexes 1 and 2 for adults and children, respectively. These can be used in radiological assessments of the effects of the discharges from the Sellafield site.

The consumption and occupancy data have been analysed in three ways. Firstly, the 'cut-off' method described by Hunt *et al.* (1982) was used. With the 'cut-off' method, the appropriate high rate was calculated by taking the arithmetic mean of the values between the maximum observed rate and one third of the maximum observed rate. In this report, the term 'high-rate group' is used to represent the individuals derived by the 'cut-off' method. The mean of the high-rate group was calculated for each food group and occupancy over each intertidal substrate identified in the survey. Secondly, 97.5th percentile rates were calculated using the Excel mathematical function for calculating percentiles. Thirdly, profiles have been produced that give a complete view of the habits of the individual that might lead to exposure to all the discharges and radiation from the site. The profiles are based on values calculated by the 'cut-off' method. The profiled data can be used to assess total dose, integrated across all pathways of exposure. The profiled habits matrix in this report contains data from the 2008 Sellafield full habits survey which has been updated with the 2009 Sellafield review data.

5. INTERNAL EXPOSURE

Adults' and children's consumption data for crustaceans are presented in Tables 1 and 2, respectively and adults' consumption data for molluscs are presented in Table 3. The consumption of molluscs by children was not identified.

5.1 Crustaceans

Adults

The main species of crustaceans consumed by adults were brown crabs, common lobsters and *Nephrops Norvegicus* (referred to as *Nephrops* in this report), with a small amount of pink shrimps. A high-rate group of seven individuals was identified with a maximum consumption rate of 31 kg y⁻¹ and a mean of 16 kg y⁻¹. The observed 97.5th percentile rate based on 17 observations was 26 kg y⁻¹.

Table 1. Adults' consumption rates of crustaceans in the Sellafield area (kg y⁻¹)

Observation number	Brown crab	Common lobster	<i>Nephrops</i>	Pink shrimp	Total
10	19.5	1.7	9.5	-	30.7
16	-	18.4	1.6	-	19.9
17	-	18.4	1.6	-	19.9
9	2.2	1.7	7.3	-	11.1
5	10.1	-	-	0.5	10.6
19	2.8	6.1	1.4	-	10.3
20	2.8	6.1	1.4	-	10.3
1	1.7	-	6.1	-	7.8
2	1.7	-	6.1	-	7.8
3	1.7	-	6.1	-	7.8
22	2.2	4.7	-	-	6.9
23	2.2	4.7	-	-	6.9
18	-	6.1	-	-	6.1
4	5.6	0.3	-	-	5.9
7	3.1	-	-	-	3.1
29	1.0	1.0	-	-	2.0
28	1.0	-	-	-	1.0

Observations in bold type are the members of the high-rate group

Children

Only children in the 15-year-old age group were identified consuming crustaceans.

15-year-old age group

The main species of crustaceans consumed by the 15-year-old age group were brown crabs and common lobsters, with a small amount of *Nephrops*. A high-rate group of three individuals was identified with a maximum consumption rate of 10 kg y⁻¹ and a mean of 8.0 kg y⁻¹. The observed 97.5th percentile rate based on three observations was 10 kg y⁻¹.

Table 2. Children's consumption rates of crustaceans in the Sellafield area (kg y⁻¹)

Observation number	Age	Brown crab	Common lobster	<i>Nephrops</i>	Total
15-year-old age group					
21	14	2.8	6.1	1.4	10.3
24	14	2.2	4.7	-	6.9
25	12	2.2	4.7	-	6.9

Observations in bold type are the members of the high-rate group

5.2 Molluscs

The main species of molluscs consumed by adults were winkles and mussels, with smaller amounts of razor shells, cockles, Pacific oysters, whelks and limpets. A high-rate group of five individuals was identified with a maximum consumption rate of 45 kg y⁻¹ and a mean of 28 kg y⁻¹. The observed 97.5th percentile rate based on 11 observations was 42 kg y⁻¹.

Table 3. Adults' consumption rates of molluscs in the Sellafield area (kg y⁻¹)

Observation number	Cockle	Limpet	Mussel	Pacific Oyster	Razor shell	Whelk	Winkle	Total
5	6.2	-	10.3	5.8	11.5	-	11.2	45.0
16	-	-	8.2	-	-	-	24.0	32.2
35	-	-	7.7	-	-	-	21.3	29.0
7	-	-	7.8	-	-	5.2	5.4	18.4
27	-	1.0	-	-	-	-	16.0	17.0
4	2.3	-	3.6	-	-	-	8.0	13.9
17	-	-	8.2	-	-	-	-	8.2
15	-	-	-	-	-	-	2.7	2.7
28	-	-	-	-	1.0	-	-	1.0
9	-	-	0.4	-	-	-	-	0.4
10	-	-	0.4	-	-	-	-	0.4

Observations in bold type are the members of the high-rate group

5.3 Species composition of the shellfish high-rate groups for adults and comparison with 2008 data

The percentage composition for the predominant shellfish species consumed in the adult high-rate groups from the 2009 Sellafield review, rounded to the nearest 10% for use in dose assessments, are as follows:

- Crustaceans - 50% common lobster, 30% brown crab and 20% *Nephrops* (mean consumption rate for the high-rate group 16 kg y⁻¹)
- Molluscs - 60% winkles and 40% other molluscs (mean consumption rate for the high-rate group 28 kg y⁻¹)

By comparison, the percentage composition for the predominant shellfish species consumed in the adult high-rate groups from the 2008 full Sellafield habits survey, and used in RIFE-14 (EA, FSA, NIEA and SEPA, 2009) for dose assessments, were:

- Crustaceans - 70% brown crab, 20% common lobster and 10% *Nephrops* (mean consumption rate for the adult high-rate group 17 kg y⁻¹)
- Molluscs - 50% winkles and 50% other molluscs (mean consumption rate for the adult high-rate group 31 kg y⁻¹)

In 2009, the mean consumption rate for the high-rate group for crustaceans decreased by 1 kg y⁻¹ compared to 2008. There was a decrease of 3 kg y⁻¹ in the mean consumption rate for the high-rate group for molluscs in 2009. The main species of crustaceans and molluscs consumed in 2009 remained the same as in 2008. The percentage breakdown of species changed in both groups in 2009. For crustaceans, due to a reduction in fishing there was a decrease in brown crab consumption. There was, however, an increase in the consumption of common lobster and *Nephrops*. For molluscs, there was an increase in winkle consumption and a decrease in the consumption of other molluscs.

5.4 Consumption trends

The consumption rates for the adult high-rate groups for crustaceans and molluscs over the previous ten years (2000 - 2009) are shown in Figures 2 and 3. These figures were plotted using means for the high-rate groups distributed according to the percentage breakdowns described as in section 5.3. The raw data are presented in Annex 3a.

Figure 2. Consumption rates for the adult high-rate groups for crustaceans, 2000 – 2009 (kg y^{-1})

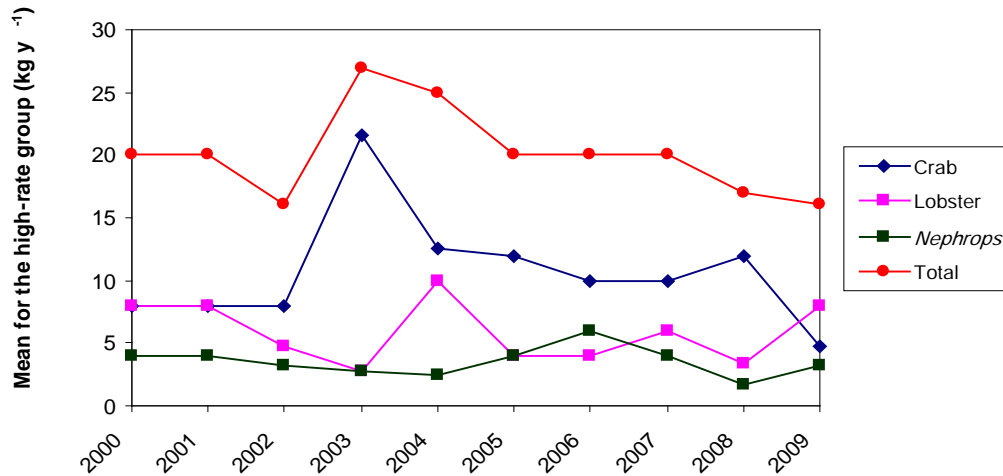
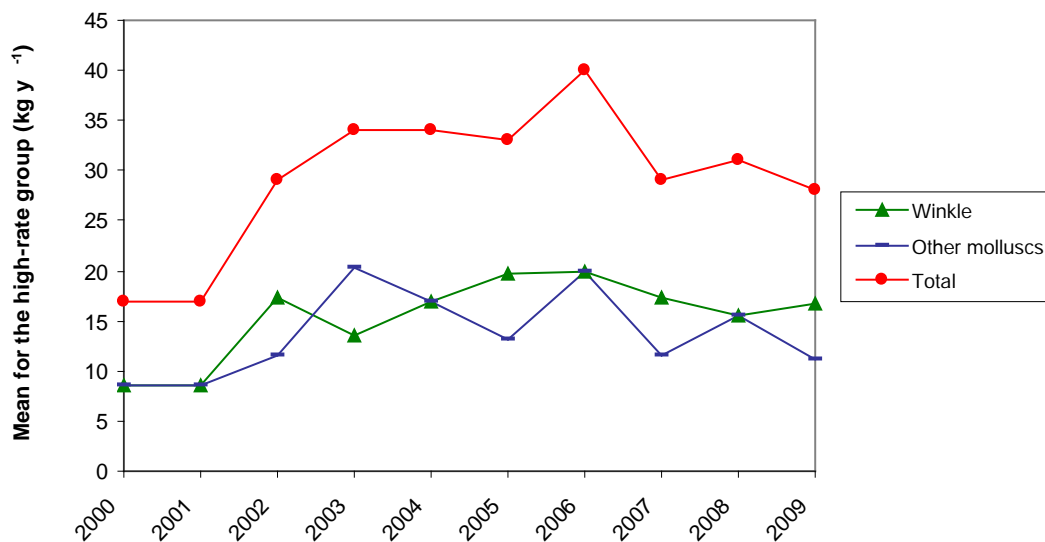


Figure 3. Consumption rates for the adult high-rate groups for molluscs, 2000 – 2009 (kg y^{-1})



For external exposure pathways, the 2009 review investigated intertidal occupancy in the Sellafield area.

6.1 Intertidal occupancy

Intertidal occupancy rates were noted for seven different substrate types: mud; mud and sand; mud, sand and stones; rock; salt marsh; sand; and sand and stones. These results are shown in Tables 4 and 5 for adults and children, respectively.

Adults

A single individual undertaking bait digging formed the high-rate group over mud, with an occupancy rate of 230 h y⁻¹. The maximum occupancy rate over mud was 230 h y⁻¹ for the same individual. The observed 97.5th percentile rate based on six observations for mud was 210 h y⁻¹.

Four individuals undertaking bait digging, collecting winkles, nature reserve warden duties and walking formed the high-rate group over mud and sand with a mean occupancy rate of 300 h y⁻¹. The maximum occupancy rate over mud and sand was 520 h y⁻¹ for an individual who was carrying out nature reserve warden duties. The observed 97.5th percentile rate based on nine observations for mud and sand was 460 h y⁻¹.

The only occupancy rate recorded over mud, sand and stones was 110 h y⁻¹ for an individual who was collecting mussels. No other individuals were identified spending time over mud, sand and stones, so the mean occupancy rate for this group was 110 h y⁻¹. The observed 97.5th percentile rate is not applicable for 1 observation.

The only occupancy rate recorded over rock was 27 h y⁻¹ for an individual who was collecting winkles. No other individuals were identified spending time over rock, so the mean occupancy rate for this group was 27 h y⁻¹. The observed 97.5th percentile rate is not applicable for 1 observation.

A single individual undertaking nature reserve warden duties formed the high-rate group over salt marsh with an occupancy rate of 160 h y⁻¹. The maximum occupancy rate over salt marsh was 160 h y⁻¹ for the same individual. The observed 97.5th percentile rate based on two observations for salt marsh was 150 h y⁻¹.

Four individuals undertaking shore angling, bait digging, setting nets, collecting winkles, collecting razor shells and dog walking formed the high-rate group over sand with a mean occupancy rate of 810 h y⁻¹. The maximum occupancy rate over sand was 1100 h y⁻¹ for an individual who was setting

nets and collecting winkles. The observed 97.5th percentile rate based on nine observations for sand was 1000 h y⁻¹.

Five individuals collecting winkles, shore angling, walking, collecting crabs, playing and beach combing formed the high-rate group over sand and stones with a mean occupancy rate of 150 h y⁻¹. The maximum occupancy rate over sand and stones was 220 h y⁻¹ for an individual who was walking, collecting crabs, playing and beach combing. The observed 97.5th percentile rate based on ten observations for sand and stones was 200 h y⁻¹.

These rates compare with the mean occupancy rates for adults identified during the 2008 full Sellafield habits survey of 120 h y⁻¹ over mud for six individuals (maximum rate 160 h y⁻¹), 580 h y⁻¹ over mud and sand for four individuals (maximum rate 940 h y⁻¹), 510 h y⁻¹ over mud, sand and stones for five individuals (maximum rate 720 h y⁻¹), 30 h y⁻¹ over rock for three individuals (maximum rate 50 h y⁻¹), 110 h y⁻¹ over salt marsh for two individuals (maximum rate 160 h y⁻¹), 610 h y⁻¹ over sand for 20 individuals (maximum rate 940 h y⁻¹), and 570 h y⁻¹ over sand and stones for ten individuals (maximum rate 1000 h y⁻¹).

Table 4. Adults' intertidal occupancy rates in the Sellafield area ($h\ y^{-1}$)

Observation number	Location	Activity	Mud	Mud and sand	Mud, sand and stones	Rock	Salt marsh	Sand	Sand and stones
26	Whitehaven outer harbour	Bait digging	228	-	-	-	-	-	-
	Eskmeals	Bait digging	-	228	-	-	-	-	-
	Coulderton, Nethertown and Braystones	Collecting winkles	-	-	-	27	-	-	-
	Braystones and Drigg	Angling and bait digging	-	-	-	-	-	911	-
30	River lrt	Wildfowling	63	-	-	-	-	-	
31	River lrt	Wildfowling	63	-	-	-	-	-	
32	River lrt	Wildfowling	63	-	-	-	-	-	
33	River lrt	Wildfowling	63	-	-	-	-	-	
4	Ravenglass	Bait digging	12	-	-	-	-	-	-
	Nethertown and St Bees	Collecting winkles	-	207	-	-	-	-	-
34	Eskmeals Range Reserve	Nature reserve warden duties	-	520	-	-	-	-	-
			-	-	-	156	-	-	-
16	Parton	Walking	-	224	-	-	-	-	-
		Collecting mussels	-	-	112	-	-	-	-
	Whitehaven beach	Collecting winkles	-	-	-	-	-	-	112
5	Ravenglass	Collecting cockles	-	117	-	-	-	-	-
	Drigg to Sellafield	Beachcombing	-	-	-	-	-	286	-
	Nethertown to Braystones	Collecting winkles	-	-	-	-	-	-	117
9	Drigg to Whitehaven	Bait digging	-	60	-	-	-	-	-
	Braystones	Setting nets	-	-	-	-	-	1072	-
	Parton to Drigg	Collecting winkles	-	-	-	-	-	-	-
	St Bees to Drigg	Angling	-	-	-	-	-	-	160
35	Barrow Mouth and Whitehaven	Collecting winkles	-	60	-	-	-	-	-
	White Rock and Whitehaven	Collecting mussels	-	-	-	-	-	-	19
1	Various locations	Walking	-	37	-	-	-	-	-
	Braystones	Bait digging	-	12	-	-	-	-	-
15	Various locations	Angling	-	-	-	-	-	288	-
	Nethertown	Collecting winkles	-	-	-	-	-	-	60
22	Near Muncaster	Wildfowling	-	-	-	-	32	-	-
28	Braystones	Setting nets, bait digging and collecting razor shells	-	-	-	-	-	878	-
	Nethertown to Sellafield	Shore angling	-	-	-	-	-	-	-
	Braystones and Sellafield	Walking and beachcombing	-	-	-	-	-	-	-
	Braystones	Playing	-	-	-	-	-	-	216
23	Netherton to Sellafield	Collecting crabs	-	-	-	-	-	-	-
	Seascale, Drigg and Sellafield	Dog walking	-	-	-	-	-	365	-
8	St Bees beach	Dog walking	-	-	-	-	-	330	-
29	Braystones	Setting nets	-	-	-	-	-	120	-
		Playing	-	-	-	-	-	-	24
10	Braystones	Setting nets	-	-	-	-	-	48	-
	St Bees to Drigg	Angling	-	-	-	-	-	-	160
19	Barrow Mouth, Whitehaven	Collecting winkles	-	-	-	-	-	-	28
7	St Bees, Ravenglass and Fleswick	Collecting mussels	-	-	-	-	-	-	12

Observations in bold type are the members of the high-rate groups

Children

The only substrates for which intertidal occupancy was noted for children were salt marsh, and sand and stones. No children in the 1-year-old age group or the 3-month-old age group were identified spending time on intertidal substrates.

15-year-old age group

The mean occupancy rate recorded over salt marsh was 32 h y⁻¹ for two individuals who were wildfowling. These individuals had identical occupancy rates of 32 h y⁻¹. The observed 97.5th percentile rate based on two observations for salt marsh was 32 h y⁻¹.

A single individual undertaking angling and playing on the beach formed the high-rate group over sand and stones, with an occupancy rate of 460 h y⁻¹. The observed 97.5th percentile rate is not applicable for 1 observation.

10-year-old age group

The mean occupancy rate recorded over sand and stones was 460 h y⁻¹ for two individuals who were angling and playing on the beach. These individuals had identical occupancy rates of 460 h y⁻¹. The observed 97.5th percentile rate based on two observations for sand and stones was 460 h y⁻¹.

5-year-old age group

A single individual undertaking angling and playing on the beach formed the high-rate group over sand and stones, with an occupancy rate of 460 h y⁻¹. The observed 97.5th percentile rate is not applicable for 1 observation.

Table 5. Children's intertidal occupancy rates in the Sellafeld area ($h\ y^{-1}$)

Observation number	Age	Location	Activity	Salt marsh	Sand and stones
15-year-old age group					
24	14	Near Muncaster	Wildfowling	32	-
25	12	Near Muncaster	Wildfowling	32	-
11	13	Braystones St Bees to Drigg	Playing Angling	-	462
10-year-old age group					
12	11	Braystones St Bees to Drigg	Playing Angling	-	462
13	10	Braystones St Bees to Drigg	Playing Angling	-	462
5-year-old age group					
14	6	Braystones St Bees to Drigg	Playing Angling	-	462

Observations in bold type are the members of the high-rate groups

7. USE OF HABITS DATA FOR DOSE ASSESSMENTS

7.1 Aquatic combinations for adults in the Sellafeld Fishing Community

The consumption rates of crustaceans and molluscs, and intertidal occupancy rates for each individual are presented in Table 6. Fish consumption rates are also shown. The table shows that several individuals are members of multiple high-rate groups. For example, observation number 16 is in the high-rate groups for crustaceans, molluscs and intertidal occupancy and also consumes significant amounts of fish. This supports the continuation of assessing the dose to the representative person based on a combination of internal and external pathways. Therefore, the Radioactivity in Food and the Environment (RIFE) Sellafeld Fishing Community aquatic assessments for 2009 will be based on these combinations of consumption and occupancy pathways.

Table 6. Aquatic combinations for adults in the Sellafeld Fishing Community

Observation number	Internal exposure (kg y ⁻¹)			External exposure (h y ⁻¹)						
	Fish	Crustaceans	Molluscs	Mud	Mud and sand	Mud, sand and stones	Rock	Salt marsh	Sand	Sand and stones
1	21.9	7.8	-	-	37	-	-	-	-	-
2	17.1	7.8	-	-	-	-	-	-	-	-
3	17.1	7.8	-	-	-	-	-	-	-	-
4	17.8	5.9	13.9	12	207	-	-	-	-	-
5	16.2	10.6	45.0	-	117	-	-	-	286	117
6	16.2	-	-	-	-	-	-	-	-	-
7	57.3	3.1	18.4	-	-	-	-	-	-	12
8	-	-	-	-	-	-	-	-	330	-
9	24.8	11.1	0.4	-	60	-	-	-	1072	160
10	25.4	30.7	0.4	-	-	-	-	-	48	160
15	17.4	-	2.7	-	12	-	-	-	288	60
16	17.5	19.9	32.2	-	224	112	-	-	-	112
17	17.5	19.9	8.2	-	-	-	-	-	-	-
18	3.9	6.1	-	-	-	-	-	-	-	-
19	3.0	10.3	-	-	-	-	-	-	-	28
20	1.2	10.3	-	-	-	-	-	-	-	-
22	5.9	6.9	-	-	-	-	-	32	-	-
23	5.9	6.9	-	-	-	-	-	-	365	-
26	-	-	-	228	228	-	27	-	911	-
27	-	-	17.0	-	-	-	-	-	-	-
28	38.0	1.0	1.0	-	-	-	-	-	878	216
29	19.0	2.0	-	-	-	-	-	-	120	24
30	-	-	-	63	-	-	-	-	-	-
31	-	-	-	63	-	-	-	-	-	-
32	-	-	-	63	-	-	-	-	-	-
33	-	-	-	63	-	-	-	-	-	-
34	-	-	-	-	520	-	-	156	-	-
35	-	-	29.0	-	60	-	-	-	-	19

Observations in bold are the members of the high-rate groups

7.2 Sellafeld 5-year averages

Annex 3a shows the consumption and occupancy rates for the Sellafeld Fishing Community which are presented in the RIFE reports. The consumption rates of crustaceans and molluscs, and intertidal occupancy rates are updated annually using the Sellafeld review data or full survey data. The fish consumption rates are updated when a full survey is conducted. Annex 3b presents the 5-year averages of the data in Annex 3a. The 5-year average (2005 - 2009) of the high-rate groups (for fish, crustaceans, molluscs and intertidal occupancy) will be used in RIFE-15 assessments in order to provide a longer term trend of dose to members of the Sellafeld Fishing Community group.

7.3 Profiled habits data

The Environment Agencies and the Food Standards Agency have considered ways of using habits data to calculate total dose retrospectively. The adopted approach is to use the adult consumption and occupancy data collected in each habits survey to create a matrix with a series of habits profiles for each nuclear licensed site. The National Dose Assessment Working Group (NDAWG) has considered this approach to assessing retrospective total doses (Camplin *et al.*, 2005) and has agreed that using habits profiles is an appropriate approach. Retrospective total doses around Sellafield are made using these profiles and reported in the RIFE reports (e.g. EA, FSA, NIEA and SEPA, 2009).

The relevant matrix for the 2009 Sellafield adults' profiled habits data is presented in Annex 4. It is based on data from the 2008 Sellafield full habits survey (aquatic, terrestrial and direct radiation pathways), which has been updated with data from this 2009 Sellafield annual review. All pathways and observations from the original 2008 profiled habits matrix were retained and for the 2009 profile, only data asked about during the 2009 review were updated; that is intertidal occupancy and consumption of crustaceans, molluscs and fish. If data were collected for new interviewees, these were added as new observations. Because the profile has been created using the data from 2008 and 2009, the profiled data shown in Annex 4 are not comparable with the raw data presented in Annex 1.

8. SUMMARY AND RECOMMENDATIONS

The survey investigated the consumption of shellfish and intertidal occupancy, relating to liquid discharges from the Sellafield nuclear site. Consumption and occupancy data were collected for 28 adults and 7 children. The recommendations are based on the adult data.

The mean rates for the adult high-rate groups from the 2009 Sellafield review are as follows:

- Crustaceans 16 kg y⁻¹
- Molluscs 28 kg y⁻¹
- Occupancy over mud 230 h y⁻¹
- Occupancy over mud and sand 300 h y⁻¹
- Occupancy over mud, sand and stones 110 h y⁻¹
- Occupancy over rock 27 h y⁻¹
- Occupancy over salt marsh 160 h y⁻¹
- Occupancy over sand 810 h y⁻¹
- Occupancy over sand and stones 150 h y⁻¹

In comparison to the 2008 Sellafield full habits survey, the mean rates for the high-rate groups in 2009 decreased by 1 kg y⁻¹ for crustaceans, decreased by 3 kg y⁻¹ for molluscs, increased by 110 h y⁻¹ for occupancy over mud, decreased by 280 h y⁻¹ for occupancy over mud and sand, decreased by 400 h y⁻¹ for occupancy over mud, sand and stones, remained the same for rock, increased by 50 h y⁻¹ for occupancy over salt marsh, increased by 200 h y⁻¹ for occupancy over sand, and decreased by 420 h y⁻¹ for occupancy over sand and stones.

The mean rates for the adult high-rate groups retained from the 2008 Sellafield full habits survey for assessments purposes are as follows:

- Fish 40 kg y⁻¹
- Handling sediment 960 h y⁻¹
- Handling fishing gear 980 h y⁻¹

The recommended 5-year averages for use in RIFE 15 dose assessments are as follows:

- Fish 41 kg y⁻¹
- Crabs 9.8 kg y⁻¹
- Lobsters 5.1 kg y⁻¹
- *Nephrops* 3.8 kg y⁻¹
- Winkles 18 kg y⁻¹
- Other molluscs 14 kg y⁻¹
- Occupancy over a combination of intertidal substrates (called mud and sand) 820 h y⁻¹

9. REFERENCES

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**Annex 1. Adults' consumption rates (kg y⁻¹) and intertidal occupancy rates (h y⁻¹)
in the Sellafeld area**

Observation number	Sex	Age (years)	Fish	Crustaceans	Molluscs	Intertidal occupancy over mud	Intertidal occupancy over mud and sand	Intertidal occupancy over mud, sand and stones	Intertidal occupancy over rock	Intertidal occupancy over salt marsh	Intertidal occupancy over sand	Intertidal occupancy over sand and stones
1	M	67	21.9	7.8	-	-	37	-	-	-	-	-
2	F	65	17.1	7.8	-	-	-	-	-	-	-	-
3	F	37	17.1	7.8	-	-	-	-	-	-	-	-
4	M	U	17.8	5.9	13.9	12	207	-	-	-	-	-
5	M	67	16.2	10.6	45.0	-	117	-	-	-	286	117
6	F	66	16.2	-	-	-	-	-	-	-	-	-
7	M	73	57.3	3.1	18.4	-	-	-	-	-	-	12
8	F	35	-	-	-	-	-	-	-	-	330	-
9	M	U	24.8	11.1	0.4	-	60	-	-	-	1072	160
10	F	U	25.4	30.7	0.4	-	-	-	-	-	48	160
15	M	54	17.4	-	2.7	-	12	-	-	-	288	60
16	M	70	17.5	19.9	32.2	-	224	112	-	-	-	112
17	F	69	17.5	19.9	8.2	-	-	-	-	-	-	-
18	F	37	3.9	6.1	-	-	-	-	-	-	-	-
19	M	44	3.0	10.3	-	-	-	-	-	-	-	28
20	F	45	1.2	10.3	-	-	-	-	-	-	-	-
22	M	50	5.9	6.9	-	-	-	-	-	32	-	-
23	F	47	5.9	6.9	-	-	-	-	-	-	365	-
26	M	U	-	-	-	228	228	-	27	-	911	-
27	F	U	-	-	17.0	-	-	-	-	-	-	-
28	M	U	38.0	1.0	1.0	-	-	-	-	-	878	216
29	F	54	19.0	2.0	-	-	-	-	-	-	120	24
30	M	U	-	-	-	63	-	-	-	-	-	-
31	M	U	-	-	-	63	-	-	-	-	-	-
32	M	U	-	-	-	63	-	-	-	-	-	-
33	M	U	-	-	-	63	-	-	-	-	-	-
34	M	74	-	-	-	-	520	-	-	156	-	-
35	M	52	-	-	29.0	-	60	-	-	-	-	19

Notes

Observations in bold type are the members of the high-rate group
U = Unknown

Annex 2. Children's consumption rates (kg y⁻¹) and intertidal occupancy rates (h y⁻¹) in the Sellafield area

Observation number	Sex	Age (years)	Fish	Crustaceans	Intertidal occupancy over salt marsh	Intertidal occupancy over sand and stones
15-year-old age group						
11	M	13	3.4	-	-	462
21	F	14	1.2	10.3	-	-
24	M	14	5.9	6.9	32	-
25	M	12	5.9	6.9	32	-
10-year-old age group						
12	M	11	-	-	-	462
13	M	10	3.4	-	-	462
5-year-old age group						
14	F	6	-	-	-	462

Notes

Observations in bold type are the members of the high-rate group

Annex 3a. Sellafield Fishing Community consumption and intertidal occupancy data reported in AEMR and RIFE (kg y ⁻¹ and h y ⁻¹)																		
Year (report)	FISH					CRUSTACEANS					MOLLUSCS			INTERTIDAL OCCUPANCY		Source of habits data		
	Species Composition	Total	Cod	Plaice	Other fish	Species Composition	Total	Crab	Lobster	Nephrops	Species Composition	Total	Winkles	Other molluscs	Substrate	h y ⁻¹	Consumption	Occupancy
1994 (AEMR 45)	Plaice and Cod (50%:50%)	26.0	13.0	13.0	0.0	Crabs and Lobsters (65%:35%)	12.0	7.8	4.2	0.0	Winkles and other molluscs (85%:15%)	9.7	8.2	1.5	-	0	1993/94 Survey	-
1995 (RIFE 1)	Plaice and Cod (50%:50%)	26.0	13.0	13.0	0.0	Crabs and Lobsters (75%:25%)	8.6	6.5	2.2	0.0	Winkles and other molluscs (50%:50%)	12.0	6.0	6.0	-	0	1995 Review (crust and moll) and 1993/4 survey (fish)	-
1996 (RIFE 2)	Plaice and Cod (50%:50%)	25.0	12.5	12.5	0.0	Crabs and Lobsters (60%:40%)	12.0	7.2	4.8	0.0	Winkles and other molluscs (60%:40%)	12.0	7.2	4.8	-	0	1995 Review (crust and moll) and 1996 logging data (fish)	-
1997 (RIFE 3)	Plaice and Cod (25%:75%)	37.0	27.8	9.3	0.0	Crabs, Lobsters and Nephrops (50%:40%:10%)	17.0	8.5	6.8	1.7	Winkles and other molluscs (40%:60%)	4.2	1.7	2.5	-	0	1997 Review	-
1998 (RIFE 4)	Plaice and Cod (50%:50%)	45.0	22.5	22.5	0.0	Crabs and Lobsters (85%:15%)	28.0	23.8	4.2	0.0	Winkles and other molluscs (30%:70%)	15.0	4.5	10.5	Sand and mollusc beds	1100	1998 Survey	1998 Survey
1999 (RIFE 5)	Plaice and Cod (50%:50%)	43.0	21.5	21.5	0.0	Crabs and Lobsters (80%:20%)	24.0	19.2	4.8	0.0	Winkles and other molluscs (50%:50%)	25.0	12.5	12.5	Sand and mollusc beds	1000	1999 Review	1999 Review
2000 (RIFE 6)	Cod and other fish (40%:60%)	31.0	12.4	0.0	18.6	Crabs, Lobsters and Nephrops (40%:40%:20%)	20.0	8.0	8.0	4.0	Winkles and other molluscs (50%:50%)	17.0	8.5	8.5	Sand and mollusc beds	1000	2000 Review	2000 Review
2001 (RIFE 7)	Cod and other fish (40%:60%)	31.0	12.4	0.0	18.6	Crabs, Lobsters and Nephrops (40%:40%:20%)	20.0	8.0	8.0	4.0	Winkles and other molluscs (50%:50%)	17.0	8.5	8.5	Sand and mollusc beds	900	2000 Review	2000 Review
2002 (RIFE 8)	Cod and other fish (40%:60%)	51.0	20.4	0.0	30.6	Crabs, Lobsters and Nephrops (50%:30%:20%)	16.0	8.0	4.8	3.2	Winkles and mussels (60%:40%)	29.0	17.4	11.6	Mud and sand	1200	2002 Review	2002 Review
2003 (RIFE 9)	Cod and other fish (60%:40%)	41.0	24.6	0.0	16.4	Crabs, Lobsters and Nephrops (80%:10%:10%)	27.0	21.6	2.7	2.7	Winkles and other molluscs (40%:60%)	34.0	13.6	20.4	Mud and sand	870	2003 Survey	2003 Survey
2004 (RIFE 10)	Cod and other fish (60%:40%)	41.0	24.6	0.0	16.4	Crabs, Lobsters and Nephrops (50%:40%:10%)	25.0	12.5	10.0	2.5	Winkles and other molluscs (50%:50%)	34.0	17.0	17.0	Mud and sand	1000	2004 Review (crust and moll) and 2003 Survey (fish)	2004 Review
2005 (RIFE 11)	Cod and other fish (60%:40%)	41.0	24.6	0.0	16.4	Crabs, Lobsters and Nephrops (60%:20%:20%)	20.0	12.0	4.0	4.0	Winkles and other molluscs (60%:40%)	33.0	19.8	13.2	Mud and sand	790	2005 Review (crust and moll) and 2003 Survey (fish)	2005 Review
2006 (RIFE 12)	Cod and other fish (60%:40%)	41.0	24.6	0.0	16.4	Crabs, Lobsters and Nephrops (50%:20%:30%)	20.0	10.0	4.0	6.0	Winkles and other molluscs (50%:50%)	40.0	20.0	20.0	Mud and sand	580	2006 Review (crust and moll) and 2003 Survey (fish)	2006 Review
2007 (RIFE 13)	Cod and other fish (60%:40%)	41.0	24.6	0.0	16.4	Crabs, Lobsters and Nephrops (50%:30%:20%)	20.4	10.2	6.1	4.1	Winkles and other molluscs (60%:40%)	28.9	17.3	11.6	Mud and sand	830	2007 Review (crust and moll) and 2003 Survey (fish)	2007 Review
2008 (RIFE 14)	Cod and other fish (25%:75%)	40.0	10.0	0.0	30.0	Crabs, Lobsters and Nephrops (70%:20%:10%)	16.8	11.8	3.4	1.7	Winkles and other molluscs (50%:50%)	31.4	15.7	15.7	Mud and sand	930	2008 Survey	2008 Survey
2009 (RIFE 15)	Cod and other fish (25%:75%)	40.0	10.0	0.0	30.0	Crabs, Lobsters and Nephrops (30%:50%:20%)	16.0	4.8	8	3.2	Winkles and other molluscs (60%:40%)	28.0	16.8	11.2	Mud and sand	960	2009 Review (crust & moll) 2008 Survey (fish)	2009 Review

Annex 3b. Sellafield Fishing Community 5-year average consumption and intertidal occupancy rates (kg y⁻¹ and h y⁻¹)

5-year period	FISH				CRUSTACEANS			MOLLUSCS			EXTERNAL	
	Total fish	Cod	Plaice	Other fish	Total crustaceans	Crab	Lobster	<i>Nephrops</i>	Total molluscs	Winkles	Other molluscs	Intertidal occupancy
1994-98	31.8	17.8	14.1	0.0	15.5	10.8	4.4	0.3	10.6	5.5	5.1	1100
1995-99	35.2	19.5	15.8	0.0	17.9	13.0	4.6	0.3	13.6	6.4	7.3	1050
1996-00	36.2	19.3	13.2	3.7	20.2	13.3	5.7	1.1	14.6	6.9	7.8	1033
1997-01	37.4	19.3	10.7	7.4	21.8	13.5	6.4	1.9	15.6	7.1	8.5	1000
1998-02	40.2	17.8	8.8	13.6	21.6	13.4	6.0	2.2	20.6	10.3	10.3	1040
1999-03	39.4	18.3	4.3	16.8	21.4	13.0	5.7	2.8	24.4	12.1	12.3	994
2000-04	39.0	18.9	0.0	20.1	21.6	11.6	6.7	3.3	26.2	13.0	13.2	994
2001-05	41.0	21.3	0.0	19.7	21.6	12.4	5.9	3.3	29.4	15.3	14.1	952
2002-06	43.0	23.8	0.0	19.2	21.6	12.8	5.1	3.7	34.0	17.6	16.4	888
2003-07	41.0	24.6	0.0	16.4	22.5	13.3	5.4	3.9	34.0	17.5	16.4	814
2004-08	40.8	21.7	0.0	19.1	20.4	11.3	5.5	3.7	33.5	18.0	15.5	826
2005-09	40.6	18.8	0.0	21.8	18.6	9.8	5.1	3.8	32.3	17.9	14.3	818

Annex 4. Summary of adults' profiled consumption data (kg y⁻¹ and l y⁻¹) and occupancy data (h y⁻¹) in the Sellafield area (2008 Sellafield full habits survey data updated with the 2009 Sellafield review data)

Profile Name	Number of individuals	Pathway Name																												
		Crustacea	Direct ^a	Eggs	Fish - Fresh	Fish - Sea	Fruit - Domestic	Fruit and nuts - Wild	Gamma ext - mud/sand ^b	Gamma ext - salt marsh	Honey	Marine plants/algae	Meat - Cow	Meat - Game ^c	Meat - Poultry	Meat - Sheep	Milk	Mollusca	Mushrooms	Occupancy IN water	Occupancy ON water	Plume (IN; 0-0.25km) ^d	Plume (MID; >0.25-0.5km) ^d	Plume (OUT; >0.5-1km) ^d	Vegetables - Green	Vegetables - Other Domestic	Vegetables - Potatoes	Vegetables - Root		
		kg	-	kg	kg	kg	kg	kg	h	h	kg	kg	kg	kg	kg	kg	l	kg	kg	h	h	h	h	h	h	h	kg	kg	kg	kg
Crustacean consumers	22	16.8	-	-	-	25.2	-	-	250	-	-	-	-	-	-	-	4.7	-	-	410	-	-	-	-	-	-	-	-	0.2	-
Occupants for direct radiation	52	-	1	5	-	1.6	1.8	0.5	70	-	0.2	-	4.3	0.2	0.2	0.9	11.9	-	0.1	-	-	1250	1320	2050	0.8	1.9	3.3	0.8	-	
Egg consumers	16	-	0.7	22	-	2	3.9	0.7	-	-	0.2	-	6.1	-	0.1	-	46.6	-	0.2	-	-	1320	190	2400	0.3	2.9	19.6	0.3	-	
Freshwater fish consumers	1	-	1	-	2.3	16.8	-	-	680	-	-	-	-	-	-	-	-	-	-	-	-	290	-	-	-	-	-	-	-	
Sea fish consumers	19	10.6	0.1	-	-	35.2	0.1	0.4	330	-	-	-	-	-	-	-	1.7	0.1	-	410	-	-	-	-	-	0.4	0.3	0.5	0.7	
Domestic fruit consumers	4	-	-	4.4	-	-	45.5	0.2	10	-	4.3	-	-	-	-	-	-	-	0.9	-	-	-	-	-	19.8	35.3	54.4	23.3	-	
Wild fruit and nut consumers	5	0.6	0.6	3.5	-	11.4	4.4	6.2	260	-	0.3	-	-	-	0.1	-	23.6	0.2	0.7	-	-	-	510	500	3.6	4.5	13.4	5	-	
Occupants for exposure - mud/sand	28	5.4	0.1	-	0.1	13.6	-	0.3	710	10	-	-	-	-	-	-	2.1	0.1	-	180	10	-	-	-	0.3	0.2	0.5	0.4	-	
Occupants for exposure - salt marsh	1	-	-	-	-	-	-	-	520	160	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Honey consumers	3	-	0.3	-	-	-	18.9	-	20	-	8.7	-	-	-	-	-	-	-	-	-	-	-	-	570	-	7.8	17.3	-	-	
Marine plants/algae consumers	3	14.1	-	-	-	17.7	-	-	500	-	0.2	-	-	-	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-	
Cattle meat consumers	14	-	0.3	7.5	-	0.6	3.2	0.5	10	-	0.1	-	33.9	-	0.2	6.1	108.9	-	1	-	-	1440	40	-	-	0.3	15.1	-	-	
Game meat consumers	5	2.8	-	-	0.1	6.3	0.5	1.3	70	10	-	-	-	14.4	2.4	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	
Poultry meat consumers	5	-	-	1.8	0.4	1.8	-	0.6	10	-	-	-	-	0.9	9	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	
Sheep meat consumers	10	0.1	0.2	3.9	-	0.7	0.9	0.6	-	-	-	-	20.7	-	0.3	14.4	35.5	-	1.2	-	-	260	-	-	-	-	-	-	-	
Milk consumers	37	-	-	3.3	-	0.2	0.7	0.5	-	-	-	-	6.1	0.1	0.3	1.6	221.3	-	0.2	-	-	-	20	-	-	3.3	0.1	43.7	4.6	
Mollusc consumers	6	5.6	-	-	-	15.2	-	-	180	-	-	-	-	-	-	-	28.6	-	-	10	-	-	-	-	-	-	-	0.6	-	
Mushroom consumers	16	0.2	0.1	9.4	-	5.1	9.4	1.8	80	-	-	-	9.2	-	0.2	5.4	41.6	0.1	1.9	-	-	-	-	-	5.8	8	14.8	7.4	-	
Occupancy IN water	28	-	-	0.1	-	-	-	-	-	-	-	1	-	-	-	5.2	-	-	30	30	-	-	-	-	-	-	-	-	-	
Occupancy ON water	12	14.6	-	-	-	25.8	-	-	300	-	-	-	-	-	-	-	1	-	-	1020	-	-	-	-	-	-	-	-	-	
Occupants for plume pathways (inner area)	9	-	1	6.6	-	0.9	3.3	-	-	-	-	17.3	-	-	-	26.3	-	-	-	-	-	6780	-	-	-	-	-	-	-	
Occupants for plume pathways (mid area)	8	-	1	0.6	-	-	0.6	-	50	-	-	-	-	-	0.1	1.4	-	-	-	-	-	-	7490	-	-	-	-	4.2	-	
Occupants for plume pathways (outer area)	15	-	1	8.3	-	1	1.2	0.4	60	-	-	-	-	-	0.1	-	-	-	0.1	-	-	-	-	6640	2.2	5.3	2.4	1.9	-	
Green vegetable consumers	5	-	0.2	4.8	-	-	29.6	0.2	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	1490	40.7	33.3	38.6	31.6	-	
Other domestic vegetable consumers	6	-	0.3	7	-	-	24.7	0.2	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	2610	16.6	37.6	57.1	21	-	
Potato consumers	23	-	-	3.1	-	0.3	6.1	-	-	-	-	2.3	0.1	0.2	-	153.3	-	0.2	-	-	-	-	-	-	8.2	7.6	89.7	9.7	-	
Root vegetable consumers	6	-	-	3	-	-	23.6	0.5	-	-	-	-	-	0.2	0.6	1.3	60.8	0.1	0.6	-	-	-	-	-	33.4	23.1	46	35.2	-	

Notes

^aExpressed as the proportion of the profile members who are exposed to direct radiation.

^bGamma ext - mud/sand includes occupancy over mud; mud and sand; mud, sand and stones; sand; and sand and stones

^cGame meat includes venison, rabbits/hares and wildfowl

^dPlume times are the sums of individuals' indoor and outdoor times

The means of the high-rate groups are determined by the 'cut-off' method and are highlighted on the diagonal

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Cefas Technology Limited (CTL) is a wholly owned subsidiary of Cefas specialising in the application of Cefas technology to specific customer needs in a cost-effective and focussed manner.

CTL systems and services are developed by teams that are experienced in fisheries, environmental management and aquaculture, and in working closely with clients to ensure that their needs are fully met.
(www.cefastechnology.co.uk)

Customer focus

With our unique facilities and our breadth of expertise in environmental and fisheries management, we can rapidly put together a multi-disciplinary team of experienced specialists, fully supported by our comprehensive in-house resources.

Our existing customers are drawn from a broad spectrum with wide ranging interests. Clients include:

- international and UK government departments
- the European Commission
- the World Bank
- Food and Agriculture Organisation of the United Nations (FAO)
- oil, water, chemical, pharmaceutical, agro-chemical, aggregate and marine industries
- non-governmental and environmental organisations
- regulators and enforcement agencies
- local authorities and other public bodies

We also work successfully in partnership with other organisations, operate in international consortia and have several joint ventures commercialising our intellectual property.

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