NDAWG
National Dose Assessment Working Group

NDAWG OPEN MEETING
15th-16th November, 2006

Paper 10.03: The Collection and Use of Habit Data, and the Assessment of Total Dose

Bill Camplin

1 Background

An important part of any dose assessment is the selection of appropriate data for people's habits. The principles for prospective and retrospective dose assessment (see Paper 10:02) give guidance on the selection of the critical group and their habits. This paper is concerned with the collection of relevant habit data for use in dose assessments for controlled releases, with particular emphasis on the assessment of total dose integrated across pathways. The work of the NDAWG Sub-group on habit data and critical groups is also outlined together with future areas that NDAWG needs to address.

2 The collection of habit data

There are three potential sources of radiation exposure from a site using radioactive material: liquid and gaseous radioactive discharges, and direct radiation. The public can come into contact with these sources of radiation in a number of different ways. Examples of these exposure pathways include consumption of fish caught near to the aquatic discharge outlet, occupancy over intertidal sediments near the site (liquid discharges), consumption of food grown locally to the site, exposure to the discharge plume (gaseous discharges), or occupancy within the immediate vicinity of the site (direct radiation), Assessment of radiation dose from these pathways requires an estimate of consumption and occupancy rates. In the United Kingdom (UK) these are obtained either from UK national surveys of diets, consumption rates and other habits or by local surveys in the vicinity of licensed nuclear facilities known as 'habits surveys'. The habits survey methodology essentially involves visiting the local area surrounding a nuclear site, identifying groups of individuals who have the greatest potential for exposure to radiation from site discharges or direct radiation, and collecting information about the type and extent of these people's habits. These habits data, together with concentrations of radioactivity in food and the environment, and dose coefficients, allow a combined dose from all pathways to be calculated. Over the years, the methodology for conducting habits surveys has evolved as emphases change. This paper highlights some of the more recent changes incorporated into the methodology and

summarises the uniqueness of certain pathways of exposure at specific sites. Further information is presented in the full paper from which this is taken (Grzechnik et al, 2006a).

Habits surveys have been conducted by the Centre for Environment, Fisheries & Aquaculture Science (Cefas) and its predecessor organisations at nuclear sites in England, Scotland and Wales since 1954. In addition, habits surveys have also been conducted on the south-west coast of Scotland, the eastern coast of Northern Ireland and the Channel Islands. In recent years combined surveys have been introduced. Combined surveys investigate pathways of exposure for all three sources of radiation (liquid and gaseous discharges and direct radiation) for each individual involved. Consumption and occupancy rates are recorded in a purpose-built database and in a single site-specific report. These surveys were introduced in 1999 in Scotland for the Scottish Environment Protection Agency (SEPA) and in 2001 in England and Wales for the Food Standards Agency (FSA). Since 2002, combined habits surveys in England and Wales have been carried out jointly for the Environment Agency (EA), FSA and HSE – that is those organisations responsible for ensuring that the public is protected in accord with national policy. The combined approach has enabled the calculation of doses for the combination of pathways. Habits survey reports can be accessed via the Cefas website (www.cefas.co.uk).

2.1 Habits survey methodology

Preparatory work for habits surveys involves identifying relevant site-specific exposure pathways and establishing the individuals or groups of individuals involved. This is undertaken by liaising closely with people who have a wide knowledge of the local area, such as local authorities, Fisheries Inspectors, local clubs (including angling, beekeeping and horticultural associations), as well as nuclear site representatives and EA or SEPA site inspectors.

The areas potentially affected by the three sources of radiation (liquid and gaseous discharges and direct radiation) are used to determine the geographical extent of the survey areas. Pathways relating to liquid discharges are investigated in an aquatic survey area defined by considering site-specific local parameters; for example at coastal sites hydrographic information such as the tidal excursion is used. Pathways relating to gaseous discharges are investigated in a terrestrial survey area, which is defined as being the area contained within a circle of radius 5 km from the site centre. At Scottish sites there is the option of extending this radius up to a maximum of 20 km if conditions dictate that it is necessary. In the case of direct radiation exposure pathways, the survey area is defined as the area within 1 km of the licensed site. Table 1 shows the commonly identified pathways of exposure, that is those identified at 6 or more of the 20 sites where combined habits surveys have taken place.

Table 1. Commonly identified pathways of exposure

Pathways of exposure relating to liquid radioactive waste discharges
Consumption of: fish, crustaceans, molluscs, wildfowl. Intertidal occupancy over: mud, rock, salt marsh, sand, sand and mud, sand and stones. Handling of: fishing gear, sediment. Occupancy: in water, on water.
Pathways of exposure relating to gaseous radioactive waste discharges
Consumption of: green vegetables, other vegetables, root vegetables, potato, domestic fruit, milk, cattle meat, pig meat, sheep meat, poultry, eggs, wild/free foods, rabbits/hares, honey, wild fungi, venison, fish
Pathways of exposure relating to direct radiation
Occupancy: indoors, outdoors

During the survey individuals who have been identified as having a higher potential to be exposed to radiation from a nuclear site are contacted and asked whether they would be willing to be interviewed about their relevant activities. Questions are used to establish

consumption, occupancy and handling rates for all exposure pathways. At this stage familiar terms such as the number of chicken eggs consumed per week are used in order to quantify the results. In combined surveys interviewees are asked, where possible, about exposure pathways relating to all three sources of radiation. For example, although a fisherman might initially be approached because of his potential exposure due to liquid discharges, he would also be asked to provide information relating to gaseous discharges and direct radiation. Data are only recorded for consumption, occupancy and handling rates that take place in the survey area of interest in relation to each source of radiation. For example, when being asked about the consumption of green vegetables, the interviewee would only need to provide data for green vegetables grown in the terrestrial survey area.

All data collected during fieldwork are input into a custom-made database, which has been designed to facilitate reliable data processing and archiving of habits data. The raw data are entered into the database where each individual is assigned a unique identifier (observation number) to assist in maintaining data quality, and to enable data protection issues to be adhered to. The database converts the survey data into the relevant units (kg/y or l/y for consumption and h/y for occupancy and handling) using a variety of conversion factors. It is important to distinguish between the edible fraction of food items and the total weights, since this can make a significant difference to the overall consumption rates. For example, an interviewee who claims to consume 1 kg/y of winkles would only be consuming approximately 0.2 kg/y of flesh weight if 1 kg/y were the total weight, including the shells.

Since one of the criteria for selecting a critical group is homogeneity based on age, and because different dose coefficients apply to children, ingestion data are structured into age groups consistent with those used in ICRP 72 (1996). The six groups are: 3 months old (0 to 1 year old), 1 year old (1 to 2 years old), 5 year old (>2 to 7 years old), 10 year old (>7 to 12 years old), 15 year old (>12 to 17 years old), adults (>17 years old). In order to identify the critical group the ‘cut-off’ method described by Hunt et al (1982) is used. With this method, critical rates for each exposure pathway are calculated by taking the arithmetic mean of the maximum observed rate and all rates observed within a factor of 3 of the maximum value (termed the lower threshold value). For example, for intertidal occupancy over sand, if the highest occupancy rate were 900 h/y, all occupancy rates equal to or greater than 300 h/y would be averaged to derive the critical rate. The factor of 3 is based on considerations of homogeneity (ICRP, 1966).

Each group of people whose data has contributed to a critical rate for an exposure pathway is called a ‘potential critical group’. Assessments are carried out to calculate the average dose to each potential critical group, and the group with the highest dose can then be denoted the critical group.

2.2 Evolution of habits survey methodology and results

Habits survey methodology must be flexible enough to incorporate new pathways and site-specific issues as they arise. It must also accommodate evolving assessments needs. The evolution in methodology has recently brought to light a range of unusual exposure pathways and foods. For example, people in the vicinity of some nuclear sites consume razor fish, crayfish and sea kale. At other sites people have been identified who consume foods such as sheep milk, peacock eggs, nettles and garden snails (Grzechnik et al, 2006a). However, the number of individuals consuming such items is extremely small compared to the total number of people surveyed.

Since combined habits surveys were introduced, increasing emphasis has been placed on using a holistic approach. Information is collected regarding pathways, however minor, in order to perform accurate integrated dose assessments. This development has been driven by the Environment Agencies’ responsibilities, under the relevant Directions, to assess the total dose from all pathways. Four pathways of exposure recently introduced into habits surveys are occupancy rates ‘in’ and ‘on’ water affected by either liquid or gaseous discharges. These data are used in two ways; firstly, to assess potential dose from contaminated water, suspended sediment in the water column or substrate under the water, and secondly, to assess the potential dose from water inhalation (sea spray) or ingestion. Additional pathways include exposure to liquid or dried sewage sludge. The first habits survey

to include these pathways was Cardiff in 2003. Subsequent sites were Devonport and Amersham, both in 2004. In all three cases, these pathways were investigated because the nuclear sites' liquid discharges flowed through nearby sewage works. Employees from the sewage works could potentially be exposed to the liquid discharges when dealing with sewage sludge.

Data from existing pathways have recently been utilised in new ways for dose assessment purposes. Two examples relate to the use of surveyed occupancy rates. Occupancy rates for exposure over intertidal sediments were previously used only to assess external exposure, but are now also used to assess internal exposure from inhalation and ingestion of sediments. Occupancy rates within 1 km of the site were previously only used to assess direct radiation, but are now also used to assess the dose that people receive from various pathways directly related to the gaseous discharge plume.

In the future it is envisaged that further sites will be surveyed using the combined technique. Other pathways of potential radioactivity exposure are always being investigated, and the methodology refined to help ensure optimal data quality.

3 Methods of assessing total doses integrated across pathways

The Radioactivity in Food and the Environment (RIFE) report series (Environment Agency et al, 2005) presents data from monitoring on behalf of the United Kingdom Government and retrospective dose calculations relating to disposals of radioactive waste from nuclear sites. In the past, total (or integrated) doses have been calculated from the addition of doses due to liquid discharges with those from gaseous discharges and those from direct radiation (where applicable). This approach ensured that dose calculations were generally overestimated, but was not always realistic. This is because the calculated doses apply to specific high-consumption/occupancy groups for each of these sources which, in reality, rarely overlap. The new integrated habits survey methodology, outlined above and described by Grzechnik et al, (2006a) has enabled more realistic methods to be developed for assessing total doses. The development of the methods is discussed here and in more detail in Grzechnik et al (2006b) and Camplin et al (2005).

There are a number of options for determining total dose, each with its own strengths and weaknesses. The most obvious methodology is to calculate the doses for each individual within the scope of the habits survey (the 'Individual' method). Dose for comparison with regulatory limits can then be determined from the upper parts of the distribution of individual doses. The significant disadvantage of this method is that it may only be independently reproduced if all data from the habits survey is available. As such, four other options have been proposed to overcome this problem, with the Individual method (referred to here as 'A') and the baseline used for comparison (Grzechnik, 2006b)

Each of the 5 methods was labelled (A to E) and given a short, relevant name for identification. The methods and their calculation are described in Table 2.

Table 2. Description of 5 options for determining total dose

Option, short name and description	***Process***
A. INDIVIDUAL Full calculation of dose to each individual in habits survey; dose for comparison with limit derived by cut-off method	• Combine the data from the most recent site-specific habits survey with concentration and dose rate data to determine doses to each individual • Select individuals with doses above 1/3 of the maximum dose • Average the doses to these individuals NB: Alternatively, percentiles may be taken from the distribution of calculated doses.

B. INDIVIDUAL PLUS As A, but in year 1, derive average rates of consumption and occupancy by the critical group and apply these to future years	• In year 1, combine the data from the most recent site-specific habits survey with concentration and dose rate data to determine doses to each individual • Select individuals with doses above 1/3 of the maximum dose • Average the consumption and occupancy habits in each pathway for these individuals, including zero habits • Use this derived set of habits data to determine doses by summation over all pathways until a new survey is available **NB: Methods A&B have been combined in results tables as they will give identical results in year 1 calculations.**
C. CONSTRUCT In year 1, construct a secondary habits dataset made up of all those individuals with habits rates defined to be critical ones, then average the rates and apply these to future years	• For each pathway, determine those individuals who have consumption and occupancy rates above 1/3 the maximum rate • Construct a secondary database of all such individuals and their rates for all pathways • Average the rates excluding zeros • Use this derived set of habits data to determine doses by summation over all pathways until a new survey is available
D. TOP-TWO In year 1, derive critical and average rates for each pathway and apply these to future years. Determine doses using the Top-two method previously adopted for terrestrial pathways	• For each pathway determine critical consumption and occupancy rates by averaging those rates higher than 1/3 the maximum rate. Apply these until a new survey is available • Divide critical rates by three to obtain average rates. This simplifying assumption has been chosen to correspond to observations made with national habits survey data. Other group specific factors could be used. • Calculate doses for all sets of rate combinations that include two critical rates and the remainder as averages • Use the set of habits which gives rise to the highest dose for comparison with the dose limit
E. PROFILING In year 1, derive profiles of habits rates that correspond to high consumers for each pathway and apply these to future years. Calculate doses for each profile and select the highest dose.	• Starting with the first pathway, use the cut-off method to determine critical individuals. Average the consumption and occupancy rates of each of these individuals and assign the habits rates determined as 'Profile A' • Repeat for the second pathway (Profile B), and subsequent pathways. Use these data until a new survey is available • Use the habits profiles to calculate doses • Use the set of habits which gives rise to the highest dose for comparison with the dose limit

To compare the 5 methods calculations were carried out using local habits and environmental monitoring data (Grzechnik, 2006b). Taking into account the different approaches used, each of the new methods agrees reasonably well with the baseline dose. As such, it is difficult to draw distinct comparisons on the basis of dose alone. Generally, it can be expected that options A & B gave the most realistic dose because they reflect individuals' habits directly. Doses using Method E were closer to those obtained using the individual method than either of methods C & D. Method E doses were slightly more conservative than those obtained using methods A & B, and were also closer to the RIFE baseline doses in two out of the three sites presented.

The criteria used to judge which method should be used to calculate total doses were:

Reproducibility – can the approach be easily used for an independent reassessment?
Rigour and realism – how good is the match with reality?
Transparency – a measure of the ease with which others can understand how the calculations are performed and what they mean.
Homogeneity – is the group receiving the dose relatively homogeneous with respect to age, diet and those aspects that affect the dose received? This feature has been recommended as being one to use when defining a critical group.

A qualitative comparison of the criteria described above is shown in Table 3.

Table 3. Qualitative comparison of the five methods for total dose assessment

Method	***Positive***	***Negative***
A. Individual	Most rigorous and realistic for assessing dose.	Difficult to present and for others to reproduce. Potentially inhomogeneous.
B. Individual Plus	Easy to reproduce and present.	Less rigorous and potentially inhomogeneous.
C. Construct	Easy to reproduce.	Difficult to explain. Potentially very large critical group which does not actually exist.
D. Top-Two	High homogeneity.	Not fully scientifically robust. Critical group does not actually exist. Data manipulation difficult to explain.
E. Profiling	Homogeneity criteria most likely to be met. Easy to present and replicate.	Chance of overestimating dose due to unrealistically small number of individuals in critical group.

A suitability ranking was performed by an NDAWG working group comprising of RIFE, industry and other representatives using a paired comparison technique resulting in a quantitative measure of relative suitability of each option in relation to its features (Camplin et al, 2005). For example, if option A was decided to exhibit better rigour and realism when compared with option E, then A was awarded one point and E none. The result of the ranking exercise is shown in Table 4.

Table 4. Results of ranking Options using paired comparisons

Feature Option	Reproducibility	Rigour and realism	Transparency	Homogeneity	Total score
A. Individual	***0***	***4***	***2***	***1.5***	***7.5***
B. Individual plus	***3.5***	***2***	***3***	***1.5***	***10***
C. Construct	***3.5***	***1***	***1***	***0***	***5.5***
D. Top-two	***1.5***	***0***	***0***	***3***	***4.5***
E. Profiling	***1.5***	***3***	***4***	***4***	***12.5***

The option found to be awarded the highest number of points (Method E, Profiling) was taken to be the optimal choice in terms of the features considered, with Method B (Individual plus) the second ranked option.

The profiling method has been applied at 10 sites around the United Kingdom in recent RIFE reports (Appendix 7, Environment Agency et al, 2005). Consumption rates for critical profiles have been presented for gaseous/direct, liquid and combined discharge scenarios. Total dose and baseline calculations have been conducted simultaneously in RIFE reports, and a data comparison for combined releases is shown in Table 5. Comparisons thus far are promising, and it is expected that further comparison will be undertaken in the future.

Table 5. Comparison of adult baseline and profiling method (including direct radiation) dose outputs (μSv y^{-1})

Site	***Baseline***			***Profiling Method***
	Direct	*Liquid*	*Gaseous*	
Aldermaston & Burghfield	Bkgd	1.2	2.2	<5.0
Amersham	240	<5.0	17	240
Cardiff	Bkgd	17	18	12
Devonport	N/A	<5.0	<5.0	<5.0
Dounreay	<10	6.6	7.8	11
Hartlepool	<20	<5.0	<5.0	21
Hunterston	<90	10	22	100
Sellafield	Bkgd	630	36	600
Winfrith	Bkgd	<5.0	<5.0	<5.0
Wylfa	<10	<5.0	<5.0	11

At this stage the profiling method has been shown to be a viable and reproducible alternative to baseline dose assessments.

4 Work of the NDAWG Sub-group on habit data and critical groups

The aim of this sub-group is to consider the use of habits data in assessing individual doses and in defining critical groups. The initial emphasis was on retrospective assessments (doses from routine discharges and direct radiation). In particular, the subgroup was asked to consider:

- Methods for obtaining integrated habits data around particular sites;
- What is meant by 'locally produced food' – how plausible is it for certain foods to be produced and consumed by individuals;
- Assumptions regarding where people are assumed to live and to obtain their food in dose assessments together with the combination of pathways;
- Data analysis including the relationship between the sample population and assessment of individual doses including the use of critical groups;
- The adequacy of data on occupancy, eg, general beach occupancy and time spent indoors and outdoors;
- The use of national survey data and site specific data, including how regularly site specific data should be reviewed and updated;
- Use of habits survey and dosimetric data for infants, children and adults (including pregnant women).

The sub-group has produced a position paper on the collection and use of habits data for retrospective dose assessments, which has been published as NDAWG/4/2005.

It was agreed by the NDAWG main meeting that there was a need for the Habits sub-group to continue its work and prepare a second position paper on the collection and use of habits data for prospective assessments. The need for the group to consider the use of habit data in prospective assessments originates from the outcome of the original CEDA meeting in 2000. The CEDA recommendation was that 'there should be more consistency in gathering survey data and FSA, operators and EA should co-ordinate their requirements for fieldwork. There should be more consistency in the treatment of data for constructing the aquatic and terrestrial critical groups'. At the NDAWG meeting in November 2005, prospective assessments made for Winfrith were reviewed. That review indicated that different and inconsistent approaches continue to be taken to prospective assessments, including the way habits data are being used in those assessments. The NDAWG meeting view was that too little progress has been made to achieving greater consistency of approach in prospective assessments. The aim of the Habits sub-group is, therefore, to consider the use of habits data in prospective assessments and to identify good practice and areas for improving consistency. The group proposes to review the current approaches to the use of habit data in

prospective assessments and determine the appropriateness of these approaches (taking into consideration factors such as scientific basis, rigour, transparency, realism, degree of caution). The group will consider the approach taken in related areas (eg, in radioactive solid waste management) and in other countries. We will then identify good practice, including those aspects of the use of habits data that should be adopted consistently by all organisations carrying out assessments and those aspects for which alternative approaches would be acceptable.

Based on these considerations, the following revised Terms of Reference (ToR) are proposed.

> The aim of this sub-group is to consider the use of habits data in assessing individual doses and in defining critical groups for both retrospective and prospective assessments. Following an initial emphasis on retrospective assessments, prospective assessments are now to be considered.

In particular, in the context of prospective assessments, the sub-group will consider and identify:

- The contexts in which prospective assessments are undertaken;
- The current use of local and national habits data in such assessments;
- The current use of supplementary data in such assessments;
- The types and amounts of data available;
- Locations of groups and of food production currently assumed;
- The need for the acquisition and analysis of additional data, or the processing of existing data collected for other purposes;
- Approaches taken in other countries and IAEA guidance;
- Approaches taken to identifying and defining critical groups in the context of solid radioactive waste disposal;
- The implications of the various approaches used;
- Good practice for habits data use in prospective assessments;
- Approaches that should be used, including any core/common parts that should be adopted in all assessments.

The sub-group will consider prospective assessments for both nuclear and non-nuclear (small users) sites.

5 The way forward for NDAWG

Although good progress has been made relating to the collection of habit data and its use in critical group dose assessments, further work is still required. Advice has been given for retrospective dose assessments and NDAWG has endorsed the method for estimating total doses. Further work is required for prospective assessments and in particular, the work of the Habits sub-group needs to be completed. The NDAWG Sub-group on modelling also identified various issues relating to habits (see NDAWG/2/2006) and these also need to be addressed.

Other issues that could be considered by NDAWG in the future include:

- The implications of the new recommendations of ICRP relating to the representative individual (the replacement for the critical group concept).
- A review of how the total dose methodology is working in practice and whether it is still appropriate.
- Is the situation regarding habit data for non-nuclear sites satisfactory and does more need to be done?
- Should more be done to determine distributions in habits data for the whole population, rather than just the potential critical group?

6 References

Camplin B, Grzechnik M and Smedley C (2005). Methods for Assessment of Total Dose in the Radioactivity in Food and the Environment Report. Presented to the *National Dose Assessments Working Group (NDAWG)*. Paper NDAWG/3/2005.

Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency (2005). Radioactivity in Food and the Environment, 2004. RIFE-10. Environment Agency, EHS, Food Standards Agency and SEPA, Bristol, Belfast, London and Stirling.

Grzechnik M, McTaggart K and Clyne F (2006a). Understanding Pathways of Exposure Using Site-Specific Habits Surveys, Particularly New Pathways and Methodologies. In the proceedings of the *Second European IRPA Congress on Radiation Protection*, 15-19 May 2006, Paris, France.

Grzechnik M, Camplin W, Allott R, Webbe-Wood D and Clyne F (2006b). Methods of Assessing Total Doses Integrated Across Pathways. In the proceedings of the Second European IRPA Congress on Radiation Protection, 15 – 19 May 2006, Paris, France.

Hunt GJ, Hewett CJ and Shepherd JG (1982). The identification of critical groups and its application to fish and shellfish consumers in the coastal area of the north-east Irish Sea. *Health Physics*, **43** (6), 875-889.

ICRP (1966). Recommendations of the International Commission on Radiological Protection. Pergamon Press, Oxford, (ICRP Publ (9)).

ICRP (1996). Age-dependent doses to members of the public from intake of radionuclides. *Ann ICRP*, **26** (1). Elsevier Science, Oxford, 91 pp (ICRP Publ (72)).