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Acquisition and Use of Habits Data for Prospective Assessments

NDAWG Habits Sub-group

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1. INTRODUCTION

This is the second paper produced by the Habits Subgroup of the National Dose Assessment Working Group (NDAWG). The first paper addressed the use of information on human habits in the context of retrospective assessments of radiation exposure of members of the public. This second paper correspondingly gives guidance on the use of habits data in the prospective assessment of radiation doses from routine discharges of radionuclides to the environment.

As discussed further in subsequent sections, prospective assessments are undertaken both by operators of facilities and by regulators and statutory consultees. A primary aim of this report is to inform these parties of the considerations that arise in defining habits data for use in prospective assessments. It is recognised that the information contained herein will also be of interest to other parties, including Non-Governmental Organisations (NGOs), the media and individual members of the public.

1.1 Terms of reference of the subgroup

The Terms of Reference of the Habits Subgroup were revised following completion of its first paper. The revised Terms of Reference reflect the change in emphasis of the work of the group, with a new focus on prospective assessments. These updated Terms of Reference state that the aim of the Subgroup is to consider the use of habits data in assessing individual doses and in defining critical groups for prospective assessments. Overall, the Terms of Reference require the Subgroup to consider and identify:

- 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 need for acquisition and analysis of additional data, or the processing of data collected for other purposes.

To do this the Subgroup was required to consider:

- The contexts in which prospective assessments are undertaken;
- The current use of local, national and other habits data in such assessments;
- The types and amounts of data available;
- Locations of groups and food production;
- Approaches taken in other countries and in the context of solid waste disposal;
- The implications of the various approaches.

1.2 Scope of prospective assessments

Prospective assessments are required to predict the radiological impacts of future discharges of radionuclides to the environment and of the future direct irradiation of members of the public from facilities using, storing or discharging radioactive materials. Such assessments can relate either to ongoing activities at a site or to the proposed introduction of new activities at a site. Such prospective assessments will generally relate to the next few years of operation, as there is the potential and indeed the desirability for revisiting such assessments at regular intervals to determine whether circumstances have changed, either in respect of radionuclide discharges and the external exposure regime, or in terms of factors such as land use and human habits in the vicinity of the site. It is the role of human habits in prospective assessments that is the focus of this report.

Results from prospective assessments are used to compare with dose limits for members of the public, but more often with dose constraints, since they relate to the authorization and control of future discharges and irradiation conditions from a particular facility or site. Furthermore, the results of prospective evaluations may be used in optimization studies. The role of prospective assessments in optimization means that although cautious assumptions may have to be used, excessive caution has to be avoided, as this could lead to undue expenditure of resources to reduce cautiously over-estimated doses. In selecting and documenting habits data for use in prospective assessments, there is a need to provide sufficient and appropriate information to ensure that robust optimization analyses can be conducted.

In general, the quantity of relevance in prospective assessments is annual effective dose[1] to the representative person (taken to be equivalent to the representative member of a critical group, see Appendix A). Although annual equivalent doses to skin and lens of the eye could be of relevance, in practice annual effective doses are generally more limiting relative to constraints and are of more direct application in optimization studies.

1.3 The scope of this report in determining the use of habits data in prospective assessments

This report considers the legislative and regulatory context within which prospective dose assessments are undertaken and in which habits data are used (see Appendix A). It also examines the types of habits data that are appropriate for use in a UK context, considering both site-specific and generic data (see Appendix B). This provides a basis for discussing how such data have been used in prospective assessments. Based on this review of legislative and regulatory requirements, available data and approaches to assessment that have previously been used, and various alternative approaches to prospective assessment that make use of habits data in different ways, have been identified. These alternatives have been evaluated, and recommendations are made relating to the preferred approaches and their implementation. It is emphasised that this report does not address all issues relating to prospective assessments, since it is concerned only with the role of habits data in such assessments.

Prospective assessments rely on either site-specific or generic habits data. These data are used to determine the likely locations and habits of individuals in the vicinity of a facility or site over the next few years. Thus, where site-specific habits data are to be used in a prospective assessment, there may be an additional degree of interpretation of the survey data that is not required in a retrospective assessment. A judgement may need to be made as to whether the survey data have to be modified for activities that are not occurring at the present time, or that are only occurring to a limited degree, that might be initiated or become more important over the period for which the assessment is intended to apply. This paper considers the implications of these judgements for the use of habits data in prospective assessments and compares the approaches to uses of habits data in retrospective assessments.

2. USE OF HABITS DATA IN PROSPECTIVE ASSESSMENTS

Habits data may be derived from surveys specific to the site of interest. This is generally the case for licensed nuclear sites in the UK. However, for other sites a combination of information specific to the site and generic habits data derived from UK surveys may be used. For many of the smaller sites that are authorized to release radionuclides to the environment, reliance has been placed entirely upon generic data.

The selection and use of habits data in prospective assessments must be considered in conjunction with the overall approach that is adopted for such assessments. This section provides a brief overview of the approach to prospective assessments that is adopted in the UK.

[1] Throughout this report, the term annual effective dose refers to the sum of annual effective dose from external exposure and the committed effective dose from an annual intake of radionuclides by both ingestion and inhalation for internal exposure. Sometimes, the term dose is used to signify effective dose when no ambiguity is involved.

This provides a context for discussion of how assessments are undertaken both where integrated surveys of habits related to the site of interest have been undertaken and where such integrated surveys have not been undertaken. However, in both contexts the issue is how the site-specific and generic habits data that are available are integrated into the overall prospective assessment, including consideration of the location or locations at which the habits data are taken to apply.

2.1 Overall approach to prospective assessment

In England and Wales operators are required to make radiological assessments of their discharges. These assessments are carried out using a variety of assessment methodologies. These have not been reviewed in detail. However, most assessments take into account habits of humans around the site as these affect the outcome. Nuclear site operators may use site-specific habits data, where such data are available, or rely on generic habits data. For the non-nuclear sector, generally an assessment using a generic approach to the use of habits data, such as that adopted in NRPB-W63 (McDonnell, 2004) is undertaken by the applicant.

In England and Wales, the Environment Agency (EA) may elect to make its own appraisal of the application by the operator. The appraisal will be a review of the assessment undertaken by the operator and there is an expectation that the applicant will have followed the radiological assessment principles document (EA et al, 2002). The appraisal will be supported where necessary by an independent assessment to provide further validation. If an independent assessment is undertaken, the EA follows the approach laid down in the principles document (EA et al, 2002). This requires an initial screening of doses using an agreed and published initial assessment methodology (EA, 2006)[2]. If the initial screen gives annual effective doses greater than 20 µSv, a refined assessment may be made using site-specific data where available.

For nuclear sites, if the outcome of the screening assessment gives an annual effective dose of >20 µSv, the EA will normally make a site-specific assessment. This would usually be based on the use of site-specific data for the local environment and include site-specific habits characterised from habits surveys.

For non-nuclear sites, if the outcome of the screening assessment is an annual effective dose of >20 µSv, the EA assessment assumptions are reviewed for conservatism and made more realistic where possible. In general, the first assessment assumptions that are scrutinised are those relating to the source term, which is reviewed to see if more radionuclide-specific information can be obtained for permit limits where the radionuclide is not specified, followed by dispersion in the environment, as the degree of initial dilution can be several orders of magnitude larger than the default value adopted in the initial assessment methodology. Typically, key site-specific information is sought and the assessment refined. Once the assessment has been refined and made as realistic as possible, a decision is made as to whether a site-specific assessment is required or whether additional information (typically from monitoring) needs to be acquired.

The Food Standards Agency (FSA) also adopts an initial screening approach to assessments, complemented by site-specific assessments, as appropriate.

In Scotland, the Scottish Environment Protection Agency (SEPA) carries out an appraisal of the prospective dose assessment made by the nuclear-sector operator. Additional assessments, typically made using PC CREAM (NRPB, 1998), are undertaken by SEPA if this is considered necessary. For the non-nuclear sector, generally an assessment using NRPB-W63 (McDonnell, 2004) is undertaken by the applicant. For off-shore installations, assessments are made by the operators using various methodologies based on simple modelling assumptions, fish concentration factors (IAEA, 2004) and appropriate dose coefficients for humans (ICRP, 1996).

[2] All references cited in the main text of this report or in the appendices are listed in Section 5.

For both non-nuclear sites and off-shore installations, SEPA carries out independent checks on the computational procedures and the assumptions included in the submitted assessments. For each of the three sectors considered in Scotland, an initial screening criterion of 20 μSv per year is used. If the screening assessment indicates an annual effective dose in excess of this threshold value, a detailed site-specific assessment would be necessary.

2.2 Habits data and their application in screening assessments in England and Wales

As noted in Section 2.1, an initial screening approach is used by both the EA and the FSA to make conservative prospective assessments for the main types of releases from both nuclear and non-nuclear sites. However, these initial screening assessments differ in various aspects; including their approaches to the definition of habits (see Appendix C). Similarities and differences between these two approaches to screening assessment and NRPB-W63 are summarised in Table 2.1. In Scotland, a similar screening approach to that adopted by the EA is used by SEPA.

The EA treatment of habits in its screening analyses is to use UK generic data and the worst-case habits across all exposure pathways for the worst-case age group (including the foetus). This is simple and robust but very conservative. The FSA adopts the so called “top two” approach (which is explained in chapter 3) to selecting habits in its initial assessment. This approach also draws on UK generic data, and is less conservative but more complex than the EA approach. It considers only adults. The NRPB-W63 approach uses worse-case habits and considers adults only.

Table 2.1: Comparison between the FSA and EA initial assessment methodologies and the approach in NRPB-W63 (Note: *Although the NRPB-W63 method estimates doses to adults only, some guidance is provided on how to take account of doses to children and infants where these may be important)

Assumption	FSA	EA	W-63
Discharges to atmosphere			
Where people live	100 m	100 m	100 m
Where arable crops are produced	100 m	500 m	500 m
Where animal products are produced	100 m	500 m	1000 m
Age groups	Adult	Foetus, infant, child, adult	Adult*
Habits	Top two from UK generic data	97.5^{th} percentile from UK generic data	97.5^{th} percentile from UK generic data
Discharges to the marine environment			
Where marine foods are obtained	N/A	Local compartment that takes discharge	N/A
Where beach occupancy occurs	N/A	Local compartment that takes discharge	N/A
Age groups	N/A	Foetus, infant, child, adult	N/A
Habits	N/A	Data from NRPB W-41 based on habits at specific locations	N/A
Discharges to river			
Where fish are obtained	First river section below outfall	First river section below outfall	First river section below outfall
Where drinking water is obtained	N/A	First river section below outfall	First river section below outfall
Where water for irrigation is obtained	First river section below outfall	First river section below outfall	N/A
Age groups	Adult	Foetus, infant, child, adult	Adult*
Habits	Top two from UK generic data	Data from NRPB W-41 based on habits from specific locations	97.5^{th} percentile

2.3 Habits data and their application in site-specific assessments by the Environment Agency and the Food Standards Agency

In current dose assessments, sites are distinguished into two categories. These comprise those sites for which the initial screening assessment gives an annual effective dose of <20 μSv and those for which the annual effective dose is >20 μSv. In the latter case, a site-specific assessment may be made, in particular for nuclear sites. Under certain circumstances, site-specific assessments may be made for some sites for which the annual effective dose from the screening assessment is <20 μSv (high profile or contentious sites or sites where there is local concern, etc). Such assessments will normally require site-specific modelling, identification of locations were people live, work, and carry out recreational activities, and information on current and potential future food production locations and types and site-specific habits data.

In England and Wales, since 2002, the EA, FSA and the Health and Safety Executive (HSE) have been cooperating to obtain integrated habits data around nuclear sites. These are obtained by carrying out surveys of the habits of people that might lead to exposure to either direct radiation, or to discharges to the environment and/or to consumption of food from areas local to the site and containing radionuclides derived from the site. Prior to 2002, only partially integrated habits information was gathered around nuclear sites. Also, some sites do not have any site-specific habits data.

In England and Wales, the prospective dose assessment process has been triggered where periodic major reviews of nuclear site authorisations have led to substantial variations in the conditions attached to those authorisations. Typically, the site regulator initiates a prospective assessment if a substantial variation is warranted. A specification is prepared within the EA describing what is to be considered in the assessment and agreeing the outcomes. The specification will include, where appropriate, an identification and consideration of local concerns to which the regulator may have been alerted.

The assessment is then made against the specification, normally assuming discharges at current limits and for a set of proposed future limits (that may be lower or higher than the current limits). Allowance is made for past and future discharges and doses from contiguous or nearby sites.

Site-specific habits data are of greatest value in assessments where the standard of the assessment made needs to be demonstrated to be particularly high to retain the confidence of groups of the population living or working near the site. This requirement is normally around the larger nuclear sites, where discharges are ongoing and some of the radionuclides in the discharges persist in the environment for many years. The requirement may arise for a variety of reasons, including the magnitude of the assessed doses, assessed doses that arose from past discharges, or a more general concern that the activities taking place at the site have the potential to cause relatively high radiological impacts.

The outputs of site-specific habits surveys are used in a number of ways by the regulator and by the operators of the sites. The main uses are in retrospective assessments of doses to the public, prospective assessments of the radiological impacts of future discharges, during authorisation reviews and in defining and revising monitoring programmes around sites.

Habits surveys have been used in prospective assessments historically and the prospective assessment principles document (EA et al, 2002) implies that use of site-specific habits surveys continues to be appropriate. Principle 8 states that “The realistic habits adopted for the critical group should be those which are actually observed year-on-year at the site, or at similar sites elsewhere, either currently or in the recent past.”

Details of approaches adopted by the EA and FSA in carrying out site-specific assessments are given in Appendix C. A summary of the assumptions made by the EA and FSA is provided in Table 2.2.

Table 2.2: Assumptions Made by the FSA and EA in Site-specific Assessments around Nuclear Sites

Factor	FSA Practice	EA Practice
Assumed location for inhalation and exposure to plume.	The existing habitation (including permanent caravan sites and houseboats) at which the highest doses from these pathways would be obtained.	Nearest occupied habitation and/or place of employment (if unrelated to the discharging site). The appropriate habit profiles that imply living within 1 km of the site are applied.
Location of external exposures from aquatic discharges.	Locations identified from the relevant habits surveys at which the appropriate habits have been observed and reported, eg, use of beaches, bait digging, wildfowling etc. These locations may, in some circumstances, be a significant distance from the site (eg, houseboat dwellers in the Ribble Estuary exposed as a result of discharges from Sellafield).	Local marine compartment into which discharges are assumed. Local compartments are defined in EUR 15760EN (RP-72) for some nuclear sites. Where profiles are available, the appropriate profiles which imply high beach occupancy are applied. Where profiles are not available, assumptions of high occupancy in the nearest dwellings are made based on generic UK habits data.
Location for the production of terrestrial foods.	The location where, in terms of dose received by consumers, food contamination from gaseous discharges is predicted to be greatest. The location of food production must be at least 100 metres from the site fence to allow sufficient area ($\approx$1000 m^2) to grow a full range of crops and raise livestock. The land selected should be suitable for agricultural production, even if the land is not currently used as such; eg, it may presently be recreational ground or fallow land. Where the reference location cannot support the production of certain food groups another location that can support the production of these food groups is identified. Similarly, ground that may be too poor for arable use could be used for livestock, eg, grazing sheep. Land that is built upon is considered unsuitable for agricultural production.	For farmland: If farmland is extensive and approaches the site fence, then a representative point is chosen, normally assumed to be 500 m from site fence. If farmland is located well away from the site, land around the site is reviewed for potential agricultural use. Waste land, nature reserves, parks, forests, plantations and golf courses are not considered to be potential agricultural land. Fallow land would be considered to be potential agricultural land. If there is no land near the site considered to have potential for agricultural use, the nearest agricultural land is considered. Food production in line with what is produced within 10 km of the site is assumed on the nearest land. For example if only livestock are found in the area, then cows, milk and sheep are considered. If only arable (not cereals) then only arable assumed. If it is unclear if there is sufficient land, a cross check is made against yield per unit area of each food type. Allotments: Foods produced on allotments are assumed to be produced at the nearest allotment or nearest houses if there is evidence of adequate gardens. Food types are fruit, green vegetable and root vegetables.

Table 2.2 (Continued): Assumptions Made by the FSA and EA in Site-specific Assessments around Nuclear Sites

Factor	FSA Practice	EA Practice
Location for the production of aquatic foods	Marine foods are assumed to be sourced from the fisheries area closest to the point of discharge. Calculations for other areas are sometimes also carried out, eg, other locations in the Irish Sea are also considered for Sellafield discharges.	Marine foods are considered to be sourced from the local marine compartment into which discharges are modelled. Local compartments are defined in EUR 15760EN (RP-72) for some nuclear sites. Account is taken of information from habits surveys if they suggest that certain marine foods are not available or occur in inadequate numbers. Consideration is given to any long standing food bans in place.
Habits data used for consumption and other exposure rates where site specific data are available.	The modified profile method is used. Judgement is applied to ensure that the combination of occupancies does not result in a lifestyle that is not reasonably foreseeable. Foods are assumed to sourced and occupancies occur at the locations identified above.	Unmodified profiles have been used where available and as appropriate. Habits profiles are applied at the nearest habitations.
Habits assumed for direct shine where site specific habits data are available	Direct shine doses are not added to the doses assessed for other pathways due to it not being known what assumptions have been made with regard to locations, occupancy and any dependence of direct shine doses on site operations.	Direct shine doses to the so called shine critical group are added into the assessment of doses from discharges for those profiles where living local to the site is implied. This can be a conservative assumption, because it is not known what assumptions were made in the derivation of the direct shine doses.
Habits data used where site-specific data are not available	Generic UK habits data are used and the top two pathways are established for gaseous discharges and terrestrial exposure. Generalised habits data for marine-related consumption are used.	Generic UK habits data from the National Food Survey are used and the top two pathways are established for gaseous discharges and terrestrial exposure. Generalised habits data from site-specific habits surveys are used for marine-related consumption (see Smith and Jones, 2003).

2.4 Other approaches to the use of habits data in prospective assessments

Limited information is available as to the use of habits data in prospective assessments in other countries with nuclear sites where discharges to the environment are made. More extensive information is available on the use of habits data in assessments relating to solid radioactive waste disposal, but these data are of limited relevance in the present context. Information on both of these areas is summarized in Appendix D.

In the past other approaches to use of habit data in prospective assessment were used by the FSA. The approaches were designed to be similar to other assessments made of food safety for non-radioactive contaminants in the environment. These involved use of site-specific habits data to generate assessments of dose on an individual basis before establishing the critical group based on the individual doses calculated.

Similarities and differences between the approaches used by the EA and FSA are described in Appendix C. More details of the methods that have been considered and applied, together with illustrative examples, are given in Appendix E and Appendix F.

3. REVIEW OF THE AVAILABLE APPROACHES FOR USE OF HABITS DATA

3.1 Main approaches currently or recently used

Based on the review provided in previous sections and in appendices to this report, seven broad approaches to the use of habits data in site-specific prospective assessments have been identified. These are:

- The screening approach used by the EA;
- The generic approach set out in NRPB W-63 (McDonnell, 2004);
- Top two using generic habits data - consumption rates or occupancies are identified for the top two contributing pathways at high percentile values and the rest set to average;
- Top two using local or site-specific habits data;
- Habits profiles;
- Adjusted habits profiling (taking into account the potential for changes in consumption rates or occupancies over the assessment period);
- Two individual-based methods using data from either a single site-specific survey or data aggregated over several such surveys.

The EA screening approach is included as an example of the screening approaches adopted by the various regulatory authorities (EA, FSA and SEPA). NRPB-W63 is included as a representative, and widely used, generic assessment approach.

The characteristics of approaches 3 to 7 are summarised in Table 3.1. The two screening-type approaches (1 and 2) make use of generic habits data and a variety of simple modelling assumptions.

Table 3.1: Characteristics of Approaches to the Use of Habits Data

Approach	Description
Top two with generic data	Is used where no site-specific habits data are available but a detailed site-specific assessment is still required. For terrestrial foods contaminated by atmospheric releases the assessment generally uses generic data for the UK (NRPB-W41) as the basis. The assessment is initially made with all the relevant habits data (mainly food intakes) set to "critical levels" (95th or 97.5th percentile). The assessment results identify the two habits that give rise to the highest doses ("top two"). These habits are retained at 'critical levels', whereas the other habits are reduced to 50th percentile levels and the assessment is repeated. This adjustment to the assessment ensures that the calorific intake is not unreasonably high. The top two habits are radionuclide specific and vary for different source terms or changes in relative radionuclide contributions to the source. For liquid discharges an assessment may be made using top two approach or may use generalised habit data representative of coastal locations and river locations taken from NRPB-W41, as these data indicate higher intakes. The calculation is relatively simple. The approach works well for multiple age groups because there are sufficient national data for children and infants. National data are for all foods consumed and not just locally produced foods. National data may underestimate seafood consumption by coastal communities. Works well when considering individual modes of release (release to atmosphere or release to marine environment), but is more difficult to apply when integrating an assessment across multiple release modes.
Top two with local habits data	As top two generic but makes use of site-specific habits data. Similar to generic top two, except does not work so well for children and infants, because there are insufficient data to establish reliable high percentiles. Often fall back to the generic top two approach for non-adults or use scaling factors derived from national data to derive rates for children and infants.

Table 3.1 (Continued): Characteristics of Approaches to the Use of Habits Data

Approach	Description
Profile	The habits survey data are obtained and tabulated by observation number and pathway. For the first pathway, the observations are ordered by descending rate of this pathway. Observations for individuals who have consumption rates between the maximum and one third of the maximum are identified and retained for the next step of the analysis. For this subset of observations, the mean rates for all pathways are calculated. These mean rates are adopted for the group associated with the first pathway, referred to as the pathway 1 profile, eg, if pathway 1 was fish consumption, this would be the fish profile. The process is then repeated for each of the other pathways to give as many profiles as there are pathways. The dose for each profile can then be calculated and the values compared. Each profile is homogeneous with respect to the habits. The approach works well for multiple release modes and is a relatively straightforward calculation. Doses in each profile may appear inconsistent if habits data used to define a habits profile are sparse. There are rarely enough habits data for children and infants to construct profiles. In such cases, scaling of adult profiles using UK generic data is carried out.
Adjusted profile	As profile method, but some adjustments made to add conservatism and future proofing. Adjustment involves rounding (upwards) of rates and adjustment of rates for non-food pathways to reflect a lifestyle that involves high occupancy near the site and (if appropriate) locations where exposure to aquatic discharges may be received.
Individual single survey	Site-specific habits data for each individual person are used and an assessment is made for each person, but without taking into account their actual location. Doses are sorted and selection is made from the top end of the assessed doses (95^{th} percentile or 97.5^{th} percentile). The approach works well for multiple release modes if habits data are integrated, but is a complex calculation. Sparse amounts of data for children and infants. Data are created by scaling adult data for food pathways by factors derived from national surveys.
Individual multi-survey	As individual single survey, but combines habits survey results from other similar sites to provide a wider range of possible habits combinations and to account for the possibility of an individual with habits more extreme than those observed close to the site, but observed elsewhere, moving into the area.

3.2 Evaluation of the approaches

An assessment of the various approaches was made for each of these options. This was done by identification of a set of attributes that were considered important and scoring each method against each. The attributes chosen were transparency, homogeneity of habits, realism, robustness, defensibility, and degree to which the approach is future proof.

In the context of these various attributes, **transparency** relates to the ease with which the approach can be understood, and the degree to which there is a straightforward and readily perceived relationship between the habits data used and the results obtained.

Another way of viewing this is whether the implications of a change in habits on the results of the assessment can be immediately estimated either qualitatively (eg, whether a change in the results will occur and the direction of that change) or semi-quantitatively.

Homogeneity of habits addresses the issue of whether the approach ensures that the critical group adopted for assessment purposes is reasonably homogeneous with respect to habits and behaviour. This relates to the issue of transparency, as the change in radiological impact for a specific change in habits will be more difficult to estimate for a group with a range of habits than for a group with specific, well-defined habits.

Realism addresses the issue of whether the habits of the group are closely related to what is observed at the present day, or what might reasonably be expected to be observed over the period for which a prospective assessment might be carried out (typically about 5 years).

Conversely, **robustness** relates to the issue of whether the results of the assessment will remain broadly valid in the face of a range of changes in habits that could plausibly occur, but are not necessarily likely to occur over the period for which a prospective assessment might be carried out.

Defensibility relates to whether the approach can be justified to interested parties. It is related to transparency, in that a defensible approach would be expected to be internally coherent and conform to principles and assumptions commonly employed in other areas. Defensibility also includes the more general requirement that the approach adopted should be acceptable to a reasonable person.

The degree to which an approach is **future proof** is closely related to issues of robustness, in that an assessment approach that gives results that are strongly affected by reasonable changes in habits will not be future proof. However, it is a more broadly based consideration, as it also takes into account whether an authorisation would be significantly affected by changes in the environment as well as changes in habits. Overall, in evaluating the degree to which an approach is future proof, consideration has to be given to the current characteristics of the locality and also to reasonably foreseeable changes on a timescale of a few years that may lead to habits changes that could increase assessed doses. For example, although a food may not be grown currently in the locality, the fact that it could be produced with minimal changes in land use means that it should not be excluded from consideration. Similar considerations apply to houses which may be currently unoccupied. It is likely that the approaches adopted where site-specific habit data are not available are very cautious, and, therefore, strongly future proof, particularly in those contexts in which a screening approach is used.

Ease of application is self explanatory, but is of considerable importance to small users, who may have only limited resource and experience with undertaking radiological impact assessments.

Compliance with Principles relates to the degree to which the method complies with EA et al (2002). The basis of this scoring is set out in Appendix G. Principles 7, 10, 11 and 12 are not directly applicable for habits and were not evaluated against the habits methods. Principles 1, 2, 3 and 5 are relatively precise and straightforward to consider and assess.

Principles 4, 6, 8 and 9 all make reference to degrees of future proofing, with a requirement to take into account current observations and future expectations around a site. Principle 8 calls for the use of site-specific habits data in this process. Future proofing requires judgement and therefore cannot be undertaken objectively or necessarily consistently between sites. The methods that make use of site-specific data can typically take into account the current observation requirements well and objectively. However the future proofing element is subjective and either requires adaptation of the observed habits to fit a view of the future or the application of generic cautious data that are not specific to the site. These principles are not easy to meet objectively with any of the methods.

From the above discussion, it should be clear that the various criteria selected are not independent of each other. However, they are considered to be the main dimensions over which options can reasonably be compared. Also, it is not immediately obvious what relative weight each of the criteria should be given. In the analysis presented below, the reference case weights all the criteria equally, but sensitivity studies have also been undertaken in which the weights assigned differ between the criteria.

Each of the options was rated against the various criteria on a scale ranging from 1 to 5, where 1 represented very poor performance and 5 represented very good performance. In this analysis, the 'top two' option was distinguished into two variants. In the first of these, the evaluation was based on generic data (which may be all that are available for some sites) and in the second variant it was assumed that data are available from a local habits survey. A neutral performance scored 3. Results of this evaluation are presented in Table 3.2.

Table 3.2: Scoring of Alternative Options (*Method applicable only where local habits data are available)

Criterion	Approach							
	EA Screen	NRPB W-63	Top Two: Generic Data	Top Two: Local Habits Survey	Profile	Adjusted Profile	Individual: Single Survey	Individual: Multi-Survey
Transparency	5	5	4	3	4	3	2	1
Homogeneity	1	2	3	3	5	5	2	2
Realism	1	2	2	3	4	3	5	3
Robustness	3	3	3	2	5	5	4	5
Defensibility	2	2	3	3	4	3	5	4
Future Proof	5	5	5	3	3	4	3	4
Ease of Application	5	4	3	3*	2*	2*	1*	1*
Compliance with Principles	2	2	2	4	4	5	4	4

The ranges of scores for each attribute are readily understood. Transparency is greatest for the top two method using generic data and the profiling method because the habits data used can be readily tracked to their origin (assuming that the supporting habits data are published in a readily available source that can be referenced when the method is used), which is not the case for the individual survey based approaches. The profiles-based methods score high on homogeneity of the exposed group, as these methods were designed explicitly to achieve this end. In contrast, the individual-survey based approaches score low, as the habits within the most exposed subgroup are not constrained and can vary widely. Realism is high for the individual single survey because the results of the assessment can be directly related to habits data for particular individuals. Conversely, it is low for the top two generic data approach, as the data used are not even specific to the site under consideration. Robustness is high for the profiling methods, because these take local data and map them into profiles that would generally not be significantly modified by inclusion of data for a limited additional number of individuals. The multi-survey approach also scores highly because of the large number of individuals on which the habits data are based. Conversely, the top two local habits survey scores low, because inclusion of a single extra individual could significantly change the habits data adopted for a specific key pathway. Defensibility is highest for the individual single survey, as this relies directly on locally relevant data. Conversely, defensibility is lowest for approaches relying on generic data or on data that have been subject to significant manipulation. Future proofing is high when generic data are used and low when the reliance is directly upon snapshot results obtained in a single survey. Ease of application is highest for generic screening methods and lowest where individual survey results have to be subject to detailed manipulation. Compliance with EA et al (2002) is a more complex, multi-dimensional issue and is addressed in Appendix G.

Results of the reference case analysis are shown in Table 3.3. Note that the sum of the weights is normalised to 1.0. This facilitates comparisons between the overall scores for different weighting schemes.

Table 3.3: Results for the Reference Case

Criterion	Approach									
	EA Screen	NRPB W-63	Top Two: Generic Data	Top Two: Local Habits Survey	Profile	Adjusted Profile	Individual: Single Survey	Individual: Multi-Survey	Weight	Normalised Weight
Transparency	5	5	4	3	4	3	2	1	1	0.125
Homogeneity	1	2	3	3	5	5	2	2	1	0.125
Realism	1	2	2	3	4	3	5	3	1	0.125
Robustness	3	3	3	2	5	5	4	5	1	0.125
Defensibility	2	2	3	3	4	3	5	4	1	0.125
Future Proof	5	5	5	3	3	4	3	4	1	0.125
Ease of Application	5	4	3	3	2	2	1	1	1	0.125
Compliance with Principles	2	2	2	4	4	5	4	4	1	0.125
Score	3.000	3.125	3.125	3.000	3.875	3.750	3.250	3.000	8	

On this basis, the two profiling based methods are preferred because of neutral to good scores on all criteria, except for ease of application. The top two method using generic data gets a rather lower score because of a perceived lack of realism, whereas the top two method using local habits survey data lacks robustness. The individual-based methods receive lower scores than the profiling methods because of a lack of transparency and homogeneity, and because of a lack of ease of application. The EA screening and W63 approaches lack homogeneity and realism.

However, it should be noted that only the EA screening, W63 and top two with generic data approaches are applicable in the absence of local habits survey data.

In a sensitivity study, the un-normalised weight for each criterion was increased from 1 to 3 or decreased from 1 to 0.3 in turn. All other un-normalised weights were kept at 1.0. Of course, the normalised weights changed in consequence, as the sum of the normalised weights was required to be 1.0. Results of this sensitivity analysis are shown in Table 3.4.

Table 3.4: Results of Single-parameter Sensitivity Study

Sensitivity Change	EA Screen	NRPB W-63	Top Two: Generic Data	Top Two: Local Habits Survey	Profile	Adjusted Profile	Individual: Single Survey	Individual: Multi-Survey
Transparency = 3.0	3.400	3.500	3.300	3.000	**3.900**	3.600	3.000	2.600
Transparency = 0.3	2.808	2.945	3.041	3.000	**3.863**	3.822	3.370	3.192
Homogeneity = 3.0	2.600	2.900	3.100	3.000	**4.100**	4.000	3.000	2.800
Homogeneity = 0.3	3.192	3.233	3.137	3.000	**3.767**	3.630	3.370	3.096
Realism = 3.0	2.600	2.900	2.900	3.000	**3.900**	3.600	3.600	3.000
Realism = 0.3	3.192	3.233	3.233	3.000	**3.863**	3.822	3.082	3.000
Robustness = 3.0	3.000	3.100	3.100	2.800	**4.100**	4.000	3.400	3.400
Robustness = 0.3	3.000	3.137	3.137	3.096	**3.767**	3.630	3.178	2.808
Defensibility = 3.0	2.800	2.900	3.100	3.000	**3.900**	3.600	3.600	3.200
Defensibility = 0.3	3.096	3.233	3.137	3.000	**3.863**	3.822	3.082	2.904
Future Proof = 3.0	3.400	3.500	3.500	3.000	3.700	**3.800**	3.200	3.200
Future Proof = 0.3	2.808	2.945	2.945	3.000	**3.959**	3.726	3.274	2.904
Ease of Application = 3.0	3.400	3.300	3.100	3.000	**3.500**	3.400	2.800	2.600
Ease of Application = 0.3	2.808	3.041	3.137	3.000	**4.055**	3.918	3.466	3.192
Compliance with Principles = 3.0	2.800	2.900	2.900	3.200	3.900	**4.000**	3.400	3.200
Compliance with Principles = 0.3	3.096	3.233	3.233	2.904	**3.863**	3.630	3.178	2.904

In each case, the preferred option is shown in bold. This demonstrates the general robustness of the preference for profiling. If future proofing or compliance with principles is given high weight then adjusted profiling is preferred over unadjusted profiling.

Overall, where site-specific habits data are available, unadjusted profiling is the preferred option. However, if such data are not available, one of the first three methods has to be adopted. Based on the reference case results (Table 3.3) and the overall performance in sensitivity studies (Table 3.4), the top two method with generic data and the NRPB-W63 approach are of comparable quality.

3.3 Comparison with retrospective assessment evaluation

The various criteria have been developed in the context of prospective assessments. They were also compared with the criteria previously used to assess the most appropriate approach for retrospective assessments (see Appendix H). Several of the attributes are similar and relevant to both types of assessment. In retrospective assessments there are broadly similar requirements for transparency, homogeneity, realism and defensibility. The differences are that there is no direct equivalent of robustness for retrospective assessments and there is no requirement to consider the degree to which the assessment is future proof. Retrospective assessments have also previously been evaluated against a criterion of reproducibility, ie, can the approach be easily used for an independent reassessment – which is similar to the criterion of transparency - allied with a requirement for comprehensive reporting of any assessment, irrespective of the approach adopted.

Overall, the approaches recommended from the evaluation of retrospective and prospective assessments are the same. This is advantageous, since issues of inconsistency between the approaches do not then arise.

3.4 Summary

The various options for the use of habits data in prospective assessments, both for cases in which substantial amounts of site-specific data are available and for cases in which reliance has to be placed primarily on generic data.

Where site-specific habits data are available, use of a profiling method is strongly preferred. Unadjusted profiling scores reasonably well across all criteria and is generally the method of choice. However, a strong emphasis on future proofing or compliance with EA et al (2002) would marginally favour adjusted profiling relative to unadjusted profiling. Profiling methods are in reasonable accordance with the principles for prospective assessments. Some questions can be raised as to the degree to which such methods comply with the requirement of future proofing (Principle 8), but it should be recognised that this requirement was included mainly to ensure that some consideration was given to potential future developments rather than as a requirement for detailed forecasting of such developments. Although adjusted profiling is marginally favoured if there is a strong emphasis on future proofing, it raises difficult issues as to what basis should be adopted for adjustment and the justification that should be provided for any such adjustments. Therefore, although adjusted profiling could be seen as a proportionate approach to future proofing, it is considered that the difficulties with making this approach transparent outweigh the marginal advantages in future proofing that it provides. It is noted that the repetition of habits surveys every few years at some sites gives the possibility of applying profiling to the results of multiple habits surveys and that this could give a greater degree of future proofing than using results from a single survey. This is a matter that would need to be considered on a case-by-case basis.

Even where site-specific habits data are available, those data will be primarily for adults. The limited amount of data available for children and infants means that their habits will typically be obtained from those of adults using scaling factors based, at least in part, on generic data. Nevertheless, the data derived as applicable to children and infants do include a significant site-specific element and are therefore described as site specific.

Where site-specific habits data are not available, there is not a very strong distinction between the three methods used to illustrate the approaches that are available. However, the top two approach using generic data and the NRPB W-63 approach are marginally preferred. The NRPB-W63 approach is only directly applicable to adults, though some guidance is given on how account may be taken of children and infants where these may be important. Overall, the top two approach is recommended for general application. Where, assessed annual effective doses are less than 20 µSv, application of this approach alone is adequate. However, if assessed annual effective doses are larger than 20 µSv, it would be prudent to use a second method, such as NRPB-W63, to provide a complementary assessment. In addition, for annual effective doses in excess of 20 µSv, there would be a requirement to refine the assessment, as discussed in Section 4.

A further consideration that arises is the nature of the generic data that should be adopted where site-specific habits data are not available. One possibility that has not been considered previously would be to generate generic habits profiles from national UK data. These could be generated using methods similar to those applied in generating the profiles adopted in the RIFE reports, but applied to national survey data. Because of the way the national data are collected, such national profiles would tend to be more homogeneous than site-specific profiles, with a reduced emphasis on specific foods that are mainly consumed in specific local contexts, eg, by members of coastal communities, and with more crossover, due to the consumption of a greater number of food groups. Profiling complements the method used to collect site-specific data around nuclear sites, where habits and food consumption data are collected that are relevant to the specific local context. Applied to generic national data, it is not clear that profiling would offer any advantages over the top two approach. Indeed, the outputs are likely to be more complex and imply undue precision. Further exploration of this approach may be required to confirm whether the outputs would be usable or appropriate.

It is emphasised that an assessment that an annual effective dose of 20 µSv will be exceeded, even after refinement of the assessment, using a suitable tool such NRPB-W63 or PC-CREAM, does not imply that site-specific habits data should necessarily be collected. In general, the assessed dose will still include a number of cautious assumptions, so the need to determine site-specific habits is more closely tied to considerations of whether the annual effective dose could approach 300 µSv, or whether there are specific aspects of the site that give rise to regulatory or public concerns that should be addressed through the collection of local information, eg, relating to habits, land uses and potential future changes in these characteristics.

4. RECOMMENDED APPROACHES AND THEIR IMPLEMENTATION IN PROSPECTIVE RADIOLOGICAL ASSESSMENTS

The recommended approach to carrying out prospective radiological assessments for routine discharges of radionuclides to the environment is set out in a series of NDAWG Guidance notes and associated reports (see www.ndawg.org). This follows the recommendations made in the 'Principles for the assessment of prospective public doses' (EA et al, 2002), which gives a set of principles and provides guidance on the assessment of public doses for the purpose of authorising discharges of radioactive waste to the environment. A staged approach is recommended and, as discussed in Section 2, the approaches used in the UK use two main steps. First, there is a screening or initial assessment, although this can be omitted if wider policy considerations mean that a full assessment will be carried out anyway. Second, if required, the assessment is refined.

In this report, the screening approaches used by EA, FSA and in NRPB-W63 (McDonnell, 2004) have been compared and some key differences in the ways that habits data are used have been identified. The EA approach adopts a more conservative and simpler approach to its use of habits data in its screening assessment than does the FSA. However, the FSA makes some more conservative assumptions about land use and food production around a site. This reflects the different purposes of the assessments carried out by the two organisations; the EA is concerned with the overall authorisation process, whereas the FSA has a responsibility to ensure that doses to consumers of local foods remain acceptable.

The EA and FSA are working to harmonise their approaches to dose assessments for authorisations, in particular with respect to key input data.

The NRPB-W63 approach is only directly applicable to adults, though some guidance is given on how account may be taken of children and infants where these may be important, and, without site-specific data, there is limited scope to refine the assessment, allow for site-specific habits or allow for future changes in land use. Nevertheless, overall it scores comparably with the top two approach using generic data and can be used in combination with other approaches to provide a broader basis for evaluation of the radiological impacts of discharges in prospective assessments, eg, by taking uncertainties into account. This may be particularly useful in cases in which assessed doses are high and site-specific data are limited or unavailable.

For the refined assessment step, consideration has been given to five options that are available for use of site-specific habits data, where such data are available, and three options that can be applied where site-specific data are not available. The approach that emerged as the best from the evaluation of options for which site-specific habits data are available was the unadjusted habits profile. The preferred approach where no site-specific habits data are available is the top two method using generic data, complemented by the NRPB-W63 approach, as appropriate (see above).

Based on the information summarised in this report the NDAWG Habits Sub-group make the following comments and recommendations.

Where a high standard of assessment is required, use of site-specific habits data, where they exist, can be an important contribution to building the assessment standard. Good practice would be that an assessment is made using a screening assessment to identify the main pathways and then the assessment refined using the site-specific data. The habits data should be profiled and used un-adjusted. This has the advantage that doses from different release modes can readily and consistently aggregated.

Where a high standard of assessment is required and no site-specific habits data are available, recourse should be made to generic habits data. Currently the top two approach using generic data can be adopted following on from a screening assessment. With the top two approach, care has to be taken in combining doses from different modes of discharge, as there is the potential for introducing inconsistencies and inappropriate conservatisms into the assessment.

Site-specific habits data surveys are currently carried out for many nuclear sites, primarily in relation to the assessment of retrospective doses as published in the RIFE series of reports. However, there are a number of factors that will influence whether site-specific habits surveys will be carried out in future around both existing and potential new sites, so it cannot be assumed that up-to-date, site-specific data will necessarily be available.[3]

Where the standard of assessment required is less, including around a wide range of non-nuclear sites that may discharge radionuclides into the environment, there is less need for detailed habits data. For sites where site-specific habits surveys have not been carried out, such surveys should only be necessary if doses estimated using generic data approach the recommended source-related dose constraint of 300 μSv y^{-1} (see Appendix A) and where there

[3] The use of unadjusted profiles is most readily justified at Sellafield, where habits survey data are updated annually, so future proofing requirements are minimal. However, this gives rise to the issue of whether the habits data used should be based only on the most recent survey or whether a moving average from several surveys should be used in order to reduce the significance of short-term variations in habits or their reporting. This is a matter that could be usefully investigated in the future, when sufficient survey data are available, by determining the difference in assessment results obtained from application of the alternative approaches.

are indications that such surveys would be worthwhile. Otherwise the top two method is likely to be acceptable.

Consideration should be given to strengthening the habits element of the approach used by the non-nuclear community. Whatever approach is adopted should be easy to use, proportionate to the context, and ensure that all relevant age groups are adequately protected.

Some principles in the principles document are difficult to assess objectively because they require subjective judgement as to where and to what degree future proofing of the assessment is required. When the principles document is updated, a review and clarification of some of the principles will need to be undertaken.

The Sub-group notes that the generic UK data were collected some time ago and, given the dependence on them for assessments where site-specific data are not available, considers that the data should be reviewed to determine if a comprehensive re-evaluation is required. The food consumption habits data are based on old surveys and need to be updated. The FSA has begun the review process for adult and child data, with the intention of completing the work by April 2009. Currently, the FSA does not have the source data to do the same for infants. A survey of the consumption rates of infants is planned to commence in 2009. Once data from this survey are available, the FSA will revise the generic infant consumption rates.

Generic habits data, notably food intakes, often use the 97.5th percentile of the distribution for the intake by the critical group (representative person). Recent recommendations by ICRP (ICRP, 2006) indicate that it is appropriate to use the 95th percentile. This possible change needs to be addressed in the update of the recommended food intake data.

The development of habits profiles from generic UK habits data has been considered. However it is not clear that profiling would offer any advantages over the top two approach. Further exploration of the profiling approach may be required to confirm whether the outputs would be usable or appropriate.

The EA and FSA should continue to explore differences between their prospective dose assessment methodologies with the aim of reconciling them where possible. It is recognised that this is constrained by the different applications of the dose assessments carried out EA and FSA, which may lead to differences in approach and hence assessed doses (see Section 2.2).

The Sub-group notes that other factors may be responsible for inconsistencies in the outcome of site-specific radiological assessments, these being - stack height for atmospheric releases, receptor locations and assumptions about radionuclides in the source term. The Sub-group supports the standardisation of these factors for each site as part of the assessment approach.

It is important that key aspects of the prospective dose assessment are fully documented, so that the assessment is transparent and can be reproduced by others (see NDAWG Guidance Note 1). In particular, the habits adopted should be described in the documentation together with the sources of the habits data and any assumptions on how they are used in the assessment.

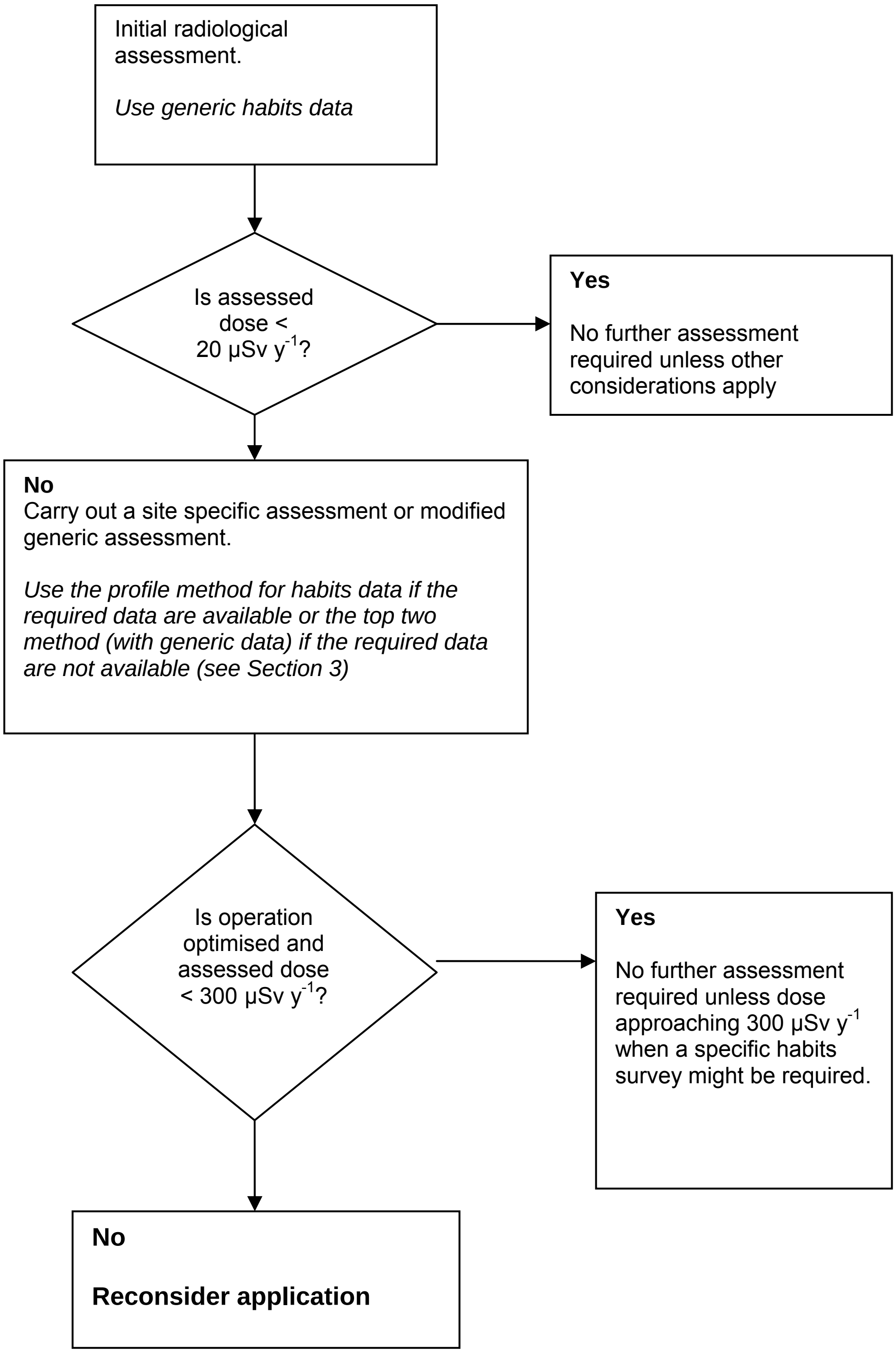
In carrying out dose assessments for authorisation purposes, habits and other data are required for infants (one year old), children (10 years old) and for adults. In a few cases, the foetus/breast fed infant will also need to be considered, but, in such cases, adult habits data apply to the mother. Generic data are particularly important for infants and children, as the detailed site-specific habits surveys carried out do not usually have sufficient data for these age groups. Improved habits data are required for infants and children.

In some situations, it will be necessary to consider unusual as well as standard exposure pathways and further guidance on this is given in the relevant NDAWG guidance note and reports (see www.ndawg.org).

For discharges to sewage works, doses to workers at the plant can be relatively important and depend to a large extent on the time spent in different parts of the plant and on the presence of hard gamma emitters in the discharge, since external irradiation is typically the primary route of exposure. There are currently few data on the habits of sewage workers whilst at work, other than limited information acquired during surveys around a few nuclear sites where discharges occur to sewer (see Appendix B2.4). Data currently used are generic and based on assumptions about working patterns. It would be helpful if further data were collected for this exposure route.

The recommended use of habits data within the overall prospective assessment approach is summarised in Figure 4.1.

Figure 4.1: The use of Habits Data in Prospective Radiological Assessments



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APPENDIX A : INTERNATIONAL AND NATIONAL GUIDANCE, LEGISLATION AND REGULATIONS

A1 International Guidance

Current international and national radiation protection legislation derives primarily from the 1990 recommendations of the International Commission on Radiological Protection (ICRP, 1991). The system of protection recommended by the ICRP is based on the principles of justification, optimisation and dose limitation.

The 1990 ICRP recommendations underline the need to undertake prospective assessments of doses from discharges as part of the overall system of protection. Because it is not practicable to assess doses to each individual member of the public, the 'critical group dose' approach has been recommended by the ICRP. The critical group is intended to be "*representative of those individuals in the population expected to receive the highest dose*" (ICRP, 1977). The ICRP has recommended that the mean dose to members of this group can be compared with the public dose limit and with any public dose constraint (ICRP, 1977; 1991).

The Euratom Basic Safety Standards Directive 1996, that was developed from the 1990 ICRP Recommendations, does not use the critical group terminology, instead referring to the need to make realistic assessments of doses to reference groups of the public. In practice, 'reference groups' are considered as broadly equivalent to critical groups.

The ICRP has provided guidance in a number of publications on the definition of the critical group that relate to their assumed habits. For example, ICRP Publication 43 (ICRP, 1985) states that "*The* [critical] *group should be representative of those individuals in the population expected to receive the highest dose equivalent; the group should be small enough to be relatively homogeneous with respect to age, diet and those aspects of behaviour that affect the doses received*." Details of the ICRP critical group concept and its current interpretation and application in the UK are provided in the interim guidance from the Environment Agencies (EA et al, 2002).

The ICRP has recently published new recommendations (ICRP, 2007). Although the main principles remain the same (justification, optimisation and limitation) there are a number of changes to the terminology. In Publication 101 (ICRP, 2006), the ICRP has introduced the term 'representative person' for assessing individual doses. This term is also used in the 2007 recommendations and is defined as "*an individual receiving a dose that is representative of the more highly exposed individuals in the population. This term is the equivalent of and replaces 'average member of the critical group' described in previous ICRP Recommendations"*. As noted by the ICRP, this is a change in terminology rather than a significant change in how doses are calculated for comparison with criteria.

In UK legislation and guidance the term 'critical group' has been used for some time and there is a widespread understanding of its use.

In general it is considered that the terms 'Representative Person', 'Critical Group' and 'Reference Group' are all broadly equivalent and refer to those people in the population of interest who receive, or are expected to receive, the highest dose.

The ICRP continues to "endorse the principles developed in Publications 26, 43 and 60 relating to the selection of individuals for the purpose of assessing compliance with the dose constraint". The purpose of ICRP Publication 103 (ICRP, 2007) is to clarify and elaborate on the application of these principles by taking into account recent experience and advances in assessing doses to members of the public.

Importantly, the ICRP has clarified advice relating to the age groups that should be considered. The ICRP recognises that the level of detail afforded by its provision of dose coefficients for six age categories is not necessary in making prospective assessments of dose, given the inherent uncertainties usually associated with estimating dose to the public and with the identification of the representative person. It now recommends the use of three age categories for estimating annual dose to the representative person for prospective assessments. These categories are 0-5 years (infant), 6-15 years (child) and 16-70 years (adult). For practical implementation of this recommendation, dose coefficients and habits data for a 1 year old infant, a 10 year old child and an adult should be used to represent the three age categories (ICRP, 2006). This recommendation is consistent with current UK practice (eg, as set out in EA et al, 2002) and EC guidance (EC, 2002).

In selecting the characteristics of the representative person it is stated that "*three important concepts should be borne in mind: reasonableness, sustainability, and homogeneity*" (ICRP, 2006). Reasonableness implies realistic, ie, not abnormal, characteristics. In general, maintenance of exposure situations for a period of at least 5 years would be considered sustainable. Again, these recommendations are in line with current UK practice.

It is acknowledged in ICRP Publication 101 that the dose to the representative person can be calculated using a number of approaches that range from simple deterministic to probabilistic methods. For any of these approaches, appropriate habits data are required. It is noted that "*if specific habit data for the exposed population are not available, values may be derived from appropriate national or regional ... data".* This is consistent with current UK practice. It is noted that a distribution may be used in probabilistic assessments, or a value from such a distribution may be selected for deterministic calculations. As established databases suggest that the 95th percentile of consumption rates tend to exceed the mean values by approximately a factor of three, the ICRP considers that using the 95th percentile of behaviour in deterministic calculations is a cautious basis for defining an intake rate. However, if more than one intake route provides a significant contribution to dose then it may not be reasonable to assume that the 95th percentile habits data are applicable to all routes, and a lower value should be assigned to other pathways, consistent with the requirement that the set of habits assumed form a reasonable and sustainable set. UK practice on the use of percentiles of habits distributions varies. In some instances, 97.5th percentiles are explicitly used (eg, terrestrial food consumption rates) and in others the percentile of the value chosen, whilst high, is not explicit. However, in broad terms, the approach recommended by the ICRP is consistent with UK practice.

In general, it is considered that the guidance given in ICRP Publication 101 on assessing doses to the representative person for the purpose of radiation protection of the public is broadly compatible with current UK practice as, for example, defined in EA et al (2002) (see Section 2.2).

The International Atomic Energy Agency (IAEA) has also produced guidance on the determination of doses for prospective assessments (IAEA, 2000), as has the European Union (EU) (eg, EC, 2002). This guidance is consistent with ICRP recommendations.

A2 UK legislation and regulations

The Radioactive Substances Act 1993 provides the framework for controlling the generation and disposal of solid, liquid and gaseous radioactive waste so as to protect the public and the environment. The Environment Agencies are responsible for determining applications for authorisations made by producers of radioactive waste and for reviewing those authorisations on a regular basis. The process of determining whether to grant an authorisation to dispose of waste to the environment includes an assessment of the impact on the environment. The assessment of impact usually involves an assessment of annual doses to the public and scrutiny to ensure that the foodchain is protected.

The assessed doses to the public are compared with dose limits and dose constraints. The current effective dose limit for the public is from the 1990 recommendations of ICRP (ICRP, 1991), implemented in the European Union by the Euratom Basic Safety Standards Directive 1996 (Euratom, 1996). In the UK, the effective legal dose limit of 1 mSv per year for members of the public from the Directive is implemented by the Ionising Radiations Regulations 1999 (IRR, 1999).

Directions to the Environment Agency and SEPA (Defra, 2000; Scottish Executive, 2000), formalised the requirement that the Environment Agencies ensure, when exercising their duties and functions under the RSA 93, that:

- All public ionising radiation exposures from radioactive waste disposal are kept ALARA;

- The sum of the doses arising from such exposures does not exceed the individual public dose limits set out in European Union Basic Safety Standards (effective dose limit, skin dose limit and the limit for the lens of the eye).

For use with defined sources at the planning stage in radiation protection, requirements are that:

- The individual effective dose received from any new source from which discharges are first made since 13th May 2000 does not exceed 0.3 mSv in a year;

- The individual effective dose received from the discharges from any single site does not exceed 0.5 mSv in a year.

The Environment Agencies' are required to observe the following requirements of the 1996 Directive:

(a) when estimating effective dose and equivalent dose: Title V, Article 15 and 16;
(b) in estimating population doses: Article 45.

Title V of Article 15 and 16 of the Directive refers to 2 annexes which relate to radiation quantities and methods of calculation using external dose and committed effective dose coefficients for internal exposure assessment. This element is of limited relevance in the current context.

Article 45 is relatively explicit on aspects of the dose calculation for the public. It states that where conditions for authorisations of practices involves a risk from ionizing radiation for the population, the competent authorities shall ensure that dose estimates are made as realistic as possible for the population as a whole and for reference groups of the population in all places where such groups may occur. The competent authorities shall decide on the frequency of the assessments and take all necessary steps to identify the reference groups of the population taking into account the effective pathways of transmission of the radioactive substances. The estimates of population dose should include doses due to external irradiation, assessments of intakes of radionuclides, the nature of the radionuclides and where necessary their physical and chemical states. A specification of the characteristics of reference groups of the population and an assessment of the doses that they are liable to receive are also required. The competent authorities are required to keep records of external exposure, estimates of intakes of radionuclides, and the results of the assessment of doses received by reference groups of the population.

These requirements are met by the Environment Agencies by reporting retrospectively and annually in RIFE on doses to the public near nuclear sites from discharges made to date. These assessments make use of site-specific habits survey data. The use of site-specific habits data helps to ensure that the assessments are realistic. The habits data are profiled to provide a series of reference groups whose characteristics are known.

For prospective assessments it is less easy to meet the requirement for realism in the dose assessments. This is because it is not possible to be confident in the future habits of individuals or groups. Although habits surveys are likely to be repeated every 5 to 10 years, in the intervening periods habits may change significantly. Where food pathways of exposure are of importance, it is relevant to note that consumption rates can change markedly over a few years, which will affect intakes of radionuclides and doses. It is often possible to adopt a similar approach for establishing reference groups of the population as in retrospective assessments. This approach helps to meet the 1996 Directive requirement for realism. However, some consideration of possible changes to observed habits may need to be made, acknowledging, for example, that members of the local population may increase the amount of fish that they eat. This could require the introduction of more cautious assumptions into prospective assessments as to habits than those observed in habits surveys.

Various general principles for prospective dose assessments have been set out in interim guidance by the Environment Agencies (EA et al, 2002). Several of these principles have implications for the type of habits data that should be used in prospective assessments (see also Appendix G). In particular, for the purpose of determining discharge authorisations:

- Workers, such as farmers, sewage workers and fishermen, who are exposed to discharges of radioactive waste, but do not receive direct tangible benefits from the organisation making the discharge, should be treated as if they are members of the public;

- The mean critical group dose should be assessed;

- Adults, ten-year-old children and one-year-old infants should be considered and doses to the most exposed age group should be adopted;

- All relevant future exposure pathways should be included;

- Possible changes in the habits and locations of critical groups should be taken into account, whilst being as realistic as possible;

- The realistic habits adopted for the critical group should be those that are actually observed year-on-year at the site, or at similar sites elsewhere, either currently or in the recent past;

- Sustainable habits leading to greater exposure that are reasonably foreseeable over the period until the next review of the authorisation should be considered;

- Land use and infrastructure should have sufficient capacity to support the habits of the critical group;

- Any changes to land use and infrastructure that are reasonably foreseeable over the period until the next review of the authorisation and are sustainable year-on-year should be considered.

In defining what is meant by the recent past, the interim guidance states that, where site-specific habits survey data are used, they should be no more than about five years old. In relation to the inclusion of all relevant future exposure pathways, it is stated that it is not appropriate to define separate critical groups for discharges to different environmental media. The potential significance of uncertainty and variability is recognised and it is recommended that where the assessed mean annual critical group effective dose exceeds 20 μSv, the uncertainty and variability in the key assumptions for the dose assessment should be reviewed. The sources of uncertainty and variability to be taken into account include the selection of exposure locations and sources of food production together with the selection of habits relating to both consumption and occupancy.

More recently, the Secretary of State for Environment, Food and Rural Affairs and the Secretary of State for Health in relation to England and the Welsh Ministers in relation to Wales have given guidance to the Environment Agency relating to the Environment Agency's functions in the regulation of aerial and liquid radioactive discharges into the environment, under sections 13, 14, 16 and 17 of the *Radioactive Substances Act 1993*.

In applying this guidance, the Environment Agency is required to have regard to all other relevant matters, such as the Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000, Meeting the Energy Challenge: A White Paper on Nuclear Power: January 2008 and undertakings made by Ministers in the context of the July 1998 and June 2003 Ministerial meetings of the OSPAR Commission.

In relation to its radioactive discharge functions, the Environment Agency is required to base its regulatory decisions on applying the environmental principles set out in the 2008 UK Strategy for radioactive discharges. These principles are:

- Sustainable development;
- The use of Best Available Techniques (BAT);
- The precautionary principle;
- The polluter pays principle;
- Optimisation of protection on the basis that radiological doses and risks to workers and members of the public from a source of exposure should be kept as low as reasonably achievable (the ALARA principle).

There is a preferred use of ‘concentrate and contain’ in the management of radioactive waste over ‘dilute and disperse’ in cases where there would be a definite benefit in reducing environmental pollution, provided that BAT are being applied and worker dose is taken into account.

The Environment Agency is also required to ensure that BAT are applied in place of the current techniques of Best Practicable Means (BPM) and Best Practicable Environmental Option (BPEO). The Ministers believe that BAT will deliver an environmental protection regime in relation to radioactive discharges that is more consistent with similar regimes applied in other countries.

Discharge limits should be set at the minimum necessary levels to permit “normal” operation or decommissioning of a facility. However, in regulating the normal operation or decommissioning of a facility the Environment Agency is required to take into account the relevant operational fluctuations, trends and events that are expected to occur over the likely lifetime of the facility. Flexibility in setting discharge limits may also be necessary in those cases where other key Government objectives need to be met, for example the safe and timely decommissioning of redundant facilities, clean-up of the historic legacy of radioactive wastes, security of energy supply; maintaining defence nuclear and non-nuclear capabilities; and the use of radionuclides in medicine.

Before granting or significantly varying authorisations for radioactive discharges, the Environment Agency is required to ensure that a systematic and proportionate examination is made of waste management options having regard to the waste hierarchy. The Environment Agency is also required to ensure that the waste management strategy chosen by holders of authorisations under the Radioactive Substances Act 1993 represents the use of BAT to provide proper protection for people and the environment. This is in order to:

- Prevent the unnecessary creation of waste or discharges;
- Minimise waste generation; and
- Minimise the impact of discharges on people and the environment.

When determining whether holders of authorisations under the Radioactive Substances Act 1993 are applying BAT, the Environment Agency is required to consider if the holder is taking account of:

- All relevant guidance and good practice;

- The technical characteristics of the facility;

- Its geographical location and local environmental conditions.

Where a legally binding obligation requires stricter conditions and limits than those which would be required by the application of BAT, then the Environment Agency is required to ensure that those stricter conditions and limits are applied.

Where the prospective dose to the most exposed group of members of the public is below 10 Sv y^{-1} from the overall discharges of an authorised site under the Radioactive Substances Act 1993, the guidance is that the Environment Agency should not seek to reduce further the discharge limits that are in place, provided that the holder of the authorisation applies and continues to apply BAT.[4]

In relation to any designs for new nuclear power stations, the Environment Agency is required to ensure that BAT are applied so that the design is capable of meeting high environmental standards. This requirement is to be imposed at an early stage, so that the most modern technology can be incorporated into the design of the stations. The application of BAT should ensure that radioactive wastes and discharges from any new nuclear power stations in England and Wales are minimised and do not exceed those of comparable stations across the world. Similarly the Environment Agency is required to ensure that BAT are used in all other new nuclear facilities.

[4] The issue of whether a value of 20 μSv y^{-1} or 10 μSv y^{-1} should be used for this purpose is a matter that is the subject of on-going discussion.

APPENDIX B : TYPES OF HABITS DATA

Habits data may be derived from surveys specific to the site of interest. This is generally the case for licensed nuclear sites in the UK. However, for other sites a combination of information specific to the site and more general information may be used. For many of the smaller sites that are authorized to release radionuclides to the environment, reliance may be placed entirely upon generic data. The various types of habits data that are available are described below.

B1 Habits data that are specific to a site

Full details of the methods of collection of data in radiological habits surveys have been given in the previous report of this group (NDAWG, 2005). Similarly, the previous report gives full details of the surveys that had been carried out between 1991 and the writing of the report. Up-to-date details of the surveys that have been carried out and survey reports are available from the CEFAS website (www.cefas.co.uk).

Currently, habits surveys carried out around nuclear licensed sites are 'combined surveys' jointly funded by the FSA, EA and HSE in England and Wales. As such, they provide data on consumption rates of terrestrial foods, aquatic foods, occupancy indoors and outdoors in the vicinity of the site, time spent handling fishing gear and taking part in activities that could result in exposure to radioactive material in water and sediments. This information is recorded for each individual in the survey (including zero values).

In Scotland, habits surveys have been carried out at each nuclear licensed site within the last 5 years and these site-specific surveys are repeated regularly at intervals not exceeding 5 years. Surveys undertaken at Hunterston (2001), in Dumfries and Galloway (2002) and at Dounreay (2003) are available from the CEFAS website. No surveys were conducted in 2004, but surveys related to Chapelcross (2005) and Rosyth (2005) have been published and will be available on the CEFAS website in the near future. Earlier reports on Rosyth (1999), Faslane (2000) and Torness (2001) are available only on the SEPA website (http://www.sepa.org.uk/publications/rad_habits/index.htm).

Surveys have also been carried out in areas such as the Solway coast, Northern Ireland and the Channel Islands, as these areas may be affected by discharges into the sea.

Also, as part of a project jointly funded by the HPA, SEPA and FSA to investigate the doses received by crofters in the Scottish Highlands and Islands resulting from the use of locally collected seaweed as fertiliser or animal feed, the HPA has collected data on consumption of foods grown on the treated land. These data will be reported in early 2009 as part of the project report. It is emphasised that these data are only appropriate to the population surveyed and the rates derived cannot be directly applied to other groups.

Surveys around nuclear sites are generally repeated at approximately 5 yearly intervals. In the case of Sellafield, an annual review is carried out to identify major changes in habits.

Previously, separate habits surveys were carried out for the terrestrial and aquatic pathways or for aquatic pathways only. Even when information relating to the same individual is contained within terrestrial and aquatic survey reports for the same site, it is not possible to 'match up' the two halves of the data. In the case of infants and children, it is possible that the individual may have moved into a different age group in the time between the two surveys being carried out.

Often habits surveys will report food consumption rate data for a large number of adults but for few if any children or infants. Where this is the case, data sets for these age groups may be constructed by multiplying the rates observed for adult consumers by the ratio of the adult and infant or child consumption rates derived from the National Diet and Nutrition Surveys (NDNS) and reported in Byrom et al (1995).

B2 Habits data that are not specific to a site

Non-site specific habits data are available from various sources. Categories include regional, national and internationally applicable data. Some of these data are obtained from habits surveys and others from scientific studies. Some non-site specific data are also generated by combining information from site-specific surveys to produce habits data relevant to particular types of communities. For example, information from habits surveys around nuclear installations have been used to derive generic critical group consumption rates representative of coastal communities as distinct from those for the population as a whole (Smith and Jones, 2003). The various types of non-site specific data that can be used are discussed below.

B2.1 Generic food consumption data

Where site-specific habits data are not available, data from other sources need to be used. There are a number of such sources of data on food consumption rates. Details of such sources are given below.

National diet and nutrition surveys
An ongoing programme of National Diet and Nutrition Surveys (NDNS) is carried out on behalf of the Food Standards Agency (and previously the Ministry of Agriculture, Fisheries and Food) and the Department of Health. These surveys have been carried out for a range of age groups. Specifically, data have been collected for children 1 ½ to 4 ½ years old, people aged 65 and over, schoolchildren aged 4 to 18 and adults aged 19 to 64 years. The sample size varies between surveys, but is approximately 2000 individuals. The data from the surveys are available from the Office of National Statistics (www.ons.gov.uk) or from the Economic and Social Data Service (www.esds.ac.uk). These are extensive data sets and processing the data may be difficult. Data from surveys carried out prior to 1995 (specifically OPCS (1990) for adults, DH (1989) for children, and Mills and Tyler (1992) for infants) have been used to develop generalised food consumption rates (Byrom et al, 1995). These rates have also been used in compilations of more generalised habits data such as Smith and Jones (2003).

The data collected in the NDNS and reported in raw or derived form are intended to inform decisions on nutrition policy and, therefore, differ from the data collected in radiological habit surveys. Specifically:

- The information is on the amounts of foods consumed and no attempt is made to ascertain the source of the foods, whether from local production, national or international sources;

- The data are intended to be representative of the UK population as a whole and groups who consume above average amounts of, eg, sea foods are likely to have been missed by the survey or to have had their consumption rates ‘masked’ by the averaging process;

- No information is collected on habits that may result in exposure from non-food pathways.

Expenditure on food survey
The Expenditure on Food Survey has been carried out annually on behalf of Defra (http://statistics.defra.gov.uk/esg/publications/efs/default.asp) since 2001/02. This survey contains information on the amounts of different foods purchased by individuals in approximately 6800 households. Prior to 2001/02, data were collected as part of the National Food Survey and Family Expenditure Survey. Again, the data collected and reported in these surveys differ from those that would be collected as part of a radiological habits survey. Specifically:

- The information is on the amount of food purchased per person and not the amount consumed;

- It is not possible to ascertain the individual rates of consumption within a household;
- There is no information as to whether the food was obtained from local, national or international sources;
- The data are not distinguished by age group;
- Free foods, which may be an important pathway in some circumstances, are not included;
- No information is collected on habits that may result in exposure from non-food pathways.

International consumption data
Both the World Health Organisation (WHO) and the International Atomic Energy Agency (IAEA) have published dietary consumption data. The WHO produces the Global Environment Monitoring System (GEMS) Regional Food Diets (GEMS, 2003). These are derived using information on the production, import and export of food in a representative country in each of 5 geographical regions. Again these data differ from what would be collected in a radiological habits survey:

- Information had been collected for Europe using one country as representative, but it is not clear which country was selected;
- The data are not distinguished by age group;
- The information is on the amounts of foods consumed and no attempt is made to ascertain the source of the foods, whether from local production, national or international sources;
- No information is collected on habits that may result in exposure from non-food pathways.

The IAEA has published data on the consumption of sea foods (IAEA, 2001). These data represent world-wide averages and, therefore, are not appropriate for use in prospective radiological assessments of sites in the UK.

Compilations of consumption data for 17 Member States of the European Union are available from the European Food Safety Authority website (EFSA, 2008). The data for the UK is derived from the NDNS. As such, the data are not suitable for use in radiological exposure assessments. Specifically:

- The information is on the amounts of foods consumed and no attempt is made to ascertain the source of the foods, whether from local production, national or international sources;
- The data are intended to be representative of the UK population as a whole and groups who consume above-average amounts of, eg, sea foods are likely to have been missed by the survey or to have had their consumption rates ‘masked’ by the averaging process;
- No information is collected on habits that may result in exposure from non-food pathways.

Compilation of data from habits surveys

Where habits survey data for a specific site are not available an alternative approach is to make use of the data collected in habits surveys at other sites. A compilation of such information has been reported by Smith and Jones (2003). Consumption rates are given for sea and freshwater fish and for molluscs and crustaceans.

Free foods survey

Research was carried out by the NRPB (now the HPA RPD) and British Market Research Bureau Ltd (BMRB) for the Food Standards Agency on the impact of discharges from a number of nuclear sites on consumers of free foods collected close to the sites (Green et al, 1998). This work includes the results of a habits survey investigating the rate of consumption of free foods such as mushrooms, blackberries and rabbits.

B2.2 Data on home-grown food

There is limited information available on consumption rates of home-grown foods. Some information is available in Prosser et al (1999), which includes an analysis of the 1993 National Food Survey results relevant to home-grown foods. However, the data are limited, as only 100 of the households involved in the survey consumed home-grown food. In general, radiological assessments including intakes rates of home-grown foods assume that pre-specified fractions of total intakes are home grown.

B2.3 Water consumption

Information on water intake rates is available from a number of sources. Values derived from the ICRP Task Group report on Reference Man (ICRP, 1975) are commonly used (Smith and Jones, 2003). Total fluid intakes by ingestion for male adults and children are given (ICRP, 1975) as 3 litres per day and 2 litres per day, respectively. The reference adult value, although greater than other published fluid intake rates, is based on consideration of total water balance and the physiological premise that 1 ml of water is required for each kcal of energy expended. Neglecting any water ingested in food and milk, and produced by the oxidation of food, ICRP (1975) suggested a water intake rate by ingestion of 1.65 litres per day for adults and 0.95 litres per day for a child (10 years old). The ICRP does not suggest a total fluid intake by ingestion for infants (1 year old). However, a value may be derived on the basis of an energy expenditure of 1200 kcal per day (ICRP, 1975). This gives a daily intake of 1.2 litres. By assuming that the average milk intake for an infant is 0.5 litres per day, and neglecting intake from food, the daily water intake rate has been estimated to be 0.7 litres (Smith and Jones, 2003). The ICRP produced a further report on basic anatomical and physiological data in 2002, ICRP Publication 89 (ICRP, 2002), to supplement and update as necessary the information in the earlier Reference Man report. In relation to water intakes, this provides reference values for water intakes for adults (male and female) that are broadly the same as those in the earlier report.

The World Health Organisation (WHO) uses an adult water intake rate of 2 litres per day, which represents a worldwide average (WHO, 1993). A survey conducted by BMRB for the Water Research Centre in 1980, also provides information on water intakes and is generally in line with the other sources discussed (Hopkin and Ellis, 1980).

The above discussion relates to total water intakes. The information relevant for some assessment purposes is the intake of tap water. The total water intakes can be considered as conservative upper bounds for tap water intakes (ie, assuming intakes via other routes, eg, canned and bottled drinks, are negligible). However, for some assessments, more specific information on tap water intakes may be required. Hopkin and Ellis (1980) provide some information directly on tap water consumption. The mean and 90th percentile tap water intake rates for the whole sample, which included children, were approximately 1 litre per day and 1.6 litres per day, respectively. The highest intake rates were by the men in the 31-54 y age group, with mean and 90th percentile tap water intake rates of around 1.2 and 1.8 litres per day, respectively. In some studies, it has been assumed that approximately half of an individual's total water intake comes from tap water (HPA, 2005).

It is difficult to distinguish between average and critical intakes for water. However, as ingestion of tap water is only occasionally a dominant pathway (and tends to become less significant when a more realistic approach is adopted in assessments) and the above estimates are expected to be at the upper end of the range of tap water intake rates, this is not considered a major problem.

B2.4 Occupancy

There is the potential for reduction in dose rates to members of the public due to external exposure and inhalation during periods spent inside buildings. As a result, information on the amount of time spent indoors, *indoor occupancy*, is required for many dose assessment purposes. This information is not generally obtained from site-specific surveys but from national surveys. It is assumed that the information from such studies is generally applicable to the whole population. As it also appears to vary little over time, it is also suitable for prospective assessments over a reasonable time period. Suggested indoor occupancies and associated information derived from a 1984 BBC survey are available in a number of reports (Francis, 1986; Smith and Jones, 2003).

There are a number of national surveys carried out to investigate behaviour and activities that are potentially useful for providing occupancy information.

BBC surveys
The BBC Daily Life study has been carried out every 5 to 10 years since the 1930s. Following the 1984 study mentioned above, surveys were carried out in 1989 and 1995. The most recent survey was undertaken in 2002/3 (Griffiths and Holden, 2004). The primary focus of the studies relates to the use of media, but there is some information on time spent on a variety of other activities, including gardening.

Office for National Statistics surveys
The Office for National Statistics (ONS) carried out a time use survey in May 1999 (an earlier one was undertaken in 1995). The 1999 survey is based on completed diaries from 1,777 adults (over 16). However, although nationally representative, breakdowns by gender, employment, etc, may be unreliable due to the small sample sizes that arise after such disaggregation. Brief summary information from the 1999 survey is reported in the ONS publication Social Trends No 31 (ONS, 2001) with greater detail provided by Short (2000).

The 'UK Time Use Survey 2000' undertaken by ONS began in June 2000 and was completed in July 2001. Results from the analysis of the data became available in mid May 2002 from the UK data archive, the central repository for social science data used by ONS to distribute its data to commercial and academic users. This survey expected responses from approximately 12,000 individuals and consisted of a household questionnaire and individual questionnaires for those over 16 and those between 8 and 16 in the household. The survey also included one-day diaries from both children and adults. Unlike previous surveys it did not partition activities into approximately 30 categories or codes, but used over 170 to allow activities to be allocated correctly to different headings. The data are available for loan from the UK data archive, subject to complex restrictions on their use.

Other occupancy data
Discharges of liquid radioactive wastes are made direct to water courses from a number of nuclear sites. Some smaller nuclear sites discharge some or all of their liquid wastes to water company sewers: Harwell, Aldermaston, GE Healthcare at Cardiff and at Amersham, Rolls Royce at Derby and Bae Systems at Barrow in Furness. Non-nuclear site liquid discharges are made almost exclusively to water company sewers. Discharges made to sewers are normally transferred to sewage treatment works. Here, the raw sewage is treated to remove materials that would reduce dissolved oxygen concentrations in the aquatic environments receiving effluents from such sewage treatment works. The main two processes are removal of suspended solids (by settling and filtration) and removal of dissolved organic matter by biological digestion processes, using bacteria. Effluents may be subject to additional treatments to remove phosphate and pathogens, and are then discharged direct to water courses inland or on the

coast. Separated solids are treated and disposed of in a variety of ways, including incineration, disposal to agricultural land, use in land reclamation and to landfill.

Exposure of sewage workers from sewage during treatment needs to be considered. The main exposure pathways at sewage treatment works involve external exposure to gamma-emitting radionuclides, in particular when concentrated in sewage sludges. Internal exposure from ingestion and inhalation of materials derived from sewage is a minor consideration, as intakes of these materials are generally restricted because of the biological hazard that they present. The main habits data required are occupancy times at the sewage works close to contaminated sewage-derived materials. The annual occupancy times are typically a working year (2000 hours per year) or less. Site-specific habits data for sewage treatment works have been gathered during habits surveys around some nuclear sites. Thus, data exist relating to the Cardiff East, Maple Lodge and Didcot sewage treatment works. The available data are, or will be, available in the integrated habits surveys for GE Healthcare (Grove Centre, Amersham and Maynard Centre, Cardiff) on the CEFAS web site (www.cefas.co.uk).

There is also a need to consider exposures of the public from discharges of treated effluents to natural water courses and from disposals of sludge. Site-specific data for natural water courses close to Maple Lodge (Grand Union Canal), Cardiff East (River Severn) and for the River Thames have been collected during nuclear site habits surveys. No site-specific habits data for sewage sludge disposal to land have been gathered. For such scenarios, generic assumptions related to occupancy on or close to fields and on land around farms, and generic UK-wide data for food consumption are normally applied, taking into account the foods that can be produced. For non-nuclear sites where disposals occur to sewer, the assessment of sewage effluent and sludge-related pathways makes use of reasonable assumptions based on the types of habits data outlined above.

B2.5 Inadvertent and deliberate ingestion of soil

Information on ingestion rates is available from a number of small studies carried out in various countries. Summaries of the literature provide data from which indicative rates can be obtained (Simon 1998; Smith and Jones, 2003; Smith and Bedwell, 2005). The results of more recent studies (eg, Davis and Mirick, 2006) are also a useful input to decisions on appropriate rates to assume. The results from these studies are sometimes referred to as inadvertent soil ingestion rates. However, this is somewhat misleading. It is well known that relatively short-term deliberate ingestion (exploratory mouthing) is widespread among young children and that such behaviour may be regarded as a ‘normal’ temporary phenomenon among some young children. The majority of the studies referred to above provide ingestion rates that reflect both inadvertent ingestion and exploratory mouthing by infants and young children.

In contrast, the rates from these studies exclude the deliberate consumption of large quantities of soil or sediment (pica) as too rare a condition to warrant inclusion in an environmental exposure assessment.

B2.6 Inhalation rates

The ICRP model of the respiratory tract was developed considering the available literature on the characteristics and behaviour of the respiratory tract. The ICRP Task Group report on the model of the respiratory tract, ICRP Publication 66 (ICRP, 1994), gives ventilation rates for various age groups and activity levels. It also provides a number of average inhalation rates for both members of the public and workers. These average inhalation rates were determined from the ventilation rates by making assumptions about the time spent at each activity level.

ICRP Publication 66 gives inhalation rates for two categories of adult workers involved in, respectively; 'heavy' and 'light' work. A worker involved in light work breathes 9.6 m^3 during an 8 hour working day, ie, an average inhalation rate over the working day of 1.2 $m^3\ h^{-1}$. For 'heavy' workers (construction workers, farm workers) it is assumed that 13.5 m^3 of air are breathed during an 8 hour working day, ie, an average breathing rate of 1.69 $m^3\ h^{-1}$. This was determined by assuming the individual spends 7 hours doing light exercise (breathing rate 1.5 $m^3\ h^{-1}$) and

1 hour doing heavy exercise (breathing rate 3.0 $m^3\ h^{-1}$). The report makes clear that the breathing rate for heavy exercise, 3.0 $m^3\ h^{-1}$, is appropriate for periods of time not exceeding 2 h d^{-1} for firemen, construction workers, athletes, etc.

For members of the public, Smith and Jones (2003) provide recommended rates for individuals of different ages and for various levels of activity. The long-term average rates for different age groups are 0.22 $m^3\ h^{-1}$ (5.28 $m^3\ d^{-1}$) for a one year old, 0.64 $m^3\ h^{-1}$ (15.36 $m^3\ d^{-1}$) for a ten year old and 0.92 $m^3\ h^{-1}$ (22.08 $m^3\ d^{-1}$) for an adult. For adults, rates are also given for sleep (0.45 $m^3\ h^{-1}$) and non-occupational activities (1.21 $m^3\ h^{-1}$), comprising a combination of rest, light exercise and heavy exercise.

APPENDIX C : ASSESSMENT APPROACHES ADOPTED BY THE ENVIRONMENT AGENCY AND THE FOOD STANDARDS AGENCY

C1 Screening assessments

C1.1 Environment Agency

In the Environment Agency initial screening system, four main release types are evaluated. These are discharges to:

- Atmosphere;
- River;
- Coastal environment;
- Sewer.

The last of these includes consideration of the sewage works where sludge and liquids are treated and separated; farmland treated with sewage sludge on which animal food products are produced; a brook receiving treated effluent and frequented by children; discharges to a river and to the coastal environment.

For each receiving environment there are a set of generic habits the allow calculation of doses. The habits data used are UK generic data.

Habits assumptions for releases to atmosphere
There is one dispersion and receiving environment – a semi-rural environment with dwellings at 100m and food production at 500 m from the point of release. The habits are intakes of all the main food types (green and root vegetables, fruit, sheep meat and liver, cow meat, liver and milk) by three age groups (habits data taken from Tables 2, 4 and 5 of Smith and Jones (2003)). All these foods are considered to be consumed at 97.5th percentile rates with 100% local production at an average distance of 500 m from the release point. The habits include year-round occupancy of an assumed dwelling at 100 m, with that occupancy partitioned between indoor and outdoor components. Doses calculated from these habits assumptions are summed. These habits and their combination (resulting in total food intake from local production and year-round local occupancy) lead to a conservative estimate of doses.

Habit assumptions for releases to river
Two discrete dispersion and receiving environments are considered:

- Upstream of drinking water abstraction point and of a recreational area of river bank used for angling and from which fish are taken and eaten;

- Upstream of a stretch of river that is used to irrigate fruit and vegetables that are consumed locally.

The habits applied to the first receiving environment assume intakes of untreated river water by three age groups - as though it were the only drinking water supply (drinking water rates from Table 10 of Smith and Jones (2003)) and representative consumption of freshwater fish by three age groups (from Table 13 of Smith and Jones (2003)). The time spent on river banks for recreation uses the representative critical group riverbank occupancy from Table 16 of Smith and Jones (2003). Doses calculated for the different pathways of exposure using these habit assumptions are summed. The use of these habits and the summation over pathways leads to conservative estimates of doses.

The habits applied to the second receiving environment assume intakes of food associated with irrigation of fruit, green vegetables and root vegetables by three age groups (consumption rates taken from Tables 2, 4 and 5 of Smith and Jones (2003)). All these foods are considered to be consumed at 97.5th percentile rates with 100% local production. Doses calculated for the different pathways of exposure using these habit assumptions are summed. The use of these habits and the summation over pathways again leads to conservative estimates of doses.

Habit assumptions for discharges to a coastal environment
One receiving environment is considered; this is a local well-mixed region in which radionuclides are homogeneously distributed that is used by one or more families for recreation, and from which fish and shellfish are caught and consumed.

The habits data applied assume intakes of fish and shellfish from the local well-mixed region by three age groups (Table 13 of Smith and Jones (2003)). The time spent on inter-tidal areas for recreation is the representative critical group inter-tidal occupancy from Table 16 of Smith and Jones (2003) (adopting the high end of the occupancy data). Doses calculated for the different pathways of exposure using these habit assumptions are summed. The use of these habits and the summation over pathways leads to conservative estimates of doses.

Habit assumptions for discharges to sewer
Three discrete dispersion and receiving environments considered:

- The sewage works where sludge and liquids are treated and separated;
- Farmland treated with sewage sludge on which animal food products are produced;
- A brook receiving treated effluent.

For the sewage works environment, worker exposure is considered. In a sewage discharge situation, it is unlikely that the sewage works itself would be permitted to make discharges. Therefore, for assessment purposes, sewage workers are treated as members of the public and included in the assessment. The habit assumptions are occupancies of 1500 hours per year adjacent to tanks of raw sewage and 500 hours per year adjacent to tanks of sludge, and a breathing rate of 1.2 $m^3\ h^{-1}$. The breathing rate adopted is a value that is generally used for work activities involving exposure to radioactive materials (see Appendix B, Section B2.6).

For application of sludge to farmland, the modelling assumes a farm and farmland using sludge for dressing of pasture and producing animal products. Habits are intakes of all the main food types that can be produced on land treated with sludge (sheep meat and liver, cow meat, liver and milk) by three age groups (taken from Tables 2, 4 and 5 of Smith and Jones (2003)). All these foods are considered to be consumed at 97.5th percentile rates with 100% local production. Habits include year-round occupancy on the farm, some of which is inside and some outdoor. Doses calculated for the different pathways of exposure using these habit assumptions are summed. The use of these habits and the summation over pathways leads to conservative estimates of doses.

For discharge of effluent to a brook, the modelling assumes dispersion in a low-flowing brook with limited dispersion. This brook is assumed to be accessible by children. The duration of occupancy by 10 year old children is taken to be 500 hours per year and high inadvertent ingestion rates of brook water and sediment are assumed.

In addition, the treated effluent may be transported onward to river and coastal environments, so the pathways associated with these are included.

C1.2 Food Standards Agency

In the screening approach used by the Food Standards Agency, three release types are considered. These are discharge to:

- Atmosphere;
- Rivers;
- The sewage system.

In the case of discharges to atmosphere, a set of cautious assumptions regarding habits and other parameters are used to derive a set of 'dose per unit release' values. As rounding is applied to the calculated values, there is not an exact relationship between the habits assumed and the calculated values. In deriving these values of dose per unit release, it is assumed that:

- The release is from a stack 5 m high and that terrestrial foods are grown and exposures are received at a distance of 100m from the discharge point;
- Standard breathing rates are as recommended by the ICRP;
- The occupancy factor is 100%;
- Doses received via the food chain are calculated on the basis that the two food types giving the highest doses are consumed at the 97.5th percentile rate reported by Byrom et al (1995), whereas other foods are consumed at the median rate.

For discharges into rivers or other watercourses the pathways considered are:

- Consumption of freshwater fish;
- Consumption of animal products from livestock drinking from the watercourse;
- Consumption of crops irrigated from the watercourse;
- External exposure from radioactivity incorporated into soil following irrigation;
- Inhalation of re-suspended radioactivity.

Freshwater fish are assumed to be consumed (by an adult) at the rate of 10.5 kg y^{-1}. This rate is used as it is the highest freshwater fish consumption rate identified in a habits survey. Doses from the consumption of terrestrial foods are calculated using the 'top two' method, taking the mean and 97.5th percentiles of the consumption rates from Byrom et al (1995).

Occupancy of the irrigated area of 1000 hours per year is used for both the direct irradiation and inhalation of re-suspended activity pathways.

In the case of discharges into sewers, the following pathways for exposure of a sewer worker are considered:

- External exposure in sewer pipes;
- Inadvertent ingestion of sewage whilst in sewer pipes;
- Inhalation of tritiated water vapour;
- External exposure from sewage sludge at a sewage works;
- Inadvertent ingestion of sewage at a sewage works;
- Inhalation of re-suspended sewage sludge.

The occupancy values assumed for these pathways are:

- In sewer pipes: 200 hours per year;
- At a sewage works for exposure to direct radiation and inhaled re-suspended material: 1000 hours per year;
- At sewage works for inadvertent ingestion: 125 hours per year.

Exposures resulting from activity remaining in the raffinate leaving the sewage works are assessed in the same way as exposures from discharges direct to watercourses and the same habits are assumed.

C2 Site-specific assessments

In undertaking site-specific assessments, consideration is given to the locations of representative persons, the areas from which their foods are obtained and their habits, in terms of consumption rates and occupancies. These various aspects are described below.

C2.1 Identification of locations used by representative persons

Locations used by representative persons are identified from the location of housing and land use around the site and from the habits survey reports. The receptor information is then combined with habits data to provide a coherent and robust set of data for calculating doses. Locations are either identified from qualitative information from habits survey reports, maps and by information about land use and the locations of houses, caravan parks, work places, recreation areas, etc. From this information, a set of realistic reference locations for assessing the consequences of atmospheric discharges, liquid discharges and direct radiation are identified. These reference locations take into account where food is produced and locations of available agricultural land near the site, where people live, work and participate in recreational activities, and where direct external radiation dose rates are significant. The Food Standards Agency also takes into account the off-site areas where atmospheric and environmental concentrations are expected to be highest and includes these as reference locations, as appropriate (ie, if these areas could reasonably practicably be used for occupation or food production).

These assumptions and the resulting receptor locations are documented in the assessment report. Non-adult receptors are considered to occupy the same locations as adults except in the case of working environments (factories, sewage works).

The habits survey provides information on the presence or absence of children and infants in the local groups.

C2.2 Application of fully integrated habits data in assessments

Where fully integrated habit data are available (around many nuclear sites) these are now normally used in prospective assessments. The integrated data for prospective assessments are currently treated in the same way as in retrospective assessments (ie, habits profiles are defined; see Camplin et al (2005)). The profiles are assumed to be representative of individuals living at the nearest reasonable locations. The integrated data are profiled by age group. There are normally profiles for high consumption rates of milk, green vegetables, root vegetables, other animal products and various sea foods, as well as high occupancies near the site and on beaches. These profiles are matched with known land uses and activities around the site and are used to refine food production locations.

As to refining food production locations, if there is a high milk-consuming profile from the habits survey, the nearest dairy farm will be located and the pasture land around identified to determine the most appropriate location for the milk concentrations to be modelled. Similar consideration is given to pathways involving consumption of other food products, eg, vegetables and fruit. The nearest locations where these food products can be grown are factored into the assessment. Local housing and land is assessed to see whether any houses have gardens, whether any are used for vegetables and other crops, the size of the gardens *etc*. These observations determine how the modelling of radionuclide transfers to local vegetables and other crops is factored into the assessment.

Each profile includes information on other habits, if the habits survey finds that that such exist. For example, the root-vegetable profile may include information on secondary habits such as milk consumption, beach occupancy and seafood consumption. A seafood consuming profile or beach-occupancy profile may include, for example, secondary habits data on milk consumption and root vegetable consumption. The secondary habits in the profile would normally adopt the same assumptions about the modelled locations as those adopted in relation to the leading pathway in the profile.

The profiles are only normally constructed for adults, because there are usually insufficient data in the habits surveys for other reference age groups (infants and 10 year old children). Infant and child profiles are derived from the adult profiles, and ratios of consumption are calculated from national consumption data applicable to adults and children.

The Food Standards Agency adjusts these profiles for use in prospective assessments, to provide a degree of ‘future proofing’ of the consumption rates and occupancies adopted. The future proofing is intended to provide a degree of assurance that any reasonably foreseeable changes in habits in the near future (typically 5 years) are not overlooked. In contrast, the Environment Agency does not currently adjust the profiles for future proofing purposes.

Modifications to profiles to give adjusted profiles for future proofing prospective assessments are:

- Rounding upward of consumption rates and occupancies to remove any undue impression of precision in the values;

- Including higher than average consumption rates and occupancies where it is reasonably foreseeable that the recorded values may change.

It is recognised that a considerable degree of judgement is needed in making these amendments, and it is not possible to give detailed guidance applicable across all the situations in which the need for such adjustments may arise. However, all such adjustments are described explicitly in the reports on the assessments.

Exposure to direct radiation from nuclear licensed sites may contribute to the total dose received by a group and is primarily relevant to groups located within 1 km of the site boundary. The regulation of direct radiation is the responsibility of the Health and Safety Executive (HSE). Nuclear site operators provide estimates of exposure to the HSE, which are made use of in the assessments. The information that licensees are requested to supply is:

- The assessed annual contribution from direct radiation from the site to the ‘all pathways’ critical group, giving contributions separately for neutron and x plus gamma radiations, if relevant;

- The assessed annual dose from direct radiation to the most exposed group for that pathway alone, including details of location, occupancy and dose rates used in making the assessment;

- Summary information relating to the dose rates measured at the site perimeter (maximum and average) over the course of the year, including contributions from neutron, and x and gamma radiations, as appropriate.

The methodology used by the licensees generally involves deploying environmental thermo-luminescent dosimeters (TLDs) at assigned locations around the facilities. Total exposure, including contributions from cosmic and natural terrestrial background radiation are assessed quarterly and are reported to the regulator on an annual basis. For dose assessment purposes, the contribution from natural radiation is deducted. In addition, licensees may undertake specific local monitoring using techniques such as gamma spectrometry surveys, but results from these are used as reassurance monitoring and not directly for dose assessment purposes. The regulator may also undertake independent surveys in co-operation with the licensee.

In assessing the radiological impacts of direct radiation, consideration is given to dwellings such as mobile homes that offer limited shielding from direct radiation and to irradiation from noble gases in any plume of radioactive material released from the site.

C2.3 Application of habits data in assessments if site-specific habits data are incomplete

Prior to 2002, habits data were collected around nuclear sites in a non-integrated way, though comprehensive data were acquired through the various surveys. For example, the data may have been collected separately in relation to atmospheric discharges, liquid discharges and for direct external irradiation, and may have been obtained in different years. In these circumstances, the data cannot be profiled objectively.

In situations in which separate terrestrial and aquatic surveys are available for the site possible approaches include:

- Carrying out and reporting separate assessments for the terrestrial and aquatic pathways;

- Carrying out separate assessments for the aquatic and terrestrial pathways and reporting the total assessed dose as the sum of the values from the two assessments, recognising that this is likely to give an overestimate of the dose;

- Carrying out an assessment using a series of constructed profiles, using representative individual rates for the terrestrial pathways and mean rates for the aquatic pathways and *vice versa*. The assessment that results in the highest dose is reported as the representative individual dose (this approach is used by the Environment Agency).

Whatever method is used, the assumptions and method adopted are usually clearly stated in any report on the assessment.

The numbers of data for children and infants included in the survey are often too few to allow their habits data to be used directly. Food consumption rates differ significantly between age groups. A data set for the infant and child age groups can be constructed by multiplying the observed adult consumption rates by the ratios of infant and child consumption rates to those of adults. These consumption rates are given in Byrom et al (1995) and are based on national survey data. These constructed data sets can be then used in assessments. For occupancies, adult data have often been considered to be representative also for children. The argument has been that infants and young children will be accompanied by adults and that the adult occupancy data will have been recorded.

If only a terrestrial or aquatic survey is available, the options available for replacing the missing information include:

- Making use of one of the generic, non-site specific data sets for the missing data in constructing some representative profiles (used by the Environment Agency);

- Using data from another site with similar characteristics.

In respect of this latter approach, it is noted that the rates of consumption of terrestrial foods are broadly similar between different sites. However, rates of consumption of aquatic foods are dependent on the availability of the relevant edible species. This in turn is affected by the local characteristics of the freshwater, estuarine or marine environment. Consumption rates can vary markedly between different sites. Similarly, occupancies for exposure to activity incorporated into sediments can vary substantially between sites.

Whatever method is used to substitute for the missing data this is usually described explicitly in the report of the assessment.

Where habits survey data are available for the majority of pathways, but data are missing for some pathways, generic non-site specific data can be used to substitute for the missing data. Care has to be taken to ensure that the resulting assessment does not contain any implausible assumptions, eg, total times for occupancy close to the site and on sediments incorporating radioactive material that are greater than the number of hours in a year. Again, the methods used are usually described explicitly in any report of the assessment.

C2.4 Approach to assessment if no site-specific habits data are available

Nuclear sites

In the past, where no site specific data was available, the main approach adopted was to adapt UK generic habits data published by the HPA/NRPB to construct a series of candidate critical groups, taking into account local factors. This involved establishing critical habits for terrestrial exposure to atmospheric discharges and adopting generalised data for exposure to liquid discharges made to the marine environment or freshwater environment. The so called 'top two approach' was adopted for foods, wherein the assessment was made following a review of likely food production and probable occupancy near the site. Habits that matched to land use around the site were included and an assessment was initially made by inclusion of all relevant terrestrial foods assuming consumption at 97.5th percentile rates. From this assessment, the two foods making the largest contribution to dose could be identified. The remaining food consumption rates were reduced to 50th percentile values and the dose was recalculated for the candidate critical group with the top two foods at 97.5th percentile consumption rates and the remainder at 50th percentile rates. This approach helps to avoid undue pessimism in overall food consumption rates and limits calorific intakes to within reasonable bounds.[5]

Where the terrestrial group was located on the coast, the terrestrial group habits were further modified by inclusion of 50th percentile consumption of marine foods and average beach occupancy, totalled to ensure that total occupancy did not exceed 8760 hours in a year. Assumptions about habitation location were factored in, taking into account the locations of the nearest farm or other habitations, and direct shine and irradiation from the dispersing plume were included where appropriate. The total doses to the terrestrial candidate critical groups exposed to gaseous and liquid releases and direct shine were then determined.

Candidate critical groups were also identified for the liquid releases. For coastal locations, generalised habit data for fish consumption (100 kg y^{-1}), mollusc consumption (20 kg y^{-1}), and crustacean consumption (20 kg y^{-1}) by adults, and a high beach occupancy of 2000 h y^{-1} were adopted. The group was assumed to consume some terrestrial foods produced locally and 50th percentile rates from UK generic data were adopted for these. In this case, candidate critical groups were assumed not to live close to the site and, therefore, doses from the plume and direct external irradiation were not normally included. Doses from the included food pathways were then summed to form a reasonably realistic assessment of doses to the marine candidate critical group.

The critical group was then identified from the highest dose to the marine or terrestrial candidate critical group.

Non-nuclear sites

For most non-nuclear site dose assessments, no site-specific habits data are usually available. Where the non-nuclear site is located near a nuclear site, site-specific habits data for the nuclear site may be utilised. In the past, the assessments often adopted the approach given by the NRPB and HPA for small users (McDonnell, 2004) which makes use of generic habits data. Increasingly, the approach now is to carry out a staged dose assessment, starting with a screening assessment using tools such as the EA Initial Radiological Assessment Methodology (EA, 2006) and the HPA Generalised Derived Constraints approach (NRPB, 2005), with further refinement of the assessment if initially assessed dose rates exceed 20 μSv y^{-1}. In many cases in which the initial assessment requires refinement, consideration of non-habits related dispersion factors, such as release height or stream flow rate, will be sufficient to demonstrate that annual effective doses are below 20 μSv. Further refinements may be to consider the pathways assumed in the initial assessment to confirm that they are valid and appropriately

[5] ICRP advice (ICRP 2005) is that if probabilistic assessments are carried out then the representative person should be defined such that the probability is less than 5 % that a person drawn at random from the population would receive a greater dose. This implies the use of a 95th percentile consumption and other habits rates. Joint guidance from the Food and Agriculture Organisation and the World Health Organisation is that when assessing exposure from contaminants in food 'higher percentiles' of the distribution of exposures should be considered. The Committee on Toxicology in Food, Consumer Products and the Environment (COT) which provides advice to the Food Standards Agency, the Department of Health and other Government Departments and Agencies, has endorsed the use of the 97.5th percentile for assessing exposure to contaminants in food.

parameterised for the situation. Adoption of elements of the NRPB and HPA approach for small users may also be considered.

It is unlikely that a full site-specific habits survey for a non-nuclear site would be justified, due to the high cost that might have to be borne by the small non-nuclear organisation involved. However, a smaller targeted survey may be appropriate, or targeted monitoring of the local environment.

APPENDIX D : OTHER APPROACHES TO THE USE OF HABITS DATA IN ASSESSMENTS

The other approaches considered comprise those adopted overseas, those used in other contexts such as in post-closure assessments of facilities for solid radioactive waste disposal, and those considered or adopted in the UK for both retrospective and prospective assessments.

D1 Approaches used overseas

There are a wide range of approaches to setting discharge authorisations and carrying out the related dose assessments in different countries in the world (Haywood, Cooper and Mansfield, 2000). In most cases dose assessments are carried out for hypothetical critical groups using generic habits data. Also, regulatory models with defined parameter values can be used in the assessment process, notably in the USA and Germany. Habits surveys play a much more limited role in assessments than is the case in the UK. However, habits surveys have been carried out in the Nord Cotentin region of France and the results have been used to estimate doses from the discharges from the Cap de la Hague nuclear site (GRNC, 2007).

D2 Approaches used in assessments of solid radioactive waste disposal

In the case of solid radioactive waste disposal, the assessment timescale is generally hundreds to many thousands of years into the future. Therefore, present-day land uses and habits in the vicinity of an existing or proposed disposal facility are not necessarily an appropriate basis for defining biosphere characteristics and human habits for use in post-closure performance assessments of such facilities. In consequence, an approach based on reference biosphere characteristics has been proposed and widely adopted internationally. This approach has been set out in detail in the IAEA Report on BIOMASS (2003) and further elaborated to take climate and landscape evolution into account in BIOCLIM (2004).

The BIOMASS methodology involves first defining the context within which the assessment is being performed. Within this context, biosphere system identification and justification is undertaken. This identifies the typology of the main components of the biosphere system using a series of tables, and determines whether and how biosphere change is to be represented. The biosphere systems identified through this process are then used to construct biosphere system descriptions using an approach that is based on the identification and characterisation of relevant Features, Events and Processes (FEPs) and involves the use of interaction matrices to represent the ways in which processes relate the various components of the biosphere systems of interest (see also IUR, 2006). In the original methodology, this process of analysis was applied to time-invariant biosphere states (BIOMASS, 2003), but it was subsequently also applied to periods of transition between such states (BIOCLIM, 2004).

It is within these defined reference biosphere states and transitions that Potentially Exposed Groups (PEGs) are defined. These correspond to the critical groups that are used in prospective assessments of radioactive waste discharges. However, explicit consideration is given to their likelihood of occurrence. Also, the methodology recognises two broad approaches to the definition of PEGs. These are characterised as the *a priori* and *a posteriori* methods. In the *a priori* method, the assumed habits of candidate critical groups are fixed prior to performing the exposure calculations, and the highest calculated dose to a representative member of any one of those groups then serves as an indicator of exposure. In the *a posteriori* approach, each pathway is assessed separately and the critical group is constructed in the light of the results obtained.

BIOMASS (2003) identifies deficiencies in both the pure *a priori* and *a posteriori* methods and recommends an approach that starts from a table of human activities leading to potential radiation exposure to identify groups whose activities would lead to a high degree of interaction with potentially contaminated environmental media in the biosphere system. An iterative approach is then adopted in which preliminary dose calculations are used to modify both exposure group characteristics and other assumptions in the calculations.

Although the approach used in assessments of solid radioactive waste disposal are of general interest, it is emphasised that for prospective assessments of radiation exposures from existing facilities:

- During the period of applicability of a proposed discharge authorisation, the environment in which the critical group is present will not change to a significant degree, so there is no need to identify groups living in environments analogous to potential future climatic and landscape characteristics of the site of interest;

- Because the period of application is short, the habits of critical groups can legitimately be based on data from surveys around a site or on generic data applicable at the present day, though with adjustments to achieve future proofing; in this context use of an *a priori* approach, in which the habits of critical groups are fixed before the assessment is undertaken is well justified.

Notwithstanding this last comment, it is noted that the ‘top two’ approach (see Section D3.1) does involve an *a posteriori* adjustment of the critical group habits, based on an examination of the relative radiological significance of the different pathways of exposure.

APPENDIX E :APPROACHES ADOPTED OR CONSIDERED IN THE UK

E1 Historical approaches used by MAFF and FSA

Historically MAFF and later the Food Standards Agency adopted various approaches to the use of terrestrial and aquatic habits data in prospective dose assessments.

Early on, for terrestrial foods the 'top two' method was used. In this method, consumption rate data from the National Diet and Nutrition Survey (NDNS) as reported in Byrom et al (1995) were used. For each food group under consideration, the annual effective doses that would be received by consumption at both the 'critical group' (97.5th percentile) and average consumption rates were evaluated. For the two foods that gave the largest contributions to annual effective dose the 'critical group' rate was used. For all other foods, the average consumption rates were used. The annual effective doses for all food groups were summed to give a total annual effective dose. This calculation was repeated for three age groups (adult, child and infant) and in some cases also for a fourth (adolescent) group, and the annual effective dose for the age group receiving the highest assessed annual effective dose was reported as the critical group dose.

On occasions, the annual effective dose that would be received as a result of consuming all food groups at the average consumption rates was also calculated.

For aquatic foodstuffs and exposure pathways, data were available from site-specific habits surveys. In this case, for each of the food groups or exposure pathways the individuals who had a consumption rates or occupancies between the maximum observed value and one third of the maximum value were identified. The mean rate for this group was calculated. This calculation was carried out separately for each food group or pathway and the rates or occupancies calculated were used as the 'critical group' values. Total critical group doses were calculated by adding the annual effective doses received *via* the separate pathways and food groups. As experience had shown that adult doses would be greater than those of other age groups, due to their higher consumption of fish, molluscs and crustaceans, calculations were carried out for adults only.

No attempts were made to combine the assessed doses from the terrestrial and aquatic discharges other than by simple addition.

This approach suffered from the drawback that doses from terrestrial foods were calculated making use of data on the consumption of foods from all sources, rather than by considering only locally derived foods.

E1.1 Individual method

When the programme of terrestrial habits surveys commenced, it became possible to use the rates of consumption of locally produced foods in both retrospective and prospective dose assessments. The first method proposed and used by the FSA was presented to the 5th meeting of the NDAWG (Paper 5-02: The FSA Assessment Methodology, http://www.ndawg.org/documents/Paper5-02.pdf) in April 2004.

This method was termed 'individual' consisted of creating two combined data sets from the habit surveys; one for the coastal sites and one for the inland sites. (In the case of children and infants, these data sets were constructed by adding adult consumption data scaled by the ratios of child and infant consumption rates as reported by Byrom et al (1995)). For each individual in the appropriate data set, annual effective doses from all pathways were calculated and a total dose calculated by addition. This resulted in a distribution of annual effective doses that could be received. The 97.5th percentile of this distribution was reported as the 'possible dose' and the median value as the 'probable dose'. Aquatic doses were calculated in a similar manner using data from the site-specific habit surveys and total doses for both terrestrial and aquatic exposure were obtained by addition.

Following discussion at the 5th NDAWG meeting (Paper 6-01: Summary of Agreements and Actions from the 5th Meeting. http://www.ndawg.org/documents/Paper6-01.pdf) this method was discontinued because of the difficulty of interpreting the outputs in terms of defining the critical group and its dose from the outputs.

E2 Current approach used by the FSA

Currently the method used is the 'adjusted profiles' method - a variation on the 'profiles' method developed for use in the retrospective assessments and published in RIFE (Camplin et al, 2005). Appendix F gives a worked example of the application of the adjusted profiles method). The adjustments to the 'profiles' method as used for the production of the RIFE report are:

- Rounding of the habits rate values to avoid an impression of undue precision;
- Using occupancy rates such that the total occupancy exposed to activity in the plume and from activity incorporated in sediments totals 8000 hours in a year.

Rounding has been performed on an *ad hoc* basis. However, in the course of preparation of this paper a codification of the rounding rules adopted has been developed. This codification is shown in Table E1.

Table E1: Codification of Rounding Rules for Use in the 'Adjusted Profiles' Method

Range of Original Value	Rounding Rule
0.1 to 0.99	Round to 1
1 to 4.99	Round up to nearest integer
5 to 9.99	Round up to 7.5 or 10
10 to 99.9	Round up to nearest number divisible by 2.5
> 100	Round up to nearest number divisible by 10

Note: These rounding rules apply to annual rates of consumption of foods in units of kg y^{-1} or L a^{-1} and to occupancies in units of h y^{-1}. Non-zero values of <0.1 are not used, so all positive values of <1.0 are rounded up to 1.

It is noted that, when developing the 'profiles' method for use in the RIFE report, a number of other potential methods were considered (Camplin et al, 2005). Although these methods were not developed for use in prospective assessments they potentially could be used, either with or without modification. The methods are summarised below.

- Calculation of the annual effective dose received by each individual identified in the habits survey. This will result in a distribution of doses. Those individuals with doses between the maximum assessed and one third of the maximum are identified and the mean dose to this group is the dose to the representative individual.
- Calculation of the annual effective doses received by each individual identified in the habits survey. Those individuals with doses between the maximum assessed and one third of the maximum are identified. For each pathway, the mean rate of consumption or occupancy (excluding zero values) is calculated for this group. These rates are then used to calculate the dose to the representative individual.
- For each pathway, those individuals who have annual effective doses between the maximum and one third of the maximum are identified. For each pathway, the mean rate of consumption or occupancy is calculated. These rates are used to calculate the dose to the representative individual.

- For each pathway, those individuals who have annual effective doses between the maximum and one third of the maximum are identified. Both the mean rate and one third of the mean rate of consumption or occupancy are calculated. For the two pathways that give the maximum annual effective dose the mean rate is used for calculation of the dose to the representative individual. For any other pathway, one third of the mean rate for the group with annual effective doses for that pathway of between the maximum and one third of the maximum is used.

E3 Comparison of various past methods and the current methods

A comparison of the 'top two', using site specific data, 'top two' using generic national data, 'profiles' and 'adjusted profiles' methods has been performed for the purposes of this study. The generic national data that were used for this comparison are listed in Table E2.

Table E2: Generic Consumption Rates and Occupancies used in the 'Top Two' Method

Foodstuff or Occupancy	Higher rate	Mean Rate
Potato (kg y^{-1})	120.0	50.0
Milk (L y^{-1})	240.0	95.0
Beach/sediment occupancy (h y^{-1})	2000.0	300.0
Other vegetables (kg y^{-1})	50.0	20.0
Root vegetables (kg y^{-1})	40.0	10.0
Pig meat (kg y^{-1})	40.0	15.0
Cattle meat (kg y^{-1})	45.0	15.0
Green vegetables (kg y^{-1})	45.0	15.0
Domestic fruit (kg y^{-1})	75.0	20.0
Sheep meat (kg y^{-1})	25.0	8.0
Poultry (kg y^{-1})	30.0	10.0
Occupancy (h y^{-1})	7880.0	6000.0
Eggs (kg y^{-1})	25.0	9.5
Molluscs (kg y^{-1})	9.0	3.5
Fish (kg y^{-1})	40.0	15.0

Notes:

- The rates are based on those given in Smith and Jones (2003);
- As separate rates are not given by Smith and Jones (2003) for crustacea and molluscs the 'shellfish' rate has been used for mollusc consumption, as molluscs have, in these examples, a higher dose per unit consumption value;
- The higher rate for occupancy has been obtained by assuming 90% time at the location. The mean rate is the higher rate less 2880 hours corresponding approximately to 2000 hours at work elsewhere and an average of 2 hours a day spent elsewhere.

Care needs to be exercised using the occupancy and beach/sediment occupancy rates. If both are considered at high rates, this would correspond to a total greater than the number of hours in a year.

Overall results of that comparison, which was undertaken for Hinkley Point B and Sizewell B, are given in Table E3. Further details of the comparison are given in the following subsections.

Table E3: Comparison of Results of Alternative Dose Assessment Methodologies for Two UK Nuclear Licensed Sites

Site	Top Two Method		Generic Top Two		Profiles Method		Adjusted Profiles Method	
	Annual Effective Dose to Adults (μSv)	Comment	Annual Effective Dose to Adults (μSv)	Comment	Annual Effective Dose to Adults (μSv)	Comment	Annual Effective Dose to Adults (μSv)	Comment
Hinkley Point B	65.7	Top two pathways: potato and milk consumption	51.4	Top two pathways: potato and milk consumption	29.9	Root vegetable profile	39.4	Root vegetable profile
Sizewell B	26.2	Top two pathways: beach occupancy and milk	66.8	Top two pathways: beach occupancy and pig meat	24.6	Beach/sediment occupancy profile	26.4	Milk profile

It will be noted that the differences in the results obtained are no more than about a factor of two.

E3.1 Hinkley Point B

Consumption rates used in the Top Two method are shown in Table E4. The annual effective dose is assessed as 65.7 μSv for a high-rate consumer of potatoes and milk.

Table E4: Consumption Rates (kg y^{-1}) and occupancies (h y^{-1}) used in the Top Two Method for Hinkley Point B

Pathway	Higher Rate	Median Rate
Potato	100.0	58.5
Milk	207.4	137.5
Other vegetables	90.3	67.1
Beach/sediment	1515.0	228.0
Root vegetables	59.0	34.4
Pig meat	27.5	19.0
Cattle meat	58.1	38.8
Green vegetables	61.7	45.2
Domestic fruit	64.8	43.6
Sheep meat	35.2	28.1
Poultry	14.4	8.5
Occupancy	8143.0	2920.0
Eggs	35.3	18.5
Molluscs	1.9	1.9
Crustaceans	15.3	12.2
Fish	47.2	39.6

Characteristics of the various groups considered in the unadjusted profiles method are given in Table E5.

The dose obtained using the Hinkley Point specific top two method is approximately 28% greater than that obtained using the generic top two method. In both cases, the top two pathways are potato and milk consumption. Counter-intuitively both the top two rates are lower for Hinkley Point than for the generic data. The increase in the assessed dose is due to the majority of the rates considered at the median rate being greater for Hinkley Point than for the generic case.

Table E5: Annual Consumption Rates and Occupancies for Profiles at Hinkley Point B

Profile Name	Crustaceans	Eggs	Fish - Sea	Fruit - Domestic	Gamma ext. - Sediment[2]	Meat - Cow	Meat - Pork	Meat - Poultry	Meat - Sheep	Milk	Molluscs	Plume	Vegetables - Green	Vegetables - Other Domestic	Vegetables - Potatoes	Vegetables - Root
	kg	kg	kg	kg	h	kg	kg	kg	kg	l	kg	h	kg	kg	kg	kg
Crustacean consumers	12.2	0	44.2	0	1040	0	0	0	0	0	1.3	0	0	10	54.6	13.6
Egg consumers	0	18.5	0.3	9.5	10	0	0	0.6	0.3	0	0	90	20	20	16.3	12.8
Sea fish consumers	2.7	0	39.6	0	460	0	0	0	0	0	0.3	0	0	0	10.9	2.7
Domestic fruit consumers	0.1	2.9	0.5	43.6	10	8.6	2.5	2.6	2.3	15.4	0	0	30	30	40.2	20.7
Occupants for exposure - Sediment	3.1	0	23.4	0	1590	0	0	0	0	0	0.4	0	0	0	8.2	2
Cattle meat consumers	0	1.5	0.1	7.3	10	38.8	4.5	2	2.5	32.8	0	0	10	10	33.7	4.1
Pig meat consumers	0	0	0	3.7	10	16	19	1.7	0	40.4	0	0	0	0	20.8	1.5
Poultry meat consumers	0.1	1.3	0.3	17.1	0	38.7	6.9	8.5	0	28.8	0	10	10	10	27.5	7.9
Sheep meat consumers	0	0.1	0.3	12.3	0	12.9	0	1.5	8.1	4.7	0	0	10	10	16.1	5.5
Milk consumers	0	0.5	0.2	3.4	0	17.3	6.7	0.6	0	137.5	0	20	0	0	27.2	2.8
Mollusc consumers	15.3	0	44.2	0	1560	0	0	0	0	0	1.9	0	0	10	41	10.2
Occupants for plume pathways	0	2.4	0	0	40	3.2	0	0	0	24.3	0	440	0	0	0	0
Green vegetable consumers	0.1	5.9	0.7	49.4	20	0	0	1.4	4.2	9.1	0	0	50	50	41.7	29.5
Other domestic vegetable consumers	0.1	8.9	0.9	42.5	20	0	0	1.8	5.7	12.1	0	0	50	70	34.4	29.3
Potato consumers	0.7	1.5	3	21	50	10.3	2.9	1.2	2.4	30.6	0.1	0	20	20	58.5	20.8
Root vegetable consumers	0.1	3.2	0.7	37.4	10	11.8	0	1.7	3.2	21.2	0	0	30	30	65.7	34.4

Annual effective doses for each of the profiles are listed in Table E6. It should be noted that a wide variety of profiles give annual effective doses of between 17 and 30 µSv.

Table E6: Annual Effective Doses for Different Profiles at Hinkley Point B

Profile Name	Annual Effective Dose (µSv)
Crustacean consumers	18.51
Egg consumers	10.51
Sea fish consumers	4.87
Domestic fruit consumers	23.05
Occupants for exposure - Sediment	8.85
Cattle meat consumers	17.21
Pig meat consumers	11.63
Poultry meat consumers	17.47
Sheep meat consumers	9.87
Milk consumers	17.07
Mollusc consumers	17.71
Occupants for plume pathways	2.05
Green vegetable consumers	28.23
Other domestic vegetable consumers	29.51
Potato consumers	24.08
Root vegetable consumers	29.89

Adjusted profiles were developed for Hinkley Point B, using the principles set out in this appendix. Details of these adjusted profiles are given in Table E7.

Table E7: Annual Consumption Rates and Occupancies for Adjusted Profiles at Hinkley Point B

Profile Name	Crustaceans	Eggs	Fish - Sea	Fruit - Domestic	Gamma ext - Sediment[2]	Meat - Cow	Meat - Pork	Meat - Poultry	Meat - Sheep	Milk	Molluscs	Plume	Vegetables - Green	Vegetables - Other Domestic	Vegetables - Potatoes	Vegetables - Root
	kg	kg	kg	kg	h	kg	kg	kg	kg	l	kg	h	kg	kg	kg	kg
Crustacean consumers	12.5	0	45	0	2000	0	0	0	0	0	2	6000	0	10	55	15
Egg consumers	0	20	1	10	2000	0	0	1	1	0	0	6000	20	20	20	15
Sea fish consumers	3	0	40	0	2000	0	0	0	0	0	0.3	6000	0	0	10.9	2.7
Domestic fruit consumers	1	3	1	45	2000	10	2.5	3	3	17.5	0	6000	30	30	40	21
Occupants for exposure - Sediment	3.5	0	25	0	2000	0	0	0	0	0	1	6000	0	0	10	2
Cattle meat consumers	0	1.5	1	7.5	2000	40	5	2	2.5	35	0	6000	10	10	35	5
Pig meat consumers	0	0	0	4	2000	17.5	20	2	0	42.5	0	6000	0	0	22.5	2
Poultry meat consumers	1	2	1	17.5	2000	40	7.5	10	0	30	0	6000	10	10	27.5	8
Sheep meat consumers	0	1	1	12.5	2000	15	0	2	10	5	0	6000	10	10	17.5	6
Milk consumers	0	1	1	4	2000	17.5	7.5	1	0	140	0	6000	0	0	27.5	3
Mollusc consumers	7.5	0	45	0	2000	0	0	0	0	0	2	6000	0	10	42.5	11
Occupants for plume pathways	0	2.5	0	0	2000	4	0	0	0	25	0	6000	0	0	0	0
Green vegetable consumers	1	6	1	50	2000	0	0	2	5	10	0	6000	50	50	42.5	30
Other domestic vegetable consumers	1	10	1	42.5	2000	0	0	2	6	12.5	0	6000	50	70	35	30
Potato consumers	1	2	3	22.5	2000	12.5	3	2	2.5	32.5	1	6000	20	20	60	22.5
Root vegetable consumers	1	4	1	37.5	2000	12.5	0	2	4	22.5	0	6000	30	30	67.5	35

Annual effective doses for these adjusted profiles are shown in Table D8. These annual effective doses are given in absolute terms and also as percentages of the values for the unadjusted profiles.

Table E8: Annual Effective Doses for Adjusted Profiles at Hinkley Point B

Profile Name	Annual Effective Dose (μSv)	Percentage of Value for the Unadjusted Profile
Crustacean consumers	23.19	125
Egg consumers	20.42	194
Sea fish consumers	11.69	240
Domestic fruit consumers	32.29	140
Occupants for exposure - Sediment	11.25	127
Cattle meat consumers	26.68	155
Pig meat consumers	21.23	183
Poultry meat consumers	26.72	153
Sheep meat consumers	19.56	198
Milk consumers	26.30	154
Mollusc consumers	20.22	114
Occupants for plume pathways	10.76	525
Green vegetable consumers	37.40	132
Other domestic vegetable consumers	38.51	130
Potato consumers	33.73	140
Root vegetable consumers	39.36	132

The cautious nature of the change in moving from the original to the adjusted profiles is well illustrated by the percentages of the values for the adjusted profile, all of which are larger than 100. Also, the low-dose profiles tend to increase more than the high-dose profiles, leading to a reduction in the range of annual effective doses assessed for the various profiles.

E3.2 Sizewell B

Consumption rates used in the Top Two method are shown in Table E9. The annual effective dose is assessed as 26.2 μSv for a high-rate consumer of potatoes and milk.

Table E9: Consumption Rates (kg y^{-1}) and occupancies (h y^{-1}) used in the Top Two Method for Sizewell B

Pathway	Higher Rate	Median Rate
Beach	729	181
Milk	210.4	208.4
Cattle meat	47.3	28
Pig meat	25.3	22
Potato	117.9	73.9
Other veg	71.8	55.2
Domestic Fruit	63.9	41.8
Molluscs	6.2	5.1
Poultry	28.5	19.2
Eggs	25.4	15.5
Occupancy	8341	3319
Crustaceans	11.2	7.8
Green vegetables	38.6	28.6
Fish	28.9	23
Root vegetables	86.2	47.7
Sheep meat	2.8	2.4

Characteristics of the various groups considered in the unadjusted profiles method are given in Table E10.

In the case of Sizewell B, the generic top two data gives a dose approximately 2.5 times greater than the use of the Sizewell top two data. This is a result of the dose being dominated by exposure to radiation arising from radioactive material incorporated into beach material/sediment. The generic higher occupancy rate is 2000 hours per year compared with the rate from the Sizewell data of 729 hours per year.

Table E10: Annual Consumption Rates and Occupancies for Profiles at Sizewell B

Profile Name	Crustaceans	Eggs	Fish - Sea	Fruit - Domestic	Gamma ext - Sediment[1]	Meat - Cattle	Meat - Pig	Meat - Poultry	Meat - Sheep	Milk	Molluscs	Plume	Vegetables - Green	Vegetables - Other Domestic	Vegetables - Potatoes	Vegetables - Root
	kg	kg	kg	kg	h	kg	kg	kg	kg	l	kg	h	kg	kg	kg	kg
Crustacean consumers	11.2		26.7		83						1.6					
Egg consumers	0.2	15.5	1.2	0.3	67		4.3	5.3	0.5	43.7		351	8.2	13.0	44.8	8.3
Sea fish consumers	2.1		23.0	0.6	81			0.1			0.5		0.3	0.7	2.0	1.4
Domestic fruit consumers	0.3		4.7	41.8	123								18.8	45.6	58.2	26.6
Occupants for exposure - Sediment	0.5	2.0	8.8		731			1.1				751			2.7	1.5
Cattle meat consumers		0.7	0.4	0.6		28	4.7	0.9	0.7	52.6			8.7	4.5	6.8	9.2
Pig meat consumers		5.6	0.9			9.5	22	1.6	1.5	125.0			0.4	2.1	10.2	1.3
Poultry meat consumers	0.4	8.9	2.6	3.5	181			19.2					2.6		21.9	4.4
Sheep meat consumers		9.4	1.5			15.8	19.8	2.6	2.4	208.4			0.6	3.5	16.9	2.2
Milk consumers		9.4	1.5			15.8	19.8	2.6	2.4	208.4			0.6	3.5	16.9	2.2
Mollusc consumers	9.3		16.2		50						5.1					
Occupants for plume pathways (inner area)	0.5	1.1	0.5	0.6								7150		1.8	9.6	1.7
Green vegetable consumers	0.1	1.2	1.8	8.4	7	0.9							28.6	37.0	55.9	37.6
Other domestic vegetable consumers	0.2	1.9	2.1	4.5	11								31.1	55.2	62.9	52.0
Potato consumers	0.1	4.0	0.5	2.9	130			1.8				327	17.5	26.5	73.9	27.9
Root vegetable consumers	0.1	0.3	1.4	5.4	198	1.3							26.4	42.5	63.2	47.7

Annual effective doses for each of the profiles are listed in Table E11. It should be noted that, in contrast to the situation at Hinkley Point B, a single profile gives by far the largest annual effective dose.

Table E11: Annual Effective Doses for Different Profiles at Sizewell B

Profile Name	Annual Effective Dose (μSv)
Crustacean consumers	3.06
Egg consumers	2.79
Sea fish consumers	2.85
Domestic fruit consumers	4.82
Occupants for exposure - Sediment	24.57
Cattle meat consumers	0.56
Pig meat consumers	0.84
Poultry meat consumers	6.32
Sheep meat consumers	1.13
Milk consumers	1.13
Mollusc consumers	2.00
Occupants for plume pathways	0.18
Green vegetable consumers	0.79
Other domestic vegetable consumers	1.05
Potato consumers	4.86
Root vegetable consumers	7.23

Adjusted profiles were developed for Sizewell B, using the principles set out in this appendix. Details of these adjusted profiles are given in Table E12.

Table E12: Annual Consumption Rates and Occupancies for Adjusted Profiles at Sizewell B

Profile Name	Crustaceans	Eggs	Fish - Sea	Fruit - Domestic	Gamma ext - Sediment[1]	Meat - Cattle	Meat - Pig	Meat - Poultry	Meat - Sheep	Milk	Molluscs	Plume	Vegetables - Green	Vegetables - Other Domestic	Vegetables - Potatoes	Vegetables - Root
	kg	kg	kg	kg	h	kg	kg	kg	kg	l	kg	h	kg	kg	kg	kg
Crustacean consumers	12.5	0	45	0	2000	0	0	0	0	0	2	6000	0	10	55	15
Egg consumers	0	20	1	10	2000	0	0	1	1	0	0	6000	20	20	20	15
Sea fish consumers	3	0	40	0	2000	0	0	0	0	0	0.3	6000	0	0	10.9	2.7
Domestic fruit consumers	1	3	1	45	2000	10	2.5	3	3	17.5	0	6000	30	30	40	21
Occupants for exposure - Sediment	3.5	0	25	0	2000	0	0	0	0	0	1	6000	0	0	10	2
Cattle meat consumers	0	1.5	1	7.5	2000	40	5	2	2.5	35	0	6000	10	10	35	5
Pig meat consumers	0	0	0	4	2000	17.5	20	2	0	42.5	0	6000	0	0	22.5	2
Poultry meat consumers	1	2	1	17.5	2000	40	7.5	10	0	30	0	6000	10	10	27.5	8
Sheep meat consumers	0	1	1	12.5	2000	15	0	2	10	5	0	6000	10	10	17.5	6
Milk consumers	0	1	1	4	2000	17.5	7.5	1	0	140	0	6000	0	0	27.5	3
Mollusc consumers	7.5	0	45	0	2000	0	0	0	0	0	2	6000	0	10	42.5	11
Occupants for plume pathways (inner area)	0	2.5	0	0	2000	4	0	0	0	25	0	6000	0	0	0	0
Green vegetable consumers	1	6	1	50	2000	0	0	2	5	10	0	6000	50	50	42.5	30
Other domestic vegetable consumers	1	10	1	42.5	2000	0	0	2	6	12.5	0	6000	50	70	35	30
Potato consumers	1	2	3	22.5	2000	12.5	3	2	2.5	32.5	1	6000	20	20	60	22.5
Root vegetable consumers	1	4	1	37.5	2000	12.5	0	2	4	22.5	0	6000	30	30	67.5	35

Annual effective doses for these adjusted profiles are shown in Table E13. These annual effective doses are given in absolute terms and also as percentages of the values for the unadjusted profiles.

Table E13: Annual Effective Doses for Adjusted Profiles at Sizewell B

Profile Name	Annual Effective Dose (μSv)	Percentage of Value for the Unadjusted Profile
Crustacean consumers	25.55	835
Egg consumers	25.86	927
Sea fish consumers	25.42	892
Domestic fruit consumers	25.98	539
Occupants for exposure - Sediment	25.33	103
Cattle meat consumers	25.85	4616
Pig meat consumers	26.13	3111
Poultry meat consumers	25.53	404
Sheep meat consumers	26.42	2338
Milk consumers	26.42	2338
Mollusc consumers	25.62	1281
Occupants for plume pathways	25.32	14067
Green vegetable consumers	25.85	3272
Other domestic vegetable consumers	25.97	2473
Potato consumers	25.78	530
Root vegetable consumers	25.89	358

The cautious nature of the change in moving from the original to the adjusted profiles is again well illustrated by the percentages of the values for the unadjusted profile, all of which are larger than 100. However, the key factor to note is that the values for all the adjusted profiles are almost identical. This arises because occupancies of sediments and for plume exposure are set equal in all the adjusted profiles (see Table E12).

APPENDIX F : EXAMPLE OF APPLICATION OF THE PROFILES METHOD

The use of habit data to derive profiles is illustrated below. In order to allow the easy presentation of the tables a sub set of the data from a habits survey has been used. Real survey data will contain significantly more pathways and more individuals. However, the principles described will be the same.

Step 1

The relevant habits survey data are obtained.

Observation number	Fish	Green vegetables	Root vegetables	Potato	Domestic fruit	Milk	Indoor occupancy	Outdoor occupancy
1	17.0				4.5	365.0	1598	282
2	23.0	14.9	1.8	3.6		365.0	1598	282
3	9.8		2.5		5.7		1598	282
4	8.3	27.3	17.5	82.6		285.2	5557	650
5	8.2				0.9	285.2	7440	868
6	5.0	27.3	17.5	82.6		285.2	6814	410
7	5.0	27.3	17.5	82.6		103.7	6052	410
8	4.9			25.0	3.4	91.3	7269	364
9	4.8	27.3	17.5	82.6		285.2	6672	542
10	4.2				0.9		1081	1081
13	3.5		2.5		3.4		1598	282
14	3.1					273.8	4340	4200
16	2.6				4.5	365.0	1598	282
17	2.4	14.9	1.8	3.6		365.0	1598	282
18	2.3	14.3	0.7	20.5	0.5	273.8		2184
19	2.3	27.1	20.8	16.4	5.7	365.0	500	1997
20	2.3	14.9	1.8	3.6		365.0	1598	282
21	2.0	14.9	1.8	3.6		284.2	1598	282
22	0.8			25.0	3.4	91.3	1440	360
23		14.3	0.7	20.5	0.5			2184
24		2.7			38.5	365.0	5551	1092
25		2.7			38.5		1081	1081
26		27.1	20.8	16.4		91.3		365
27					3.4	91.3	1598	282
28						365.0	1598	282
29		14.9	1.8	3.6		365.0	1598	282
30						284.2	4811	208

Step 2

For the first pathway, in this case fish, the data are ordered by descending rate of this pathway. Those individuals who have consumption rates between the maximum and 1/3rd of the maximum are identified (highlighted in yellow below).

Observation number	Fish	Green vegetables	Root vegetables	Potato	Domestic fruit	Milk	Indoor occupancy	Outdoor occupancy
2	23.0	14.9	1.8	3.6		365.0	1598	282
1	17.0				4.5	365.0	1598	282
3	9.8		2.5		5.7		1598	282
4	8.3	27.3	17.5	82.6		285.2	5557	650
5	8.2				0.9	285.2	7440	868
6	5.0	27.3	17.5	82.6		285.2	6814	410
7	5.0	27.3	17.5	82.6		103.7	6052	410
8	4.9			25.0	3.4	91.3	7269	364
9	4.8	27.3	17.5	82.6		285.2	6672	542
10	4.2				0.9		1081	1081
13	3.5		2.5		3.4		1598	282
14	3.1					273.8	4340	4200
16	2.6				4.5	365.0	1598	282
17	2.4	14.9	1.8	3.6		365.0	1598	282
18	2.3	14.3	0.7	20.5	0.5	273.8		2184
19	2.3	27.1	20.8	16.4	5.7	365.0	500	1997
20	2.3	14.9	1.8	3.6		365.0	1598	282
21	2.0	14.9	1.8	3.6		284.2	1598	282
22	0.8			25.0	3.4	91.3	1440	360
23		14.3	0.7	20.5	0.5			2184
24		2.7			38.5	365.0	5551	1092
25		2.7			38.5		1081	1081
26		27.1	20.8	16.4		91.3		365
27					3.4	91.3	1598	282
28						365.0	1598	282
29		14.9	1.8	3.6		365.0	1598	282
30						284.2	4811	208

Step 3

For this subset of the population the mean rates for all pathways are calculated.

Observation number	Fish	Green vegetables	Root vegetables	Potato	Domestic fruit	Milk	Indoor occupancy	Outdoor occupancy
2	23.0	14.9	1.8	3.6		365.0	1598	282
1	17.0				4.5	365.0	1598	282
3	9.8		2.5		5.7		1598	282
4	8.3	27.3	17.5	82.6		285.2	5557	650
5	8.2				0.9	285.2	7440	868
Mean Rate	**13.2**	**21.1**	**7.3**	**43.1**	**3.7**	**325.1**	**3558.2**	**472.8**

These mean rates then form the rates for the fish consumption group (referred to as the fish profile)

Step 4

The process is then repeated for the next habit (in this case consumption of green vegetables).

Observation number	Fish	Green vegetables	Root vegetables	Potato	Domestic fruit	Milk	Indoor occupancy	Outdoor occupancy
4	8.3	27.3	17.5	82.6		285.2	5557	650
6	5.0	27.3	17.5	82.6		285.2	6814	410
7	5.0	27.3	17.5	82.6		103.7	6052	410
9	4.8	27.3	17.5	82.6		285.2	6672	542
19	2.3	27.1	20.8	16.4	5.7	365.0	500	1997
26		27.1	20.8	16.4		91.3		365
2	23.0	14.9	1.8	3.6		365.0	1598	282
17	2.4	14.9	1.8	3.6		365.0	1598	282
20	2.3	14.9	1.8	3.6		365.0	1598	282
21	2.0	14.9	1.8	3.6		284.2	1598	282
29		14.9	1.8	3.6		365.0	1598	282
18	2.3	14.3	0.7	20.5	0.5	273.8		2184
23		14.3	0.7	20.5	0.5			2184
24		2.7			38.5	365.0	5551	1092
25		2.7			38.5		1081	1081
1	17.0				4.5	365.0	1598	282
3	9.8		2.5		5.7		1598	282
5	8.2				0.9	285.2	7440	868
8	4.9			25.0	3.4	91.3	7269	364
10	4.2				0.9		1081	1081
13	3.5		2.5		3.4		1598	282
14	3.1					273.8	4340	4200
16	2.6				4.5	365.0	1598	282
22	0.8			25.0	3.4	91.3	1440	360
27					3.4	91.3	1598	282
28						365.0	1598	282
30						284.2	4811	208

And the mean rates are again calculated to give the rates for the green vegetable profile.

Observation number	Fish	Green vegetables	Root vegetables	Potato	Domestic fruit	Milk	Indoor occupancy	Outdoor occupancy
4	8.3	**27.3**	17.5	**82.6**		**285.2**	5557	650
6	5.0	**27.3**	17.5	**82.6**		**285.2**	6814	410
7	5.0	**27.3**	17.5	**82.6**		103.7	6052	410
9	4.8	**27.3**	17.5	**82.6**		**285.2**	6672	542
19	2.3	**27.1**	20.8	16.4	5.7	**365.0**	500	1997
26		**27.1**	20.8	16.4		91.3		365
2	**23.0**	**14.9**	1.8	3.6		**365.0**	1598	282
17	2.4	**14.9**	1.8	3.6		**365.0**	1598	282
20	2.3	**14.9**	1.8	3.6		**365.0**	1598	282
21	2.0	**14.9**	1.8	3.6		**284.2**	1598	282
29		**14.9**	1.8	3.6		**365.0**	1598	282
18	2.3	**14.3**	0.7	20.5	0.5	**273.8**		2184
23		**14.3**	0.7	20.5	0.5			2184
Mean Rate	**5.7**	**20.5**	**9.4**	**32.5**	**2.2**	**286.1**	**3358.5**	**780.9**

The process is then repeated until profiles have been calculated for all pathways.

APPENDIX G : EVALUATION OF THE VARIOUS APPROACHES TO THE USE OF HABITS DATA AGAINST THE PRINCIPLES FOR PROSPECTIVE DOSE ASSESSMENTS

The various proposed approaches for using habits data are evaluated against the twelve principles from EA et al (2002) in the following summary analysis.

Principle 1: Workers who are exposed to discharges of radioactive waste, but do not receive direct tangible benefits from the organisation making the discharge, should be treated as if they are members of the public for the purpose of determining discharge authorisations.

There is an expectation that all assessments would take such workers into account where appropriate. However habits data collected around some sites may not have included relevant workers. The NRPB-W63 and the EA screening approaches explicitly include some workers of this type.

Principle 2: The mean critical group dose should be assessed for the purpose of determining discharge authorisations.

The majority of the methods for processing the habits data point in this direction. Profiles and adjusted profiles are the closest to meeting principle 2. Individual-related approaches are less good as they do not consider an homogeneous group. The generic top two and local top two approaches relate to artificially constructed groups. NRPB-W63 and the EA screening method use generic habits data that cannot be shown to be applicable in a specific context, though they were selected to cover a wide range of pathways of exposure and parameterised to be broadly representative of the habits that would typically be characteristic of critical groups.

Principle 3: Doses to the most exposed age group should be assessed for the purposes of determining discharge authorisations.

All the methods except W63 consider a range of age groups. W63 considers only adults.

Principle 4: Critical group doses to be assessed for comparison with the source constraint and, if appropriate, the site constraint should include all relevant future exposure pathways.

Methods that use site-specific habits data only consider pathways that are current around the site. These may be the relevant future exposure pathways. However there is no objective way to look for pathways that are not currently seen around the site.

Generic data used in the top two approach may not relate to the pathways currently seen or even pathways that are potentially relevant in the future.

NRPB-W63 and the EA screening assessment approach have fixed worse-case groups that may or may not be relevant exposure pathways today or in the future.

Principle 5: Significant additional doses to the critical group from historical discharges from the source being considered and doses from historical and future discharges and direct radiation from other relevant sources subject to control should be assessed and the total dose compared with the dose limit of 1 mSv y^{-1}.

Historical doses would normally be included using either the same habits assumptions as the prospective assessment or by using the habits used in retrospective assessments, in particular the RIFE report. If the profile method is used for the prospective assessment and combined with retrospective doses from RIFE, the habits will be very consistent.

If generic top two approach is used combined with past assessment of doses from RIFE the two set of habits data will not be the same – although the differences could be considered justified.

If W63 or the EA screening approach is used for the prospective element and the retrospective dose calculated using RIFE total retrospective doses, there will be considerable inconsistency in the two elements of the assessment.

Principle 6: Where estimates of the critical group dose exceed 0.02 mSv y^{-1}, the assessments should be refined and, where appropriate, more realistic assumptions made. However, sufficient caution should be retained in assessments to provide confidence that actual doses received by a representative member of the critical group will be below the dose limit.

Adopting a screening approach followed by a realistic assessment meets this principle.

Principle 7: The assessment of critical group doses should take account of accumulation of radionuclides in the environment from future discharges.

This is not directly applicable as it is a modelling issue.

Principle 8: The realistic habits adopted for the critical group should be those which are actually observed year-on-year at the site, or at similar sites elsewhere, either currently or in the recent past. Sustainable habits leading to greater exposure that are reasonably foreseeable over the period until the next review of the authorisation (about 5 years), should be considered.

This principle relates closely to that of future-proofing. Although site-specific habits data methods will meet the first part of this principle, they do not necessarily meet the second. In contrast, the generic top two approach can meet the second part but not the first.

NRPB-W63 and the EA screening approach exceed the second but do not meet the first.

Principle 9: Land use and infrastructure should have sufficient capacity to support the habits of the critical group. Any changes to land use and infrastructure should be reasonably foreseeable over the period until the next review of the authorisation (about 5 years) and be sustainable year-on-year for them to be considered.

With use of site-specific habit data then the first part of the principle is automatically and objectively met. The second part is subjective.

Selection of the generic top two can be adjusted to take land use into account.

NRPB-W63 and the EA screening approach cannot easily meet this principle as assumptions are "hardwired" into these two approaches. The only flexibility to vary the assumptions is to ignore a pathway and the doses that are evidently absent.

Principle 10: The dose assessed for operational short-term release at proposed notification levels or limits should be compared with the source constraint (maximum of 0.3 mSv y^{-1}) and the dose limit (1 mSv y^{-1}), taking into account other relevant contributions.

This principle does not distinguish between approaches.

Principle 11: For authorisation purposes, collective doses to the populations of UK, Europe and the World, truncated at 500 y, should be estimated

Not relevant.

Principle 12: Where the assessed mean critical group dose exceeds 0.02 mSv y^{-1}, the uncertainty and variability in the key assumptions for the dose assessment should be reviewed.

Not relevant.

A scoring evaluation was developed against these principles and is shown in the following table. The rounded scoring was carried across to the evaluation of options presented in Section 3 of the main text.

Compliance with Principle	Topic	Site-specific or realistic habits required in principle?	Subjective judgement about future required in principle?	Approach							
				EA Screen	NRPB-W63	Top Two: Generic Data	Top Two: Local Habits Survey	Profile	Adjusted Profile	Individual: Single Survey	Individual: Multi-Survey
1	Workers	No	No	4	4	1	5	5	5	5	5
2	Mean critical group dose	No	No	1	1	1	3	5	5	2	2
3	Age group	No	No	5	1	5	5	5	5	5	5
4	Future exposure	No	Yes	2	2	3	3	3	4	3	3
5	Inclusion of historical discharges	No	No	1	1	2	3	5	4	2	2
6	Refine assessment > 0.02 mSv y^{-1}	Yes	Yes	2	2	3	5	5	5	5	5
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	Site-specific habits but future proofed	Yes	Yes	2	2	2	3	3	5	3	3
9	Future land use	Yes	Yes	2	2	2	3	4	4	4	4
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Average				**2.375**	**1.875**	**2.375**	**3.75**	**4.375**	**4.625**	**3.625**	**3.625**
Rounded				**2**	**2**	**2**	**4**	**4**	**5**	**4**	**4**

APPENDIX H : RELEVANCE OF EVALUATION CRITERIA TO RETROSPECTIVE AND PROSPECTIVE ASSESSMENTS

Comparison of criteria used to judge the habits approach in prospective and retrospective dose assessments. Ease of application and compliance with the principles for prospective assessments are not included in this comparison.

Prospective assessments	Retrospective assessments	Comment
Transparency	Transparency	Broadly equivalent
Homogeneity	Homogeneity	Broadly equivalent
Realism	Rigour and realism	Similar
Robustness	N/A	No direct equivalent for retrospective assessments
Sustainability of habits over time	See comment	Retrospective assessments are repeated annually, but five-year rolling averages are used to limit inter-annual variability in assessment results. However, the underpinning habits surveys are often only repeated every 5 to 10 years, so consideration has to be given to this issue.
Defensibility	Rigour and realism	Similar
Future proof	See comment	Retrospective assessments are repeated annually, but five-year rolling averages are used to limit inter-annual variability in assessment results. However, the underpinning habits surveys are often only repeated every 5 to 10 years, so consideration has to be given to this issue.
N/A	Reproducibility	Similar to transparency

Criteria for assessing methods for habit data in retrospective assessments of total dose

1) Transparency – a measure of the ease with which others can understand how the calculations are performed and what they mean.

2) Homogeneity is the group receiving the dose relatively homogeneous with respect to age, diet and those aspects of behaviour that affect the dose received? This feature has been recommended as being one to use when defining a critical group.

3) Reproducibility – can the approach be easily used for an independent reassessment?

4) Rigour and realism – how good is the match with reality?

Criteria for assessing methods for habit data in prospective assessments of total dose

1) Transparency relates to the ease with which the approach can be understood, and the degree to which there is a straightforward and readily perceived relationship between the habits data used and the results obtained.

2) Homogeneity of habits addresses the issue of whether the approach ensures that the critical group adopted for assessment purposes is reasonably homogeneous with respect to habits and behaviour.

3) Realism addresses the issue of whether the habits of the group are closely related to what is observed at the present day, or what might reasonably be expected to be observed over the period for which an authorisation is expected to be applied before it is subject to review (typically about 5 years).

4) Robustness relates to the issue of whether the results of the assessment will remain broadly valid in the face of a range of changes in habits that could plausibly occur, but are not necessarily likely to occur over the period for which an authorisation is expected to be applied before it is subject to review.

5) Sustainability of habits recognises that observations of habits are typically snapshots made over a short interval against the need for a prospective assessment to stand for a number of years. It addresses the issue of whether the habits could persist over the period for which an authorisation is expected to be applied before it is subject to review, independent of any changes in the environment or decisions by individuals to modify their habits.

6) Defensibility relates to whether the approach can be justified to interested parties. It is related to transparency, internal coherence and the adoption of appropriate principles and assumptions. It can be considered to address the issue of whether the approach is acceptable to a reasonable person.

7) Future proof - is closely related to issues of robustness and sustainability, in that an assessment approach that gives results that are strongly affected by reasonable changes in habits will not be future proof. It addresses the issue of whether an authorisation would be significantly affected by changes in the environment that might affect habits.