NDAWG
National Dose Assessment Working Group

NDAWG/4/2005

Position paper on the collection and use of habits data for retrospective dose assessments

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NATIONAL DOSE ASSESSMENT WORKING GROUP

POSITION PAPER ON THE COLLECTION AND USE OF HABITS DATA FOR RETROSPECTIVE DOSE ASSESSMENTS

Contents

1.	**Introduction**	**1**
1.1	Background	1
1.2	Terms of Reference	1
1.3	Scope of the Paper	1
2.	**Current Approach to the Acquisition of Habits Data**	**2**
2.1	Regulatory Context	2
2.2	Habits Surveys related to Individual Sites	2
2.3	Cost Recovery and Availability of Results	3
2.4	Overall Approach Adopted in Habits Surveys	3
2.5	Stages of a Survey	4
2.6	Determination of Food Consumption Rates	4
2.7	Inclusion of Non-Food Pathways	5
2.8	Inclusion of Children	5
2.9	Surveys of Specific Areas	5
2.10	Requirements for Surveys related to Other Sites	5
3.	**Desirability of Complete or Sampling-based Habits Surveys**	**6**
3.1	Complete Survey	6
3.2	Sample Surveys	6
3.3	Complete Survey of a Sub-population	7
3.4	Overall View on the Strategy for Habits Surveys	7
4.	**Key Issues in the Collection and Application of Habits Data**	**10**
4.1	Consumption of Several Foodstuffs at High Rates	10
4.2	Collection and Application of Habits Data for Children and Infants	10
4.3	Problems of Sample Size	11
4.4	Relevance of the Total Dose Approach	11
4.5	Realism in the Consumption of Locally Produced Foods	11
4.6	Relationship between Habits Surveys and Monitoring	13
4.7	Non-food Exposure Pathways	13
4.8	Robustness of Occupancy Data	13
4.9	Ingested Soils and Sediments	14
5.	**Use of Critical Groups in Estimating Individual Exposure**	**14**
6.	**Conclusions and Recommendations**	**17**
6.1	Methods for Obtaining Integrated Habits Data associated with Particular Sites	17
6.2	What is Meant by 'Locally Produced Food'	18
6.3	Assumptions regarding where People are assumed to live and to obtain their Food in Dose Assessments together with the Combination of Pathways	19
6.4	Data Analysis including the Relationship between the Sample Population and Assessment of Individual Doses including the use of Critical Groups	19

6.5 The Adequacy of Data on Occupancy 20
6.6 The Use of National Survey Data and Site Specific Data 20
6.7 Use of Habits Survey and Dosimetric Data for Infants, Children and Adults (including Pregnant Women) 21

7. References 22

Appendix A: Integrated Habits Surveys 23
A.1 Introduction: Purposes of Surveys 23
A.2 A Brief History of Habits Surveys 24
A.3 Scope of Current Surveys 25
A.4 Conduct of Surveys 26
A.4.1 Planning 26
A.4.2 Fieldwork 26
A.4.3 Results of Surveys 27
A.5 Strengths and Weaknesses 28
A.6 Dose Assessments 28
A.7 Availability of Data and Reports 29

Appendix B: Rates of Consumption of Various Food Types as reported in Terrestrial Habit Surveys 33

1. Introduction

1.1 Background

Discharges of radioactive wastes occur from a range of facilities in the UK. These include nuclear power plants, nuclear reprocessing plants, hospitals, research establishments, sewage works, and industries processing Naturally Occurring Radioactive Materials (NORM). It is necessary to assess doses to members of the public due to such discharges for comparison with regulatory criteria and also for optimisation purposes. The types of dose of relevance include both effective dose and equivalent doses to specific organs and tissues (the skin and lens of the eye). In order to estimate such doses, information on the habits of individuals living in the vicinity of the installations from which the discharges occur is required. Such information comes from a range of sources. For nuclear facilities, extensive use is made of data collected from detailed surveys of the habits of individuals living in the vicinity. For other facilities, more reliance is placed on generic UK habits data including those from national dietary surveys. Decisions relevant to the determination of doses have to be made both in designing the surveys to be undertaken and in interpreting the results obtained. In view of the importance of this topic in the determination of individual doses, the National Dose Assessment Working Group (NDAWG) established a Habits Subgroup to review this issue. As a result of the deliberations of that Subgroup, this position paper has been produced to inform the ongoing work of the NDAWG.

This position paper has been produced in conformity to the Terms of Reference of the Habits Subgroup. Those Terms of Reference were agreed at the Fifth Meeting of the NDAWG and are reproduced below.

1.2 Terms of Reference

The aim of this subgroup is to consider the use of habits data in assessing individual doses and in defining critical groups. The initial emphasis was to be on retrospective assessments (doses from discharges and direct shine), but with prospective assessments to be considered at a later date. In particular, the subgroup was asked to consider:

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

1.3 Scope of the Paper

In Section 2, a brief account is provided of the approach that is currently adopted to obtaining integrated habits data (more details are given in Appendix A). This leads on to a discussion, in Section 3, of alternatives for sampling in such surveys. In the context of such surveys, a wide variety of issues arise with respect to the collection and application of habits data. These issues are addressed in Section 4 and include accounting for consumption of multiple food types at high rates, collection and application of habits

data for children and infants, issues of sample size, estimation of the total dose over all pathways, attaining realism in defining the consumption of locally produced foods, taking account of unusual foods, relationships between habits surveys and monitoring for environmental radioactivity, the relevance of non-food exposure pathways, the robustness of occupancy data, and ingestion of soils and sediments.

Although the effective dose limit and other equivalent dose limits for members of the public are defined on an individual basis, the critical group concept is often used to define representative habits that are used as a basis for calculating dose for the purpose of making comparisons with those limits, or with source- or site-related dose constraints. The validity of the critical group approach together with considerations in defining reasonable homogeneity of such a critical group, either in terms of habits or in terms of doses received, are addressed in Section 5.

Conclusions and recommendations for further work are provided in Section 6.

It is emphasised that this paper gives guidance on issues of principle and overall methodological considerations. It does not attempt to provide detailed guidance on the undertaking of habits surveys, nor does it include compilations of data arising from such surveys.

2. Current Approach to the Acquisition of Habits Data

2.1 Regulatory Context

The Environment Agencies have received direction from Government to ensure doses to the public do not exceed specified dose criteria. These include the dose limits in the EC Basic Safety Standards (BSS) Directive and also require consideration of the maximum source effective dose constraint of 0.3 mSv/y and site effective dose constraint of 0.5 mSv/y at the planning stage for discharges. The Food Standards Agency (FSA) requires information on radiation doses to members of the public to ensure that the food chain is protected. Also, the Nuclear Installations Inspectorate (NII) of the Health and Safety Executive (HSE) has a statutory responsibility to assess the degree of direct radiation exposure of members of the public from nuclear installations. In addressing the requirement to assess doses to the public, account needs to be taken of authorised discharges of radioactive wastes and direct emissions of ionising radiation. Dose assessments require a range of input data, including habits data. Habits data can be taken from UK-wide habits surveys (such as the National Diet and Nutrition Surveys) or from habits surveys local to a particular site. The latter data may be pooled over a number of sites or nationally to give more generic data. Such pooled data have sometimes been referred to as ‘national’ data, but this terminology invites confusion with UK-wide habits surveys, such as the National Diet and Nutrition Surveys, and is not used here.

2.2 Habits Surveys related to Individual Sites

Habits surveys are conducted around licensed nuclear installations on a regular basis, typically at intervals of several years for each installation. These surveys are site specific, rather than location specific, ie, they take into account groups that may be located at a distance from the site, but are more highly exposed because of particular pathways involving factors such as the export of foods produced locally to the installation. The aim has been to survey the habits of those individuals that are most exposed to discharges from a single site. Such individuals are identified by the survey organisation on a judgemental basis. Site-specific habit surveys ensure that relatively realistic site specific habits are available to make assessments of doses. This is

important around the main nuclear sites where use of national UK habit data may lead to an overestimate of doses relative to those assessed using site-specific data.

More details as to how integrated habits surveys around nuclear sites are conducted are provided in Appendix A.

Site-specific surveys have not, in general, been undertaken in relation to premises authorised to discharge radioactive wastes other than licensed nuclear sites. However, some non-site specific surveys have been undertaken (see below).

2.3 Cost Recovery and Availability of Results

Site-specific habits survey costs are directly recovered from nuclear sites under regulatory recharging schemes, following the polluter pays principle. The cost recovery scheme allows funding for an ongoing programme of habits surveys around nuclear sites. The ongoing programme ensures that regular surveys can be made and that a database of information can be established. Surveys can also be planned in advance to ensure that up to date information is available when authorisation reviews are carried out. Site-specific habits data defined through such surveys are generally less cautious than data gathered from national surveys, because they explicitly consider the fractions of food consumption from local sources, and allow a more realistic assessment of dose to be made (but see also Section 4.6). This consequently allows a more realistic assessment of the impact of the discharges.

Under the Environmental Information Regulations the results of habit surveys are available to all, including the site operators, with the exception of information that may infringe an individual's privacy.

2.4 Overall Approach Adopted in Habits Surveys

Until 2002, habit surveys around nuclear sites were separated into three; those related to the aquatic environment, the terrestrial environment and direct radiation, and were performed separately. Because the surveys were conducted separately, it was often not possible to establish the total habits of individuals and therefore total doses from combined pathways could not be determined in a realistic way.

The current tri-party programme for England and Wales (involving the EA, FSA and NII) was established in 2002. The habit surveys are combined such that integrated habits data appropriate to the surveyed population for aquatic, terrestrial and external pathways are available for use in assessing total dose. External pathways include direct shine from the facilities and exposure to contaminated environmental media, including soils and sediments, atmospheric plumes, water bodies and contaminated items, such as fishing gear. Similar arrangements for integrated habits surveys are being put in place for Scotland by the Scottish Environment Protection Agency (SEPA). There are currently no nuclear installations in Northern Ireland. If any surveys in Northern Ireland were required, they would be the responsibility of Department of Environment (NI).

The surveys exclude the habits of workers on site at the installation of interest, as the concern is only with exposure of members of the public. However, the habits of workers when not at work may be included in the survey, as they are then considered members of the public. Also, the habits of workers not directly involved in the use of radiation may be surveyed. Such workers include sewage treatment workers and farmers.

In undertaking the surveys, attention is concentrated on those who are likely to be most exposed from the site under consideration and the surveys can be considered to be 'targeted'. Those to be surveyed are identified by the survey team as likely to be the most exposed, with an aim to be comprehensive in respect of this sub-set of the

population. Although every effort is made to invite people to participate in a survey, it is their choice as to whether they accept or decline. This results in biasing of the sample. It is noted that this pre-selection of a subset of the local population ('targeting') needs to be recognized when interpreting the results obtained (see Section 3).

2.5 Stages of a Survey

There are three broad stages to each survey: planning, fieldwork and reporting. The planning process begins by assessing information from previous surveys in the light of possible changes both in site operations and local activities, what environmental monitoring is undertaken, the results of dose assessments and the specific requirements of the sponsors. Definition of the overall scope and design of a survey involves liaison between the surveying organization and the relevant national and local authorities. The process of survey involves contact being made with people in local organisations to obtain relevant information. These include the site operators, Defra and EA fisheries officers, Defra field officers, the local sea fisheries committee, the local councils, the local associations, allotment wardens, wildfowling organisations and the local tourist office. Through this liaison, local issues to be addressed in the survey are identified. A principal aim is to ensure that no pathways are missed in the survey, even though they may not be major contributors to dose.

Although each survey is conducted in a single campaign, account is taken of seasonal variations in consumption rates and occupancy factors in deriving data from the survey for use in assessment calculations. More generally, active follow-up of each survey is conducted by the surveying organization. Individuals may be contacted at a suitable time after the initial survey both for purposes of clarification and, if appropriate, to obtain assurance that their habits have not changed significantly from those reported. One reason for such change could be seasonal factors. In addition, 'diary studies' are used to reduce the chance that a survey is an unrepresentative snapshot of the habits of the individuals surveyed.

2.6 Determination of Food Consumption Rates

In terms of food consumption data, the surveys are directed to determining the consumption of locally produced or sourced food. Thus, individuals are asked whether the produce they eat is local, farm or home-produced, or locally caught (eg, fish and shellfish or game). It is considered appropriate to continue to place the emphasis on consumption of locally produced food, as imported food is less likely to be affected by discharges. Exported food is likely to be mixed with food from other sources. However, surveys may need to determine where food is being sent outside the local area, eg, the export of Morecambe Bay cockles to Europe, in case there are export routes to specialist processors or retailers that do not involve substantial dilution.

Results from aquatic surveys have shown that there are distinct localised patterns of occurrence and consumption of food, making site-specific habits data essential. In particular, some aquatic foods, such as shellfish, are available only from particular locations. It is not obvious that such clear distinctions apply with respect to terrestrial foods, which are not generally associated with such localised production, but it is considered prudent to assume that such distinctions may apply and to base assessments on site-specific habits data wherever possible. However, it is appropriate to compare such site-specific habits data with data from national surveys to identify any major differences, as these can be used to determine priorities for follow-up investigations. Although such differences could arise from limitations in either the local habits survey or the national survey, many of them will simply reflect differences between the local context and the overall national context. Wherever such differences arise, it is useful to understand the cause, so that the local habits data can be shown to be suitable for use in assessment studies.

2.7 Inclusion of Non-Food Pathways

Non-food pathways are included in habits surveys. External dose rates from the environment, atmospheric plumes or direct from the site may be detectable and need to be combined with occupancy data in the assessment of individual doses. Inhalation of atmospheric plumes may be important for dose and associated occupancy data are required. Sea spray is sometimes of concern, but generally leads to low doses. However, it is targeted as appropriate.

2.8 Inclusion of Children

Habits surveys include observations of children wherever possible, usually as a result of interviewing a spokesperson for the whole family. However, in many cases it is found that child data are sparse, and surrogate data are generated by scaling adult data with generic ratios derived from food surveys, or, for other pathways, on the basis of reasonable assumptions. Most radionuclides of importance in the aquatic environment have dose coefficients that are not significantly greater for children than for adults. This means that adult data are usually satisfactory for protection purposes, because of generally greater consumption and occupancy rates for adults than for children. However, among terrestrial foods, milk consumption by children and infants is usually higher than for adults, and the dose coefficients for many radionuclides of relevance (eg, I-131) decrease with increasing age. Thus, it is important to derive milk and other terrestrial food consumption rates typical of children and infants. This is usually achieved by reference to generic data (Byrom et al, 1995)

2.9 Surveys of Specific Areas

In addition to surveys carried out specifically to address exposures around nuclear sites, surveys can be carried out to inform assessments of doses to inhabitants of particular areas, due to the sources of radiation exposure which may affect them. These surveys are carried out to address the requirements of customers and are funded by them. Examples of surveys of this nature carried out in the past are those for Northern Ireland (CEFAS, 2002) and the Channel Islands.

2.10 Requirements for Surveys related to Other Sites

For other, non-nuclear, sites that are authorised to discharge radioactive wastes, habits surveys are not currently carried out on a regular basis. This is because the radiological impacts of most such sites taken separately are very small, so a specific survey is not warranted in each case, particularly as there are many more non-nuclear premises authorised to make discharges (about 800 in England and Wales) than there are licensed nuclear sites.

This position has long been recognised, so a cost recovery system to include habits surveys has not been established for non-nuclear sites and there is no regular funding stream available. The current position, therefore, is that it is not justified to set up and fund a regular habits survey programme. The advantage of not having a regular habits survey programme would appear to be that costs are minimised. However, when dose assessments around non-nuclear sites are made, habits data from UK-wide data sets must be used. These data often lead to more cautious assessments than would data from site-specific surveys and hence result in over-estimation of doses. Such over-estimated doses may lead to additional costs in the form of greater scrutiny of discharge authorisations, or restrictions on the authorised discharge limits, which may in turn lead to the need for engineered abatement such as decay storage.

At some locations there may be a number of non-nuclear sites in close proximity all discharging to the same part of the environment, frequently via a sewage works. In

these cases, contributions to effective dose from several sites may need to be taken into account. For this reason, a methodology for assessing effective doses from multiple sources has been developed (Hancox et al, 2002). The EA has also sponsored a study on modelling the combined impact of radionuclide discharges reaching rivers (Hilton et al, 2003). In the present context, the main implication is that there may be a need for habits surveys targeted on specific groups, eg, sewage workers, rather than related to specific sites authorised to discharge radioactive wastes.

3. Desirability of Complete or Sampling-based Habits Surveys

In principle, habits surveys around sites authorised for discharges of radioactive wastes could be for a number of purposes. They could be to provide input to an overall picture of exposures of the local population, or could be directed to quantifying the distribution of exposures in the most highly exposed subgroup or subgroups of that population. For any of these purposes, there are various options as to the extent of the survey. In broad terms, and in relation to the whole of the local population, the options comprise:

- Complete survey;
- Sample survey with random sampling;
- Sample survey with non-random sampling;
- Complete survey of a pre-defined sub-population selected with the aim of characterising the most highly exposed subgroups in the local population.

Surveys of populations remote from sites authorised to dispose of radioactive wastes may also be undertaken. These could be for the purposes of reassuring a particular population group, or could be required if it is identified that export of contaminated foods or other materials could result in doses to a remote population subgroup of comparable or greater magnitude than those to the most exposed local population subgroup. The options for different types of survey also apply in the context of surveys of such remote groups.

3.1 Complete Survey

A complete survey of the local population would be ideal, as the most exposed subgroups and individuals could be identified without ambiguity. However, in practice, it is unlikely to be possible to identify all members of such a population. Furthermore, even if they could be identified, not all individuals would necessarily wish to participate in the survey. However, the over-riding consideration is that such a survey would be extremely resource intensive. In practice, the relatively low doses received by individuals around sites in the UK do not justify the deployment of the level of resources that would be required to conduct such surveys on a regular basis.

3.2 Sample Surveys

To achieve a useful survey with more limited resources, reliance can be placed on statistical sampling techniques or on expert judgment to identify the sub-population or sub-populations of interest. Statistical sampling could be on a simple random basis. This would provide a good basis for characterizing typical individuals from the local population, but it is likely to be inadequate for identifying a representative number of individuals from the more highly exposed sub-populations. However, stratified or weighted sampling schemes can be developed that bias the sampling in a well-defined way to specific sub-populations. If this is done in an explicit manner, results from the survey will be susceptible to standard techniques of statistical analysis for data sets in which the individual samples do not have equal weight. In such an approach, there would be an element of judgment as to which sub-populations are likely to be most exposed, but the survey would not focus exclusively on those sub-populations.

However, this approach would probably require a preliminary, general survey of the whole local population in order to define the various sub-populations and determine their relative size. Therefore, the resources required would, almost certainly be greater than those required for the habits surveys as they are currently conducted (see Section 3.3 and Appendix A).

National Nutrition Survey habits data are, of course, obtained on a sampling basis. These data have a well-defined statistical interpretation at a national level, but this does not mean that they are appropriate to a local population. Considerable care has to be taken when employing national, or other generic, data to address local information deficiencies. Nevertheless, employment of such data can be useful, eg, in order to estimate whether a lack of local data is likely to contribute substantially to overall uncertainties in dose estimation.

3.3 Complete Survey of a Sub-population

The current approach is also based on expert judgment to identify those sub-populations that are likely to be most exposed. All other groups in the local population are subsequently excluded from consideration. However, within the identified sub-populations, an attempt is made to achieve complete coverage, recognizing that some relevant individuals may be missed or may decline to participate. This approach is adopted because the aim of the current integrated habits surveys programme is to obtain data relevant to assessing effective and equivalent doses to the most highly exposed members of the public around nuclear sites. This arises from the requirement to identify the critical group so that the critical group dose can be calculated. The surveys are therefore ‘targeted’.

In this context, it is important to note that the habits survey data have to be used in conjunction with environmental monitoring data to assess doses. As with the habits surveys, the relatively low doses received by individuals around sites in the UK do not justify detailed monitoring studies with a high degree of spatial and temporal resolution. To obtain statistically reliable information from which the distribution of radiation exposures to the whole of the population local to a site could be assessed would require a much broader base of information on environmental concentrations and dose rates than is currently available. In the current approach, there is a close feedback between habits surveys, environmental monitoring and radiological assessments. Thus, the habits surveys and monitoring together help to identify and quantify exposure pathways that require assessing, whereas the radiological assessments quantify both the absolute and relative importance of those pathways, so providing guidance on subsequent survey and monitoring requirements.

3.4 Overall View on the Strategy for Habits Surveys

Strong points of the different potential survey techniques and issues arising from their use are summarised in Table 1.

Table 1: Advantages of Various Survey Types and Issues Arising

Survey Type	Aspect	Strong Points	Issues
Complete survey of the local population as a whole	Conduct	a) Habits data for highly exposed individuals are likely to be obtained b) A clear definition of the limits of the survey is possible for atmospheric and direct-shine related pathways c) A link to consumption rates for local foods should be obtained and all relevant food types should be identified d) Potential for bias is limited	a) Expensive b) Considerable amounts of unnecessary data on individuals who have only low exposure may be obtained c) Survey extent and cost out of proportion to risk/dose d) May not be possible to reach and survey all individuals in the population d) May not be possible to define a 'full' survey for liquid discharges, as beach users and or consumers of aquatic foods may not live near the site and may be seasonal users/consumers e) Anonymity of individuals may be lost, in particular where there are unique or otherwise readily identifiable locations
	Use of results	a) Full 'statistical' use of the results in probabilistic assessments for atmospheric releases and direct shine pathways is likely to be valid b) Unlikely that doses would be underestimated, as the most exposed individuals should be surveyed	a) Full statistical use of the results in probabilistic assessments for groups exposed to liquid discharges may not be valid because of the possibility that relevant members of the population remote from the site have not been included

Table 1 Continued

Survey Type	Aspect	Strong Points	Issues
Sample survey with stratified or randomized sampling	Conduct	a) Standard approach to carrying out market-type surveys b) Anonymity of individuals will be maintained if unique or otherwise readily identifiable locations are not sampled c) Relatively inexpensive d) Low level of bias	a) The most highly exposed individuals are unlikely to occur as a normal distribution and there will be a strong geographical skew related to proximity to the site – high heterogeneity, with a few relatively highly exposed individuals, is likely and the most highly exposed individuals might be missed, even with a sophisticated sampling scheme
	Use of results	a) Full statistical use of the results in probabilistic assessments is likely to be valid	a) A link to consumption of local foods may not be obtained b) Doses may be missed, if some of the most exposed individuals are not sampled
'Targeted' survey (Sample survey with non-random, judgement-based sampling, including the current practice of 'complete' sampling of the targeted sub-population)	Conduct	a) Habit data for highly exposed individuals likely to be obtained b) A clear definition of the limits of the survey is possible for atmospheric and direct-shine related pathways c) A link to consumption rates for local foods should be obtained d) Relatively inexpensive e) Survey extent and cost in proportion to risk/dose f) Local issues can be addressed by targeting survey	a) Judgement required in selection of those surveyed b) Bias is inbuilt c) Approach needs clear explanation so that results are appropriately interpreted d) Anonymity of individuals may be lost, particularly when there are unique or otherwise readily identifiable locations
	Use of results	a) Unlikely that doses would be underestimated as the most highly exposed individuals should be surveyed	a) Limited ways in which the data can be used b) Full statistical use of the results in probabilistic assessments is unlikely to be valid

Overall, the regulators and the FSA consider that the most effective use of resources is to continue to focus on the sub-populations around sites that are likely to be subject to the highest exposures. In this context, it seems reasonable that these local sub-populations should be identified on the basis of experience by consultation between the relevant regulatory bodies and the survey organisation. However, as this identification is necessarily subjective, it should be presented explicitly, so that it can be readily scrutinised by interested parties. This suggests that each survey report needs to begin with a description of demography, land use and related issues for the area of interest. This material is already largely present in the reports that the subgroup examined.

Based on this description, local sub-populations with different broad characterisations of habits should be identified and an argument presented as to which of these populations are likely to be most highly exposed and, therefore, need to be included in the survey. At some sites, several such sub-populations may be identified, as it will not be clear, *a priori*, which will be the most highly exposed.

However, it may be useful to complement such focused surveys with occasional, more resource intensive, broadly based statistical surveys, as discussed in Section 3.2. By use of a preliminary overall survey of the population followed by weighted sampling of a full range of sub-groups from within that population, it should be possible both to demonstrate that the expert judgments made in defining the standard focused surveys are well justified and to provide a basis for relating the exposures of the most highly exposed and typically exposed individuals. However, it might well be appropriate to complement such broader based surveys with an enhanced programme of environmental monitoring.

Finally, it is noted that for installations other than licensed nuclear sites, it is not generally appropriate to conduct full surveys. In these circumstances, an initial assessment can be undertaken using generic data based on a mixture of national survey data and site-specific data from various sources (Smith and Jones, 2003). If this assessment reveals the potential for significant exposure by particular pathways, limited targeted local habits surveys could be undertaken. In this context, it is important that the national survey data are regularly updated. It is relevant to note that regularly updated national data are also required for radiological assessments related to licensed nuclear sites, eg, in scaling local survey results for infants and children.

4. Key Issues in the Collection and Application of Habits Data

4.1 Consumption of Several Foodstuffs at High Rates

Individuals may receive significant contributions to effective dose by consumption of several different foodstuffs at higher than average rates. This could be a substantial concern if the diet was partitioned into many detailed categories, for which information relevant to individuals were not available. If it was then assumed that only one of those foodstuffs was consumed at a high rate, with all the rest consumed at average rates, individual doses could be significantly underestimated.

However, in practice, the diet is partitioned into broad categories, commensurate with the level of detail available in the monitoring data. Analyses have shown that, at this level of aggregation, individuals typically consume only one or two of these broad categories of foodstuffs at high rates (see Appendix B). This matter has also been examined in detail by Hunt (2004), who has determined the pathways giving, in total, >90% of the mean dose to representative members of critical groups for various licensed nuclear sites in England and Wales. The most heterogeneous critical group comprises 65 infants in the Aldermaston area. Their mean annual effective dose was only 0.56 μSv. Of this 41%, 21%, 14% and 7% came from root vegetables, potatoes, fruit and green vegetables. These foods were consumed by between 56 and 63 members of the group. Milk was the other food of relevance, contributing 13% of the average effective dose, but only consumed by 8 members of the group. At other sites, a single type of food generally contributed more than 50%, and sometimes more than 90%, of the average dose and was consumed by most, or all, of the individuals in the group.

4.2 Collection and Application of Habits Data for Children and Infants

Data for children and infants may be used directly, if there are sufficient observations. However, more usually, data are sparse and, for protection purposes, surrogate data

need to be generated. Such surrogate data are derived by scaling adult values with generic ratios, derived from national food survey data (Byrom et al, 1995). Even where data for children and infants are available, these need to be treated with some care, as they are typically reported by the household representative, who will be an adult and not the child or infant under consideration. This means that the usual issue of recall bias will be compounded by the possibility that household representatives will not have an adequate appreciation of the habits of the children and infants on whose behalf they are responding, eg, in respect of occupancy of contaminated areas or consumption of local, wild foods.

4.3 Problems of Sample Size

Although local habits data are generally preferred to national data, additional considerations arise when the number of relevant local observations is small. This may be because a small number of infants and children are included in the survey, or because only a small number of local people consume a particular food type. In these circumstances, a comparison with national data may be illuminating. For example, if locally sourced consumption rates of a particular food type are much lower than typical total consumption rates from national data, it would be appropriate to investigate the reason for this. If it turns out to be because the food type is not produced locally in significant quantities, this may legitimise the use of a low consumption rate in assessment studies. However, if the food type is produced locally in significant quantities, the lack of high rate consumers may reflect a limitation in the survey. In these circumstances, it would be appropriate to investigate the radiological significance of substituting local with national data, as a guide to requirements for follow-up or future habits surveys.

Additional considerations arise in respect of exposure of the embryo and foetus, as it is unlikely that a significant number of pregnant women will be included in any one survey (see also Section 5). However, a substantial fraction of the local population of women of child-bearing age is likely to become pregnant over the period during which the habits survey data are used for radiological assessment purposes. Currently, little relevant information seems to be available on distinctions between the habits of pregnant and non-pregnant women of child-bearing age. Although it seems likely that the distinctions in habits of pregnant relative to non-pregnant women will have only a limited effect on assessed doses to the foetus, it would be useful to have quantitative data on such distinctions in habits in order to confirm this judgement.

4.4 Relevance of the Total Dose Approach

Having obtained habits survey and environmental monitoring data, a wide variety of approaches for determining total dose are available. This issue is discussed in detail in another NDAWG paper (Camplin et al, 2005). Here, it is sufficient to note that five alternative options have been explored, each with its particular strengths and weaknesses. The most basic approach is simply to determine doses to each individual using individual-related consumption and occupancy data. This basic approach requires all the habits data to be used and does not lend itself to reproduction by others. The other options require manipulation of the underlying habits information, eg, by averaging specific subsets of the data. However, none of the options requires collection of data additional to those currently acquired in habits surveys, nor do they permit a reduced amount of information to be collected from such surveys (see also Section 5).

4.5 Realism in the Consumption of Locally Produced Foods

The EC BSS Directive requires that dose estimates from discharges should be realistic. Assumptions made in dose assessments regarding the consumption of locally produced food should reflect this requirement by considering both UK-wide and local agricultural

practices. This consideration needs to be kept in mind when defining and conducting habits surveys. Instances of relevant national and local considerations are described below, but should not be taken as comprehensive.

For example, almost all grain grown in the UK is taken for processing to a limited number of mills around the country. Any activity within the grain is, therefore, significantly diluted by mixing with grain grown in areas far from the release site. Thus, it is not generally appropriate to include doses from the consumption of grain when determining individual doses from locally produced foods. Another example relates to milk products. This category includes butter, cheese and other milk products. It is very unlikely that these would all originate from locally produced milk. Therefore, it may not be appropriate to assume that locally produced milk products are consumed at high rates when determining individual doses from activity concentrations in such products monitored around nuclear sites. However, consideration would have to be given to situations where a particular farm produced a wide range of such products that were labelled by their origin, as consumer preferences might then dictate the preferential purchase and consumption of such products. Furthermore, consideration needs to be given to particular dietary preferences and requirements, eg, a preference for goat's milk or an allergy to dairy products could result in heavy reliance on goat's milk and associated products from a single supplier.

It should be noted that where habits data that may be used in assessments are determined by reference to a particular producer or supplier, care has to be taken in reporting the associated information, to avoid the possibility of any adverse economic effects on that producer or supplier.

Foods such as poultry, eggs and pork may be produced locally and consumed locally at high rates. However, these products may be produced from continuously housed animals and the feed used in their production will probably not be locally produced. Therefore, care should be taken when evaluating the appropriate consumption rates for such foods when determining individual doses from activity concentrations measured in such products around nuclear sites, ie, the activity concentrations may relate to animals raised on locally produced and contaminated feed (eg, free-range birds kept in limited numbers), but the consumption rates may relate mainly to animals raised on uncontaminated feed.

Some farm-produced foods are sold at local farm shops and 'pick your own' farms. It is important to recognise that, although during the summer and autumn a large percentage of the fruit and vegetables sold at farm shops may be locally produced, in winter this proportion drops considerably (Simmonds et al, 2004). Therefore, individuals may consider that they are eating locally produced food when in fact they are not.

It is clear that a wide range of food can be, and is, grown in gardens and allotments around the country (Prosser et al, 1999). It is possible for individuals to produce large quantities of fruit and vegetables on allotments and so it may be appropriate to assume high consumption rates in such cases. However, if examination of the local area around a discharge location reveals no farms or allotments and only relatively small gardens, then the possibility of consuming locally produced food is low and the amounts potentially consumed small. This fact should be reflected in the consumption rates reported from local habits surveys. If high rates are reported, follow up studies should be used to determine their origin and degree of realism.

There has also been concern that individuals might be highly exposed by the consumption of unusual foods. However, such foods are generally consumed in limited quantities. In this case, the issue is not so much one of consumption rates as of collection of such foods at particular locations associated with an unusually high degree of contamination.

In summary, it is appropriate to continue to report habits data in terms of broad categories of foodstuffs, recognising that this is commensurate with the monitoring data that are available. Because the data are collected for individuals in integrated surveys, correlations between the intakes of different foodstuffs can be determined, but this is not likely to be a major factor in the assessment of doses, as it is unlikely that individuals would consume more than two or three broad classes of foodstuffs at high rates (see Appendix B). Identification of unusual foodstuffs as potentially making an important contribution to effective dose is most likely to arise from determination of high concentrations of radionuclides in those foodstuffs or from the *ad hoc* identification of collection from locations in which high concentrations could occur. In either case, determination of consumption rates by exposed individuals would be part of a follow-up investigation and would not be expected to be based on results from a routine survey.

4.6 Relationship between Habits Surveys and Monitoring

The monitoring programmes that are carried out by the EA and the FSA are undertaken for various purposes, including reassurance, and the results provide inputs to the public dose assessment process. The monitoring is carried out in locations or media where radionuclides occur and where the public may be subject to exposure. Habits survey information is compared with monitoring locations or media such as food types. Thus, the habits surveys may identify:

- that the public may be present at a location, but monitoring is not carried out;
- monitoring is carried out, but the public is not normally present at a location;
- foods are consumed that are not monitored;
- foods are monitored that are not consumed.

The Environment Agency and the Food Standards Agency review their monitoring programmes on a regular basis and take into account the findings of habit surveys as well as other suggestions in determining the need for changes to those programmes.

It is also relevant to note that although habits surveys are intended to provide a realistic characterisation of patterns of food consumption and occupancy, the results obtained may be used in both retrospective and prospective assessments in a cautious manner. Thus, for retrospective assessments, the activity concentrations used are those measured close to the discharge point, or where they are expected to be highest. For prospective assessments, the EA normally bases calculations on the nearest habitable dwelling and assumes that food is produced on the nearest suitable land, irrespective of whether it is currently active or fallow.

4.7 Non-food Exposure Pathways

Non-food exposure pathways of general relevance comprise external irradiation, either from environmental media or directly from an installation, inhalation of radioactively contaminated gases and aerosols, and ingestion of contaminated soils and sediments. In the case of external irradiation, the radiation field at any location can be measured, or computed based on the distribution of the source and the shielding properties of the intervening media. Thus, what is required from a habits survey is the spatial pattern of occupancy in those areas where dose rates are significantly increased relative to background. In the case of inhalation, occupancy data are again the primary requirement. For ingestion of soils and sediments, knowledge of rates of consumption is the primary requirement. These various requirements are discussed further in Sections 4.8 and 4.9.

4.8 Robustness of Occupancy Data

Information on indoor and outdoor occupancies for use in dose assessments is very robust. However, information on occupancies in particular areas, for example, beaches,

is limited. Also, occupancy data for children and infants may be limited because of the small numbers included in surveys. For nuclear sites, relevant information on occupancies is obtained from local habits surveys, although it must be recognised that in some cases the small numbers involved and factors such as seasonal variability result in a high degree of uncertainty as to the values obtained. For assessments of other facilities, this is more of a problem. Generic occupancies for activities, for example, time spent on river banks, are important inputs to some dose assessments and there are few sources of such information. It is also useful to have information on activities undertaken at a location, as this can impact upon other factors such as the breathing rates or dust loadings used.

Since 2002, information on occupancy within 0.25, 0.5 and 1 km radius concentric rings around each licensed nuclear site has been available, with greater detail for occupancies close to the site if the population density is high. This information should be adequate for assessing the contribution of direct radiation from the site to individual exposure. In principle, time-averaged direct shine dose rate contour maps could be provided, though there are questions as to whether the available data would be sufficient for their derivation. Also, if the habits data were then broken down into quadrants to improve the match with the refined direct radiation data, it might become possible to identify individuals.

For inhalation, occupancy factors have to be combined with information on radionuclide concentrations in air, respirability and inhalation intake-to-effective-dose conversion factors. These factors can be correlated. An individual may be present in a particular area because of regularly undertaking a specific activity there, eg, gardening, and that activity may determine both the amount and characteristics of radioactive material available for inhalation. Thus, habits surveys addressing the occupancy of different areas should also address the activities undertaken during the occupancy of those areas, so that air concentrations of radionuclides, intake rates and effective-dose-per-unit-intake values can be estimated consistent with those activities.

4.9 Ingested Soils and Sediments

In the case of ingested soils and sediments, it is unlikely that any useful information would be obtained from habits surveys. Estimates of intakes of such materials can be made by faecal monitoring, but this would not be an acceptable component of a survey. Indeed, it is considered prejudicial to participation in such surveys to include even such simple biometric information as height and weight (which could be used to compute basal metabolic requirements for comparison with the energy content of the reported diet). In conclusion, for defining rates of ingestion of soils and sediments, reliance has to be placed on experimentally determined values reported in the literature (eg, Simon, 1998).

5. Use of Critical Groups in Estimating Individual Exposure

As has been discussed by Hunt (2004), the concept of the critical group was developed by the ICRP during the 1960s. In ICRP Publication 9 (1966), it was recommended that:

> In practice, it is feasible to take account of these [age, size, metabolism and customs] sources of variability by the selection of appropriate critical groups within the population, provided the critical group is small enough to be homogeneous with respect to age, diet and those aspects of behaviour that affect the doses received. Such a group should be representative of those individuals in the population expected to receive the highest dose, and the Commission believes that it will be appropriate to apply the appropriate Dose Limit for members of the public to the mean dose of this group. Because of the innate variability within an apparently homogeneous group, some members of the critical group will receive doses somewhat higher than the Dose Limit; however, at the very low levels of risk implied, it is likely to be of minor consequence to their health if the Dose Limit is marginally or even substantially exceeded.

By ICRP Publication 26 (1977), the statement was somewhat modified. There, its latter part read:

> Because of the innate variability within an apparently homogeneous group some members of the critical group will in fact receive dose equivalents somewhat higher than the mean. However, because of the maximizing assumptions used, the dose equivalent actually received will usually be lower than the estimated dose equivalent...

ICRP Publication 60 (1991) does not provide any further modification of this statement, but does comment that the dose constraint should be applied to the mean dose in the critical group from the source for which the protection is being optimised.

The identification of representative individuals for whom dose calculations should be undertaken for comparisons with dose limits or constraints is being addressed elsewhere in the NDAWG (see, eg, Camplin et al, 2005). Broadly speaking, the alternatives are to define:

- Representative **habits** for the most exposed group, defined as being reasonably homogeneous with respect to age, diet and those aspects of behaviour that affect the doses received;
- A representative **member** of the most exposed group, defined as being reasonably homogeneous with respect to the dose received, but with no requirement placed on homogeneity with respect to age, diet or behaviour.

The first alternative takes the diet and occupancy data from the survey, and then selects a sub-set of individuals that are reasonably homogeneous in terms of age, diet and behaviour. Mean values of dietary and occupancy quantities are calculated for this group, and these mean values are used to compute the annual dose to a representative individual. The representative individual does not correspond exactly to any one member of the group, but the requirement of reasonable homogeneity means that all members of the group have quantitatively similar characteristics to the representative individual.

The second alternative considers that selection of individuals that constitute a group that is reasonably homogeneous in terms of age, diet and behaviour can be taken to be a surrogate for selecting individuals that constitute a group that is reasonably homogeneous with respect to annual dose. With the data handling capabilities of modern computers, it is easy to carry out complete dose calculations for all individuals included in a survey and then to examine the distribution of annual doses that arises.

This second alternative places the greater demands on a habits survey, as it requires comprehensive data over all pathways to be collected for all individuals included in the survey. However, as this is what is now done under the tri-party programme mentioned in Section 2, the choice of individuals for whom to perform dose calculations is not found to have any substantial implications for the way in which habits surveys are conducted, over and above the requirements for suitable identification, and possibly sampling, of the population group of interest, as discussed in Section 3.

The use of an approach that did not require the critical group to be homogeneous with respect to age might have practical advantages, as the numbers of infants and children included in habits surveys are generally rather small, making assessments of representative doses for these groups difficult. However, society is generally very concerned to protect those members it sees as most vulnerable, especially infants and children. It may be that the use of a single dose to represent all age groups would not sufficiently address public concern in this area, especially as historically doses for different age groups have been presented separately. However, as the habits data for children and infants are often obtained by scaling of adult data (see Section 4.2), it could

be argued that the dose estimates presented for children and infants are somewhat artificial.

A more detailed discussion of various approaches to the determination of total doses from monitoring data is presented elsewhere (Camplin et al, 2005). A wide number of options for determining total dose are possible, each with its own strengths and weaknesses. As outlined above, the most basic approach is simply to determine doses to each individual with the benefit of individual related consumption and occupancy data at each site. A dose representing the total dose for comparison with limits can then be derived by selecting those doses at the higher end of the spectrum observed.

However, this basic approach requires all the habits data to be used and does not lend itself to reproduction by others. Therefore, four other options were proposed to overcome this problem. These had various benefits and limitations that required consideration and comparison. In each case, there was a degree of arbitrariness in the choices made in the derivation of data, for example in the categorisation of pathways. There was no wholly 'correct' method. Indeed there were other options that could have been considered.

Overall, an approach termed profiling was preferred. In this approach, consumption and occupancy rates for each pathway are derived for groups of individuals who exhibit high rates for one of the pathways. This gives a profile. Other profiles are then built by repeating for other pathways and the total dose is determined as being the highest dose for any profile.

Consideration needs to be given of the potential for pregnancy in women in exposed groups for purposes of protection of unborn children. It is reasonable to expect that a proportion of people in the critical groups will be women of childbearing age and that a proportion of them will be pregnant. However, in the majority of cases the likelihood that a pregnant woman will be in such a group is low: the average expectation for a person, randomly selected from the population, being pregnant with a child who will be live born at term is about 1 in 100. During habits surveys, a record is made of the sex and age of interviewees, but no questions are asked about pregnancy. To do so would increase intrusiveness, without ensuring complete accuracy. It is probably more important to recognise the potential, and to allow for it in any important cases. The ratio of foetal to adult dose coefficients for the public is generally less than 1, but there are some radionuclides, notably tritium, C-14, P-32, P-33, S-35 and Sr-90 where the ratio is greater. The main aspect of assessments that may be affected by the presence of these radionuclides is that associated with consumption of terrestrial foods or freshwater fish, which are not critical in many cases. However if there were a group containing a large proportion of women of child-bearing age eating terrestrial foods or freshwater fish at high rates, higher dose coefficients may be considered to be applicable. At current levels of exposure to critical groups, and with the relatively small increases that could arise from explicit consideration of the embryo and foetus, it is most unlikely that embryonic or foetal doses would approach the dose limit.

It is emphasised that the above remarks apply mainly to licensed nuclear sites, as habits surveys are not routinely undertaken around other premises authorised to discharge radioactive wastes. For those other premises, greater emphasis has to be placed on the use of generic data (see Smith and Jones, 2003).

6. Conclusions and Recommendations

6.1 Methods for Obtaining Integrated Habits Data associated with Particular Sites

Current methods for obtaining integrated habits data associated with particular sites have been reviewed (Section 2 and Appendix A). The methods adopted were generally found to be appropriate (Section 3). At a more detailed level, the following conclusions are drawn.

- The introduction of integrated programme combining assessment of doses from aquatic, terrestrial and external pathways in a single report is welcome. In the underpinning habits surveys, it is considered to be appropriate to concentrate on the population groups that are likely to be most exposed from the site under investigation. Such population groups are best identified on the basis of experience by consultation between the regulators, the FSA and the survey organisation. As this identification is necessarily subjective, it has to be presented explicitly, so that it can be readily scrutinised by interested parties. This is currently largely achieved by beginning each survey report with a description of demography, land use and related issues for the area of interest. Based on this description, local populations with different broad characterisations of habits can then be identified and arguments presented as to which of these populations are likely to be the most highly exposed. At some sites, several such populations may be identified.

- Once the potentially most highly exposed populations have been identified, survey of all individuals within those populations, as at present, is the preferred approach.

- The frequency of repeat surveys needs to be given a clear rationale. Annual updates for Sellafield are considered appropriate. At other sites, it is considered that seven years is probably too long to wait for a repeat survey in the light of potential changes in local practices. When a survey is repeated, significant changes in the data could be an indicator of the rate of change and justification for reducing the time interval to the next repeat survey. The existing data should be examined to indicate which sites would merit adjustment of priority in this way.

- For installations other than licensed nuclear sites, it may not be appropriate to conduct full surveys. For such installations, an initial assessment can be undertaken using generic data. This could be enhanced by limited targeted local habits surveys, as required. Some such surveys may need to be targeted on specific groups, eg, sewage workers, which are of interest because of dose contributions from multiple sites authorised to discharge radioactive wastes.

- Non-food pathways should continue to be included in habits surveys. For external exposure the requirement from a habits survey is the spatial pattern of occupancy in those areas where dose rates are significantly increased relative to background. Annual effective doses from external irradiation should be estimated for individuals included in the survey, but spatial information that would allow those individuals to be identified should not be reported in generally available documents. For inhalation, habits surveys addressing the occupancy of different areas should also address the activities undertaken during the occupancy of those areas, so that air concentrations of radionuclides, intake rates and effective-dose-per-unit-intake values can be estimated consistent with those activities.

- In the case of ingested soils and sediments, it is unlikely that any useful information would be obtained from habits surveys. Instead, reliance has to be placed on experimentally determined values reported in the literature.

6.2 What is Meant by 'Locally Produced Food'

Issues related to the characterisation of locally produced foods are addressed in Section 4.5. Overall conclusions are set out below.

- Assumptions made in dose assessments regarding the consumption of locally produced food should be realistic and consider both UK-wide and local agricultural practices.

- It is not generally appropriate to include doses from the consumption of grain when determining individual doses from locally produced foods.

- It may not appropriate to assume that locally produced milk products are consumed at high rates when determining individual doses from activity concentrations in such products monitored around nuclear sites. However, consideration would have to be given to situations where a particular farm produced a wide range of such products that were labelled by their origin, as consumer preferences might then dictate the preferential purchase and consumption of such products. Furthermore, consideration needs to be given to particular dietary preferences and requirements, eg, a preference for goat's milk or an allergy to dairy products could result in heavy reliance on goat's milk and associated products from a single supplier.

- Foods such as poultry, eggs and pork may be produced locally and consumed locally at high rates. However, these products may be produced from continuously housed animals and the feed used in their production will probably not be locally produced.

- Some farm-produced foods are sold at local farm shops and 'pick your own' farms. It is important to recognise that, although during the summer and autumn a large percentage of the fruit and vegetables sold at farm shops may be locally produced, in winter this proportion drops considerably. Therefore, individuals may consider that they are eating locally produced food when in fact they are not.

- It is clear that a wide range of food can be, and is, grown in gardens and allotments around the country. It is possible for individuals to produce large quantities of fruit and vegetables on allotments and so it may be appropriate to assume high consumption rates in such cases. However, if examination of the local area around a discharge point reveals no farms or allotments and only relatively small gardens, then the possibility of consuming locally produced food is low and the amounts potentially consumed small. This fact should be reflected in the consumption rates reported from local habits surveys. If high rates are reported, follow up studies should be used to determine their origin and degree of realism.

- Identification of unusual foodstuffs as potentially making an important contribution to dose is most likely to arise from determination of high concentrations of radionuclides in those foodstuffs or from the *ad hoc* identification of collection from locations at which high concentrations could occur. In either case, determination of consumption rates by exposed individuals

would be part of a follow-up investigation and would not be expected to be based on results from a routine survey.

6.3 Assumptions regarding where People are assumed to live and to obtain their Food in Dose Assessments together with the Combination of Pathways

Issues relating to assumptions regarding where people are assumed to live and obtain their food are addressed in Section 4.6. The following conclusion is drawn.

- It is also relevant to note that although habits surveys are intended to provide a realistic characterisation of patterns of food consumption and occupancy, the results obtained may be used in both retrospective and prospective assessments in a cautious manner. Thus, for retrospective assessments, the activity concentrations used are those measured close to the discharge point, or where they are expected to be highest. For prospective assessments, the EA normally bases calculations on the nearest habitable dwelling and assumes that food is produced on the nearest suitable land, irrespective of whether it is currently active or fallow.

Other issues related to sources of food are largely addressed in the context of the conclusions relating to locally produced foods (Section 6.2). Issues relating to the adequacy of data on occupancy of different areas are addressed in Section 6.5. The other issue to be covered here is the combination of pathways. This is discussed in Section 4.1, where the following conclusion is drawn.

- Individuals may receive significant contributions to effective dose by consumption of several different foodstuffs at higher than average rates. However, in practice, analyses have shown that individuals typically consume only one or two of the broad categories of foodstuffs relevant to assessment studies at high rates. Furthermore, because habits data are now collected for individuals in integrated surveys, correlations between the intakes of different foodstuffs can be determined.

6.4 Data Analysis including the Relationship between the Sample Population and Assessment of Individual Doses including the use of Critical Groups

Alternative approaches to sampling are addressed in Section 3.

Overall, the regulators and the FSA consider that the most effective use of resources is to continue to focus on the sub-populations around sites that are likely to be subject to the highest exposures. In this context, it seems reasonable that these local sub-populations should be identified on the basis of experience by consultation between the relevant regulatory bodies, the FSA and the survey organisation. However, as this identification is necessarily subjective, it should be presented explicitly, so that it can be readily scrutinised by interested parties. This suggests that each survey report needs to begin with a description of demography, land use and related issues for the area of interest. This material is already largely present in the reports that the subgroup examined. Based on this description, local sub-populations with different broad characterisations of habits should be identified and an argument presented as to which of these populations are likely to be most highly exposed and, therefore, need to be included in the survey. At some sites, several such sub-populations may be identified, as it will not be clear, *a priori*, which will be the most highly exposed.

However, it may be useful to complement such focused surveys with occasional, more resource intensive, broadly based statistical surveys. By use of a preliminary overall survey of the population followed by weighted sampling of a full range of sub-groups

from within that population, it should be possible both to demonstrate that the expert judgments made in defining the standard focused surveys are well justified and to provide a basis for relating the exposures of the most highly exposed and typically exposed individuals. However, it might well be appropriate to complement such broader based surveys with an enhanced programme of environmental monitoring.

It is noted that for installations other than licensed nuclear sites, it is not necessarily appropriate to conduct full surveys. In these circumstances, an initial assessment can be undertaken using generic data based on a mixture of national survey data and site-specific data from various sources. If this assessment reveals the potential for significant exposure by particular pathways, limited targeted local habits surveys could be undertaken.

Finally, it is noted that habits surveys and subsequent assessments of doses should have a feedback to monitoring programmes. Specifically, the pattern and amount of monitoring should be modified to take account of the exposure pathways identified as being of greatest importance in the dose assessment.

Further considerations on the determination of total doses from monitoring data are set out in Section 6.7.

6.5 The Adequacy of Data on Occupancy

Issues relating to occupancy are discussed in Section 4.8. Conclusions are summarised below.

- Information on indoor and outdoor occupancies for use in dose assessments is very robust. However, information on occupancies in particular areas, for example, beaches, is limited. Also, occupancy data for children and infants may be limited because of the small numbers included in surveys.

- For nuclear sites, relevant information on occupancies is obtained from local habits surveys, although it must be recognised that in some cases the small numbers involved and factors such as seasonal variability result in a high degree of uncertainty as to the values obtained. For assessments of other facilities, this is more of a problem. Generic occupancies for activities, for example, time spent on river banks, are important inputs to some dose assessments and there are few sources of such information. It is also useful to have information on activities undertaken at a location, as this can impact upon other factors such as the breathing rates or dust loadings used.

- Since 2002, information on occupancy within 0.25, 0.5 and 1 km radius concentric rings around each licensed nuclear site has been available. This information should be adequate for assessing the contribution of direct radiation from the site to individual exposure.

6.6 The Use of National Survey Data and Site Specific Data

Uses of national and site specific survey data are addressed at various places throughout this position paper. Generally, for licensed nuclear sites, it is recommended that local habits survey data should be used. However, national survey data should also be considered for various purposes. These include the identification of substantial differences between the local and national survey data, and the substitution of national data for non-existent or poorly supported local data in a radiological assessment. The identification of substantial differences should trigger an investigation to determine whether those differences arise from genuine distinctions between the local and national

contexts, or a deficiency in either the national or local survey data. Substitution of national data into a radiological assessment should help to determine whether the absence or weakness of local data is likely to be of radiological significance.

For other premises authorised to discharge radioactive wastes, it would be unusual for site-specific habits surveys to be justified (see also Section 6.4). This means that there is much greater reliance on national data. However, at some locations there may be a number of non-nuclear sites in close proximity all discharging to the same part of the environment, frequently via a sewage works. In these cases, contributions to dose from several sites may need to be taken into account. In these circumstances, there may be a need for habits surveys targeted on specific groups, eg, sewage workers, rather than related to specific sites authorised to discharge radioactive wastes.

This paper is directed mainly at issues relating to site-specific habits surveys. However, the various applications of national survey data outlined above mean that there is a need to continue to collect comprehensive national survey data and analyse those data in ways appropriate to the assessment of radiological impacts. An illustration of such an analysis is presented in Appendix B, but the range of such analyses that could be undertaken is a matter that could be studied in greater depth in a separate paper.

6.7 Use of Habits Survey and Dosimetric Data for Infants, Children and Adults (including Pregnant Women)

Habits survey data for children and infants are discussed in Section 4.2. Data for children and infants may be used directly, if there are sufficient observations. However, more usually, data are sparse and, for protection purposes, surrogate data need to be generated. Such surrogate data are derived by scaling adult values with generic ratios, derived from food survey data. Even where data for children and infants are available, these need to be treated with some care, as they are typically reported by the household representative, who will be an adult and not the child or infant under consideration.

A detailed discussion of various approaches to the determination of total doses from monitoring data is presented elsewhere (Camplin et al, 2005). A wide number of options for determining total dose are possible, each with its own strengths and weaknesses.

Overall, an approach termed profiling is currently preferred. In this approach, consumption and occupancy rates for each pathway are derived for individuals who exhibit high rates for one of the pathways. This gives a profile. Other profiles are then built by repeating for other pathways and the total dose is determined as being the highest dose for any profile.

Neither profiling nor any of the other proposed approaches places any additional requirements on habits surveys.

Additional considerations arise in respect of exposure of the embryo and foetus, as it is unlikely that a significant number of pregnant women will be included in any one survey. However, a substantial fraction of the local population of women of child-bearing age is likely to become pregnant over the period during which the habits survey data are used for radiological assessment purposes. Currently, little relevant information seems to be available on distinctions between the habits of pregnant and non-pregnant women of child-bearing age. Although it seems likely that the distinctions in habits of pregnant relative to non-pregnant women will have only a limited effect on assessed doses to the foetus, it would be useful to have quantitative data on such distinctions in habits in order to confirm this judgement.

Whatever approach is adopted for the estimation of annual doses, it should be explicitly described in a way that is comprehensible to interested parties. It would also be

desirable to document how the detailed habits survey results link to the critical group habits given in RIFE and in the habits survey reports themselves. Also, the RIFE reports would benefit from inclusion of a schematic diagram that shows all pathways considered in dose assessment calculations, including both food and non-food pathways.

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Appendix A: Integrated Habits Surveys

A.1 Introduction: Purposes of Surveys

Habits surveys provide information to help in protection of members of the public from the effects of radioactive waste discharges and site operations. Data on people's eating habits, recreational pursuits, occupational activities and other factors that are relevant to their radiation exposure are gathered around specific nuclear sites and in other areas affected by radioactive waste discharges. Data are processed to define characteristics of critical groups, according to the principles established by the ICRP, and subsequently used to assess radiation doses. The radiological protection system in the UK is based on dose limits which ICRP have recommended as appropriate for critical groups. Most surveys carried out are specific to a particular nuclear site and any adjacent sites, to provide information that is directly relevant to the habits of the public local to those sites. Surveys help identification of relevant exposure pathways. For liquid waste discharges, those pathways would typically include consumption of locally-caught aquatic food, occupancy of inter-tidal or riverbank areas whilst angling, and handling sediment during bait digging or tending nets. For atmospheric discharges, typical pathways include consumption of locally-grown fruit and vegetables and locally-produced meat, eggs and milk; consumption of groundwater and/or freshwater biota may also be important. For direct radiation, they include time spent on indoor and outdoor activities. Unusual pathways are also identified during surveys. Examples include consumption of uncommon sea foods (eg, razor shells; sea mice), or use of seaweed as a soil conditioner on vegetable plots. Habits surveys are repeated at intervals to keep exposure pathways under review.

The surveys also provide information that is used to define monitoring programmes. For example, routine monitoring of one type of shellfish may be replaced by another if, because of availability or for some other reason, this has become the preferred species for high-rate consumers. Monitoring of an unusual foodstuff may be adopted if local production and consumption is found to have started.

One further important benefit of habits surveys is the opportunity they provide for liaison directly with the public, demonstrating to them that their health and safety are being protected. Interviewees are often reassured to hear that this is happening and that it is carried out independently of nuclear site operators.

In 2000, the Government put a duty on the Environment Agency to observe the requirements of the 1996 BSS Directive. The Environment Agency was required, wherever applicable, to ensure that:

a) All exposures to ionising radiation of any member of the public and of the population as a whole resulting from the disposal of radioactive waste are kept as low as reasonably achievable, economic and social factors being taken into account;
b) The sum of the doses resulting from the exposure of any member of the public to ionising radiation should not exceed the dose limits set out in article 13 of the Directive (subject to the exclusions set out in article 6(4) of the (BSS) Directive).

In discharging its duties under the BSS Directive, the Environment Agency is required to have regard to the following maximum effective doses to individuals that may result from a defined source, for use at the planning stage in radiation protection:

- 0.3 mSv/y from any source from which radioactive discharges are first made on or after 13th May 2000;
- 0.5 mSv/y from the discharges from any single site.

The Scottish Environmental Protection Agency (SEPA) has received a similar direction. In Northern Ireland a duty was placed on the Chief Radiochemical Inspector similar to the Directions that were made in respect of EA and SEPA.

Doses to the public can arise from discharges to atmosphere (affecting the foodchain and the environment), from liquid discharges (affecting mainly the marine or freshwater environments) and direct radiation, or combinations of these. Therefore, in order to assess doses, habits surveys are designed to identify and quantify the habits of the public around sites that can lead to exposure to the main pathways arising from atmospheric and liquid discharges and direct radiation. The surveys also need to enable the dose assessments that are subsequently made to cover total exposure from all pathways. Therefore, the most appropriate surveys are those that establish the total habits of the individuals who are most exposed around the sites. The intention is to calculate the dose to individuals or groups who may be exposed to atmospheric discharges, liquid discharges and direct radiation either individually or in combination.

A programme has now been established of joint integrated habits surveys looking at those members of the public who are most exposed to discharges and emissions from nuclear sites in England and Wales. Three Government bodies are responsible for ensuring that different aspects of exposure are assessed. The Food Standards Agency has responsibility for ensuring the food chain is safe, the HSE (NSD) has responsibility for ensuring that doses to the public from direct radiation are assessed and the Environment Agency has responsibility for assessing exposure from the environment and overall responsibility for total doses. A joint collaborative habits survey programme has therefore been established between the Environment Agency, the Food Standards Agency and the HSE (NSD). This programme facilitates the collection of integrated habits data to cover pathways related to direct radiation, exposure to the food chain and the environment. The results of the surveys can be used to calculate doses to the public around the sites for discharges to air or liquid discharges or direct radiation, and total doses from exposure to combinations of these.

Similar arrangements for joint surveys are being put in place in Scotland.

At present the integrated habits surveys are carried out on a regular basis around the nuclear sites in England and Wales. Surveys are generally repeated about every five to seven years, depending on the radiological significance of the sites. At some sites, the repeat interval has been longer, whereas at Sellafield the full surveys are reviewed annually. The costs of the surveys are recovered under the regulatory recharging schemes. Equivalent arrangements for habit surveys around non-nuclear sites are not in place at present. For non-nuclear sites, assessments currently make use of habits data based on national surveys.

A.2 A Brief History of Habits Surveys

The recent trend in the main programme of surveys has been towards providing data for integrated assessments across all relevant pathways. In the past, practices were driven by the needs of different customers. Aquatic habits surveys relevant to liquid radioactive waste discharges were carried out as far back as the early 1950s in relation to Sellafield. The importance was recognised of following up exposure pathways where the exposed population was distant from the site: this extended to surveys of the *porphyra* (laverbread) pathway, important to consumers in south Wales. With the burgeoning nuclear power programme, surveys were carried out at all the major nuclear sites in the UK (eg, Winfrith from 1958, Bradwell, Berkeley, Oldbury and Hinkley Point ‘A’, from 1960). Aquatic surveys subsequently continued routinely around the main nuclear sites as well as in areas remote from, but affected by discharges (eg, along the Cumbrian Coast, in Northern Ireland and in the Channel Islands).

Initially, assessment of atmospheric discharges through terrestrial pathways relied on national food consumption data. In 1996, a programme of site-specific terrestrial surveys in England and Wales was begun, to provide confidence that the system based on national survey data was robust. By 2000, this had covered 14 major nuclear sites.

In the case of direct radiation, assessment is primarily undertaken by site operators. However, from 1993 independent surveys began to be carried out for HSE. By 2001, a total of 19 sites had been surveyed in respect of direct radiation pathways, including sites in Scotland.

In 2001, the FSA programmes of aquatic and terrestrial surveys were amalgamated, and combined surveys were carried out at Berkeley and Oldbury (considered together), Heysham and Sizewell. In 2002, the programme was further modified to include direct radiation surveys for HSE and non-food interests for the Environment Agency. A tripartite agreement (EA/FSA/HSE) was set up, referred to above, which resulted in combined surveys at Aldermaston and Burghfield, Drigg and Hartlepool in 2002, and Cardiff, Sellafield and Winfrith in 2003.

Surveys are also undertaken in Scotland on behalf of SEPA and are also directed, on occasion, to the characterisation of specific pathways, eg, occupancy near the Chapelcross pipeline and turf cutting in coastal areas of the Irish Sea. In addition, site operators occasionally sponsor habits surveys to complement existing data at particular sites.

In addition to surveys carried out specifically to address exposures around nuclear sites, surveys can be carried out to inform assessments of doses to inhabitants of particular areas, due to the sources of radiation exposure which may affect them. These surveys are carried out to address the requirements of customers and are funded by them. Examples of surveys of this nature carried out in the past are those for Northern Ireland and the Channel Islands.

Table A.1 gives a description of surveys carried out from 1991 with the type of survey and the potential critical groups.

A.3 Scope of Current Surveys

Current surveys around nuclear establishments are based on 3 defined areas in their vicinity which reflect where liquid and gaseous discharges and direct radiation, respectively, may be considered to influence radiation exposure. The choice of survey area is a judgement taking into account cost and the likely extent of the radiological effects of the site.

For coastal establishments, a marine area is chosen: this covers a region determined by local dispersion characteristics, eg, predicted by tidal cycles around the liquid discharge point or between prominent geographical features. In this area, surveys target people fishing within the area or consuming fish from it, and people undertaking water-based activities (eg, windsurfing, diving). In addition, inter-tidal activities such as angling, bait digging, shellfish collecting, wildfowling, or beach-related pursuits are identified on the coast of the marine area. Retail and wholesale outlets trading in sea foods obtained from the survey area are also covered.

Terrestrial surveys include the area within a circle of 5 km radius centred on the nuclear site centre. People within this area targeted for interview include farmers, allotment holders, wholesalers and beekeepers. Information on collection and consumption of wild/free foods, and game and freshwater species is also gathered.

If the site is inland and liquid discharges are made to a local river, the area of study is defined to include people angling near the discharge point.

Direct radiation surveys are conducted within 1 km of the licensed site perimeter. They include residences, leisure activities and any businesses not directly related to the operation of the nuclear site.

Although the surveys are carried out in these 3 separately-defined areas, each interviewee is asked about all habits, whether aquatic, terrestrial or related to direct exposure. Habits data generally exclude activities carried by radiation workers for the nuclear sites. The surveys do not attempt to interview every person within the areas, nor are they random. Instead, a subset of people is targeted who are identified by the survey team as potential critical group members because of their likely consumption rates or occupancies. The frequency at which surveys are repeated is variable and depends on resources, the radiological significance of the site and the requirements for formal assessments. Full surveys are not repeated more frequently than every 3 years, but at Sellafield there is an annual review survey.

A.4 Conduct of Surveys

A.4.1 Planning

There are 3 broad stages to each survey: planning, fieldwork and reporting. The planning process begins by assessing information from previous surveys in the light of possible changes both in site operations and local activities, what environmental monitoring is undertaken, the results of dose assessments and the specific requirements of the sponsors. Contact is made with people in local organisations to obtain relevant information. They include the site operators, Defra and EA fisheries officers, Defra field officers, the local sea fisheries committee, the local councils, the local associations, allotment wardens, wildfowling organisations and the local tourist office. Letters are sent to farmers within the 5 km terrestrial survey area and residents within the 1 km area likely to be influenced by direct radiation. The letters inform recipients about the survey and that they are likely to be visited.

A.4.2 Fieldwork

At the start of the fieldwork, a meeting is held with the site operators to establish contact and find out relevant local information. This includes a wide range of factors about local activities, including the potential for wildlife to transfer activity off-site. Contact is also made with individuals and organisations identified during the pre-fieldwork preparations. Interviews with individuals cover other members of their families including children. As the fieldwork progresses, other potential interviewees are identified and contacted, thus gradually building up a picture of the area, relevant pathways and the habits of the people engaged in them. Areas are visited where relevant recreational and commercial activities occur. Locations include harbours, beaches, angling shops, allotments, wholesalers, local food shops and farms.

Interviews are conducted by scientific staff experienced in following up activities of relevance to radiation exposures. Sometimes a questionnaire is used, but more as an aide-memoir than a ‘tick-box’ approach. The work requires good interpersonal skills and the ability to elicit the required data about people and pathways. Full training for new staff is provided. The fieldwork is usually undertaken by several habits survey team members, and regular contact and networking is carried out in order to maintain quality assurance of data gathering and comprehensiveness of the survey.

There are some hazards involved with interviewing, and interviewers are trained in identifying tricky situations and locations, as well as diffusing awkward confrontations. However, in the vast majority of cases, co-operation by interviewees is excellent.

A.4.3 Results of Surveys

Information obtained during surveys is processed to obtain, wherever practicable, quantitative information that can be used to assess doses. Data are processed into annual rates (eg, consumption in kg/y, occupancy in h/y) by the use of established conversion factors, edible fractions, etc, and categorised into age and pathway groups. The age groups are from 0 to 1.0 y of age (called 3 months); more than 1.0 y to 2.0 y (called 1 year old); more than 2.0 y to 7.0 y (called 5 year old); more than 7.0 y to 12.0 y (called 10 year old); more than 12.0 y to 17.0 y (called 15 year old); more than 17.0 y (called adults). Non-adult data are usually obtained from interviews with a spokesperson for the whole family.

Data include consumption of aquatic foods (fish, crustaceans, molluscs, marine plants and wildfowl) and terrestrial foods (milk, green vegetables, root vegetables, other vegetables, potatoes, domestic fruit, cattle meat, pig meat, sheep meat, poultry, eggs, wild/free foods, honey, fungi, rabbits/hare and venison). Freshwater aquatic foods in the terrestrial survey area are also included. Data are included which further sub-divide these activities by species or food type (eg, consumption of crabs, cabbages, plums).

External exposure pathways cover occupancies and handling. Inter-tidal occupancies are grouped according to sediment type (eg, sand, mud), and handling is grouped into sediment and fishing gear. Occupancies in water and on water are grouped separately, as are occupancies indoors and outdoors that are relevant to direct radiation. For the latter, the data are further grouped by distance from the site perimeter (0 – 0.25 km, 0.25 – 0.5 km and 0.5 – 1 km). Complete surveys of occupancy are not necessarily undertaken in each of the distance ranges, because of the high population densities around some sites. In such cases, the focus is on the 0 – 0.25 km range. Where the population density is low, a near-complete determination of occupancies out to 1 km is achieved.

During the surveys information also arises which is of a more qualitative nature. Such instances include unusual pathways which have been identified during a survey and may indicate situations where quantitative data may be needed subsequently. The information is considered during the assessment stage and indicative calculations used to make preliminary assessments that can be followed up should the associated pathway prove to be important. Examples include activities at sewage treatment works through which discharged liquid effluents from a site may pass, and cattle grazing on foreshores affected by discharges.

Quantitatively defined data are presented as annual rates in report tables. Annexes to reports list all rates of consumption and occupancies, as well as the age group for each individual. Summary tables are also provided.

The habits data are analysed to give rates of consumption typical for those people most exposed. Two methods are used. The first one analyses all the data for a given age and pathway group to give the 97.5^{th} percentile rate. This approach is consistent with that adopted by FSA for the derivation of food consumption rates based on national statistics. The second method averages all the values from the highest observation down to one third of the highest. This approach is called the ‘cut-off’ method and is related to the homogeneity criterion of ICRP.

A.5 Strengths and Weaknesses

Data on exposure pathways and habits are site-specific, which suggests that assessed doses are likely to be more realistic than those based on data that are derived generically, eg, from national household surveys. Habits surveys can result in higher doses because national statistics may miss higher rates or specific local pathways. However the converse can also be true: individuals may turn out not to eat as much of particular foods as national data may indicate, or their consumption may not be from local sources. Integrated site-specific surveys enable pathway combinations for real individuals to be assessed.

Habits survey data are relevant to the survey year, appropriate for a dose assessment for that year, but not necessarily for prospective assessments for future dose. This problem can be overcome by appropriate averaging and extrapolating of results of surveys done over a period of time. The frequency of surveys is prioritised according to the radiological significance of sites.

Many activities are seasonal, and whilst interviewers take care in eliciting information relevant to the whole year, there is the possibility of recall bias towards recent habits. Assurance of the quality of habits survey data can be achieved by training, by verifying unusual results with repeat interviews, and by checking using logging or diary surveys. For these surveys, a (usually high-rate) consumer is asked to fill in a diary sheet with information on his/her consumption over a fortnight each quarter. This is usually done offering a small monetary recompense. The data are analysed and correlated with the information obtained at interview.

An important benefit of the surveys is that the public and local organisations see independent health protection in action. Interviewees often comment that they welcome the independence from site operators. A further advantage of habits surveys is that they inform radioactivity monitoring programmes, making them more relevant to the local area and more cost effective.

A.6 Dose Assessments

Habits survey data are used in two main ways in dose assessments. For the annual RIFE report (now jointly sponsored by FSA, SEPA, EA and EHS), retrospective assessments for the year of the report are carried out. The methodology is described in the reports and has recently been developed to include integration of doses from all pathways, in contrast to the earlier methodology, which treated aquatic and terrestrial groups separately. The habits data typical of critical groups, as reported in RIFE, are selected both using 97.5^{th} percentiles of the recorded data (for consumption of terrestrial foods) and averaging over all consumers within a factor of three of the maximum (aquatic foods, occupancies and handling rates). Ingestion of drinking water, inhalation exposures and a few consumption and occupancy factors are based on generic data.

Prospective assessments by FSA are based on data from the habits surveys. Outputs from models of predicted concentrations in a food group are combined with consumption rates of individual adults. Separate groups are considered for the effects of atmospheric and aquatic discharges. Where possible, a habits survey for the site being assessed is used. Where data for that site are not available, a surrogate data set created by combining results from other surveys is used. Data for children derived for the age groups specified in Section A.4.3 may be used directly, if there are sufficient observations. However, more usually, data are sparse and, for protection purposes, surrogate data need to be generated. Such surrogate data are derived by scaling adult values with generic ratios, derived from food survey data (Byrom et al, 1995). Within each age group, the critical group dose is determined by calculating the dose for each

individual, summing contributions across all relevant food groups, and averaging over doses between the maximum recorded and one third of the maximum.

A.7 Availability of Data and Reports

When making results of habits surveys available, there is a need to respect the confidentiality of information on individuals. Recent reports have been produced taking this into account and are currently being considered for publication:

- Berkeley and Oldbury; Heysham; and Sizewell (EA, FSA and HSE reports) (also Hunterston and Torness from SEPA)
- Aldermaston and Burghfield; Drigg; and Hartlepool (EA, FSA and HSE) (also S W Scotland from SEPA)

Published summaries of aquatic habits data are routinely included in RIFE reports on a site-by-site basis. In addition, published scientific papers have addressed specific issues. The following list contains the main papers published from the 1980s:

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

Leonard DRP and Smith BD (1982). Sizewell nuclear power station. Investigation of radiation exposure pathways from liquid effluents: local habits survey, 1981. Sizewell Inquiry Series, MAFF Directorate of Fisheries Research (1) 19pp.

Leonard DRP, Hunt GJ and Jones PGW (1982). Investigation of individual radiation exposures from disposals to the aquatic environment: techniques used in habits surveys. In: Proceedings of the 4th International Symposium on Radiological Protection, Inverness. *Soc Radiol Prot*, 512-517.

Leonard DRP and Hunt GJ (1985). A study of fish and shellfish consumers near Sellafield: assessment of the critical groups including children. *J Soc Radiol Prot*, **3 (5)** 129-138.

Leonard DRP and Hunt GJ (1988). The use of thermoluminescence dosemeters in measuring external exposure of potential members of a critical group near Sellafield to verify data from habits surveys. In: Proc 7th Int Congr IRPA, Sydney, 1988. 642-645.

Doddington TC, Camplin WC and Thurston LM (1989). External exposure in the Eastern Irish Sea. Proc 4th Int Symp *Soc Radiol Prot*, Malvern, 1989, 367-370.

Smith BD and Hunt GJ (1989). A technique for reducing diverse habits survey data and its application to seafood consumption near Winfrith. Proc 4th Int Symp *Soc Radiol Prot*, Malvern, 1989, 401-404.

Doddington TC, Jones PGW and Leonard DRP (1989). Investigation of radiation exposures from liquid effluents at Hinkley Point Power Station. Local Habits Survey, 1986. Fisheries Research Data Report 13, Lowestoft. (23pp).

Smith DL, Winpenny K, Eaton T and Naylor GPL (1999). The role of site specific habits surveys in radiological assessments. In: Proceedings of the 6th International Symposium on Achievements and Challenges: Advancing Radiation Protection into the 21st Century, Southport, UK, 14-18 June 1999, 359-362.

In addition to surveys carried out specifically to address exposures around nuclear sites, surveys can be carried out to inform assessments of doses to inhabitants of particular

areas. An example of a survey of this nature carried out in the past is that for Northern Ireland (CEFAS, 2002).

CEFAS (2002). An Assessment of Aquatic Radiation Pathways in Northern Ireland by the Centre for Environment, Fisheries and Aquaculture Science. SNIFFER Report SR(02), CEFAS Environment Report RL20/02. Available at www.sniffer.org.uk.

Table A.1: Surveys carried out from 1991 with the type of survey and the main exposed groups and pathways of interest

Year	Site surveyed	Type of survey	Critical groups recommended in RIFE
1991			
1991	Aldermaston	Aquatic	Anglers (fish consumption and external in intertidal areas).
1991	Amersham	Aquatic	Anglers (fish consumption and external in intertidal areas).
1991	Harwell	Aquatic	Anglers (fish consumption and external in intertidal areas).
1992			
1992	Devonport	Aquatic	Local community (fish+shellfish consumption and external in intertidal areas).
1992	Dungeness	Aquatic	Bait diggers (fish+shellfish consumption and external in intertidal areas).
1993			
1993	Bradwell	Shine	Local residents.
1993	Dungeness	Shine	Local residents.
1993	Chapelcross	Shine	Local residents.
1993	Dounreay	Aquatic	Mollusc collectors (Mollusc consumption and external in intertidal areas). Local fishermen (fish+shellfish consumption and handling fishing gear).
1994			
1994	Trawsfynydd	Aquatic	Local fishing community (fish consumption and external in intertidal areas).
1994	Torness	Aquatic	Local fishing community (fish consumption and external in intertidal areas). Local community (external in intertidal areas).
1995			
1995	Calder	Shine	Local residents.
1995	Heysham (and Morecombe)	Shine	Local residents.
1995	Fleetwood	Aquatic	Local fishing community (fish+shellfish consumption and handling fishing nets).
1995	Hunterston	Aquatic	Local fishing community (fish+shellfish consumption and external in intertidal areas).
1995	Hunterston	Shine	Local residents.
1996			
1996	Berkeley and Oldbury	Shine	Local residents.
1996	Drigg	Shine	Local residents.
1996	Hartlepool	Shine	Non-site related employees.
1996	Hinkley Point	Terrestrial	Local terrestrial food consumers.
1996	Sellafield	Shine	Local residents.
1996	Sizewell	Terrestrial	Local terrestrial food consumers.
1996	Springfields	Aquatic	Local fishing community (fish+shellfish consumption and external in intertidal areas). Bird Warden (external in intertidal areas and sediment handling. Houseboat dwellers (external in intertidal areas).
1996	Springfields	Terrestrial	Local terrestrial food consumers.
1996	Dounreay	Shine	Local residents.
1996	North Solway Coast	Aquatic	Local fishing community (fish+shellfish consumption). Winkle collectors (external in intertidal areas and sediment handling).
1997			
1997	Aldermaston	Terrestrial	Local terrestrial food consumers.
1997	Amersham	Terrestrial	Local terrestrial food consumers.
1997	Capenhurst	Terrestrial	Local terrestrial food consumers.
1997	Sellafield/Eastern Irish Sea	External	Boat dwellers (fish+shellfish consumption and external in intertidal areas). Baitdiggers and mollusc collectors (fish+shellfish consumption, external in intertidal areas and sediment handling). Herdsmen (external in intertidal areas).
1997	Sellafield	Review	Local fishing community (fish+shellfish consumption and external in intertidal areas). Local consumers (consumption of fishing by-catches). Local consumers at Sellafield (seaweed used to fertilize terrestrial crops).
1997	Wylfa	Shine	Local residents.
1997	Torness	Shine	Local residents.
1998			
1998	Cardiff	Aquatic	Local fishing community (fish+shellfish consumption and external in intertidal areas).
1998	Cardiff	Terrestrial	Local terrestrial food consumers.
1998	Sellafield	Aquatic	Local fishing community (fish+shellfish consumption and external in intertidal areas). Yachtsman (external in intertidal areas).
1998	Sellafield	Terrestrial	Local terrestrial food consumers.
1999			
1999	Bradwell	Aquatic	Houseboat dwellers (fish+shellfish consumption and external in intertidal areas).
1999	Bradwell	Terrestrial	Local terrestrial food consumers.
1999	Dungeness	Aquatic	Bait diggers (fish+shellfish consumption and external in intertidal areas).
1999	Dungeness	Terrestrial	Local terrestrial food consumers.
1999	Harwell	Terrestrial	Local terrestrial food consumers.
1999	Sellafield	Review	Local fishing community (fish+shellfish consumption and external in intertidal areas).

Table A.1 (continued)

2000			
2000	Capenhurst	Shine	Local residents.
2000	Hinkley Point	Aquatic	Local fishing community (fish+shellfish consumption and external in intertidal areas).
2000	Hinkley Point	Terrestrial	Local terrestrial food consumers.
2000	Sellafield	Review	Local fishing community (fish+shellfish consumption and external in intertidal areas).
2000	Springfields	Aquatic	Local fishing community (fish+shellfish consumption and external in intertidal areas). Local fishermen (handling fishing gear).
2000	Springfields	Terrestrial	Local terrestrial food consumers.
2000	Wylfa	Terrestrial	Local terrestrial food consumers.
2000	Chapelcross	Combined	Local fishing community (fish+shellfish consumption and external in intertidal areas). Local terrestrial food consumers. Local residents.
2000	Chapelcross pipeline	External	Local community.
2000	Faslane	Combined	Local community (fish+shellfish consumption and external in intertidal areas). Local terrestrial food consumers. Local residents.
2001			
2001	Berkeley and Oldbury	Combined	Local community (fish+shellfish consumption and external in intertidal areas). Local terrestrial food consumers. Local residents.
2001	Berkeley	Shine	Local residents.
2001	Heysham (and Morecombe)	Combined	Local community (fish+shellfish consumption and external in intertidal areas). Local terrestrial food consumers. Local residents.
2001	Sellafield	Review	Local fishing community (fish+shellfish consumption and external in intertidal areas).
2001	Sizewell	Combined	Local fishing community (fish+shellfish consumption and external in intertidal areas). Local terrestrial food consumers. Local residents.
2001	Springfields	Shine	Local residents.
2001	Trawsfynydd	Shine	Local residents.
2001	Hunterston	Combined	Local fishing community (fish+shellfish consumption). Local community (external in intertidal areas). Local terrestrial food consumers. Local residents.
2001	Torness	Combined	Local fishing community (fish+shellfish consumption and external in intertidal areas). Local terrestrial food consumers. Local residents.
2002			
2002	Aldermaston/Burghfield	Combined	Anglers (fish consumption and external over river banks). Local terrestrial food consumers. Local residents.
2002	Drigg	Combined	Consumers of river and stream water. Local terrestrial food consumers. Local residents.
2002	Hartlepool	Combined	Local fishing community (fish+shellfish consumption and external in intertidal areas). Local terrestrial food consumers. Non-site related employees.
2002	Sellafield	Review	Local fishing community (fish+shellfish consumption and external in intertidal areas).
2002	Chapelcross pipeline	External	Local community.
2002	North Solway Coast	Aquatic	Local community (fish+shellfish consumption and external in intertidal areas).
2003			
2003	Cardiff	Combined	Local community (fish+shellfish consumption and external in intertidal areas). Local terrestrial food consumers. Wildfowl consumers. People inadvertently ingesting water from River Taff.
2003	Sellafield	Combined	Local fishing community (fish+shellfish consumption and external in intertidal areas). Local terrestrial food consumers. Local residents.
2003	Winfrith	Combined	Local fishing community (fish+shellfish consumption and external in intertidal areas). Local terrestrial food consumers. Local residents.
2003	Dounreay	Combined	Local fishing community (fish+shellfish consumption and external in intertidal areas). Local terrestrial food consumers. Local residents.
2004			
2004	Amersham	Combined	Data not yet available.
2004	Capenhurst	Shine	Local residents.
2004	Devonport	Combined	Data not yet available.
2004	Sellafield	Review	Data not yet available.
2004	Wylfa	Combined	Data not yet available.

Notes: The 'Combined' surveys for Aldermaston/Burghfield and Harlepool (2002), Cardiff, Sellafield and Winfrith (2003), and Amersham, Devonport and Wylfa (2004) are fully integrated surveys. Other combined surveys are not fully integrated. Surveys relating to Northern Ireland and the Channel Islands were also conducted.

Appendix B: Rates of Consumption of Various Food Types as reported in Terrestrial Habit Surveys

A comparison has been carried out between the reported rates of consumption in terrestrial habits surveys around licensed nuclear sites and rates derived from the National Diet and Nutrition Surveys (NDNS). The analysis, which was based on approximately 1300 adult responses, was intended to provide information as to the proportion of foods consumed by those surveyed that were obtained from local sources rather than the retail distribution chain. The NDNS records total consumption of food from all sources of foods by a representative sample of the UK Adult Population. The comparison has been carried out against the mean rates and the 97.5th percentile rates derived from the NDNS data (referred to as the generic mean and high rates, respectively). Table B.1 gives the proportion of both the total sample population and the subset of the sample who reported consumption of the foodstuff who consume at a rate above half the generic mean, equal to or greater than the generic mean and equal or greater than the high rate.

Table B.1: Consumption Rates of Surveyed Individuals compared with Rates from the National Diet and Nutrition Surveys

Food Type	Above Half Generic Mean		Above Generic Mean		Above Generic High Rate	
	Total Sample	Consumers	Total Sample	Consumers	Total Sample	Consumers
Milk	0.12	0.87	0.11	0.83	0.03	0.19
Beef	0.08	0.96	0.08	0.90	0.02	0.21
Fruit	0.28	0.42	0.16	0.24	0.02	0.02
Fish	0.12	0.72	0.08	0.48	0.01	0.04
Green Veg	0.53	0.77	0.36	0.53	0.06	0.08
Pork	0.06	0.80	0.05	0.62	0.00	0.06
Lamb	0.08	0.76	0.06	0.58	0.01	0.11
Legumes	0.38	0.54	0.17	0.23	0.04	0.06
Potatoes	0.34	0.52	0.21	0.32	0.05	0.08
Root Veg	0.58	0.85	0.45	0.66	0.26	0.38
Eggs	0.29	0.91	0.22	0.67	0.03	0.10
Poultry	0.11	0.61	0.07	0.38	0.01	0.08
Shellfish	0.03	0.81	0.02	0.38	0.00	0.08

As can be seen, of consumers more than half consume, from local sources, at a rate greater than the generic mean for 7 of the 13 food groups. In the case of root vegetables, nearly 40% of those who report consumption from local sources do so at a rate greater than or equal to the generic higher rate. For both milk and beef, approximately 20 % consume above this higher rate.

A calculation was also made of the number of those in the sample that consumed more than one of the food groups at a rate greater than or equal to the generic mean. The results of this calculation are presented in Table B.2.

Table B.2: Percentage of the Sampled Population Consuming Two or More Food Groups at Above the Generic Rate

Number of food groups	Percentage
2	19.68
3	15.20
4	9.26
5	5.02
6	2.93
7	1.47
8	0.85
9	0.00
10	0.23

Similarly, a calculation was made of the percentages of the sample consuming two or more food groups at a rate greater than or equal to the generic high rate. Results of this calculation are summarised in Table B.3.

Table B.3: Percentage of the Sampled Population Consuming Two or More Food Groups at Above the Generic High Rate

Number of food groups	Percentage
2	7.72
3	3.70
4	0.46
5	0.23

As can be seen more than 10% of the sample consume at least 5 food groups from local sources at rates equal to or greater than the generic mean rate. Consumption of 10 food groups at this level is reported by 0.23% of the sample (3 individuals).

At least 2 foodgroups are consumed at a rate equal to or greater than the generic higher rate by 12% of the sample. Consumption of 5 food groups at this level is reported by 0.23% of the sample (3 individuals).

In order to quantify the total consumption of locally sourced foods, the total mass of food consumed by each individual was calculated. This total mass was compared to the total of all the generic mean rates. The results of this calculation are given in Table B.4.

Table B.4: Proportion of Total Food Mass from Local Sources

Proportion of sum of generic mean rates	Percent consuming
<0.25	41.30
0.25 to 0.5	24.23
0.5 to 0.75	14.47
0.75 to 1.00	10.16
1.00 to 1.25	5.85
1.25 to 1.50	2.28
1.50 to 1.75	1.38
1.75 to 2.00	0.24
2.00 to 2.25	0.08

Consumptions of local foods which, in terms of mass, are greater than the sum of the generic mean rates were reported by approximately 10% of the sample and 1 individual reported a consumption equal to more than twice the sum of the generic mean. These high rates are not necessarily implausible, as the typical energy content per unit mass differs substantially amongst the different food groups.

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Title: Pos Paper on Habit Survey
Subject: NDAWG Report No 4
Author: M Thorne
Keywords:
Comments:
Creation Date: 11/23/2005 5:04 PM
Change Number: 4
Last Saved On: 11/24/2005 1:57 PM
Last Saved By: Kedward
Total Editing Time: 4 Minutes
Last Printed On: 11/30/2005 10:49 AM
As of Last Complete Printing
Number of Pages: 39
Number of Words: 18,016 (approx.)
Number of Characters: 96,932 (approx.)