NATIONAL DOSE ASSESSMENT WORKING GROUP

PAPER 11-03: USE OF MEASUREMENTS IN DETERMINING RETROSPECTIVE DOSE ASSESSMENTS IN RIFE

Bill Camplin and Stuart Jenkinson, Cefas

1. Introduction

Measurements of radioactivity in food and the environment are routinely made at locations around the UK and subsequently used in retrospective dose assessments. The purpose of such assessments is to help ensure that members of the public are not being exposed to levels of radiation exceeding national and European (annual) dose limits. The assessment process inevitably involves judgement when marrying together necessarily limited monitoring information with an understanding of the occupancy and food habits of those exposed. Two earlier NDAWG papers have helped to add rigour to the process. Jones (2004) has provided a discourse on the main issues involved in the use of measurements in making assessments and Allott (2005) has developed a set of Principles for the assessment of total retrospective public doses. This paper considers the practice adopted in the RIFE report, the annual publication of the government authorities who undertake monitoring in the UK (EA, EHS, FSA and SEPA, 2006), and reflects on the match between RIFE and the Principles document. This information can then be brought alongside that from industry and other assessments to explore areas for improvement and to reduce uncertainties in methods and data.

The paper begins with a short summary of the method used in RIFE for calculating total retrospective dose (TRD) and then continues with a

commentary of performance against each of the Principles. The comparison is made against the most recent published assessment, that issued in 2006. A brief reference to the other RIFE method for determining dose is made (known as the baseline method) and the paper finishes with suggestions relating to the main areas for further development.

2. Method for TRD assessment in RIFE

The total effective dose received by an individual in age group *i* can be considered as the summation of dose over each relevant pathway *j*, such as:

$$E_i = \sum_j C_j R_{i,j} D_{i,j}$$

where *E* is the effective dose, *C* is the concentration of radioactivity in food or air for ingestion or inhalation pathways, or the external dose rate for external radiation pathways, *R* is the consumption, inhalation or occupancy rate, and *D* is the dose coefficient for intakes or unity for external radiation. A group of individuals for whom *E* is the highest around each assessed nuclear site is defined as the 'critical group'.

Details of the approach used are given in RIFE Section 2 on pages 38 - 41 and in Appendix 7 pages 268 - 269.

TRD is determined at each major site where there has been a habits survey using methods that record rates for all relevant pathways for each individual interviewed. The sites considered in 2006 were :

- Aldermaston and Burghfield
- Amersham
- Cardiff
- Chapelcross
- Devonport
- Dounreay
- Dungeness

- Hartlepool
- Hunterston
- Rosyth
- Sellafield
- Sizewell
- Trawsfynydd
- Winfrith and
- Wylfa

Concentrations and dose rates

In nearly all cases, the concentrations and dose rates were determined by monitoring of food and the environment sponsored. Modelling was used to supplement the monitoring data in two cases:

- In terrestrial food at Sellafield and Drigg where high limits of detection for certain radionuclides are known to distort the assessment (see RIFE Appendix 2) and
- For sites with significant gaseous discharges where plume related pathways are not monitored . Pathways include inhalation of resupended material and external radiation from the plume.

The Health and Safety Executive provided information on the dose received by the public from direct radiation pathways and this was included in the assessment of TRD.

For aquatic foodstuffs, drinking water sources, sediments and air, the assessment is based on the mean concentration or external dose rate near the site in question. For milk, the mean concentration at a nearby farm with the highest individual result is used in the dose assessment. This procedure accounts for the possibility that any farm close to a site can act as the sole source of supply of milk to high-rate consumers.

For other foodstuffs, the maximum concentrations are selected for the assessment. This allows for the possibility of storage of food harvested at a particular time when the peak levels in a year may have been present in the environment.

'Less-than' results are treated in assessments as though they were positive determinations under conditions related to (i) the presence or absence of the radionuclide in the site authorisation, (ii) the method of analysis and (iii) the presence of the radionuclide in other samples from the site.

Consumption and occupancy rates

Consumption and occupancy data are determined by surveys at the sites of interest (see e.g Clyne et al, 2006). The surveys target high-rate individuals in the population and record information for adults and children using interview techniques. All relevant pathways are considered to enable the assessment of dose across all pathways. These data are sorted into age and pathway groupings. Those people who are regarded as having the potential to receive the highest doses are identified for each major pathway at each site. This approach is called profiling (see RIFE Appendix 7 page 268). A profile of consumption and occupancy data is set up for each pathway representing the high rate observations for that pathway. Doses are determined by combining concentrations and dose rates with the profiles and the profile that gives the highest dose becomes the critical group.

Post-natal child doses are calculated using observations for adults and applying appropriate dose coefficients and consumption and occupancy ratios for 1y and 10y age groups. Too few child observations are made in surveys to use their data directly in assessment.

Pre-natal child doses are calculated as an extension to the adult dose assessment using relevant dose coefficients.

3. Performance against the Principles

The approach used in RIFE is discussed against each of the Principles for Total Retrospective Dose assessment (Allott, 2005).

Principle 1 – Total retrospective dose assessment methods and data should be transparent

This Principle relates to the need to make assessment methods and data publicly available such that another party can repeat the assessment. The RIFE report contains an extensive description of the results of monitoring and the basis for the assessment to calculate TRD. An accompanying CD provides Excel files of the specific concentrations, dose rates, consumption rates and occupancies used in the assessment. Included in the CD is a description of which monitoring data are mapped onto the habits profiles.

The RIFE report does not contain all of the information that is generated by the various programmes supported EA, EHS, FSA and SEPA. This additional data is available on request. The main categories of the additional data are:

- Data for individual samples prior to averaging
- Uncertainties in measurements
- Data for very short-lived radionuclides supported by longer-lived parents
- Data which are not relevant to a site's discharges for naturally occurring radionuclides and for artificial radionuclides below detection limits
- Measurements carried out as part of the research programme described in RIFE Section 10
- Intermediate data created during the modelling of terrestrial food at Sellafield and Drigg and of gaseous discharges for pathways that are not monitored

Principle 2 – Workers who are exposed to discharges of radioactive waste, but do not work directly with ionising radiation and are therefore not normally exposed to ionising radiation, should be included in the

assessment and reporting of total retrospective doses to members of the public

Local workers, whose off-site occupation may lead to them being exposed to ionising radiation due to waste discharges or direct radiation, are actively identified during habits surveys. Such workers include farmers of land within the direct radiation zone, commercial fishermen and bait diggers. Corresponding monitoring is undertaken to support their dose assessment and the results are reported in RIFE.

The exposure of sewage workers is not considered in the RIFE report because the monitoring is not designed to determine their doses. Other assessments have been made of such exposures and have been reported separately (Titley et al. (2000).

The exposure of nuclear site workers as a consequence of their work is not considered by RIFE.

Principle 3 – The mean critical group dose should be assessed for the purpose of assessing compliance with the dose limit

The purpose of retrospective assessments is to determine compliance with the annual dose limit. Doses in RIFE are assessed each year on the basis of the calendar year.

The TRD assessment in RIFE makes use of monitoring and habits survey data designed to match the need to identify those most exposed in the population. The calculational method determines the dose as an average of the doses of those most exposed in each age group. All significant pathways are considered in the dose assessment.

The monitoring data used is specific to the assessment year under study. The consumption and occupancy data used is the most up-to-date that is available. The prioritisation of effort in updating habits information is based on

risk. For the higher risks on the Cumbrian coast, annual updates to seafood consumption information are provided for assessment. For lower risk sites, the update frequency is reduced. A target for update of every 5 years is used.

The RIFE report discusses the methods for selecting monitoring data taken at different times and from different places near a site. Most data is taken to be an average in time in the year at the locations where exposure of the critical group is expected. For terrestrial foods, more stringent rules apply to allow for the potential storage and subsequent consumption of food harvested at one time.

Principle 4 – Doses to the most exposed age group present in the affected population should be assessed for the purpose of determining compliance with the dose limit

Four age groups are considered in the RIFE TRD assessments – adults, children (10y old), infants (1y old) and pre-natal children. The age-dependent dose coefficients used are listed in RIFE Appendix 5 pages 264 - 266. Doses to the most exposed age group are chosen for comparison with dose standards. Consumption and occupancy rates representative of 1 and 10 y old children are determined from adult rates by applying generic scaling factors for each pathway. This is principally due to the sparsity of child and infant data. The consumption rate used in the calculation of pre-natal dose is the same as the one taken for adults.

Principle 5 – All significant sources and exposure pathways of authorised historical and current radioactive waste discharges and direct radiation from sources subject to control should be assessed and the total dose compared with the dose limit

The intent of the RIFE TRD assessments is to include all significant exposure pathways for the assessment of waste disposal and direct radiation sources from the major sites discharging radioactive wastes. The monitoring and habits survey programmes are designed to provide information for the

pathways and radionuclides which are likely to present the highest risks. Where monitoring is not feasible, models are used to supplement the information. This is done for gaseous discharges at Aldermaston and Burghfield, Amersham, Cardiff, Chapelcross, Devonport, Dounreay, Dungeness, Heysham, Hunterston, Sellafield, Sizewell, Trawsfynydd, Winfrith and Wylfa.

In some cases the contamination from prior accidents such as Chernobyl will also be detected in monitoring at UK sites. This activity is included in the assessment however its contribution is a small fraction of the dose limit. Monitoring at the major sites will also include small contributions from other sources such as discharges from hospitals and overseas industrial sources. These are generally small.

RIFE does not assess the impact of transportation of radioactive materials, the use of consumer products, medical exposures or natural sources such as radon in buildings.

Principle 6 – Where estimates of the total critical group dose exceed 0.02 mSv/y, the assessments should be critically examined and, where appropriate, more realistic assumptions made

All assessments of TRD in RIFE are critically examined by the contractor when the report is being prepared. A further review takes place when the report is considered by the Environment and Food Standards Agencies and their stakeholders. More emphasis is placed on those assessments which give doses above 0.005 mSv/y and those above 0.05 mSv/y receive detailed attention. Examples of the application of more realistic assumptions have included:

- Experimentation to establish specific gut-uptake factors for key radionuclides

- The use of a model to calculate external dose rate from concentrations in sediments when the use of a measured dose rate net of background is uncertain
- The use of a terrestrial foodchain model when monitoring data includes high LoD data at Sellafield and Drigg
- Changes to the monitoring programme to supplement information when the scope of data is limited (e.g. at Hartlepool in relation to possible enhancement of polonium-210 in shellfish)
- Supplementary interviews when habits survey information has revealed unusually high consumption or occupancy rates

Principle 7 – Positive monitoring results should be used, where available, for assessing TRDs. Results at limit of detection and data gaps should be enhanced with more realistic data where the dose from limit of detection data or dose from data gaps could exceed 0.02 mSv/y

Positive monitoring results are used for assessing TRD in RIFE where they are available. Results at LoD are also used under certain conditions. The use of modelling to provide more realistic data at Sellafield and Drigg is undertaken to avoid overestimating doses based on high limit of detection measurements. Gaps in observations of child consumption rates are dealt with by scaling adult consumption rates.

Gaps in monitoring of the effects of gaseous discharges are filled using models to predict doses from external radiation of the plume, inhalation of the plume, external radiation from deposited activity and inhalation of resuspended activity.

Principle 8 – Critical groups should be selected so that the habits and the doses of the members of the group are homogeneous within a factor of three

The method for defining habits profiles in RIFE relies on the choice of maximum and minimum consumption and occupancy rates which are within a factor of three for the lead pathway being considered for profiling. This does not necessarily mean that doses are homogeneous within a factor of three since there are separate contributions from minor pathways. However in practice the dose Principle is generally satisfied because the effect of minor pathways is usually small.

Principle 9 – Where collective doses are retrospectively assessed for the population of UK, Europe and the World, they should be truncated at 500y

Collective dose is not currently assessed in the RIFE reports.

Principle 10 – Where the assessed total critical group dose exceeds 0.02 mSv/y, the uncertainty and variability in the key assumptions for the dose assessments should be reviewed

The process of review in RIFE related to the level of dose assessed has been considered under Principle 6. It includes all aspects of the calculation – concentrations, dose rates, consumption rates, occupancies and dose coefficients. In some cases the need for experimentation or changes to monitoring or survey programmes is identified to reduce uncertainties.

The approach used in RIFE to consider uncertainty is qualitative and no full quantitative analysis has been undertaken. For the highest doses from waste discharges in RIFE, those received by seafood consumers on the Cumbrian coast, the following has been carried out to reduce uncertainties in the assessment:

- Monitoring programmes have been increased to extend the range of radionuclides determined in seafood
- Monitoring has been changed to better reflect the sources used by local consumers

- Research into the statistical basis for the number of animals in samples has been performed
- Investigations into the temporal fluctuations in seafood concentrations have been carried out
- The variability of natural concentrations of polonium-210 in seafood and of external dose rates in intertidal areas has been determined
- The frequency of habits surveys has been increased to provide contemporary data
- The uncertainty of interview information from habits surveys has been challenged and repeat studies performed for critical consumers
- Dose coefficients have been updated by experimentation to reduce uncertainties in gut uptake factors.

Activity to reduce uncertainty in other assessments has been proportionate to the risk assessed.

4. Performance of the 'baseline' method

The TRD method in RIFE has been recently introduced with the specific intention of providing a measure of critical group dose which draws together the three main sources of exposure for members of the public at major industrial sites – liquid wastes, gaseous wastes and direct radiation. Another method, the baseline method, considers the effects of liquid and gaseous waste discharges separately.

A critical group for each waste source is defined. For liquid wastes, it is often formed from high-rate fish and shellfish consumers. For gaseous discharges, those consuming high rates of terrestrial food and those spending long periods of time in the plume form the critical group.

The correspondence of the baseline method to the Principles has much in common with the TRD method described above. The interpretation of concentrations and dose rates is very similar. The main differences relate to how consumption and occupancy rates are defined and, by definition, to the

completeness with which all sources and pathways are considered. Further discussion of this topic is beyond the scope of this paper.

5. Discussion

The use of measurements in assessing TRD in RIFE broadly follows the relevant Principles stated above. A trend towards more open reporting has led to a substantially increased set of monitoring and habits data being listed in RIFE; the volume of raw monitoring and habits data precludes complete publication in one report, but the full dataset is available from the relevant Environment and Food Standards Agencies. Habits data for use in assessments are being updated via the habits survey programme, and where new and significant changes to pathways are identified, the monitoring programme is updated to ensure realistic concentration and dose rate measurements are available in order to integrate these pathways into TRD assessments.

In the absence of positive determinations, radioactivity concentrations at the limit of detection are used in assessments as a conservative 'best available' value. Food chain modelling is now routinely used to evaluate radioactivity concentrations in foodstuffs at certain sites when the use of LoD data offers relatively high dose estimates.

Further improvements to the system for determining TRD are worthy of consideration and these are listed below:

Monitoring programme design

The programmes of monitoring in the UK have evolved over many years and are subject to formal review on an annual basis and on an ad-hoc basis when new findings come to light. The foundation of the programmes is the objective to provide sufficient information for those sources, pathways, radionuclides and people which are important to produce a reliable comparison with dose standards. There are gaps in monitoring. It is not possible to measure all

things in all places at all times. One approach to evaluating the significance of gaps is to formally compare the scope of monitoring programmes with model predictions. Whilst the use of models is also not perfect, and is also uncertain due to gaps, such a comparison could be used to stimulate ad-hoc investigations to test if differences are important and if there is further scope for the use of models to fill gaps in monitoring. The review could be prioritised according to risk and could draw on existing prospective assessments of waste discharges.

Limits of detection

The main uncertainties due to the use of high limits of detection have been addressed by the use of models. In some low risk assessments, LoDs continue to determine the headline doses. This the case when americium-241 LoDs are used in some assessments of seafood consumption. Further investigation of such LoD data is unlikely to change the broad picture of the risks associated with waste discharges from major UK industrial sites but it would provide more realistic estimates of dose .

Children

One of the key assumptions in the TRD assessment is driven by the paucity of observations of children consuming large quantities of locally harvested food at sites. The assumption is that child doses can be based on adult consumption rates adjusted by a scaling factor. The observations of child consumption have not been fully assessed to check whether the scaling factor approach is robust. A preliminary assessment could be based on existing data of child consumption rates without the cost of further additional survey work.

Natural background

A major uncertainty in determining the effect of waste discharges using monitoring techniques in the UK is due to the variability in natural

concentrations of polonium-210 in seafood and carbon-14 in terrestrial food and in external dose rates over intertidal areas. In both cases the approach used in RIFE is to define a single value to represent the natural level in food and the environment. In the dose assessment this natural level is subtracted from the measured one.

Direct radiation

The data provided by the HSE on direct radiation is based on industry assessments. This data is incorporated into the TRD calculation in RIFE assuming that all people who live close to the site in question are exposed to this level of direct radiation. This is a cautious approach which has been adopted in the absence of a full and detailed review of the basis of the industry assessments. Such a review, which could be prioritised according to risk, would allow a greater realism to be built into the TRD assessment in RIFE.

6. References

Allott, R (2005) Principles for the assessment of total retrospective public doses, NDAWG/2/2005. Environment Agency, Food Standards Agency, NRPB, NII, Chilton.

Byrom, J., Robinson, C.A., Simmonds, J.R., Walters, C.B. and Taylor, R.R. (1995) Food consumption rates for use in generalised radiological dose assessments, J. Rad. Prot., **15(4)**: 335 – 342.

Clyne, F J, et al. (2006) Radiological habits survey: Sizewell, 2005. Environment Report RL 02/06. Cefas, Lowestoft.

Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency (2006) Radioactivity in food and the environment – RIFE 11, Environment Agency, Environment and

Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, Bristol, Belfast, London and Stirling.

Jones, S (2004) Use of measurements in assessing doses to the public: a discussion paper, NDAWG/1/2004. Environment Agency, Food Standards Agency, NRPB, NII, Chilton.

Mayall, A., Cabianca, T., Attwood, C., Fayers, C.A., Smith, J.G., Penfold, J., Steadman, D., Martin, G., Morris, T.P. and Simmonds, J.R. (1997) PC CREAM. Installing and using the PC system for assessing the radiological impact of routine releases, EUR 17791 EN, European Commission, Luxembourg.

Titley, J (1999) Investigation of the sources and fate of radioactive discharges to public sewers. R&D Report P288. Environment Agency, Lancaster.