EMRAS:
Modelling the Transfer of Tritium and C-14 to Biota and Man
Notes of the
Eighth Working Group Meeting
Bucharest, Romania
30 May – 1 June 2007

EMRAS, Tritium and C-14 Working Group,
Meeting Report 8

Notes of the Eighth IAEA EMRAS Tritium and C-14 Working Group Meeting, Bucharest, Romania 30 May – 1 June 2007

The eighth meeting of the IAEA EMRAS Tritium and C-14 Working Group was held in Bucharest, Romania. The meeting was hosted by the Institute of Atomic Physics & Nuclear Engineering "Horia Hulubei" (IFIN-HH).

These Meeting Notes have been prepared by Karen Smith (Technical Secretariat) and Phil Davis (Working Group Leader). In addition, the following people attended the meeting and contributed to the discussions and decisions documented in these Meeting Notes.

Name	Organisation	Country
D Atanassov	National Institute of Meteorology and Hydrology (METEO)	Bulgaria
V Soulanen	Technical Research Centre of Finland (VTT)	Finland
L Patryl	Commissariat à l'Energie Atomique (CEA)	France
P Guétat	Commissariat à l'Energie Atomique (CEA)	France
C Boyer	Commissariat à l'Energie Atomique (CEA)	France
F Siclet	Electricité de France (EDF)	France
Y Belot	Private Consultant	France
F Baumgärtner	Munich Technical University (TUM)	Germany
V Berkovskyy	International Atomic Energy Agency (IAEA)	Austria
J Koarashi	Japan Atomic Energy Agency (JAEA, former JNC)	Japan
K Miyamoto	National Institute of Radiological Sciences (NIRS)	Japan
Y Inoue	National Institute of Radiological Sciences (NIRS)	Japan
H Takeda	National Institute of Radiological Sciences (NIRS)	Japan
K Yamamoto	Yfirst Consultants	Japan
T Masuda	Institute for Environmental Sciences	Japan
C Lee	Korea Atomic Energy Research Institute (KAERI)	Korea
A Melintescu	Institute of Atomic Physics & Nuclear Engineering "Horia Hulubei" (IFIN-HH)	Romania
D Galeriu	Institute of Atomic Physics & Nuclear Engineering "Horia Hulubei" (IFIN-HH)	Romania
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Introduction

The eighth meeting of the EMRAS Tritium and C-14 Working Group was held on 30 May – 1 June 2007, hosted by IFIN-HH. The objectives of the meeting were to:

- Discuss the final reports for the H-3 Pickering and Soybean Scenarios;
- Discuss the draft final report for the H-3 Pine Tree Scenario;
- Discuss and agree the final Definition of OBT;
- Discuss results and the draft final report of the C-14 Potato Scenario;
- Discuss the draft final report of the H-3 Mussel Uptake Scenario and results and draft report of the Mussel Depuration Scenario;
- Discuss the draft final report of the H-3 Hypothetical Release Scenario;
- Discuss the draft final report of the C-14 Rice Scenario;
- Discuss the contribution of the working group to the TRS-364 revision;
- Discuss results and the draft final report of the H-3 Pig Scenario; and,
- Plan future work activities.

Participants were welcomed to the meeting by the Working Group Leader, Phil Davis, who also thanked participants for their contribution to the progression of the Working Group (WG) scenarios. Each participant was then invited to introduce themselves and describe briefly their background and interest in the WG.

All participants are invited to the next Tritium and Carbon-14 WG Meeting, which will be held during the final EMRAS plenary meeting in Vienna, November 2007. Further information on EMRAS meetings can be found on the website.[1] Meeting notes and scenario descriptions for this WG can also be found on the website.[2]

Final reports are due to be completed by autumn 2007. Scenario leaders are therefore requested to ensure that final or draft final reports are progressed for presentation and agreement at the November 2007 meeting. All of the reports will be published together in a single IAEA Technical Document (TECDOD). Volodymyr Berkovskyy requested, on behalf of the IAEA, that all model descriptions be provided in as much detail as possible, ideally to enable model reconstruction by other users. However, where models have been published, these publications may be referred to.

A summary of the main points of discussion on each of the scenarios in the tritium and C-14 WG from the 8th WG meeting is provided in the subsequent sections. Brief scenario descriptions are provided in the Appendices.

[1] http://www-ns.iaea.org/projects/emras/
[2] http://www-ns.iaea.org/projects/emras/emras-tritium-wg.htm

Nature and definition of OBT

Presented by P Davis

Since one of the main focuses of the WG is on OBT, it was considered important at the outset that a definition of OBT be produced, the intention being to distinguish naturally formed OBT from tritiated organics that may be industrially derived. As the definition has progressed through discussions at WG meetings, the issue of buried tritium has been highlighted and discussions have therefore focussed on whether buried tritium exists and, if so, whether it contributes to what we know as OBT. In defining OBT, it is a focus of the WG to ensure the final definition is consistent with laboratory measurements procedures and dose conversion factors.

A short definition has been produced with a series of explanatory notes. Meeting participants were provided with a copy of the current definition and comments invited. The circulated definition is provided below.

Definition: OBT is carbon-bound and buried tritium that was originally formed in living systems through natural environmental or biological processes from HTO (or HT via HTO). It is the activity remaining in dry biomatter that has been washed repeatedly with tritium free water. Other types of organic tritium (e.g. tritiated methane, tritiated pump oil or radiochemicals) should be called tritiated organics, and these can exist in any chemical or physical form.

Notes:
(i) OBT should not include the exchangeable fraction (tritium bound to sulphur, nitrogen or oxygen) that can be removed by washing with tritium-free water. This fraction depends strongly on the HTO concentration in effect at the time of sampling and can exchange quickly with water vapour during analysis. Inclusion of the exchangeable fraction would lead to results that are highly variable and difficult to interpret.

(ii) Exchangeable tritium should be removed by moderately drying the sample without decomposing the molecular structures, washing the residue repeatedly with tritium free water and then drying the material again. The OBT concentration can then be determined as the tritium activity in the dry sample. This is generally done by combusting the sample and determining the activity in the combustion water by liquid scintillation counting, or by analysing the sample by He-3 mass spectrometry.

(iii) In the washing process, exchangeable tritium nuclei are removed and replaced by hydrogen nuclei, but exchangeable hydrogen nuclei are simply replaced by other hydrogen nuclei. Thus measurements of OBT do not reflect the specific activity of the non-exchangeable hydrogen. This specific activity can be estimated by dividing the measured concentration by the fraction of non-exchangeable hydrogen nuclei in the dry sample. For example, this fraction has been empirically determined to be 0.78 for leaf tissues but different values may apply for other plant or animal materials. Care must be taken in comparing model predictions and experimental data that the same quantity (OBT concentration or specific activity of non-exchangeable hydrogen nuclei) is being considered.

(iv) OBT concentrations should be reported in units of Bq/L of combustion water. This is the fundamental unit that can be converted, if necessary, to the specific activity of the non-exchangeable hydrogen nuclei. Use of Bq/L makes it easy to compare concentrations in

different media and to determine whether specific activity is depleted, preserved or enriched when tritium is transferred from one compartment to another.

(v) OBT refers to organic tritium formed from HTO by natural processes in living organisms, or in materials such as soils or lake sediments that are derived from living material. Put another way, OBT is that organic tritium that imparts a dose consistent with the dose coefficient traditionally used for OBT. All other types of organic tritium, no matter how they form or how they appear in the environment, should be called tritiated organics and assigned their own dose coefficient for purposes of dose calculation.

A number of issues/comments were raised for discussion:

- Franz Baumgärtner noted that OBT in analytical procedures can be exchanged not only with water, but also with saline solutions. He also noted that molecular structure could be decomposed to enable exchange. Therefore, he recommended that note (i) be amended to take account of these alternative methods of exchange/analysis. However, in response, Yves Belot commented that the method currently described is that routinely used for the measurement of OBT with the alternatives being more suited to specific research needs. It was therefore agreed that it would be made clear within the TECDOC that the definition is based on common accepted analysis methods and that deviation from this definition would be required in some instances.

- Volodymyr Berkovskyy suggested that it be made clear that the definition of OBT is consistent with that of the ICRP model.

- The term buried tritium is used initially in the definition, but is then not mentioned further. Phil Davis therefore suggested that an additional note be added to explain that this is tritium that is attached to exchangeable sites of large biomolecules and that it behaves as exchangeable tritium in the body, but not during analytical procedures. The addition of this note was agreed by participants.

In addition, some specific changes to terminology were suggested and agreed by the group:

- It was agreed that the term ‘molecular structures’ in note (ii) would be replaced by ‘organic molecules’; and,

- Note (v) will be updated to explicitly mention the ICRP, for example by amending ‘dose consistent with the dose coefficient’ to ‘dose consistent with the ICRP dose coefficient’.

Next steps

Minor changes to the definition as suggested will be made and the new note on buried tritium will be added by Phil Davis. The revised final definition will be circulated by the end of September.

Tritium scenarios

Discussion of the final report for the Soybean Scenario

Presented by P Davis

The Soybean scenario considers the dynamics of tritium in soybean plants following short-term exposures at different growth stages. Since the last Working Group meeting, model descriptions have been edited, primarily for consistency of format. Once amendments have been checked the report will be finalised and loaded to the EMRAS website.

Next steps

Revised model descriptions will be provided at the end of June to those participants for whom more major amendments were undertaken. Participants are requested to check the revised descriptions to ensure these remain accurate.

Discussion of the final report for the Pickering Scenario

Presented by P Davis

The final report for the Pickering Scenario was due to be completed prior to the previous WG meeting. However, during that meeting, Phil Davis presented results of an examination of the influence on predictions of different averaging assumptions for HTO concentrations in air. In the scenario, air concentrations for the 2 months prior to harvest of crops were provided. The uncertainty in these concentrations was high because they were an amalgamation of monitoring data from sites in the vicinity of the harvest area. More accurate air concentrations for the harvest site were subsequently derived from a site-validated model with daily source term as input. Both daylight (to represent photosynthetically active period) and 24-hour concentrations were estimated. Higher concentrations were obtained for the 24-hour period due to the higher atmospheric stability at night.

The model predictions of OBT concentrations in plants and animals that were submitted by participants based on the original air concentrations all overestimated the observations by a factor of about 4. The observations were still overestimated (by about a factor 2) when the new 24-hour average air concentrations were used to drive the models, but much better agreement was obtained using the new daylight air concentrations.s It was therefore concluded that air concentration averaged over daylight hours provided the most accurate input for the models.

Since the 7th WG meeting, further consideration has been given to the role of air concentrations in model over-predictions. The AECL model, which did not participate in the original scenario, was run with both the initial and revised air concentrations. This model achieved more accurate predictions on the basis of the 24-hour air concentrations.Conclusions regarding the best averaging time for air concentrations therefore appear to be model dependant and more work is required to determine whether the 24-hour or daylight averaging periods is most appropriate.

Next steps

A new appendix will be added by Phil Davis to the report describing the additional calculations undertaken and key conclusions by the end of July. The revised report will be circulated to the WG for comment before uploading to the IAEA website.

Discussion of the draft final report for the Pine Tree Scenario

Presented by Y Inoue

The Pine Tree scenario considers continuous releases of tritium to the air from four sources, the resultant air concentrations at various sites and subsequent uptake into pine trees. The specific objectives of the scenario are to evaluate the modelling approaches used to predict monthly and yearly mean HTO concentrations in air, tissue free water tritium (TFWT) and OBT in pine needles and annual rings, and HTO in groundwater, for the conditions and factors given in the scenario description. The draft final report of the scenario was presented and amendments were made to the text as the presentation progressed.

There were five participants in the scenario. NIRS, SRA and IFIN calculated all endpoints requested. LLNL calculated all but groundwater concentrations. EDF predicted only air, rain and groundwater concentrations. With the exception of NIRS, which used a random walk model, all participants employed Gaussian plume models.

Overall, the NIRS model predictions were most accurate, particularly for air concentrations and TFWT at site P3 and for groundwater predictions. The SRA model over-predicted air concentrations and TFWT at P3 by a factor of 2. Other models under-predicted concentrations at this site. For groundwater, EDF over-predicted HTO concentrations, whereas other modellers, with the exception of NIRS, under-predicted. The general under-prediction in annual averages may have arisen from models ignoring factors such as sea breeze inversions that restrict the upward dispersion of the airborne plume.

Since the 7th WG meeting, amendments have been made to model descriptions.

Next steps

The current version of the draft final report will be distributed to all participants by the end of June. Participants are requested to review model descriptions and summary tables (Tables 4 and 5) and report any errors to the scenario leader by the end of August, including their interpretation of ‘retention period’ in Table 4. Participants are also requested to review the draft final report and provide any comments or further reasons for differences in model predictions by this date.

A final report will be produced by the end of September.

Discussion of the draft final report for the Dynamic Mussel Uptake Scenario

Presented by P Davis

Phil Davis presented the final draft report on behalf of the scenario leader, Tamara Yankovich.

The dynamic mussel uptake scenario is based on data collected in Perch Lake, a small, shallow freshwater body in Canada with historical inputs of tritium. The lake supports a natural population of Barnes mussels, which are the focus of the scenario. Mussels (9-11 cm in length) were transplanted from a background site in the Ottawa River into mesh cages in Perch Lake at a location where *in situ* mussels are found. Four cages, each containing 64 mussels, were used. Two cages were suspended in the water column and received exposure to radionuclides in the water only; the other two cages were placed at the sediment-water interface and filled with sediment to provide exposure to radionuclides in both the water and the sediments. The mussels were sampled 1 and 2 hours after transplantation and then at increasing time intervals up to 86 days. The modellers were provided with the background concentrations in the animals, the HTO concentrations in the water, the HTO and OBT concentrations in the sediments, the dimensions of the mussels and the water temperature and asked to predict the dynamics of HTO and OBT uptake in mussel soft tissue at the various sampling times. No change in shell length or weight of the mussels was observed over the study period and no mortalities occurred. Five modelling teams participated in the scenario.

A draft report of the mussel uptake scenario was distributed prior to the November 2006 WG meeting.

HTO concentrations in mussels reached equilibrium with water concentrations within 1 hour. The Biochem model was found to predict initial mussel HTO concentrations with reasonable accuracy. However, other models slightly under-estimated initial concentrations. All models were in reasonable agreement with observed HTO data for longer exposure times. Similar results were obtained for water and sediment/water exposures.

All models under-predicted mussel OBT concentrations over the first few hours of exposure. Over the next few hours, most models over-predicted the formation rate although the actual concentration was still under-predicted. In general, however, final predictions were within a factor of 3 of the observations. Two-compartment models, which assumed that new organic matter that formed in the mussel had the same OBT concentration as the food, predicted mussel OBT levels well. Most models (with the exception of the IFIN-HH model) did not predict any difference in uptake of OBT between sediment-water and water only exposures.

Observations of OBT in mussels towards the end of the exposure period dropped by a factor of 2. This may have been due to analytical error or, more likely, could result from the transfer of OBT from soft tissues to reproductive organs and loss through gamete release. However, alternative explanations for the observed reduction in OBT are invited.

Based on the results of the field study, it is estimated that it could take between 4 and 7 years for OBT concentrations in transplanted mussels to reach equilibrium concentrations with *in situ* mussels for water only exposures and up to 15 years for sediment-water exposures. HTO concentrations on the other hand reach equilibrium, regardless of the exposure conditions, within 2 hours of transplantation. Therefore, should an accidental tritium release to water occur, HTO concentrations in mussels would equilibrate rapidly, but it may be possible to remediate the situation before tritium is translocated to organic compartments as OBT.

Next steps

No comments have been received following distribution of the draft report last fall. Since then, model descriptions have been edited. Participants are therefore requested to review the draft final report and provide any comments by the end of July.

A shortened version of the report that is intended for journal publication has also been provided. All participants in the scenario will be listed as authors. Participants are therefore requested to provide comments on the draft paper by the end of July.

Discussion of results and draft report for the Dynamic Mussel Depuration Scenario

Presented by P Davis

The Scenario for the mussel depuration phase is very similar to that for the uptake phase except that the mussels were exposed to an abrupt decrease in their ambient tritium levels. Mussels that had spent all their lives in Perch Lake and were therefore in equilibrium with environmental tritium concentrations of around 5,000 Bq/L were transplanted to a control site with a background activity of 50 Bq/L. Following transplantation, HTO and OBT measurements were taken hourly for the first two hours and then at longer time intervals for the duration of the study. The same supporting information was made available as for the initial uptake scenario. Four models were applied to the scenario.

For HTO concentrations in mussels, EDF assumed equilibrium with water concentrations within 1 hour of transplantation. For OBT, the OURSON model, which was originally developed for fish, was employed. The model takes into account ingestion rate and digestibility of food. For the uptake scenario, the model was not sufficient to predict the fast increase in OBT during the initial stages following transplantation. In order to address this, an additional stomach content compartment was added to account for OBT associated with food that has not yet been digested. The stomach compartment is assumed to comprise 30% of the soft tissue mass of the mussel. The stomach content turnover rate (0.33 per day) was estimated from mussel filtration rate and suspended matter concentration in lake water. Soft tissue turnover rate (10^{-2} per day) corresponded to metabolic activity.

Following the presentation of observed to predicted ratios for models at the 6th WG meeting in June 2006, the NIRS model was modified. Revised transfer parameters were derived from the simulation of the uptake scenario by application of a modified 3-compartment dynamic model. For HTO, greater intake and excretion rates were assumed. For OBT, a larger exchange between mussel HTO and the fast OBT compartment was assumed and direct excretion of OBT to lake water accounted for. Only a small exchange between the fast and slow OBT compartments was assumed.

IFIN-HH employed a simple compartment model for tritium processes in aquatic animals that considers uptake from food and water. OBT in the mussel results from metabolism of HTO with some contribution from OBT in food consumed. For OBT in food, food dry matter is used to calculate OBT transfer between food and mussel on the basis of hydrogen content. Biological loss was taken into account using a loss rate of 0.22 per day based on data for the mussel *Mytilus edulis*. Temperature effects on metabolism were also taken into account although no specific data were available for Barnes mussels and therefore data for giant clams was used as a substitute. For the depuration scenario, a similar approach was taken to that for the uptake scenario, but a high initial OBT concentration in mussels was assumed.

The TUM Biochem approach was to reverse OBT formation from the uptake scenario. The approach was based on reaction kinetics. It was assumed that there are 5 OBT pathways in mussels, two for buried OBT, two associated with reproduction and one for OBT associated with digestion. However, for the depuration scenario, no reproduction was assumed and therefore only digestion and buried OBT pathways were considered.

Most models under-predicted the rate of HTO equilibration between mussels and water. The Biochem and NIRS model predictions were similar, but HTO concentrations were over-estimated due to an under-estimate of HTO exchange. The EDF model was reasonably accurate with respect to observed data with the exception of the initial observation (equilibrium was reached within around 2 hours opposed to the 1 hour assumed). However, fluctuations were evident with respect to observed data, which may have arisen from the use of average water concentrations to predict mussel HTO concentrations.

For OBT, all models under-predicted concentrations up to 10 days by a factor of 2 to 3. After 10 days, the Biochem and NIRS models were both in reasonable agreement with observations. EDF and IFIN-HH models over-estimated the rate of loss from mussels. Differences in OBT predictions may have arisen as a result of dietary OBT uptake assumptions or from parameters describing OBT formation rate in mussels. The number of OBT compartments within models may also have had an effect on OBT predictions.

Next steps

Participants are requested to check that predictions are accurate and have been correctly plotted by end June. Observations will also be circulated to all participants by the end of June. A table of key parameter values and assumptions may also be circulated for completion by participants. The date for return of completed tables will be confirmed by the scenario leader.

A report will be prepared and distributed for comment by the end of September.

Discussion of results and draft final report for the Pig Scenario

Presented by D Galeriu

The pig scenario was defined on the basis of an unpublished data set, and considers a pregnant sow of around 180 kg that was given feed contaminated with OBT for 84 days before delivery. After giving birth the sow was slaughtered and tritium activity in various organs measured. In the 84-day contamination period, concentrations in urine and faeces were also monitored. Modellers were asked to predict time-dependent concentrations of total tritium in urine and of HTO and OBT in faeces. HTO and OBT concentrations in various organs at slaughter were also requested. The number of piglets in the litter was unknown, as was information on maternal growth. Food composition was known, but the metabolisable energy of food was not available. The increase in food intake during the exposure period reflected maintenance need, gestation need and maternal growth.

This scenario was split in two parts, a model-data blind test and a model inter-comparison. There were seven participants from five organisations (FSA, SRA, EDF, LLNL and IFIN) for the blind test and three participants (FSA, SRA and IFIN) for the model inter-comparison.

Model blind test

Models of differing complexities were applied to the scenario.

SRA employed a model that was derived for tritium in humans and took account of both slow and fast compartments for tritium incorporation. IFIN and LLNL together applied STAR, a model that was derived initially for UK conditions for cow and sheep on pasture all year round, focusing on HTO intake. The model has subsequently been extended to include pigs, but the intake is still assumed to be from pasture. IFIN also applied MAGENTC, which is based on energy and hydrogen metabolism and requires input on organ metabolic rates, body and organ composition and animal growth. FSA used PRISM for its calculations. EDF used a simple four-compartment model (OURSON) that contains a single organic compartment.

Due to problems previously encountered in the predictions from the PRISM model, this model has been reconstructed within the model-maker platform by IFIN in order to investigate reasons for differences in model predictions.

Overall, with the exception of the FSA and STAR results, models gave reliable predictions. STAR was developed considering pasture intake, which is not directly applicable to the current scenario.

Predictions of total tritium in urine were in general within a factor of 10 of the observed concentrations. However, the FSA PRISM predictions were many orders of magnitude greater than observations. The reconstructed PRISM model predictions were similar to observations.

Concentrations in faecal matter were underestimated by IFIN, EDF and SRA, possibly because there was more indigestible food in the diet than that assumed. Data for HTO and OBT in organs were, with the exception of FSA, in reasonable agreement with the observations. The EDF model predicted OBT concentrations in most tissues close to observations. However, muscle concentrations were overestimated and this difference requires further consideration.

Model inter-comparison

The model inter-comparison comprised two scenarios. The first was based on a hypothetical pig of conventional strain, which was given uncontaminated food and water for the first 55

days of life, and was then fed food and water contaminated with HTO at a concentration of 10,000 Bq/L for 50 days. Uncontaminated feed was then provided for the next 50 days, at which time the pig weighed 110 kg and was slaughtered. Modellers were asked to predict concentrations in urine, faeces and meat. IFIN, SRA and FSA participated. A 15-fold difference in the model predictions was observed. Further consideration is required to understand the reasons for these differences. A factor of 100 difference was observed for predictions of meat concentrations with FSA again over-predicting.

The second scenario aimed to determine whether accurate results could be obtained by considering a single generic pig or whether the specific strain and diet must be taken into account. The scenario considered pigs that were fed OBT contaminated food for 1 day at a concentration of 1 MBq/kg. Modellers were asked to predict both meat and liver OBT concentrations at slaughter (body mass 110kg) for various pig masses on the day of contamination. Results were supplied by FSA and IFIN. Results from both models indicate that genotype is not important in determining uptake of OBT to meat, but differences were observed for liver in the IFIN model.

Next steps

AECL expressed continued interest in submitting results for the pig scenario and these are to be submitted by the end of June.

Further information on the models applied is required and the scenario leader will therefore contact participants in June. The draft final report will be completed by the end of September.

Discussion of the draft final report for the Hypothetical Short-term Release Scenario

Presented by L Patryl

The Hypothetical scenario considers an accidental release of tritium to the atmosphere under three different environmental conditions as detailed below:

	Case 1	Case 2	Case 3
Time of release	day	day	midnight
Wind speed (m s^{-1})	2	5	2
Direction (° from N)	45±25	45±10	45±3
Diffusion conditions	unstable	neutral	stable
Weather	fine	cloudy	clear
Pasquill category	A	D	F
Solar radiation (W m^{-2})	700	300	0
Temperature (°C)	20	20	10
Rain (mm)	-	15	-
Relative humidity (%)	70	90	95

Results for this scenario were submitted by P. Davis (AECL), D. Galeriu and A. Melintescu (IFIN), H. Lee (KAERI), K. Miyamoto (NIRS), L. Patryl (CEA), W. Raskob (FZK), P. Ravi (BARC) and M. Saito (SRA). Since the last WG meeting, corrections have been made to some model calculations. The draft final report was presented and discussed.

The model parameter tables were noted as having a number of data gaps and inconsistencies. Therefore, all participants are requested to revise Table 6, particularly with regard to re-emission parameters. Where possible, participants are requested to enter parameters and assumptions in a manner similar to that provided by Wolfgang Raskob.

With regard to Chapter 4 on total doses, it was noted that an additional paragraph could be added to describe concentrations in salad and wheat. It was therefore agreed that a new table would be added containing this data and explanatory text added as appropriate.

A number of other amendments were agreed:

- Page 25, Case 3, second paragraph ‘and Romania’ to be added to sentence beginning ‘Germany uses an elaborate model’;
- Page 28, figure 10, distance to be removed from figure title;
- Page 31 figures, it was suggested a note be added to explain that figures are only indicative;
- An additional column will be added to Table 6 to describe the approach used to model wet deposition; and,
- Appendix A will be amended to include both ingestion dose and total dose.

With regard to HT dose calculations, it was noted that the relative importance of the milk pathway increased in Case 2 for the FZK model. Possible explanations for this are invited.

From the results of the inter-comparison, a Derived Intervention Level of 10^7 Bq/kg has been proposed that is independent of weather conditions at the time of the release. This value is applicable to measurements made in the first day following release. However, Volodymyr Berkovskyy noted that an ICRP document (Publication 101), released in May 2007, has resulted in a change to the concept of intervention following an accident. Optimisation to reduce doses below the intervention level must now also be considered. The intervention level is no longer therefore a threshold below which no action is required. This revision is currently being considered by the IAEA. It was therefore recommended that this new approach should be mentioned within the scenario report since the method used for deriving the intervention level is now not consistent with that proposed by the ICRP. It was also proposed that details

of the critical group or most exposed person and relevant parameters and assumptions could be added to the report to provide greater clarification.

Finally, it was agreed that an additional appendix would be added that details full model descriptions in addition to the tables currently provided within the main body of the report that summarise modelling approaches and parameters.

Next steps

All participants are requested to provide information on the approach used to model wet deposition by the end of June. Participants are also requested to complete any missing data from the model description tables in a manner consistent with that from Wolfgang Raskob. This should be completed by the end of June.

Amendments will be made to the report by the end of August.

Carbon-14 scenarios

Discussion of results and draft final report for the Potato Scenario

Presented by A Melintescu

The Potato Scenario is based on experiments conducted by Scott Tucker, a PhD student at Imperial College, London. The experiments involved potato tubers (*Solanum tuberosum* - Romano) that were seeded in August 1995 (later in the year than usual for the UK) and subsequently exposed to $^{14}CO_2$ in a wind tunnel. Fumigation occurred for approximately 10-hour periods at 6 different plant growth stages (P1–P6). Both temperature and humidity increased during fumigation.

Following exposure, the plants were transplanted to the field to continue growing. Plant samples were taken at various times following fumigation to determine the concentrations of C-14 that were fixed by the plants. The biomass (average dry weight) of roots, leaves, stems and tubers were determined at harvest. Meteorological data for 1995, when the experiments were conducted, was not available and therefore 30-year average data for Cambridge was employed, leading to some uncertainty. Modellers were asked to calculate C-14 in leaves at each sampling time for all 6 plant growth stages and the concentrations in tubers at final harvest. 95% confidence intervals for model predictions were also requested.

There were four participants for the scenario: EDF, FSA, UTTY and IFIN. IFIN employed two models, WOFOST and Scottish. UTTY submitted two sets of results, one of which was submitted after the release of observed data.

Experimental results were initially presented. The main findings were:

- Incorporation of C-14 into leaves was lowest for P1 and P6. For P1, this was considered to be as a result of a low leaf area index at this development stage. For P6, plant senescence and low leaf area index were considered to be the main contributing factors.

- Concentrations of C-14 in leaves and shoots dropped for all fumigations (P1-P6) just prior to harvest, reflecting a translocation of labile photosynthetic compounds to tubers at senescence. Translocation to tubers was also observed at the start of the reproductive period with around 20% to 40% of dry matter in stems being translocated.

- Tubers represent the most important sink for C-14 fixed by potato plants.

Overall, model predictions were variable:

- At P1, the IFIN WOFOST and Scottish models both under-predicted leaf C-14 concentrations by a factor of < 5. In contrast, the FSA, EDF and UTTY models all over-estimated with EDF and UTTY over-estimating to the greatest degree (between a factor of 5 and 40 difference from observed data). The revised UTTY model was more accurate.

- P2 predictions showed a similar trend to those reported for the P1 fumigation.

- For P3, large overestimates were obtained from all models for leaf concentrations at harvest. This results from the use of the reported green leaf mass and not taking into account contaminated dead leaves.

- For P4, the IFIN WOFOST model failed to predict any C-14 in leaves whereas the Scottish model underestimated initially by a factor of 10, but over-predicted by a factor of 40 for the last sampling period. The FSA model provided reasonably accurate predictions with the exception of the last sampling point. Both EDF and UTTY again over-predicted with the revised UTTY model providing more accurate results (within a factor of 1 to 5).

- For P5, the WOFOST model again failed to predict any C-14 in leaves and the UTTY model only predicted concentrations in leaves for the initial sampling periods. The predictions of the IFIN Scottish model were variable in relation to observed data. Both FSA and EDF models over-estimated, with the FSA model giving the largest predictions (between a factor of 10 to 50 greater than the observations).

- Finally, for P6, the WOFOST and UTTY (original and revised) models failed to predict any C-14 in leaves. Both the Scottish and FSA models provided reasonable estimates, with predictions being within a factor of 2 and 6 of the observed data, respectively. The EDF model again over-predicted leaf concentrations.

The general over-prediction of leaf concentrations at the last sampling point (with the notable exception of the WOFOST and UTTY models) is considered to result from models not taking into account translocation from leaves to tubers. The EDF model didn't consider light or temperature effects on photosynthetic rate, instead applying a maximum value for the rate of photosynthesis. aThis may account for the over-predictions observed for all sampling points. Given the uncertainty in the experimental data in combination with the complex partitioning and translocation processes occurring in the plant, a factor of 5 variation in the observed to predicted ratio is considered reasonable.

For C-14 in tubers, the FSA model was found to give the most accurate predictions (within a factor of 3 of observed data). Other models tended to over-predict tuber concentrations by factors up to 10.

Overall, the scenario provided a good blind test for models. Most models poorly reproduced the dynamics of C-14 in plants (in this case, in leaves through the growing cycle), but predictions of C-14 incorporation into tubers at harvest were more accurate. Difficulties in predicting plant concentrations may have arisen as a result of the late seeding and early and sudden onset of senescence, whereas models have been developed on the basis of a more normal plant growth scenario.

Following the presentation and discussion of results, model descriptions were discussed and a brief overview is provided below.

The EDF model (OURSON) is a dynamic model that was initially developed for assessing radionuclide concentrations in the aquatic and terrestrial environment resulting from liquid effluent discharges. Translocation between leaves and storage organs is taken into account. For the potato scenario, the model considered two growth phases: a vegetative stage that takes into account general plant growth and a tuber-specific growth stage.

The FSA model (PRISM, 3.0) is used for compliance testing and is therefore conservative. It is a dynamic model with both biological and environmental compartments. For the purposes of the current scenario, exposures were modelled as a complex series of spikes with different

exposures for each experimental run. Adjustments were made to the plant growth curve to allow for some growth prior to exposure. No detailed description of the FSA model has been provided to date and this is therefore requested in time for inclusion in the final report.

IFIN employed two models. The WOFOST model is a dynamic model, although no uptake from soil is incorporated, since it is assumed that over 90% of plant carbon is derived from the atmosphere. The model considers initial incorporation within the total plant, loss through maintenance and respiration, translocation and growth dilution. Default potato parameters were employed in the model and biomass dynamics were therefore slightly under-predicted due to the late experimental seeding. Maintenance and growth respiration are accounted for with fast and slow components, for which rates of 2 and 0.2 per day were applied, respectively.

The IFIN simple model (Scottish) only considers plant dry matter production but takes into account light use efficiency, incoming photosynthetically active radiation and light interception as a function of leaf area index. The results of the simple model were found to be similar to the WOFOST model. However, the more complex WOFOST model can be used to assess parameter sensitivity and areas of uncertainty.

The NIRS UTTY model is a dynamic compartmental model which adopts a similar approach to modelling C-14 uptake by potatoes as that employed for the rice scenario. The model is comprised of 1 inorganic (whole plant) and 2 organic plant compartments (stem-leaf-root and tuber[3]) and 2 environmental compartments (air and soil). C-14 in air is directly exchangeable with the inorganic plant compartment. Photosynthesis products are then transferred to the stem-leaf-root compartment until flowering. Subsequently, all fixed C-14 is transferred to the potato tubers. Following the release of observed data, the model was revised by altering C-14 in the inorganic compartment to match that in air during the 10-hour exposure. Further explanation of the model structure and turnover relationships, and the revisions introduced after receipt of the observed data, are requested.

Next steps

Participants are requested to provide more detailed model descriptions, particularly in relation to the processes considered, and to provide reasons for observed differences between observations and model predictions by the end of July. The scenario leader will contact participants directly for points of clarification as required. Any uncertainty estimates should also be submitted by the end of July, together with the calculational basis of the uncertainty modelling.

Following the submission of the required information, a revised draft report will be circulated by the end of September.

[3] For rice, this compartment is used to represent the grain.

Discussion of final draft report of the Rice Scenario

Presented by J Koarashi

The C-14 rice scenario is based on JAEA monitoring data around the Tokai reprocessing plant (TRP). The data include discharge rates at three stacks, atmospheric C-14 concentrations at five stations (Stations 1 to 4 and Station N) and C-14 concentrations in rice grain at 3 sites (R1 to R3). Stations 4, N and R3 were control sites. Modellers were provided with data on weekly C-14 discharges, stack characteristics and information on the growth of rice plants. Hourly meteorological data were also provided, as was the annual average background level of C-14 in Japan. Modellers were asked to predict the mean monthly C-14 concentrations in air and in rice grain. Results were submitted by five participants (AECL, IFIN, NIRS-UTTY, SRA and EDF). IFIN provided predictions from two models.

The draft report was distributed to participants in February and amended following receipt of comments. The revised report was presented and the remaining issues highlighted, particularly with regard to areas where further information is required from participants.

With the exception of EDF, which used a straight-line Gaussian model, all participants employed a sector average approach. However, parameterisation of these approaches varied. Most participants employed meteorological data at 100m. However, the approach used by EDF was unclear and further information is therefore required. Anca Melintescu explained that the IFIN approach was to use hourly averaged meteorological data and one stack release.

Overall, air $^{14}CO_2$ predictions were within a factor of 3 of the observed data. However, all models under-estimated atmospheric $^{14}CO_2$ concentrations from May to August 1993 when there was only a small release from the tritium processing plant. At ST1, AECL and IFIN predictions agreed with both the magnitude and trend of discharges in 1992; however EDF and UTTY predictions were high compared to observed data. Plume rise assumptions were considered to be one of the most important factors in explaining differences between air $^{14}CO_2$ predictions and observations. The different dispersion parameters used in the two IFIN dispersion models resulted in around a 20% difference in $^{14}CO_2$ air predictions at ST1.

With the exception of EDF, all models predicted rice concentrations at R1 and R2 in 1992 that were within a factor of 2 of the observations. EDF predictions were an order of magnitude lower than those from other participants. In discussions, Francoise Siclet explained that the translocation factor used in the EDF model may have been too low and this could have accounted for the difference in predictions observed.

In 1994, rice concentrations at R1 and R2 were over-predicted by AECL and UTTY, but under-predicted by IFIN and SRA. Both SRA and AECL used specific activity models to predict rice concentrations. However, different averaging times were employed and this may explain the difference in the results obtained.

Since different approaches were used to predict air concentrations at R1 and R2 that were subsequently used in the calculation of rice concentrations, rice predictions were standardised against air concentrations to allow comparison of model predictions. Out of the different models used, no one model was found to produce more accurate results than the others with even simple models producing good predictions at distances close to the point of discharge.

Next steps

The revised report will be distributed to participants who are requested to check it for accuracy and address any data gaps or uncertainties as highlighted. In particular, EDF are requested to check what meteorological data were used and to check that the approach documented for the treatment of plume rise is correct. IFIN are requested to provide data on

model parameterisation for inclusion in Table 3. Responses to highlighted text are to be provided by the end of June.

In addition, all participants are requested to check that the standardisation of rice concentrations at R1 and R2 against air concentrations is correct for their model predictions.

A revised report will be produced by the end of July.

Contribution to the revision of TRS-364

Presented by P Davis

A summary document of the contribution of the Tritium and C-14 WG to the revision of TRS-364 has been produced. This contribution will form Chapter 9 of the TECDOC written by the Transfer Parameter WG. The TECDOC will then be condensed to provide the revised TRS-364 document. In addition, a special issue of the Journal of Environmental Radioactivity will be produced.

The initial models proposed by the group for inclusion in TRS-364 were reviewed by Mike Thorne and comments received have been incorporated into the revised document. The revised document was presented and comments/discussion invited. An overview of the main discussion points is provided below.

HTO in plants

For the transfer of HTO from air to plants, the equation recommended (Equation 9.2) is intended for leafy vegetables and forage. It was discussed as to whether the equation should be modified for fruit and root crops. Overall it was considered that the use of the equation in its current form provides a conservative approach in most, but not necessarily all instances. It was therefore recommended that a caveat be added to explain that the equation could be applied to a variety of crops and would be considered conservative for most applications, but that its main application is for leafy vegetables.

Consistency of units (e.g. kg/m^3 or kg/l) was an issue raised by Volodymyr Berkovskyy in that the units applied in the Tritium and C-14 WG contribution may not be consistent with the rest of the TECDOC. However, the units used throughout the document were considered applicable to the models employed and would only therefore be amended if required by the Transfer Parameter WG.

For the transfer of tritium from air moisture to soil pore water a concentration ratio approach has been employed and a default value of 0.3 recommended on the basis of available data. Discussion focused on the applicability of this recommended value and it was suggested that 0.3 could remain as the default, but an upper range of 0.5 could also be included, which would be considered conservative. The possibility of changing the approach from an air moisture-soil water ratio to a rain water-soil water ratio was also discussed. Due to a lack of data, it has not been possible to derive ratios according to different soil types.

Ring Peterson highlighted a study conducted in the USA in which irrigation water concentrations, air moisture concentrations and soil water concentrations were determined resulting in an air to soil water concentration ratio of 0.5. Reference details for this study are to be provided and the study will be reviewed to determine whether data are appropriate for entry into Table 9.2. Participants are requested to provide any further data they are aware of.

Following discussions, it was agreed that additional text would be added to provide further description and guidance relating to this parameter. In addition, the use of local data, where available, will be recommended.

Since the purpose of the document is to help in dose calculations, it may be more appropriate to use the term TFWT rather than HTO concentrations in plant leaves. It was therefore agreed that a note would be added to provide clarification on this point.

Finally, it was noted that food preparation may affect HTO concentrations and this should therefore be mentioned within the document. This is also applicable to plants used for animal diets, which may be dried prior to feeding. Plant water contents provided in Table 9.3 may not

therefore be applicable in all circumstances. Both Ring Peterson and Yoshikazo Inoue were aware of publications relating to the loss of tritium due to food preparation and these will be made available. All participants are requested to research food processing factors and to provide these for inclusion within the document.

OBT in plants

A discrimination factor approach has been recommended for the calculation of OBT in plants and Table 9.4 of the document provides all values contributed by participants where these were considered accurate (i.e. from long term average data on HTO and OBT concentrations in plants). The term 'discrimination factor' was discussed as to whether this was applicable and the recommendation made that this term be replaced with 'isotope ratio of HTO to OBT under steady state' or alternatively, it should be made clear that this is an empirical discrimination factor.

A mean factor of 0.7 has been recommended for chronic conditions based on values at harvest. However, there was concern as to the methods that have been used to derive the published values since it is the fixed OBT concentration in dry material that is of concern. Exchangeable tritium should not be included. Franz Baumgärtner explained that, in deriving the isotopic discrimination factors in Kim & Baumgärtner (1994), samples were washed and dried prior to analysis and therefore these values are applicable. The analysis methods for the other factors displayed in Table 9.4 will be reviewed to ensure these are also appropriate for their intended use.

To derive fresh weight concentrations of OBT in plants, water equivalent factors are required. It is proposed that these will be derived through consideration of the hydrogen content of proteins, fats and carbohydrates and the relative proportions of these in different plant types.

Tritium in terrestrial animals

It was agreed during the 6th WG meeting that the metabolic model developed at IFIN-HH would be used to derive appropriate parameter data for terrestrial models. However, in review, this model appears more complex and less transparent than others being proposed and it was considered that it may be difficult to present in a way that would enable non-expert users to apply under different animal husbandry conditions; an understanding of animal metabolism would be required. An alternative was therefore proposed that is based on a specific activity approach with input from drinking water, food and HTO in air. This approach would be readily adaptable for different animals by varying diet assumptions. Problems may be encountered in the case of OBT in that there is a lack of data on steady state OBT concentrations in animals and how these should be calculated from HTO. However, a worst case assumption that HTO is equal to OBT could be employed and there is some evidence to suggest that this is the case.

In discussions it was noted that the variability in concentration ratios derived from the metabolic model for HTO and OBT is low and therefore it may not be so important to adapt these values to account for differences in mass etc between different animals. The variability for OBT is larger than that for HTO as a result of differences in the fat content of animals. Tables have been produced by Dan Galeriu that indicate the range of concentration ratios for different animals and that can be incorporated directly into the document.

Following discussions, it was agreed that the animal metabolic approach would be suitable due to the overall low variability observed. However, suggestions were made that the tables of parameter values could be amended to clearly document the basis for their derivation (modelled or measured) and an additional column could be added on daily water intake to indicate the link between water intake and animal HTO and OBT concentrations.

Contamination of HTO to soil

Contamination of soil with HTO considers two main pathways: release of HTO from waste management practices to groundwater and upwelling to surface soils, and irrigation using contaminated water.

For the contamination of soil and uptake to plants the suggestion was made that the HTO concentration in the plant could be assumed to be the same as that in soil water. However, it was noted that this may not be applicable to tall vegetation or to root crops.

For contamination of soil by irrigation water, Francoise Siclet provided a model that was subsequently modified by Phil Davis. The initial model assumed that irrigation water was diluted in the total water supplied to the plant (precipitation, groundwater and irrigation) represented by the evapotranspiration rate (ETP) during the growing season. Therefore, the ratio between soil water tritium concentration and irrigation water tritium concentration ratio was equal to the ratio between irrigation rate and ETP. This was simplified by Phil Davis, in order to use a more readily available parameter than ETP. His approach assumed a dilution of irrigation water by precipitation water only. Participants are requested to provide feedback on their preferred approach and reasons for selection.

Release of HTO to water

A full specific activity approach has previously been agreed for the uptake of HTO by fish. This requires fractional water contents for fish, for which some data have been provided. Any additional data that participants are aware of should be provided to Phil Davis.

Isotopic discrimination factors for OBT in fish have been determined for a variety of fish from long-term field studies and therefore there is reasonable confidence in the values that have been put forward.

Release of Tritiated Hydrogen Gas

An empirical model has been selected that is based on Chalk River experiments in which HT was released over a 12-day period, allowing tritium concentrations in the environment to come to equilibrium conditions. Measurements were made of HTO concentrations in plants relative to HT in air and the model is based on this ratio. The best estimate of the value for the ratio is 6 $Bq.L^{-1}/Bq.m^{-3}$. However, this may be specific to the environmental conditions and therefore a conservative value of 12 $Bq.L^{-1}/Bq.m^{-3}$has been recommended.

Comments on this approach are invited.

Release of C-14 to air

For the uptake of C-14 by plants from air, a specific activity approach has been recommended, which requires stable carbon concentrations in plants and air to be known. Air concentrations are known and the carbon content of plants can be calculated from the relative contributions of protein, fat and carbohydrate in the plants of interest, together with the carbon contents of these compounds. Calculated plant concentrations have been compared with published data and are in reasonable agreement.

For uptake into animals, a specific activity approach is again recommended. A factor has been incorporated to take into account uncontaminated feed. The stable carbon content of animals has been derived from the literature. However further data, where available, are requested.

Release of C-14 to soil

For the release of C-14 to soil from waste management activities, it is assumed that the groundwater C-14 concentration is known. The model then assumes that specific activity of air in the plant canopy is the same as in the soil water, taking into account dilution with

uncontaminated air. Once the air concentration has been calculated, the approach to the modelling of uptake by plants and animals is the same as that applied for releases direct to air.

It was noted that a number of chemical forms may be present as a result of release from waste management facilities and this may affect behaviour. However, for the purposes of this document, it has been assumed that the C-14 is in soluble form.

For irrigation, an equation has been derived from a dynamic model in which it is assumed that the irrigation rate is controlled to prevent leaching. The model is conservative, particularly where a soil has a high pH. Under such conditions most carbon would be fixed in soil. Canopy dilution factors of 0.3 and 0.5 have been incorporated for open and closed canopy plants, respectively.

It was suggested that the model could be improved through the consideration of volatilisation for which a range of values are available in a publication by Steve Sheppard. However, these values are not soil specific and have large uncertainty. Comments on this addition to the approach are requested.

Transfer of C-14 to fish

The various carbon pools that may be available to fish have been discussed previously with the conclusion that dissolved inorganic carbon should be the focus. This has therefore been taken forward and a specific activity approach has been applied. This again requires the stable carbon content of fish, which has been calculated on the basis of fat, protein and carbohydrate contents.

Comments on the approach are invited.

Additional amendments

In addition to those points detailed above, a number of specific changes were requested to the document:

- First paragraph – the terminology of ‘flux’ to be amended and ‘essential elements’ to be replaced with ‘regulated elements’;
- Section 9.1.1.1 – Murphy (1994) reference to be amended to primary reference;
- References are to be added to Table 9.1 - Default values of the relative and absolute humidity for different climates averaged over the growing season;
- Column 1 (Soil type) in Table 9.2 will be amended to ‘ecological conditions and soil type’ with additional data provided such as temperature and mm of rainfall to assist in selection of appropriate values;
- Section 9.1.2 – ‘release’ to be amended to ‘contamination’; and,
- The term ‘non-leafy vegetables’ should be defined or an alternative used as this led to some confusion within the WG.

Next steps

All participants are requested to review the document and provide any comments, particularly in relation to points noted above, or additional supportive data, by July 31.

In addition a number of specific actions were noted:

- Dan Galeriu is requested to provide references for data on relative and absolute humidity for different climates (Table 9.1); and,

P. Ravi is requested to provide further detail on the parameter value for the transfer of HTO from air to soil (Table 9.2) as these are considered high compared to other values available.

- All participants are requested to research food preparation loss factors for tritium, and irrigation rates for different climatic conditions (Table 9.8).

Phil Davis will make the agreed amendments to the text of the TECDOC in consultation with the TRS-364 WG.

Other Working Group Activities

Additional presentations

An update on the results of an experiment of C-13 uptake in humans and biokinetic modelling was presented by T. Masuda. A number of presentations were given from Romanian colleagues on national programmes of relevance to the WG. A. Golubev presented a field study being conducted on OBT build up in crops following short-term exposure to HTO in air, under a French, Russian and American collaboration. D. Atanassov described a new model of HTO washout by precipitation.

Future activities

The actions and future activities coming out of this meeting are listed in Annex A. Participants are reminded that the agreed deadlines must be respected since we are now nearing the end of the programme.

A follow-up programme to EMRAS is currently under consideration by the IAEA and all participants are requested to consider a future working group that would combine issues such as safety assessment, radioactive waste management and routine assessments of present operations. It is intended that such future work programmes would provide a multidisciplinary, comprehensive system that will assist the IAEA in carrying out facility safety assessments.

Status of Work Programme

Item	Status for next Working Group meeting	Person Responsible
Definition of OBT	Complete	P Davis
Perch Lake H-3 scenario	Complete	
Pickering H-3 scenario	Final report available on EMRAS website	P Davis
Soybean H-3 scenario	Final report available on EMRAS website	H Lee / P Davis
Pine tree H-3 scenario	Draft final report	Y Inoue & modellers
Mussel H-3 scenario	Draft final reports for uptake and depuration phases	T Yankovich & modellers
Pig H-3 scenario	Draft final report	D Galeriu & modellers
Hypothetical H-3 short term release scenarios	Draft final report	P Guetat, L Patryl & modellers
Rice C-14 scenario	Draft final report	J Koarashi & modellers
Potato C-14 scenario	Draft final report	A Melintescu & modellers
TRS-364	Draft final chapter and tables of parameter values	P Davis & D Galeriu

Next Meeting

The next meeting of the Working Group will be in Vienna, Austria. The meeting is scheduled for 5-9 November 2007.

Technical Secretariat Arrangements

Funding for Enviros to supply Technical Secretariat services to the Tritium and C-14 WG ceased at the end of the Eighth WG Meeting. However, efforts will be made to try to secure further funding to enable services to be maintained to the end of the EMRAS programme.

Further Information

Information on the activities within EMRAS generally and on the Tritium and C-14 WG in particular (including the scenarios being used for model testing), can be obtained from the following people, respectively:

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ANNEX A: Summary of Actions

Date due	Activity	Persons Responsible
Mid June	Distribution of the current final report for the C-14 Rice Scenario	J. Koarashi
End June	Review of model descriptions for Soybean scenario and finalisation of report	D. Galeriu & P. Davis
	Distribution of final draft report for the Pine Tree Scenario	Y. Inoue
	Circulation of mussel depuration scenario observations	T. Yankovich
	Checking of accuracy of mussel depuration predictions	All modellers
	Provision of detail on modelling approaches for wet deposition and completion of model descriptions for the Hypothetical scenario	All modellers
	Submission of model predictions for the Pig Scenario	P. Davis
	Completion of data gaps and return of comments on the draft final report for the Rice Scenario	All modellers
End July	Addition of appendix on air concentration averaging periods and finalisation of report for the Pickering Scenario	P. Davis
	Provision of further information on models, reasons for differences between predictions and observations, and submission of uncertainty estimates for the Potato Scenario	All modellers
	Review of draft final report and paper for the Mussel Uptake Scenario and provision of comments	All modellers
	Circulation of draft final report for the Rice Scenario	J. Koarashi
	Provision of food preparation loss factors for tritium and data on irrigation rates by climate for the TRS-364 contribution	All WG participants
	Provision of references for data supplied in Table 9.1 of TRS-364 document	D. Galeriu
	Provision of further information on parameter value supplied for Table 9.2 of TRS-364 document	P. Ravi
End August	Comments on draft final report for the Pine Tree Scenario and reasons for differences between predictions and observations for the different models to be submitted	All modellers
	Completion of amendments to Hypothetical report	L. Patryl
	Review of TRS-364 document and provision of comments	All WG participants
End September	Circulation of final report for the Pine Tree Scenario	Y. Inoue
	Circulation of revised draft final report for the Potato Scenario	A. Melintescu
	Circulation of revised OBT definition	P. Davis
	Completion of mussel uptake report	T. Yankovich
	Circulation of draft final report for the Mussel Depuration Scenario	T. Yankovich
	Completion of the draft final report for the Pig Scenario	D. Galeriu
	Completion of amendments to TRS-364 document	P. Davis

ANNEX B: Summary of Scenario Descriptions

Perch Lake (H-3) Scenario (study complete)

The scenario is based on data collected in Perch Lake, a shallow freshwater lake located within the borders of AECL's Chalk River Laboratories in north-eastern Ontario. The lake contains elevated levels of tritium due to long-term discharge from nearby waste management areas. Tritium concentrations were measured in samples of air, lake water, sediments, aquatic plants (algae, bladderworts, hornworts and cattails) and animals (clams, bullheads and pike) collected in summer and autumn 2003.

Given the measured HTO concentrations in water, sediments and air, participants in the scenario were asked to calculate:

(i) HTO and non-exchangeable OBT concentrations in near-shore cattails and worts and offshore algae for the summer period. For cattails, concentrations were requested for both the above water and below water parts of the plant.
(ii) HTO and non-exchangeable OBT concentrations in clams, bullheads and pike for each of the sampling periods. For bullheads and pike, concentrations were requested in head, flesh and internal organs (liver, gonads, stomach and intestines).
(iii) Non-exchangeable OBT concentrations in near shore sediments for the summer period.
(iv) 95% confidence intervals on all predictions.

Soybean (H-3) Scenario

The soybean scenario is based on experimental data collected at the Korean Atomic Energy Research Institute (KAERI). Commercially available soybean was sown in May 2001 in 6 plastic pots (41cm x 33cm x 23cm high). Tritium exposure was carried out six times at different growth stages: July 2 (SB1), July 13 (SB2), July 30 (SB3), August 9 (SB4), August 24 (SB5) and September 17 (SB6). The pots were introduced into a glove box for the tritium exposure and the experiments were conducted under natural solar conditions, which resulted in high temperatures within the glove box. The surface of the soil was covered with vinyl paper so that uptake was only through the foliage. After exposure, the pots were placed in an open field among other soybean plants.

Modellers were asked to predict:

(i) HTO concentrations in the free water of the plant body and pods in the SB1 and SB4 experiments at the times the plants were sampled;
(ii) the non-exchangeable OBT concentrations in the plant body and pods at harvest for each of the six experiments SB1 to SB6; and
(iii) the 95% confidence intervals on all predictions.

Information on biomass growth rates, HTO concentrations in air, background concentrations and meteorological conditions were provided to modellers.

Pickering (H-3) Scenario

Small amounts of tritium are released continuously from the CANDU reactors that make up Pickering Nuclear Generating Station (PNGS) on the north shore of Lake Ontario. The releases have been going on for many years and concentrations in various parts of the environment are likely to be in equilibrium. A large number of environmental and biological

samples were collected in July and September 2002 from four sites in the vicinity of the station. HTO concentrations were measured in air, precipitation, soil, drinking water, plants (including the crops that make up the diet of the local farm animals) and animal products. OBT concentrations were measured in the plant and animal samples.

Modellers were provided with site locations, meteorological data (including air temperatures and rainfall), animal diets, and HTO concentrations in air, precipitation and drinking water. From this information, modellers were asked to estimate:

(i) HTO (as Bq L^{-1}) and non-exchangeable OBT (as Bq L^{-1} in combustion water) concentrations in plants and animal products.
(ii) HTO (Bq L^{-1}) concentrations in the top 5-cm soil layer for each site.
(iii) 95% confidence intervals on all predictions.

Pine Tree (H-3) Scenario

Since 1981, NIRS has conducted a monthly monitoring programme (including measurements of HTO concentrations in air, rain, groundwater, pine needles and tree rings) in the vicinity of nuclear sites in Tokaimura, Japan, where a few sources have released HTO vapour into the atmosphere continuously for many years.

A description of the area, meteorological data and HTO discharge rates from 4 sources were provided to the modellers, who were requested to calculate the following end points:

1. Monthly HTO concentrations in air moisture, precipitation and tissue free water, and non-exchangeable OBT (nOBT) in pine tree needles from 1982 to 1986 at sampling site P3;
2. Yearly HTO concentrations in air moisture and precipitation and nOBT in pine tree trunk year-rings; and TFWT and nOBT in needles of pine trees separately collected from the tree at sampling site MS-2. All predictions are to be for the period from 1984 to 1987 at MS-2;
3. Monthly tritium concentrations in groundwater at the well G4 from 1984 to 1987; and,
4. 95% confidence intervals on each prediction.

Mussel (H-3) Scenario (uptake and depuration study)

Perch Lake is a small shallow water body that receives tritium inputs from upstream waste management facilities. The mussel scenario considers the dynamic uptake of tritium by adult freshwater mussels (approximately 15 years of age) that were transplanted in cages from a tritium-free environment into the lake. Sixty-four mussels were transplanted into each of 4 mesh cages. The mussels in cages 1 and 2 were exposed to water only whereas those in cages 3 and 4 were exposed to both water and sediments.

Modellers were given information on the mussels and on tritium concentrations in water and sediments, and asked to predict the time-dependent HTO and OBT concentrations in the mussels in each set of cages, together with the 95% confidence intervals on all predictions.

Pig (H-3) Scenario

A. Model-Data Scenario
A pregnant sow of the Belgische Landras strain, weighing about 180 kg, was given feed that was contaminated with organically bound tritium (OBT) for 84 days before delivery. The food had an average concentration of 577 Bq/g dry matter (dm). The sow was slaughtered

after giving birth and the tritium activity in various organs was measured. In the 84-day contamination period, urine and faeces were also monitored for tritium content.

Modellers were asked to predict the following:

1. Total tritium concentration in urine and HTO and OBT concentrations in faeces; and,

2. HTO and OBT concentrations in various organs at delivery (84 days after the start of contamination);

B. Model Inter-comparison
Two exercises based on hypothetical data were proposed:

1. A pig of conventional strain was given uncontaminated food and water for the first 55 days of its life, at which point it weighed 20 kg. It was then fed food and water contaminated with HTO at a level of 10,000 Bq/L for 50 days. Its feed was uncontaminated for the next 50 days, at which point it was 155 days old and weighed 110 kg, and was slaughtered. At no time was any of the feed given to the pig contaminated with OBT.

   Modellers were asked to predict the total tritium in urine, HTO and OBT in faeces and OBT in muscle from the time the pig was 55 to 155 days old (50 days of contaminated diet and 50 days of clean) at various times and to estimate also the 95% confidence intervals of all predictions.

2. All animals on a large pig farm were fed OBT-contaminated food for a single day at a level of 1 MBq/kg dm. Modellers were asked to predict the meat and liver OBT concentration at slaughter (body mass 110 kg) for the following pig masses in the day of contamination: 20, 40, 60, 80 and 100 kg.

   One of the aims of Exercise 2 is to determine if accurate results can be obtained by considering a single generic pig or if the specific strain and diet of the pig must be taken into account. Accordingly, the modellers were asked to assess the influence of growth rate and genotype on their results by carrying out calculations for their default pig (and default diet) and for slow-growth and fast-growth pigs.

Hypothetical (H-3) Scenario

The aim of this study is to analyse the consequences of an acute atmospheric release of tritium, by considering various pathways in terms of activity in biosphere compartments and food products, for various forms of tritium (HT, HTO and OBT). The objective is to provide information that would be useful to decision makers in managing an accident involving a short-term tritium release to the atmosphere. The basic assumption is that 10 g of tritium is released over a period of 1 hr and the calculation period is 1 year. Three cases are considered, based on the meteorological conditions given in the table below. Modellers were asked to predict concentrations in all environmental compartments and total doses to members of the public from all exposure pathways.

	Case 1	Case 2	Case 3
Timing of release	day	day	midnight
Wind speed (m s^{-1})	2	5	2
Direction (° from N)	45±25	45±10	45±3
Diffusion conditions	unstable	neutral	stable
Weather	fine	cloudy	clear
Pasquill category	A	D	F
Solar radiation (W m^{-2})	700	300	0
Temperature (°C)	20	20	10
Rain (mm)	-	15	-
Relative humidity (%)	70	90	95

Potato (C-14) Scenario

Two hundred potato tubers were seeded in August 1995 (later in the year than usual for the UK, where the experiments were carried out) and plants were exposed to $^{14}CO_2$ in a wind tunnel. The plants were fumigated for approximately 10 hours at six different growth stages. Samples from the plants were taken immediately following fumigation to determine the concentrations of C-14 that were fixed by the plants. Plants were then moved outside to continue growing. The plants were subject to a range of temperatures and photosynthetically active radiation during exposure.

The biomass dynamics (average dry weight) of roots, leaves, stems and tubers were determined at harvest time. Meteorological data for 1995, when the experiments were conducted, was not available and therefore 30-year average values for Cambridge were employed.

Modellers were requested to calculate C-14 concentrations in leaves at each sampling time for each of the six experiments and the concentrations in tubers at final harvest (including 95% confidence limits).

Rice (C-14) Scenario

C-14 has been released to the atmosphere from three discharge points at Tokaimura over several decades. Weekly monitoring of the release rates is available from October 1991. Discharges have decreased considerably over that period, from about 800 GBq in 1991 to near zero in 2000. Measurements of C-14 concentrations in air and rice are available at a number of sampling sites in the area. Analysis of wines undertaken through the 1990s can be used to establish general background C-14 levels.

From information on C-14 release rates and meteorological conditions, modellers were requested to:

(i) Calculate monthly mean C-14 concentrations in air at three locations for 1992 to 1997;
(ii) Calculate C-14 concentrations in rice grain at harvest for 1992 to 2001; and,
(iii) Express 95% confidence intervals on all estimates.

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