IAEA EMRAS, Tritium and C-14 Working Group

EMRAS:
Modelling the Transfer of Tritium and C-14 to Biota and Man
Notes of the
Sixth Working Group Meeting
Chatou, France
7–9 June 2006

EMRAS, Tritium and C-14 Working Group,
Meeting Report 6

Notes of the IAEA EMRAS Tritium and C-14 Working Group Meeting
Chatou, France
7–9 June 2006

The sixth meeting of the IAEA EMRAS Tritium and C-14 Working Group was held in Chatou, France. The meeting was hosted by EDF.

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

Name	Organisation	Country
V. Suolanen	Technical Research Centre of Finland (VTT)	Finland
P. Calmon	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)	France
E. Desroches*	Electricité de France (EDF) R&D (presentation of EDF R&D)	France
E. Gilbert	Electricité de France (EDF)	France
P. Guétat	Commissariat à l'Energie Atomique (CEA)	France
J.-M. Hervouet*	Electricité de France (EDF) R&D (Hydraulic models)	France
T. Kestens*	Electricité de France (EDF) R&D (Hydrogeologic models)	France
L. Patryl	Commissariat à l'Energie Atomique (CEA)	France
F. Siclet	Electricité de France (EDF)	France
B. Sportiss*	CEREA (Atmospheric models)	France
F. Baumgärtner	Munich Technical University (TUM)	Germany
W. Raskob	Forschungszentrum Karlsruhe (FZK)	Germany
J. James	Bhabha Atomic Research Centre (BARC)	India
Y. Inoue	National Institute of Radiological Sciences (NIRS)	Japan
J. Koarashi	Japan Atomic Energy Agency (JAEA, former JNC)	Japan
K. Miyamoto	National Institute of Radiological Sciences (NIRS)	Japan
M. Saito	Kyoto University Safety Reassurance Academy (SRA)	Japan
K. Yamamoto	YFirst Inc.	Japan
H. Lee	Korea Atomic Energy Research Institute (KAERI)	Korea
D. Galeriu	Institute of Atomic Physics & Nuclear Engineering "Horia Hulubei" (IFIN-HH)	Romania
A. Melintescu	Institute of Atomic Physics & Nuclear Engineering "Horia Hulubei" (IFIN-HH)	Romania
P. Kennedy	Food Standards Agency (FSA)	UK
P. Lloyd	Enviros Consulting Ltd	UK

* Invited speaker.

CONTENTS

The financial support of the Technical Secretariat by GE Healthcare (UK) and the Food Standards Agency (UK), and of the Working Group Leader by the CANDU Owners Group (Canada), is gratefully acknowledged.

Introduction

The sixth meeting of the EMRAS Tritium and C-14 Working Group was held on 7-9 June 2006, hosted by EDF. The objectives of the meeting were to:

- Present and discuss the final report for the H-3 Pickering (foodchain) Scenario;
- Present and discuss the final report for the H-3 Soybean Scenario;
- Present and discuss the results from the third round of calculations for the H-3 Pine Tree Scenario;
- Present and discuss the results from the second round of calculations for the C-14 Rice Scenario;
- Compare gaussian plume and random walk models for atmospheric dispersion;
- Present and discuss the scenario description and first round results for the C-14 Potato Scenario;
- Present and discuss the second round of calculations for the uptake phase, and the scenario description for the elimination phase, of the H-3 Mussel Scenario;
- Discuss the definition of OBT;
- Discuss the scenario description and first round results for the H-3 Pig Scenario;
- Discuss the contribution of the working group to the revision of TRS-364;
- Present and discuss the latest results of the Hypothetical Scenario; and,
- Plan future work activities.

Participants were welcomed to the meeting by the Working Group Leader, Phil Davis and contributors to the various scenarios were thanked for their contributions since the last meeting. Francoise Siclet and EDF were thanked by both Phil Davis and Mikhail Balonov for arranging and hosting the meeting. Each participant was then invited to introduce themselves and describe briefly their background and interest in the working group.

The current status of the EMRAS programme as a whole was then briefly described by Mikhail Balonov. Report preparation is currently being considered within EMRAS. Final reports are due to be completed by Autumn 2007, and 1 year following this it is anticipated that the reports will be publicly available. The EMRAS programme as a whole will therefore end in the Autumn of 2007. Mikhail retired from the IAEA in April 2006 and is now working as a consultant to the IAEA. It is therefore anticipated that he will continue as the Scientific Secretary to the group for the forthcoming year at least.

All participants are invited to the next Tritium and Carbon-14 Working Group Meeting, which will be held during the Fourth EMRAS Combined Meeting, 6–10 November 2006 at the IAEA Headquarters in Vienna. Further information on EMRAS meetings can be found on the website.[1] Meeting notes and scenario descriptions for this Working Group can also be found on the website.[2]

A summary of the main points of discussion on each of the scenarios in the tritium and C-14 Working Group (WG) from the 6th WG meeting are provided in the subsequent sections. The actions coming out of the meeting are summarized in Annex A, brief scenario descriptions are provided in Annex B and contact information for the participants is given in Annex C.

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

Perch Lake Scenario

Presented by Phil Davis

The Perch Lake scenario report was finalised in November 2005 and has now been posted on the EMRAS website. The report for this scenario will be incorporated into the final working group document when it is published at the end of the EMRAS program.

Soybean Scenario

Presented by Hansoo Lee

The Soybean scenario considers the dynamics of tritium in soybean plants following short-term exposures at different growth stages. The final results and model descriptions were presented at the last Working Group meeting (November 2005). However, since that meeting, analysis of uncertainties has been advanced and general corrections made to the report.

Next steps

The report will be distributed by Enviros as the Technical Secretariat to all participants. Any comments or amendments are requested within one month of distribution. If none are received, the report will be considered final and will be made available on the EMRAS website.

Final report for the Pickering Scenario

Presented by Phil Davis

The final report for the Pickering Scenario was circulated to participants prior to the meeting and comments invited. Phil Davis went through the discussion and conclusions section and participants were invited to highlight any areas they did not agree with or where additional information was required. The objective is to try and explain why model results are different, and why they differ from the observations, but this is difficult due to the sometimes substantial differences between the models employed.

Overall, the models predicted HTO in soil water accurately, but OBT in plants at the dairy farms was over-predicted (by a factor of 2 to 3) by all models. It is not clear to what extent this is due to simple over-prediction of OBT:HTO ratios because of the lack of observations of HTO concentrations in leaves, from which OBT predictions are derived. Only spot HTO measurements are available and these are not representative of the long-term concentrations that the models are trying to predict.

Plant concentrations at location F27 were over-predicted by a factor of 3 to 4. At this location, translocation from leaves is important and may not have been modelled correctly. Also, air concentrations at this location have been estimated and are therefore subject to some uncertainty, and this may be a cause of the over-prediction observed.

Predictions of concentrations in cow meat and milk were found to be quite accurate, due to intake being primarily from water ingestion for which data was provided in the scenario description. Predictions for chicken and egg concentrations were less accurate, consistently over-estimating the observations. Consumption rates of food and water by chickens were not provided in the scenario description and the intake may therefore have been over-estimated.

Next steps

A number of comments were made and those for which actions are required are detailed below:

- Franz Baumgärtner noted that, in his calculations, not all of the OBT is dose relevant. A statement to this effect is to be included in the conclusions section. If this model is correct, non-exchangeable OBT is lower than traditionally thought, which may have implications for dose.
- It was noted that the number of observations for both chickens and eggs, given in Table 7, is small and it was felt that this point was not made clear for the reader. A comment to this effect should therefore be added to the conclusions.

In addition, Phil requested that all participants check the model descriptions to confirm that their models are accurately described. Any additional suggestions for changes to the report should also be highlighted. In addition, the following specific actions were raised:

- Paul Kennedy (FSA) is requested to provide data on ingestion rates for cows and chickens, plus assumptions made when modelling the scenario, for inclusion in Table 12.
- Professor Saito is requested to provide the full reference for Kirchmann et al (Section 4.5.1, second to last paragraph).

It is requested that all the information detailed above be provided by mid-July. The report will be finalized and placed on the EMRAS website by mid-August.

Third round results for the Pine Tree Scenario

Presented by Yoshikazu Inoue

The Pine Tree scenario considers continuous releases of tritium from four sources and the resultant air concentrations at various sites and subsequent uptake into pines. Three of the tritium sources are located at a JAERI site and the smaller fourth source at a JNC site. The dispersion of tritium is largely governed by the north to south wind direction.

Predictions for site P3

Discussion of third round results indicated that, in general, predicted HTO concentrations in air at site P3 were lower than the observed data. Monitoring at the P3 site only began in mid-1984 and therefore no observations are available for comparison with predicted values prior to this date. The most accurate predictions were made by the NIRS model, with a predicted/observed (P/O) ratio close to one. Results from EDF, IFIN and SRA were about half the observed values. The LLNL model only calculated annual means. For HTO concentrations in rain, the P/O ratio was around 0.8, with the lowest values predicted by the EDF model.

It was noted that the observations of tissue free water tritium (TFWT) concentrations in pine needles could not be fully relied upon since these were spot measurements rather than multiple measurements averaged over time. However, trends in concentrations were, overall, similar between the observed and predicted concentrations. Observations and predictions in pine needles were similar for 1982 and 1983 and also for 1985 and 1986. However, results for 1984 were more variable. The NIRS model was again the most accurate with other models under-predicting concentrations (LLNL predictions were less than half the observed values). Comparison of predicted and monitored results standardised against air concentrations from the P3 site also indicated that the models underestimate TFWT concentrations in needles.

Results for OBT in pine needles were more variable. All models under-predicted OBT in needles, but again NIRS was closest with a ratio of around 0.75. In the case of OBT in tree rings, predictions were similar for most models, the results from LLNL being the lowest. Observations of OBT in needles were higher than the ring observations by around a factor of 2. It was mentioned that this may be a function of plant metabolism, but an overall conclusion has not been reached. EDF did not submit results for OBT in pine needles.

Modellers were also requested to submit results for annually averaged concentrations. Predictions were higher than observations averaged over the year in the majority of cases. On the whole, the NIRS model provided the closest predictions.

HTO predictions in groundwater were generally in reasonable agreement with observed data, with NIRS providing the closest predictions, EDF the highest results (a factor of 2 greater than the observed values), and IFIN the lowest results. Results from SRA were also in reasonable agreement with the observed values. Prior to modelling groundwater concentrations, NIRS were aware of both the results and parameters so it is to be expected that their model would be accurate. It was concluded that, overall, groundwater results were in fair agreement, but improvements could be made. Modellers were therefore invited to resubmit groundwater results if they wished.

Predictions for site MS2

The models underestimated the observed air concentrations by a factor of 2-3, although the trend with time was correct. Predictions for HTO in rain water produced by SRA and EDF were around a factor of 2 greater than observations. IFIN were closest to observations with a

ratio of predicted to observed values of around 0.75. The predicted TFWT concentrations in needles were lower than the observations for all models. The predicted OBT concentrations in the tree rings scattered about the data, but the trend with time was wrong. The observed OBT concentration in the needles was higher than in the rings, by almost a factor of 10 in 1987.

The parameters and assumptions used in the different models were tabulated for comparison where model descriptions were available. However, not all modellers have provided descriptions (EDF in particular were requested to provide a model description) and, of those available, not all were detailed enough for a rigorous comparison. Differences between parameters and assumptions in models included:

- Number of HTO sources considered;
- Type of model used (Gaussian plume or random walk);
- Consideration of plume rise;
- Meteorological data used;
- Dispersion parameters (Briggs formula, Pasquill-Gifford curves etc);
- Source of HTO for pine trees (proportion from soil and air);
- Assumed concentration ratio between OBT and TFWT;
- Ratio of needle OBT to annual ring OBT;
- Complexity of groundwater models (e.g. one-box compartmental models or Gaussian dispersion models that take account of both horizontal and vertical flow); and,
- Travel time of HTO in rain water deposited on surface soil to the water table.

EDF briefly described the models they had employed for atmospheric dispersion and groundwater transport. The dispersion model was built in ADMS 3.2 and is an advanced Gaussian plume model. The source characteristics include height, exit velocity, diameter and emission rate. The dispersion parameters were derived from surface similarity theory, with the Monin-Obukhov length estimated from routine data. The model was run hour by hour and concentrations calculated for the specified points using meteorological data at 10 m as derived from the scenario description. The output grid was 100 x 100 m. Wet deposition was modelled to provide input for groundwater predictions. The hourly predictions were averaged to give monthly means data. The terrain was considered to be flat.

Groundwater concentrations were predicted using the Argus model, which was developed to provide EDF operational sites with an emergency assessment and management tool to deal with soil and groundwater pollution incidents. A conservative approach was applied based on a semi-analytical solution of the constant-parameter transport equations. The scenario modelling involved a 500 m long and 200 m wide injection area. The input was the tritium deposition rate ($Bq/m^3/s$) from the atmospheric dispersion and precipitation calculations. The injection area was divided into 6 zones with a centred injection point within each. Concentrations were calculated as the sum of contributions from sections 1 to 6. The porosity of the soil was assumed to be 0.53 and the water content was 28.4 %. The unsaturated zone was assumed to be 15 m deep. Water table thickness was considered in deriving the groundwater concentration.

Possible reasons for differences between the EDF predictions and those of the other modellers were put forward. These included:

- the use of a centred injection point;
- the assumption of a mean tritium deposition value for each of the sub-zones;
- the assumed water table thickness; and,
- the use of a simplified model for the unsaturated zone.

Next steps

No further changes to results are permitted unless mistakes have been made (for example, it was agreed that EDF would submit second round results using alternative meteorological data). Any amended results are to be submitted by the end of July.

Information on how HTO air concentrations were calculated by the various models is requested as a priority. These enable plant, rainwater and groundwater predictions to be normalised for each model, which in turn allows a more thorough comparison of the model predictions. Full model descriptions are to be provided by the end of July, and will be used to prepare tables comparing the parameters used and assumptions made. EDF are requested to supply the presentations on their modelling approach directly to Yoshikazu Inoue.

Once the results and requested data are provided, a draft report will be prepared and circulated by mid-October for discussion at the next working group meeting.

Comparison of Gaussian Plume and random walk models

Presented by Yoshikazu Inoue

The accurate prediction of HTO concentrations in air is of primary importance for all modellers since this will affect the predictions of tritium concentrations in the other environmental compartments (groundwater, rain water, biota). Yoshikazu Inoue presented a comparison of the Gaussian plume and random walk dispersion models employed in the pine tree scenario. NIRS used a random walk model (EESAD) and predicted HTO concentrations that were most similar to the observations of all the models employed. However, it is important to note that the differences between observations and predictions are small for all models compared with other scenarios (e.g. hypothetical scenario). Moreover, the differences depend not only on the models themselves, but also on how the meteorological data are treated.

Both Gaussian plume and random walk models were very similar in predicting HTO concentrations a significant distance downwind of the source, but differences were observed in the near field For example, the Gaussian plume model predicted HTO concentrations four times lower than the random walk model 1 km downwind of the source. This may be due in part to the use of a 100-m rectangular mesh in the EESAD random walk model, whereas the Gaussian plume model used either a sector-average approach or a 100 m mesh in the crosswind direction. The 100-m mesh size generated better predictions than the sector approach (both using Gaussian plume models).

Following the presentation a number of points of possible relevance to the comparison were raised:

- Dan Galeriu noted that, for the same input, there appeared to be little, if any, difference between the model predictions, and any slight difference between the random walk and Gaussian plume models was considered to be due to chance.
- Phil Davis noted that random walk models have the potential to be better than Gaussian plume models as long as the extra data they require are available. This was not the case for the pine tree scenario. It would therefore be useful to see a comparison of the two models (Gaussian plume and random walk) using more complex meteorological data.

Round 2 results for C-14 in rice

Presented by Jun Koarashi

The C-14 rice scenario is based on JAEA monitoring data around the Tokai reprocessing plant (TRP). Monitoring 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 discharges, stack height, diameter of the outlet, stack gas temperature and exit velocity and information on the growth of rice plants (which was updated following the 4th working group meeting). Hourly meteorological data was 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. Initially there were three participants in the modelling scenario (AECL, IFIN, and NIRS), but following the 5th working group meeting, both SRA and EDF also contributed results.

The AECL and IFIN predictions agreed well in both magnitude and trend with the observed concentrations in both air and rice. The predictions of SRA for C-14 in air were higher than observations at both sites, and higher for rice in 1992. The NIRS model predictions were close to the observed data in rice with the exception of 1994–1996 when over-estimates were produced. EDF failed to predict the two peak concentrations in 1992 and 1996, but were otherwise close to observed data. At the control rice site, AECL, IFIN and EDF predictions were all similar to observations.

All participants used a Gaussian plume model to predict air concentrations at the sites. The differences in the results are likely due to the different treatment of plume rise. Differences were also noted in the approach to modelling C-14 concentrations in rice:

- AECL assumed specific activity equilibrium between plant and air on the basis of averaged air concentrations from May to October.
- IFIN applied a C-14 transfer model that took account of three development stages of the rice plant, the advance in the development stage depending on the environmental temperature above a plant specific base temperature. Transfer to the plant was only considered during daylight hours.
- NIRS applied a dynamic compartment model for rice, with a sigmoidal curve used for growth.
- SRA assumed a linear relationship between concentrations in air and rice.
- EDF used a two-compartment model, with one compartment for the vegetative part of the plant and one for the grain. The retention of C-14 was assumed to be proportional to the growth of each part of the plant. Transfer between the vegetative compartment and grain was taken into account.

Jun Koarashi explained that specific reasons for the differences in the results for rice were difficult to identify because the models were different with respect to both air dispersion and plant uptake. It will therefore be necessary to standardise rice concentrations against air concentrations to enable a thorough comparison of the different uptake models. Phil Davis responded that the air concentration predictions were actually very close to the observed data, at least for some models. It was suggested that tables be drawn up to compare the different modelling parameters and assumptions as has been done for the pine tree scenario.

Additional points of relevance for the comparison of results and discussion are provided below:

- Professor Saito postulated that the difference between his predictions and those of other modellers for rice concentrations may be a result of the way in which the meteorological data were processed.
- Phil Davis questioned why the air concentration predictions from EDF showed peaks. Francoise Siclet responded that these peaks were a result of peaks in emissions, although one peak in air concentrations in 1992 was not reflected in the rice predictions and will be checked. The NIRS results also showed peaks in concentrations, although it was noted that plume rise was modelled incorrectly, which led to high air concentration predictions, particularly at station 1 (close to the source). Mikhail Balonov suggested that the peaks in spring could be due to entrainment of fallout C-14 from the stratosphere into the troposphere.
- Phil Davis questioned the use of dynamic models for predicting long-term average rice concentrations and whether such models would be used in real situations. He noted that the AECL model, which is based on specific activity concepts, produced effectively the same results as those from the IFIN dynamic model. Dan Galeriu responded that the use of dynamic models helps improve the understanding of uptake in the case of accidents and therefore their use is important.
- The inclusion of background concentrations in the predictions was questioned and it was agreed that Jun Koarashi would subtract background in future analyses.

Next steps

All participants are requested to provide predictions for air concentrations at Station 3 (2.8 km southwest of the discharge point) for the period 1991 to 1997. Since a draft report is required for the 7th working group meeting, results should be provided by the end of August.

All model descriptions are to be provided by the end of July. A template is available for the writing of model descriptions and participants are requested to use this where possible. Any insights into why modelling results are different from those of other participants are also invited.

First round results for C-14 in potatoes

Presented by Anca Melintescu

The C-14 in potatoes scenario was developed following the 5th working group meeting in Vienna. The scenario is based on experiments conducted by a PhD student at Imperial College, London. The experiments involved 200 potato tubers that were seeded in August 1995 (later in the year than usual for the UK), and the developed plants were subsequently exposed to $^{14}CO_2$ in a wind tunnel. Three planting densities were employed and fumigation occurred for approximately 10-day periods at 6 different plant growth stages. Samples from 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. A range of temperatures and photosynthetically active radiation was employed. Temperatures increased with time during fumigation and relative humidity increased by around 10%. Plants were not under water stress. The biomass dynamics (average dry weight) of roots, leaves, stems and tubers were determined at each harvest time. Meteorological data for 1995, when the experiments were conducted, was not available and therefore 30-year average data for Cambridge was employed, although it is noted that this leads to some uncertainty. The seeding of potatoes was very late, again giving rise to inherent uncertainty.

Modellers were requested to calculate C-14 concentrations in leaves at each sampling time for each of 6 experiments and the concentrations in tubers at final harvest (including 95% confidence limits). Results were provided by two participants, IFIN and FSA.

The IFIN approach assumed that, since >90% of plant carbon comes from the atmosphere, contamination of potato plants was solely from atmospheric C-14. Modelling of C-14 transfer was assumed to be the same as the modelling of natural carbon transfer. Consideration was therefore given to the initial carbon incorporation, loss through maintenance and gross respiration, distribution in plant parts, growth dilution and translocation. Two approaches were used, one complex and one simple. The complex approach used the crop growth model (WOFOST) where growth is dependent upon climate.

The WOFOST model underestimated tuber biomass dynamics, but was quite accurate for the above ground biomass. Following initial incorporation of C-14 there was a decrease due to respiration (C-14 uptake involves both a fast and a slow component). The predictions of tuber C-14 concentration for the third growth stage (P3) were greater than the observations, as were the predictions at the late fumigation stages. Too high a translocation rate from stems to tubers may partly explain these differences. However, overall the predictions were acceptable considering the variability in the observed data and the uncertainty in the model predictions. Experimental uncertainty was at least a factor of 2, and this has made detailed analysis of the results difficult. Model uncertainty was larger than a factor of two, and access to the real meteorological data is required to reduce this.

The simple model employed by IFIN considered dry matter production only and on the whole produced results in reasonable agreement with the WOFOST model. The simple model can therefore be used to predict the initial incorporation of C-14. However, a process-orientated model is required to help explain areas of uncertainty.

FSA used a simple form of expert elicitation in deciding how to model the potato scenario and what parameter values to select. The FSA model predictions for leaves were contradictory to the observations for all scenarios, but results for tubers were quite good. There may therefore have been an error with the input data rather than with the model itself. Paul Kennedy agreed to check this.

Points of note from the scenario were that the plant genotype was found to be important, as were the respiration dynamics shortly after fumigation and the translocation from stems to tubers during early fumigation. The issue of whether the yield could be considered correct due to the late seeding was raised by Francoise Siclet. In response, Anca explained that the growth was unlikely to be typical, but the opinion of the student who conducted the experiments is not known.

Discussions on the route of uptake of C-14 by plants then took place. Franz Baumgärtner noted that for photosynthesis, plants take up water from the ground and carbon from air. However, Dan Galeriu explained that $^{14}CO_2$ dissolved in water could also contribute to C-14 concentrations within the plant, although this pathway makes up only by a small percentage (2-10 %) of the total plant concentration. This contribution can be more important in the case of radioactive waste management activities when C-14 in soil solution, and thus C-14 uptake by roots, may increase. However, even in such situations the primary route of uptake would be as a result of degassing of $^{14}CO_2$ from soil into the canopy atmosphere and uptake by the plant through photosynthesis. C-14 in roots is therefore primarily a result of translocation from leaves to roots via the stem.

Next steps

Paul Kennedy is requested to check the FSA model to ensure the input data were correct and to produce second round results for the scenario. Francoise Siclet also indicated that EDF would be interested in submitting results. It is requested that any new or revised results be provided by 1st October. Following this, results will be analysed and a draft report produced for the plenary meeting in November.

Second round results for the mussel H-3 scenario (uptake phase)

Presented by Phil Davis

The mussel scenario is based on data from Perch Lake, a shallow water body that receives input of radionuclides, including H-3, from upstream waste management areas. The lake supports diverse biota including Barnes mussels, which are the focus of the scenario. Mussels were transplanted from a control site (Ottawa River) into Perch Lake in two separate locations where *in situ* populations of mussels are found. Four mesh cages, each containing 64 mussels (9-11 cm length), were used. Two were suspended in the water column and therefore received exposure to radionuclides within the water column only; the other two were placed at the sediment-water interface and filled with sediment to provide exposure to radionuclides both within the water column and associated with sediments. Following transplantation, the mussels were sampled after 1 and 2 hours and then at increasing time intervals up to 86 days. Mussels at the control location (Ottawa River) were also sampled and water and sediment samples were taken at matching time intervals at all sampling sites. Analysis included OBT and HTO in tissues, water HTO concentrations, water and air temperatures and mussel shell length and fresh weight. No change in shell length or weight was observed over the study period and no mortalities occurred.

Observations indicated that HTO concentrations in the mussels increased to that of the lake water rapidly (within the first hour). Concentrations of OBT increased from a background level of around 45 Bq/l to around 170 Bq/l within the first hour, remained at this concentration for the duration of the first day, and then began to increase once again. Over the last 40 days, a decrease in OBT was observed. It was noted by Mikhail Balonov that, due to the lifespan of the mussels, the 3-month exposure was probably insufficient to allow equilibrium to be reached and this should be explained in the report.

Modelling results were provided by five participants (NIRS, SRA, IFIN, EDF and TUM). Most modellers underestimated the initial rate at which HTO was taken up, and therefore underestimated the HTO concentration in the mussels in the first few hours following transplantation. However, all models predicted (correctly) that the HTO concentration in the mussels eventually reached equilibrium with the water concentration. All modellers underestimated the initial OBT concentration, partly because background concentrations were not accounted for. Only one model (EDF) predicted the dynamics of OBT concentrations well. The TUM and IFIN models predicted small differences in concentrations as a result of exposure from water only or water plus sediment; in contrast, the observed concentrations were the same for these two exposure scenarios.

Particular differences in modelling approaches were identified:

- IFIN assumed that mussels grew throughout the exposure period, but measurements indicated that mussel length and weight did not change over the course of the study (as expected since the mussels were approx 14 to 15 years old); and,
- TUM predicted buried tritium rather than what is traditionally considered to be non-exchangeable OBT.

Following the initial presentation of results, individual modellers were asked to describe their models and to try to explain why their predictions did not match the observations. Possible reasons for differences included:

- The values of the transfer co-efficients used;
- Use of mean HTO concentrations for lake water (in reality the HTO concentration decreased slowly throughout the exposure period);
- The assumption that equilibrium was reached, whereas the experimental results indicated that this was not the case even after 86 days;
- The type of mussel on which models were based (there may be physiological differences between species); and,
- The inclusion or exclusion of factors to take account of the effect of temperature on mussel metabolism.

Possible reasons for the under-prediction of the initial OBT concentration were discussed. Phil Davis questioned whether Perch Lake was perhaps special in some way that means the standard transfer parameters do not apply. Mikhail Balonov suggested that in transporting mussels from one environment to another, changes in food abundance may have resulted in a rapid uptake when entering a food-rich environment. The decrease in concentrations between days 40 and 80 could result from the catabolism of proteins no longer required at that time of year (September). Catabolism could occur more rapidly than any further increase in OBT attributable to food intake, resulting in a net loss.

Finally, Francoise Siclet noted that no information has been made available on phytoplankton concentrations in the lake and this data would help to improve the stomach turnover rate in the EDF model. Information on the filtration rate of Barnes mussels would also be advantageous since that of *Mytilus edulis* was used as representative of the lake mussels.

Next steps

Participants are requested to further consider explanations for the changes in tritium concentrations within the mussels.

Any mistakes in submissions should be corrected and amended results sent to Tamara Yankovich by mid-September. Model descriptions should also be provided in EMRAS format by this date. It is also requested that uncertainties be estimated and provided along with information on how these were derived. Where results are revised following the release of the observations, this will be noted in the report.

If available, information on the metabolism of Barnes mussels and phytoplankton concentrations during the transplantation period within Perch Lake are to be provided.

The first draft of the report will be distributed by October 24th for discussion at the next plenary meeting.

Scenario description for the mussel H-3 scenario (depuration phase)

Presented by Phil Davis

The Scenario for the depuration phase is very similar to that of the uptake phase, but with the difference that mussels that had spent all their lives in Perch Lake and were therefore in equilibrium with environmental 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 for longer periods. The same supporting information was made available as for the initial scenario.

Next steps.

Modelling results are requested from any interested participants by 30th September.

Nature & definition of OBT

Presented by Phil Davis/Franz Baumgärtner

There have been a number of iterations of the OBT nature and definitions document, the most recent of which was provided prior to the meeting for discussion, and is reproduced below.

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

Phil Davis explained that the definition is from the analytical perspective and therefore preserves current analytical techniques. Essentially the same methods are used worldwide for analysis so, if the definition is changed, there may be a requirement to also change these methods. Current dose coefficients for OBT are based on current measurement techniques. Therefore, if the definition of OBT were now changed to only carbon bound tritium then dose coefficients would also have to be modified.

Due to the concern over buried tritium, both AECL and Franz Baumgärtner previously conducted experiments to determine whether buried tritium is a large component of what is traditionally measured as OBT. The experiments of both groups were conducted using denaturing agents to unfold molecules, which enabled any buried tritium to be exchanged, and results were compared to samples analysed by the traditional technique. AECL results indicated a reduction in OBT following denaturing, but this was only by a few percent. AECL therefore concluded that less than 20% of OBT could be buried tritium. Franz however found that a large proportion of measured OBT could be buried tritium. Due to the contradictory results, there is still debate on this issue.

Franz explained that the definition should not be linked to particular experimental procedures. However, if it is necessary to retain some link to such procedures, the following amendment to the definition was suggested. '*OBT concentrations are determined experimentally as the activity of non-exchangeable tritium in the combustion water of the dried sample in question. Care has to be taken that buried tritium which is not dose relevant is excluded*.' If further details of analysis are required, then the following could be added. '*That can be achieved by extraction with tritium free water of the biomatter that is degraded to the primary structures. At low temperatures, water has to be volatilized without evaporation isotope effect (non-equilibrium sublimation). At elevated temperatures, loss of total organic carbon has to be avoided. The residual water in the final sample ready for combustion should be in the low ppm range*'. Any further definition would require more detail of the analytical steps (such as exact temperature during freeze-drying etc).

Phil voiced concern over this proposed definition since, if only carbon bound OBT was measured, then analysis results would be lower than those using the current methods, which would result in lower dose calculations. As noted previously, dose coefficients are based on the traditional definition that includes buried tritium. Therefore, if lower sample concentrations were measured then there would be a need to increase the dose coefficient to take this into account. The overall dose would not therefore change.

Mikhail Balonov noted that the dose is not strongly dependent on the exact form of tritium in the sample. If all of the tritium in a given dry sample is carbon bound, the current OBT dose coefficient (4.2×10^{-11} Sv/Bq) would apply. If all the tritium were buried tritium, the current HTO dose coefficient (1.8×10^{-11} Sv/Bq) would be used. This is a difference of a factor 2.3 only and so is not a major issue.

Following the discussions, Mikhail Balonov proposed a few minor alterations to the current definition. Firstly, it was requested that the definition, as given above, be altered slightly so that the definition is given in the first instance and is followed by the procedure for determining OBT. It was also noted that not all methods use combustion to analyse OBT, Mikhail therefore suggested the definition be changed to '*OBT is generally determined as combustion water*'. An amendment to the third note was also requested to ensure that it is made clear that '*0.78 for leaf tissues*' refers to dry leaves. Mikhail also requested that in the third and fourth notes, typical procedures for drying matter be referred to since differences in procedure may affect the analytical results. Finally, it was agreed that '*exchangeable OBT*' would be changed to '*exchangeable tritium*'.

Next steps

The overall consensus following discussions was that the current definition should be retained with the modifications suggested by Mikhail Balonov. The opinion of Franz was noted and, in the future it may be possible to take his comments on board.

Any additional amendments to the definition above are requested by the end of July. These should be sent either to Phil Davis or to the Secretariat for incorporation. These will either be accepted outright or will be put for discussion at the next meeting.

First round results from pig scenario

Presented by Dan Galeriu

The pig scenario was developed following the recommendation at the November 2005 meeting that the group adopt a scenario to test models that describe the transfer of tritium in large farm animals. The 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 total tritium in urine, HTO and OBT in faeces and HTO and OBT concentrations in various organs. 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 the maintenance need, gestation need and maternal growth.

FSA and IFIN participated in this scenario. FSA used the model PRISM whereas IFIN used two models, ROUK$^+$ and STAR. The STAR model uses separate compartments for fast and slow exchange, and was derived primarily for the calculation of HTO in cows and sheep. ROUK$^+$ uses energy and hydrogen metabolism and requires a knowledge of the composition and metabolic rate of organs and contains 5 slow compartments for OBT compared to the 1 slow compartment in STAR.

All models gave predictions in reasonable agreement with the observations for tissue HTO concentrations, with predicted to observed ratios ranging from 0.5 to 3.0. But there was a large variability in predictions for OBT, as one model under-predicted in some tissues by a factor of 10 and another over-predicted by a factor of 10. Overall, the ROUK$^+$ model was closest to the observations. Its urine tritium predictions were very close to the observations, although its faecal tritium did not agree so well.

A model inter-comparison scenario was also conducted. This was based on a 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. Again both FSA and IFIN contributed, with the FSA meat predictions being high compared to IFIN. Reasons for these differences require consideration.

Finally, a third exercise was conducted that 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.

IFIN results for different genotypes were provided. On the whole predictions were quite similar to each other, but were slightly lower for a fattier genotype. It was concluded that, for meat, the genotype of the animal is not too important.

Next steps

Francoise Siclet, Phil Davis and Masahiro Saito all expressed an interest in contributing results to the scenario. But it was noted that there could be some difficulty since their models do not distinguish different organs, whereas the scenario requires individual organ concentrations to be calculated. Since the observed organ concentrations are all similar however, Dan Galeriu will be happy to receive averaged results. These should be submitted by 12 October. The predictions will be discussed at the next plenary meeting in November.

Contribution to the revision of TRS-364

Presented by Philippe Calmon, Dan Galeriu and Phil Davis

At the 2005 EMRAS plenary meeting, the TRS-364 WG requested assistance from the Tritium and C-14 WG to provide parameter values for HT/HTO/OBT and C-14 transfer to plants and animals under both dynamic and equilibrium conditions, for inclusion in the revised TRS-364. Ideally, the recommended parameters would have values for which a large amount of high quality data are available, for which distributions can be derived, that are robust, that can be made plant and animal-specific, that can be extended to climates other than temperate and that match the complexity of the transfer parameters recommended for other radionuclides.

Before parameters can be recommended, it is necessary to have conceptual models of tritium and C-14 transfer in mind. Various modelling approaches were presented by Phil Davis for discussion for the pathways of interest.

Steady-State Conditions

Tritium – Atmospheric Releases

Uptake into plants

Three possible approaches were presented for modelling plant uptake of tritium following an atmospheric release. For HTO the simplest approach is to assume full specific activity equilibrium in all terrestrial compartments. This involves simple equations that only require a few parameters (absolute humidity, water content and water equivalent factors). This approach is easily defensible in terms of conservatism and uses parameters that are readily available. It may however result in overestimates of dose by a factor of three of four. The full specific activity approach can be modified to avoid these over-predictions. It can be assumed that the concentration in the plant is proportional to the concentration in air moisture. This is the concentration ratio approach, which indirectly takes account of tritium entering the plant via root uptake from contaminated soil. Values for the proportionality constant are available in the literature, but they tend to be plant-specific and variable. A more complex approach is to use Murphy's equation, which distinguishes the contributions to the plant from both air and soil. However, for this approach the soil water concentration is required and this is not easy to obtain. Options include the concentration ratio approach (in which the soil concentration is assumed to be proportional to the air concentration, with the proportionality constant determined from empirical data), or more process-oriented models. The more complex the models are made, the more parameter values are required and the less usable the models become.

Following discussions between the Tritium/C-14 WG and Philippe Calmon (TRS WG leader), it was agreed that Murphy's equation would be used for calculating tritium concentrations in plants following a release to air, with the soil concentration determined by the concentration ratio approach.

For predicting plant OBT concentrations, the only simple approach for a steady state system is to assume proportionality between plant HTO and OBT. This was adopted by the WG.

Uptake into animals

Simple transfer parameters have traditionally been used to model the incorporation of tritium into animals in steady state situations. These parameters are empirical and tend to be specific

to the feed, and type of animal. Another option is a water balance approach where the HTO concentration in the animal is calculated as the weighted mean of the concentrations in the various sources from which the animals draws its water (drinking water, plant water, plant combustion water and air moisture). The approach is considered quite robust and the values of the required parameters are well known and available for different species and diets, so that the model can easily address different climates. However, there is no correspondingly simple model for OBT concentrations in the animal.

Another, fairly complex option suggested by Dan Galeriu (IFIN) is to use a metabolic model based on fundamental data (fraction of water in body parts, turnover rate within body compartments and so on). The required data are available for different species and can be put in the form of concentration ratios to model the transfer of both HTO and OBT from plant to animal. Dan Galeriu has produced these ratios for various different animals. There was some concern that this approach may be too complicated, but overall it was supported, although certain formulae require explanation. Dan's approach was therefore tentatively adopted.

Tritium – Aquatic Releases

The full specific activity model is appropriate for HTO transfer from water to aquatic plants and animals. Plants growing in water or animals living in water quickly come into equilibrium with the water. Isotopic discrimination will occur in the case of OBT in aquatic plants and animals, so OBT concentrations are generally lower than HTO, but an isotopic discrimination factor can be used to model this. The WG therefore adopted the use of a specific activity model for HTO and a modified specific activity model for OBT.

Carbon-14 – Atmospheric Releases

For modelling C-14 releases to air, there is only one approach - full specific activity. Plants take up the vast majority of their carbon from the air (there is essentially no uptake via the root) and animals draw their carbon from ingestion. Full specific activity models are simple and only require the stable carbon content of air and stable carbon content of plants or animals as parameter values. The WG therefore adopted the use of specific activity models for C-14 releases to air.

Carbon-14 – Aquatic Releases

The specific activity approach is also the approach of choice in modelling C-14 uptake from water to aquatic plants and animals. Dissolved Inorganic Carbon (DIC) is the form of C-14 that is normally released with liquid effluents and is the form most readily taken up by aquatic plants. Thus it was proposed to base the specific activity model on DIC concentrations. It was originally thought that such a model would exclude benthic molluscs and fish, which access Total Organic Carbon (TOC). However, Francoise Siclet pointed out that DIC is a good basis for specific activity modelling for these species as well, and the WG adopted this approach generally for C-14 transfer in aquatic systems.

Tritium and Carbon-14 – Release to soil

Parameters are also required for models that address releases of both tritium and C-14 to soils, including soils contaminated via irrigation. It was confirmed by Philippe Calmon that these should be considered but they were not discussed at this meeting.

Dynamic Models

TRS-364 addresses dynamic models as well as steady-state conditions. Dan Galeriu presented an IFIN model that may be of use in deriving the required factors. However, following discussions, Phil Davis recommended that, due to the difficulties and uncertainties involved in modelling both C-14 and tritium dynamically, the WG would not recommend a dynamic model to the TRS-364 WG, but will discuss the issues and indicate why a generic model cannot be used at this point in time.

Next steps

Lists of parameter values are requested for the November meeting. By mid-August, Phil Davis will prepare and distribute a table of the required parameters, to which all WG members are requested to contribute values from their databases.

The minutes from this meeting will be provided to the TR-364 WG and similarly Philippe Calmon will distribute the TRS-364 minutes to the Tritium/C14 WG. Agreement from both WGs will be obtained before moving on.

Phil Davis will amend the draft TRS-364 revision document presented at this meeting by removing the models that won't be used and adding more description for those that will. This will be done by the end of September.

Francoise Siclet is requested to draft a note by November on modelling carbon concentrations in air from contaminated soil.

First draft report for the Hypothetical Scenario

Presented by Philippe Guétat & Luc Patyrl

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
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

The first draft paper for the scenario was presented and participants were requested to provide comment. P. Davis (AECL), D. Galeriu (IFIN), H. Lee (KAERI), K. Miyamoto (NIRS), L. Patryl (CEA), W. Raskob (FZK), P. Ravi (BARC) and M. Saito (SRA) submitted results for this scenario.

Atmospheric dispersion

The air concentrations predicted by the various models were generally within a factor of 10, which is considered acceptable. For case 1, CEA did not include any lateral dispersion of the plume and therefore the results were higher than those of the other participants. For case 2, model results were within a factor of 10 at the beginning of the modelling period, but become more variable with time. This appears to reflect differences in the amount of precipitation scavenging predicted by the models. For case 3, results were more or less within a factor of 10 and agreed best within a short distance of the point of release. Overall it was concluded that the spread in dispersion results depends on the lateral and vertical dispersion parameters employed.

Dose calculations

With the exception of results from CEA, all modellers calculated doses that were less than 1 mSv for Case 1. Results from CEA were around 10 mSv. The results for Cases 2 and 3 were more variable (around a factor of 10) with doses calculated around 10 mSv in both cases.

Dose results for each model were normalised by the corresponding predicted air concentration to allow an assessment of the way in which different participants modelled biosphere transfer:

- Case 1 - the inhalation and skin doses were similar for all models. However, doses from the consumption of corn were highly variable. Cereal consumption was the main dose contributor for both FZK and CEA. The consumption of green vegetables was the most important pathway according to the modelling results from SRA and BARC.
- Case 2 – normalized results from NIRS were substantially (a factor of 10) higher than other predictions, likely because of the rain intensity assumed.
- Case 3 - CEA assumed no difference in photosynthesis between night and day whereas AECL assumed that no photosynthesis occurred at night. All other modellers assumed some OBT incorporation at night, but at a lower rate than during the day. This resulted in

large differences in predicted plant OBT concentrations and a factor of 10 difference in normalised doses.

The main factor that will determine the length of time for which a dose problem persists following a release of tritium is the incorporation of OBT into plants and animals. If HTO is dominant then the dose will reduce after a few days. However, if the main contributor is OBT then this may persist for some time.

Intervention levels

Based on results for this scenario, an intervention level of 10^7 Bq/kg has been derived to avoid a dose of 5 mSv. However, the NIRS result for case 1 would indicate an intervention level of 10^4 Bq/kg, which is orders of magnitude less than that of the other modellers: this therefore requires some discussion. It is intended that this criterion would be applied to cautious first model evaluations to determine where food consumption bans would be implemented (i.e. early countermeasures). Monitoring would then take place to confirm the food ban area and determine the true area of intervention required. The intervention level is based on salad food items. These were taken as an indicator since salad is routinely grown in gardens and the total plant is consumed. The effect of OBT on dose for salad items can be considered significant on the basis of the scenario results and no salad should be consumed within a few kilometres of the release point.

Mikhail Balonov noted that a CAC (Codex Alimentarius Commission) accepted intervention level for tritium will be available in one month. This will be a binding limit for international trade and is likely to be 10^4 Bq/kg in food based on consumption over a whole year (i.e. continuous contamination). However, the CAC intervention level will not apply for the release phase and therefore during this time nationally accepted intervention limits can be applied.

Next steps

There is still a need to try and determine why the results of the models differ by so much. Wolfgang Raskob suggested that transfer rates for OBT and HTO (e.g. OBT formation rate for day and for night) used in each of the models be tabulated to enable easy identification of any differences. All participants are therefore requested to report these values for their models. Philippe Guétat will draw up a table of the required parameters and distribute it for completion by all participants. Completed tables are to be returned by mid July. Any changes to model predictions, and full model descriptions, should also be submitted by mid July.

A draft final report for this scenario will be distributed prior to the November meeting for discussion.

Future activities

The actions and future activities coming out of this meeting are listed in Annex A. Participants are requested to ensure they meet deadlines and submit all the required information.

Status of Work Programme

Item	Status for next Working Group meeting	Person Responsible
Perch Lake H-3 scenario	Complete	
Pickering H-3 scenario	Final report available on EMRAS website	P Davis
Soy bean H-3 scenario	Final report available on EMRAS website	H Lee
Pine tree H-3 scenario	Draft final report	Y Inoue & modellers
Hypothetical H-3 short term release scenario	Draft final report	P Guetat, L Patryl & modellers
Mussel H-3 scenario	Draft report for uptake phase and first round results for depuration phase	T Yankovich & modellers
Rice C-14 scenario	Draft final report	J Koarashi & modellers
Animal H-3 scenario	Second round results	D Galeriu & modellers
Potato C-14 scenario	Second round results and draft report	A Melintescu & modellers
Definition of OBT	Final definition	P Davis
TRS-364	Draft chapter and table of parameter values	D Galeriu & Phil Davis

Next Meetings

The next meeting of the Working Group will be held during the Fourth EMRAS Combined Meeting, IAEA Headquarters in Vienna, from 6–10 November 2006. The 2007 spring meeting of the Working Group will be in Bucharest, Romania. It is anticipated that this will be a 3-day meeting. Further details of this will be provided in November.

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:

Mr. M. Balonov (Scientific Secretary)
c/o Waste Safety Section
Division of Radiation, Transport & Waste Safety
International Atomic Energy Agency (IAEA)
Wagramer Strasse 5
PO Box 100
1400 Vienna
Austria
Tel: +43 (1) 2600-22854
Fax: +43 (1) 26007
Email: M.Balonov@iaea.org

Mr. P. Davis (Working Group Leader)
Senior Scientist
Environmental Research Branch, Station 51A
Atomic Energy of Canada Limited (AECL)
Chalk River Laboratories
K0J 1J0 Chalk River, Ontario
Canada
Tel: +1 (613) 584-3311 x3294
Fax: +1 (613) 584-1221
Email: davisp@aecl.ca

ANNEX A: Summary of Actions

Date due	Activity	Persons Responsible
End June	Hypothetical Scenario: Distribution of parameter tables for completion	L. Patryl & P. Guétat
	Soybean Scenario: Distribution of final report	H. Lee
	TRS-364: circulation of meeting notes	Technical Secretariat
Mid July	Pickering Scenario: Provision of data on ingestion rates and assumptions for completion of Table 12, & Kirchman reference	P. Kennedy M. Saito
	Pickering Scenario: check model descriptions	Relevant modellers
	Hypothetical Scenario: return completed model parameter tables	Relevant modellers
End July	Soybean Scenario: return comments on the draft report	Relevant modellers
	Pine Tree Scenario: Submission of amended results and full model descriptions	Relevant modellers
	C-14 Rice Scenario: model descriptions to be submitted	Relevant modellers
	OBT Definition: final amendments to be submitted	All WG members
Mid August	TRS-364: distribution of tables of the required parameter values	P. Davis
	Pickering Scenario: publication of final report on EMRAS website	P. Davis
End August	Soybean Scenario: publication of final report on EMRAS website	H. Lee
	C-14 Rice Scenario: provision of modelled air concentrations at Station 3	Relevant modellers
Mid September	H-3 Mussel Scenario: submission of revised results for the uptake phase, model descriptions and uncertainty estimates.	Relevant modellers
	TRS-364: return of completed parameter value tables	All WG members
End September	H-3 Mussel Scenario: Submission of round 1 results for depuration phase	Relevant modellers
	C-14 Potato Scenario: submission of new/revised results	P. Kennedy, F. Siclet & other interested participants
	TRS-364: draft chapter and parameter values	P. Davis & D. Galeriu
Mid October	H-3 Pig Scenario: submission of new/revised results	Relevant modellers
	TRS-364: draft note on modelling carbon concentrations from contaminated soil to air	Francoise Siclet
End October	Pine Tree Scenario: circulation of draft report	Y. Inoue
	C-14 Potato Scenario: circulation of draft report	A. Melintescu
	H-3 Mussel Scenario (uptake phase): distribution of draft report	T. Yankovich
	Hypothetical Scenario: distribution of draft report	P. Guetat, L.Patryl
	H-3 Rice Scenario: distribution of draft report	J. Koarashi
November 2006	Next WG meeting	All WG members

ANNEX B: Summary of Scenario Descriptions

Perch Lake Scenario

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 northeastern 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 nearshore 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.

Pickering 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.

Soybean 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.

Pine Tree 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 from 4 sources were provided to modellers who were requested to calculate the following end points:

1. Monthly tritium concentrations in air moisture, precipitation, tissue free water (TFWT) and non-exchangeable OBT (nOBT) in pine tree needles from 1982 to 1986 at sampling site P3;
2. Yearly tritium concentrations in air moisture, 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.

Hypothetical 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, as well as the contribution of the various forms of tritium (HT, HTO and OBT) to total exposure. 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 meteorological conditions.

	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

Mussel Scenario

Perch Lake is a small shallow water body that receives tritium inputs from upstream waste management facilities. The 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.

Rice Scenario

C-14 has been released from three discharge points at Tokaimura over several decades. Weekly monitoring data are available from October 1991. Discharges have decreased considerably over that period, from about 800 GBq in 1991 to near zero in 2000. Corresponding measurements of C-14 concentrations in air and rice are available. Data Obtained in 1991 indicate that any effect from earlier discharges was negligible in the plants. 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 two 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.

Potato 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. Three planting densities were employed and fumigation occurred for approximately 10-day periods at 6 different plant growth stages. Samples from 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. Temperatures increased with time during fumigation and relative humidity increased by around 10%. Plants were not under water stress.

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 data for Cambridge was employed.

Modellers were requested to calculate C-14 concentrations in leaves at each sampling time for each of 6 experiments and the concentrations in tubers at final harvest (including 95% confidence limits).

Pig 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 Intercomparison

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

   One of the aims of Exercise 2 was to determine if accurate results could 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.

ANNEX C: List of Participants

Mr. Mikhail Balonov
Scientific Secretary
c/o Waste Safety Section (Room B0765)
Division of Radiation, Transport & Waste Safety
International Atomic Energy Agency (IAEA)
Vienna International Centre
Wagramer Strasse 5
P.O. Box 100
A-1400 Vienna
Austria
Tel: +43 (1) 2600-22854
Fax: +43 (1) 2600-7
Email: M.Balonov@iaea.org

Mr. Franz Baumgärtner
Director Emeritus, Institute für Radiochemie
Technische Universität München
Grosostrasse 10d
82166 Gräfelfing
Germany
Tel: +49 (89) 851-347
Fax: +49 (89) 854-4487
Email: bgtbgt@web.de / bgt@rad.chemie.tu-muenchen.de

Mr. Dan Galeriu
Senior Researcher, Life & Environmental Physics
Institute of Atomic Physics & Nuclear Engineering "Horia Hulubei"
IFIN-HH, Section 5
407 Atomistilor Street
P.O. Box MG-6
RO-077125 Bucharest-Magurele
Romania
Tel: +40 (21) 404-2359
Fax: +40 (21) 457-4440
Email: galdan@ifin.nipne.ro / dangaler@yahoo.com

Mr. Philippe Guétat
Deputy Head of Department
Department DTMN
CEA - Centre de Valduc
21120 Is sur Tille
France
Tel: +33 (3) 8023-4280
Fax: +33 (3) 8023-4481
Email: philippe.guetat@cea.fr

Mr. Philip Davis
Working Group Leader
Senior Scientist
Environmental Technologies Branch, Station 51A
Atomic Energy of Canada Limited (AECL)
Chalk River Laboratories
K0J 1J0 Chalk River, Ontario
Canada
Tel: +1 (613) 584-8811 x3294
Fax: +1 (613) 584-1221
Email: davisp@aecl.ca

Mr. Philippe Calmon
Head of Laboratory
IRSN/DEI/SECRE/LME (Bâtiment 159)
Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
Centre de Cadarache
B.P. 3
13115 Saint Paul-lez-Durance, Cedex
France
Tel: +33 (4) 4219-9447
Fax: +33 (4) 4219-9145
Email: philippe.calmon@irsn.fr

Mr. Eric Gilbert
Electricité de France (EDF)
Département Environement (R&D)
6, Quai Watier
B.P. 49
78 401 Chatou Cédex
France
Tel: +33 (1) 3087-7244
Fax: +33 (1) 3087-8109
Email:

Mr. Yoshikazu Inoue
Senior Researcher
Environmental Radiation Effects Research Group
Research Center for Radiation Protection
National Institute of Radiological Sciences (NIRS)
4-9-1 Anagawa, Inage-ku
263-8555 Chiba-shi
Japan
Tel: +81 (43) 206-3051
Fax: +81 (43) 251-7819
Email: y_inoue@nirs.go.jp / yoshi_inoue2001@hotmail.com

Mr. Joshy Philip James
Scientific Officer, Environmental Survey Laboratory
Bhabha Atomic Research Centre (BARC)
Kaiga Generating Station
Utta Kannada District
581 400 Kaiga, Karwar, Karnataka
India
Tel: +91 (8382) 254-092
Fax: +91 (8382) 264-025
Email: jpjames@npcil.co.in / joshypjames@sancharnet.in

Mr. Jun Koarashi
Researcher, Radiation Protection Division
Japan Atomic Energy Agency (JAEA)
4-49 Muramatsu
Tokai-mura, Naka-gun
319-1184 Ibaraki-ken
Japan
Tel: +81 (29) 282-1111 x61233
Fax: +81 (29) 282-3838
Email: koarashi.jun@jaea.go.jp

Ms. Pamela Lloyd
Enviros Consulting Limited
Building D5
Culham Science Park
Abingdon, Oxfordshire OX14 3DB
United Kingdom
Tel: +44 (1235) 468-814
Fax: +44 (1235) 468-828
Email: Pamela.lloyd@enviros.com

Ms. Anca Melintescu
Senior Researcher (Physicist)
Environmental & Life Sciences Department
Institute of Atomic Physics & Nuclear Engineering "Horia Hulubei"
IFIN-HH, Section 5
407 Atomistilor Street
P.O. Box MG-6
RO-077125 Bucharest-Magurele
Romania
Tel: +40 (21) 404-2359
Fax: +40 (21) 457-4440
Email: ancameli@ifin.nipne.ro / melianca@yahoo.com

Mr. Paul Kennedy
Emergency Planning, Radiation & Incidents Division
Food Standards Agency (FSA)
Aviation House
125 Kingsway
London WC2B 6NH
United Kingdom
Tel: +44 (20) 7276-8703
Fax: +44 (20) 7276-8789
Email: paul.kennedy@foodstandards.gsi.gov.uk

Mr. Hansoo Lee
Project Manager
Nuclear Environment Research Division
Korea Atomic Energy Research Institute (KAERI)
P.O. Box 105
150 Dukjin, Yuseong
305-353 Daejeon
Republic of Korea
Tel: +82 (42) 868-2395
Fax: +82 (42) 861-1761
Email: hslee5@kaeri.re.kr

Ms. Kiriko Miyamoto
Senior Researcher, Environmental & Toxicological Sciences Research Group
National Institute of Radiological Sciences (NIRS)
4-9-1 Anagawa, Inage-ku
263-8555 Chiba-shi
Japan
Tel: +81 (43) 206-3156
Fax: +81 (43) 251-4853
Email: kiriko@nirs.go.jp

Mr. Luc Patryl
DIF/DASE/RCE/CCI
Commissariat à l'Energie Atomique (CEA)
Centre de Bruyères le Châtel
B.P. 12
91680 Bruyères le Chatel
France
Tel: +33 (1) 6956-5133
Fax: +33 (1) 6926-7065
Email: luc.patryl@cea.fr

Mr. Wolfgang Raskob
Institut für Kern und Energietechnik (IKET), Bau 433
Forschungszentrum Karlsruhe - Technik und Umwelt
Postfach 3640
D-76021 Karlsruhe
Germany
Tel: +49 (7247) 82-2480
Fax: +49 (7247) 82-5508
Email: wolfgang.raskob@iket.fzk.de

Mr. Masahiro Saito
Professor
Kyoto University Safety Reassurance Academy
Okubo-Naka 3-17-4, Kumatori-cho
Sennan-gun
590-0403 Osaka
Japan
Tel: +81 (72) 452-6709
Fax: +81 (72) 452-6709
Email: hmsaito@vega.ocn.ne.jp

Mrs. Francoise Siclet
Research Scientist
National Hydraulics & Environment Laboratory
Electricité de France (EDF)
Département Environement (R&D)
6, Quai Watier
B.P. 49
78 401 Chatou Cédex
France
Tel: +33 (1) 3087-7847
Fax: +33 (1) 3087-7336/8109
Email: francoise.siclet@edf.fr

Ms. Karen Smith
(Technical Secretariat)
Consultant, Risk & Resource Management
Enviros Consulting Limited
61 The Shore
Leith
Edinburgh, Scotland EH6 6RA
United Kingdom
Tel: +44 (1946) 824-761
Fax: +44 (1946) 824-762
Email: karen.smith@enviros.com

Mr. Vesa M. Suolanen
Research Scientist, Nuclear Energy
VTT Technical Research Centre of Finland
Lämpömiehenkuja 3
P.O. Box 1604
FIN-02044 VTT Espoo
Finland
Tel: +358 (20) 722-5063
Fax: +358 (20) 722-5000
Email: vesa.suolanen@vtt.fi

Mr. Kazuhide Yamamoto
President/Senior Engineer
YFirst Inc.
4-937 Nishiya-cho Hodogaya-ku
Kanagawa
240-0052 Yokohama
Japan
Tel: +81 (45) 382-0639
Fax: +81 (45) 382-0829
Email: yamamoto@yfirst.co.jp