EMRAS: Modelling the Transfer of Tritium and C-14 to Biota and Man Notes of the Ninth Working Group Meeting Vienna, Austria 5 – 9 November 2007

EMRAS, Tritium and C-14 Working Group Meeting Report 9

Notes of the Ninth IAEA EMRAS Tritium and C-14 Working Group Meeting
Vienna, Austria
5 – 9 November 2007

The ninth meeting of the IAEA EMRAS Tritium and C-14 Working Group was held in Vienna, Austria, at the offices of the International Atomic Energy Agency. These Meeting Notes were prepared by the Working Group Leader, Phil Davis (AECL, Canada). In addition, the following people attended the meeting and contributed to the discussions and decisions documented herein.

Name	Organisation	Country
V Berkovskyy	International Atomic Energy Agency (IAEA)	Austria
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
L Vichot	Commissariat à l’Energie Atomique (CEA)	France
F Siclet	Electricité de France (EDF)	France
F Baumgärtner	Munich Technical University (TUM)	Germany
W Raskob	Forschungszentrum Karlsruhe (FZK)	Germany
P Ravi	Bhabha Atomic Research Centre (BARC)	India
A Melintescu	“Horia Hulubei” National Institute for Physics and Nuclear Engineering (IFIN-HH)	Romania
D Galeriu	“Horia Hulubei” National Institute for Physics and Nuclear Engineering (IFIN-HH)	Romania
V Golubeva	Russian Federal Nuclear Centre (VNIIEF)	Russia
M Brennwald	National Co-operative for the Disposal of Radioactive Waste (NAGRA)	Switzerland

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1. Introduction

The objectives of the meeting were to:

- Discuss the draft final report for the Pickering tritium scenario, particularly the appendix on the effect of averaging time on the predicted concentrations;
- Discuss the draft final reports for the pig, potato, mussel and hypothetical scenarios;
- Discuss and finalize the definition of OBT;
- Discuss the contribution of the Working Group (WG) to the revision of TRS-364 and the TECDOC on which it is based; and
- Plan future work to ensure that the final TECDOC covering all WG activities is completed on schedule.

Participants were welcomed to the meeting by the WG Leader, Phil Davis. Phil thanked participants for their contributions to the progression of the WG scenarios and noted that, since this was the last EMRAS meeting, all final scenario reports should be completed by the end of the 2007 calendar year. All of the reports will be published together in a single IAEA Technical Document (TECDOC).

Further information on the EMRAS program as a whole can be found on the EMRAS website.[1] Meeting notes, scenario descriptions and final reports for the Tritium/C14 WG are also available on the website.[2]

Summaries of the main points of discussion on each of the activities of the tritium and C-14 WG are provided in the subsequent sections.

2. Nature and Definition of OBT (Phil Davis)

Throughout the EMRAS program, the Tritium/C14 WG has attempted to formulate a definition of OBT, consistent with traditional measurement procedures and dose conversion factors, to promote common understanding and usage within the international tritium community. As the definition has progressed through discussions at WG meetings, the issue of buried tritium has been highlighted. The current definition, which is given in Appendix A, was distributed to participants in October and discussed at the meeting. The following issues/comments were raised:

- The second sentence of the main definition should be moved to a note and tied to analytical procedures for determining OBT concentrations in environmental samples.
- The concept of buried tritium would be easier to understand if it were related to "buried hydrogen", which is a commonly used term in biochemistry.
- There is a contradiction between the phrase "tritium in exchangeable positions" in Note (i) and "the exchangeable fraction" in Note (ii) that should be removed.
- In Note (vi), make it clear that what we consider OBT is organically bound tritium found in a normal diet.

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

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

- The last sentence in Note (i) should be deleted.
- The word “quickly” should be deleted from line 4 of Note (ii).
- In Note (iii), add a reference to OBT analytical methods
- In Note (iv), “hydrogen” should be added to the end of the third sentence.
- In Note (vi), change “ICRP dose coefficient” to “ICRP ingestion dose coefficient”.

Phil Davis agreed to send a revised definition to WG members for comment by December 15.

3. Completed Scenarios

The final report for the Perch Lake tritium scenario is complete and has been posted on the EMRAS website. Draft final reports for the Soybean, Rice and Pine Tree scenarios were distributed to WG members for review in October and were discussed briefly in Vienna. Anca Melintescu was asked to ensure that the description of the IFIN model given in the Soybean scenario is satisfactory. Françoise Siclet suggested that the observations for the Rice scenario should be provided in a table as well as in figures. Françoise also noted that the model she used for the Pine Tree scenario did not take rainfall rate into account, which may explain some of the differences between her results and the observations. Apart from these issues, participants were satisfied with the reports. Further comments will be accepted until November 23, after which time the reports will be finalized.

Phil Davis reported some additional work he did for the Pickering scenario to investigate the effect of averaging time on the predicted tritium concentrations in plants and animals. He calculated results using air concentrations averaged over all hours in the two months prior to sampling, and over daylight hours only. Most models produced better results when they were driven by daylight air concentrations but the AECL model performed better using the 24-hour concentrations. Thus more work is required to determine which averaging period is most appropriate. This question is directly related to the amount of OBT that is formed at night. If most OBT is produced during the day, the models should be run with daylight air concentrations. If significant amounts of OBT are produced at night, the 24-hour concentrations would be more appropriate. Françoise Siclet noted that, even if OBT is formed only during the day, night-time conditions will have an impact on plant concentrations through uptake from the soil, which receives tritium deposition at night as well as during the day. Further comments on the Pickering report will be accepted until November 23, after which time it will be finalized.

4. Hypothetical Short-term Release Scenarios (Luc Patryl and Philippe Guetat)

The Hypothetical scenarios involve an accidental release of tritium to the atmosphere under three different environmental conditions. Modellers were asked to predict tritium concentrations in all environmental compartments and total doses to members of the public from all exposure pathways. The objective was to provide information that would be useful to decision makers in managing an accident involving a short-term tritium release to the atmosphere.

The draft final report for the scenario was presented and discussed at the previous WG meeting in Bucharest in June, and the changes recommended there have been incorporated in a new version. In addition, Figure 6 showing total dose was changed to present the information in a more useful way. Model descriptions for three participants (P. Ravi, H. Lee and D. Galeriu) are missing.

Section 4.4 of the report on intervention levels was discussed. The model predictions suggest that a dose of 5 mSv will be saved if garden crops are interdicted when the concentration exceeds 10^7 Bq kg^{-1} fresh weight in leafy vegetables in the first day after the accident. The intervention level drops to 10^6 Bq kg^{-1} in the second day. Dan Galeriu thought the decrease should be more than a factor of 10, but the results appear to confirm this value. 5 mSv was initially used as the basis for the intervention level following U.S. practice, but it was decided to switch to 10 mSv to be consistent with the recommendations of the ICRP and other international groups.

The report will be revised and circulated to WG members for comment by November 30, after which time it will be finalized.

5. Mussel Scenarios (Tamara Yankovich)

The mussel scenarios consider tritium dynamics in adult freshwater mussels subject to an abrupt increase or decrease in tritium concentrations in their surrounding environment. Modellers were asked to predict the HTO and OBT concentrations in the mussels as a function of time over the course of the study period.

Tamara Yankovich briefly reviewed the draft final report for the mussel uptake scenario. Participants had no comments at the meeting but were given a further two weeks (until November 23) to review the document, at which time it will be finalized.

Tamara made a more detailed presentation on the mussel depuration scenario. Noting that the IFIN model underestimated OBT concentrations in the mussels beginning 10 days after transplantation, she asked if uptake rates by the mussels were too fast, leading to a dilution of OBT by uncontaminated dry matter. Dan Galeriu responded by noting that, in reality, the OBT turnover rate in mussels has fast and slow components, but that in the IFIN model only the fast component is included, resulting in low concentrations.

The EDF model also underpredicted OBT concentrations beginning 30 days after transplantation, although not as severely as the IFIN model. For the uptake scenario, this model was not able to predict the fast increase in OBT during the initial stages following transplantation. To address this, an additional stomach content compartment was added to account for OBT associated with food that had not yet been digested. The stomach compartment was assumed to comprise 30% of the soft tissue mass of the mussel. Turnover rates of the stomach contents were assumed to proceed rapidly (0.33 per day) under the control of the mussel filtration rate. The turnover rate in soft tissue corresponded to metabolic activity and proceeded slowly (0.01 per day). These rates may have to be adjusted to bring the model predictions into line with the observations.

The neglect of buried tritium in the models and an incorrect specification of the food uptake rate may account for some of the differences between observations and model predictions. Additional measurements would be needed to sort these factors out.

Participants made some specific suggestions for improving the draft report:

- Figures 7 and 8 are not particularly useful and should be deleted.
- The approach of the OBT concentrations in the transplanted mussels to background levels is likely to be more gradual than shown in Figure 9.
- Table 5 shows that the OBT concentrations in the fish resident in Upper Bass Lake are higher than the HTO concentrations. Tamara will look into this.

WG members were requested to check that their results are properly represented in the report, and to send corrections and other comments to Tamara by November 30. Tamara will incorporate the comments into a revised draft that will be re-circulated by the end of December.

6. Pig Scenario (Dan Galeriu)

The pig scenario consisted of two parts, a model-data blind test and a model intercomparison. In the blind test, the modellers were asked to predict the dynamics of total tritium in urine and faeces and the concentration of HTO and OBT in organs for a pregnant sow fed an OBT diet for 84 days before delivery. Seven participants from five organizations submitted predictions. Due to problems previously encountered in the FSA results, the PRISM model was reconstructed within the model-maker platform by IFIN; the conclusions below are based on the reconstructed results.

All of the scenario endpoints were overestimated by some models and underestimated by others, but the predictions were within a factor of 2-3 of the observations in most cases. The exceptions were the STAR results, which overestimated the total tritium in urine by a factor of 5 and underestimated the OBT in organs by almost a factor of 10. STAR assumes that animals eat pasture with little OBT intake and is not directly applicable to the current scenario.

The model intercomparison comprised two scenarios. In the first, a hypothetical pig was given uncontaminated food and water for the first 55 days of life, and was then fed food and water contaminated with HTO for 50 days. Uncontaminated feed was then provided for the next 50 days, at which time the pig was slaughtered. Only three modelers (IFIN, SRA and FSA) participated in this scenario, predicting concentrations in urine, faeces and meat that differed by a factor of 15 or more. Results from the two models that participated in the second scenario, which involved pigs fed OBT-contaminated food for 1 day, indicated that genotype is not important in determining uptake of OBT to meat.

A revised version of the draft final report for the pig scenario that addresses comments made at the meeting will be distributed for review by November 30. This draft will include results submitted by AECL at the meeting.

7. Potato Scenario (Anca Melintescu)

The Potato Scenario is based on experiments in which potato tubers were exposed to $^{14}CO_2$ in a wind tunnel for approximately 10-hour periods at 6 different stages of plant growth (P1-P6). Following exposure, the plants were transferred to the field to continue growing. Modellers were asked to calculate C-14 concentrations in leaves at various sampling times and in tubers at final harvest.

Anca Melintescu discussed the main points of the draft final report, which was essentially unchanged from the version presented at the spring meeting of the WG. A new description of the UTTY model was provided but it was still not clear why this model overpredicts the C-14 concentration in leaves to such a large extent. A possible explanation was put forward by Françoise Siclet, who noted that the predictions can be reduced by a factor three by driving the models with an air concentration that is a weighted average based on photosynthetic rate, rather than a straightforward arithmetic average.

The predictions were poor for experiment P6, which involved plants at a late stage of growth. Most models adopted a high photosynthetic rate for this case based on the time between seeding and exposure. However, a much lower rate would have been more appropriate given that the plants were seeded much later in the year than normal. The late seeding and early and sudden onset of senescence may have contributed to the poor predictions in general, since the models were developed on the basis of a more normal plant growth scenario.

Although the modelers were asked to calculate the uncertainties on their model predictions, none did so. Similarly, uncertainty estimates were not provided for several of the other WG scenarios. It appears that participants are willing to estimate uncertainties for simple scenarios involving steady-state conditions, but more reluctant to do so in more complex situations involving time-dependent concentrations.

Anca will revise the report to address comments made at the meeting, to correct a mistake in units in the EDF results, and to replot the EDF data in Figures 1-6. The report will be distributed to WG members for final comment by November 30.

8. Contribution to the Revision of TRS-364 (Phil Davis)

The Tritium/C14 WG is responsible for writing the chapter on specific activity models in the revision of TRS-364, and in the TECDOC that supports the TRS. A draft chapter for the TECDOC was discussed in the 2006 EMRAS fall plenary meeting. Comments from the WG and from an outside reviewer were taken into account in a revised draft that was discussed at the spring meeting of the WG. Comments made there were incorporated into the latest draft, which was presented in Vienna in November. WG members suggested the following changes to the document:

- Paragraph following Table 12.1: It is stated that “concentrations in soil water are diluted by uncontaminated precipitation that falls when the plume is not present, and so are lower than the concentrations in air moisture’. This is correct, but Philippe Guetat noted that soil water concentrations are also relatively low because precipitation is less contaminated that air moisture.
- Eq. (12.3): The model for calculating tritium concentrations in soil water is based on the ratio CR_s of concentration in soil water to that in air moisture. It should be pointed out in the report that this model cannot be applied close to an elevated source, where air concentrations are low or zero but the soil water concentration could be high due to wet deposition.
- Table 12.2: The Japanese value of CR_s should be checked and the country where each value was obtained should be added to the table.
- Table 12.4: Françoise Siclet questioned the value of 0.78 used to deduce the non-exchangeable OBT concentration from the total OBT concentration. This value was suggested by Yves Belot, and an action was placed on Françoise to sort the issue out with Yves.
- General: Françoise asked if the contribution of exchangeable OBT to dose was included in the model or if it needs to be added in. Considerable discussion failed to resolve this question and Phil Davis agreed to pursue it further.

- Section 12.1.1.2: The units of the concentration ratios CR_a^{HTO} and CR_a^{OBT} in the model of plant-to-animal transfer are not consistent in different places in the document. An action was placed on Dan Galeriu to rationalize the units.
- Table 12.6: The units for the intake rate should be kg DW d^{-1}, not kg FW d^{-1}.
- Table 12.8: The lower values in the range of French irrigation rates should be greater than zero. Phil will revise the values based on data supplied by Françoise.
- Table 12.11: Some members of the WG felt that tritium concentrations in food products should not be reduced when the food is processed. The cooking water may itself be contaminated, in which case there would be no losses. Moreover, it is the custom in some cultures to drink the cooking water, in which case any tritium lost to the water would still be ingested. In the absence of site-specific information, it was agreed to recommend no processing losses as a conservative assumption. A similar change should be made with respect to C-14 in Table 12.16 (Section 12.2.4)
- Section 12.1.2.1: The discussion of the canopy dilution factor should be removed as it is not essential to the model.

A joint session was held with the Transfer Parameter WG, which suggested a number of additional changes to the tritium and C-14 contribution to the TRS TECDOC. Phil Davis will amend the text and distribute it to WG members for review by November 30.

A first draft of the specific activity chapter for TRS-364 itself was written and distributed to WG members for comment prior to the meeting. This draft is basically a condensed version of the TECDOC, and is too long to be incorporated into the TRS as it stands. A number of ways were discussed to reduce the length, with the most promising being to include only the most important pathways and refer to the TECDOC for the others. All WG members were requested to send ideas to Phil Davis by December 15 on how to reduce the specific activity chapter in TRS-364 to 10 pages

9. Additional Presentations

Two additional presentations were made at the meeting:

- “The dynamics of OBT formation – its biological and biophysical growth”, by Franz Baumgärtner. This presentation served as a good lead into the discussion of the definition of OBT.
- “Environmental tritium modelling in India”, by P.M. Ravi.

10. Future Activities

The actions placed on WG members at the meeting are listed in Table 1. Participants are asked to stick as closely as possible to the agreed deadlines in order to complete the program on time.

A follow-up program to EMRAS is currently under consideration by the IAEA. All participants are invited to submit ideas for this program by filling out the questionnaire located at http://www-ns.iaea.org/projects/emras/proposal-form.htm.

Table 1. Actions Placed on Tritium/C14 WG Members

Name	Action	Due Date
All WG members	Review new appendix to the Pickering report and send comments to Phil Davis	Nov 23
	Review rice report and send comments to Phil Davis	Nov 23
	Review pine tree report and send comments to Phil Davis	Nov 23
	Review mussel uptake report and send comments to Tammy Yankovich	Nov 23
	Review mussel depuration report and send comments to Tammy Yankovich	Nov 30
	Send ideas to Phil on how to reduce the specific activity chapter in TRS-364 to 10 pages	Dec 15
	Fill out internet questionnaire on the IAEA's proposed new program (http://www-ns.iaea.org/projects/emras/proposal-form.htm)	Dec 1
Anca Melintescu	Check that IFIN model description is correct in soybean report	Nov 23
	Revise potato report (taking EDF corrections into account) and distribute to WG members	Nov 30
Françoise Siclet	Discuss with Yves Belot the correct value to use to remove exchangeable OBT from the values of D_p in Table 12.4 of the specific activity chapter in TRS-364	Nov 30
Phil Davis	Revise OBT definition taking WG comments into account and distribute to WG members	Dec 15
	Revise the specific activity chapter in the TRS-364 TECDOC and circulate to WG members for comment	Nov 30
	Revise the specific activity chapter in TRS-364 and circulate to WG members for comment	Jan 10
Dan Galeriu	Sort out the units for CR_a^{HTO} and CR_a^{OBT} in the plant-animal model in the specific activity chapter of TRS-364	Nov 30
	Revise pig report, include new AECL results, and distribute to WG members	Nov 30
	Re-send IFIN results for the mussel depuration scenario to Tammy Yankovich	Nov 23
Tammy Yankovich	Incorporate comments on depuration report from meeting and from WG review, and re-circulate report	Dec 30
Luc Patryl	Revise the final report for the hypothetical scenario and circulate to WG members	Nov 30

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. V Berkovskyy (Scientific Secretary)
Assessment & Management of Environmental Releases Unit
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APPENDIX A

Definition of Organically Bound Tritium (OBT)
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Definition: OBT is carbon-bound and buried tritium 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, radiochemicals and so on) should be called tritiated organics, which can exist in any chemical or physical form.

Notes:

(i) Buried tritium is tritium in exchangeable positions in large biomolecules that is not removed by rinsing with tritium-free water. Buried tritium therefore appears as part of OBT in the traditional experimental determination of OBT. However, buried tritium quickly exchanges with hydrogen atoms in the body and acts as HTO rather than OBT following ingestion.

(ii) 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 measurements that are highly variable and difficult to interpret.

(iii) Exchangeable tritium should be removed by moderately drying the sample without decomposing the organic molecules, 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.

(iv) 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.

(v) 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.

(vi) 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 ICRP dose coefficient 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.