EMRAS: Modelling the Transfer of Tritium and C-14 to Biota and Man Notes of the Fifth Working Group Meeting Vienna, Austria 21–25 November 2005

EMRAS, Tritium and C-14 Working Group, Meeting Report 5 (draft)

Notes of the IAEA EMRAS Tritium and C-14 Working Group Meeting Vienna, Austria 21-25 November 2005

The fifth meeting of the IAEA EMRAS Tritium and C-14 Working Group was held in Vienna, Austria. The meeting was hosted by the IAEA.

These Meeting Notes have been prepared by Karen Smith and Ian Barraclough (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**
T Yankovich	Atomic Energy of Canada Limited (AECL)	Canada
V Soulanen	Technical Research Centre of Finland (VTT)	Finland
F Siclet	Electricité de France (EDF)	France
C Dovlete	Private Consultant	France
P Guétat	Commissariat à l'Energie Atomique (CEA)	France
S Le Dizés-Maurel	Institut de Radioprotection et de Surete Nucleaire (IRSN)	France
L Patryl	Commissariat à l'Energie Atomique (CEA)	France
F Baumgärtner	Munich Technical University (TUM)	Germany
P Ravi	Bhabha Atomic Research Centre (BARC)	India
Y Inoue	National Institute of Radiological Sciences (NIRS)	Japan
K Miyamoto	National Institute of Radiological Sciences (NIRS)	Japan
J Koarashi	Japan Atomic Energy Agency (JAEA, former JNC)	Japan
K Yamamoto	YFirst	Japan
M Saito	Kyoto University Safety Reassurance Academy	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
S Conney	Food Standards Agency (FSA)	UK
R Peterson	Lawrence Livermore National Laboratory	USA
W Gulden*	European Fusion Development Agreement (EFDA)	EC

* Observer

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 fifth meeting of the EMRAS Tritium and C-14 Working Group was held on 21-25 November 2005, hosted by the IAEA.

The objectives of the meeting were to:

- Discuss the final report for the H-3 Perch Lake (aquatic) Scenario;
- Present and discuss the draft 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 second round of calculations for the H-3 Pine Tree Scenario;
- Present and discuss the results from the third round of calculations for the H-3 Hypothetical (short term release) Scenario;
- Present and discuss the first round of calculations for the H-3 Mussel Scenario;
- Present and discuss results from the first round of calculations for the C-14 Rice Scenario;
- Present data on plant OBT/air HTO ratios at Lawrence Livermore National Laboratory;
- Discuss the definition of OBT;
- Discuss new scenarios, especially C-14 and large animal scenarios; and,
- Plan future work activities.

Participants were welcomed to the meeting by the Working Group Leader, Phil Davis. Each participant introduced themselves and described briefly their background and interest in the working group.

All participants are invited to the next Tritium and Carbon-14 Working Group Meeting, which will be hosted by EdF in Paris, France, on 7-9 June 2006. 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 5th 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 the Annex Band contact information for the participants is given in Annex C.

Final report for the Perch Lake Scenario

Presented by Phil Davis

The Perch Lake Scenario report was finalised at the previous working group meeting in Cardiff, UK and should have been published on the website as planned. However, one participant has not yet provided a model description for inclusion in the report. This participant was not present at the meeting and therefore it was decided one further opportunity to provide the required information would be given. Failing this, the report will be published with the results of this participant deleted.

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

Draft report for the Pickering Scenario

Presented by Phil Davis

A draft report on the Pickering Scenario has been produced. Participants were taken through this page by page, and asked to pay particular attention to model-specific sections and to highlight any inconsistencies or errors.

Particular points to note from discussions were:

- All models but one (LIET) successfully predicted the HTO concentration in soil water.
- The model results for OBT from one participant (TUM) represented exchangeable OBT plus buried tritium. All other participants calculated OBT as traditionally understood. Since the OBT predictions provided by TUM were calculated on a different basis, these have not been included when averaging results from participants.
- Most models overpredicted the OBT concentration in plants by a factor of 2-3, partly because the HTO concentrations were overestimated and partly because the effect of isotopic discrimination in OBT formation was underestimated.
- Only one participant (FSA) failed to accurately predict HTO concentrations in cows and it was noted that only one participant used the traditional transfer factor approach to predicting concentrations.
- In the case of chickens and eggs, three models produced reasonable estimates of HTO concentrations, but there was a tendency for overestimates. The agreement between predictions and observed data was not as good as for cows even though HTO was derived primarily from drinking water in both cases. It was not therefore clear why predictions were less accurate: one possible explanation could be differences in diet and metabolism between free range and battery farmed hens. Also, concentrations in the chicken diet were overestimated to a greater extent than in the cow diet. OBT in chickens and eggs was overestimated by a factor of 3 by the majority of participants.

Model descriptions were then discussed. No participants from FSA, IRSN or GE were present to discuss their model descriptions and therefore clarification on the accuracy of these is still required. The descriptions of IFIN and SRA models were confirmed as accurate.

Finally, Phil Davis requested that participants provide details on the averaging time of the air concentrations used to drive their models. The IFIN approach for OBT was to average the last 2 months' data. However, HTO averaging was more difficult and was considered to be a weak point in the input data. The averaging time employed for the SRA model was dependant upon plant species being considered.

Next steps

The timetable for requested actions is:

- participants to supply information on averaging times and parameter value data, particularly for Table 12, and (especially those not present at the meeting) to confirm the accuracy of model descriptions in the draft report, by end of January 2006;
- Phil Davis to produce final draft and circulate for comment, by end of February 2006;
- comments to be returned to Phil Davis for inclusion in the final report, by end of April 2006.

Final report for the Soybean Scenario

Presented by Hansoo Lee

Twelve participants submitted results for this scenario for which a final report has been produced. Participants were taken through the final report page by page and asked to check individual contributions to ensure that information is accurately reflected in the report.

A number of points of particular note were raised by participants:

- Dan Galeriu questioned the uncertainty values associated with the IFIN results and thought that his results and those of Ring Peterson may have been switched. All participants were therefore requested to check that their uncertainty data have been correctly transcribed. A particular error was noted for SB2 in that the wrong uncertainty results have been provided by IFIN. Dan Galeriu will therefore resend the correct uncertainty data.
- OBT concentrations were under-predicted by a factor of 10 at harvest time, although trends in concentrations were expressed well. It is important to understand the reasons for this as the OBT concentration will determine the dose received. Some, but not all of the under-prediction could be explained by differences in plant growth rates employed by the modellers. Soybean is not a familiar plant for some modellers and lack of understanding of the particular plant may have contributed to under estimates. Some models applied to this scenario have been developed for temperate crops and therefore it was questioned whether they should have been modified for soybean. It was noted that, if time was available, it would be possible to compare soybean to other crops for which similar data are available.
- Francoise Siclet noted that an important factor in the underestimation of OBT for SB1 appears to be the underestimate in the HTO concentrations used to derive the OBT concentrations at the time of pod formation. Loss of tritium from the leaves was modelled to be too rapid in several models. Hansoo Lee agreed that the loss rate constant employed may be too high and demonstrated results (contributed by Ring Peterson) to show that loss processes occur in 3 stages. Participants agreed that it would be useful to look at loss rate data from other studies in the literature, but this is beyond the scope of the present study.
- It was noted by Dan Galeriu that temperature affects the behaviour of HTO uptake and OBT formation and therefore the experimental results may be very different from natural conditions due to the high temperature in the chamber during the exposure experiments: this may be difficult for models to account for. KAERI results for other plants under similar experimental conditions did not appear to be significantly different to those for soybean. However Hansoo Lee acknowledged that growth impacts may have occurred as a result of the high temperatures in the experiment.
- Dan Galeriu proposed another explanation for the relatively high HTO concentrations in the leaves long after the exposure. Some HTO may be diffusing into the soil from the roots early in the experiment and then being taken up by the roots again once the concentration in the plants decreases sufficiently.

Overall, participants were happy with the report and it was therefore accepted for publication once the additional required information has been provided and incorporated. Information submitted by each of the scenario participants on the approaches taken to modelling and the model descriptions are to be attached to the report as appendices. Participants were therefore requested to check these for accuracy.

Next steps

All scenario participants are requested to check model descriptions and the transcription of their uncertainty data into the report by the end of December 2005. Dan Galeriu is to supply his uncertainty data also by the end of December. Following this, a final draft will be produced and circulated to participants by the end of January 2006, and any final comments are to be returned by the end of March 2006.

Finally, participants were invited to use results of this scenario to improve or modify their models. Any results could be presented at the next meeting and time will be set aside for this. However, results would not be incorporated into the present report.

Round 2 results for the Pine Tree Scenario

Presented by Yoshikazu Inoue

Four sets of model predictions were returned (NIRS, Kyoto University, IFIN and LLNL) and these indicated that:

- Model predictions of air moisture concentrations for 1982 were similar to one another with the exception of LLNL. However, predictions for 1983-1986 were more variable. Predictions for 1985 were in agreement with observed concentrations, but again were more variable than the other years for which predictions were made. In general, NIRS predictions of air moisture were closest to the observations, with other participants under-predicting.
- Rain concentration predictions were reasonably consistent with observed values. Some differences were observed, but on the whole predictions were in agreement with one another and with observed values.
- Predictions of pine needle TFWT in 1982 and 1986 were, on the whole, quite similar to observations, but for intervening years predictions tended to be lower than observations. NIRS predictions were closest to the observations.
- Predictions of non-exchangeable OBT (nOBT) in pine needles by NIRS were again closest to the observed values, with the other participants tending to under-predict concentrations.
- Similarly, nOBT concentrations in tree rings were predicted most accurately by NIRS. In general, predictions for 1985 to 1987 were reasonable, but under-predictions were made for 1984.

It is important to understand why predictions are good in some years, but not in others. Discussions therefore focussed on how the NIRS model differs from the others employed in the scenario since predictions by NIRS were most accurate.

For atmospheric dispersion, NIRS employs a random walk model with advection and dispersion steps whilst others use sector-average Gaussian plume models that lack lateral dispersion. Other differences in the models include:

- Sector mesh size. The NIRS model's resolution is 100 m x 100 m whereas the other models used a sector average approach.
- Dispersion parameters. A sigma value of 40 m was used in the IFIN model, compared to 10 m in the NIRS model. A larger sigma results in a smaller concentration prediction so this could be one of the main factors causing the differences. It was noted that it may be worth plotting the different dispersion parameters used as a

function of stability class and downwind distance to further investigate the differences between the model approaches.

- Washout coefficients. These varied in the different modelling approaches adopted. It is likely that these will affect ground concentrations, but they are unlikely to significantly affect the air concentrations.
- Re-emission of HTO. Only NIRS considers this factor.
- Isotopic discrimination factors. These varied for both needle and tree ring OBT with NIRS using the greatest value of 0.8.
- Period of photosynthesis. NIRS assumed a constant rate whereas the Kyoto University and IFIN models assumed set periods of photosynthesis.
- Groundwater concentration calculation method. NIRS used a 2-compartment model, Kyoto University an infiltration rate and IFIN used an analytical approach. Only IFIN required information on aquifer depth and horizontal flow velocity. It was noted that the results from Kyoto University were very variable on short time scales and unlikely to represent actual variability.

It was therefore agreed that further analysis is required in order to determine the best modelling approach for this particular scenario. There is also a need for a systematic analysis to determine the effects of variability in parameter values on the variability in the predicted air concentrations and other endpoints.

Next steps

The next step for this scenario is for a systematic analysis of the models to be conducted to interpret the differences in modelling results. Full model descriptions are required from each participant for use in this analysis: these should be submitted by end of December 2005. Participants are also requested to submit round 2 results for groundwater, by end of February 2006. These results will be analysed and presented for discussion at the next WG meeting in June 2006, and a draft report prepared following that meeting.

It was agreed no further iterations would be required for air concentrations since results were in reasonable agreement.

Yoshikazu Inoue agreed to provide graphs (by end of December 2005) showing the comparison of results for dissemination amongst participants. Participants are requested to provide any insights into why models are accurate or not prior to the next WG meeting.

Round 3 results for the hypothetical short term release scenario

Presented by Philippe Guétat

The Hypothetical Scenario considers three cases that are based on different meteorological conditions.

	Case 1	Case 2	Case 3
Timing of release	day	day	midnight
Wind speed (m s^{-1})	2	5	2
Direction (°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	-	15mm	-
Relative humidity (%)	70	90	95

A few corrections were received immediately prior to the meeting and therefore not all information could be included in the presentation of results. A summary of the results comparison is provided below.

Air concentrations

- Case 1 – results from round 3 predictions were variable. However, once errors in two sets of results had been removed, there was around a factor of 10 difference between the predictions, which was not considered to be too bad.
- Case 2 – round 3 model results were also variable: those from CEA were particularly high, but this is believed to be the result of calculation error.
- Case 3 – there was ‘only’ a factor of 10 difference between predictions.

Total dose

- Case 1 – all doses were calculated to be below 1 mSv with the exception of CEA’s value of 10 mSv (which is known to be too high due to a calculational error).
- Case 2 – all results are below 20 mSv within 5 km of the source;
- Case 3 – many predictions are above 10 mSv, with some staying above that level for downwind distances as great as10 km.

It was noted that, although there was variation in the results, conclusions of this type could be used to set release criteria for the quantity of tritium released that would not exceed a given dose.

Food doses

- Case 1 – all food doses were, with the exception of those from CEA, below 1 mSv.
- Case 2 – EFDA, NIRS and CEA predicted much higher food doses (> 10 mSv) than the other participants, with the majority of the dose contribution arising from cereals. Results from AECL were the lowest (excluding results known to be incorrect).
- Case 3 – NIRS and BARC predicted the highest values. The main contribution was from garden vegetables.
- In all the models, a concentration of $1x10^5$ Bq/kg fw in leafy vegetables produced a dose of at most 1 mSv, which provides the starting point for establishing intervention levels in crops.

Dose breakdown by pathway (normalised by air concentration)

- Case 1 – doses from the consumption of cereals and garden vegetables were particularly variable. For example, the doses resulting from garden vegetables ranged from 10% to around 75% of the dose contribution. Dose estimates from participants could be divided into two groups, one where vegetables are of maximum importance and the second where cereals are more important.
- Case 2 – dose from the consumption of cereal was again variable with both NIRS and EFDA in particular predicting high doses as a result of grain consumption.
- Case 3 – the dose from garden vegetables was very variable.

Dose versus chemical nature (HTO or OBT) and pathway (air or soil)

The contribution to dose from each of the pathways (air or soil) and each form of tritium were discussed for each of the model results. For Case 1, the air pathway dominated in most models, with OBT being of equal or greater importance than HTO.

If it rains (Case 2), the air pathway should not change much, but the contribution of the soil pathway should increase. However, the change was found to be small between Cases 1 and 2. Rain was therefore interpreted as being of low importance for this scenario.

Case 3 is a release during the night. No large differences were noted compared with day calculations with the exception of AECL, which did not consider OBT contributions from air since there would be no photosynthesis in the dark. However it was noted that although most photosynthesis occurs during the day, some formation of organic molecules occurs at night so there would be some binding of tritium to carbon during darkness. The formation of OBT at night should not therefore be ignored. Several participants assumed that the rate of OBT formation at night was about 20% of the daytime value.

Changes in concentrations over time

The calculation of decreased concentrations over time (from release to release + 48 hours) was variable. For example, KAERI results indicated little difference in concentrations with time whereas AECL results suggested a reduction in concentration between 1 and 2 orders of magnitude. Explanation of these differences is therefore required.

Water activity concentrations in soils with time were also calculated by EFDA, AECL and CEA. Contributions from others for each case would be of benefit to enable a more thorough comparison.

Discussion

Following the presentation of the results a number of potential reasons for the variability in results were discussed. The main points of note were:

- The basic assumptions made by the different modellers should be further analysed to determine any differences. For example, the time of release relative to cereal flowering and harvest would be of importance. The Scenario description detailed the release as occurring at the time of grain formation. However, it is necessary to check that this has been taken into account by the different participants. Participants were therefore requested to consider and identify where data from the scenario had been modified.
- For Case 1, AECL results for both air and food (lettuce and grain) concentrations were on the high side, but the resultant doses were low. If concentrations in endpoints other than grain and lettuce are also high then the dose calculation may be wrong. Provision of data on these other foods would therefore be helpful in determining where errors have occurred. Since the dose calculation is straightforward, the explanation may lie with the assumptions made concerning the diet and when foods are eaten with respect to the end of the release.
- Cereals are likely to be of greater importance than green vegetables during an accident scenario due to their consumption throughout the year whereas green vegetable consumption is likely to be more limited over time. It is therefore important that the scenario takes account of a standard diet and how much of each foodstuff is consumed within the accident time. Clarification of the scenario is therefore required.

Finally, it was agreed that this scenario may be suitable for submission by the WG to a peer reviewed journal.

Next steps

The next steps agreed for this scenario are:

- Revised results (including crops additional to lettuce and grain) will be e-mailed by CEA to all participants, including a note of amendments made during the meeting, by mid-December 2005. It is requested that all participants check this information and highlight any errors by the end of December so that the report writing can progress.
- Hansoo Lee to confirm whether KAERI air concentration results are the most recent submitted under round 3.
- Model descriptions are requested including key information on calculation parameters from all participants.
- Participants are also requested to try to explain why their parameters are high or low. For example, are models set to be conservative or is there an important factor that needs to be taken into account in interpreting the results.
- Finally, CEA are to try to explain why their predicted values appear to be too high by around a factor of 5. It was noted that the use of normalised data would be helpful for this as it allows the predicted air concentration to be eliminated as a variable.
- Any final amendments to be supplied by modellers by mid-January 2006.

Round 1 results for the Mussel scenario

Presented by Tamara Yankovich

Results from four participants have been submitted for this scenario and additional participants have also noted their interest in submitting results. Therefore observations were not released. Model results, normalised against observed data, were presented to enable discussion to proceed without revealing the observations.

Initial results indicate that:

- there is little difference between mussels exposed from water alone and exposed from both water and sediment.
- models are similar in predicting tissue concentrations at the end of the exposure period, but for earlier time periods there was greater variability.
- Model 2 under-predicted HTO concentrations except at the end of the study.
- in the ratio of modelled to measured OBT concentrations, model 1 showed a rapid increase followed by a slower decline, whereas models 2 to 4 showed a slower, but prolonged, increase.

It was noted that there appears to be a drop in HTO concentrations over the first day, which could be real or experimental error. There was a reasonable amount of variability, which would be expected as a result of natural variability in the mussels themselves. For example, stomach contents of the mussels, which were not cleared to ensure that no HTO was lost prior to analysis, may have contributed to variability.

The observed OBT accumulation appeared to be at a greater rate than model predictions although predictions and observations converged later in the study period. Growth rate will be an important factor for model predictions as this is a factor of metabolism. There was no observed difference in growth rate between the various cages, but mussels were not thawed before analysis (to prevent loss of HTO) and this may have resulted in measurement errors. The lipid/protein content is likely to have changed over the period of exposure as a result of reproductive activity, but was not measured. An additional factor that may be of importance for accurate modelling is the change in temperature in the lake during the exposure period, which will affect metabolism and uptake of HTO (and in-growth of OBT). Tamara Yankovich offered to investigate the optimal temperature for this species and will compare with lake temperatures.

A complementary study to that modelled in the present scenario was conducted by AECL over the summer to look at depuration/elimination of HTO and OBT from mussels following uptake over their lifetime. The availability of this data sparked a lot of interest from the WG participants, some of whom are interested in modelling this additional scenario. Tamara Yankovich was therefore tasked with devising an additional scenario on mussel elimination of HTO and OBT on the basis of this additional data. It may also be possible to analyse mussels for C-14, which could be included in the scenario. However, it is thought likely that concentrations would be below the limit of detection. This will be investigated.

Next steps

Tamara Yankovich will distribute additional information, which was originally sent to Francoise Siclet only, to all members of the WG. Tamara will also supply data on the fresh weight of each mussel prior to and following the study. Background information on this mussel species will also be made available. Information will be sent to Dan Galeriu in the first instance, who is requested to identify any omissions prior to the information being made more widely available to the group. This material should be distributed to participants by end of January 2006. Participants are requested to submit any revised/new predictions for analysis by end of March 2006.

Tamara Yankovich will also produce, for the next WG meeting, a second scenario based on the depuration of HTO and OBT from mussels following exposure. Initial interest in participating in this study was given by D. Galeriu, F. Siclet, F. Baumgärtner, M. Saito, Y. Inoue and S. Dizés-Maurel.

Round 1 results for the C-14 in Rice scenario

Presented by Jun Koarashi

Results for this scenario have been submitted by three participants (NIRS, AECL and IFIN), which formed the basis for discussions. Brief descriptions of the three modelling approaches were provided:

- The NIRS model did not consider dry and wet deposition as C-14 will be mainly in the form of CO_2. To simplify the calculation, it was assumed that all discharged C-14 was from one stack (stacks are all located in close proximity) with a release height of 90 m. Plume rise was not considered. However, Phil Davis explained that plume rise is likely to be an important factor for this scenario, particularly for sampling sites that are within 1 km of the discharge. Rice was represented by a dynamic model with three compartments. These comprised an organic compartment for the whole plant minus ear, an organic ear compartment and an inorganic compartment for the whole plant. Two additional environmental compartments were also included for soil and air. The growth curve for the rice was sigmoidal for both the ear and whole plant. It was assumed that the respiration rate is proportional to the increased weight.

- AECL considered three sources for C-14 discharge for the closest receptor (ST-1) and a single source for the more distant receptors. Plume rise and dry deposition were taken into account, but wet deposition was not. Rice concentrations were calculated assuming specific activity equilibrium between plant and air.

- The IFIN model is a rice growth and C-14 transfer model. The model considers the influence of air C-14 on three development stages of the rice plant and takes into account temperature and year to year temperature variability on rice growth. Dark respiration is not considered. Dan Galeriu noted that the results for 1996 require revision due to high air and rice concentrations.

Differences in model predictions appear to arise from differences in the timing of high air concentrations. In 1992, air concentrations were highest between 20 and 50 days, but in 1994 highest between 50 and 70 days. Ear accumulation of C-14 is dependant upon the whole plant concentration. In 1992, dark respiration is thought to have reduced concentrations leading to reduced plant and therefore ear C-14 concentrations. However, in 1994, whole plant concentrations were greater due to later peaks in air concentration resulting in a greater ear C-14 concentration. It was also noted that differences may have arisen through overly conservative estimates of air concentrations, including the neglect of plume rise in the NIRS model.

Particular issues raised by participants for further consideration are as follows:

- The respiration rate applied in the NIRS model appeared too rapid compared to the information provided in the scenario.
- The growth rate will be dependant upon the rice species, which has not been made available in this scenario.
- The use of wine samples to derive background concentrations for rice was questioned. The use of this data assumes that wine and rice are similar without the need for correction. Normally in such instances, C-13 would be used to normalise data, but this does not appear to have been done in this case and may be important to account for differences in C3 and C4 plants.
- It may be more useful to analyse the results in terms of the incremental concentration due to the source emissions rather than the total concentration including background.

Next steps

It was agreed that no further revision of the scenario was required. Dan Galeriu is to submit revised results for 1996 predictions in air and rice and IRSN expressed an interest in submitting results. New and/or revised results are to be submitted by the end of April 2006 and participants are also requested to submit model descriptions by this date. Results will be discussed at the next WG meeting where observations will also be released.

Additional Presentations

Two additional presentations were given which are not linked to specific Scenarios, but are of general interest to the WG. These are summarised below.

Nuclear Power in India

Presented by P.M. Ravi

At present there are 15 nuclear reactors operational in India in 6 locations. All are small (~220 and 540 MW) and all but two are pressurized heavy water reactors. There is an independent regulatory body to ensure safety at each of these sites.

Tritium is one of the constituents of emissions to the environment and is therefore routinely monitored by environmental survey laboratories. The detection limit is around 15 Bq/l and recorded activities around public areas are normally below the limit of detection. Environmental modelling and monitoring methods are used to estimate public dose using ingestion and inhalation pathways, with measurement data for ingestion pathways being used whenever available. Public doses are always below regulatory limits.

Experimental studies on air-plant and plant-animal transfer of tritium are in progress based on chronic routine releases. OBT estimation in plants (e.g. banana, mango) and animals (fish) is also progressing, as is work to identify the main parameters that influence ecological tritium distribution.

Plant OBT/air HTO ratios at LLNL

Presented by Ring Peterson

Results of OBT concentrations in foliage from six plants (herbaceous vegetation and shrubs) sampled in December 2004 at locations close to H-3 monitoring stations at LLNL were presented for discussion.

The OBT concentrations are higher than observed annual mean HTO air moisture concentrations. This is an unexpected result and a number of explanations were put forward:

- Air concentrations may be higher during the day when OBT is being formed.
- Catabolism of bound tritium from years of higher air concentrations.
- The soil water accessed by the plants may have concentrations representative of previous years when concentrations were higher.
- Measurement uncertainty may account for the differences seen.
- Inconsistencies in the wind direction used in the models may help explain the results by underestimating HTO concentrations at the point of sampling.

These explanations were all discounted for one reason or another. A number of suggestions for additional measurements were put forward to help explain the results:

- Repeat sampling should be conducted. If the concentrations are the result of high soil water concentrations, then leaf concentrations would be expected to remain high; but if air HTO is responsible, the plant OBT results should be more variable.
- Carry out air sampling at the locations at which leaves were collected;
- Analyse the total free water tritium (TFWT) of the same plants to determine if they are higher than air moisture concentrations;
- Analyse soil water to determine if concentrations are higher at depth; and,

- Carry out further sampling and analysis of plants including root tissue for TFWT and OBT.

Additional ideas to explain the anomaly are invited.

Nature and definition of OBT

Presented by Phil Davis and Franz Baumgärtner

The most recent draft of a definition for OBT was circulated for review at the beginning of the meeting. Franz Baumgärtner and Phil Davis presented the results of recent experimental work into the existence of buried tritium. Franz's data suggest that buried tritium makes up a significant fraction of what is traditionally considered to be non-exchangeable OBT. However, Phil's data indicate that the fraction of buried tritium is at most 5-10%. It was decided that the question must remain open pending new experimental results.

The definition of OBT was reviewed in the light of the experimental results. Franz Baumgärtner provided suggested written amendments to the draft definition, which were discussed and modified by the WG as a whole.

Next steps

A revised definition will be circulated to the WG by the end of February. Comments are requested to be returned by the end of April.

Consideration of Additional Scenarios

Large animal scenarios

Presented by Dan Galeriu

Dan Galeriu presented the case for the inclusion of an additional scenario on H-3 and/or C-14 uptake into large farm animals such as chickens, sheep and cows. It was proposed that blind and/or benchmark tests could be conducted. The availability of data was discussed and a number of options were put forward.

Particular interest was shown by IRSN, EdF and IFIN in a potential scenario on H-3 transfer from food to pig meat. The available data are for pigs fed with OBT-contaminated food for 80 days. Food composition and activity concentrations are known. The output would be tritium concentrations in urine during the period of exposure plus final tissue concentrations.

There was much discussion on whether the scenario should be a benchmark or blind test. It was concluded that the scenario will include some endpoints with data and some without, so that it will be part model validation and part benchmarking.

The WG continues to encourage large animal experiments to provide additional data to assess the transfer of tritium and C-14 from contaminated food to animals.

Next steps

Dan Galeriu will provide a scenario description for distribution to members of the WG by the end of January. Interested participants should submit model results by the end of April 2006.

C-14 in Plants

Presented by Ian Barraclough

During the previous WG meeting in Cardiff, considerable interest had been shown by participants in pursuing a C-14 plant scenario. Data are available from laboratory studies conducted for a PhD thesis at Imperial College, UK, involving controlled releases and uptake of C-14 into western vegetables. In the absence of a volunteer with the necessary resources to act as Scenario Leader, efforts had been made to find funding to support a Scenario Leader, but with little success.

BARC, IRSN, EdF and IFIN were all still interested in this scenario. Anca Melintescu volunteered to be scenario leader to ensure this moved forward and was therefore provided with a copy of the experimental data on which a scenario could be developed. It was noted that the author of the experimental data is happy to be contacted should any clarification be required.

Next steps

Anca Melintescu will develop a scenario description to be circulated to participants by the end of February. Interested participants are requested to provide results and model descriptions by the end of April for discussion at the next WG meeting.

Tritium and C-14 parameter values for TRS-364

Presented by Phil Davis

During the initial plenary session, the TRS-364 WG requested assistance from the tritium and C-14 working group 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. The particular focus is on data for relatively simple models. Dan Galeriu volunteered to take the lead on this, although all members of the WG are requested to submit data they think may be appropriate. The parameters should cover the following conditions:

- The species of interest are HT, HTO, OBT and C-14, although HT is not a priority. C-14 can be assumed to be in the form of $^{14}CO_2$.
- The focus is on specific activity parameters but the more traditional transfer parameters should also be included.
- Parameter values are required for both equilibrium and dynamic conditions. The difficulties in applying specific activity concepts to dynamic conditions should be made clear.
- Parameters are required for models that address releases to air, surface water and groundwater. The groundwater source is actually a soil water source, and there is no requirement to model the movement of tritium through the soil profile.
- Parameters are required for both terrestrial and freshwater ecosystems.
- If possible, values for specific plant and animal species should be provided, but plants and animals can be grouped into broader categories if necessary.
- If possible, distributions for the various parameters should be supplied as well as best estimates. Arithmetic means should be used for parameter values that range over less than a factor of 10; geometric means should be used otherwise.
- All parameter values should be screened for relevance and quality but there are no existing protocols for doing that.

The inclusion of irrigation was questioned and Phil Davis confirmed that irrigation should be considered for an aquatic source.

Next steps

Before parameter values can be defined, it is necessary to have a conceptual model in mind. Dan Galeriu will provide a brief written document that includes a description of the available models and the models recommended as the basis for defining parameter values. This will be circulated amongst the TRS-364 WG to ensure that the approach is suitable for their needs. The deadline for the production of this document is end of January 2006. A more detailed report documenting the models and parameter values will be produced for the beginning of May 2006. This report should make clear the limits of applicability of the models and should provide a detailed discussion of the processes that affect the environmental transport of tritium.

Status of Work Programme

Item	Status for next Working Group meeting	Person
Perch Lake H-3 scenario	Final report to be completed and published on website	P Davis
Pickering H-3 scenario	Final report to be produced and circulated to participants for comment	P Davis
Soy bean H-3 scenario	Final report to be completed and published on website	H Lee
Pine tree H-3 scenario	Groundwater results to be submitted for analysis and discussion	Y Inoue & modellers
Hypothetical H-3 short term release scenario	Confirmation of results required from modellers and draft report to be written.	P Guetat, L Patryl & modellers
Mussel H-3 scenario	Additional scenario information (including additional depuration scenario) to be provided and second round results to be submitted for analysis and discussion	T Yankovich & modellers
Rice C-14 scenario	Final results to be submitted for analysis and discussion	J Koarashi & modellers
Animal H-3 scenario	Draft scenario to be prepared and first round results submitted	D Galeriu & modellers
Plant chamber C-14 scenario	Draft scenario to be prepared and first round results submitted	A Melintescu & modellers
Definition of OBT	Amended definition to be circulated to participants for comment	P Davis
TRS-364	Brief description of available models and approach to be drafted; more detailed description of recommended models and parameter values to be drafted.	D Galeriu

Additional Points

The EMRAS Steering Committee confirmed that publication of results from working groups in the open literature is strongly encouraged. Scenario leaders are therefore encouraged to consider whether particular scenarios are suitable for publication.

Model descriptions are required for all scenarios for which results are submitted. Where these are not made available, the model results cannot be included in scenario. Participants are therefore encouraged to submit descriptions.

Finally, the draft Technical Report from this scenario is to be completed by spring 2007. This will enable review and corrections to take place prior to the final EMRAS plenary session in the fall of 2007. The Technical Report will cover all scenarios considered by the WG.

Next Meeting

The next meeting is scheduled for Paris, on 7-9 June 2006, and will be hosted by Francoise Siclet (EdF).

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)
Head, Radioactive Discharges Unit
Waste Safety Section (Room B0713)
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
December 2006	Soybean H-3 Scenario: model descriptions and uncertainty data to be checked for accuracy	Relevant modellers
	Pine tree H-3 Scenario: full model descriptions to be provided	Relevant modellers
	Pine tree H-3 Scenario: graphs from current model comparison to be distributed for comment	Yoshi Inoue
	Hypothetical H-3 Scenario: model results for food products to be distributed	Luc Patryl
	Hypothetical H-3 Scenario: confirmation of accuracy in reporting model results	Relevant modellers
January 2006	Pickering H-3 Scenario: parameter value data to be supplied and accuracy of model descriptions to be confirmed.	Relevant modellers
	Pickering H-3 Scenario: revised model results to be submitted	Franz Baumgartner
	Soybean H-3 Scenario: final draft to be circulated for comment	Hansoo Lee
	Hypothetical H-3 Scenario: model descriptions and final amendments to model results to be submitted	Relevant modellers
	Mussel H-3 Scenario: distribution of additional mussel information (incl. fresh weights)	Tamara Yankovich
	Animal HTO Scenario: Draft Scenario description to be circulated	Dan Galeriu
	TRS-364: draft description of models and approach to be circulated to TRS-364 WG	Dan Galeriu
February 2006	Pickering H-3 Scenario: Final draft report to be circulated for final comment	Phil Davis
	Pine Tree H-3 Scenario: round 2 groundwater results to be submitted	Relevant modellers
	C-14 Temperate Plant Scenario: Draft Scenario description to be circulated	Anca Melintescu
	OBT Definition: Revised definition to be circulated for comment	Phil Davis
March 2006	Soybean H-3 Scenario: final comments to be returned to scenario leader	All working group members
	Mussel H-3 Scenario: revised/new results to be submitted for uptake phase	Relevant modellers
April 2006	Pickering H-3 Scenario: Final comments to be returned for inclusion and publication of final report	All working group members & Phil Davis
	Mussel H-3 depuration scenario: Draft Scenario description to be circulated	Tamara Yankovich
	Rice C-14 Scenario: revised/new results to be submitted (incl model descriptions)	Dan Galeriu & relevant modellers
	Animal HTO Scenario: first round model results and model descriptions to be submitted	Relevant modellers
	C-14 Temperate Plant Scenario: first round model results and model descriptions to be submitted	Relevant modellers
	TRS-364: Parameter values to be passed to Dan Galeriu	All WG members
May 2006	TRS-364: Draft document describing transfer processes for tritium and C-14, the conceptual model and available parameter values to be circulated to the TRS-364 WG	Dan Galeriu
June 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, July 13, July 30, August 9, August 24 and September 17. 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 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 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 (°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	-	15mm	-
Relative humidity (%)	70	90	95

Mussel Scenario

Perch Lake is small shallow (~2-3.5 m) 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 whereasthose 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 Tokamurai 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 samples of C-14 in 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 tritium 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.

ANNEX C: List of Participants

Mr. M. Balonov (Scientific Secretary) Head, Radioactive Discharges Unit Waste Safety Section (Room B0713) 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 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. I. Barraclough Enviros Consulting Limited 61 The Shore Leith Edinburgh, Scotland EH6 6RA United Kingdom Tel: +44 (131) 555-9500 Fax: +44 (131) 555-9515 Email: ian.barraclough@enviros.com	Mr. F. Baumgärtner Director Emeritus Institute für Radiochemie Technische Universität München Grosostrasse 10d D-82166 Gräfelfing Germany Tel: +49 (89) 851-347 Fax: +49 (89) 854-4487 Email: bgt@rad.chemie.tu-muenchen.de / bgtbgt@web.de
Mr. S. Conney Food Standards Agency (FSA) Aviation House 125 Kingsway London WC2B 6NH United Kingdom Tel: +44 (20) 7276-8000 Fax: +44 (20) 7276-8771 Email: stuart.conney@foodstandards.gsi.gov.uk	Mr. C. Dovlete Private Consultant 4 Quaio Antoine 1er 06360 Eze sur Mer France Tel: +33 (4) 9301-5899 Fax: +33 (4) 2248-0808 Email: cdovlete@yahoo.fr
Mr. D. 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 077125 Bucharest-Magurele Romania Tel: +40 (21) 404-2359 Fax: +40 (21) 457-4440 Email: galdan@ifin.nipne.ro / dangaler@yahoo.com	Mr. P. Guétat Deputy Head of Department, Department DTMN CEA – Centre de Valduc 21120 Is sur Tille France +33 (3) 8023-4280 +33 (3) 8023-4481 Email: philippe.guetat@cea.fr

Mr. W. Gulden Field Co-ordinator, Safety & Environment EFDA Boltzmanstrasse 2 D-85748 Garching Germany Tel: +49 (89) 3299-4216 Fax: +49 (89) 3299-4224 Email: werner.gulden@tech.efda.org	Mr. Y. Inoue Visiting Researcher Environmental & Toxicological Sciences Research Group National Institute of Radiological Sciences (NIRS) 4-9-1 Anagawa, Inage-ku 263-8555 Chiba Japan Tel: +81 (43) 206-3051 Fax: +81 (43) 251-7819 Email: y_inoue@nirs.go.jp / yoshi_inoue2001@hotmail.com
Mr. J. 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) 282-111 x61233 Fax: +81 (29) 282-3838 Email: koarashi.jun@jaea.go.jp / koarashi.jun@jnc.go.jp	Ms. S. Le Dizès-Maurel Scientist, 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) 4219-9584 Fax: +33 (4) 4219-9143 Email: severine.ledizes-maurel@irsn.fr
Mr. H. Lee Project Manager Nuclear Environment Research Division Korea Atomic Energy Research Institute (KAERI) P.O. Box 105 150 Dukjin-dong, Yuseong-gu 305-600 Daejeon Republic of Korea Tel: +82 (42) 868-2395 Fax: +82 (42) 861-1761 Email: hslee5@kaeri.re.kr	Ms. A. 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 077125 Bucharest-Magurele Romania Tel: +40 (21) 404-2359 Fax: +40 (21) 457-4440 Email: ancameli@ifin.nipne.ro / melianca@yahoo.com
Ms. K. Miyamoto Senior Researcher Environmental Toxicological Sciences Research Group National Institute of Radiological Sciences (NIRS) 4-9-1 Anagawa, Inage-ku, Chiba-City 263-8555 Japan Tel: +81 (43) 206-3156 Fax: +81 (43) 251-4853 Email: kiriko@nirs.go.jp	Mr. L. Patryl Ingenieur Département Analyse Surveillance Environement Commissariat à l'Energie Atomique (CEA) Centre de Bruyères le Châtel B.P. 12 F-91680 Bruyères le Chatel France Tel: +33 (1) 6956-5133 Fax: +33 (1) 6926-7065 Email: luc.patryl@cea.fr

Ms. S.R. Peterson Environmental Tritium Modeler/Analyst Operations & Regulatory Affairs Division (MS L-629) Lawrence Livermore National Laboratory (LLNL) 7000 East Avenue P.O. Box 808 CA-94551 Livermore United States of America Tel: +1 (925) 424-6453 Fax: +1 (925) 422-8684 Email: peterson49@llnl.gov	Mr. P. Ravi Officer-in-Charge, Environmental Survey Laboratory Health Physics Division Bhabha Atomic Research Centre (BARC) Kaiga Generating Station Utta Kannada District 581 400 Kaiga, Karwar India Tel: +91 (8382) 254-092 Fax: +91 (8382) 264-025/264-034 Email: pmr9@sancharnet.in
Mr. M. 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	Ms. F. Siclet Research Scientist National Hydraulics & Environment Laboratory Electricité de France (EDF) - Département Environement (R&D) 6, Quai Watier B.P. 49 F-78401 Chatou Cédex France Tel: +33 (1) 3087-7847 Fax: +33 (1) 3087-7336/8109 Email: francoise.siclet@edf.fr
Ms. K. Smith 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. V. 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. K. Yamamoto President/Senior Engineer YFirst Inc. 4-937 Nishiya-cho Hodogaya-ku Yokohama Kanagawa 240-0052 Yokohama Japan Tel: +81 (45) 382-0639 Fax: +81 (45) 382-0829 Email: yamamoto@yfirst.co.jp	Ms. T. Yankovich Research Scientist Environmental Technologies Branch Building 513, Station 51A Atomic Energy of Canada Limited (AECL) Chalk River Laboratories K0J 1J0 Chalk River, Ontario Canada Tel: +1 (613) 584-8811 x4732 Fax: +1 (613) 584-1221 Email: yankovicht@aecl.ca