EMRAS II
Approaches for Assessing Emergency Situations
Working Group 7
"Tritium" Accidents

M E E T I N G   N O T E S

of the the 2nd Working Group Meeting held at
EDF/R&D, Chatou, France
28–29 September 2009

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History

The second meeting of the IAEA EMRAS II "Tritium" Accidents Working Group was held in Chatou, France. The meeting was hosted by Electricite de France (EDF), Chatou.

These Meeting Notes have been prepared by Anca Melintescu ("Horia Hulubei" National Institute for Physics and Nuclear Engineering, Bucharest-Magurele, Romania), with the valuable help of Dan Galeriu (Working Group Leader) and Pierre Cortes (ITER Organisation, Cadarache, France). In addition, the attendees of the meeting contributed to the discussions and decisions documented in these Meeting Notes.

Financial support of the people who contributed to the Technical Secretariat was assured by IFIN-HH, Romania (Anca Melintescu, Dan Galeriu) and ITER Organization, France (Pierre Cortes), respectively, and of the Working Group Leader by IFIN-HH (Romania) and is gratefully acknowledged.

Presentations and documents circulated with these Meeting Notes

All presentations given during Chatou meeting are available alongside these Meeting Notes on the EMRAS II WG7 webpage. Please note that the words underlined in the main presentation titles below, correspond to the name of the presentation document on the webpage.

Introduction

The second meeting of the IAEA EMRAS II "Tritium" Accidents Working Group was held in Chatou, France, on 28–29 September 2009. The meeting was hosted by Electricite de France (EDF), Chatou. The objectives of the meeting were the following:

- to discuss and harmonize the views of participants concerning the approaches for developing the conceptual model for tritium accidents (atmospheric and aquatic);
- to agree on the structure and scope of the conceptual model;
- to identify potential gaps in knowledge and expertise, which should be addressed during the model development;
- to define the structure of the technical document and share tasks according to the expertise of each participant and the interests of his/her organization or institute;
- to elaborate the work plan for developing the conceptual model;
- to distribute specific tasks to be accomplished and reported at the next EMRAS II Technical Meeting (25–29 January 2010).

Participants were welcomed to the meeting by the Working Group Leader, Dan Galeriu and Volodymyr Berkovkyy, Scientific Secretary, IAEA. Then, Jean-Daniel Mattei, Deputy Director at EDF, Laboratory of Hydraulics and Environment, addressed his welcome and briefly presented EDF activities connected with hydraulics and environment. Participants introduced themselves and briefly described their background and interest in the working group.

Dan Galeriu gave an introductory talk concerning general properties of tritium, a briefing of past results in BIOMOVS (1995), and conclusions from recent works presented at 8th International Conference on Tritium Science and Technology, held in Rochester NY (USA) on 12–21 September 2007, UE Scientific Seminar on Emerging Issues on Tritium, held in Luxembourg, on 13 November 2007 and Radioecology and Environmental Radioactivity, held in Bergen (Norway), on 15–20 June 2008.

Previously to this meeting, the Working Group Leader sent a questionnaire to the participants and some preliminary conclusions, after 11 participants answered to this questionnaire, can be reached. These are as following:

- there is interest in both liquid and atmospheric releases;

— about half of the respondents have an interest in HT emissions;
— plants of interest include: pasture, alpha-alpha, vegetables (leafy and root vegetables), rice, wheat, corn, tomatoes, potatoes, apples and citrus fruits, grapes; for Cernavoda NPP (Romania) it must add sunflower and sugar beat;
— animals of interest include cow (meat and milk), sheep (meat and milk), beef, goat, pork, chicken, fish, boars;
— all respondents agree that the local climate and soils have a large influence on tritium transfer;
— some respondents prefer compartmental models with site-specific parameters;
— there is an increased interest in process level modelling of minimal complexity;
— the requirement is to be conservative, but with no details on how to control the robustness.

At the end of this introductory talk, Dan Galeriu presented the expert view of IAEA. These are as following:

— it is especially important to focus on the uncertainties and sensitivities that are involved in modelling the behaviour of tritium in the environment after accidents;
— although we know much about the behaviour of water in the environment, the reliable prediction of tritium concentrations in environmental media subsequent to an accident is the result of the complex interaction of a number of factors that are subject to hourly, daily and annual fluctuations. Due to these large uncertainties related to the environmental conditions at the time of the accidental release, predictions are unavoidably associated with considerable uncertainties;
— however, these inherent problems in tritium modelling are not clear to everybody; therefore, it would be very important for the work:
  - to identify the main contributors to uncertainty;
  - to identify the critical periods during the year in relation to resulting exposures to tritium;
  - to identify the important and sensitive parameters, having in mind hourly, daily and annual variations in parameters/processes;
  - to explore the practical possibilities in determining those parameters;
  - to get an idea about the achievable reliability of tritium modelling under practical, this means under accidental field conditions;
  - to get a clear idea for which phases of the tritium accident the application of a tritium model is desirable and useful.

The participants agreed on the meeting priorities and it was established to make a list with the existed literature which must be distributed by email between participants.

Preparatory discussion on Processes and Parameters of relevance for WG7

Presented by Dan Galeriu

First, Dan Galeriu presented the conclusions of Journées Tritium SFRP 2009, held in Paris on 23–24 September 2009. These are as following:

— Importance of tritium speciation;
— Problems with definition and measurements units for low doses;
— Importance of measurement techniques in field work and research;
— Importance of appropriate vocabulary: e.g. bioaccumulation;
— Difficulties in epidemiology: multi-parameters;
— Problems with disposal and treatment of H-3;
— Difficulties of ICRP: REB, models, management of exposure and risk;
— Problems with OBT analytical techniques.

Dan Galeriu pointed out also the importance of CETAMA meeting concerning the OBT measurements, held in Paris on 25 September 2009, emphasizing the fact that good experimental data are needed also for model development and testing and Philippe Guetat commented and supported this assertion.

Following the practice in radioecology, WG Leader recommended to start with an interaction terrestrial matrix for tritium and gave and example from IUR. Then it was decided that Séverine Le Dizès Maurel to accomplish this task for tritium and to present and discuss the results to the next meeting.

The WG Leader presented the macro-processes involved in tritium modelling such as:

- Wet deposition of HTO;
- Deposition in case of snow;
- Dry deposition of HT and HTO;
- Reemission of HTO from soil;
- Reemission of HTO from plants;
- Transfer of HTO from soil to plants;
- Secondary source due to reemission – influences on final plant and soil dynamics;
- Reemission from forest;
- Dynamics of the soil – plant complex;
- Losses in storage – preparation of feed – HTO;
- Losses/concentration in food preparation – HTO;
- Contribution of OBT metabolism to plant HTO at harvest;
- OBT formation in daylight;
- OBT formation in night;
- OBT respiration;
- OBT partition to edible plant part;
- OBT speciation;
- OBT oxidation in feed preparation and storage;
- OBT oxidation in food preparation and storage;
- OBT in litter and soil.

After this brief presentation of the previous macro-processes, it was decided the appropriate participants who are able to accomplish different tasks as following:

- Luc Patryl, Dan Galeriu, and Anca Melintescu have to prepare wet deposition of HTO and to present and discuss the results at the next meeting in January;
- For the interception by plants in rain conditions must be done a review of existed literature, but this task was delayed until the next meeting in January;
- Uptake by leaves was delayed also until the next meeting in January;
- For penetration in soil, it was decided to wait the report which must be finalized by Philippe Ciffroy until January;
- Deposition in case of snow will be prepared and presented by Dan Galeriu to the next meeting and it is possible that Philippe Guetat will provide some measurements by the next meeting.

Dan Galeriu asked the participants about keeping into account or not the HT transfer, but it was not a straight answer. However, all the participants agreed that HT transfer cannot be ignored from nuclear risk assessment.

Uncertainty and WG7

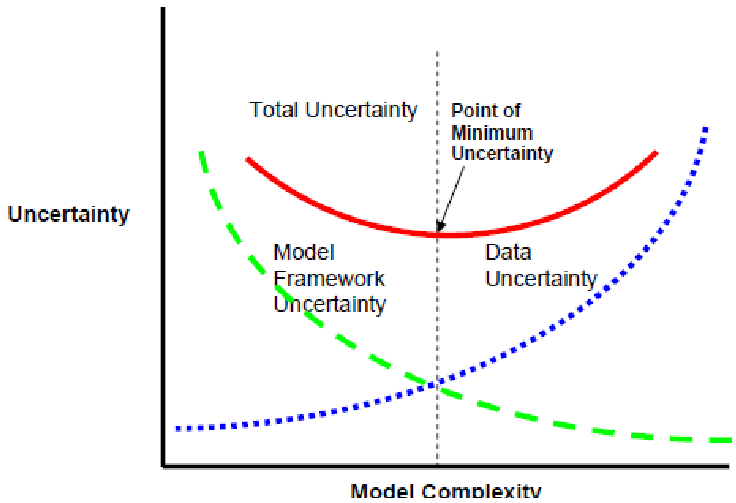
Presented by Dan Galeriu

The uncertainty and sensitivity analysis are part of quality assurance and validation tests of the models. The WG goal is to have at the end a robust conceptual model which must be used for licensing and accident preparedness and management. Decrease the uncertainty of the models is the main aspect in this respect. Both simple and complex models have big uncertainties: simple models miss the complexity of the world and complex models miss the important parameters. So, it is not possible to ignore *a priori* any process.

Models have two fundamental types of uncertainty:

— Model framework uncertainty, which is a function of the soundness of the model's underlying scientific foundations;
— Data uncertainty, which arises from measurement errors, analytical imprecision and limited sample size during collection and treatment of the data used to characterize the model parameters.

These two types of uncertainty have a reciprocal relationship, with one increasing as the other decreases, like in the figure below.



Peer review provides the main mechanism for independent evaluation and review of environmental models. Peer review provides an independent, expert review of the evaluation; therefore, its purpose is two-fold:

— To evaluate whether the assumptions, methods, and conclusions derived from environmental models are based on sound scientific principles;
— To check the scientific appropriateness of a model for informing a specific regulatory decision (the latter objective is particularly important for secondary applications of existing models).

Sources of uncertainty:

— Measurement uncertainty;
— Parameter value uncertainty;
— Conceptual modelling uncertainty;
— Computational uncertainty;
— Scenario uncertainty;
— Ignorance – "We don't know what we don't know".

There is no international standard for uncertainty. The acceptability is usually defined by user acceptance criteria and demonstrated by model validation. Although, in some specialised contexts, there is a movement toward the development of more physically based models, radiological impact assessment models have relied, and will continue substantially to rely, on large databases of empirical parameter values or distributions. Thus, many of the data that might be used for validation are already incorporated in the underlying databases. The issue of how new datasets could be generated for validation purposes and the identification of appropriate techniques for carrying out such validation studies are not addressed in this paper, but are potential topics for future consideration by the National Dose Assessment Working Group (NDAWG) from UK.

It was pointed out that it is not possible to have a model very close to the data: a factor 2–3 is good, a factor more than 5 is wrong and a factor more than 10 is catastrophic.

Sources of uncertainties for tritium:

Tritium is a life element, so its transfer into the biosphere is subjected to environmental conditions, season and time of the day, as well as genotype, adaptation to soil and climate, etc. Tritium has a large natural variability.

To test the full model, we must have a data base of past accidents with coherent description.

Fortunately, there were few accidental emissions of tritium and unfortunately, there are not well documented for our purposes (see Ch. Murphy for SRS, R. Peterson for LLNL).

Some specific sources of uncertainties for tritium are:

A. Missing communication:
   1. Experiments and OBT modelling in AECL undisclosed,
   2. Cardiff case: experiments ordered by GE Healthcare undisclosed (but Environmental Agency and FSA report available on request),
   3. Many reports, PhD thesis difficult to access, or delay for unrestricted;
B. Incomplete documentation – ignoring past achievements (BIOMOVS, EMRAS I, selective uptake of dissolved organic tritium);
C. No common knowledge data base due to copyright restriction;
D. Missing appreciation – S. Strack case – lost information about T in wheat;
E. Limits in allocation of time and budget;
F. Missing dedication – only a job;
G. Missing peer review;
H. Insufficient parameter uncertainty;
I. Need of interdisciplinary approach;
J. Lumped parameters and steady state approach;
K. Avoid calibration with a single experiment or a limited number of experiments;
L. Incomplete use of recent advances in soil water-plant modelling;
M. OBT (non-exchangeable) definition, analytical technique, bioavailability;
N. Incomplete use of plant physiology and growth processes (OBT formation, loss by respiration, partition to edible plant parts);
O. Incomplete use of carbon knowledge (common pathways).

Next steps:

1. Analyze model simplification without loss of predictive power, using sensitivity and uncertainty approach;
2. Run on a full year of meteorological data to observe consistency;
3. Test on different soils and climate;
4. Test with available data;
5. Peer review for operational application adding land use, population distribution, production and habits and considering an improved atmospheric model, site adapted.

ITER[♣] Tritium impact accidents

Presented by Pierre Cortes

For ITER there are more than 25 reference events (incidents and accidents) considered in the design, and selected to ensure coverage of major systems, significant inventories, initiator types. For ITER

[♣] This presentation will be uploaded once the presenter receives approval/permission from the ITER Organisation.

licensing purposes, all the reference events have been updated and analysed in depth during 2008. There are four main types of events that could release tritium and there are:

- Cooling water system pipe break in Tokamak building;
- Fire in rooms containing tritium;
- Failure of a detritiation system;
- Loss of confinement in the hot cell.

In ITER routine operation there is only one pathway for tritium releases: the stack (probable height: 58m) and this probable stack height is just 4 m above the tokamak roof.

In ITER incidents and accidents, there are three possible tritium release pathways:

- HVAC (controlled, non-detritiated): at the stack;
- Detritiation Systems (controlled and detritiated): at the stack;
- Leakage through walls (uncontrolled): considered at ground level.

Tritium releases in ITER accident analysis are conservatively separated into:

(a) Pure tritiated water – HTO;
(b) Dust and ACP mainly as beta-gamma sources.

In reality, for tritium, the releases may also consist of (some in negligible amounts):

- HT;
- Tritiated Dust:
  - Tritium incorporated into Be dust or into tungsten dust,
  - Aerosols with condensed/adsorbed HTO/HT,
  - LiOT (Test Blankets),
  - Metal hydrides from T-storage;
- Tritiated Hydrocarbons (soots or methane for accidents such as fire).

Codes and models:

For ITER there are used two types of codes for radiological consequences:

- Source term codes;
- Radiological impact calculations.

As source term code, ITER uses MELCORE code which is a worldwide qualified code for fission activities; it predicts coolant pressure, temperature, flow rates, structural temperatures from decay heat and/or chemical reactions, and simulates transport of aerosols and tritium.

For radiological consequences, ITER uses CEA CERES code (MITHRA-EA, former GAZAXI). This code is able to predict:

- Atmospheric dispersion;
- Biosphere transfer;
- Impact calculation.

ITER has chosen this code because:

- it uses robust models (benchmark with UFOTRI made in the past for ITER releases calculations);
- it is used for CEA accident impact calculations (French safety authority is used to assess results from this code);
- it is used for CEA Cadarache impact calculations (Consistency with the "neighbor" Cadarache CEA centre).

Dan Galeriu commented that GAZAXI is a French code and ITER is an international organization, so they must optimize somehow this fact. Pierre Cortes said that tritium will be introduced at ITER around 2026 and ITER will support international codes, but for conservative source term and realistic impact calculations.

Philippe Guetat pointed out that ITER must take into account tritium before 2026 and also Pierre Cortes supported this assertion.

Dan Galeriu added the fact that it would be good for ITER to have teams working at the same topic as it was recommended in the past coordinated research programmes (VAMP, BIOMOVS, BIOMASS), as long as ITER has still large technological problems to solve. Pierre Cortes answered that's why ITER supports these types of international programmes. Volodymyr Berkovskyy also, added that ITER is international and it is good to be part of these international coordinated research programmes.

Pierre Cortes pointed out the reference groups for accidents, the specific meteorological conditions which must be take into account in case of a potential accident, and the food items characteristic for ITER.

ITER potential needs:

ITER is an R-D facility for which the goal is to demonstrate feasibility of magnetic confinement fusion energy, but it is not an R-D facility for tritium effects. The doses associated to routine tritium releases are very low and those associated to accidents are low. ITER could support international programs that could assess potential excessive conservatisms for accident tritium impact.

Contribution of CEA-Valduc centre on knowledge about atmospheric tritiated water transfers in the different compartments of the environment from survey data

Presented by Philippe Guetat

Philippe Guetat presented atmospheric HTO transfer in different compartments of environment, using survey data for CEA Valduc centre. It was taken into account atmospheric and water transfer and food chain transfer as well.

It was presented a comparison between different measurements for different locations.

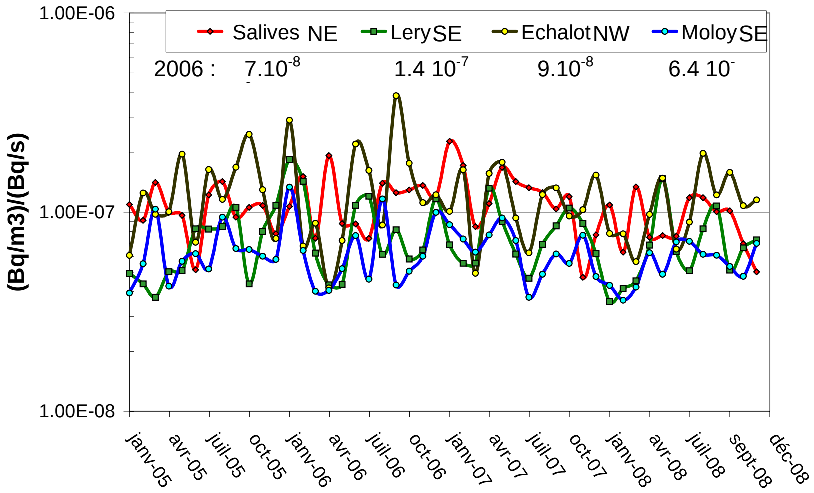


Figure 1. Comparison between different measurements for different locations.

The measurements done for tritium transfer in surface water are given in Figure 2.

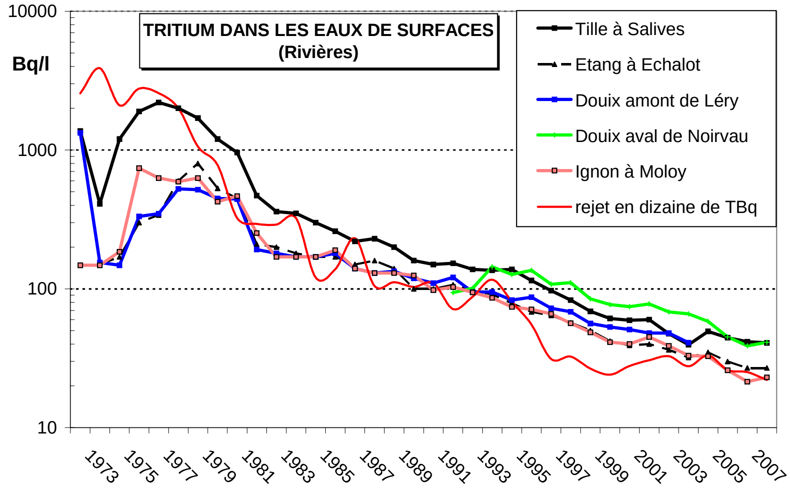


Figure 2. Tritium measurements in surface water.

They also measured HTO in atmospheric water vapours and in rain water and this is given in Figure 3 and observed that in rain water is less tritium than in atmospheric water vapours.

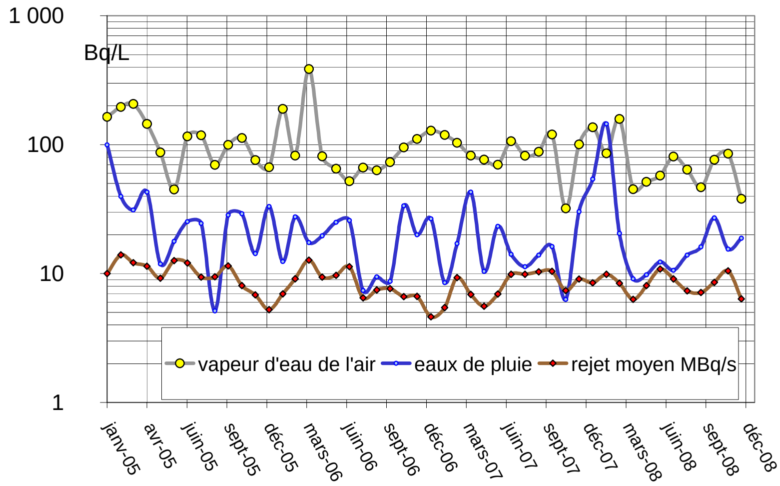


Figure 3. Comparison between HTO measured in atmospheric water vapours and rain water.

Surface water is poor influenced by rain. It was also measured HTO in grass and milk. The results are presented in Figure 4.

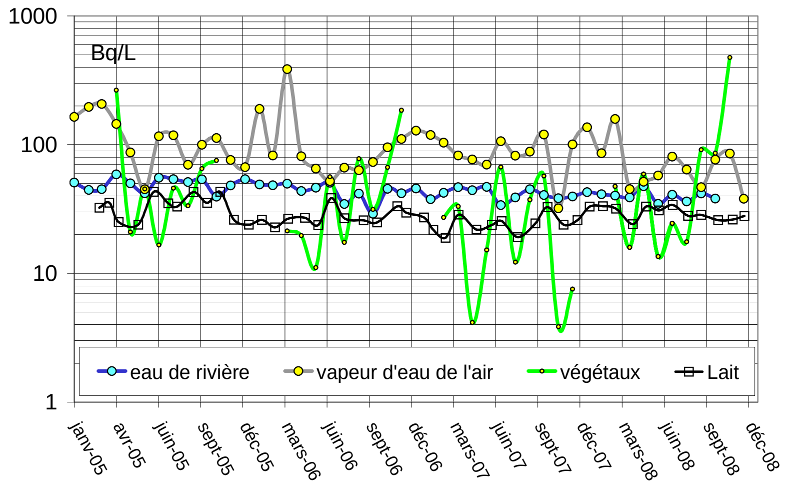


Figure 4. HTO measurements for surface waters, atmospheric water vapours, grass, and milk.

Organically bound tritium:

They measured tritium in water and combustion water for air, rain and vegetables and the results are given in Figure 5.

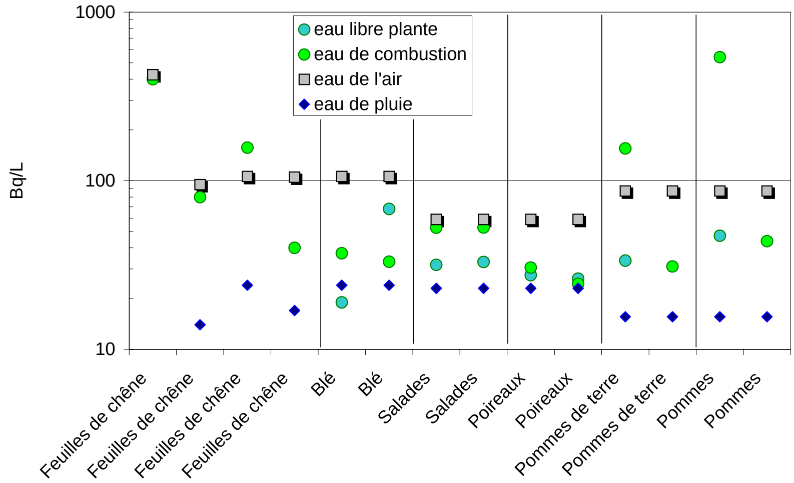


Figure 5. Tritium in water and combustion water for air, rain and vegetables.

Combustion water/free water

Aliment ou végétal	ratio CEA	ratio SEIVA	Tritium eau libre Bq/l SEIVA	OBT eau de combustion Bq/L SEIVA
Girolles	0.7	0.4	*214*	*91*
	2.3	1.9	*7*	*13*
Blé	0.4	0.5	*142*	*77*
	0.5	2	*19*	*37*
Salades	0.6	1.8	*1*	*2*
	1.6	2.8	*4*	*12*
	1.6	1.7	*32*	*53*
Poireaux	1.7	0.7	*2*	*1*
	2.6	8	*3*	*24*
	0.9	1	*28*	*31*
Pommes de terre	*0.9*	5	*34*	*155*
	1.0	5	*7*	*35*
	0.8	5	*2*	*9*
Pommes	*0.9*	11	*47*	*540*
	0.9	11	*9*	*93*
	0.9	11	*2*	*18*

Conclusions:

- Wet deposition (rains) more important than supposed for water table.
- Air vegetable transfer more important than free water OBT transfer.
- Must we measure OBT for survey purpose?
- Which parameters in case of accident?
- Validation of codes.

Philippe Guetat presented also some experimental results from Cecile Boyer's PhD thesis and pointed out that they are interested how to quantify the processes implied in these experiments.

Atmosphere-soil-vegetation Model Including CO_2 Exchange Processes: <u>SOLVEG2</u> & SPEEDI-MP of JAEA

Presented by Haruyasu Nagai

He briefly presented the Rokkasho site, where the major radionuclides emitted are Kr-85, H-3 (the largest quantity), C-14, I-129, I-131. Then, he presented the SOLVEG model, designed for C-14 transfer and their needs to include H-3 in SOLVEG.

SOLVEG is a sophisticated land surface model (independent on parameter tuning using observation data), which describes and predicts atmosphere-land surface exchanges (studies by numerical experiment).

The model was developed in 3 steps:

- Step 1: Heat and water exchange processes;
- Step 2: Canopy radiation and stomatal resistance → SOLVEG;
- Step 3: CO_2 exchange processes → SOLVEG2;
- Coupled water cycle and dispersion model (SPEEDI-MP) → Radionuclide transport in the whole environment.

Description of the model:

Structure:
- One-dimensional multi-layer sub-models for atmosphere, soil, and vegetation;
- Scheme for radiation transmission in the canopy and CO_2 exchange processes.

Function: simulation of water, heat, and CO_2 exchanges in the atmosphere-soil-vegetation system.
Objectives:
- Diurnal variation and seasonal change;
- Atmospheric surface layer, root zone soil, and vegetation canopy.

Variables for:
- Atmosphere: horizontal wind components (u, v), potential temperature, specific humidity, fog water, CO_2 concentration, turbulence kinetic energy, length scale;
- Soil: temperature, volumetric water content, specific humidity of soil air, CO_2 concentration;
- Vegetation: leaf surface temperature, leaf surface liquid water, vertical liquid water flux in canopy, leaf CO_2 concentration;
- Radiation: down/upward solar radiation (direct and diffuse, visible and near-infrared), down/upward long-wave radiation.

Then, Haruyasu Nagai presented the extension of the previous model to SOLVEG2, which is also a complex dynamic model developed in steps, as following:

Step 1: Heat and water exchange processes (Nagai, 2002):
- Coding of basic model for heat and water exchanges,
- Performance test using CASES-97 data (Le Mone, et al. 2000);

Step 2: Canopy radiation and stomatal resistance (Nagai, 2003):
- New canopy radiation scheme,
  Short-wave components: direct/diffuse and visible/near-IR,
- New stomatal resistance scheme,
  Photosynthetic active radiation (PAR) and sun-lit/shade leaf;

Step 3: CO_2 exchange processes (Nagai, 2005):
- Inclusion of CO_2 exchange processes,
  Air/soil transport, soil/plant respiration, photosynthesis,
- Model validation: CASES-97 data and AmeriFlux data at grassland in Oklahoma (Suyker and Verma, 2001).

Haruyasu Nagai presented all the basic equations necessary to describe the radiation scheme, stomatal resistance for CO^2, soil CO_2, and the model tests for albedo at winter wheat field, fluxes for winter wheat field, water and CO_2 fluxes for grassland, CO_2 exchanges for grassland ecosystem within the inter-comparisons with CASES-97.

The atmospheric transport and deposition of HTO in case of an accidental release is included in the Japanese code for accident management SPEEDI-MP and its performances have been presented also.

Cernavoda site

Presented by Dan Galeriu

Romania has two CANDU units at Cernavoda NPP on the Danube River. At about 2.5 km, there is Cernavoda town with 30 000 habitants and around there are many settlements and agricultural lands. The site map, agricultural productions and soil types have been presented and specific demands for modelling have been pointed. Contrary to other sites, there is an interest for modelling tritium transfer in sun flower, sugar beet, and grapes.

Overview of ETMOD and Environmental Tritium Research

Presented by Sang Bog Kim

First, Sang Bog Kim made an introduction concerning Canadian nuclear industry, emphasizing the AECL site. He pointed out that Canada has 17 operating power reactors, 3 being refurbished and 2 in guaranteed shutdown state, emphasizing the fact that they do not know actually how much OBT is produced from HT and HTO, respectively. After he presented the typical share of nuclear energy in total electricity generation, the research reactors at CRL, and the tritium releases from Canadian facilities, Sang Bog Kim presented in detail ETMOD model.

ETMOD model description:

The model takes into account:

- The transport and dispersion of elemental tritium (HT) and tritiated water vapour (HTO) in the atmosphere;
- Deposition of HT and HTO from the plume to the ground;
- In-ground conversion of HT to HTO by microbial action;
- Uptake of HTO by plants;
- Re-emission of HTO from plants or soil;
- Atmospheric dispersion of this re-emitted material;
- Inhalation and ingestion doses to an in-plume resident;
- Plume depletion by deposition and direct in-plume oxidation of HT to HTO are accounted for;
- Wet deposition of HTO;
- Transfer to animals (All H-3 in animals is assumed to be in the form HTO).

After a brief history of ETMOD, Sang Bog Kim presented the strength and limitations of ETMOD. The model is robust because it is a dynamic, process oriented code; the code is fairly easy to run and provides a lot of information; and treats HT as well as HTO. The model has also limitations like:

- The documentation is limited;
- The model verification is limited;
- The user’s manual does not show any sample output files;
- Wind direction is assumed constant.

Then, it was presented ETMOD input parameter requirements and ETMOD output summary and pointed out that since 2008, AECL uses ETMOD 3, which considers:

- OBT formation and retention in animal products;

— Ingestion doses from intake of animal produce containing OBT;
— Slow conversion of OBT to HTO in plants;
— HTO uptake and OBT formation at night in plants – Hydathode;
— Accumulation and retention of activity in grain;
— Total doses to children and infants.

It was pointed out that for their modelling purposes, they must take into consideration the Canadian environment, which is a little bit specific (a lot of snow), emphasizing the main aspects.

They validated the model, considering data from different experiments:

— OBT formation in animals and plants (road-killed animals and vegetables);
— OBT formation at night;
— Tritium re-emission in soil;
— Exchangeable and non-exchangeable OBT.

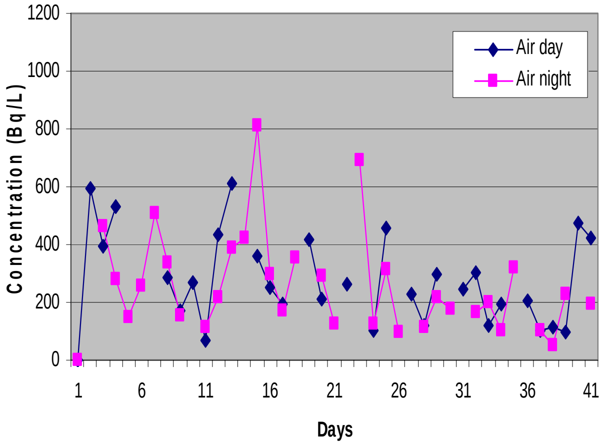
They also made inter-comparison tests with: ADDAMS, IMPACT, EMRAS and improve their model and parameters using Canadian Standard Association (CSA) and Derived Release Limits (DRL).

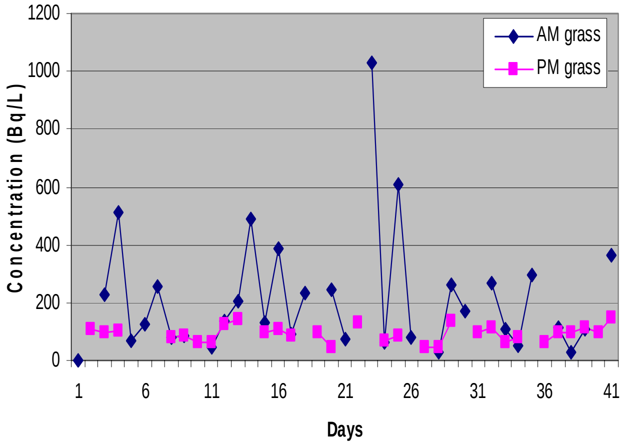
The tritium data obtained at AECL are:

— OBT formation at night time (tomato plants with an exposure chamber and field experiments) – rapid OBT formation;
— Perch Lake data for EMRAS including longer-term experiments – longer OBT residence;
— Duke Swamp data (underground contamination) – waste management area;
— Acid Rain Site data (tomato and potato) – spatial distribution.

They do experiments with large rainbow trout. They fed them with HTO and measure OBT, and hopefully in the future they will consider OBT intake also.

It is interesting to note that there are differences in HTO grass concentration comparing to HTO air concentration. An example is given in figures below:





Conclusions:

— AECL receives continual support to improve the understanding of environmental tritium's behaviour in nature.
— In order to test the environmental tritium model, well-organized and systematically designed experiments are required.
— Regulation of environmental tritium experiments is getting tight and complicated.
— In order to reduce the gap between observation and prediction, do we need site-specific experiments?
— Could you suggest any specific types of tritium experiments that will be useful for EMRAS II?

D_2O release experiments

Presented by Noriyuki Momoshima

Noriyuki Momoshima presented a review of experimental results with D_2O vapours performed in Japan, pointing out the fact that field experiments on environmental behaviour of tritium are quite difficult to do because there is a public acceptance problem in Japan. They started their experiments with heavy water in green-houses in 1995–1996 and continued with transfer of tritium and its retention in crops, animals and fish during an accidental release (1997–1999). The experiments have been done at Ibaraki University in a large team coordinated by Prof. M. Ichimasa.

The topic of research was:

- Uptake and release of D_2O by plants – rice, radish, tomato, komatsuna, cabbage, orange, soybean, maize, potato;
- Uptake and reemission by soil - sandy soil;
- OBD formation – rice.

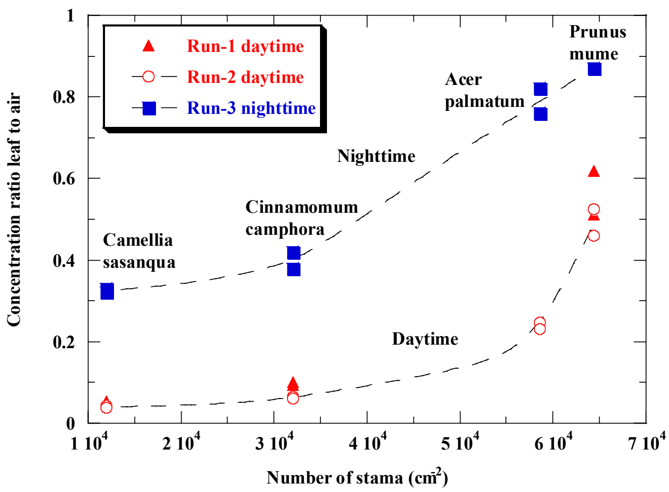
It was presented also the list of publications related to D_2O experiments. In the table bellow are given some representative results of D_2O kinetics.

Table 2
D_2O uptake kinetics in plant leaves

		Rate constant k (h^{-1})	Steady-state conc. C_{max} (ppm)	Initial uptake rate $C_{max}k$ (ppm h^{-1})
Day '95	Komatsuna	0.95 ± 0.16	$10\,080 \pm 910$	9580
	Orange	0.25 ± 0.08	$17\,040 \pm 4580$	4260
Day '96	Komatsuna 1[b]	0.74 ± 0.16	$17\,130 \pm 1320$	12700
	Komatsuna 2[b]	0.84 ± 0.19	$17\,820 \pm 1240$	15000
	Radish 1[b]	0.91 ± 0.17	$19\,070 \pm 1230$	19000
	Radish 2[b]	1.38 ± 0.38	$18\,610 \pm 1630$	25700
	Tomato[b]	1.03 ± 0.14	$16\,430 \pm 770$	16900
	Rice[b]	3.63 ± 0.31	$20\,310 \pm 430$	73700
Night '95	Komatsuna	0.65 ± 0.19	$15\,780 \pm 2850$	10300
	Orange	0.06 ± 0.29	$278\,00 \pm 127810$	1670
Night '96	Komatsuna	0.20 ± 0.04	$18\,300 \pm 1330$	3660
	Radish	0.31 ± 0.05	$20\,600 \pm 1590$	6390
	Tomato	0.12 ± 0.02	$19\,160 \pm 1630$	2300

[a] Rate constant calculated using porometer data, $k' = \rho_s/(aWr)$.
[b] Komatsuna 1, Radish 1 and Tomato were exposed on 8/24 and Komatsuna 2, Radish 2 and Rice were

The uptake of deuterium by dead leaves exposed to D_2O vapour in greenhouse daytime and night time is given in the figure below. These experimental data are very useful for models testing.



<u>Behaviour</u> of environmental tritium and assessment of influence on environment

Presented by Shinji Sugihara

Shinji Sugihara presented the Large Helical Device (LHD) research project developed at National Institute for Fusion Science (NIFS), connected to generation and confinement of high temperature and high plasma.

In the D-D experiment the production of tritium will be of 55.5 GBq/year and tritium releases in the environment will be below 3.7 GBq/year. In this respect, it is necessary to guarantee the safety of released tritium and mainly to:

- understand the tritium behavior in the environment;
- show that there is not a significant increase of individual dose;
- inform the public.

Then Shinji Sugihara presented the former compartmental model used for tritium assessment in environment and the actual compartmental model. This model contains different compartments like: rain, different layers of soil, river water and the processes implied are: washout, transpiration, evapo-transpiration, water movement to soil layers.

<u>UFOTRI</u> – Accident assessment model for tritium

Presented by Dan Galeriu

UFOTRI is a process oriented model developed by Wolfgang Raskob (FZK Karlsruhe, Germany). It is deterministic (defined set of variables, e.g. predefined and constant weather) and probabilistic (assessment of all possible weather for a certain period) code. It is applied for near and/or far range. The plant species considered in UFOTRI are: grass (fodder), leafy vegetables (continuous harvested), wheat, potato, rice. The endpoints of UFOTRI are:

- Concentration:
  - Air concentration and deposition;
  - Time dependent concentration in air, soil and foodstuffs for selected points;
  - time dependent dose values for selected points.
- Organ doses:
  - Short term effective doses;
  - long term effective doses.
- Countermeasures:
  - Food restriction, areas and duration.
- Coupling with COSYMA for further evaluation.

UFOTRI has a short term sub-model (hourly time steps) and a long term sub-model. The short-term sub-model considers:

- Transport and dispersion in the atmosphere:
  - primary plume by Gaussian trajectory model;
  - secondary plume by an area source model.
- Exchange atmosphere – plant – soil:
  - deposition and reemission is expressed via resistance functions dependent on the prevailing meteorological conditions (for both tritium and water vapour).
- Exchange atmosphere – soil:
  - deposition of tritium to soil and evaporation of tritium and water is modelled via resistance functions.
- Transport in soil:
  - water and tritium movement depends on the matrix forces.
- Cycling through the food chains.

The long-term sub-model is in fact, a compartment model for calculating the longer term behaviour of tritium in the food chains and considers:

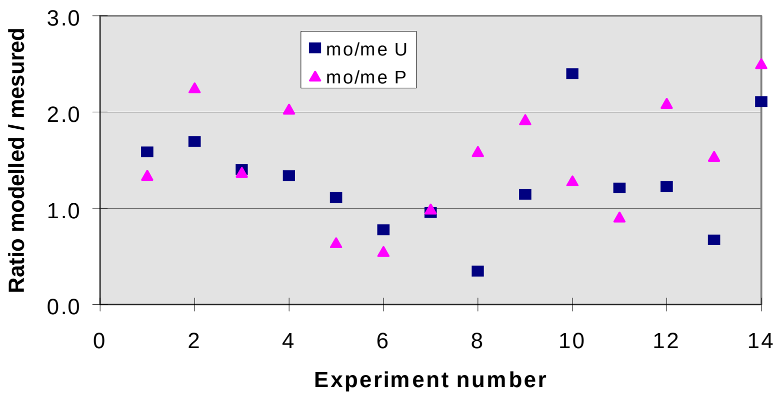
- transfer rates are means, valid for the vegetation period and derived from equilibrium conditions;
- HTO and OBT are treated separately.

UFOTRI considers resistance approach for plants tritium uptake; for stomata resistance considers Jarvis approach; for actual evapo-transpiration considers Penman-Monteith approach; for water movement in soil uses simplified version of Darcy's law.

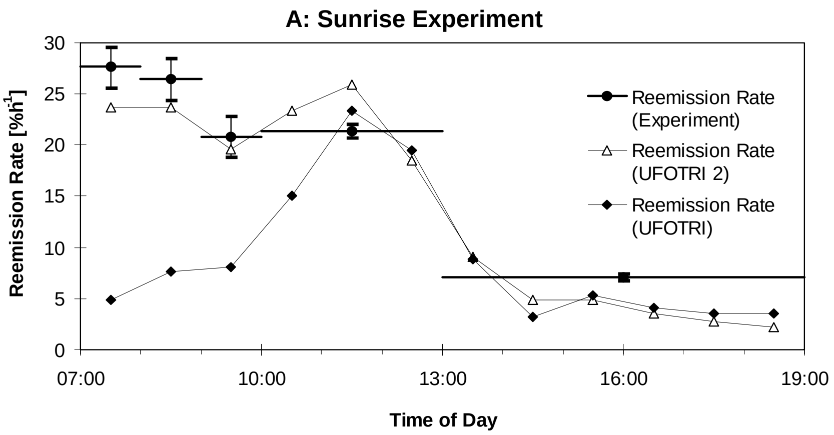
Tritium food-chain model considers processes like:

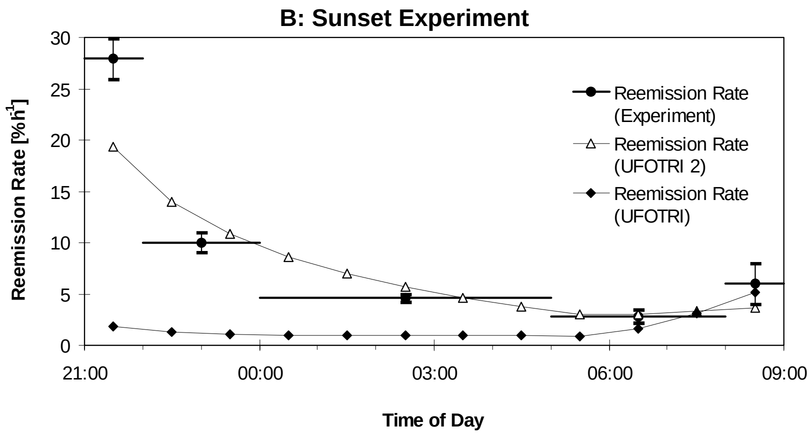
- phenological stages of crop development – sowing, emergence, anthesis, harvest;
- growth of crop based on photosynthesised organic matter – photosynthesis rate, respiration rate.

The code was tested with experimental data on German winter wheat (see figure below).

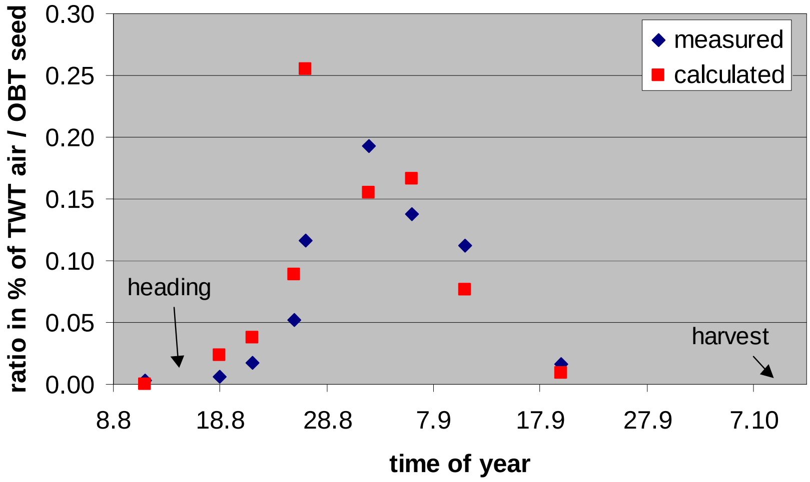


It was tested with HTO re-emission experiments from soil (figure below).





UFOTRI was tested with experiments on rice performed in Japan (figure below).



All the comparisons with different experiments are good, that's why UFOTRI has different applications:

- Assessment calculations for the potential European fusion sites Cadarache (France), Studsvik (Sweden), one site in Italy and Greifswald (Germany);
- Application in the ITER (International Thermonuclear Experimental Reactor) study to define the release limits for a generic site;
- Assessment calculation in the frame of the SEAFP (Safety and Environmental Aspects of Fusion Power) study.

Conclusions:

- UFOTRI considers most of the relevant transfer processes with dynamical approaches.
- UFOTRI is widely accepted in the frame of ITER.
- UFOTRI was applied for generic assessments and also site specific assessments in Europe.
- Ongoing effort is addressed to improve the modelling of formation and translocation of OBT as well as the reemission from soil.
- Tests for the generic rice model support the approach to use plant physiological parameters within tritium models.

FDMH–RODOS and more

Presented by Dan Galeriu

Food Dose Module Tritium (FDMH) is a process level oriented module developed by Romania in the frame of EU RODOS program (1998–2000). The requirement for developing FDMH was to be compatible with FDMT (Food Dose Module Terrestrial), developed by GSF Munich (Germany). In this respect, the main crops, growth dynamics, leaf area development, crops production, animal products, animal diet and forage, human diets, irrigation are similar with those in FDMT.

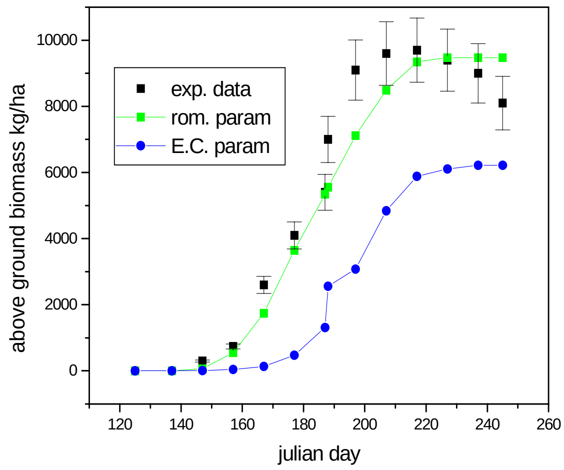
Plants and animals considered are:

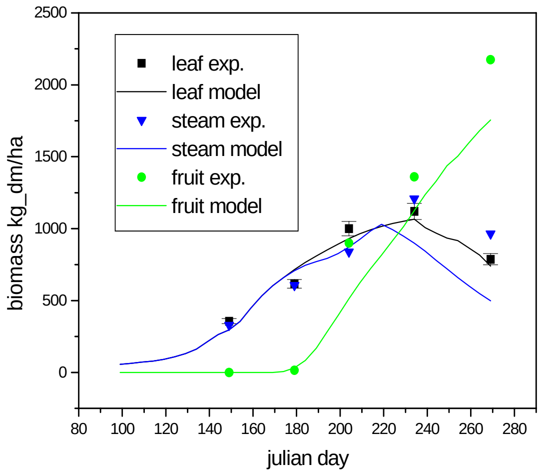
- all plants in Central Europe, but as fruit vegetables it was considered tomato; sunflower; rice – preliminary;
- fruits: apple- preliminary; berries – preliminary; grapes– preliminary;
- all animals in Central Europe;
- sheep milk – preliminary;
- lamb, pork, chicken – based on few experimental data and hydrogen metabolism;
- sheep based on unpublished experimental data and hydrogen metabolism;
- egg, chicken – very preliminary.

The approaches used for uptake, release and conversion of HTO in plants are:

- Resistance approach for uptake and loss;
- Canopy resistance determined from gross photosynthesis and CO_2 gradient (not Jarvis approach);
- Conversion from HTO to OBT driven by dry matter production rate;
- Plant physiological parameters determined using crop growth model and experimental dynamic data on LAI, leaves mass, storage organ mass, total aboveground mass at the field scale;
- More consistent parameters, NOT a collection of laboratory data;
- Same set of parameters for canopy resistance and conversion to OBT;
- NO need of leaf to canopy scaling;
- Easy control with plant growth;
- Easy to apply in various pedoclimatic conditions;
- Easy to expand to other plants;
- Care on sun set and sun rise;
- Care on OBT formation in night (some calibration).

The updated code, not FDMH, was favourably tested with many experimental data, but are presented here some tests for sunflower (left) and grapes (right) (see figures below).





Dan Galeriu presented a comparison between experimental and theoretical data for maximum stomata resistance, given in the table below.

Plant type	Experimental val.(s/m)	Theoretical val. (s/m)	References
Wheat, vegetative stage	41–52	56	Baldocchi, 1994
Wheat, anthesis	62–100	60	Baldocchi, 1994
Maize, vegetative	121–131	111	Baldocchi, 1994
Wheat	17–20	18	Choudhury, 1998
Potato	100–130	130	Vos, 1987
Alpha-alpha	100–120	110–130 (dep. VPD)	Saugier, 1991
Soya	66	70	Oliosa, 1996
Grass C3	74	74–120 (dep. VPD)	Knap, 1993
Grass C4	151	156–178 (dep. VPD)	Knap, 1993

The partition of newly formed dry matter is used as in the WOFOST crop growth model, but plant parameters have been adapted for Romanian cultivars around Cernavoda NPP, using Romanian experimental research results on plant growth characteristics. OBT formation in day time is directly linked with plant photosynthesis rate and actual leaf HTO concentration. In the night time, OBT formation is linked with previous day photosinthate production and night leaf HTO concentration. The full model was favourably tested with German data for wheat and Romania and German data for potato. The model predicts a diurnal variation of dose to public, as well as a seasonal one.

The model was updated and is under revision.

Structure and scope of the proposed model

Presented by Dan Galeriu

In order to develop a standard conceptual dynamic model for tritium dose assessment for acute releases to atmosphere and water bodies, it is mandatory to start with receptor air or water concentration. The most important thing is to harmonize approaches, to asses and decrease the uncertainty. In this respect, Dan Galeriu suggested to have documents for each sub-model incorporating the last results from life science research, dependence of weather, local climate and soil and recommend procedures for adaptation of local crops, animals and a framework for operational model and to distinguish between acute phase (process level) and late one (compartmental model)

Potential gaps in knowledge and expertise which should be addressed during the model development

Presented by Dan Galeriu

There are many gaps in knowledge, mainly connected to:

- HTO transfer in vegetation, such as:
    1. deposition from the atmosphere particularly at night when leaf stomata are closed or partly closed;
    2. effective rooting depth of different species;
    3. uptake by plants in rain conditions;
    4. reemission from soil and plants;
    5. soil and climate influence for persistence of tritium in rooting zone.
- OBT transfer in vegetation, such as:
    1. rates of OBT formation, particularly at night;
    2. translocation to fruits and roots;
    3. perennial plants.

Dan Galeriu pointed out that the predictions for contamination of fish, eggs or broilers must be experimentally checked. In this respect, Sang Bog Kim express his interest and availability to do some experiments to study tritium transfer in large rainbow trout fed with food marked with OBT at AECL. Dan Galeriu pointed also that for cold climate, tritium behaviour in winter, including washout by snow, dry deposition to snow and the fate of tritium in the snow pack must be studied and he takes this task to be accomplished by the next meeting in January.

Dan Galeriu emphasized the fact that there are gaps not only in knowledge, but there are also gaps connected to expertise, which depend on each utility and participant and can be minimized through collaboration with national research in agriculture and aquaculture.

Structure of technical document

Presented by Dan Galeriu

The WG Leader suggested the technical document to have the following structure:

- Tritium, being a life element, has implication for environmental transport modelling, and this must be emphasized;
- To include a briefing of past achievements;
- To make an analysis of each process, forcing parameters, potential simplification in mathematical approach;
- To include sensitivity and uncertainty analysis (if possible) for each main process with focus on ingestion dose;
- To include a demo version for the code, in order to help further analysis on sensitivity and uncertainty

— To include liquid pathway separately and to use simpler models than for terrestrial pathways.

There were not objections regarding the proposed structure and WG members were kindly invited to participate to the final form of this document.

Modelling the dynamic tritium transfer to farm animals – Extension to wild mammals and birds

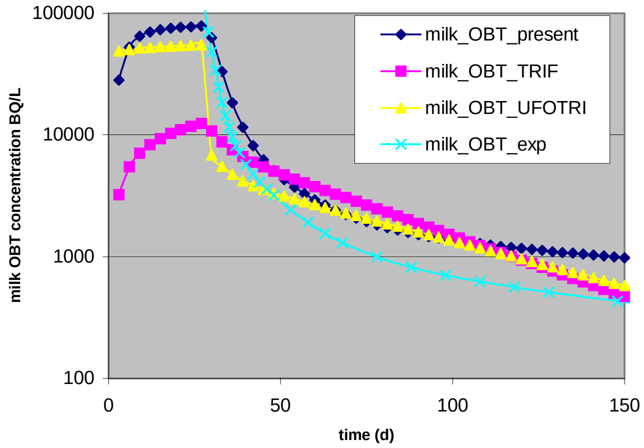
Presented by Anca Melintescu

First, Anca Melintescu made a revision of the models and experimental data base existed in literature. She pointed out that the existed models are simple and non-validated or are empirically derived and cannot be used out of initial data set. The experimental data base is sparse, because it refers to old experiments insufficiently reported. There are very good experimental data for rats fed with tritium and C-14 in different forms, done in the past by Hiroshi Takeda from NIRS Japan, and this data base could be used to validate the models. She emphasized the fact that animal products contribute significantly to the diet, and that's why it is mandatory to have reliable dynamical models, but using different approaches based on comparative metabolism and OBT-C links.

The she described the model developed in IFIN-HH, already published. Their model is called MAGENTC; it is a dynamic process level oriented model for H-3 and C-14 transfer in growing and mature mammals (domesticated and wild) and birds. The model is based on the assumption that organic matter turnover time is directly linked with the net maintenance energy. The model has 6 organic compartments and distinguishes between organs with high transfer and metabolic rate (viscera), storage and very low metabolic rate (adipose tissue), and 'muscle' with intermediate metabolic and transfer rates. Liver, kidney, heart, the gastrointestinal tract, stomach and small intestine walls organs are included as a combined "viscera" compartment. Blood is separated into red blood cells (RBC) and plasma, because plasma is the vector of metabolites in the body (and also as a convenient bioassay media). The remaining tissues are bulked into one model compartment ('remainder') in order to achieve mass balance. The stomach and small intestine compartment refers to the content, as an input pathway.

The model had been successfully tested with experimental data on rats, sheep, cows, and pigs and the model's predictions without calibration are close to all experimental data with a factor less than 3.

Below, it is given an example of inter-comparison between MAGENTC, UFOTRI, TRIF and experimental data for OBT concentration in cows' milk after OBT continuous intake for 26 days. Experimental data were reported only after stop dosing. It is seen, that MGENTC gives better predictions than the other models, but the simple model UFOTRI gives also reasonable predictions.



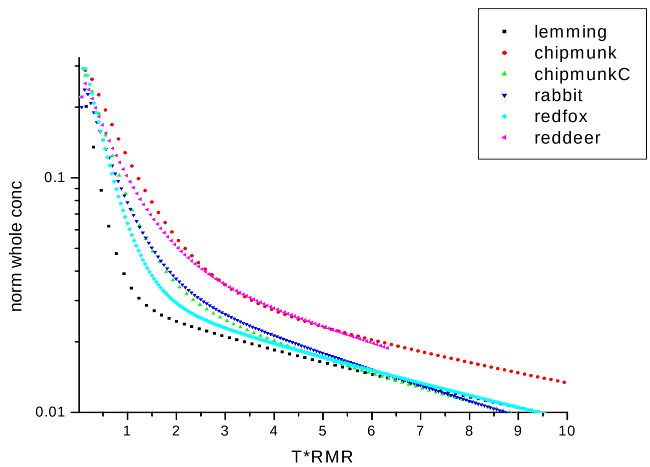
Extension of MAGENTC to wild mammals and birds:

Because MAGENTC gives good predictions for domesticated mammals, the authors extended the model to wild animals and birds in the context of a clear need to explicitly consider non-human biota within radiological assessments (ICRP 2007). Data for radionuclides in wild animals are sparse and a number of approaches including allometry have been proposed to address this issue. Unlike to laboratory or housed farm animals, wild mammals and birds are subjected to large environmental and dietary variability for which they must adapt. There are many studies demonstrating allometric (mass dependent) relations for basal metabolic rate, daily energy expenditure (DEE) and organs' masses. For DEE there is considerable evidence of taxon specific allometric relationships, but dietary habits can still have a large influence for rodents with herbivorous, omnivorous or granivorous diets. The biological halftime does not only depend on animal mass but also on taxon either. For the same body mass, taxon and diet may affect the biological half time with a factor 2.

MAGENTC needs as input the Basal Metabolic Rate (BMR), the field energy expenditure (FMR), organ mass and organ Specific Metabolic Rate (SMR). Body mass is not the only predictor of BMR, but body temperature, taxon, diet and climate are also important. A gap in the database for wild animals is the assessment of maintenance energy needed per kg tissue and time unit, the so called specific metabolic rate (SMR) for organs in basal and active states. Due to adaptation to various environmental constraints it is possible that the organ metabolism of wild mammals to differ from domesticated ones. The organ mass for wild mammals also is less documented than for farm animals and the intraspecific variability can be higher. This explains why MAGENTC predicted BMR values are sometimes close to observed values, but there are cases of 50% discrepancies. In practice the authors considered the relative contribution of organs to whole body BMR and use the experimental BMR in the model input values.

The authors reassessed all input data and also select red deer as a large herbivore. They include two rodents (lemming and chipmunk), a small herbivore – rabbit and a carnivore – red fox. The lemming from Arctic regions is modelled with enhanced energy needs. As much as possible input data correspond to same habitat, diet, temperature and subspecies for each considered mammal. The effect of a coherent selection of model parameters is exemplified for chipmunk, for which the authors considered mixed literature data but also measured BMR and FMR of the same population (Quebec – personal data from V. Careau).

Short term dynamics of C-14 in whole body (generalised coordinates) is given in the figure below.



Generalised coordinates in the figure represent that for x axis, it is used T*RMR – non-dimensional time, which represents time multiplied by mature RMR and for y axis it is used normalized concentration, which represents whole body concentration multiplied by mature mass. Despite these shortcomings, the results presented above are less uncertain than for many other radionuclides and can provide useful results for biota radioprotection.

Extension of MAGENTC to birds:

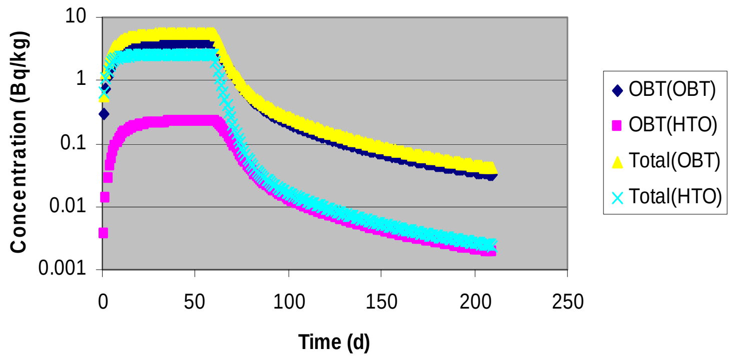
The model developed for mammals is based on energy metabolism and body composition with the assumption that the turnover rate of organics is linked to energy turnover rate. There are not reasons to restrict the model to mammals, if the assumptions are qualitatively correct. The allometry of basal metabolic rate of birds has close mass exponent to mammals.

After a selection of good data and correction for phylogenetic bias, the authors found that BMR = 303*M-0.33 (mass in kg and metabolic rate in kJ day-1). There is no difference between passerine and non passerine and the higher values for birds comparing to mammals are explained by higher body temperatures. The scaling exponent of BMR in captive birds (0.670) is significantly lower than in wild-caught birds (0.744) due to phenotypic plasticity. The scaling exponents of FMR for birds and mammals were not significantly different:

birds: FMR = 1.02 M0.68,
mammals: FMR = 0.68 M0.72

Disregarding the effect of increased body temperature the comparison between model BMR predictions to experimental data is good. For small birds the model under predicts with 20–40%.

For food chain modelling, laying hens and broilers are of special concern and there are not experimental data for eggs or meat contamination with H-3 and C-14. The authors considered a tritium intake (1 Bq day^{-1}) for 60 days in both forms (HTO or OBT). The dynamics of tritium in eggs after HTO or OBT intake is given in figure below.



OBT concentration in eggs is predicted to increase rapidly in the first 7 days corresponding to the duration of egg formation, and slowly thereafter, due to contribution of recycled body OBT. It is observed that the OBT concentration in egg, after stop dosing decreases in the first days with a half-time of about 5 days and slower later (halftime of about 40 days), due to contribution of body reserves.

Total tritium in eggs is 2 times higher when the intake is OBT, but share of OBT is about 75% for OBT intake and only 9% for HTO intake.

In absence of any experimental data or previous modelling assessments, MAGENTC results give a first view on the transfer of H-3 and C-14 in birds.

Conclusions:

- The authors developed a research grade model for plants and animals based on process level, pointing out that model inputs can be obtained using Life Science research in connection with National Research on plant physiology and growth, soil physics, and plant atmosphere interaction, as well as animal physiology, nutrition and metabolism.
- These knowledge was re-used with a very low cost, but spending time to learn basics from these fields (Interdisciplinary Research).
- Classical compartmental models can be derived and appropriate parameters for each case can be obtained in this way.

Review of aquatic tritium modelling and knowledge

Presented by Francoise Siclet

Francoise Siclet made a revision of dynamic models for tritium transfer in aquatic environment existed in literature. It was pointed that for routine releases it is not appropriate to use steady state models, because liquid releases from power plants are highly variable across the year and this affect tritium concentration at the sampling time. Irrigation with contaminated water must be considered to assess the impact of liquid releases. Then, it was presented the code OURSON, which is a dynamic code developed for H-3 and C-13 transfer in aquatic environment. Fracoise Siclet presented a benchmark test between OURSON and CASTEUR code, developed by IRSN to predict tritium transfer in Loire River. A test for OURSON performance in case of tritium dynamics in mussel has been presented, showing that the model underestimates the OBT concentration in mussel for the first 24 hours and then, after 24 hours, it overestimates the OBT concentration. A single model is used in OURSON for all biota (without distinction between heterotroph and autotroph species). Some questions remain to be clarified in the model, as for example, transfer from sediments to water and from water to atmosphere.

Update of AQUATRIT model for tritium dynamic transfer in aquatic foodchain

Presented by Anca Melintescu

IFIN-HH started to develop AQUATRIT model by analyzing the existed old data base and as a request from Kema NRG (The Netherlands) (2002) to add tritium in their BURN model. Initially, the report was property of NRG, but this year they disclosed the report. The initial model was described in the following paper: Dan Galeriu, Rudie Heling and Anca Melintescu, "The Dynamic of Tritium – Including OBT – In the Aquatic Food Chain", Fusion Science and Technology, Vol. 48, Number 1 – July/August 2005, P. 779–782.

AQUATRIT participated to Perch Lake Scenario and Mussel Scenario in EMRAS I, but in an updated form, not yet published. The conclusions regarding the Mussel Scenario were:

- Mussel uptake and depuration can be reproduced using an appropriate metabolic rate and stomach content;
- Metabolic rates for mussels vary with age and species.

The updated AQUATRIT model improves the OBT zooplankton loss rate, considers benthic flora and fauna and expands the assessment of OBT loss rate of fish considering species differences in metabolism and growth. Both benthic and pelagic foodchain can be treated and the model can be adapted to various ecological conditions. It was presented an application for Danube River ecosystem with representative fish species including the effect of seasonal variability of water flow and environmental light and temperature.

The Cardiff case (bioaccumulation?)

Presented by Dan Galeriu

The synthesis and purification of tritium labelled molecules involves a number of intermediate steps in which other compounds are produced which are, presumably, of less commercial value. Together with significant quantities of tritiated water (HTO) these compounds have been discharged into Cardiff Bay since the early 1980s. For the most part, discharges of tritium from nuclear plants eventually result in tritiated water in the environment and the uptake into biota of tritium from tritiated water is fairly well understood. However, the organic compounds which are discharged present a different substrate and their biokinetics in the aquatic milieu are not easily predictable. Herein lies the uncertainty and the problem. OBT levels in benthic fish have been close to 120 kBq/kg (in 1989) and are currently about 20–50 kBq/kg. To put this in perspective, this is more than two orders of magnitude greater than the tritium concentration found in fish near much larger discharges of tritium, e.g. Sellafield. Some examples are given in the following pictures.

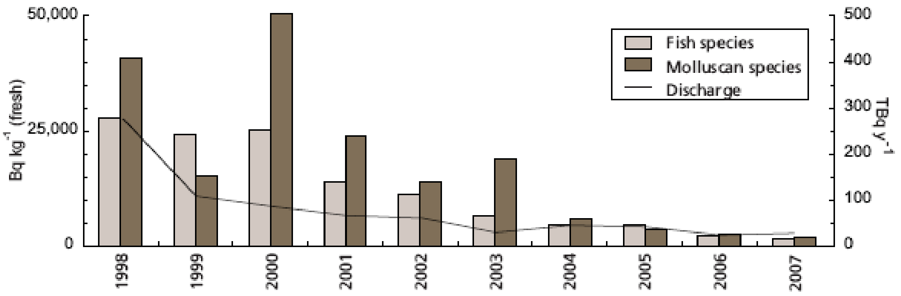


Figure 6.2. Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

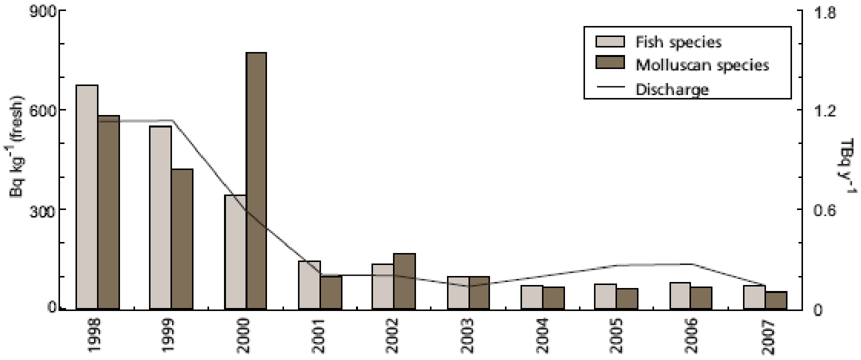


Figure 6.3. Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

It is suggested that bioaccumulation of H-3 by benthic organisms and demersal fish largely occurs via a pathway of conversion of dissolved H-3 labelled organic compounds into particulate organic matter (via bacterial uptake/physico-chemical sorption processes) and sub-sequent transfer up a web of sediment dwelling microbes and meiofauna. Variations between individual organisms may be accounted for in terms of their different feeding behaviour. Primitive organisms can selectively absorb such substances and this process is much more intense than organic matter production through photosynthesis. Plankton and molluscs have high uptake of DOT. About 0.02% impurity in water, relative to HTO, can double the OBT concentration. In Cardiff, DOT was 1–20% from total release and the selective uptake can explain the experimental results.

The WG Leader asks the participants if they have interest to consider these aspects in the next efforts of this WG7. It remains to be clarifying this issue to the next meeting in January.

Advantages and disadvantages of simple models

Presented by Dan Galeriu

The WG Leader presented two important models existed in literature: a dynamic one – UFOTRI and a compartmental model developed by KAERI (Korea) – Keum model, already published (Keum et al., Health Physics, January 2006, Volume 90, p. 42).

The advantages of simple models are they the use few accurate input data, but they have huge uncertainties in the model itself. Complex models have large uncertainties in input data, but much less uncertainties in the model itself. With some precautions, a simple model can be useful, giving good predictions and an example of cow model in UFOTRI have been presented, where a direct transfer from grass OBT to milk OBT have been introduced and tests with experimental data demonstrate that the model gives reasonable predictions. Considering the simple compartmental model of Keum et al., tested with four sets of experimental data, the week points have been pointed out explaining the discrepancy with experimental data. One of the model's limitations is that it uses a constant transfer rate from air to leaves or from leaves to air, while environmental conditions and plant development stage are major influencing factors. Also, there is not a direct of leaves OBT to storage organs.

The WG Leader made some suggestions such as:

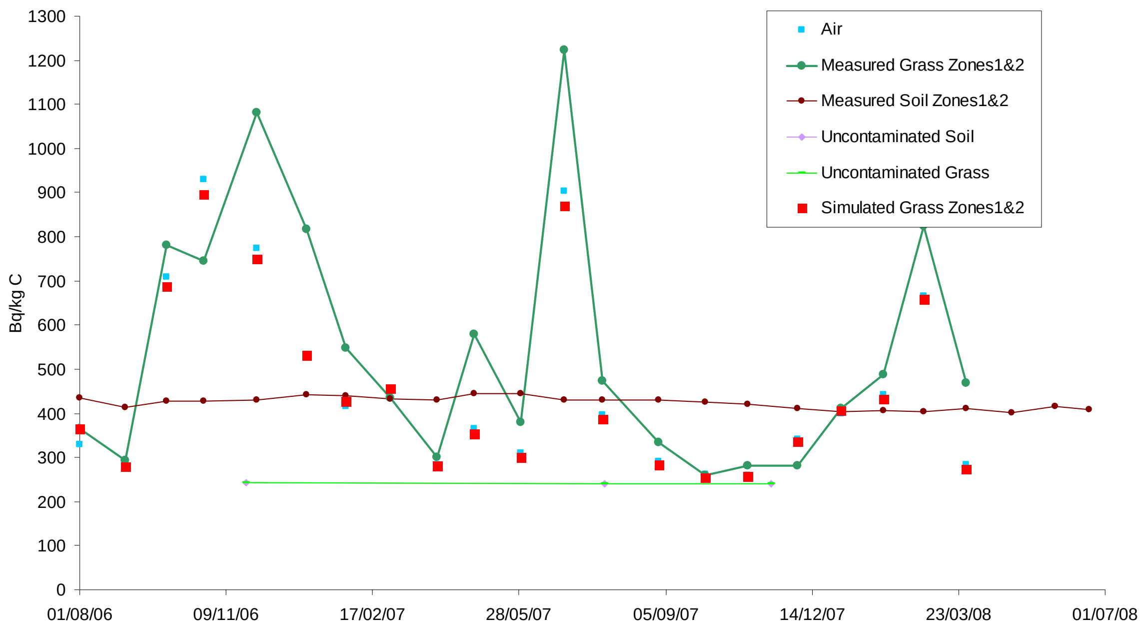
- Consider a compartmental model for late phase, with site adapted parameters;
- Initialization from a more advanced model for initial phase;
- Distinguish continuous harvested plants and perennial.

All the participants agreed these suggestions.

Current and planned experiment in IRSN; need of considering photosynthesis and plant growth in TOCATTA model

Presented by Séverine Le Dizès-Maurel

Séverine Le Dizès-Maurel started by presenting the TOCCATTA model, developed by IRSN, concerning the transfer of C-14 and H-3 in terrestrial and aquatic environments. TOCATTA comprises main environmental media: agricultural systems (soil, plants, animals) and considers routine and accidental releases. It refers to both atmospheric and liquid releases. It considers daily time steps, but also long scale: a year or several years. The doses to humans are calculated using SYMBIOSE package. The chemical forms of tritium and C-14 are directly linked with biomass. C-14 and H-3 transfers (stocks, fluxes, residence time) require dynamic models of biomass evolution (plant, animal and/or microbial). More specifically, dynamic modelling of C-14 and H-3 in plants requires knowledge of plant growth dynamics. The conceptual model and the basic mathematics have been presented. The experimental work for validating the model are in progress and first results concerning C-14 transfer in grass and cows' milk have been presented. It was concluded that the model must include in more details photosynthesis and plant growth. In the figure below it is given a comparison of the model with experiments for grass.



Conclusions:

- To adapt the model to time varying releases and meteorology, an hourly time-step is required:
  - to estimate C-14 air concentration inputs to the model, based on hourly Kr-85 data;
  - to simulate photosynthesis and plant growth dynamics.
- The validation projects supports the approach to use plant physiological parameters within C-14 (and tritium) models.

<u>Role</u> of photosynthesis, respiration, partition of new dry matter, role of reserves

Presented by Dan Galeriu

Dan Galeriu made an introduction concerning the basics of photosynthesis (C3 and C4 plants, respiration, growth, and maintenance) and the role of these processes in plant growth. It was pointed out that growth respiration coefficients can vary between plant parts in a moderate way, excepting storage organs for plants which contain more carbohydrates or more lipids. There are experimental data indicating that growth respiration is a fast process and can be considered that it ended next morning. In respect of maintenance respiration, the process takes longer and the maintenance coefficients depend on plant parts, but also on fertilization.

The WG Leader made a demonstration with WOFOST Crop Growth Model developed by Wageningen School (The Netherlands).

Conceptual models for annual and multi-annual plants have been presented, focusing on gross photosynthesis, loss due to growth and maintenance respiration, partition factor to various plant parts, and the special role of reserves. The reserves are accumulated mostly in stems, in quasi-labile chemical forms and are accumulated in vegetative phase and used later to supplement storage organs growth or to compensate bad meteorological conditions. In perennial plants, the reserves are also used for re-growth of plant in the spring until the leaves have grown enough to sustain themselves the plant growth.

A <u>kinetic</u> model of the long term dose relevant carbon bound tritium by re-evaluation of known kinetic data

Presented by Franz Baumgärtner

The presentation started with emphasizing the fact that the OBT definition is not clear by now, as well as the experimental techniques concerning the OBT measurements. It does not know exactly what is included in measured OBT. It seems that this could contain also tissue free water tritium (TFWT). Then, there have been presented the experiments done in the past:

1. Hydroponic HTO growth of maize & barley (Bgt & MA. Kim, 1995);
2. HTO exposure of tomatoes (F.S. Spencer, 1984);
3. HTO exposure of mussels (S.B. Kim & T. Yankovich, et al., 2004);
4. H2O exposure of HTO grown mussels (S.B. Kim & T. Yankovich, 2005).

In controlled growth experiments with hydroponic HTO and continuously illuminated, the OBT growth rate is about 20% higher than OBH. It is possible that measured OBT includes not only tritium linked to carbon, but also tritium formed in metabolic pathways in the form of buried quasi-exchangeable tritium and tritium in hydration shells. This can explain a fast component of OBT growth rate.

Trials to interpret the mussels' experiments in the frame multiple OBT bio-chemical theories have been presented.

Development dynamic compartment models to <u>predict</u> behaviour of radionuclides in rice paddy field

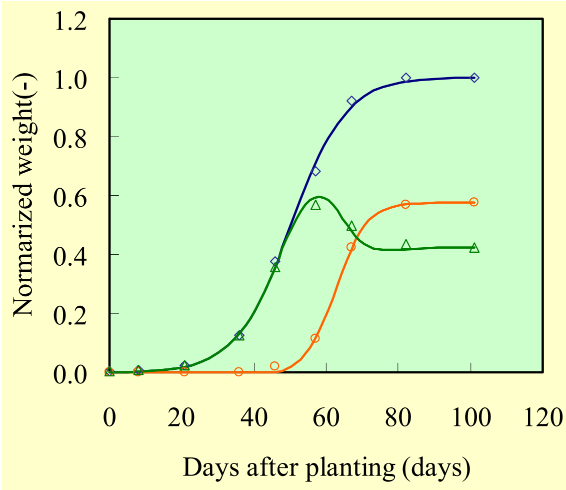
Presented by Tomoyuki Takahashi

First, Tomoyuki Takahashi emphasized his past experience concerning the development of dynamic compartmental models. For describing the radionuclides transfer in rice paddy fields it is necessary to have:

— Reasonable dose assessment caused by nuclear facilities;

— Appropriate estimation of internal dose by the pathway of ingestion of rice which is a staple food in Asian countries;
— Prediction of behavior of radionuclides in rice paddy field;
— Development of dynamic compartment models for some important radionuclides.

Then, it was presented the structure of compartmental model for I, Cs, and Sr. An example of the growing curve for the rice plant is given below:



Tomoyuki Takahashi presented the dynamic compartmental model developed for C-14 transfer to rice grains. They considered two sources terms: atmosphere and irrigation water. They validate the model with experimental data from batch experiment.

Low dose-rate irradiation and threshold dose-rate for radiation risk

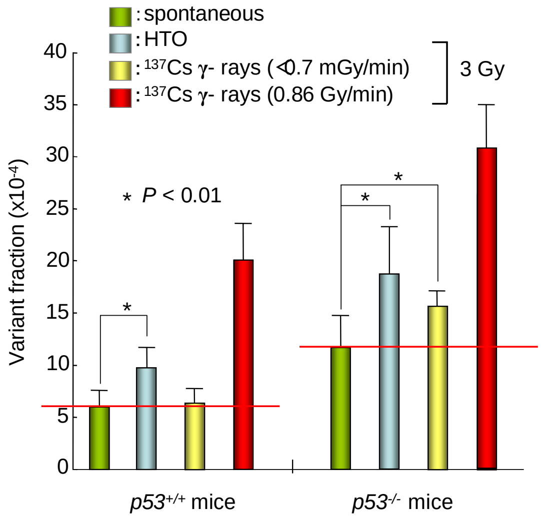
Presented by Toshiyuki Umata

Toshiyuki Umata presented two types of experiments done in past: They administered orally HTO to mice and they followed the tumours development and the low dose irradiation and threshold dose rate for radiation risks. Both of these experiments have been published. The objective of these two studies was to investigate the biological effects of tritium on mouse at low dose rate. The mice have been exposed to beta rays by continuous administration of various concentrations of HTO. As a conclusion, these studies revealed that exist two types of threshold dose rates, not only in the frequency of thymic lymphomas, but also in the life shortening. It seems that the tritium beta rays are grater than that of gamma rays. Threshold dose rate in the frequency of thymic lymphomas was 12 (0.9) mGy/day and that in life shortening was 2 (0.2) mGy/day (1.8 Gy).

Toshiyuki Umata presented also a comparison of the mutagenic effects of tritium beta rays and 137Cs gamma rays on wild and p53-deficient mice. Then, it has been explained the features of $p53^{-/-}$ mice, as following:

— p53 is a suppressor gene;
— p53 plays the role of guardian of genome;
— $p53^{-/-}$ mice have no apoptotic activity, which removes damaged cells from tissues;
— life of $p53^{-/-}$ mice is short, because the occurrence of tumours at about 8 months old; the occurrence of tumours for wild mice happens at 28 months old.

Then, it was presented the experiment itself. An example of the TCR variant fraction is given below:



Induced TCR variant fractions

mice	exposure	induced variant fraction		Relative value	
				A / B	A / C
p53$^{+/+}$	HTO	3.9×10^{-4}	A	-	0.3
	simulation	0	B	-	-
	acute γ-rays	14.2×10^{-4}	C	-	1.0
p53$^{-/-}$	HTO	7.6×10^{-4}	A	1.7	0.4
	simulation	4.5×10^{-4}	B	1.0	-
	acute γ-rays	20.1×10^{-4}	C	-	1.0

Conclusions:

— To evaluate the mutagenic effects of HTO, TCR variant functions using wild type and p53$^{-/-}$ mice were investigated;

— When compared on the basis of the induced TCR variant fractions in p53 deficient mice at 3 Gy, tritium b rays appear to be 1.7 times more mutagenic than g rays;

— p53-dependent apoptosis could suppress the increase of TCR variant fraction induced by tritium b rays.

Future Work Programme		
Action	**Participant(s)**	**Date**
Draft on uncertainty and sensibility needed in the quality assurance of the models	Juraj Duran	25–29 January 2010
Potential improvements of plant sub-model in OURSON code: detailed sub-model description and sensitivity tests	Francoise Siclet	1 January 2010*
Potential improvements of plant sub-model in OURSON code: analysis and discussion for potential improvements	All WG members	25–29 January 2010
Detailed description of expanded MAGENTC for animals and sensitivity analysis	Anca Melintescu	25–29 January 2010
Full expanded interaction matrix for terrestrial pathways of tritium transfer	Séverine Le Dizès-Maurel	25–29 January 2010
Availability of soil-water revision done Ph. Ciffroy and dissemination between WG members	Laura Marang	20 December 2009
Submission for publication of updated AQUATRIT model	Dan Galeriu, Anca Melintescu	15 December 2009

Future Work Programme		
Action	**Participant(s)**	**Date**
OBT formation versus available energy in plants	Laurent Vichot	25–29 January 2010
Review of tritium washout	Luc Patryl, Anca Melintescu, Dan Galeriu	25–29 January 2010
Correlation between air and rain HTO concentration (experimental data)	Philippe Guetat	25–29 January 2010
Comparison between UFOTRI and CERES models for 1 g of HTO and 1 g of HT	Pierre Cortes	25–29 January 2010
OBT formation in night experiments and modelling trials	Sang Bog Kim	25–29 January 2010
HTO dynamics using SOLVEG (plants and soil) after an accidental tritium release	Haruyasu Nagai	25–29 January 2010
Modelling exercise 1: HTO and OBT in fish.	Dan Galeriu	1 November 2009*
Modelling exercise 2: Dynamic of tritium in grass following 1 hour air contamination	Dan Galeriu	1 November 2009*
Results for both modelling exercises	All WG members	1 January 2010
Upload on the WG7 EMRAS 2 web page of a list of existed documents/papers in each laboratory/site to be circulated between WG members	All WG members	15 November 2009
Proposals for the content of final document to be transmitted to WG Leader	All WG members	1 December 2009

Next Meeting

The next Working Group Meeting of WG7 is scheduled to take place during the nect (Second) EMRAS II Technical Meeting, being held at IAEA Headquarters in Vienna, 25–29 January 2010.

Further Information

Information on the activities within EMRAS II generally and on the “Tritium” Accidents WG, in particular can be obtained from Volodymyr Berkovskyy (IAEA Scientific Secretary) and Dan Galeriu (Working Group Leader), who’s contact details are given at the beginning of these Meeting Notes.