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Risks from tritium exposure at Cernavoda, Romania

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MOTTO

"A more diverse mix of voices are taking a positive second look at nuclear energy-environmentalists, scientists, the media, prominent Republicans and Democrats and progressive think tanks. They are all coming to a similar conclusion: If we are to meet the growing electricity needs in this country and also address global climate change, nuclear energy has a crucial role to play."

- Patrick Moore
Co-founder, Greenpeace
Co-chair, Clean and Safe Energy Coalition
Kiplinger's Business Resource Center
September 2007

“"Nuclear energy is in Europe and it is here to stay," Mr Piebalgs said, adding that it should be under the condition of **"high safety standards and sound management."** EU energy commissioner Andris Piebalgs, Oct 10 2007

Bucharest

October 2007

What is TRITIUM?

Tritium is a radioactive form of hydrogen that occurs either naturally in the environment, as a result of cosmic ray interactions in the atmosphere, or artificially as a result of human activities. The radioactive decay of tritium is by emission of a beta particle (an electron) the energy of which is so low (it is in the range ~zero to ~18.6 keV) that it penetrates only a few micrometers in tissue. The mean range of the tritium beta particles in tissues is ~0.7 µm, and the maximum is ~6 µm. Tritium can affect animals only by respiration and ingestion.

Tritium is emitted to the environment from nuclear facilities in two chemical forms, as tritiated hydrogen and as tritiated water. Tritiated water (HTO) enters the water life cycle and is very mobile. CANDU reactor emits practically only HTO. Through natural processes (or produced by industry) tritium can be converted to organic forms

Tritium is bound to organic compounds either by exchange reactions or by enzymatically-catalysed reactions. In exchange reactions, tritium is bonded to oxygen, sulphur, phosphorus or nitrogen atoms (ie as hydroxides, thiols, phosphides and amines). Conventionally, this is termed exchangeable OBT. In enzymatically-catalysed reactions, tritium is bonded to the carbon chain of an organic molecule: this is usually termed non-exchangeable OBT. Tritium so bound is more strongly attached than exchangeable tritium and has longer retention times: such bonds are only dissolved during catabolic reactions. It is important to distinguish between organic forms of tritium in respect to their role in animal metabolism. Biogenic OBT include tritium in amino acids, sugars, protein, starches, lipids and cell structural materials and enter animal metabolism. Some biomolecules are well-preserved and long-lived, e.g. phospholipids in nerve cells, and, of course, DNA and RNA macromolecules. These longer retention times result in greater radio toxicity than tritiated water.

The Relative Biological Effectiveness (RBE) is a measure of comparative health effect of a specific radiation to a reference one (gamma ray) when the energy deposited in the body is the same. RBE for OBT is higher than for HTO. For simplicity, The International Commission of Radiological Protection considers RBE=1 for all forms of tritium. Environmental Agencies have a precautionary approach and use higher RBE for protection of biota. The retention of biogenic OBT in animal body is higher that for HTO. The health effect of OBT is higher than for HTO.

From a Greenpeace paper by Ian Fairlie:
September 2007

Summary
This brief report examines existing releases of tritium, the radioactive isotope of hydrogen, from the Cernavoda 1 CANDU reactor in Romania. It explains why these releases to the atmosphere and to the Danube River are so large, and why they increase each year as the reactor gets older. It compares tritium concentrations near Cernavoda before and after the commencement of the NPP indicating significant increases resulting from the reactor's operations. Estimates are made of future tritium releases from the total of 4 proposed reactors in the year 2030: these extremely large and will result in very serious tritium contamination of nearby areas. Estimates are also made of annual tritium intakes by local residents. These are high and are likely to lead to increased risks of cancers in the affected population in the future. Recommendations are made to relocate pregnant women and mothers with very young children, and to advise local residents not to consume produce grown in local gardens.

Our (IFIN-HH) Summary
(October 2007)

This brief report examines existing release of tritium, the radioactive isotope of hydrogen, from the Cernavoda 1 CANDU6 reactor in Romania, after 10 years of operation. It explains why the release increase in the first years of operation and how will be increasing in the future. It compares tritium concentration near Cernavoda before and after the commencement of the NPP, based on independent, quality assured measurements by IFIN-HH and will discuss recent data from the Cernavoda radiation protection laboratory. Estimate is made on future tritium releases from the planed 4 units in the year 2030, with and without a detritiation unit. Based on recent assessment tools, internationally agreed, projections on food contamination and public intake will be shown, considering tritiated water and organically bound tritium intake by a the most exposed persons. Based on this activity intakes, dose to the public are assessed considering the uttermost results on tritium dosimetry and risk. First, all potential intakes are considered, from terrestrial or aquatic food chain. Next, the contested ICRP dosimetric coefficients are disregarded and a metabolic and physiologic model of tritium retention in humans is considered, including an increase of tritium Radio Biological Effectiveness (RBE). This dose estimates are translated in potential health effects, as risk of mortality or morbidity, disregarding any threshold. Finally, recent results on biota radioprotection will be discussed, showing a 'no effect' at doses less than 30 microGy/y, close to our 2030 public dose.
Recommendations are given for intensifying the safety improvement at Cernavoda, for decreasing the probability and consequences of a tritium leak, as well as for decreasing the uncertainty of radiological assessment models. Despite limitation of humankind in understanding our future, it is concluded that pregnant women and mothers with very young children can stay safe near Cernavoda reactors with on the condition of increasing the safety culture to the plant staff and managers.

Introduction

1. We followed the debate on potential huge risks from tritium and I will point out some important steps:

- In 1997 Dr Fairlie analyzed the tritium emissions from Chapelcross, a British site emitting about 1000 TBq/y of tritium and recommended that pregnant women and infant must be evacuated from the near settlements, due to the dangers of tritium.
- In the period between October 2001 and October 2004, CERRIE was an independent Committee established by the UK Government in 2001, following concerns about the risks of internal radiation (CERRIE 2004). Dr Fairlie called for an increase of tritium dose coefficient by 15 times for tritiated water (HTO) and much more for organically bound tritium (OBT). Some members in the committee sustained this view, few accepted ICRP dosimetry and the majority accepted that current ICRP dosimetry can underestimate due to increased Radiobiological Effectiveness (RBE) by a factor 2-4. The committee analyzed a paper by Dr Harrison (HARRISON 2002) concerning uncertainties in the ICRP dose coefficients demonstrating that the central value (50 % of probability distribution) is about a factor of 2 higher than the ICRP's. All members concluded that more research is needed
- In the Subgroup on the tritium internal dosimetry of the Advisory group on Ionizing radiation (AGIR) (Health Protection Agency-UK) the debate between Dr Harrison and Dr Fairlie continued without any agreement (12 July 2005)
- Under Greenpeace Canada (2007), Dr Fairlie published this year a report on Canadian CANDU reactors and tritium risk. He again claimed a 12 time increases in the HTO dose coefficient and much more for OBT. He again recommended that pregnant women and young children (under 4 years old) and their mothers should be advised do not live near (ie within 10 km) of CANDU reactors
- A reaction to the report was published by Dr Osborne, supplying points against Dr Fairlie's opinions.
- Recently, Dr. Fairlie was accepted, as expert for NGO, in the UK National Dose Assessment Working Group
- Claims for enhanced risk from tritium are also addressed recently (Makhijani 2006) giving grounds for more research on the effects on foetus and for establishing more robust standards for tritium in drinking water, as for the possible synergism between radioactive and chemical pollution.
- The majority of researches I interacted with agree that RBE for tritium is higher than 1, OBT formation and health effects are not sufficiently understood and there are needs for further study in order to decrease the uncertainty of radiological assessment. While needs for further work were well established (Galeriu et all 2007), many researchers in the tritium international community consider the advise on evacuating pregnant women and children around tritium producing facilities operating routinely as not supported by evidence.

Present and further release of tritium from CERNAVODA CANDU6

2. As a necessary step, in IFIN-HH research on environmental tritium started with the understanding of production and release of radionuclide in a CANDU and presented our

understanding in journals and conference since 1993 (Galeriu et all1993, 1999a, 1999b). Assimilating the Korean view (SONG 1995) we checked for Unit 1 and compared with other CANDU6. An updated situation for 10 years of operation is given in Figure 1. As expected from the physics and technology of a CANDU, the release is growing but the data for UNIT1 are very close to optimal operation performance. Releases depend on plant capacity factor and tritium leaks from moderator and coolant. As coolant tritium concentration is much lower than in moderator, at the same total heavy water leak, the amount of tritium release depends strongly on the fraction released from coolant. With real data on total leak of heavy water and capacity factor, we run the model for variable fraction of coolant leak (received form the team in Cernavoda). In Figure 2 we observe that the release demonstrates that little tritiated water is leaked from moderator, due to good maintenance and operation at UNIT 1 (exception few first years at the beginning).

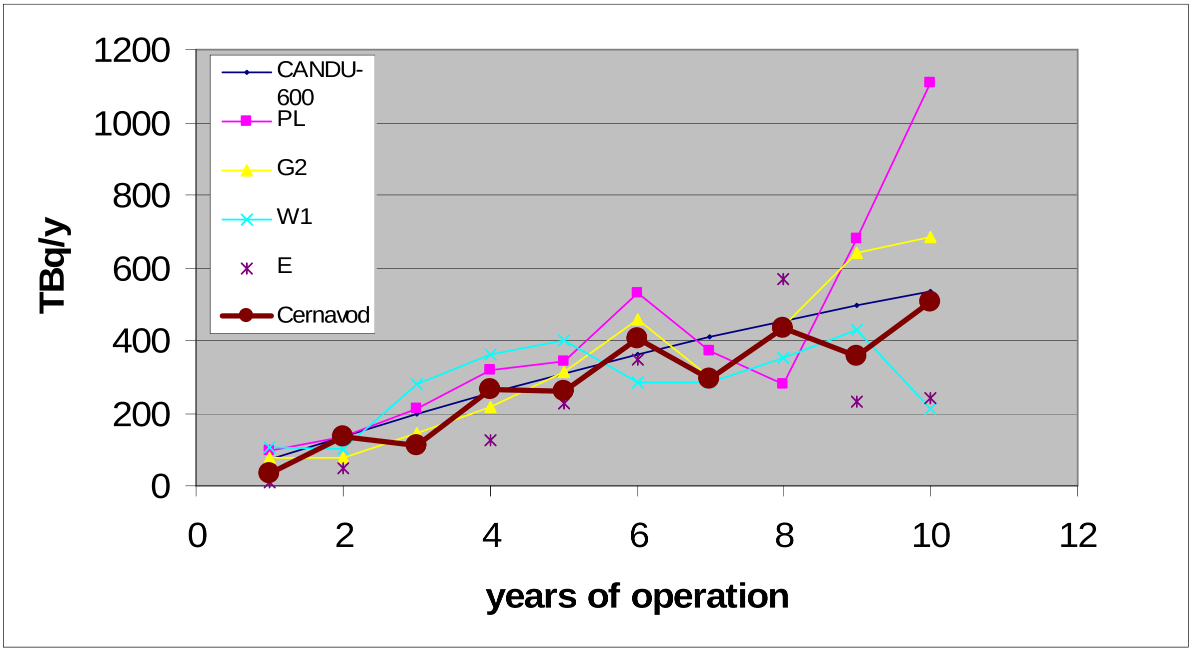

Figure 1. Total release of tritium from CANDU6 for Cernavoda Unit1, Point Lepreau, Gentily 2, Wolsong 1 and Embalse. The standard release for CABNDU600, in good operating condition is given.

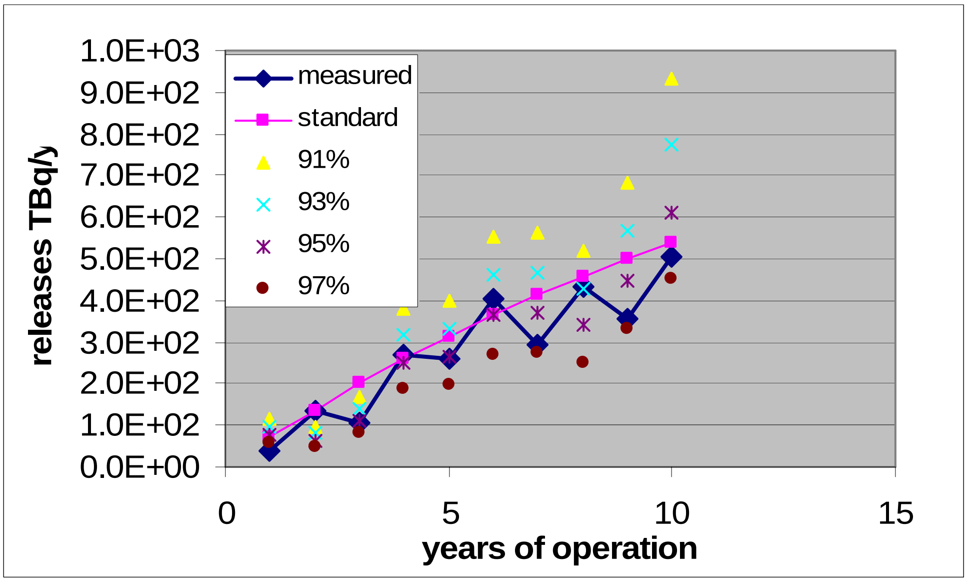

Figure 2. UNIT 1 total release and model results for variable fraction of leakage of coolant heavy water.

Releases occur in atmosphere or in Danube with variable fraction. On average 60 % is liquid release and a maximum of 75 % was released in atmosphere. For projection in the future we used average release fraction and plant performance. As Unit 2 is now in operation and Units 3 and 4 are planned, we include in our projection to 2030 all 4 units, with and without a detritiation facility. The projected total releases until 2030 are given in Figure 3. We considered a moderate detritiation facility and make our prediction following a Korean paper (Song 2005)

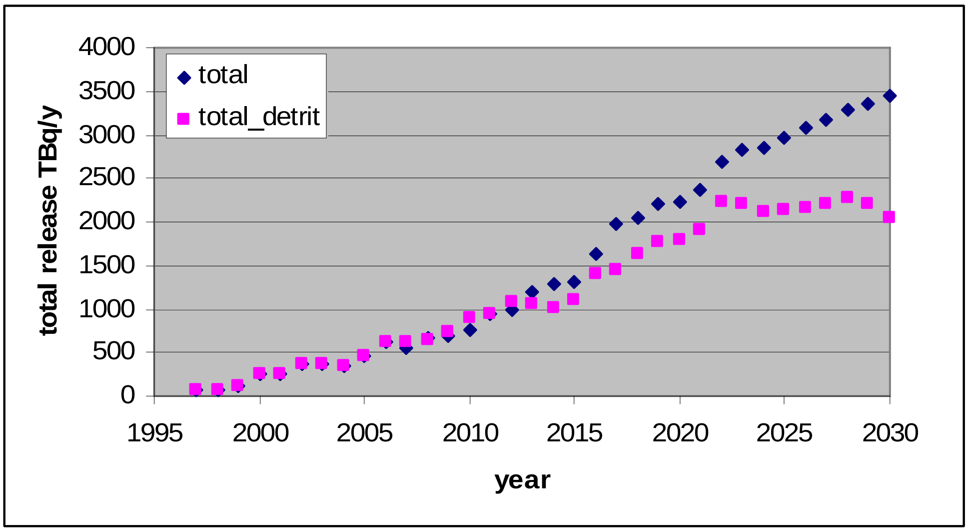

Figure 3. Total release at Cernavoda. Projection after 2006, considering Unit 2 in operation from 2007, Unit 3 from 2014 and Unit 4 from 2015. Detritiation unit fully operational from 2012

In 2030, with detritiation unit, the total release will be near 2000 TBq/y and the atmospheric release will be less than 1000 TBq/y. These figures are close to the estimate by Dr Fairlie.
At the first glance the figures seem very high but the real aspect to be addressed is the actual environmental impact and the public dose.

Environmental tritium near Cernavoda.

3. At the time when work in Cernavoda restarted, IFIN-HH decided to fully upgrade the performance of environmental research and to focus on tritium. Since 1991, technical assistance was obtained form IAEA, research funding from the Ministry of Education and Research, as well as from the European Commission. Instrumentation and techniques were upgraded, intensive training abroad (Germany, France, Canada) was carried out and many inter-comparisons of tritium measurements were done until we achieve enough skills for quality assured results (Paunescu 1995, Cotirlea 1998). Preoperational monitoring of tritium around Cernavoda was done by the team from IFIN-HH and included in the safety report of Unit 1, as well as in conferences or publications (Paunescu 1997, Margineanu 1998, Paunescu 1999).). We monitored the increase of environmental tritium until 2001, acquiring a data base on evolution in air, soil water, rain, vegetation, crops and animal produce (Paunescu 2002, Galeriu 2003). Results have been communicated not only in reports and journal but also to the public (a series of papers in mass media around Cernavoda). The evolution of tritium concentration in air, unploughed soil water and wild vegetation is given in Figure 4. Results for tritium in cereals are given in Table 1 and demonstrate variability of results due to dynamic of release and atmospheric transport.
In order to asses the tritium activity intake for the public around, monitoring data on air and produces are not enough due to space and time variability and financial limits. The international practice is to combine with environmental transport models. Involved in the international collaboration we start to improve the available models, adding OBT as well many specific product around Cernavoda (Galeriu 1994, Galeriu and Belot 2002). We improved the model for farm animals in recent years (Galeriu 2007b) and incorporating the new transfer parameters obtaining in the revision of IAEA Tecdoc TRS 364 (Davis et all 2007). Today we have robust environmental models for tritium from routine operation, tested in IAEA working group for tritium and used by us for Cernavoda. Changes of Romanian guidance are on going (it was based on the old Canadian standard) in order to agree with recent progresses. We apply our model using measured dispersion factors as reported by Cernavoda staff, in order to avoid supplementary uncertainty from atmospheric transport model.

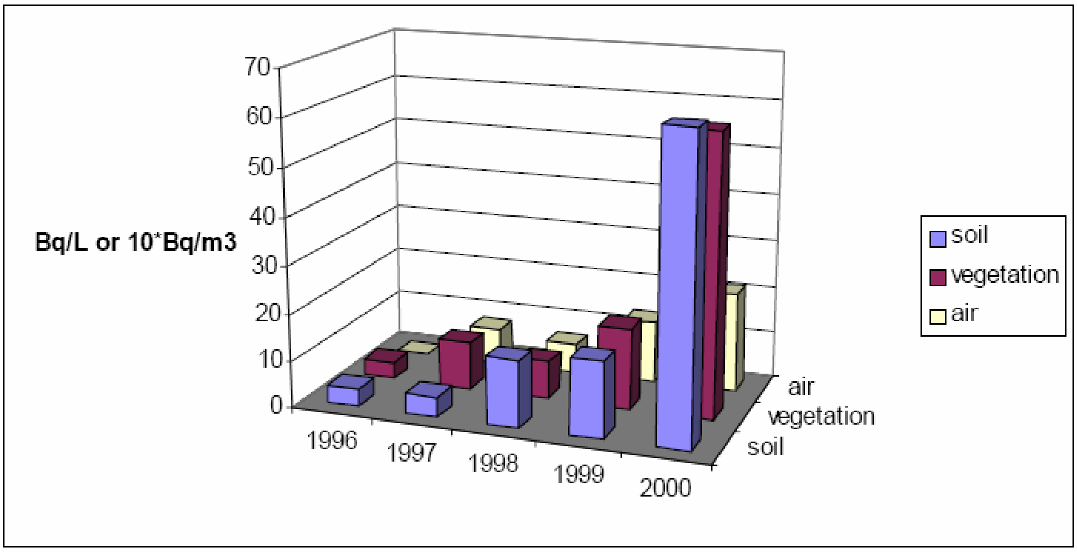

Fig. 4. Annual averages concentration in Cernavoda area (2500 m) in soil water (Bq/L), tissue water of spontaneous vegetation (Bq/L) and air (10 * Bq/m^3)

Table 1. Tritium in Cereals

year	Sampling site	concentration Bq/kg
1997	Valul lui Traian	8
1998	Valul lui Traian	6.2
1999	Satu Nou	14
1999	Faclia	35
2000	Valul lui Traian	7
2000	Faclia	18.5
2001	Valul lui Traian	5.5
2001	Faclia	35

OBT in cereals was also measured with values of 6-15 Bq/kgfw. It is suggested that high HTO in 1999 Faclia is due to previous days high HTO air concentration.

4. Case study: 2006, Cernavoda location

To illustrate the performance of our environmental transfer of tritium, when air concentration is well known, we compare our model results with reported values for Cernavoda town-Location ADI-08), taken from the environmental report (EPR2006).

Table 2. Comparison between models and data for tritium near Cernavoda NPP in 2006

produce	EPR 2006	Model HTO	Model OBT
Vegetables	14	40	3.5
Fruits	19	45	3.5
Meat	7	7	5
Milk	13	15	5
Grass	10-47	30	4.5
soil	75	60	
Rainwater	210	60	
Surface water	150 (close to UNIT 1 fence)	55	

Our model predicts higher values for vegetables and fruits (up to a factor 3) but lower values for rainwater and surface water- as measurements were closer to the NPP than we considered For fish we consider the worst situation, 50 Bq/kg and for the drinking water we consider a higher value than from only Danube.

In order to assess public dose, Cernavoda staff is using ICRP dosimetry, enforced by Romanian law. They apply two methods - one based on measured activity of air and food, other by using emission and a model, enforced by our regulatory commission and translated from the old Canadian standard) With the first method they assess 0.12 μSv/y, while with the second (old standard) 7.8 μSv/y. With our improved model we obtain 0.7 μSv/y. Note that our model values in Table 2 are higher than measurements. We used a different diet and much more detail in products (wine, sugar, oil, milk products etc). The old Canadian standard seems too conservative.

Our model predicts an annual intake of less than 22 kBq of HTO and less than 3k Bq of OBT.

Dr Fairlie, in his Table 3 Current tritium concentrations in foods at Cernavoda, gives close values to those above but note that:

“These concentrations are certainly raised and are much higher than they would have been if Cernavoda 1 not existed. In addition, we need to add up the tritium intakes which people living in Cernavoda would receive each year from all sources. We make an estimate of this in table 6 on page 9".

Considering the value in Table 6 (page 9 of Dr Fairlie report), we observe that *Dr Fairlie's estimate of intake [84 kBq of HTO and 2 kBq of OBT] are not balanced (OBT/HTO) and too high for the conditions in the last years. They reflect a worst situation- higher release and bad atmospheric dilution.*

5. PROJECTED, WORST CASE INTAKE FOR 2030 (with ICRP dose)

As from figure 2, the total release will be near 2000 TBq/y and we take the highest fraction to atmosphere, until now. In this case we will have 1500 TBq/y. We consider also the worst atmospheric dilution factor until now (2001, yearly average) and run our model. We obtain a total intake (**per year**) of 60 kBq HTO and 9 kBq OBT [close to Table 6 of Dr. Fairlie]. For ICRP dosimetry the maximum dose predicted is **19 µSv/y**. **This value is 1.3 % of the internal dose from the background.** Note that the conditions taken were worst and our model seems not to underestimate the intake. The significance of this projected dose will be discussed later.

OTHER ASPECTS OF INTEREST

6. Dr Fairlie noted that people from Fetesti and Megidia can be affected at levels close to Cernavoda. Dr Fairlie observed that Fetesti is in the direction of second prevailing wind. The town is at a distance of 18 km from the stack, Weast. We reproduce the dispersion pattern from the EIA in Figure 5 and it is clear that Fetesti is less affected than the closest location to NPP.

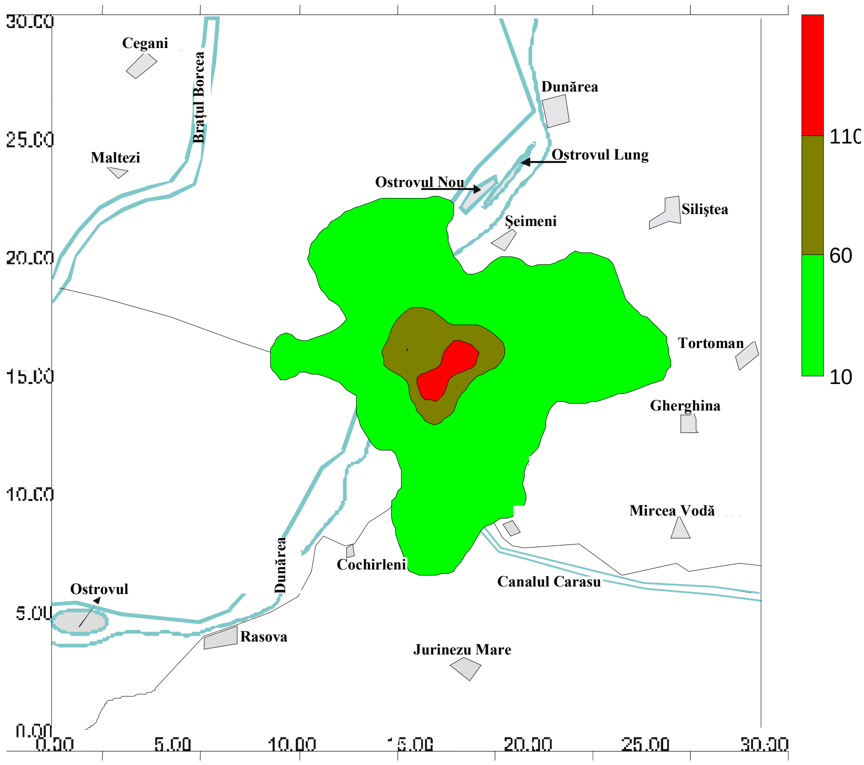

Figure 5. Dispersion factors (10^{-9} s/m^3)

7. Dr Fairlie also noted (page 10, para 35) that**:**
"There may also be a problem with members of the public who live with Cernavoda workers who are occupationally exposed to tritium. Workman et al (1998) showed that the indoor air of such homes had 70-fold elevated tritium levels compared with outdoor concentrations, and that their daily tritium intake was 18 times higher than adults living in a non-occupationally exposed home"

The above conclusion is based on observation in Deep River and report an experiment done in 1992-1993. It happens that I was on training at AECL and participated directly (Trivedi et all 1997). Deep River is 12 km far from the reactor and the worker at the reactor have a urine concentration of 30kBq/L. This corresponds to a dose of 0.8 mSv/y for the atomic worker (due to tritium). The co-occupant of the house has a urine concentration 100 times less and his dose was 7 μSv/y (15 times more than the other people). Because of large distance to the reactor, the influence of the reactor was low, and the air concentration was only 3 times more than the most far (300 km) locations. The situation differs in Cernavoda, only at 2.5 km form NPP. The co-occupant will have a dose increase by about 50 %. Many would rightfully consider this **a low price for the improved life condition for an atomic family**. The significance of an extra 10 μSv/y will be discussed latter

8. Dr. Fairlie also expresses concern for people exposed to liquid releases in the Danube-Black Sea Channel. The releases in the channel are about 10 % from total liquid releases and can be 120 TBq/y in 2030. This can increase the average water concentration by 20-80 Bq/L. This water will be used for drinking and irrigation. Settlements along the channel are at different distances from NPP and the HTO air concentration will depend on distance and meteorological conditions. For close locations, the contribution of channel to public dose will be a fraction of those from the air pathway. Only for far location the channel HTO will have a significant contribution but in any case the public dose is less than for Cernavoda. Only for the collective dose, the channel contribution must be included for far locations.

9. Dr. Fairlie also is concerned for the effect of pulsed emission- masked when we used year average. He explains: Pulsed tritium concentrations could in theory result in heavy labelling of cells being formed in the embryos and foetuses of pregnant women at that particular moment. (He cited a reference form '79)
In fact tritium emission from the NPP is not at all continuous but in a series of pulses differing in length and amplitude. Due to changing meteorological condition, pulses are spread around and in the long run we have the same pattern as for uniform emission. It is also well known that a single intake of radionuclide (X Bq) gives the same dose as a prolonged one with the same integrated activity intake (X Bq) for release of moderate intensity, as in this case. I therefore submit that the fear of Dr. Fairlie on pulsed emission is not founded. As for embryos and foetuses, we will refer later.

10. In the first part of his report for GREENPEACE, Dr. Fairlie is keen on emphasizing large numbers (1TBq=1000000000000 Bq) and insists on what he sees as the very large emissions and discharge from the CANDU reactor as well as on some situation he considers of relevance to argue on enhanced risks. We explained that most of his special situations are less relevant in discussing highest intake of tritium. As his predicted release for 2030 are not far from ours, and the numbers describing tritium intake in the public are not far from ours, it

remains to analyze the second part of his report (from para 38 to the end). It seems also that Dr. Fairlie's information on the Romanian stands and actions concerning the risk for tritium (including OBT) is not quite satifying.

11. While**,** in official reports, ICRP dosimetry is used, as in any European country and many others, the staffs in Cernavoda, nuclear regulators and researchers are aware of the debate on tritium risk and dosimetry. Uncertainty of the ICRP tritium dose coefficients (Harrison 2002) are recognized as well as the importance of OBT. Considering the potential increase of tritium dose coefficients, actual maximum worker dose at Unit 1 and heavy water efficiency, a detritiation unit is planed to be functional in 2012. In parallel research on tritium was enhanced, focusing on environmental transport, OBT formation and dynamics in plants and animals in routine or accidental situation. Work on tritium dosimetry, started in 1993 in collaboration with AECL [Trivedi Galeriu Richardson 1997, Trivedi Galeriu Lamothe 2000] continued in a large international context. Romania was present in the tritium working group of international coordinated research (BIOMOVS, BIOMASS, and EMRAS) as well as in fusion related projects. The debate on tritium risk was duly monitored and research was intensified for tritium dosimetry at the time of debate in the CERRIE group and after (see introduction).

12. Being involved from many years in the field of radiation protection, I am aware of international and national concerns and actions:

- Our Nuclear Regulatory Body (CNCAN) imposed rather tight public dose limits (0.1 mSv/y per nuclear facility), that are lower than the general one, given in the Law(1 mSv/y)
- Romania has signed the agreement with the IAEA on Country Programme Framework in full compliance with the international safety requirements (see the web www.agentia.nucleara.ro/cpf.php). After accession to EU all nuclear Law is harmonized with EC regulations. Implementation of EC practices is ongoing.
- The national nuclear authority - CNCAN - enforced the safety requirements for all institutions dealing with tritium (ICSI, IFIN_HH, ICN, CNE), in full awareness of the fact that this entails delays and extra costs.
- A full refurbishment of the tritium laboratory (Radioisotope Production Center IFIN-HH) is now started (ref) in order to enhance safety and decrease releases
- As most of routine or potential accidental tritium release is in liquid form and there is some debate on huge fish OBT in Cardiff bay (UK), we have developed and published a first dynamic model for aquatic release- including OBT (ref) and expanded the endeavor recently, with an application to Danube's ecosystem. Cardiff situation is peculiar as dissolved organic tritium compound are released in the bay and may indeed produce a considerable OBT buildup in fish. This is not the case in Romania. For an accidental release of 3.7 PBq (*3.7*1000000000000000* Bq) HTO in Danube, the public dose (fish, drink water ingestion, contamination of crops by irrigation) is close to 10 μSv (*0.000001* Sv) on average and 4 times higher as upper estimate (report available in Romanian; it was send to Cernavoda). The ability to model tritium dynamics in river was tested in the framework of international WG (EMRAS aquatic WG). This again demonstrates the low radiological impact of tritium liquid releases, as compared with the atmospheric ones.
- Researchers in IFIN-HH are involved in the international effort to clarify the environmental transport of tritium and conversion to OBT (see for example www.nipne.ro/emras). Their work is well appreciated by the scientific community and distributed to Cernavoda practitioners on radiation protection.

- IFIN-HH has implemented locally (pilot study) the EC decision support system for nuclear accident (RODOS) and produced a beta version for a new tritium module for accidental releases (Raskob 2000). Recently, the present situation on tritium radioecology and dosimetry was revised and the requirements for the new generation of accidental tritium model were established (Galeriu et all 2007a) as present uncertainties were considered too large.
- For the transfer of tritium in animal produces , under routine conditions, better transfer model were recently published (Galeriu et all 2007b)
- After publication of CERRIE report with the debate on tritium risk, dedicated project proposal were financed by Romanian Ministry for Education and Research and a new metabolic model was used for tritium public dose (Melintescu et all 2007). Results will be discussed latter.

- Dr. Fairlie referenced the IEER report on "Sciences for the Vulnerable" (Makhijani 2006) when proposals to take into account age, gender and populations in radiation protection were suggested. At the same time of publishing the above report, we issued our first results on tritium dose coefficients for various ages, genders for Caucasian and Japanese reference humans (Galeriu et all 2006). We intend to expand our research for pregnant women and infant.

- I agree with Dr Mike Thorne on the **Radiation, Chemicals, and Combined Adverse Health Outcome (see chapter 6 in** (Makhijani 2006)**),** synergism model and that exposure to toxic chemicals that will interact with radiation-induced damage in complex and poorly understood ways. . However, I see it as an intellectual challenge, and not as grounds to inhibiting positive action.

- I followed the debate on tritium standard for drink water (including California case) but consider that it must be done in a larger context considering energy resources, chemical pollution and optimization of cost, risks and benefits to human health. This must be done case by case and not imposed for a general practice. It also must be done in the frame of comparative risk assessment of all human activities. World Health Organization take a limit of 7800 Bq/L but there is a large variability in each country regulation. Recently Romania adopted a lower limit 100 Bq/L as yearly average

OUR PROPOSAL FOR TRITIUM DOSE COEFICIENTS

13. We have carefully considered all arguments of Dr. Fairlie concerning factors producing enhanced dose coefficients for tritium. In the context, we call the attention on the following aspects:

- **Hydration shell**, when hydrogen and tritium are confined in the layers of water molecule bonded around biomolecule having a long residence time. This is the source of buried tritium, which is added to OBT. Experimental work and theoretical analysis were considered and discussed in the Tritium and 14C Working Group of IAEA EMRAS research. It was concluded, again, that there are no implication on the absorbed dose and health effects are included in RBE (see Melintescu et all 2007 and web page of EMRAS WG)
- **Higher retention of tritium than in ICRP model**. For HTO intake it was demonstrated that the metabolisation and retention of OBT will not increase the dose more than 11 % (Trivedi et all 1995,2000). Concerning OBT retention, we recognized early that this is not still clear and we make attempts to find a solution, independent of ICRP assumptions. After analyzing in detail animal experiments we advanced a

new approach based on metabolism and extending the metabolic theory in ecology. We discussed the approach in many scientific media (California and Columbia University in USA, working groups of International Union of Radioecology, IAEA EMRAS etc) and published preliminary results in peer reviewed journals. A full description of the model and tests without calibration will be soon available (ref). The last application for human's tritium dosimetry is under press (Melintescu et all 2007) but results were obtained in 2006. A first review on tritium risk was recently presented in an international congress of IRPA (Galeriu 2007d)

- **Tritium RBE**. We agree with Dr. Fairlie on RBE>1(see Fairlie 2007) and the large data base on tritium RBE was considered with a probability distribution for HTO extends between 1 and 3.5. For OBT, in 2006, it was considered an upper margin of 4, but most recently we acceded a Health Canada paper on microdosimetry (Chen 2006) assessing a factor 1.7 relative to HTO RBE . Our results in (Melintescu 2007. in press) must be corrected now.

14. Revised public tritium dose coefficients (proposal)

The model we promoted is able to assess the tritium distribution in major organs groups and the non uniform distribution was demonstrated and confirmed with animal experimental data. As much of tritium is agglomerating in adipose tissue, with low radio sensitivity, we use the Effective Committed Dose with tissue weighting factor extracted from the last ICRP recommendation (ICRP2007). Our model is probabilistic considering variable key parameters (see Melintescu 2007) as water intake, RBE, metabolisable fraction and composition of the diet. For more details see ANNEX1. Previous reported result have been corrected for a higher RBE for OBT, as we intend to be conservative. The final results are given in table 3 considering the probabilistic committed effective dose with 95 % range and also with central value. We compare our results with current ICRP recommendation as well as with Harrison paper on uncertainty of ICRP public dose coefficients. In practical operational dosimetry for public, gender is not considered and central values are used, as we assess an average person. Values obtained in this case are greater than ICRP by a factor 1.7-2.5 for HTO intake and 2.6-4 for OBT intake. Our adult dose is quite close with Harrison, and much lower than claimed by Dr. Fairlie. As our results are based on intensive scientific work, documented and peer reviewed, we don't see any rationale to claim higher values. At the upper range of probability we have a factor less than 4 comparing with ICRP HTO dose coefficients and a factor less than 5.4 for OBT intake. It remains to extend the model to infants and pregnant women

At low dose, the mammal organism can adapt to radiation stress (Feinendegen 2005, Dieze 2004) and the Radio Biological Effectivnes (RBE) is lower. A dose reduction factor of at least 2 is used for dose lower than 100 mSv.

WE IGNORE THE EFFECT ON LOW DOSE FOR THE PUBLIC , TO HAVE A VERY CONSERVATIVE ESTIMATE, COVERING POTENTIAL UNUNKNOWN UNCERTAINTY

The model is developed in the past 4 years and was applied first for non-humans. It was tested with experimental data, without calibration or best input parameters. The basic ideas and results were discussed many times with internationally recognized expert groups:

- Emeritus Prof Baldwin and prof. Oltjen Animal Science at California University (2005)
- Prof Heymsfield, S. B and Dr *Dympna Gallagher (*Assistant Professor of Nutritional Medicine) Department of Medicine and Institute of Human Nutrition, Columbia University (2006)
- Prof. David Taylor (UK) with the longest record for dosimetry of tritium and carbon (2007)
- Emeritus Prof Saito (Kyoto University) internationally recognized for his work on tritium in mice and dosimetry
- Emeritus Prof. Franz Baumgartner, Technical University Munchem (Buried triutium, hydration shell)
- Prof Mihail Balonov (Rusia), who was done experiments with tritium in animals and established in the past the standards for tritum in the former Soviet union

- The tests with animal data were discussed in EMRAS (an expert group of IAEA on Environmental Modeling for Radiation Safety) and with experts of the International Union of Radioecology
- The co-authors on our work are well known scientists

1. Dr Neil Crout ,Professor in Environmental Modelling, School of Biosciences, Faculty of Science Nottingham University UK
2. Dr. N. Beresford,CEK_UK, Expert EU on radionuclide transfer in farm animals, and biota radioprotection
3. Dr H. Takeda, NIRS-Japan, With a long list of experiments on rats, modeling and dosimetry
4. Dr. R. Peterson (LLNL-USA, retired) recognized expert for tritium transfer into the environment and dose reconstruction after tritium releases
5. Wolfgang Raskob, IKET-FZK Germany, author of tritium code NORMTRI, UFOTRI and leading EU large contracts on decision support systems for nuclear accident management
6. Dr. A Trivedi (Health Canada, deceased), with recognized contribution on biology and dosimetry of tritium
7. Dr. P Davis (AECL-Canada, Chairman of the WG Tritium&14C in EMRAS)

15. As ICRP in his last recommendation still preserve an RBE =-1 for prospective and compliance dosimetry (as our Cenavoda case) we do not expect that our results will be met with immediate approval by the ICRP and other international or national organisations, but we will however use these as an assuption basis in our studies, and also for a transparent and honest communication to the public offsite Cernavoda.

Table 3 New tritium dose coefficients (units 10^{-11}Sv/Bq) with corrected RBE for OBT. Reported committed effective dose E

	ICRP	E(RBE>1)	ratio to ICRP
HTO			
1 y	4.8	8.6 (4.9-13)	1.79
10 y	2.3	5.8 (3-9.5)	2.52
Adm	1.8	3. (1.5-5)	1.67
Adf	1.8	3.2 (1.6-5.4)	1.78
adult	1.8	3.1 (1.55-5.2)	1.72
Harrison adult	1.8	3.9 (2.1-6.6)	2.17
OBT			
1 y	12	35 (16-50)	2.92
10 y	5.7	21.2 (10-30)	3.72
Adm	4.2	11 (5-21)	2.62
Adf	4.2	16.5 (7.5-23.8)	3.93
adult	4.2	14(6.2-22.5)	3.33
Harrison addult	4.2	8.7(3.9-20)	2.07

16**. Conservative estimate of pubic dose from routine emission in Cernavoda 2030**

For atmospheric release in 2030 we take the highest fraction from total release and for dispersion the worst condition observed until now as yearly average. Also our tritium activity in produces is not underestimated with present experimental data. When we apply the above proposal for dose coefficients to the predicted intake of HTO and OBT for exposed people in Cernavoda town, the following values are obtained (Table 4):

Table 4 Public dose in Cernavoda town 2030 **µSv/y**

Age	1 y		10 y		Adult	
	HTO	OBT	HTO	OBT	HTO	OBT
Dose	19	17	18	18	14	12
Total dose	36		36		26	

Values above, obtained with our recent models under very conservative conditions, must be compared with the present dose constraint of 100 **µSv/y** and we see that they are 3 times less! We included higher RBE as claimed by Dr Fairlie and sustained by many others and our human metabolic model is based on advanced modeling and tested, for non-humans, with many experimental data. **Our model** was also tested for human intake of tritiated water and **is the only to correctly predict the amount of OBT in urine after HTO intake.**
We ignored the reduction of dose (or RBE) at low doses for the assessment of public dose near Cernavoda.
It is possible that habit data will change in the future and our activity intake prediction will be altered in some respect. Also it can be asked to consider critical group with higher intake. If they are athlete, the dose coefficient is lower than in table 4. If they are obese the dose coefficient increase leas than 10 %. **In any case one believes it is hardly possible that the dose will be higher than 100 µSv/y, the present constrained upper limit.**

17. Health Risk assessments

Ionizing radiation, as tritium or radioactive potassium and many other were present around from the begin of the human society and are included in the natural background. This varies today between 1mS/y and 10 mSv/y form country to country. In Romania it is around 3 mSv/y and we must also add a small contribution from medical used of radiation. From Table 4 we observe that the dose due to tritium is 1 % from natural background. There is well established that at high dose (>1Sv/y) ionizing radiation affect human health and risk coefficients were established (mortality or morbidity due to various kind of cancers, hereditary disease etc). At doses lower than 0.1 Sv, it is difficult to observe health effects of radiation and at doses <0.01Sv no effect was observed until now to be attributed only to ionizing radiation. The general practice in radiation protection is to estimate risks for protracted exposures to low doses by extrapolating from situations of acute exposure to high doses For this, a linear dose response model with no threshold is assumed and risk estimates are divided by two to allow for the assumed reduced carcinogenicity of exposures received at low dose rates (in other word we apply a dose reducction factor). Based on this extrapolation a risk factor for lethal cancer is estimated (median value of 5.2 10^{-2} per Sv). Current recommendations form the International Commission on Radiological Protection (ICRP2007) is to limit occupational doses to 100 mSv over five years (not to exceed 50 mSv in any one year) and doses to the public to 1 mSv per year.
For a lifetime of exposure of the population to all sources of ionising radiation (natural plus man-made) could be responsible for an additional risk of fatal cancer of about 2% – this can be compared with a life-time risk of cancer of about 20–25% from all causes.
As low dose estimate of cancer risk are based on extrapolation, a large study on atomic worker form 15 countries was realized in order to assess the increased mortality of cancer due

to professional risk (Carlis et all 2005). The study includes 407 391 workers individually monitored for external radiation with a total follow-up of 5.2 million person years and find 1-2% of deaths from cancer among workers in this cohort may be attributable to radiation. This was slightly over the median risk recommended, but in the range of uncertainty.

We will ignore the dose reduction factor, to have a very conservative risk estimate for potential health effect of tritium in Cernavoda due to normal operation of 4 reactors in 2030. The risk factor we use is expressed as cases per year and are representative for average population subject of continuous irradiation, for a dose of 1 Sv/y . For mortality from cancer we use 0.012 (cases/y) while for hereditary disease 0.004 cases per year. Note that for child of 1 year, the risk is about 3 times more than for average adult. From our table 4 and the above conservative risk coefficients we obtain, for adults 4.2 10^{-7} cases per year and for child 6.1 10^{-7} cases per year. The period for operation of all 4 reactors is limited by the reactor life permit and can not be greater than 50 years. It results that, for all period, a person from the public in Cernavoda will have a mortality risk from CANDU radiation induced cancer of no more than 0.00002. We can compare this maximum estimate with the normal risk from natural induced cancer dead in Romania from the same person >0.2. The effect of tritium is insignificant, even with our very conservative estimate. The same conclusion results for hereditary disease. There is no rationale and no scientifically basis to discuss on such health effect for the normal operation of CANDU reactors for child or adults.

18. The case of pregnant woman and infant.

In his last recommendation ICRP (2007) confirm embryonic susceptibility to the lethal effect of irradiation in the pre-implantation period of embryonic development but stress that at dose under 100 mGy such lethal effects will be very infrequent, malformation will be not expected and the life time risk of cancer dead after in-utero irradiation will be similar for child, about 3 times more than population as a whole. The dispute on the special case of pregnant woman starts from the experimental observation of increased radiation risk of fish eggs and to specific processes at cell level concerning radiation effect on DNA. Experiments with OBT or HTO on animals' shows that tritium concentrate on DNA and the cell at most risk are those dividing at the time of exposure, cells in embryo, nerve cells and oocytes (female germ cell involved in reproduction). Analyzing bone on deceased Japanese people it was observed (Hisamatsu 1989) that tritium can be observed in cartilages only for peoples born in the time of atomic bomb fallout and the biological half time must be long- 5-15 years. These findings generate the hypothesis that embryos and fetus are at higher risk. Subsequent studies were done to compare DNA damage in adults and fetus. In their adaptive evolution, mammals developed repair mechanism of damaged DNA, very effective at low environmental doses. This was absent in oocytes. Recent studies (RBC 2007) shows that it is highly likely that fertilized egg or early embryo with unrepaired damage may be eliminated by apoptotic killing and prevent the heritage of damaged genome to the next generation.

In the large national program of Dose Reconstruction at nuclear sites in USA, past tritium releases were analyzed for Los Alamos, Savannah River and Lawrence Livermore Laboratories. Special attention was taken for the topic of pregnant woman and the probability of a health effect on the oocytes was assessed (ATSDR 2002). It was stressed out that:

"The conclusion is that certainly less than 1% (and, more likely, less than 0.1%) of pregnancies occurring in women who are exposed to food contaminated with tritium at the current levels observed around LLNL and SRL will have arisen in an oocyte that has experienced a dose from the beta decay of tritium that was incorporated in oocytes during oogenesis. A fertilized oocyte (a zygote) divides resulting in a rapidly developing embryo and the large number of divisions will quickly eliminate the remaining tritium in the nuclear DNA. Hence, the risk of interest is that associated with one or two tritium decays in the oocyte nucleus before fertilization. For a dose of 15 μSv the range of overall probability of a severe hereditary effect attributable to oocyte labeling at oogenesis would then be approximately is in the range 2×10^{-7} to 5×10^{-6}. "

We conclude that, for the actual and future situation at Cernavoda, the tritium released in normal operation will have an insignificant risk for pregnant women and there is no special concern (it is not the case for atomic worker- pregnant woman is not permitted to work on site; also the case of accidental tritium release must be analyzed)

It will be useful to expand our model to infants in order to check if the ICRP dose coefficient (ICRP Publication 95) is conservative. Also, if possible, to expand our model to fetus to check coherence with recent work of Harrison.

19. RECENT EPA views

In his report (para 40), Dr Fairlie refers to an intention of US EPA to increase its estimate of tritium risk posed by human exposure of tritium. We will explain in more detail the situation

During 2006, several nuclear facilities have reported unanticipated releases of tritium to groundwater near old nuclear facilities as well as in landfills. Tritium in groundwater was observed at levels over the USA limits for drink water (740 Bq/L). The public and NGO's become interested and start pressureing for better regulation on drink water limits for tritium (see IEER Memorandum on Tritium 20 March 2006 http://www.ieer.org/comments/tritium060320.html). In the state of California the Health authority was proposed a very low standard for tritium in drink water. In the same time, many researchers have pointed that the RBE for tritium is higher than 1, as it was known from the review of Straume (ref) and observed also in many recent experiments. In the dose reconstruction as well in litigations, a range of RBE was used from some years. A debate starts on changing the low, by increasing tritium risk (RBE) for actual or planed situation too [see **U.S. Environmental Protection Agency; Science Advisory Board Radiation Advisory Committee (RAC)** Summary Minutes of Public Face-to-Face Meeting September 26, 27 & 28 2006]. There is also a problem of litigation (if water quality is out of law, we can claim property damage and ask compensation!; decreasing the water tritium standard, more compensation) After internal debates in EPA, other governmental agency have been involved (see **DOE/EH-0699 2006-04 July 2006** Stakeholder Sensitivity To Tritium Releases http://hss.energy.gov/CSA/csp/advisory/SAd_2006-04.pdf) The conclusion was:

The public will likely be concerned anytime there is a release of a radioactive substance, even if the release is not in violation of any DOE Directive or regulatory standard. It is important that Departmental elements maintain proactive, frequent and open communication with interested Federal, State and Local agencies and officials and the public. Delays in communicating information on new developments may aggravate concerns. The potential environmental and human health risks should be explained in plain English. Sites should take immediate steps to implement corrective actions to mitigate potential impacts, including environmental monitoring. Site managers need to treat this issue very seriously and proactively provide information that address stakeholder questions.

To help maintain public trust, one DOE site developed a webpage which contains fact sheets on site operation that generate tritium and the potential health hazards of tritium in general. The webpage also provides weekly monitoring data of the tritium concentrations in the surface waters in proximity to the site. Additionally, staff has participated in meetings with the local community. Other sites have regular meetings with the community and states and post monitoring, radionuclide fact sheets and frequently asked questions on their websites (see Additional Sources of Information).

DOE ENVIRONMENTAL PROTECTION PROGRAM REQUIREMENTS AND GUIDANCE

Site environmental protection programs provide a mechanism for addressing tritium contamination. DOE Order 450.1, Chg. 2, Environmental Protection Program, requires sites to:

• conduct environmental monitoring, as appropriate, to support the site's ISMS [Integrated Safety

Management System];
- to detect, characterize, and respond to releases from DOE activities;
- assess impacts;
- estimate dispersal patterns in the environment;
- characterize the pathways of exposure to members of the public;
- characterize exposures and doses to individuals, to the population; and,
- to evaluate the potential impacts to the biota in the vicinity of the DOE activity .

NRC is delaying a reaction (NRC 2007).
Tuesday, June 19, 2007 in the News from the Inside EPA Environmental (NewsStand) it was published a review of the situation. Important sentence are reproduced:

- Informed sources say EPA is weighing whether to double the effectiveness factor it assigns for tritium,
- Observers say increasing the effectiveness factor for tritium could result in risk assessments that suggest human exposure to tritium is more harmful, thereby giving federal regulators grounds to tighten tritium containment and release standards at nuclear power plants, research laboratories and places where nuclear fuel is stored.
- A radiological protection expert agrees, saying such an increase in tritium effectiveness factor could "make the NRC mad."

The debate on Tritium risk start in CERRIE committee, continued in the UK Advisory Group on Ionising Radiation (AGIR, from the Health Protection agency) and continues also in the NDAWG (National Dose Assessment Working Group), where Dr. Fairlie represent NGO experts.
The debate on tritium risk at EPA and other agencies in USA resume increasing the RBE. The Environmental Protection Agencies in UK and Canada have considered from some years a RBE of 3 for biota radioprotection.
We have included an increased RBE for human also in our recent model (SEE BEFORE) We used our proposed dosimetry (upper than ICRP) to present our public dose estimates for Cernavoda in 2030. What US EPA intend, we have included.

20. The origin of 30 μSv/y as No Effect limit
In the precautionary approach it is considered that any small amount of radiation above the background can be harmful. Recently the idea of NO effect limits was proposed and some large nuclear companies (as AREVA) declare that the target is to limit the release until the impact of radiation on the public will be lower than **will never exceed the threshold dose of 30 microsieverts per year to reference members of the public. Experts consider this dose level to be synonymous with "zero impact", and it is the working translation of the zero release concept**
In the past it was considered that protecting humans we automaticaly protect the other life forms. This view is not valid today (see positions in ICRP, IAEA, E U, DOE) and a large effort was done to establish the biota radioprotection criteria . As anexternal consultant to E U project FASSET and EPIC, dealing with above topic, I am informed on the follow up projects ERICA and PROTECT (see www.erica-project.org). One of the task in PROTECT is to use ERICA data base on radiation effect for various life forms, in order to assess a no efect limit(in the sense of not posible to observe). The idea was to apply procedures in ecotoxicity of chemicals and to combimne with past experience with radioactive substances.

The project is under way but a working document is available (Protect 2007) and from the preliminary analysis they find a limit for the gamma dose rate of 0.6μGy/h. , below which there wil be no health harm for an animal. Expanding the research for chronic iradiation and considering all types of effects for the ecosystem, it resulted a provisional value of 44 mSy/y, below which the all ecosystem will be not affected in long term (millennium) The natural background varies between 0.3 and 10 mSv/y, with a world average of 2.4 mSv/y . The value for Romania is close to 3.4 mSv/y. Fluctuation of natural background are more that 10 nS/h (86000nSv/y=86μSv/y) along a solar cycle of 11 years
From all about facts, it is considered that a NO EFFECT dose is close to 30 μSv/y.

21 . DRL (COMPLAINED BY Dr Fairlie)
In his para. 23,24 Dr Ian Fairlie expressed his opinions on Derived Release Limits DRL), extremely high on his view. It happens that we have some experience (Galeriu 1993) and have exercised and agree with the general opinion that uncertainty is important. BUT DRL are indicative only in practical situation and are subject of improvement. For Cernavoda, they were established following the old Canadian standard, now under full revision and soon to be published. From 2008 DRL will be assessed following EU guidance. Improvements are also possible in the future including further IAEA technical documents, the new Canadian Standard (under approval) and EU upgrades. On last aspect IFIN-HH is involved (see http://www.nipne.ro/emras/presentations/EMRAS_2007_Bogdan_Vamanu.pps)

22. Epidemiology. Dr Fairlie , in the GREENPEACE.ro report make a short reference on epidemiological studies around tritium facilities (para 34). He recognizes the difficulties to evidentiate tritium effects on the peoples health situation around nuclear facilities, at the present level of knowledge . Still he is stressing the potential health effect. In his GREENPEACE. Canada, Dr. Fairlie give a list of supposed case when "epidemiological' studies indicate tritium health effects. In the name of Canadian Nuclear Association, Dr Osborne replies and demonstrates that it was not the case near Canadian sites. As for Romania, the radiation hygiene network in the Ministry of Health has done intensive studies and can be contacted for robust and reliable information. Also the Romanian Radioprotection Association is indicated for a review.

23. Never enough safe: list of proposed actions

IFIN-HH is involved in nuclear research, with application in nuclear energy and radiation protection, from many years and has acquired international appreciation. We are also in close relationship with IAEA and are committed to increase the nuclear safety. While the present situation in Cernavoda is fully safe for the public, we analyze the future actions needed.

- In order to preserve the quality of operation at Unit 1, in the future, training of peoples (further atomic workers) must start from the high Schools, and continue with safety culture, radiation protection (incl. Tritium) reactor physics and engineering (IFIN-HH can be of help). It is predicted that a shortage of nuclear manpower will come near 2020. To stabilize our workers at Cernavoda, affordable life and income conditions must be assured.

In order to cope with further requirements on safeguard and radiation protection, as will be imposed by EU and IAEA, some technological improvement in the emission and environmental monitoring are recommended

- Spectrometric stack monitoring of noble gasses,

- Better and faster meteorological sensor and additional instrumentation to qualify local atmospheric turbulence
- Acquisition of the local hourly full meteorological data base (needed in probabilistic radiological assessment (PSA 3)
- Enhanced food monitoring, as was started recently (cereals, OBT)
- Further improvement on DRL and routine public dose assessment guidance, including state of the art on tritium and 14 C (IFIN-HH can help)
- A new habit survey must be planed, due to change in the last years, and accompanied by a tracking of cereals production, processing and redistribution (source of uncertainty in dose assessment)
- A data base- GIS- on land use, topography, soils, population, habit. This is mandatory to implement model assessment tools for routine or accidental situations

The public does not trust the data reported by the utility- this was observed in many countries. ***It will be very useful if the Ministry of Health will enhance the Constanta Laboratory for hygiene and public health (radiation hygiene) with tritium measurements under quality assurance***. Their network is charged with food monitoring and for tritium this are the most contributor to public dose. They can add also some air measurement for tritium, to have a full , independent, assessment for the Constanta area.

Routine operation of U1-4 can be assured with moderate cost. But CANDU, with his huge load of tritiated water and circuitry can be subject of incidental releases of tritium. While the new CANDU6 have only 1 small event of such type until now (compare 6-8 for old generation) it is possible that tritiated water can escape into the environment. An intense preventive maintenance, started at Cernavoda must be continued at all Units, as it significantly decreases the probability of a major tritium leak inside the NPP. To avoid environmental release into atmosphere (larger consequences) envelope integrity must be also enhanced, including operator errors). CANDU6, with double safety system have an extremely low probability for severe accidents with core melts (as Chernobyl) and these events are included in the today decision support systems (Raskob 2000) but accidental tritium emission can not be excluded. We asked, some time ago, for a safety analysis (PSA 2) for the probability of ONLY tritium accidental releases and the staff in Cernavoda and Pitesti is working on this topic.

It is now our task to establish levels of tritium emission of concern and to decrease the uncertainty of radiological assessment under accidental atmospheric release of tritium. These are on going under international and national collaboration. The design of the next generation of accidental tritium radiological assessment models was done (Galeriu et all 2007a,) as well as realization of many sub-models. The risk and vulnerability of our infrastructures, including nuclear, have been taken into consideration and we are asking that international collaboration in the future IAEA Coordinated Research Project must concentrate on:

1. Climate change influence on our Environmental Models for Radiological Assessment (EMRAS-climate change)
2. Radiological assessment and safety enhancement for terrorist attack
3. Integrated nuclear energy cycle radiological assessment
4. Long term risk benefit comparative analysis of alternative energy chains
5. 14C environmental risk from waste disposal releases
6. tritium and 14C biota radioprotection under accidental release
7. better assessment of dosimetric coefficients for pregnant woman and infants, to clarify any concern

8. enhance cooperation with other institutes in Romania and abroad in order to successfully applies in FP7 in the area of radioecology and radiation protection
9. internationally agreed alert levels of tritium emissions and activity concentration in food for potentially accidental emissions

26 .Conclusions and perspectives

, **An up to date perspective on the safety of public around Cernavoda under routine operation, today and in the future has been offered for consideration, in what is expected to be a balanced, dispassionate, scientific debate. In our view pregnant women and infants can stay safe around Cernavoda. We believe that any claims contrary to our analytically-supported results should be likewise substantiated.**
Much more essential aspects must be considered in the future, to secure a sustainable development in the uncertain climate change and resource vulnerability that confront us. We have pointed only a few of our concerns, strictly related with the topic of tritium risk assessment (accompanied by 14C)
Nuclear safety culture must be implemented at any level of our society as a premise of coherent approach on future energy resources. Alternatives to nuclear energy are welcome, but must be accompanied by a long term risk- benefit comparative analysis including preservation of biodiversitivity, resource availability, vulnerability of infrastructures and adaptation to climate changes.
From the dawn of humankind, a permanent rush on energy control was started and continues today. Science may look as a minor actor, but a scientific view on the future must be taken into account in this game.
Activist non-nuclear organizations are called to play an important part as watch dogs against the complacency of rulers and as natural sources of research initiatives.
Personally, I am very grateful to Dr. Ian Fairlie who pointed, 15 years ago, at some confusion on tritium risks. I was working, along with many IFIN-HH researchers, to clarify his doubts. And we will continue.

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ANNEX 1

See http://lib.bioinfo.pl/auid:2502944 for important papers
Also see www.nipne.ro/emras for more information on Tritium and ^{14}C

'IRPA Regional Congress for Central and Eastern Europe' www.irpa2007romania.com Brasov Romanina Sept. 24-28 2007

Paper T9 O-3

Risk from Tritium Exposure

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The future of nuclear energy in competition with other suppliers depends, inter alias, on safety aspects. Concerns of increased risk from tritium intakes by humans have been claimed in past years. The arguments concerning the radiobiological effectiveness (RBE) of tritium, its longer retention in the human body, and the presence of tritium in the DNA hydration shell have been recently analyzed. A biokinetic model for tritiated water and organically bound tritium retention in human body was used, based on a common approach for mammals using energy and hydrogen metabolism and tested separately with animal experiments. Extension to humans considers the increased role of brain, food quality and unique growth patterns of humans. Various ages and genders for Caucasians were considered and the model was used in a probabilistic approach. For compliance and prospective dosimetry ICRP recommend an RBE=1. For an intake of tritium in organic forms (OBT) in the diet, the retention for the female is about a factor 2 compared with ICRP recommendations (averaged over gender). As retention of OBT is mostly in adipose tissue, effective committed dose coefficients are very close with ICRP. For risk estimate, when RBE is allowed to vary, effective dose coefficients are estimated to be about a factor of 2 to 3 higher than those of the ICRP, at 50 % of the distribution. A detailed discussion on acceptable risk and RBE for tritium (including OBT) is considered in order to asses an upper safety margin of tritium releases for the next decades of nuclear energy

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ANNEX2
List of publications, for Dan Galeriu
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- **D. Galeriu, P. Davis, W. Raskob, A. Melintescu** TRITIUM RADIOECOLOGY AND DOSIMETRY - TODAY AND TOMORROW ,invited lecture **8th International Conference on Tritium Science and Technology September 16-21, 2007Rochester, New York**
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- D. Galeriu, A. Melintescu, N.A. Beresford, 2007, invited lecture **Energy Metabolism – as a General Principle – for Modeling the Transfer of Carbon and Tritium across Animals** International Conference on Environment; Survival and Sustainability, 19-24 February 2007, Nicosia, Northern Cyprus
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- D. Slavnicu, D. Galeriu, D. Gheorghiu1, A. Melintescu, E. Slavnicu **RODOS EXPERT MODULE FOR THE ASSESSMENT OF TRITIUM IMPACT IN AQUATIC ENVIRONMENT** *Romanian Reports in Physics, Volume 59, Number 3, P. 855-865, 2007*

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