Dr Ian Fairlie
Consultant on Radiation in the Environment
115 Riversdale Road
LONDON N5 2SU
United Kingdom
ianfairlie@gmail.com

Cernavoda 3 and 4: Environment Impact Analysis: Report for Greenpeace

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.

Introduction

1.I am Dr Ian Fairlie - an independent consultant on radiation in the environment. I have degrees in chemistry and radiation biology, and my PhD studies at Imperial College examined the radiological impacts of nuclear discharges at Sellafield UK. I have worked for several UK government departments and regulatory agencies, and I currently advise environmental NGOs, the European Parliament, and local authorities. Between 2001 and 2004, I was Secretariat to the UK Government's Committee Examining the Radiation Risks of Internal Emitters (CERRIE) which published its report in October 2004 (www.cerrie.org). I have written extensively on the radiological hazards from environmental releases of radioactive substances, including tritium: a list of publications is attached at Annex 2.

2.I have been asked by Greenpeace Central Europe to comment on an Environmental Impact Analysis (EIA) for the proposed new nuclear reactors Cernavoda 3 and 4 in Romania. The EIA is entitled "Raport la studiul de evaluare a impactului asupra mediului pentru CNE Cernavodă Unitățile 3 şi 4" (Contract 203/2006) and was prepared by the National Institute Of Research And Development For Environmental Protection (ICIM) for the Romanian Ministry Of Environment And Sustainable Development.

3.At the time of writing, one Candu 6 type reactor (Unit 1) has been in operation at Cernavoda since 1996. A second similar reactor (Unit 2) is presently being brought into operation during 2007. In the previous EIA concerning Unit 2, many objections were made by NGOs (http://www.sierraclub.ca/national/programs/atmosphere-energy/nuclear-free/reactors/ngo-cernavoda-ea-comments.pdf which have clearly not been addressed in the new EIA. The Romanian government is now proposing to permit the construction of two more similar reactors (Units 3 and 4) Cernavoda, and the present EIA has been prepared for this proposal.

4.This comment is focussed on the very large emissions and discharges of **tritium**, the radioactive isotope of hydrogen, which are already occurring and are expected to at least quadruple with the completion of Units 2, 3 and 4, if the latter two are in fact ever constructed. As this commentary will reveal, there are likely to be health implications from such large-scale tritium releases from the Cernavoda reactors in the local communities and in cities and towns which use the Danube and the Danube-Black Sea Canal (DBSC) for their drinking water.

5.A second major difficulty with the planned expansion at Cernavoda are the planned large increases in discharges of very hot water (> 32°) into the Danube river and the Danube-Black Sea Canal particularly in the summer months. These temperatures exceed the 30° limit imposed on cooling effluent from power stations in France. This is a major problem with only one reactor operating, and it will become extremely serious problem with 4 reactors in operation. This matter is flagged up but not discussed further here.

What is tritium?

6.Tritium is the radioactive isotope of hydrogen, the lightest element. It has a radiological half-life of 12.3 years and decays by emitting a beta particle. This has a maximum energy of 18.6 keV (average energy of 5.7 keV) with a short range - a few centimetres in air, 0.9 μm in water, and about 0.6 μm in tissue. This means that tritium is not dangerous externally, but it is an internal radiation hazard when inhaled, or ingested via food or water, or absorbed through the skin. Tritium is the most commonly encountered and important beta-emitting radionuclide. For more information on tritium see the Greenpeace Canada report (2007).

7.Heavy water reactors (HWR), including Candu reactors, create and release to the environment very high levels of tritium, much more than other reactor types, eg Pressurised Water Reactors (PWR), and Boiling Water Reactors (BWR).This can be seen from table 1 which compares tritium releases from reactor types. The levels of tritium releases to the Danube Black Sea canal are so high that they have been used as a radioactive tracer in hydrology studies –see Varlam C et al (2005).

Table 1. Normalised Tritium Releases (gaseous + liquid) TBq per GW(e) year

rrReactor Type	OECD/NEA 1980	UNSCEAR 2000 table 37 1995-1997
HWR	750	670
PWR	37	21.4
BWR	7	1.7

sources: OECD/NEA (1980); UNSCEAR (2000)

8.The reason for the high tritium release levels from HWRs is that they use heavy water (deuterium) both as a coolant and as a moderator. During reactor operation, deuterium is activated by fission neutrons to form tritium via the following nuclear reaction

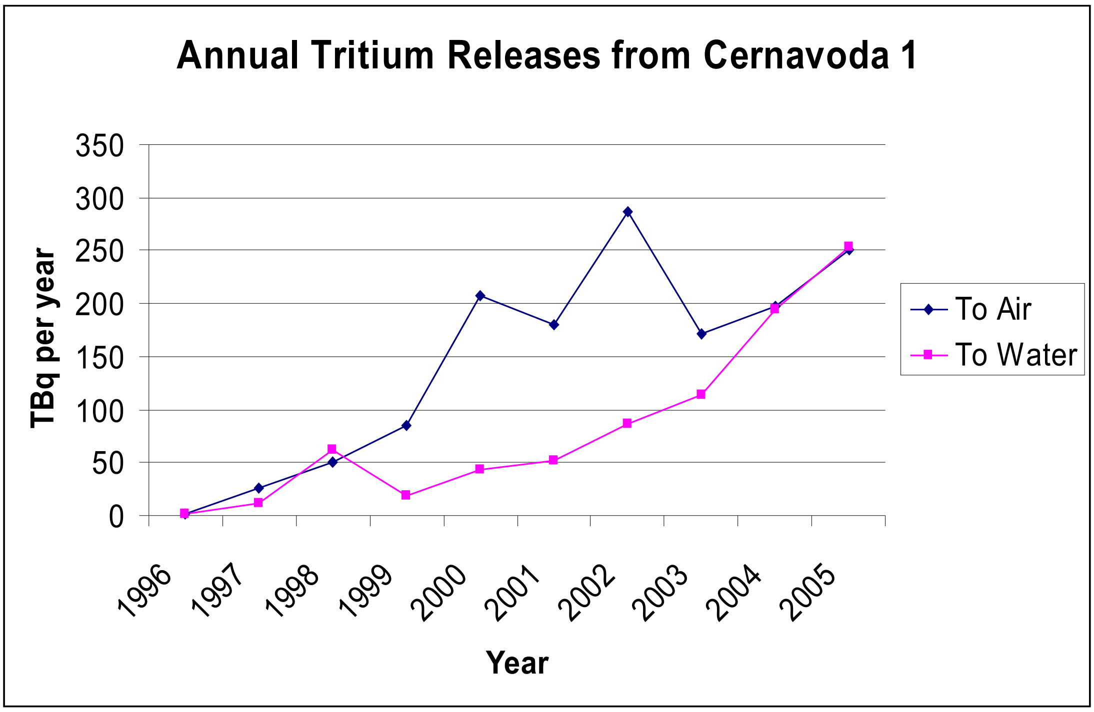
$$^{2}H + neutron \rightarrow {}^{3}H$$

9.Other reactor types use different materials as coolant and moderator, for example PWRs and BWRs use ordinary (ie light) water and AGRs use CO_2 and graphite as coolant and moderator, respectively. In these reactors, small amounts of tritium are also formed – but via tertiary fission, ie tritium is split off from U-235 and Pu-239 atoms when they undergo fission. This occurs within Candu reactors as well, but the tritium activation rate in the cooling and moderator circuits of Candu reactors is about 1,000 times greater than the tritium fission product rate.

Continual increases in tritium releases

10.A disturbing feature of Candu reactors in operation is that the tritium levels in their cooling and moderator circuits keep accumulating every year as they get older. As a direct result, tritium releases both to air and to water increase each year. This can be seen from the operating experience of Cernavoda Unit 1 shown in figure 1: water discharges to the River Danube and air emissions from Unit 1 have increased almost every year since the commencement of the reactor in 1996.

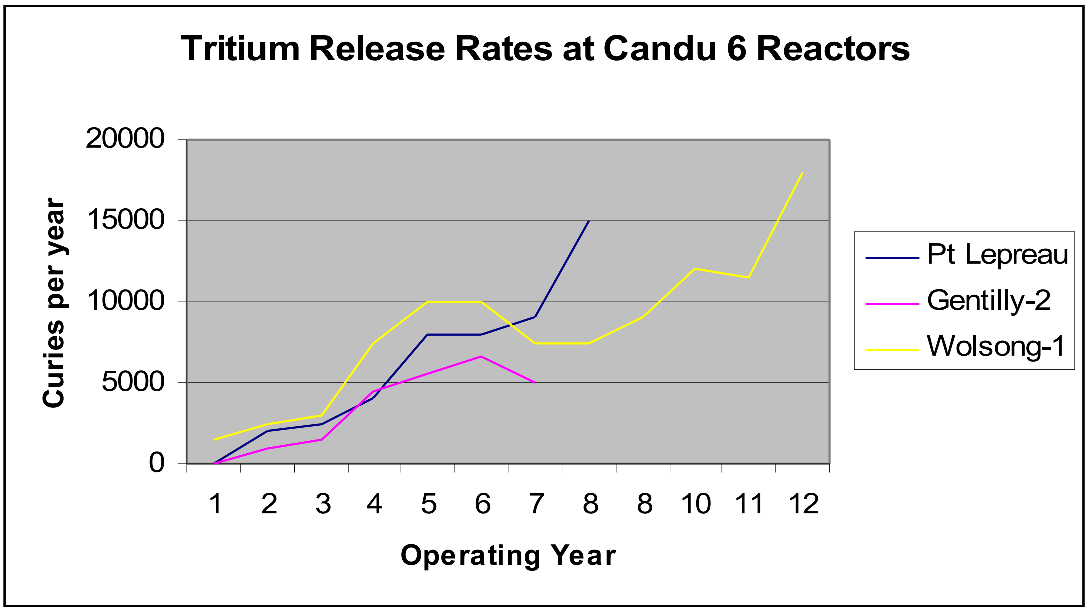
Figure 1. Annual tritium releases from Cernavoda Unit 1



data for 1996 to 2004 from tables 4.1.14.5-4 and 4.2.3.2-1 of EIA
data for 2005 from Raport di Mediu. 2005. Societatea Nationala “Nuclearelectrica” S.A. CNA Cernavoda.

11.These annual increases are similar to the operating experiences of other Candu reactors in Canada and South Korea - see figure 2 below reproduced from Song et al (1995).

Figure2



Point Lepreau Candu reactor is located in New Brunswick, Canada
Gentilly-2 Candu reactor is located in Quebec, Canada
Wolsong-1 Candu reactor is located in South Korea
1 curie = 0.037 TBq

12.The reason for the continual increases in tritium concentrations in heavy water reactors is that their tritium production is greater than the sum of tritium's decay plus tritium discharges. In fact, tritium levels in coolant and moderator circuits will continue to increase until equilibrium reached between the tritium generation rate inside the reactor and tritium releases to the environment (plus decay). This equilibrium takes more than 30 years to attain in practice. Song et al (1995) estimated that, in a Candu 6 reactor, 90% of the equilibrium level would not be reached until 27 years of reactor operation. They added that equilibrium would never be reached at all in Candu 6 moderator circuits. In the meantime, tritium releases will continue to increase.

13.In the case of Canadian Candu reactors which have the longest operating experiences, tritium emission levels reached such high levels that in the 1980s the Government put pressure on their nuclear power companies to construct a facility which would extract tritium from tritium-contaminated coolant and moderator circuits, in order to reduce tritium emissions. This (very expensive) facility was constructed at Darlington, Ontario in the late 1980s. The same may have to occur in Cernavoda.

High Levels of Tritium Contamination due to Cernavoda Unit 1

14.As a result of the 10 years' operation of Unit 1, tritium levels in the food and water from surrounding areas near Cernavoda have all markedly increased. Paunescu et al (1999) from the National Institute of Research and Development for Nuclear Physics and Engineering, Horia Hulubei (IFIN-HH) in Bucharest carried out background measurements near Cernavoda before the plant commenced operations. They found a tritium background level of approximately 3 Bq per litre, similar to the background tritium levels in other countries, including Canada.

15.Tritium concentrations near Cernavoda have now increased by factors of 5 to 45 as shown in table 2 below. It is recalled that these increases have occurred with only one reactor working.

Table 2. Tritium levels Before and After Start-up of Cernavoda Unit 1 in 1996
(Bq per litre, Bq per kg)

	Before Operation	After Operation	Increase
Air Humidity	7.4 ± 5.5	330* ± 20 (from table 4.2.1.4-7)	x 45
River Water	3.1 ± 1.0	39.9 ± 2.6 (from table 4.1.6-3)	x 13
Vegetables	3.5 ± 0.7	18.5 ± 2.9 (from table 4.3.3-8.)	x 5
Cereals	4.9 ± 1.7	25.4 ± 3.7 (from table 4.3.3-6.)	x 5

*assuming average humidity levels of 10 ml per cubic meter (a commonly-used value - see Davis et al, 1996)

The pre-operational data is contained a research article by N. Paunescu, M. Cotarlea, D. Galeriu, R. Margineanu and N. Mocanu. (1999) Evaluation of environmental tritium levels in pre-operational period of Cernavoda CANDU Nuclear Power Plant. Journal of Radioanalytical and Nuclear Chemistry Volume 239, Number 3. March 1999. pages 465-470.

16.Tritium levels have also increased in other foodstuffs near Cernavoda, as shown in table 3. These values may be compared with the pre-operational values of 3 to 7 Bq per litre/kilogram as indicated by Paunescu et al (1999). These tritium concentrations in foodstuffs will inevitably increase as units 2, 3, and 4 are constructed and brought into operation.

Table 3 Current tritium concentrations in foods etc at Cernavoda. Bq/kg or Bq/l

Fish in DBSC	River water (at D1)	Vegetables	Fruits	Milk	Eggs	Meat	Soil
66.5 ±10.4	19.0 ± 2.1	18.5 ± 2.9	62.8 ± 7.8	19.4 ± 3.1	17.2 ± 2.8	5.4 ± 0.9	30.1 ± 5.1

source: various tables in EIA

17.These concentrations are certainly raised and are much higher than they would have been had 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.

18.It is noticeable that many tables in the EIA indicate that tritium levels near Cernavoda are little different from tritium levels in towns many kilometres away from Cernavoda, eg Calarasi, Silistra, Medgidia etc. This would seem to indicate that Cernavoda Unit 1 has had little impact, but such an interpretation is directly refuted by Paunecsu et al’s data from before the start up of Cernavoda 1.

19.A likely explanation is that recent tritium samples taken in remote towns and brought to Cernavoda NPP’s laboratories for determination have become contaminated because of the ambient high levels of tritium in these labs coming from the reactor. This has happened in the past, when the laboratories at the Pickering nuclear power station near Toronto, Ontario, Canada in the 1980s had to be relocated further away from the station because samples were being contaminated by the station's tritium emissions. The management of the Cernavoda power station are recommended to make enquiries within Ontario Power Generation and to consider relocating their laboratories.

Predicted Releases

20.The EIA contains almost no figures as to the predicted releases from future Units 3 and 4. The EIA (on page 111 of chapter 4.1) contains a single estimate of an annual discharge to water of 172 TBq of tritium from a future Unit 3 or 4, which it states was derived from comparison with other Candu 6 reactors. But the EIA does not indicate when this estimate would occur, ie after how many years of reactor operation, therefore it is meaningless. In any case, the estimate of 172 TBq is already exceeded by the 250 TBq in 2005 at Cernavoda 1 - see figure 1. No estimate is attempted of tritium emissions to air, even though these are more important (exposure-wise) than tritium water discharges.

21.The estimated tritium discharges from Cernavoda will increase dramatically when Units 2, 3 and 4 are brought on line, assuming the latter two are actually constructed. And each year, tritium releases will continue to increase in each reactor.
In other words, total tritium releases will become very large indeed in the future. To assess their likely magnitude, we have made an estimate in table 4 of likely annual tritium releases from Cernavoda in the year 2030, assuming Unit 2 is brought into operation in 2010 and Units 3 and 4 in year 2020. These assumptions may not occur in actual practice, but it is important to obtain an idea of the possible scale of future tritium releases from Cernavoda if the Romanian government's plans were actually carried out.

Table 4. Author's approximate estimates of future tritium releases from Cernavoda in the year 2030 (assuming Unit 2 commences in 2010, and Units 3 and 4 in 2020) TBq

	Unit 1	**Unit 2**	**Unit 3**	**Unit 4**	**Annual Total**
Tritium emissions to air	500	300	200	200	1,200
Tritium discharges to water	500	300	200	200	1,200

22.This table indicates that future total tritium annual releases from Cernavoda if all 4 reactors are constructed will be extremely large, about 2,400 TBq or 2.4 PBq. One PBq (petabecquerel) is 1 with fifteen zeroes afterwards, ie 1,000,000,000,000,000 Bq[1] of tritium. This is a huge amount of radioactivity and it will result in large increases in tritium concentrations in the food and water in areas near the power station and downstream from it.

Derived Emission Limits (DELs)

23.The EIA attempts to justify these huge releases by referring to permitted Derived Emission Limits (DELs) which are 100s of times larger than these huge annual releases. But the derivation of these DELs is highly uncertain and of little scientific

[1] One becquerel is a unit of radioactivity equal to one disintegration of an atomic nucleus per second

merit. See discussion in Chapter 3 of the Greenpeace Canada (2007) report. In a nutshell, so-called "safe" amounts of tritium are calculated which give the maximum legal dose of 1 mSv to those people most likely to be exposed to tritium releases. But these are derived using environmental transport models, metabolic models, dose models, arbitrary tissue weighting factors, and even more arbitrary radiation weighting factors, as well as many arbitrary assumptions in the models themselves. All these have uncertainties attached to them, and these uncertainties all have to be multiplied, not added, together. As the UK Government's CERRIE (2004) report indicated - the total uncertainties in the final doses can be very large indeed.

24.The reality of the matter is that these DELs are not worth the paper they are written on. Even the management of Cernavoda only use 5% of these absurdly high DELs as their own operating limits for protecting the public.

Most exposed populations from Liquid Water Discharges

25.Tritium liquid discharges occur 24 hours a day 365 days per year as long as the reactors are operating. About 88% of tritium liquid discharges are made to the Danube River via the Seimenii canal just to the north of Cernavoda town. (See data in table 4.1.14.5-4 on page 138 of chapter 4.1). About 12% of liquid discharges are made to the Danube-Black Sea canal (DBSC) and exit into the Black Sea at Constanta city. The EIA states that the most exposed people from liquid discharges are the residents of Cernavoda town (population 21,000) [2] and Constanta city (population 310,000) as it is supplied with drinking water from the Danube-Black Sea Canal. (See pages 34 and 35 of chapter 4.9 of the EIA).

26.However there are a number of small towns and villages on the Danube downstream from Cernavoda which also might obtain their drinking water from the Danube. These include Seimeni, Dunarea, Capidava and Topalu which are all within 30 km of Cernavoda NPP. In addition, the towns and villages of Stefan del Mare, Saligny, Satu Nou, Medgidia, Castelu, Poarta Alba and Basarabi are all on the DBSC Canal also within 30 km of Cernavoda NPP and may also extract their drinking water from the canal.

Most exposed populations from emissions of tritiated water vapour

27.Tritium air emissions also occur 24 hours a day 365 days per year when the reactors are operating. It should be noted that the tritiated water vapour does not emerge from a stack but oozes out of the walls, doors and windows of the reactor buildings mostly at ground level. The EIA states that the most exposed people to these radioactive releases (see pages 34 and 35 of chapter 4.9) are the residents (both infants and adults) of Cernavoda town.

28.Table 4.7.1-1 of the EIA reveals that over 21,000 persons live within 5 km of the reactor site; over 14,000 people live within 3 km of the site. Another 5,000 persons live between 5 and 10 km of the site. These figures are presumably the population of Cernavoda town and it is these people who are likely to be most exposed to tritiated

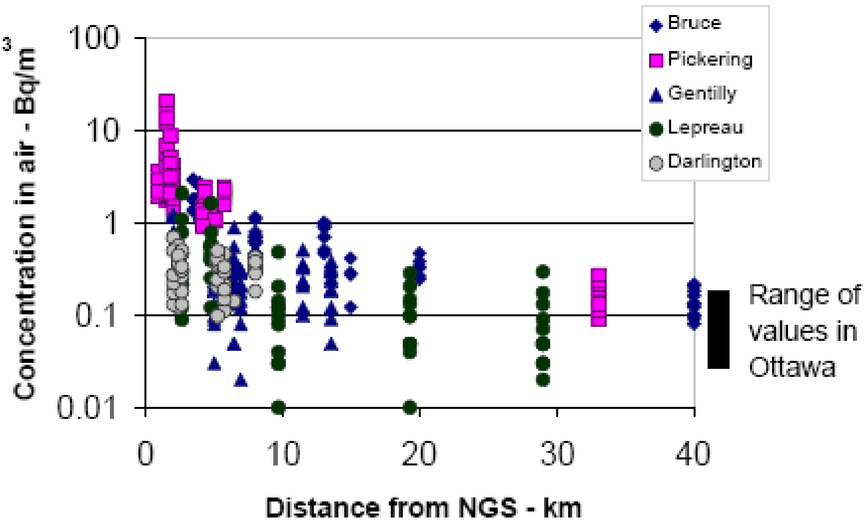
[2] In the event liquid effluents are released directly to the Danube River through the "alternate" effluent discharge tunnel - ie as opposed to the normal Seimenii canal - the critical group is considered to be the population of Seimenii Mici village situated a few km north of Cernavoda town.

water vapour which is emitted from the NPP. Of the 21,000 population of Cernavoda, 900 are less than 2 years old.

29.Tritium air emissions are more dangerous than liquid discharges because tritium exposures from skin absorption, inhalation, swimming, and food ingestion (all contaminated by tritium water vapour) are larger than the exposure from drinking tritium-contaminated water alone. For these reasons, it is important to pay particular attention to tritium air concentrations near nuclear reactors. See discussion in Chapter 6 of the Greenpeace Canada report.

30.Tritium concentrations in water vapour near nuclear stations depend on the distance from the station. This is shown in Figure 3 below reproduced with the permission of the Canadian Nuclear Safety Commission (CNSC) from Osborne (2002) using data from Health Canada (2001). The figure indicates tritium in water vapour concentrations near various Canadian nuclear power stations between 1985 and 1999. The oldest (and most polluting) station is Pickering at the far left of the figure. Tritium-in-air concentrations near Cernavoda will inevitably increase to the levels shown for Pickering.

Figure 3. Annual averages of tritium concentrations in air measured at distances from Candu nuclear power stations in Canada. 1985 – 1999.



(Figure reproduced with permission from Tritium in the Canadian Environment: Levels and Health Effects. Report RSP-0153-1. Prepared for the Canadian Nuclear Safety Commission under CNSC contract no. 87055-01-0184 by Ranasara Consultants and Richard Osborne. Data from Health Canada, 2001)

31.It should be noted that the logarithmic scale of the Y-axis compresses the data range; the highest air concentrations here (30 Bq per cubic metre) are 3,000 times greater than the lowest (0.01 Bq per cubic metre)! A second point is that we need to know tritium concentrations in the air's water vapour and not in the air's volume. If we assume a reasonable value of 10 grams of water per cubic metre of air (from Davis et al, 1996), then the tritium water vapour concentration 1 to 2 km from Pickering is 100 to 3,000 Bq per litre. The figure for Cernavoda would be 300 Bq per litre which is relatively high.

32.Thirdly, the data points are annual averages. Actual air concentrations will vary considerably, and large pulses of tritium emissions may occur but these are obscured by the publication of average annual concentrations. Pulsed tritium concentrations could in theory result in heavy labelling of cells being formed in the embryos and fetuses of pregnant women at that particular moment. This fear was expressed by Professor E Radford in his 1979 testimony to the Ontario Government's Select Committee on Ontario Hydro Affairs: Hearings on The Safety of Ontario's Nuclear Reactors. Tuesday, July 10, 1979. See http://www.ccnr.org/tritium_2.html#scoha

33.The EIA states that the most exposed persons from airborne emissions are the 21,000 residents (including ~900 infants) of Cernavoda town, with 14,000 living within 3 km. In addition, other towns nearby within 30 km of the NPP could also be affected, including Fetesti (population 37,000) and Medgidia (population 46,000). This raises the question of wind patterns at Cernavoda. Table 5 sets out the % frequencies of the prevailing winds. See the maps (autocad drawings) attached as Annex 2.

Table 5. % frequencies of wind directions (from) at Cernavoda

Calm	NNE	WNW	ESE	SSE	N	W	S	NNW	SSW	ENE	SE	NE	NW	WSW	E	SW
26.04	10.55	8.43	6.81	6.31	5.54	5.26	4.9	3.74	3.6	3.41	3.19	2.83	2.77	2.66	2.45	1.43

Source: EIA table 4.2.1-16

34.This shows that the winds tend to blow most often from the NNE, WNW, ESE, and SSE, with there being no wind 26% of the time. Unfortunately, Medgidia lies in the path of winds blowing WNW from Cernavoda, the second-most prevailing wind. Also, Fetesti lies in the path of winds blowing ESE of Cernavoda, another prevailing wind. This is different to what is said in page 1 of chapter 4.7 of the EIA which states "The town (ie Fetesti) is not on the dominant winds direction."

35.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.

Sum of tritium intakes by Cernavoda residents

36.It is useful to add up the exposures to Cernavoda residents from their various tritium intakes from food, water, breathing etc. This is estimated in table 6.

Table 6. Author's Estimated Annual Intake of tritium for a Cernavoda resident

Source of water tritium (HTO)	**Intake per annum**	**HTO Concentration**	**HTO intake Bq/year**
Water in drinks	550 litres	20 Bq/L (from DBSC value)	11,000
Water in food	500 kg x 0.85 = 425 litres	67 Bq/L (from fish value)	28,500
Air inhalation	8,400 m^3	3.3 Bq/m^3	27,700
Skin absorption	60% of inhalation	3.3 Bq/m^3	16,600
Swimming in river	0.024 l per hour x 100	20 Bq/L	44

	hours = 2.4 litres		
TOTAL			84,000

Source of organic tritium (OBT)	**Intake per annum**	**OBT Concentration**	**OBT intake Bq/year**
OBT in food	500 kg x 0.15 = 75 kg	~26 Bq/kg	2,000
TOTAL			2,000

Data from EIA
Annual intake values from Health Canada (1994)
Assumptions

- 1 kg water = 1 litre
- average specific activity of OBT = 1.3 x average specific activity of HTO (Osborne, 2002)
- 2 litres of water consumed per day in drinks
- 85% of food is water, 15% is organic matter, on average
- annual skin absorption is 60% of annual inhalation intake (Osborne, 1966)

37.While this level of tritium intake is not immediately life-threatening, it will result in increased risks of cancer although it would be difficult to trace these cancers among the high background levels of cancer. Cancers from radiation exposure are indistinguishable from ordinary cancers. But the point is that these estimated tritium exposures to Cernavoda residents are approximately 10 to 40 fold higher than they would have been if the NPP had not been built. It should be noted that nowhere in the EIA is there any mention if organically bound tritium – which is a serious omission.

38.It is necessary to examine the radiation hazards of tritium itself.

<u>The Radiation Hazards of Tritium</u>

39.It is very likely that many radiation protection managers at Cernavoda and in the Romanian Government services consider tritium to be a “weak” radionuclide associated with small radiation doses – therefore, in their view, large amounts can be discharged with few health effects. But this is incorrect. Very recently, a number of reports have been published which raise questions about the real nature of tritium’s hazards, especially its dosimetry. These reports include the US IEER report (Makhijani et al, 2006), which recommends a much stricter US standard for tritium in drinking water. In addition, Harrison et al (2003) and the report of the UK Government’s CERRIE Committee (2004) also examined current methods of determining tritium doses.

40.In a very recent article, the author (Fairlie, 2007) objected to the ICRP’s downplaying the effectiveness of tritium’s beta decay particle. In addition, the US EPA has been reported as considering a substantial increase in its estimates of the risks posed by human exposure to tritium. See “EPA Tritium Risk Plan May Force Tighter Nuclear Plant Controls” Energy Washington Week, Vol. 4, No. 25, 20 June 2007. See also the discussion in Appendix 1 of Part 2 of the Greenpeace Canada report. These recent articles and reports should be studied by the Romanian Government and by scientists and engineers at Societatea Nationala “Nuclearelectrica” S.A. CNA Cernavoda.

41.The crux of the matter is that a number of radiation protection precepts and procedures are deficient or inappropriate when we come to assess tritium's hazards. The conclusion is that official dose models for tritium significantly underestimate its doses. For example

- Tritium's unusual properties of extreme mobility, exchangeability, and binding with organic materials are poorly recognised (or not recognised at all) in official dose models.
- Because of the short range of tritium's beta particle, tritium's damage depends on its exact location in the cell. For example, tritium next to a DNA molecule exerts more damage than tritium, say, in extracellular water. At present, it is not possible to model where tritium goes in the body with any accuracy. Official models assume that tritium is distributed equally throughout the body, but we don't know that. Some scientists think we should use safer models, in case equal distribution turns out to be wrong.
- Tritium is often described as a "weak" beta-emitter, but in radiation biology, so-called "weak" beta particles are more effective (i.e. dangerous) than energetic ones. This is especially the case with tritium, but this is unacknowledged by official bodies when setting tritium's dose coefficients.
- Much evidence indicates that tritium's effectiveness (in radiation biology experiments comparing tritium with gamma rays) is two or three times that recognised by the International Commission on Radiological Protection (ICRP).
- Little official recognition is given to tritium's ability to incorporate in organic molecules to high levels as a result of chronic exposures that occur near Candu reactors.

42.It can be seen that examining tritium's doses tends to turn into a critique of current official radiation protection precepts and practices. This is unfortunate, because few people outside of the nuclear industry and its regulators understand these. However, it is important that an effort is made in order to appreciate the true degree of tritium's hazards. In a nutshell, official attitudes on tritium are unscientific and incorrect. More important, the recent evidence of tritium's hazards should be acknowledged by radiation protection agencies in Romania, and a precautionary approach should be adopted with dose factors for HTO and OBT being significantly increased.

<u>Epidemiology</u>

43.An obvious question is, can we see any adverse health effects at locations with high tritium concentrations? Health effects can sometimes be spotted by means of epidemiology studies, particularly among those who are highly exposed. But radiation health effects are notoriously difficult to pick up because cancers caused by radiation are not different from naturally-occurring cancers, and there are many such cancer cases; indeed in the UK about 25% of all deaths are from cancer. This requires us to look for small increases in cancer rates among exposed populations which already suffer many cancers. It is difficult to pick up small increases in radiation-induced cancers (the signal) among the many natural cancers (the noise). Very large expensive epidemiology studies are required to get a big enough signal to satisfy scientists that that there really is an effect and that any increase has not occurred by chance or from statistical blips. In any event, relatively few such studies have been carried out. These have shown increases in childhood leukemia but these studies are first-stage studies (often termed “ecologic”) which may be subject to bias such as social class, or to confounding factors such as smoking. The result is that their findings are indicative, not conclusive. What is needed now are second-stage (i.e., case-control or cohort) studies to match cases of cancer with people who do not have cancer, to obtain more conclusive results. These should have been carried out after the first-stage studies in the 1980s and early 1990s showed signs of increased incidences of leukemia in affected areas. See Appendix VII to Part 2 of the Greenpeace Canada report.

Conclusions

44. This report has examined existing and proposed tritium releases from the Cernavoda nuclear power station. From one reactor alone (Unit 1), tritium releases are much greater than from nuclear power stations in other countries. When Unit 2 releases and possibly Units 3 and 4 are added, tritium releases will be extremely large.

45. Tritium concentrations in drinking water, in air, and in vegetation and in food near Cernavoda are all significantly increased and will increase even further if Units 3 and 4 are built. These high tritium concentrations result in high tritium intakes in residents living within 5 to 10 km of the station and very high tritium annual intakes in residents who live within 1 to 2 km of the station.

46. However because of tritium’s very low dose factors, the radiation “doses” which result from tritium exposures are very small and are considered safe or within health limits by the Romanian government. But the report points to significant objections to tritium’s dosimetry and to the models used to estimate tritium doses especially from organically bound tritium. It notes a number of recent reports (Fairlie, 2007; CERRIE, 2004; Makhijani et al, 2006) which raise questions about tritium’s official dosimetry.

47. It is concluded that a precautionary[3] approach should be adopted as regards tritium releases from the Cernavoda reactors. The following recommendations are therefore made

a) the Romanian Government should establish a committee with representatives from environmental groups to examine tritium’s hazards. In particular, the committee should examine recent scientific reports which question aspects of tritium’s dosimetry

b) case-control epidemiology studies to be set up to ascertain the levels of health effects in the tritium-contaminated area near Cernavoda

c) the proposals to construct Units 3 and 4 should be postponed until the results of the above studies are concluded

d) in the meantime, pregnant women and young children (under 4) and their mothers should be advised not to live near (ie within 10 km) of the Cernavoda NPP

[3] “precautionary” means erring on the side of caution

e) in the meantime, people who live very near (ie within 5 km of the Cernavoda NPP) should be advised not to consume food from their gardens, bee hives and orchards, and not to consume wild foods, e.g., blackberries and mushrooms, growing near the NPP

f) increased efforts should be made to reduce tritium discharges as low as technically feasible. In particular, the Cernavoda NPP management should be requested to re-examine the option of storing highly tritiated water from moderator circuits in decay tanks.

ends

References

Canadian Nuclear Safety Commission (2001) Tritium in the Canadian Environment: Levels and Health Effects. Report RSP-0153-1. Prepared for the Canadian Nuclear Safety Commission under CNSC contract no. 87055-01-0184 by Ranasara Consultants and Richard Osborne.

CERRIE (2004) Report of the UK Government's Committee Examining the Radiation Risks of Internal Emitters. www.cerrie.org

Davis PA, Amiro BD, Workman WJG, and Corbett BJ (1996) HTO Transfer from Contaminated Surfaces to the Atmosphere: A Database for Model Validation. AECL-11222.

EIA (2007) "Raport la studiul de evaluare a impactului asupra mediului pentru CNE Cernavodă Unitățile 3 şi 4" (Contract 203/2006) National Institute Of Research And Development For Environmental Protection (ICIM) for the Romanian Ministry Of Environment And Sustainable Development.

Energy Washington Week (2007) "EPA Tritium Risk Plan May Force Tighter Nuclear Plant Controls", Vol. 4, No. 25, 20 June 2007.

Fairlie I (2007) RBE and w_R values of Auger emitters and low-range beta emitters with particular reference to tritium. Journal of Radiological Protection. Vol 27 pp 157-168. (2007) http://www.iop.org/EJ/abstract/0952-4746/27/2/003/

Greenpeace Canada. (2007) Tritium Hazard Report: Pollution and Radiation Risk from Canadian Nuclear Facilities. http://www.greenpeace.org/raw/content/canada/en/documents-and-links/publications/tritium-hazard-report-pollu.pdf

Harrison JD, Khursheed A, Lambert BE (2002) Uncertainties in Dose Coefficients for Intakes of Tritiated Water and Organically Bound Forms of Tritium by Members of the Public. Radiation Protection Dosimetry 98:299-311

Health Canada (1994) Human Health Risk Assessment for Priority Substances. Ottawa, Canada: Ministry of Supply and Services Canada. http://www.iop.org/EJ/abstract/0952-4746/27/2/003/

Makhijani A, Smith B, and Thorne MC (2006) Science for the Vulnerable: Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk. See chapter 7 on tritium. http://www.ieer.org/campaign/report.pdf

OECD/NEA (1980) Radiological Significance and Management of Tritium, Carbon-14, Krypton-85, and Iodine-129 Arising from the Nuclear Fuel Cycle Nuclear Energy Agency of OECD, Paris.

Ontario Government's Select Committee on Ontario Hydro Affairs: Hearings on The Safety of Ontario's Nuclear Reactors. Tuesday, July 10, 1979. http://www.ccnr.org/tritium_2.html#scoha

Osborne RV (1966) Absorption of tritiated water vapour by people. Health Phys 12:1527-1537

Osborne RV (2002) Tritium in the Canadian Environment: Levels and Health Effects. Report RSP-0153-1. Prepared for the Canadian Nuclear Safety Commission.

Paunescu N, Cotarlea M, Galeriu D, Margineanu R and Mocanu N (1999) Evaluation of environmental tritium levels in pre-operational period of Cernavoda CANDU Nuclear Power Plant. Journal of Radioanalytical and Nuclear Chemistry Volume 239, Number 3. March 1999. pages 465-470.

Porter Commission (1980) The Report of the Royal Commission on Electric Power Planning. Volume 6. Environmental and Health Implications of Electric Energy in Ontario. p 85. Ontario Government, Toronto, Ontario, Canada.

Societatea Nationala "Nuclearelectrica" S.A. CNA Cernavoda. (2005) Raport di Mediu.

Song MJ, Son SH and Jang CH (1995) Tritium Inventory Prediction in a Candu Plant. Water Management Vol 15 No 8 pp 593-598.

UNSCEAR (1988) Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation. New York NY USA.

UNSCEAR (2000) Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation. New York NY USA.

Varlam C et al (2005) The use of tritiated wastewater from NPP Cernavoda to estimate maximum soluble pollutants on the Danube - Black Sea channel. Fusion Science and Technology, vol. 48, n° 1., pp. 716-719.

Workman WJ, Trivedi A and Cornett RJ (1998) Tritium Concentrations inside the Homes of Occupationally Exposed Workers: Dosimetric Implications. Health Physics Vol 75 No 1, pp 56-59.

Annex 1

Maps of Cernavoda Area and Plan of Cernavoda NPP

(From the EIS)

Annex 2

Dr Ian Fairlie: Publication List

1992

- **Tritium: The Overlooked Nuclear Hazard**. The Ecologist. Vol 22 No 5. 228-232 (1992)
- **Tritium – the cause of leukemias?** Safe Energy. Vol 91. Oct-Nov 1992. available from http://www.no2nuclearpower.org.uk/articles/se91-Fairlie.pdf
- **Estimation of Radiation Doses to Critical Groups near Dungeness Nuclear Power Station.** MSC Thesis. Medical College of St Bartholomew's Hospital. London (1992)

1993

- **Magnox Gamma Shine** Safe Energy. Vol 95. June-July 1993. available from http://www.no2nuclearpower.org.uk/articles/se95-Fairlie.pdf

1994

- **Government forces NRPB to Back Down** Safe Energy. Vol 102. Autumn 1994. available from http://www.no2nuclearpower.org.uk/articles/se102-Fairlie.pdf

1996

- **Radiation and Health**. In "Health and the Environment". Published by SERA and SHA. London. 1996

1997

- **A Nuclear Waste. How Ending Reprocessing Can Benefit Public Health, Protect the Environment and Save up to £6 Billion**. SERA Publication. June 1997.
- **Radioactive Waste: International Examination Of Storage And Reprocessing Of Spent Fuel**. PhD Thesis. Centre for Environmental Technology. Imperial College of Science, Technology and Medicine. London. September 1997.
- **No Dose Too Low**. Bulletin of the Atomic Scientists. Ian Fairlie and Marvin Resnikoff. Nov/Dec 1997 pp 52-56.
- **Spent Fuel Storage Visited.** CEES Working Paper No 137. Centre for Energy and Environment. Princeton University. Princeton NJ United States. December 1997.

2000

- **In Defence of Collective Dose**. Fairlie I and Sumner D. Journal of Radiological Protection Vol 20 pp 1–10. (2000)

2001

- **Possible Toxic Effects from the Nuclear Reprocessing Plants at Sellafield (UK) and Cap de La Hague (France).** Report published by the Scientific and Technological Options Assessment (STOA) Panel of the European Parliament. Xavier Coeytaux, Yacine Faid, Ian Fairlie, David Lowry, Yves Marignac, Emmanuel Rouy, Mycle Schneider and Gordon Thompson. April 2001. Commissioned by European Parliament, Directory General for Research.

- **Transfer of radioactivity to fruit: significant radionuclides and speciation.** Ould-Dada Z, Fairlie I and Read C. Journal of Environmental Radioactivity. Vol 52 pp 159-174 (2001)

2004

- **Committee Examining the Radiation Risks of Internal Emitters** (CERRIE). Various chapters. www.cerrie.org

2005

- **Uncertainties in Doses and Risks from Internal Radiation**. Medicine, Conflict and Survival, Vol 21:2. pp 111 – 126. (2005) http://www.informaworld.com/smpp/content~content=a714004320~db=all~order=page

2006

- **The Other Report on Chernobyl (TORCH).** An independent scientific evaluation of the health-related effects of the Chernobyl nuclear disaster with critical analyses of recent IAEA/WHO reports. Ian Fairlie and David Sumner. Commissioned by Rebecca Harms, MEP, Published by Greens/EFA in the European Parliament. April 2006. www.chernobylreport.org
- **New Information on Radiation Health Hazards**. Ian Fairlie. In "Nuclear or Not. Does Nuclear Power Have a Place in a Sustainable Energy Future?" Editor David Elliott. Palgrave Macmillan. London. May 2006. http://www.palgrave-usa.com/catalog/product.aspx?isbn=0230507646

2007

- **Dispersal, deposition and collective doses after the Chernobyl disaster.** Medicine, Conflict and Survival, Vol 23:1, pp 10 –30. June 2007. http://www.informaworld.com/smpp/content~content=a770375304~db=all~order=page
- **RBE and w_R values of Auger emitters and low-range beta emitters with particular reference to tritium.** Journal of Radiological Protection. Vol 27 pp 157-168. (2007) http://www.iop.org/EJ/abstract/0952-4746/27/2/003/
- **Global warming: is nuclear power the answer?** Medicine, Conflict and Survival, Vol 23:3, pp 228 – 233. June 2007. http://www.informaworld.com/smpp/title~content=t713673482
- **Tritium Hazard Report: Pollution and Radiation Risk from Canadian Nuclear Facilities.** Published by Greenpeace Canada. June 2007. http://www.greenpeace.org/raw/content/canada/en/documents-and-links/publications/tritium-hazard-report-pollu.pdf