**The significance for the UKof reports from the Canadian Atomic Energy Control Board, linking tritium emissions with birth defects and possibly with childhood leukaemias is considered by IAN FAIRLIE* who looks at the high levels of release in the past and possible increases in the future.**

# Tritium - the cause of leukaemias?

RECENT Canadian reports linking tritium emissions from nuclear reactors with birth defects(1) and possibly with childhood leukaemias(2) raise the questions of tritium emissions and possible linked effects in the UK. Tritium is a radioactive isotope of hydrogen and is a major source of radioactive pollution from Britain's nuclear facilities, usually the largest of the radionuclide emissions from nuclear facilities. The largest UK tritium emissions come from British Nuclear Fuels' Chapelcross plant in Dumfries, which makes tritium for nuclear weapons. Other major sources are the Sellafield reprocessing plant in Cumbria and other nuclear weapons and production facilities. The table ranks the discharges according to the volume of atmospheric emissions.

All nuclear reactors produce tritium in their fuel elements as a by-product of the fission or uranium and plutonium. Tritium is also formed by the neutron activation of deuterium, lithium and boron in the moderator, coolant and control rods. With Magnox reactors and Advanced Gas Cooled Reactors (AGRs), the main activation source is lithium impurities in the graphite moderators.

Tritium does not readily diffuse through the Magnox and zircalloy fuel cladding of Magnox and Pressurised Water Reactors (PWRs), whereas it diffuses easily through the stainless steel cladding of AGRs. Consequently, the tritium formed in the AGRs is released on site, while that formed in Magnoxes and PWrs is not released until their fuel elements are reprocessed. Larger amounts of tritium are therefore emitted from AGRs than from other reactors in Britain.

Nuclear fusion, if developed, it is believed would lead to a considerable increase in tritium emissions. The core of each reactor will contain an estimated 10kg (100 million curries) of tritium. If the lithium used within the reactor were to catch fire and burn with sufficient intensity then a substantial proportion of the reactors tritium could be released. It has been estimated that for every 1,000MW of future fusion capacity 110TBq/yr of tritium will be released into the environment in the form of "routine" discharges. A further $3.7x10^4$TBq/yr could be added from "accidental" releases.

Could tritium be the cause of the leukemia clusters near nuclear sites in Britain and Canada? Let's look at the available evidence.

## Evidence against tritium

**1. Human Health Reports**
Circumstantial evidence against tritium from epidemiological studies and other health reports is beginning to mount up. For example, raised leukemia levels have been reported near Sellafield, Dounreay, and the Aldermaston/ Harwell/Burghfield area in the UK; near the Pickering and Bruce reactors in Ontario, Canada; and near the Savannah River tritium plant in South Carolina, US. In all of these plants, tritium is by far the largest of their nuclide emissions (except for rare gas emissions at Sellafield) and in the Canadian case, little else of radiological significance is emitted from their heavy water reactors.

Perhaps more important is the new evidence(1) directly linking birth defects with tritium emissions from the Canadian Pickering nuclear station. Birth defects have also been found among the offspring of nuclear workers at the giant nuclear military plant at Hanford, Washington state, US; among the public living near Hanford; and among those living downstream from the Rajasthan heavy water reactors in India. Again, all these plants are heavy tritium emitters. Interestingly, major epidemiological surveys are presently being conducted both at Hanford examining the numbers of childhood leukaemias, and at Sellafield looking at the numbers of birth defects recorded there. However apart from the first Canadian study reported above, the other studies are still only circumstantial in their implications of tritium, so we should look at other sources of information. Let's start with tritium's properties.

**2. Tritium's Properties**
a. Tritium emissions are the largest of the radionuclide emissions from most UK nuclear sites.

b. Tritium in its most common form – tritiated water – is the most mobile nuclide in the hydrosphere and biosphere. As a result residents near nuclear sites and nuclear workers will be tritiated to ambient levels in the atmosphere.

c. Tritium has the property of binding with the organic molecules of our bodies. Humans can also ingest organically bound tritium (OBT) in food grown in tritium-contaminated areas. This OBT delivers much larger radiation doses than tritiated water, because of its 30 to 60 times longer biological half-life, and because its heterogeneous distribution in cells is more serious than tritiated water's homogeneous distribution throughout body water.

d. Organically bound tritium is taken into account neither by NRPB, MAFF, DoE, or the Scottish Office in calculating doses to critical groups near nuclear sites, nor by nuclear employers in calculating radiation doses to their workers.

e. Animal experiments show that significant amounts of ingested tritiated food can wind up in the DNA of their organs. Tritium which is organically bound to chromosomes and their DNA, the crucial target for radiation's effects, will have a commensurately greater effect than tritiated water.

## How radiotoxic is tritium?

Tritium is widely considered in radiation circles to be one of the least hazardous radionuclides because it is a 'weak' beta-emitter, and because tritiated water has a relatively short biological half-life in humans. Indeed tritium atmospheric emissions from most nuclear power stations are not monitored at present, and MAFF/DoE/Scottish Office do not place limits on their tritium emissions to air. Also, tritium is commonly omitted from discussions of major radionuclide discharges in official UK reports, or relegated to brief discussion in appendices. So what is going on here? Just how radiotoxic is tritium?

The answer is that the 'official' toxicity of tritium, ie its radiation dose per Bq as calculated by the ICRP is extremely low – the lowest of all commonly encountered radionuclides. As a result, the ICRP's Annual Limit on Intake for tritium is the most lax of all common radionuclides. For example, it is more than 600 times more lax (for ingestion) than Caesium-137, and 1000 times more lax than Iodine-131, both commonly discharged from nuclear sites and comparable with tritium. Also, the Derived Generalised Limit for members of the public for tritium in green vegetables is 2400 times that for Strontium-90.[3] But are the ICRP's calculations correct? How does the ICRP measure tritium's radiation dose per unit intake?

This is called dosimetry and the dosimetry of internally incorporated nuclides is complex, as it involves the use of metabolic models with many assumptions and differences of opinion. Essentially, one has to multiply together three factors. First, the tritium concentration in human cells or tissues (in becquerels); second, a dose coefficient or dose conversion factor, to convert this to absorbed doses (in grays); and third, a Radiation Weighting Factor or Q factor, to convert this in turn to an 'equivalent dose' (in sieverts), so we can add together the effects of different kinds of radiations.

The nub of the problem is that for tritium, important research has been ignored, faulty metabolic models have been used, and strongly differing views have not been taken into account in deriving these three factors, as explained below.

**1. Organically bound tritium**
For starters, organically bound tritium (OBT) is ignored by UK radiation authorities in all three factors. For example, evidence has been ignored that OBT is metabolised and accumulates in our bodies, that significant doses can be obtained from OBT in tritiated food, and that tritium can be incorporated into our DNA – the crucial target for radiation's effects. OBT is much more dangerous to us than tritiated water, perhaps by as much as ten times.[4]

**2. Toxicity reviews**
Currently tritium's beta radiation is considered by the ICRP to be equally as hazardous (in terms of its Relative Biological Effectiveness or RBE) as gamma radiation and X-rays. However many cell and animal experiments show tritium is at least twice as dangerous and perhaps as much as 4 or 5 times more so. A major study by the US nuclear centre, the Lawrence Livermore Laboratory[5] recently published risk estimates for tritium which showed that it was about 1.5 times more carcinogenic, 2 to 5 times more mutagenic, and 2 times more teratogenic than the ICRP's risk estimates from gamma and X-rays.

**3. Chicanery over the Q Value**
More worrying is the evidence[6] from Dr Karl Morgan, a former chairman of a main Committee of the ICRP, that the ICRP has played fast and loose with tritium's Q value – reducing its value from 1.7 to 1 in 1969, allegedly in response to pressure from the US military who needed laxer limits to expand tritium production in the 1960's, during the cold war.

**Tritium emissions from nuclear plants**

| Nuclear facility | Tritiated water vapour emissions to atmosphere TBq/yr[1] | Year |
|---|---|---|
| Chapelcross | 1900 | 1990 |
| Sellafield | 593 | 1990 |
| Amersham Int'l (Cardiff Plant) | 180 | 1990 |
| AWRE Aldermaston | 100 | 1985 |
| AERE Harwell | 46 | 1990 |
| UKAEA Dounreay | 18 | 1986 |
| Amesham Int'l (Amersham Plant) | 14 | 1990 |
| Wylfa, Magnox | 13 | 1990 |
| UKAEA Winfrith | 8.4 | 1990 |
| Hunterston B | 8.2 | 1986 |
| Heysham 1, AGR | 3.2[2] | 1986 |
| Hartlepool, AGR | 3.2[2] | 1986 |
| Hinkley Point B | 3.2[2] | 1990 |
| Dungeness B | 3.2[2] | 1986 |
| Trawsfynydd | 2.7 | 1990 |
| Heysham 2 | 0.67 | 1990 |
| Pickering, Canada | 900 | 1990 |

Notes
(1) 1TBq = 27 curies
(2) Estimated figures

The result is all three factors are undervalued and their quotient even more so. Radiation doses from tritium are likely to be underestimated by the ICRP, perhaps by as much as 10 to 20 fold, depending on which factors are taken into account.

## What can be done?

First the NRPB should commission a study into OBT. Second, MAFF/DoE/ Scottish Office should place limits on tritium to air emissions from nuclear power stations and should require all nuclear operators to monitor their tritium to air discharges. The NRPB should also make recommendations on how to determine OBT concentrations using bioassay methods, and nuclear employers should use these to determine OBT concentrations in their workers and nearby residents. The ICRP should issue Annual Limits on Intake for OBT, and should increase tritium's Q factor to five as a precautionary measure, until its own researches on tritium uptake into our DNA have clarified the matter further. At least, these steps will be a start and will serve to focus badly-needed attention on tritium. □

**A fuller version of this article "Tritium: The overlooked nuclear hazard" by Ian Fairlie appears in the Ecologist, Vol 22 No 5, September/October 1992.**

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3) "Scottish Development Department Statistical Bulletin", No 2(E), July 1989.

4) "The metabolism of 3H and 14C with special Reference to Radiation Protection" Taylor DM et al, Radiat Prot Dos, 30, 87-93, 1990.

5) "Health risks from exposure to tritium" T Straume, Lawrence Livermore Laboratory, UCRL-LR105088.

6) "Comments on the May 1990 Draft EIS for Operation of the K L and P Reactors at Savannah River Plant" K Z Morgan, 1990.