Recent Results from Epidemiology

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Sources of Tritium for Study

- Cosmogenic
  - production in upper atmosphere
    - environmental exposure
- Fission product
  - nuclear reactors and weapons
    - occupational and environmental exposure
- Neutron capture product
  - ^{2}H, ^{6}Li, ^{10}B
    - occupational and environmental exposure

Tritium Epidemiology

- What are we trying to achieve by conducting epidemiological studies of tritium exposure?
- To quantify, from the *direct* experience of humans exposed to tritium, the degree of risk to health resulting from a given level of exposure to (i.e. dose received from) tritium
  - the *risk coefficient*, the Excess Relative Risk (ERR) or Excess Absolute Risk (EAR) per Gy

  and how this relates to current radiological protection standards.

Environmental Epidemiology

- Epidemiological correlation studies – "ecological studies", such as the study of certain health effects around facilities that discharge tritium – are difficult to interpret reliably
  - lack of dependable tritium-specific doses
  - frequent lack of control for other factors, including other sources of radiation dose
  - often plagued by biases, including the *post hoc* nature of some studies

Occupational Epidemiology

- Occupational exposure to tritium represents the best opportunity of studying risks (to the exposed individual and to his/her offspring) epidemiologically
  - good personnel records for tracing
  - good exposure records (not just to tritium, but to other sources of radiation)
  - reasonable measures of background risk factors (e.g. socio-economic status as an indicator of smoking and other habits)

Epidemiological Studies

- Nuclear industry workforces have been the subject of studies of external dose.
- Some of these studies have included doses due to tritium exposure, but tritium-specific doses have not been the subject of a specific assessment.
- As such, at present these studies provide only a weak indication of the risks to health posed by tritium exposure.

Canada

- The use of heavy water-moderated (CANDU) reactors leads to exposure to tritium through neutron capture by deuterons.

- Used as a source of tritium at the Tritium Removal Facility of the CANDU power station at Darlington in Ontario.

Canada

- Zablotska *et al.* (*Radiat Res* 2004; **161**: 633-641) studied 45 468 Canadian nuclear workers during 1957-94.
- Tritium-specific doses were added to doses from external sources (film badge doses).
- Cohort mean cumulative individual dose (including tritium) was 13.5 mSv; 19.7 mSv for those workers with some dose recorded.
- No indication of magnitude of tritium doses.

Zablotska *et al.*

(*Radiat Res* 2004; **161**: 633-641)

- ERR/Sv for *all solid cancers*
  - with tritium doses:

    included, 2.80 (95% CI: -0.038, 7.13);

    excluded, 2.67*.
- ERR/Sv for *all leukaemias*
  - with tritium doses:

    included, 18.9 (95% CI: <-2.08, 138);

    excluded, 16.3*.

* Confidence intervals not given.

Canadian Studies

- However, some apparent problems with the Canadian worker data need to be addressed.
- The Canadian workers exposed to tritium should then provide a suitable source of information on the risks of tritium exposure.

USA Studies

- A variety of operations at nuclear facilities in the USA will have led to occupational exposure to tritium.
- Savannah River Site in South Carolina

is of particular interest because of its tritium processing operations, but other sites (e.g. Mound) will be of relevance.

USA Studies

- Savannah River Site workers have been studied by
  - Cragle *et al.* (1988, 1998)
  - Schubauer-Berigan *et al.* (2007)
  - Richardson & Wing (2007).

Cragle *et al.*. *Am J Indust Med* 1988; **14**: 379-401, and http://www.orau.gov/ehsd/EpiProceedings-jj-9-30-98.doc (1998)

Schubauer-Berigan *et al.*. *Radiat Res* 2007; **167**: 222-232

Richardson & Wing. *Am J Epidemiol* 2007; **166**: 1015-1022

Savannah River Site

- Both Schubauer-Berigan *et al.* (2007) and Richardson & Wing (2007) studied leukaemia mortality, and found a radiation-related excess risk among the Savannah River Site workers.
- The analyses are in terms of *total* dose, so do not reveal much about the tritium-related leukaemogenic risk.

USA Studies

- Tritium-specific doses would appear to be available for these Savannah River Site studies, but tritium doses have not been used explicitly in any analysis.
- The extent of the availability of tritium doses more generally across the USA is not clear.

USA

- If tritium-specific doses can be generated (in parallel with other preparations for epidemiological studies of nuclear workers in the USA) then occupational exposure to tritium in the USA should be a valuable source of information on tritium risks.

UK Studies

- A variety of operations involving tritium production and processing, and the use of heavy water reactors, have led to occupational exposure to tritium in the UK.
- Tritium-specific doses have been, or are being, generated, but have not been used explicitly in epidemiological studies.

UK Studies

- Weak indications from some early studies, e.g. Rooney *et al.* (*BMJ* 1993; **307**: 1391-1397), that exposure to tritium might be associated with an increased risk of prostate cancer have not been supported by later studies – see Atkinson *et al.* (*J Radiol Prot* 2007; **27**: 437-445).
- Note that these studies have *not* used tritium-specific doses.

UK Studies

- Tritium exposures have occurred at nuclear establishments operated by
  - British Nuclear Fuels plc (BNFL)
  - UK Atomic Energy Authority (UKAEA)
  - Atomic Weapons Establishment (AWE)
  - GE Healthcare (formerly Amersham)
  - others (e.g. naval dockyards)

Tritium-specific Doses in the UK

- BNFL
  - Sellafield, Chapelcross (doses available)
  - Capenhurst (doses being calculated)
- UKAEA
  - Harwell, Winfrith, Dounreay (doses being calculated)
- AWE
  - Aldermaston (doses available)
- GE Healthcare (and Others)
  - Amersham, Cardiff (some doses available, but position requires investigation)

Tritium-specific Doses in the UK

- So far, tritium-specific doses have only been used in studies of AWE workers.

- However, these tritium doses have *not* been used separately, and have been added to external doses for the purposes of analysis.

UK Studies

- BNFL, UKAEA and AWE each maintains an epidemiological database, so epidemiological studies utilising tritium-specific doses should be straightforward.
- GE Healthcare (and other relevant) workers are included in the National Registry for Radiation Workers (NRRW).

Russia

- Operations involving occupational exposure to tritium in Russia could provide significant information, but it is unclear whether studies are feasible at present.
- Tritium was produced, and heavy water reactors operated, at the presently-named Mayak establishment in the Southern Urals from the early-1950s.

A Kruglov *The History of the Soviet Atomic Industry* Taylor &Francis, London, 2002

Russia

- Extent of occupational exposure to tritium in Russia is not known, and may not be available for scientific studies.
- Soloviev *et al.* (2001) reported three serious accidents involving HTO at Mayak (in 1952, 1953 and 1963) involving 5 people, 2 of whom died (after the 1952 accident).

V Soloviev *et al.* Radiation accidents in the former USSR. In: I A Gusev, A K Guskova and F A Mettler (eds), *Medical Management of Radiation Accidents, Second Edition*. CRC Press, Boca Raton, FL, 2001. pp 157-159

France

- Occupational exposure to tritium in France will have occurred through the civil and military uses of nuclear energy.
- A number of sites (e.g. Saclay, Marcoule, Valduc) could be of interest.

- French exposures require investigation, but it is unclear whether studies using tritium-specific doses are feasible.

Other Countries

- CANDU reactors operate in countries other than Canada (e.g. India, South Korea, Argentina, Romania), which could possibly provide useful additional information.
- Other countries (e.g. India) will have operated heavy water reactors, or produced or processed tritium.
- Exposures will have occurred in China, but the feasibility of studies is unknown.

Pooled Information

- Maximum scientific information will be derived from the appropriate pooling of epidemiological data for analysis.
- Indeed, it is unlikely that a study conducted in just one country could provide meaningful information.
- This suggests that careful collaboration between research groups is desirable to ensure that data may eventually be properly pooled in a combined analysis.

Tritium Dosimetry

- An essential component of scientific collaboration is to develop an agreed methodology for deriving tritium-specific doses from worker monitoring data.
- Otherwise doses may be calculated in different ways by the various research groups, which would not be sensible.

Tritium Risks

- Exposure to tritium will continue to occur as a result of operations in the nuclear industry (tritium production and heavy water reactors), luminising, and the use of radiochemical labelling in industry and research;

  but fusion power is another potential source in the future.

ITER at Cadarache

- We should take the opportunity now of the proper utilization of epidemiological data for workers to assess tritium risks.

Why Bother?

- To obtain meaningful risk estimates for tritium exposure will require substantial co-ordinated international effort, so why bother?
- It has been suggested, e.g. by Fairlie (*J Radiol Prot* 2007; **27**: 157-168), that the risks posed by tritium may have been seriously underestimated, which would have major implications for its use (e.g. in the nuclear fusion fuel cycle, using kg quantities of ^{3}H).
- Properly conducted epidemiological studies can address this suggestion.

"If the controlled thermonuclear reactor is ever developed, we would be going through tritium on the way to the release of fusion energy. So I think this means we should think about what problems might come up when we are using tritium in quantities that make our present activities look miniscule…Therefore, we must come to understand how to live with tritium and really understand it."

Willard F. Libby, "History of Tritium", in *Tritium*, A. A. Moghissi & M. W. Carter (eds.), Messenger Graphics, Las Vegas, NV (1973) pp 3-11.

Recent Reviews

- Independent Advisory Group on Ionising Radiation. *Review of Risks from Tritium. Documents of the Health Protection Agency. Radiation, Chemical and Environmental Hazards, RCE-4.* Health Protection Agency, Chilton, UK; November 2007. http://www.hpa.org.uk/publications/2007/tritium_advice/RCE_Advice_on_tritium.pdf
- Little MP & Wakeford R. Systematic Review of Epidemiological Studies of Exposure to Tritium. *Journal of Radiological Protection* 2008; **28**: 6-32.