Carbon-14 Dosimetry at Quotient Bioresearch and the latest evidence for biological half lives

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1. Introduction

Radiochemicals Business acquired by Quotient Bioresearch from GE Healthcare in June 2009, manufacturing in the new facility began in May 2010

80 Radiochemists working with open sources

Radionuclide	Maximum Scale (Bq)	Typical Scale (Bq)
Tritium	7.4×10^{11}	7.4×10^{10}
Carbon-14	5.2×10^{10}	1.5×10^{10}

A suitable system of dosimetry needed to be developed by Quotient to meet the HSE 's requirements:

- Justify staff not being Classified workers by means of a prior risk assessment
- Carry out appropriate dosimetry to assess staff doses and ensure that no worker received >6mSv per annum
- Have the dosimetry for Carbon-14 approved by an approved dosimetry service (ADS)

2. Objectives

Instigation of a dosimetry service for both Carbon-14 and Tritium that would need:

- Sufficient frequency of sample analysis to ensure that exposures were detected
- Sufficient sensitivity to ensure a low minimum detectable activity (MDA)
- Suitable dose assessment model to accurately assess doses
- Site investigation levels set to ensure that the potential to breach the annual limit of 6mSv was minimised
- A practical system to identify processes and compounds that give rise to exposures in order to alter ways of working to keep doses ALARP

The aim of the dosimetry service is to:

- Protect staff by identifying exposures and accurately assessing the resultant doses
- Identify and improve processes that may cause future exposures
- Ensure business continuity

3. Issues To Be Resolved

Large number of staff to be included in the dosimetry analysis (>80)

Daily urine samples would be needed to ensure identification of potential exposures

Analysis of urine would require a counter with high sensitivity and a low background to give an acceptably low MDA

Fume hood needed for sample dispensing

Data storage and analysis would need to be carefully considered especially at high analysis frequency

Counting times would have to be optimised to give the best MDA from the available counter time due to the large number of chemist samples

A routine monitoring regime and a non-routine regime would need to be developed to identify exposures from routine work and target work with volatile radiochemicals and post incident dosimetry.

Clearly understood investigation process for exposures that exceed the site investigation levels to be communicated

Data collection and lengthy discussion with an ADS would be necessary in order to understand and agree an appropriate dosimetry model.

4. Routine Dosimetry

Daily urine samples supplied by each member of staff with very high sample submission levels (>90%)

Monday and Thursday samples routinely analysed with the remaining daily samples held and analysed if the Monday and Thursday samples indicate that an exposure has taken place

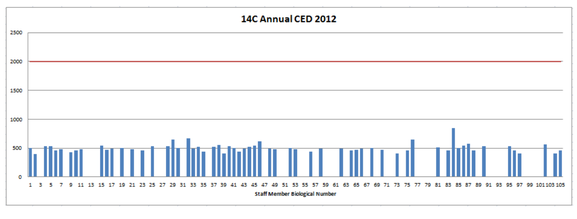
Low MDA achieved by:

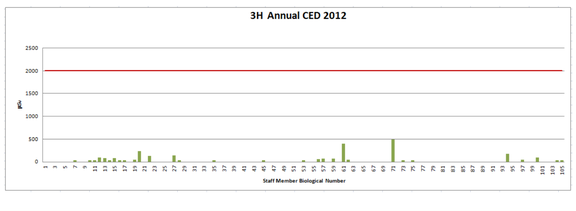
- Tricarb 3110TR purchased and run in high sensitivity mode
- Plastic scintillation vials used
- Background counted for 2 hours and staff samples for 15minutes each

Excel spreadsheet used to collate data and to calculate the routine doses.

Samples that breach the site investigation level trigger a special investigation, doses modelled using the Health protection Agency's dosimetry software IMBA™ and then added to the routine spreadsheet.

50% of the observed exposures are identified on the routine monitoring programme





5. Non-Routine Monitoring

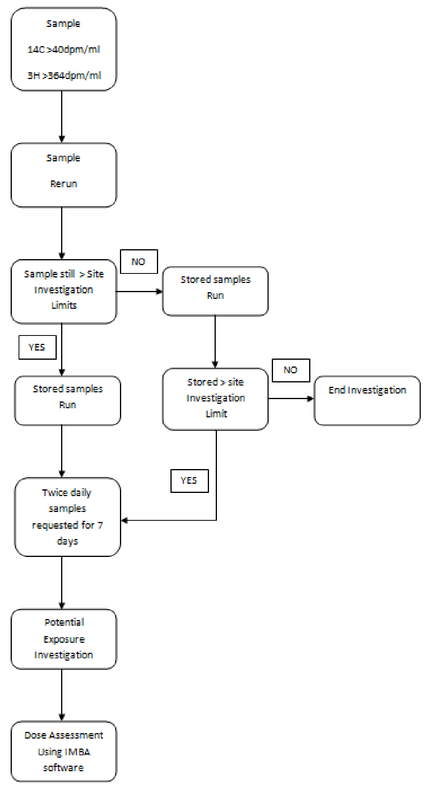
Non-routine and volatile work urine samples are provided:

- When working with volatile activity or a process that has heightened potential for causing an exposure
- Post a contamination incident, spill, etc
- Contractors
- Quotient Bioresearch staff not on routine monitoring, but who occasionally enter labs.

50% of the observed exposures are identified through non-routine and volatile work samples

6. Post Exposure Actions

Routine and non-routine samples above the Site investigation level initiate an investigation, further sample voiding and a dose assessment Using IMBA™.

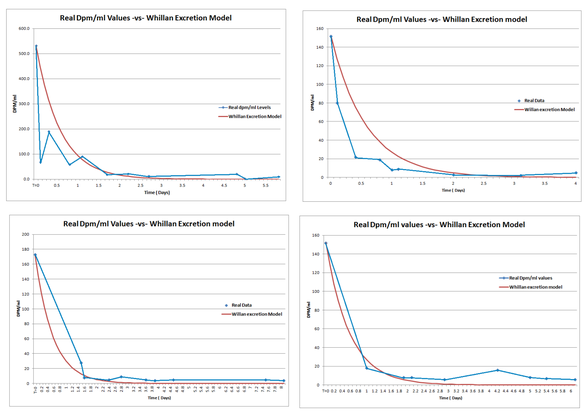


7. Dose Assessment

Discussions, over a period of 12 months, with Peak RPA and Nuvia about Quotient Bioresearch's raw dosimetry data and IMBA™ dose assessments has resulted in a practical and realistic dose assessment service.

The Whillans Physiologically Based Biokinetic (PBBK) Dosimetry multi-compartment dose model is used which has components with biological half lives of 0.4, 1.2 and 40 days.

After every exposure the real dpm/ml values are compared against a plot of concentration levels as predicted by the Whillans model based on the initial sample concentration. This check is carried out to assess the suitability of the Whillans dose model:



If a site investigation level is breached a potential exposure investigation is carried out in order to more accurately assess the potential dose by identifying:

- Approximate time of exposure
- The chemical compound responsible for the exposure
- Process involved in the exposure

8. Measured Biological Half Lives

Since the start of the dosimetry regime in May 2010 over 15000 routine samples and over 2000 non-routine samples have been analysed for both Carbon-14 and Tritium.

During this period the site investigation level has been breached 81 times.

The Whillans dose model takes account of the initial rapidly excreted radioactivity as well as components with a longer biological half life.

To date all of the measured exposures due to Carbon-14 labelled organic molecules have been consistent with the Whillans dose model.

Where the organic compound responsible for the exposure has been identified. The initial excretion of Carbon-14 the biological half life has been measured.

The data set produced by the analysis of biological samples supports the use of the Whillans dose model.

This data set will continue to grow as Quotient Bioresearch's manufacturing processes continue at The Old Glassworks.

Chemical compound	Observed biological half life in Days (Initial rate during first 2 days)	Whillan (PBBK) Dosimetry model Applicable
Methy[ring-U-14C]benzoate	0.25 – 0.36	Yes
[U-14C]Phenol	0.30 – 0.71	Yes
Diethyl[2-14C]malonate	0.94	Yes
2-Amino[U-14C]pyridine	1.92	Yes
2-Methoxy[2,6-14C]pyridine	0.59	Yes
[14C]Tetralone	2.1	Yes
[ring-U-14C]Benzoic acid	0.80	Yes
2-Nitro[U-14C]phenol	0.80	Yes
[14C]Methanol	0.48	Yes
[14C]Furfural	0.11 – 0.2	Yes
[ring-U-14C]Aniline	0.69	Yes
[ring-U-14C]Bromobenzene	0.49 – 0.68	Yes
Hydroxy[1-14C] methylpentanone	2.24	Yes
Trichloro[1-14C] methylpentanone	1.22	Yes
[carbonyl-14C]Cyclopentanone	0.32	Yes
[ring-U-14C]Phenyl acetate	0.87	Yes
Dichlorofluoro[2-14C]uracil	0.22 – 0.30	Yes
3-Chloro-2-methyl[ring-U-14C]aniline	0.64	Yes
[2-14C]Uracil	0.75	Yes
4-Chloro[ring-U-14C]aniline	0.38 – 0.73	Yes