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The human body retention time of environmental organically bound tritium

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Abstract

Tritium in the UK environment causes low radiation doses to the public, but uncertainty exists in the dose coefficient for the organically bound component of tritium (OBT). This can affect the assessment of effective doses to representative persons. Contributing to that uncertainty is poor knowledge of the body retention time of OBT and how this varies for different OBT compounds in food. This study was undertaken to measure the retention time of tritium by volunteers after eating sole from Cardiff Bay, which may contain OBT from discharges from the GE Healthcare Ltd plant. Five volunteers provided samples of excreta over periods up to 150 days after intake. The results, which are presented in raw form to allow independent analysis, suggest retention of total tritium with body half-times ranging from 4 to 11 days, with no evidence (subject to experimental noise) of a significant contribution due to retention with a longer half-time. This range covers the half-time of 10 days used by the ICRP for tritiated water. The short timescale could be due to rapid hydrolysis in body tissues of the particular form of OBT used in this study. Implications for the dose coefficient for OBT are that the use of the ICRP value of 4.2×10^{-11} Sv Bq^{-1} may be cautious in this specific situation. These observations on dose coefficients are separate from any implications of recent discussion on whether the tritium radiation weighting factor should be increased from 1 to 2.

1. Introduction

Tritium in the environment of the UK derives from both natural sources and discharges of radioactive wastes by nuclear, radiochemical, weapons, medical and research facilities.

Radiation doses to the public due to these sources are low [1], but uncertainty exists in the dose coefficient to calculate the effective dose from eating foodstuffs, particularly for the component of organically bound tritium (OBT) [2]. This uncertainty can affect the assessment of doses to the public, including poor knowledge of the body retention time of OBT and its variability with different OBT compounds in food.

A particular foodstuff of interest is seafood caught in the coastal vicinity influenced by liquid discharges from the GE Healthcare Ltd Maynard Centre at Whitchurch, Cardiff. Tritium discharges from this plant have been reduced in recent years, especially since 2006, by a waste recycling and storage programme. The diverse range of radiopharmaceuticals and biomedical research products authorised for discharge to Cardiff Bay have included a mix of organic compounds labelled with tritium. Demersal fish and other benthic organisms in this area contain higher concentrations of tritium compared with areas where tritium is discharged mainly as tritiated water; this elevation has been attributed to the content of OBT [3, 4]. Although not directly addressed in this study, knowledge of the dose coefficient is particularly important for protection of unborn children as a potential critical group [1, 5]. Currently, effective doses are reported to be small and, indeed, reducing: in 2006 the reported dose to adult high-rate fish consumers was 0.012 mSv, with the dose to any unborn children 0.015 mSv [1]. However, doses are uncertain due both to the biokinetic model for the OBT component and to uncertainties in radiobiological effectiveness (RBE). Taking into account these sources of uncertainty, it has been estimated that doses to the critical group from tritium during the years of highest discharges could have been as high as 0.133 mSv [6]. The UK Advisory Group on Ionising Radiation has recently reviewed the risks from tritium [7]. This review suggested *inter alia* that a provisional value of 2, rather than 1 as used by ICRP [8], be used for the radiation weighting factor for tritium to reflect RBE, and that in particular situations (e.g. near Cardiff) special models may be appropriate. However, the ICRP has indicated [9], on the basis of broader considerations, that it will continue to apply a radiation weighting factor of 1 to all low LET radiations including from tritium.

The dose coefficient applicable for OBT in fish from Cardiff Bay has recently been investigated, based on data for retention in rats [10]. These data suggested that retention of the Cardiff Bay OBT in humans has a 70% component with body half-time of 10 days and a 30% component with a body half-time of 100 days, compared with the default ICRP assumption [8] of 50% 10 days and 50% 40 days. This has the effect of increasing the dose coefficient for OBT from the ICRP value of 4.2×10^{-11} to 6.0×10^{-11} Sv Bq^{-1}. The present study was designed to investigate body retention of tritium in fish from Cardiff Bay in human adults directly, on the basis of excretion patterns from a small number of volunteers each having eaten a sample of this fish. The excretion data are presented in raw form to allow independent interpretation.

2. Methods

Dover soles (*Solea solea*) were obtained from a Cardiff Bay fisherman for this study. This species provides the bulk of the local fish eaten by the highest-rate consumers. Flounder (*Platichthys flesus*), which were used in the Hodgson *et al* study [10], are often easier to catch than sole and have been a reliable target species for monitoring purposes but are less palatable, often containing sediment. Fourteen soles were provided, weighing between 80 and 630 g (wet). The gutted fish were transported rapidly in fresh condition to the Cefas Lowestoft Laboratory where they were prepared by poaching for ease of removal of skin and bone; milk was used for poaching to improve the texture for consumers following freezer storage. The flesh of each fish was sampled by taking ~1 g of flesh from five different places for analysis, and the fish then individually frozen for storage. Each five subsamples were combined and

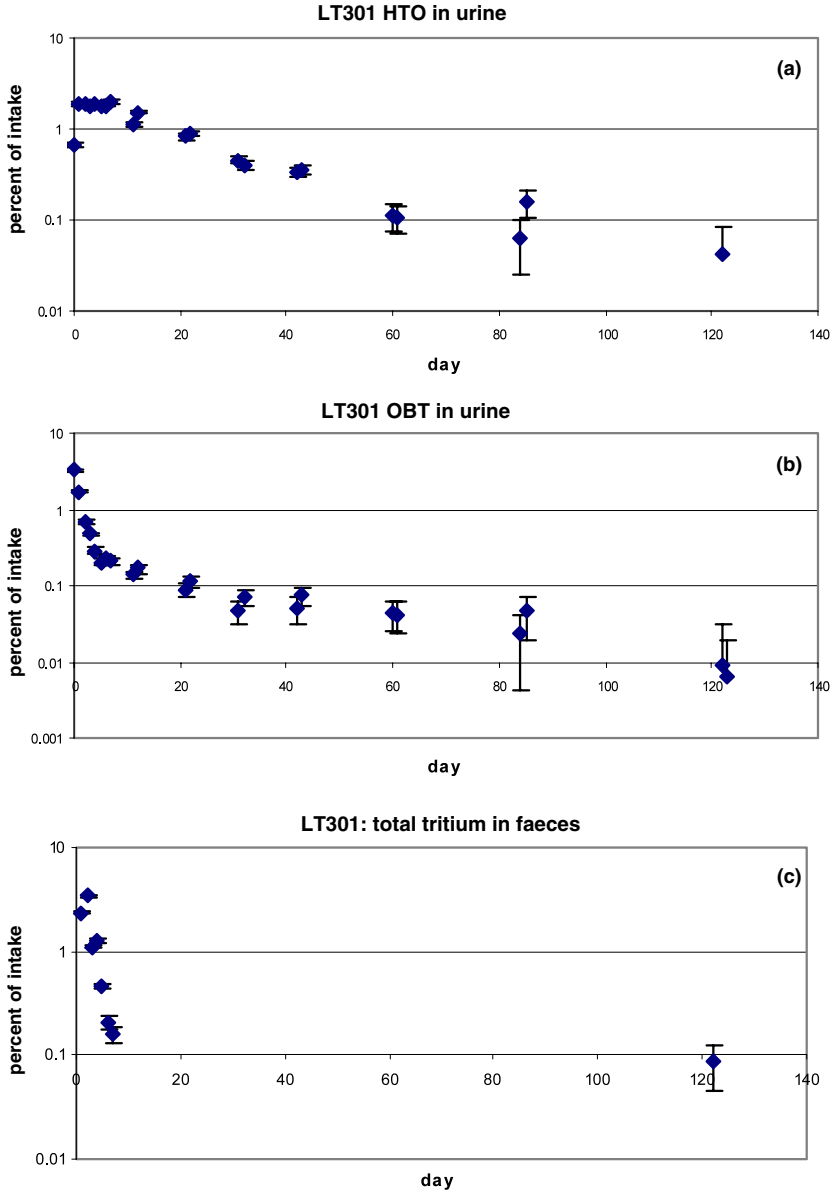

Figure 1. (a) Urinary excretion by LT301 as tritiated water, (b) urinary excretion by LT301 as OBT, (c) faecal excretion of total tritium by LT301.

analysed for total tritium using the chromic acid oxidation method described later. Tritium concentrations in the fish ranged between 0.7 and 16 kBq kg^{-1} (wet). This pre-analysis served to identify the most suitable fish for volunteers to eat, based on tritium content. For some volunteers, smaller or less active fish were combined. The objective was to provide an intake of about 3–6 kBq which could be followed over a period of ∼100 days; on the basis of the elevated dose coefficient suggested by Hodgson *et al* [9], this would lead to a committed effective dose of up to 0.4 μSv, including a very small contribution from other radionuclides in the Cardiff

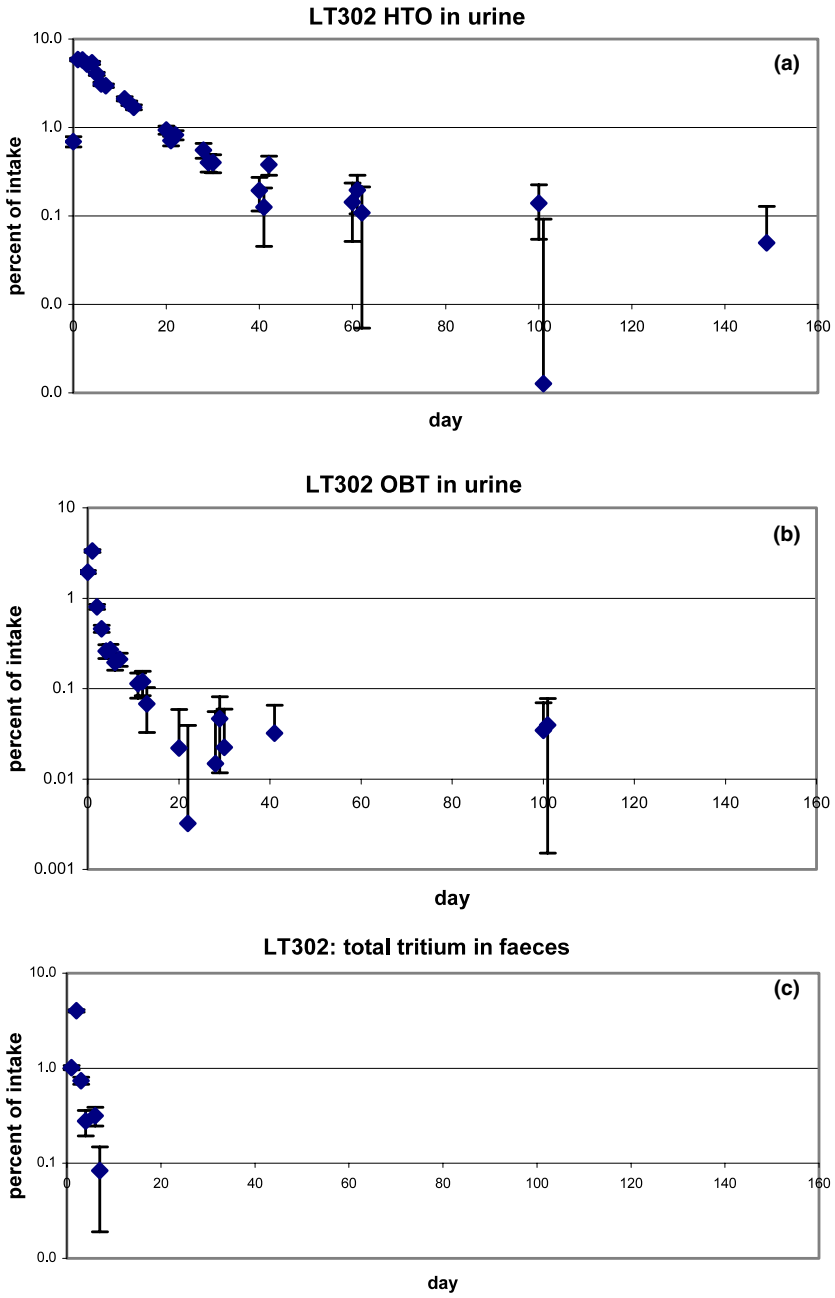

Figure 2. (a) Urinary excretion by LT302 as tritiated water, (b) urinary excretion by LT302 as OBT, (c) faecal excretion of total tritium by LT302.

Bay area [1]. This dose is well within the 'trivial' risk category of up to 100 μSv for biomedical research studies as recommended by the ICRP [11].

Five adult volunteers, three males and two females, took part in this study; their details are given in table 1. Each volunteer's programme was planned so as to minimise inconvenience, involving samples for three 'background' days (day -3 to day -1) prior to eating the fish,

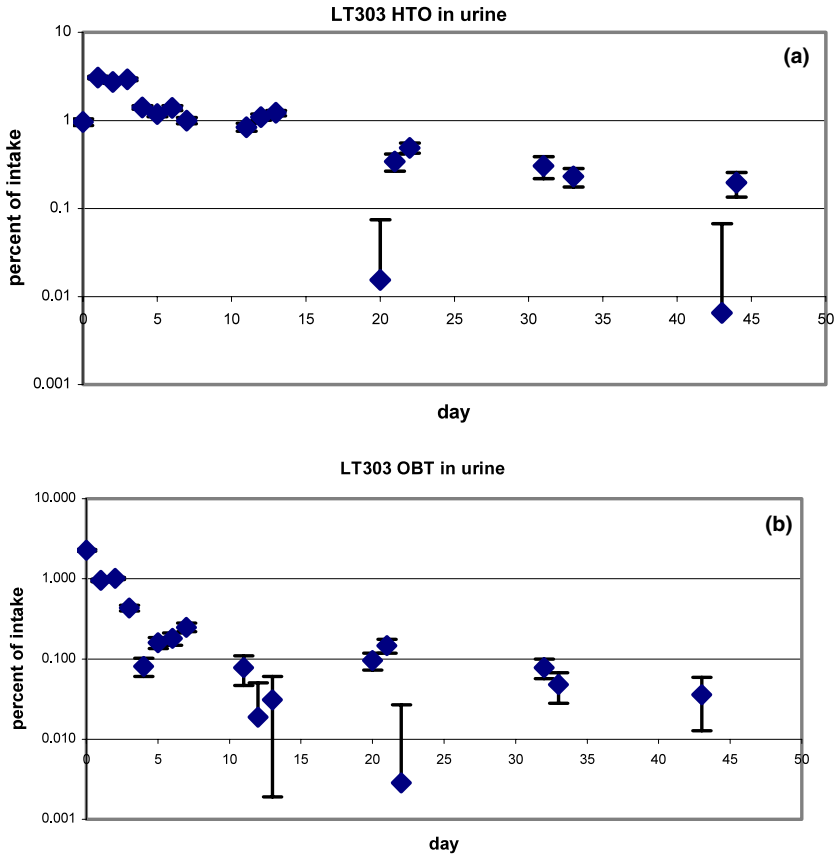

Figure 3. (a) Urinary excretion by LT303 as tritiated water, (b) urinary excretion by LT303 as OBT.

and subsequently as described below, following a 24 h sampling protocol. This study was based primarily on urinary excretion; it was not expected that faecal sampling would provide significant additional information on long-term tritium excretion in view of the lower water excretion in faeces. However, to observe clearance from the gut, three of the volunteers provided faecal samples.

On the day before their scheduled consumption date (d-1), each volunteer was provided with a sample of up to 900 g of frozen sole fillet in polybags. This was defrosted overnight in home refrigerators. On d0 the polybags were slit, any free liquid discarded, and the polybags and contents weighed in a tray on portable scales with an empty subsample pot. The fish was eaten, placing one spoonful into the subsample pot for every two taken for eating. In all cases the volunteers completed eating the fish in one day, although the protocol allowed up to two days. All the waste, including polybags and further liquid, was collected in the tray which was reweighed with the filled subsample pot to derive the weight of fish eaten.

Urine sampling continued until d7, then (as planned for the convenience of volunteers) approximately on days 11–13, and subsequently for 3 consecutive days around d20, d28, d40, d60, d100 and for two volunteers (LT302 and LT304) d150. One volunteer (LT303) only sampled till d44. Faecal sampling by three volunteers (LT301, LT302 and LT304) continued until d7, except for one volunteer (LT301) who did not carry out background faecal sampling on days -3 to -1; instead these samples were provided on d122–124.

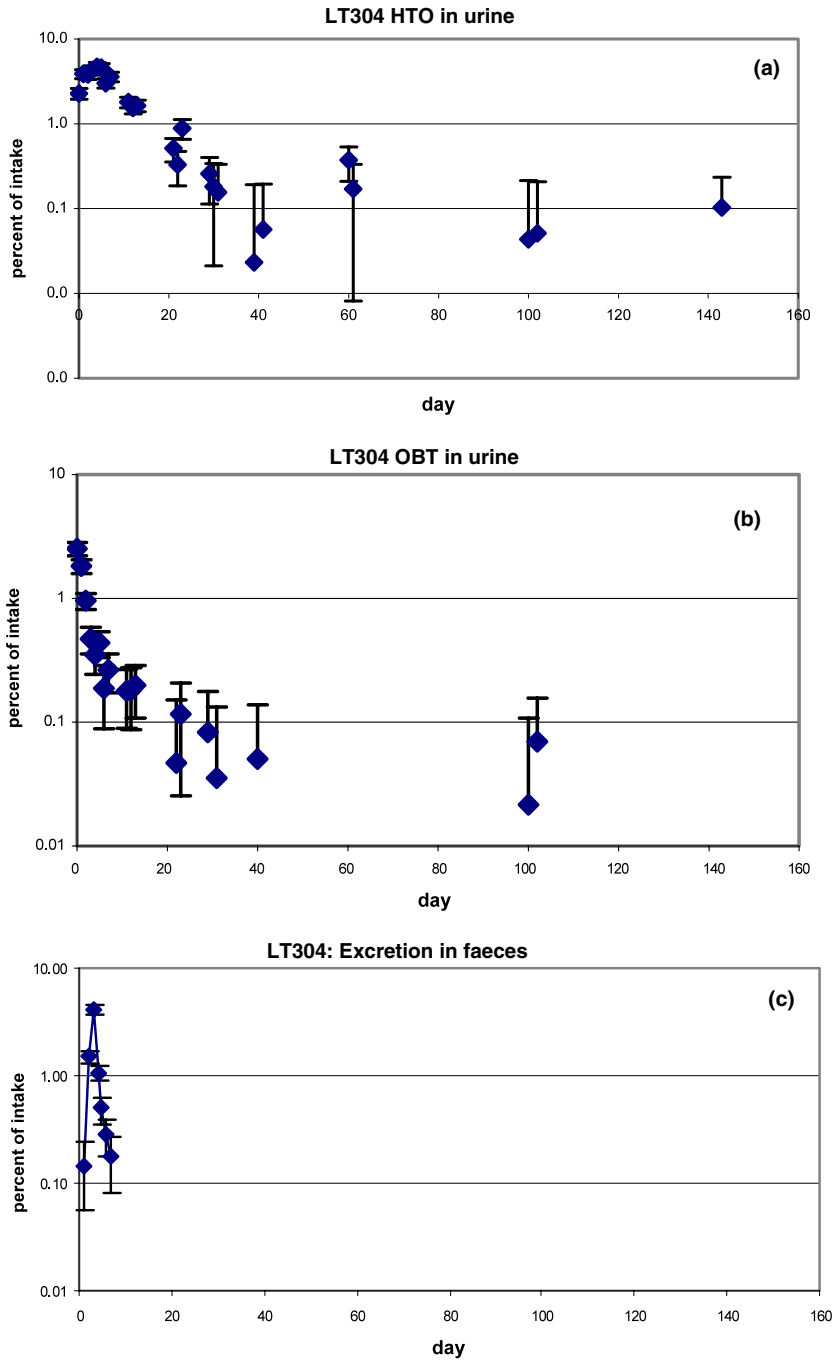

Figure 4. (a) Urinary excretion by LT304 as tritiated water, (b) urinary excretion by LT304 as OBT, (c) faecal excretion of total tritium by LT304.

Urine was analysed for tritium in the forms of tritiated water and, separately, OBT. For tritiated water, an aliquot of urine was double-distilled and the distillate counted using a Packard 2550 low level scintillation counter and Ultima Gold LLT scintillant, against a traceable tritiated

Table 1. Details of volunteers and intakes.

Volunteer	Sex	Age	Weight of sole eaten (g)	Tritium concentration (Bq kg^{-1} (wet))[a]	Intake of tritium (Bq)[a]
LT301	M	60	384	15 500 ± 600	5900 ± 200
LT302	F	38	367	13 000 ± 400	4800 ± 150
LT303	M	42	533	5 250 ± 70	2800 ± 40
LT304	F	46	240	10 400 ± 1200	2500 ± 300
LT305	M	52	552	4 300 ± 500	2400 ± 300

[a] Errors represent ±1 standard error of the mean of several measurements.

Table 2. Excretion of tritium by LT301. (Note: NS—Not sampled.)

Day	Tritiated water in urine (Bq)[a]	OBT in urine (Bq)[a]	Total tritium in faeces (Bq)[a]
−3	3.6 ± 1.3	1.2 ± 0.6	NS
−2	2.9 ± 0.8	1.1 ± 0.6	NS
−1	4.5 ± 2.0	2.7 ± 1.1	NS
0	43 ± 2	197 ± 2	NS
1	116 ± 2	103 ± 2	142 ± 3
2	118 ± 3	43 ± 1	203 ± 3
3	111 ± 2	30 ± 1	67 ± 1
4	116 ± 3	19 ± 1	76 ± 3
5	112 ± 3	14 ± 1	29 ± 1
6	112 ± 3	15 ± 1	14 ± 1
7	122 ± 3	14 ± 1	11 ± 1
11	69 ± 2	10 ± 1	NS
12	95 ± 3	12 ± 1	NS
21	52 ± 2	7 ± 1	NS
22	56 ± 3	8 ± 1	NS
31	31 ± 2	4 ± 1	NS
32	27 ± 2	6 ± 1	NS
42	24 ± 2	5 ± 1	NS
43	25 ± 2	6 ± 1	NS
60	10 ± 2	4 ± 1	NS
61	12 ± 2	4 ± 1	NS
84	7 ± 2	3 ± 1	NS
85	13 ± 3	4 ± 2	NS
122	6 ± 2	2 ± 1	7 ± 2
123	4 ± 1	2 ± 1	−1 ± 1
124	3 ± 1	1.3 ± 0.3	−2 ± 2

[a] Errors represent ±1 standard deviation based on counting statistics.

water standard. The solids residue after the first distillation (typically 2–3 g) was deemed to contain the organically bound component. This was oxidised using chromic acid, and after digestion, 20 ml water was added. It was then re-distilled, and the distillate counted in the same manner as before.

Faeces were analysed for total tritium by taking five ∼1 g subsamples from each sample, combining them, oxidising with chromic acid, distilling and liquid scintillation counting.

Samples of fish were analysed in two ways. The first method measured total tritium by taking a 5 g subsample, treating with chromic acid, distilling and scintillation counting. The second method measured the OBT content by drying a subsample and oxidising the residue with chromic acid, followed by distillation and scintillation counting. In practice the results

Table 3. Excretion of tritium by LT302. (Note: NF—No faecal excretion, NS—Not sampled.)

Day	Tritiated water in urine (Bq)[a]	OBT in urine (Bq)[a]	Total tritium in faeces (Bq)[a]
−3	0.2 ± 2.4	1.7 ± 1.0	3.1 ± 3.4
−2	4.2 ± 3.6	4.0 ± 1.5	−8 ± 4
−1	2.6 ± 3.8	5 ± 2	0.2 ± 2.5
0	36 ± 4	96 ± 2	−3.1 ± 3.2
1	282 ± 6	163 ± 3	47 ± 2
2	280 ± 7	42 ± 2	191 ± 5
3	251 ± 6	26 ± 2	34 ± 3
4	260 ± 6	16 ± 2	11 ± 4
5	196 ± 5	17 ± 2	NF
6	151 ± 4	13 ± 1	13 ± 3
7	144 ± 4	14 ± 1	2.2 ± 2.7
11	104 ± 4	9 ± 1	NS
12	92 ± 4	9 ± 1	NS
13	83 ± 4	7 ± 1	NS
20	47 ± 4	5 ± 2	NS
21	36 ± 3	0.2 ± 1.3	NS
22	42 ± 4	3.9 ± 1.5	NS
28	29 ± 4	4.4 ± 1.8	NS
29	22 ± 4	6 ± 2	NS
30	22 ± 4	5 ± 2	NS
40	12 ± 3	2.7 ± 1.3	NS
41	8 ± 3	5.2 ± 1.4	NS
42	20 ± 4	1 ± 2	NS
60	9 ± 4	−0.4 ± 2	NS
61	12 ± 4	−1 ± 2	NS
62	8 ± 5	2 ± 2	NS
99	1 ± 3	0.5 ± 1	NS
100	9 ± 4	5 ± 1	NS
101	2 ± 4	6 ± 2	NS
147	2 ± 3	1 ± 1	NS
148	1 ± 4	−1 ± 2	NS
149	5 ± 3	−1 ± 1	NS

[a] Errors represent ±1 standard deviation based on counting statistics.

were not greatly different, showing that the tritium content in the form of tritiated water was relatively small, and the tritium was overwhelmingly ($\gtrsim$90%) present in the form of OBT. This is consistent with results for fish in the regular monitoring programme [1]. The concentrations of tritium in the fish subsamples, on which the intakes have been based, are given in table 1 and were derived from repeated measurements (at least three in each case) using both methods; the standard errors represent their variability.

3. Results

Excretion data for the five volunteers are presented in tables 2–6, for tritiated water in urine; OBT in urine; and where measured, total tritium in faeces. Figures 1–5 show logarithmically the percentages of tritium intake excreted per day in the different forms over time; graphs are presented separately for clarity. Background excretion values for subtraction were derived from the means of days −3 to −1, except in two cases. For LT301, faeces were not measured for days −1 to −3, so the mean of faecal results for days 122–124 were used. The results for LT303

Table 4. Excretion of tritium by LT303. (Note: NS—Not sampled.)

Day	Tritiated water in urine (Bq)[a]	OBT in urine (Bq)[a]
−3	22 ± 2	2.5 ± 0.7
−2	25 ± 2	−0.5 ± 0.7
−1	18 ± 1	0.4 ± 0.5
0	39 ± 2	64 ± 1
1	98 ± 2	27 ± 1
2	88 ± 2	29 ± 1
3	94 ± 2	13 ± 1
4	52 ± 1	3.1 ± 0.4
5	45 ± 2	5.3 ± 0.6
6	51 ± 2	6 ± 1
7	40 ± 2	8 ± 1
11	36 ± 2	3 ± 1
12	43 ± 2	1.3 ± 0.8
13	46 ± 2	1.7 ± 0.7
20	13 ± 1	3.5 ± 0.5
21	22 ± 2	5 ± 1
22	26 ± 1	0.9 ± 0.6
31	21 ± 2	−1.0 ± 0.8
32	11 ± 1	3.0 ± 0.5
33	19 ± 1	2.1 ± 0.4
42	6 ± 1	−0.2 ± 0.4
43	12 ± 1	1.8 ± 0.5
44	18 ± 1	0.6 ± 0.5

[a] Errors represent ±1 standard deviation based on counting statistics.

were less satisfactory than for the other volunteers, having a relatively high and unexplained initial background for tritiated water in urine. For this volunteer, unrealistically negative data would have been obtained by subtraction of the initial background post day 20; thus to represent excretion better, especially at later times, the mean of results for days 42–44 were used.

4. Discussion

The results show that tritium excretion in faeces, where measured, had reduced to a low level by about day 7, with total faecal excretion of tritium <10% of the intake, suggesting a human alimentary tract transfer factor (f_A value) close to 1, the value assumed by ICRP [8]. OBT in urine also declined over the first few days, and the major subsequent form of excretion was tritiated water in urine. The tritium balance was investigated, using data up to 100 days for all volunteers except for LT303 where 50 days was used, interpolating for the days when excretion was not measured, and making an allowance for faecal excretion where it was not measured. On this basis, excretion of tritium was in the range of 72%–84% of the intake (mean 78%) for four volunteers. For LT303, the result was 48%, observed using data over 50 days against a relatively high background. The balance of tritium loss is by other routes, mainly exhalation and transpiration/sweat; these other routes account for around 50% of the water balance in Reference Man [12]. This study would suggest a rather lower result for these other routes, possibly typical of the volunteers' more sedentary occupations than average. Regarding the OBT component in each route, it is unlikely that losses involving evaporation would contain greater concentrations of OBT than urine/faeces. Thus excretion of OBT would be mainly via urine/faeces, and would have been unlikely to have been missed. Our results indicate that

Table 5. Excretion of tritium by LT304. (Note: NF—No faecal excretion, NS—Not sampled.)

Day	Tritiated water in urine (Bq)[a]	OBT in urine (Bq)[a]	Total tritium in faeces (Bq)[a]
−3	4 ± 3	3.4 ± 1.1	2.7 ± 2.9
−2	6.0 ± 3	1.3 ± 1.1	−7 ± 3
−1	1.7 ± 2.5	0.7 ± 1.0	0.2 ± 2
0	60 ± 4	65 ± 2	NF
1	100 ± 4	47 ± 2	2.4 ± 1.4
2	98 ± 3	26 ± 1	36 ± 3
3	111 ± 4	14 ± 1	102 ± 3
4	120 ± 5	11 ± 2	26 ± 2
5	117 ± 5	13 ± 2	11 ± 3
6	79 ± 4	6 ± 1	6 ± 2
7	93 ± 4	8 ± 2	3.2 ± 1.6
11	48 ± 3	6 ± 1	NS
12	42 ± 3	6 ± 1	NS
13	45 ± 4	7 ± 1	NS
21	16 ± 3	1.3 ± 1.2	NS
22	12 ± 3	3.0 ± 1.2	NS
23	26 ± 5	5 ± 2	NS
29	10 ± 3	4 ± 1	NS
30	8 ± 4	−1.0 ± 1.5	NS
31	8 ± 4	3 ± 2	NS
39	4 ± 4	−0.3 ± 2	NS
40	−1 ± 3	3 ± 1	NS
41	5 ± 3	−1 ± 1	NS
59	3 ± 4	2 ± 2	NS
60	13 ± 4	1 ± 1	NS
61	8 ± 4	1 ± 2	NS
100	5 ± 4	2 ± 2	NS
101	3 ± 3	1 ± 1	NS
102	5 ± 4	4 ± 1	NS
143	6 ± 3	1 ± 1	NS
144	2 ± 3	1 ± 1	NS

[a] Errors represent ±1 standard deviation based on counting statistics.

excretion is mainly as tritiated water in urine. It is suggested that the OBT from the sole very rapidly became incorporated in body tissues, and subsequently hydrolysed and excreted mainly as tritiated water. In what follows it has been assumed that all routes of excretion exhibit the same general time dependence for tritium.

The ICRP [8] has proposed the following simple model for retention $R(t)$ of tritium from intake of OBT:

$$R(t) = A\,\mathrm{e}^{-\lambda_1 t} + (1 - A)\,\mathrm{e}^{-\lambda_2 t} \tag{1}$$

where $A = 0.5$ is a conservative assumption, $\lambda_1 = \ln 2/10$ (corresponding to 10 days body half-time for a component which follows the behaviour of tritiated water), and $\lambda_2 = \ln 2/40$ (corresponding to 40 days body half-time for a component bonded to carbon as OBT).

Then the excretion $= -\frac{\mathrm{d}}{\mathrm{d}t}(R(t))$ (as the radioactive decay constant for tritium is relatively small):

$$\text{excretion} = \lambda_1 A\,\mathrm{e}^{-\lambda_1 t} + \lambda_2(1 - A)\,\mathrm{e}^{-\lambda_2 t}. \tag{2}$$

Curve fitting to estimate values of parameters was carried out using the statistical package Stata (v.9.2 Intercooled for Windows) [13]. This package is widely used in epidemiological

Table 6. Excretion of tritium by LT305.

Day	Tritiated water in urine (Bq)[a]	OBT in urine (Bq)[a]
−3	1.7 ± 1.4	0.9 ± 0.6
−2	−0.4 ± 1.1	−0.5 ± 0.5
−1	5 ± 1	3.2 ± 0.4
0	31 ± 1	58 ± 1
1	55 ± 2	38 ± 1
2	37 ± 1	11 ± 1
3	86 ± 3	11 ± 1
4	76 ± 3	10 ± 1
5	38 ± 2	32 ± 1
6	51 ± 2	7.0 ± 0.6
7	40 ± 2	9.4 ± 0.7
12	27 ± 2	4.4 ± 0.6
13	51 ± 3	7.0 ± 1.3
14	26 ± 2	6.2 ± 0.7
23	17 ± 1	6.3 ± 0.6
24	23 ± 2	3.3 ± 0.7
25	10 ± 1	1.5 ± 0.3
28	19 ± 2	2.8 ± 0.7
29	32 ± 2	3.8 ± 0.9
30	13 ± 2	2.8 ± 0.8
31	17 ± 2	2.3 ± 0.8
40	9 ± 1	4.8 ± 0.6
41	3 ± 1	1.9 ± 0.5
42	6 ± 1	1.6 ± 0.6
61	8 ± 2	−0.9 ± 0.8
62	3 ± 2	1.2 ± 0.7
63	2 ± 2	1.6 ± 0.7
102	5 ± 2	9 ± 1
103	−4 ± 2	1.5 ± 0.8
104	1 ± 1	2.7 ± 0.5

[a] Errors represent ±1 standard deviation based on counting statistics.

studies. Regarding first the excretion of tritiated water in urine, inspection of the excretion curves on a logarithmic scale showed very little evidence of two components with different time constants. Attempts to fit biexponential functions for each volunteer would not converge. It was concluded that, with the current data and backgrounds, a significant second exponential term could not be detected. Therefore, single exponentials were fitted for each volunteer and the derived values for the time constant λ_{HTO} and other parameters are shown in table 7. Data post day 70 were avoided for the purpose of curve fitting as they were less certain and contained negative values, thus the numbers of observations are less than in tables 2–6.

Inspection of the logarithmic scale graphs for OBT in urine suggests, for most volunteers, evidence of biexponential behaviour with an initial short time constant of only 1–2 days followed by excretion with similar time dependence to tritiated water in urine. The short-term behaviour could be due to rapid elimination of larger organically bound molecules by the kidneys. This short-term behaviour has only a small effect on excretion of total tritium (the significant quantity for dose estimation) due to the larger contribution due to tritiated water. Total tritium showed no evidence of biexponential behaviour, and again attempts at such a fit failed to converge. Fitting for a single time constant λ_{TOT} using Stata produced the parameters given in table 8.

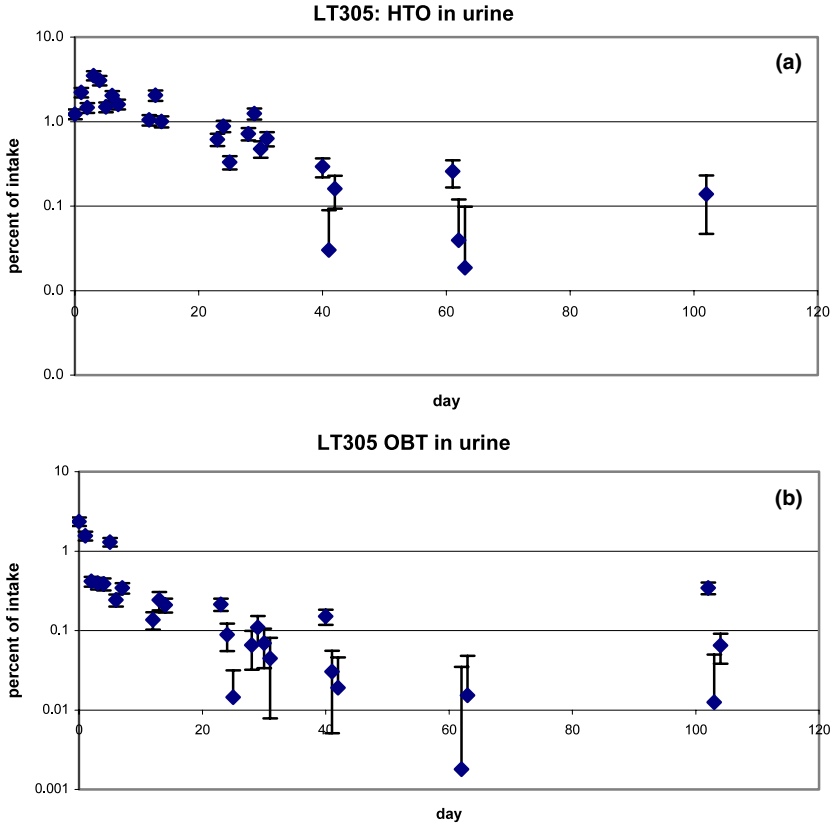

Figure 5. (a) Urinary excretion by LT305 as tritiated water, (b) urinary excretion by LT305 as OBT.

Table 7. Fitted values of retention time constant, λ_{HTO}, and related parameters.

Volunteer	λ_{HTO} (day^{-1})	Std error	$T_{1/2}$ (days)	Observations	R^2
LT301	0.035	0.008	20	18	0.92
LT302	0.068	0.018	10	23	0.83
LT303	0.111	0.039	6	20	0.74
LT304	0.071	0.013	10	23	0.90
LT305	0.044	0.010	16	24	0.85

The R^2 values indicate improved fits to a single exponential compared with the data for tritiated water excretion. The fitted data are shown in figure 6.

The data suggest, for the food and OBT content in this study, retention of total tritium with body half-times in the range 4–11 days, in apparent conformity with the main component of 10 days for tritiated water used by the ICRP [8]. There does not appear to be a significant component to retention with half-time characteristics greater than this. The noise in the data would mask a component with a half-time of 40 days as small as 3%, as in the ICRP model for retention of tritiated water [8]. Indeed, visual inspection of the data on a logarithmic scale in comparison with plotted functions suggests that the noise would also probably mask a component of half-time 100 days of as much as 10%, though possibly not 30%, as in the recent study using rats [10]. The predominant short timescale for retention observed in

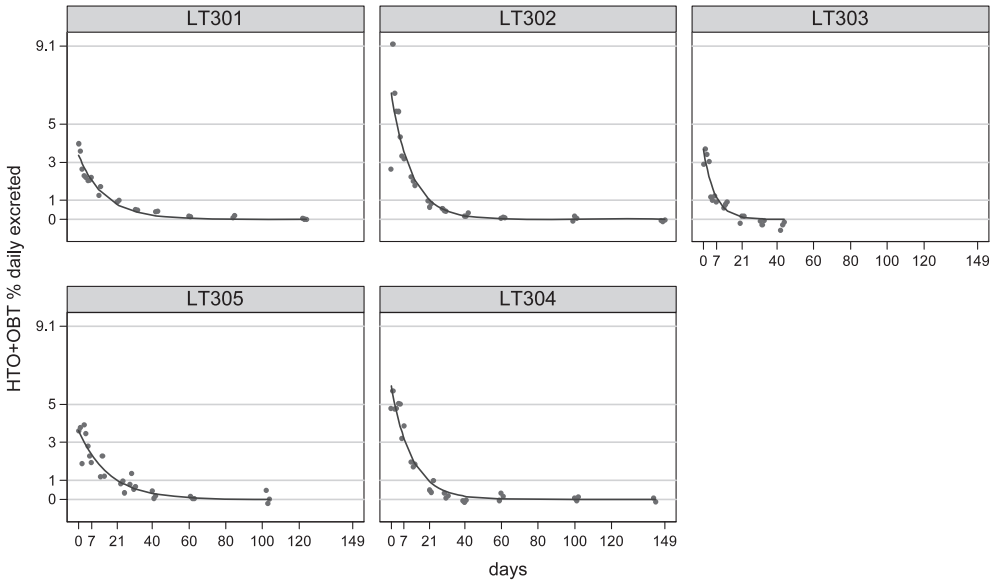

Figure 6. Total tritium excretion in urine with fitted single exponential curves.

Table 8. Fitted values of retention time constant, λ_{TOT}, and related parameters.

Volunteer	λ_{TOT} (day^{-1})	Std error	$T_{1/2}$ (days)	Observations	R^2
LT301	0.069	0.009	10	18	0.98
LT302	0.089	0.019	8	23	0.88
LT303	0.164	0.029	4	20	0.91
LT304	0.088	0.013	8	23	0.97
LT305	0.060	0.010	11	24	0.94

this study could be due to rapid hydrolysis in body tissues of the particular form(s) of OBT ingested. Implications for the dose coefficient for OBT are that use of the ICRP value of 4.2×10^{-11} Sv Bq^{-1}, which is derived from equations (1) above, may be cautious in this specific situation. These observations are separate from any implications of the recent suggestion that the tritium radiation weighting factor should be increased from 1 to 2 [7, 9].

5. Conclusions

This study has measured the excretion of tritiated water and OBT by five volunteers after eating sole containing OBT from Cardiff Bay. The results are subject to experimental noise above background at longer timescales, but suggest retention of total tritium with a body half-time in the range 4–11 days, with no detectable evidence of a significant contribution due to retention with a longer half-time. This timescale is similar to the half-time of 10 days used by the ICRP for tritiated water [8]. The short timescale observed could be due to rapid hydrolysis in body tissues of the particular form of OBT used in this study. Implications for the dose coefficient for OBT are that the use of the ICRP value of 4.2×10^{-11} Sv Bq^{-1} may be cautious in this specific situation. These observations are separate from any implications of recent discussion on whether the tritium radiation weighting factor should be increased from 1 to 2 [7, 9].

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