PCDD/Fs: OBSERVATIONS ON HUMAN INTAKE, EXCRETION & BODY BURDEN

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Introduction

Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) are omnipresent in human adipose tissue. Concentrations in the UK (Duarte-Davidson *et al*, 1993) are typical of industrialised Western countries. This paper estimates lifetime human exposure to PCDD/Fs and relates this to their levels in UK human adipose tissue.

Comparison of lifetime exposure with observed adipose tissue concentrations permits an assessment of the bioaccumulation potential of individual PCDD/Fs. Recent trends in adipose tissue concentrations are discussed. In addition, the effects of temporal variations in human exposure and age-related variations in percent body fat on human adipose tissue concentrations are assessed along with the apparent discrepancy between faecal excretion and intake.

Estimation of lifetime human exposure

A problem encountered in estimating lifetime human exposure to PCDD/Fs is that human intake has probably varied significantly over the last century. We have thus estimated past human exposure to PCDD/Fs by extrapolating the technique of Wild *et al* (in press) who estimated contemporary human exposure to PCDD/Fs by relating soil and vegetation concentrations to those in meat, milk and root crops. Using the data of Kjeller *et al* (1991) for archived soil and vegetation and the bioconcentration factors assumed by Wild *et al* (in press), we have estimated temporal trends in human exposure to PCDD/Fs.

Lifetime human exposure is calculated by assuming that from 3 months to 2 years exposure will be 12.5% of adult intake, that from 2 to 7 years exposure will be 25% of adult, that between 7 and 14 years exposure will be 50% of adult and that above 14 years intake will be identical to adult intake. Ingestion between birth and 3 months is based solely on a mean daily ingestion rate of 850 ml (fresh weight) of mother's milk. The human milk concentrations used are the mean of those reported by DoE (1989) for two pooled UK samples.

On this basis, together with our estimates of daily exposure for 1940-1960, 1960-1980 and the contemporary estimates of Wild *et al* (in press), we have estimated lifetime exposure to PCDD/Fs for the average 49 year old human - the mean age of five UK bulked adipose tissue samples analysed by Duarte-

Davidson *et al*, (1993) - living in contemporary Britain. We have subsequently calculated the levels of these compounds in the adipose tissue of a typical Briton of that age that would be expected if it was assumed that all PCDD/Fs ingested were sequestered into such tissue. Using the estimates of the ICRP (1975), we have assumed that the average 49 year old human contains 17.7 kg of fat, which we have assumed resides exclusively in adipose tissue.

We have subsequently converted these lifetime exposure estimates into estimated maximum adipose tissue concentrations by dividing our estimates of lifetime ingestion by the estimated mean weight of body fat. These theoretical maxima are listed in Table 1, where they are compared with mean PCDD/F levels detected in bulked samples of UK adipose tissue (Duarte-Davidson *et al*, 1993) and - where UK data was not available - elsewhere (Jones and Bennett, 1989). Division of measured concentrations by the corresponding theoretical values afforded bioenrichment factors (BEFs) for each 2,3,7,8-substituted PCDD/F.

Temporal variations in UK human adipose tissue concentrations.

In Table 2, human adipose tissue PCDD/F concentrations for a typical 49 year old Briton are estimated for the years 1962, 1972, 1982 and 1992. These estimated levels were derived by calculating lifetime human exposure using the consumption patterns described above in conjunction with our estimates of adult human exposure for different decades. These estimates were converted into adipose tissue concentrations by dividing by the typical fat content of a 49 year old Briton and metabolism/excretion losses were accounted for by multiplying by the appropriate BEF listed in Table 1. These data suggest that there has been a steady increase in UK human adipose tissue levels since 1962.

The relationship between age and adipose tissue concentrations.

If human exposure to PCDD/Fs and the quantity of body fat remained constant throughout the individual's lifetime, one would expect concentrations to increase linearly with age. However, given the temporal variations in human exposure, together with age-related variations in percentage of body fat, the relationship between donor age and adipose concentrations will be blurred.

In Table 3 we list estimated contemporary mean adipose tissue concentrations for UK residents of different ages. These were derived using: (a) human exposure over the individual's lifetime - taking into account temporal variations; (b) the BEFs derived earlier (Table 1) and (c) estimated variations in human body fat content (ICRP, 1975). Plotting these estimated adipose tissue concentrations against age reveals a relatively linear increase in concentrations between 20 and 35 years, after which levels reach an apparent plateau. Although temporal variations in human exposure do exert some effect on estimates of adipose tissue concentrations; the most influential factor in eliciting the observed deviations from linearity is the steady increase in the ratio of body fat to body weight with increasing age. If the latter parameter is excluded, then the relationship assumes a far more linear appearance. In short, although adipose tissue concentrations are unlikely to be linearly related to age, such a relationship probably exists between age and total body burden, as well as blood concentrations. Such a linear relationship is inconsistent with any enahanced ability of older humans to metabolise/excrete PCDD/Fs.

Human intake versus faecal excretion

The BEFs derived in Table 1 demonstrate that a significant proportion of PCDD/Fs ingested by humans are sequestered in adipose tissue. This is supported by Komer *et al* (1992) who reported that the percentage of PCDD/F dietary intake that was faecally excreted by infants was less than 10% for all congeners. However, if we assume an average daily excretion of 25 g (dry weight) faeces by an adult human (ICRP, 1975) and that 50% of total PCDD/F excretion is in the form of metabolites, then comparison of estimated UK daily ingestion with faecal excretion rates based on concentrations reported by Rappe and

Andersson (1992), reveals that for some congeners, the amount excreted exceeds that ingested. This indicates either: (a) that the human exposure estimates of Wild *et al* (submitted) are underestimates; (b) that the faecal concentrations reported by Rappe and Andersson (1992) are unrepresentative of the UK population; (c) that less than 50% are excreted as metabolites or that (d) a combination of these or other factors such as PCDD/F biosynthesis in humans are influential. In conclusion, it is clear that this area requires more detailed study and a mass balance approach - *viz* a long-term study comparing dietary intake with faecal excretion for a given individual - is recommended.

Conclusions

The salient findings of this study are: (a) A significant fraction of human PCDD/F intake is sequestered in adipose tissue; (b) that it is probable that there has been an increase in UK adipose tissue levels since 1962; (c) that a linear relationship between age and adipose tissue concentrations would not be expected, although such a link is likely between age and body burden or blood levels and (d) that more detailed investigations of the relationship between human intake and excretion are required.

References

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Congener	Total Intake over 49 Years (ng)	Calculated Adipose Tissue Concn.	Measured Adipose Tissue Concn.	BEF
2,3,7,8-T4CDD	342.7	19.4	6.4	0.330
1,2,3,7,8-P5CDD	665.8	37.6	23	0.611
1,2,3,4,7,8-HxCDD	450.6	25.5	37	1.452
1,2,3,6,7,8-HxCDD	3368.6	190.4	180	0.945
1,2,3,7,8,9-HxCDD	1724.3	97.5	28	0.287
1,2,3,4,6,7,8-HpCDD	9468.8	535.3	150	0.280
OCDD	33956.8	1919.5	820 1247.4	0.427
2,3,7,8-T4CDF	1207.3	68.2	9	0.132
2,3,4,7,8-P5CDF	1346.4	76.1	24	0.315
1,2,3,7,8-P5CDF	486.1	27.5	13	0.473
1,2,3,4,7,8-HxCDF	1160.1	65.6	26	0.396
1,2,3,7,8,9-HxCDF	34.8	2.0	17	8.652
1,2,3,6,7,8-HxCDF	657.2	37.2	15	0.404
2,3,4,6,7,8-HxCDF	452.7	25.6	- 184	-
1,2,3,4,6,7,8-HpCDF	3494.4	197.5	34	0.172
1,2,3,4,7,8,9-HpCDF	540.5	30.6	-	-
OCDF	3320.6	187.7	46	0.245

All Concentrations in pg/g (lipid weight).

Table 1: Bioenrichment of PCDD/Fs

1431.4

Congener	1962	1972	1982	1992
2,3,7,8-T4CDD	4.7	5.3	5.9	6.4
1,2,3,7,8-P5CDD	15.7	17.9	20.1	23.0
1,2,3,4,7,8-HxCDD	21.2	26.0	31.0	37.0
1,2,3,6,7,8-HxCDD	33.4	51.5	84.9	180.0
1,2,3,7,8,9-HxCDD	4.9	8.2	13.7	28.0
1,2,3,4,6,7,8-HpCDD	42.2	86.2	126.1	150.0
OCDD	205.9	448.5	672.1	820.0
2,3,7,8-T4CDF	8.8	8.9	9.0	9.0
2,3,4,7,8-P5CDF	21.9	23.4	24.4	24.0
1,2,3,7,8-P5CDF	17.2	16.2	14.8	13.0
1,2,3,4,7,8-HxCDF	21.0	23.4	25.0	26.0
1,2,3,7,8,9-HxCDF	9.3	9.3	10.6	17.0
1,2,3,6,7,8-HxCDF	14.4	15.1	15.3	15.0
2,3,4,6,7,8-HxCDF*	20.6	22.1	23.4	25.6
1,2,3,4,6,7,8-HpCDF	14.3	23.3	30.8	34.0
1,2,3,4,7,8,9-HpCDF*	17.2	23.5	28.7	30.6
OCDF	20.4	33.1	43.1	46.0
∑TEQ	43.3	45.0	52.1	67.3

*Not Corrected: BEF not available.

Table 2: Estimated Temporal Variations in PCDD/F Concentrations in Adipose tissue (pg/g lipid weight) of an average 49 year-old Briton.

	Concentrations (pg/g lipid) at...				
Congener	20 years	35 years	47 years	54 years	68 years
2,3,7,8-T4CDD	3.7	6.5	6.2	5.8	6.4
1,2,3,7,8-P5CDD	14.5	24.1	22.3	20.7	22.4
1,2,3,4,7,8-HxCDD	25.2	40.5	36.1	32.7	33.8
1,2,3,6,7,8-HxCDD	191.3	231.7	178.8	152.8	143.4
1,2,3,7,8,9-HxCDD	28.4	35.5	27.8	23.8	22.4
1,2,3,4,6,7,8-HpCDD	73.7	160.4	148.5	128.5	123.4
OCDD	422.0	888.3	813.0	699.6	664.4
2,3,7,8-T4CDF	4.4	8.5	8.6	8.4	9.9
2,3,4,7,8-P5CDF	11.7	22.9	22.9	22.2	25.5
1,2,3,7,8-P5CDF	5.4	11.0	12.1	12.7	16.0
1,2,3,4,7,8-HxCDF	13.4	25.4	25.0	23.9	26.9
1,2,3,7,8,9-HxCDF	15.9	19.9	16.5	15.2	16.0
1,2,3,6,7,8-HxCDF	7.3	14.1	14.3	14.0	16.3
2,3,4,6,7,8-HxCDF*	15.1	25.7	24.6	23.5	26.5
1,2,3,4,6,7,8-HpCDF	14.7	34.7	33.4	29.7	30.0
1,2,3,4,7,8,9-HpCDF*	13.3	30.4	29.7	27.2	28.7
OCDF	18.2	46.0	45.0	40.4	41.2

*BEFs not available - assumed to = 1.

Table 3: Estimated variations in PCDD/F adipose concentrations with age.