ESTIMATION OF DIETARY INTAKES OF PCDD/Fs & PCBs BY PROBABILISTIC MODELLING: THE EFFECT OF INCREASING SALMON CONSUMPTION

Martin Rose,[1] Graham Smith,[1] Andy Hart,[1] Roy Macarthur,[1] Alwyn Fernandes,[1] Shaun White,[1] & Dwayne Moore[2]

[1]Central Science Laboratory, Sand Hutton, YORK YO41 1LZ. United Kingdom. m.rose@csl.gov.uk
[2]The Cadmus Group, 411 Roosevelt Avenue, Suite 204, Ottawa, ON K2A 3X9, Canada

Introduction

Fish are known to contain elevated concentrations of PCDD/Fs and PCBs when compared to other components of the average UK diet. An investigation was made of the influence of salmon consumption on the dietary intake of these chemicals by combining consumption data with concentrations of PCDD/Fs and PCBs determined in food. A Monte Carlo risk analysis was used to examine the importance of uncertainty in input parameter estimates, and to establish whether the WHO TDI of 1-4 pg/kg bw/day was likely to be exceeded.

Methods and Materials

Uncertainty occurs in the measurement of each congener and in the approximation of TEF values for each congener, in the sampling of the fish used and in the TEQ distributions used for other dietary items and their level of consumption. For each of these, a distribution of uncertainty is calculated and values were chosen at random for each variable to calculate the mean total dietary exposure in pg TEQ/kg bodyweight/day. The amount of salmon in the diet was varied explicitly from 0 to 4 portions per week and 1,000 replicates performed for each scenario.

The Monte Carlo risk assessment was constructed to include all known sources of uncertainty. Twelve samples of salmon were obtained around January 1996 and analysed for selected PCDDs, PCDFs and PCBs.[1] For each sample the concentration of each congener in fat was determined. Where a congener was not detected the limit of detection was recorded. The measurement uncertainty for each concentration (calculated according to Eurachem guidelines[2] was used to calculate the upper 95^{th}% confidence limit of a normal distribution around the measurement result. Where the congener concentration was below the limit of detection a uniform distribution was used between zero and the limit of detection as this represented the maximum uncertainty.

For each salmon, where a WHO-TEF value was assigned, the concentration in fat of each congener was multiplied by the TEF value and recalculated on a whole bodyweight basis. The TEF values are estimated to the nearest half order of magnitude,[3] thus the uncertainty around these values was a triangular distribution with the minimum at the lower half-order-of-magnitude step, the best estimate is the TEF value, and the maximum is the next highest half-order-of-magnitude. 2,3,7,8-TCDD was not given any uncertainty since this is the reference congener. No TEF was permitted to exceed 1.0. We initially assumed that the TEF values were completely accurate and included the TEF uncertainty later. The samples of salmon were considered to be representative of salmon on retail sale within the UK. Therefore, the mean TEQ could be used to calculate the average long-term intake. A normal distribution was used to represent uncertainty due to sampling associated with the mean TEQ.

A table was constructed with 18 different food categories for which PCDD/F+PCB TEQ values were calculated in 1997.[4] The category of canned vegetables was excluded since the diet survey did not allow for canned and un-canned vegetables to be differentiated. The mean consumption of each food category was taken from a National diet and nutrition survey,[5] and a normal distribution with a standard deviation equal to 10% of the mean was used to represent the uncertainty in the calculation of this value (e.g. rounding errors). This represented uncertainty in the actual average consumption of each item, and did not represent variability in the population.

It was also necessary to define an uncertainty distribution for the concentration of dioxins within each food category. This distribution was not known empirically, but for simplicity was assumed to have the same form as that in salmon.

The consumption and TEQ for 'fish' was based on white fish and excluded oily fish, thus permitting the average diet to be adjusted by increasing the number of portions of salmon consumed each week. It seemed likely that when salmon consumption increased the amount of other meat and fish foods decreased. Carcass meat, offal, meat products, poultry and fish were decreased proportionately by an equivalent total mass as the salmon consumption was increased. Thus the total amount of 'meat' remained the same in the diet. The average portion size of salmon was taken as 135g, which was the average weekly consumption of oily fish[5] and was also typical of salmon steaks for sale as single portion sizes in a typical UK supermarket.

Results

The 'background intake' without salmon consumption was 1.55 pg TEQ/kg bw/day. As the number of salmon portions consumed per week increased, the total dietary intake increased and there was a slight increase in the uncertainty associated with the estimated intake. With three portions of salmon consumed per week, on average, then the mean intake was 3.93 pg TEQ/kg bw/day, but 36% of the risk distribution lay above 4.0 (Figure 1). Thus there is a 36% chance that the average consumer will exceed the limit of 4.0, when consuming 3 portions per week. Of the uncertainty associated with the total dietary intake, 56% was attributed to the TEQ in salmon and no other dietary item accounted for more than 2%. The variation in uncertainty of the concentration of dioxins in the salmon can be partitioned into two main components: sampling uncertainty and measurement uncertainty. Of the individual congeners, the greatest contribution arose from non-*ortho* PCB 126, which accounted for 7.8% of the total variance.

If four portions are consumed each week, then the mean intake was 4.74 pg TEQ/kg bw/day and 99.7% of the distribution was above 4.0 pg TEQ/kg bw/day.

When the uncertainty of the TEF values was included then the mean daily intake of dioxins, excluding salmon as a source, was 3.06 pg TEQ/kg bw/day, with a range from 2.1 to 4.4 (1.2% of the distribution was above 4.0). As the mean number of salmon portions increased, the daily intake increased and the degree of uncertainty almost doubled (Figure 2). The consumption of a single portion of salmon each week increased the mean daily intake to 4.5pg TEQ/kg bw/day with 79% of the distribution above 4.0. Not only were the mean values increased when the uncertainty of the

TEF was included (because of the skewed TEF uncertainty), but the overall uncertainty (risk distribution) was greatly increased. The main contribution to the uncertainty remained the sampling uncertainty (43.2%), but the next most important contributor became the uncertainty in the TEF value associated with PCB 126.

This analysis demonstrates that small sample size and the uncertainty associated with the TEF values are the biggest contributors to the overall uncertainty about the daily intake of PCDD/Fs and PCBs. The measurement uncertainty associated with each congener is currently less important.

References

1 Robinson, C., Rose, M., White, S., Gem, M., Gleadle, A. and Harrison, N. (2000) *Organohalogen Compounds* **47** 334-337..
2 Ellison, S., Rosslein, M. and Williams, A. (2000) Quantifying Uncertainty in Analytical Measurement. Eurachem/CITAC Guide.
3 van den Berg, M, Peterson, R.E. & Schrenk, D. (2000). *Food Additives and Contaminants*, **17**, 347-358.
4 Food Standards Agency (2000). Food Surveillance Information Sheet Number 4/00. http://www.foodstandards.gov.uk/fsainfsheet/no4/4diox.htm
5 Gregory, J.R., Foster, K., Tyler, H. and Wiseman, M. (1995). The dietary and nutritional survey of British adults. HMSO, London.

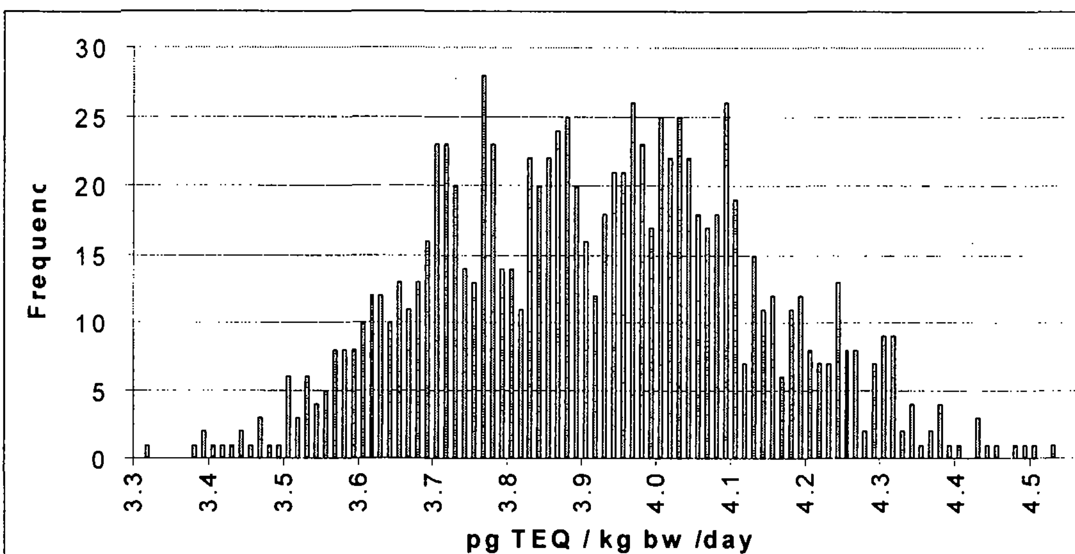

Figure 1. The distribution of risk for the consumption of 3 portions of salmon per week (TEF uncertainty not included).

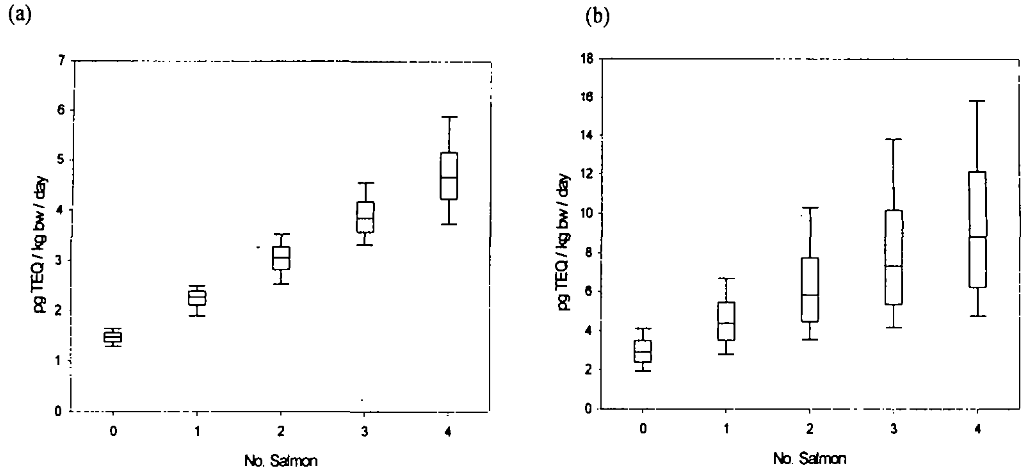

Figure 2: The distribution of risk as the consumption of salmon increases, in terms of daily consumption of dioxins per kg bw, showing the mean, ± one standard deviation, and the range. (a) TEF values do not include uncertainty, (b) TEF values include uncertainty

Table 1: The consumption and dioxin concentration in the other dietary items. All 'meat' products (above line) were proportionately reduced as salmon consumption increased. All items in italics (intake > 0.05 pg TEQ/kg bw/day) were given uncertainty in consumption and concentration.

Dietary Category	Consumption (kg/person/day)	Concentration (ng TEQ/kg)	Intake rate (pg TEQ/kg bw/day)
Carcass Meat	*0.071*	*0.2164*	*0.1484*
Offal	0.004	0.4590	0.0183
Poultry	0.025	0.1276	0.0312
Meat Products	*0.050*	*0.2016*	*0.0965*
Fish	*0.027*	*0.5648*	*0.1452*
Miscell Cereals	*0.133*	*0.0567*	*0.1077*
Fats and Oils	*0.019*	*0.5958*	*0.1593*
Eggs	0.023	0.1251	0.0408
Milk Products	*0.029*	*0.3510*	*0.1440*
Green Vegetables	0.035	0.0032	0.0016
Potatoes	*0.132*	*0.0320*	*0.0604*
Other Vegetables	0.101	0.0161	0.0232
Fresh Fruit	0.047	0.0177	0.0119
Milk	*0.234*	*0.0425*	*0.1423*
Bread	0.109	0.0277	0.0432
Sugar & preserves	*0.034*	*0.1521*	*0.0742*
Fruit products	0.025	0.0092	0.0033
Nuts	0.001	0.2863	0.0047