THE INTAKE AND CLEARANCE OF PCBs IN HUMANS - A GENERIC MODEL OF LIFETIME EXPOSURE

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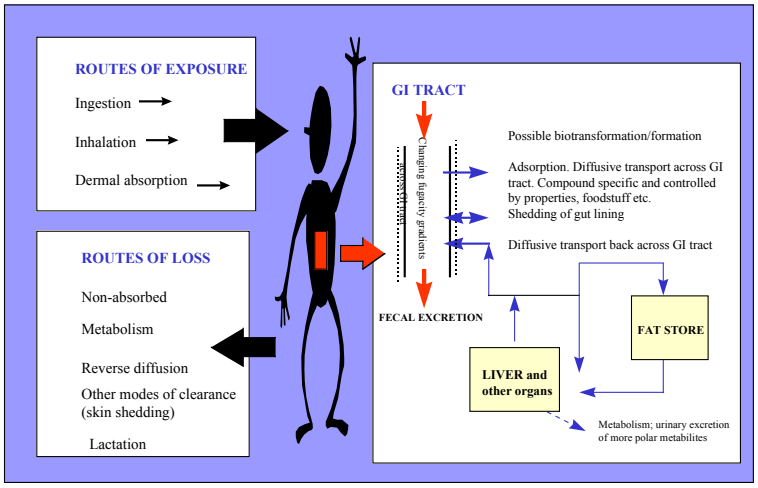
Introduction

Foods, particularly those which are animal-based, represent the most important source of human exposure for many persistent organic compounds. However, intake is just one of many factors which controls the body burden of these compounds. The effect of *cumulative* exposure, and factors such as absorption efficiency, potential formation/biotransformation in the gastro-intestinal tract and rates of metabolism and depuration influence accumulating tissue concentrations (see Figure 1). We have developed a model which not only follows burdens and clearance of PCBs throughout a human lifetime taking changes in age, body composition and diet into account, but also importantly, incorporates changing environmental concentrations of PCBs

Figure 1: Schematic representation of exposure, metabolism and transformation of PCBs in humans



We have selected PCBs, specifically PCB-101 as the group of compounds for this work as there is now a large volume of data relating to historical PCB inputs and measured dietary intake information in the UK. Importantly, this model is considered generic and applicable to other lipophilic compounds for which a historical input profile can be generated. Our objective was to simulate body and tissue burdens of humans throughout their lifetime using a variable dietary

intake function based on our knowledge of changing environmental PCB concentrations. In this way, we are in a position to predict changes in compound concentrations in the body over time and evaluate the impact of changing dietary exposure. Model predictions have been validated, where possible, with measured UK human tissue data. This approach represents an important tool in the process of risk evaluation of environmental contaminants.

Model Construction

In general terms, modelling lipophilic compounds throughout a lifetime relies on a straightforward mass balance of lipids within the body. As the model uses a time-scale of years rather than days, rapid processes such as absorption can be summarised using simple relationships and short term fluctuations, for example changes in diet (i.e. in the contaminant quality of foods) are 'smoothed' out. As a result, the amount of compound present anywhere in the body is determined by the lipid content of the material concerned and an age dependent function allowing for growth/increasing body fat composition and subsequent compound dilution with age. Within a given age cohort of a population there are males and females with a range of body weight and fat compositions i.e. contaminants can be accumulated in different lipid volumes.

Re-constructing the input curve for PCB-101

Direct data on exposure to contaminants in the past is not available. Consequently, we have developed a method to infer concentrations in the past from our knowledge of time trends in other environmental media (Alcock and Jones 1996). We have developed a method of predicting PCB concentrations in foods from modelled and measured time trend data for environmental media in the UK and our knowledge of foodchain transfer of individual PCB congeners. Concentrations of PCBs in air supply those found on vegetation and in turn grazing animals receive PCBs primarily through ingestion of grass and silage. As a consequence, atmospheric concentrations will ultimately exert a strong influence on human tissue concentrations. The derivation of PCB-101 concentration curves for principal food groups was conducted as follows:

The predicted historical air concentration profile for PCB-101 from Sweetman and Jones (1999) was used to generate a cows milk concentration profile using a recently reported relationship between air PCB concentrations and milk PCB concentrations. A study carried out by Thomas et al. (1998) found under normal UK bovine husbandry conditions, that the PCB concentration in pg. PCB-101. per g of milk fat represents the equivalent burden of 11 m^3 of air. Predicted air concentrations were also used to predict feed intake (i.e. pasture grass) and subsequently meat concentrations following the well documented relationships used in the EUSES model (1997) based on a bioaccumulation factor (BAF) approach. Similarly, fish tissue concentrations were predicted by multiplying a congener-specific bioconcentration factor (BCF) for fish by a predicted concentration in surface water (data estimated by Sweetman and Jones 1999). Despite the extensive use of predicted data, the relationships used have been applied successfully in contemporary situations and this model-based approach is considered to be a best estimate of UK dietary intake in the past, in the absence of measured data.

Model Applications

(i) Lifetime tissue concentrations for individuals born at different times
Figure 2 demonstrates the lifetime profiles of individual males born in 1922, 1930, 1950, 1960, and 1970. It clearly shows that older individuals have accumulated a greater body burden because their cumulative exposure has been greatest i.e. they have experienced the rise and peak in PCB concentrations in their diet. Concentrations are not increasing as a simple function of age, but rather represent the sum of an input profile over time, which itself has varied due to changes in compound inputs. Individuals born in the 1970s, exhibit highest concentrations in tissues early in their life. Conversely, individuals born in the 1920s and 1930s experience low tissue concentrations early in their life, peak tissue concentrations in their forties and fifties and a declining body burden into their sixties and seventies when PCB levels were declining in many environmental media.

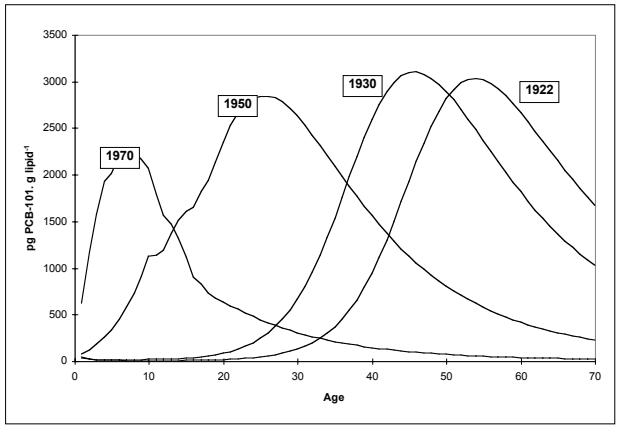


Figure 2: Predicted tissue concentrations of PCB-101 for different age classes in the UK born from 1920 to 1990 (pg kg bw d^{-1})

(ii) Breast-feeding scenario
A sub-population attracting considerable attention in terms of organic contaminant exposure are breast fed infants. Breast feeding represents a significant 'loss' of lipophilic contaminants from the mother to the baby. In general up to a 50% decrease in mothers body fat concentrations have been observed after up to 6 months breast feeding. In contrast, human milk represents a large input of contaminant during a relatively short period of time to the feeding infant. The loss of contaminants through the offtake of stored body fat was modeled based on the assumptions used by Kreutzer et al. (1997).

The amount of contaminant a mother has 'seen' during her life prior to the birth of her first child is directly related to the magnitude of potential transfer to her offspring. Figure 3 demonstrates the predicted body burden of a mother born in 1950 having her first child at age 20, second at age 22 and third child at age 24. A profile of predicted body burden for a woman having no children is

also included for comparison. These women born in 1950 have 'seen' the rise in PCB use in the UK and their exposure profile and body burden reflects this in their first 20 years of life (i.e steeply rising lipid concentrations). Importantly, sources/release of contaminant into the environment is controlling the burden of the mother and that of her offspring.

We are able to compare model predictions with measured human milk data collected in the UK in the early 1990s. Measured concentrations of PCB-101 in human milk averaged 0.95 μg kg^{-1} lipid basis (MAFF 1997). Model predictions were between ~0.3 to 1.2 μg kg^{-1} lipid assuming that mothers were aged between 20 and 40 in 1990. The agreement between measured and modeled milk concentrations is encouraging.

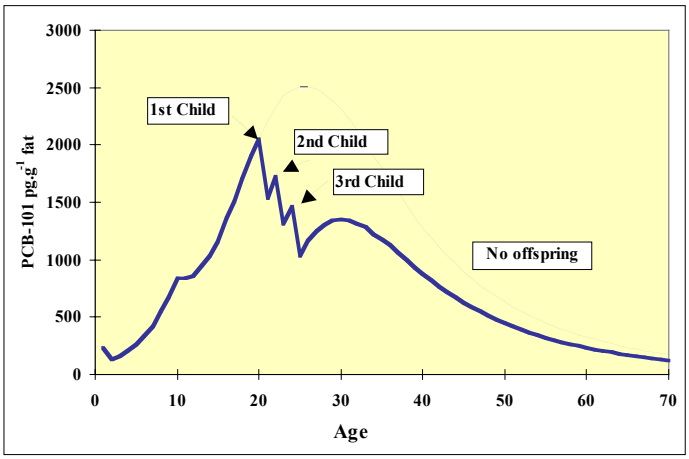


Figure 3: Effect of offspring on maternal PCB-101 body fat burden for a woman born in 1950 and having no children or 3 children at age 20, 22 and 24.

Using the variable food intake function of this model we have calculated how the importance of intake via breast feeding may have changed over the last 30 years. According to our model, breast feeding in 1970 contributed only ~1 % of cumulative PCB-101 intake until age 25. For an individual born in 1980, we estimate that breast feeding may account for up to 8% of total body burden by age 25. For an individual born in 1990, the contribution increases to 30% since breast milk concentrations remain high relative to those in foods.

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References

Alcock, R.E. and K.C. Jones. **1996**. Dioxins in the environment; A review of trend data. *Environ. Sci. Technol.,* 30, 3133-3143..

Duarte-Davidson. R. et al., **1994**. PCBs and other organochlorines in human tissue samples from the Welsh population: 1 - adipose. *Environ. Poll.* 84, 69-77.

MAFF **1997**. Dioxins and polychlorinated biphenyls in food and human milk. Food Surveillance Information Sheet No 105. MAFF Food Contaminants Division, London

Kreutzer, P.E. et al., **1997**. 2,3,7,8-TCDD and congeners in infants. A toxicokinetic model of human lifetime body burden by TCDD with special emphasis on its uptake by nutrition. *Arch Toxicol* 71, 383-400.

Sweetman, A.J. and K.C. Jones. **1999**. Modeling historical emissions and environmental fate of PCB emissions in the UK . Submitted to ES&T.