POSSIBLE RELATIONSHIPS BETWEEN DECABDE, LIFE STYLE AND DIET IN WOMEN FROM DIFFERENT EUROPEAN COUNTRIES

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INTRODUCTION

In modern life, flame retardants have become an essential part of efforts to protect society against injuries, death and economic damage due to fires. Various PBDE products have been in production for several decades and are environmental persistent and accumulate in the food chain, including that of humans [1-5]. In addition, human levels of may vary strongly between countries [6]. In the EU decaBDE is at present the only PBDE allowed to be used as a flame retardant, but in non-occupational situations it often has a limited contribution to the total amount of PBDEs human blood and milk [1, 7-9]. Within countries individual differences in PBDE levels, including those of decaBDE, can vary significantly and easily exceed more than one order of magnitude [1, 6]. The cause for this strong variability in human levels is still unclear, but lifestyle has been suggested as a relevant factor. Many lower brominated PBDEs evidently bioaccumulate in the aquatic and human food chain, but in the case of decaBDE this bioaccumulation is not apparent [2, 10-15] Nevertheless, decaBDE can be found in significant amounts in terrestrial top (avian) predators [16-18]. The present study was conducted to determine systemic exposure via blood of decaBDE in women in four different European countries (The Netherlands, The United Kingdom, Norway and Spain) and to study factors that might influence those levels. The major purpose of the study is to provide the EU authorities with insight in the long term blood levels of decaBDE in humans, possible causal relationships with specific exposure situations and provide additional information for future risk assessments of decaBDE within the EU.

MATERIALS AND METHODS

A total of 145 women from The Netherlands, United Kingdom, Norway and Spain, age 25 to 30 years, participated in the study. This study population was chosen because information obtained would provide further information about the range in systemic exposure and possible body burden of women around the age of their first pregnancy. As pre- as well as postnatal exposure could be important from toxicological point of view, the initial first round of this study focused on blood only. All volunteers were asked to fill in a questionnaire related to lifestyle, work and diet that might have a potential influence on the exposure to decaBDE. In all countries approval of a medical ethical committee was obtained before sampling of the blood. In The Netherlands a collection of two rounds of blood samples from the same volunteers (n=40) was also done with a six month interval. DecaBDE analysis was done with a gaschromatograph using electron capture negative ionisation and mass spectrometry (GC/ENCI-MS). Multiple blank analyses were performed to ensure a decaBDE clean system. The limit of detection (LOD) was calculated to be ~4 pg/g. The limit of quantification (LOQ) was defined as 10 times the s.d. of the blank. Detailed information about the analytical techniques and analytical results will be published separately (H. Lesley et al., 2010. pers. comm.). Statistical analyses were done using SAS software (SAS System for Windows version 9.1, SAS Institute, Cary, NC). Univariate analyses of variance (PROC GLM) was done for all categorical questionnaires. Variables that seem to explain any variability in decaBDE levels were further investigated by categorizing these variables (e.g. categories of increasing use of electrical equipment in tertiles) and calculate the mean decaBDE levels in each categorie (PROC MEANS).

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These results were used to determine if there was a plausible negative or positive trend. For continuous variables (e.g. hours of use of electrical equipment) pearson correlation coefficients were calculated (PROC CORR). Finally, multivariate analyses of variance (PROC GLM) were done with all variables significantly explaining variance in the univariate analyses.

RESULTS

The average concentrations of decaBDE in the four countries were in the same range, around 10 pg decaBDE/g serum (ppt) or in the very low ng decaBDE/ g serum l.w. (ppb) and levels decreased in the order United Kingdom > The Netherlands > Norway > Spain. Within all countries there was an extreme variation in individual maximum serum levels, which could be easily be one order of magnitude higher than average or median concentrations. Average levels of decaBDE in the UK group were highest, but levels from the Netherlands were almost similar, respectively 13 vs. 12 pg/g ww. The highest individual levels were observed from the Netherlands and was consistent for both rounds of sampling within a six months interval. 90% of the samples was below 20 pg/g l.w. or 5 pg/g w.w.
In spite of almost similar blood concentrations, the country of residence was found to be the only relevant variable ($p<0.05$) explaining a difference in human decaBDE levels, explaining between 8 and 26% of the difference. Type of diet did not significantly influence decaBDE levels, although average serum concentrations of vegetarians with or without fish (n=7) were higher than those with a normal diet. A possible role of specific dietary components was also taken into account, but no statistically significant contribution of eggs, dair products, fish or meat could be established. No statistical correlation was detected with the use of electronic equipment, except for coffeemakers and electric water kettles. For the duration of use of electronic equipment some trends were observed, e.g. hours of use of TV's, radio's and CD/DVD/video player, but none of these were statistically significant.
The use of synthetic materials in household and clothes was also analyzed. For all countries combined the presence of textile or synthetic material on floors or in furniture did not explain variability in decaBDE levels. The use of synthetic compared to natural clothes appeared to be associated with lower serum levels, but a statistical significant relationship between frequency of use and levels was not found. Due to differences in fire safety regulations in the UK compared with the other EU countries, separate analyses were done for this country. In the UK, carpets in a living room might explain some of the variance observed in decaBDE levels when based on a log normal distribution. However, possibly due to the limited number of individuals (n=40) in this sub-selection, this observation was not statistical significant. For the group of Dutch participants, two blood sampling rounds were included from a six months time interval and a weak but statistical significant relationship was observed between measurements.

DISCUSSION

The apparent lack of a real difference in serum levels between the United Kingdom and The Netherlands is notable, as the former country has more strict national fire regulations, which are more comparable with North America [19]. If the presented decaBDE serum levels are compared with average or median concentrations in other parts of Europe, e.g. France, Spain, Norway and Sweden, The United Kingdom and The Netherlands tend to be slightly higher [1, 7-9]. Median decaBDE levels determined in our samples from Spain are three fold higher than those reported earlier from this country [8], but still in the very low ng/g l.w. range. Average and median serum levels of decaBDE from the Norwegian group were around 3 ng/g l.w, which is almost one order of magnitude lower than those determined in pooled serum samples from the period 1998 to 2003 [20], but rather similar as those reported from Sweden [6]. In France recent median concentrations of decaBDE in woman are in the same range as in our study, respectively 5,8 versus 1 to 4 ng/g l.w. [7]. DecaBDE blood levels reported in one study for the U.S. are in the same range as those observed in our study [21]. Several studies from Japan and China have reported decaBDE levels in blood from non occupational exposed individuals. In Japan the average or medium blood levels were similar to our study, around 1 to 7 ng/g l.w. [22, 23]. However, two studies from China reported serum levels that were on average one to two orders of magnitude higher as in our study [4, 24]. Average serum levels of decaBDE in Australia are in the same range as those observed in our study [25]

House dust is suggested as a major source for exposure [19, 26-28] and DecaBDE is frequently used in electronic equipment, carpets and furniture upholstery, which might be a source of this BFR in house dust, but no relationship between electronic equipment or duration of use was found. In the UK population it was found that the presence of carpets in the living room could explain individual differences in serum levels of decaBDE (20-30%) based on log normal distribution.
With respect to the levels observed in our study the question can be raised to which extent have any toxicological significance or pose a risk to humans. Recently, several organizations or authors have focused on the possible Reference Dose (RfD) or safe level of decaBDE in humans. Results from these evaluations differ strongly and derived RfD values or safe levels vary up to three orders of magnitude and are the topic of seriously debated [15, 29, 30]. These risk evaluations and different outcomes will be further discussed in this presentation in relation to the levels observed in our study population.

CONCLUSIONS

In view of the virtual absence of the role of lifestyle factors, type of household, use of electronic equipement, diet and professional activities on individual decaBDE serum levels it is concluded that diffuse exposure via multiple sources probably accounts for individual variation in human blood levels.

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REFERENCES

1. Frederiksen, M., et al., *Human internal and external exposure to PBDEs--a review of levels and sources.* Int J Hyg Environ Health, 2009. **212**(2): p. 109-34.
2. Darnerud, P.O., et al., *Polybrominated diphenyl ethers: occurrence, dietary exposure, and toxicology.* Environ Health Perspect, 2001. **109 Suppl 1**: p. 49-68.
3. Tanabe, S., et al., *Brominated flame retardants in the environment of Asia-Pacific: an overview of spatial and temporal trends.* J Environ Monit, 2008. **10**(2): p. 188-97.
4. Zhu, L., B. Ma, and R.A. Hites, *Brominated flame retardants in serum from the general population in northern China.* Environ Sci Technol, 2009. **43**(18): p. 6963-8.
5. de Wit, C.A., *An overview of brominated flame retardants in the environment.* Chemosphere, 2002. **46**(5): p. 583-624.
6. Hites, R.A., *Polybrominated diphenyl ethers in the environment and in people: a meta-analysis of concentrations.* Environ Sci Technol, 2004. **38**(4): p. 945-56.
7. Antignac, J.P., et al., *Exposure assessment of French women and their newborn to brominated flame retardants: determination of tri- to deca- polybromodiphenylethers (PBDE) in maternal adipose tissue, serum, breast milk and cord serum.* Environ Pollut, 2009. **157**(1): p. 164-73.
8. Gomara, B., et al., *Distribution of polybrominated diphenyl ethers in human umbilical cord serum, paternal serum, maternal serum, placentas, and breast milk from Madrid population, Spain.* Environ Sci Technol, 2007. **41**(20): p. 6961-8.
9. Thuresson, K., A. Bergman, and K. Jakobsson, *Occupational exposure to commercial decabromodiphenyl ether in workers manufacturing or handling flame-retarded rubber.* Environ Sci Technol, 2005. **39**(7): p. 1980-6.
10. Debruyn, A.M., L.M. Meloche, and C.J. Lowe, *Patterns of bioaccumulation of polybrominated diphenyl ether and polychlorinated biphenyl congeners in marine mussels.* Environ Sci Technol, 2009. **43**(10): p. 3700-4.
11. Drouillard, K.G., et al., *Bioaccumulation and biotransformation of 61 polychlorinated biphenyl and four polybrominated diphenyl ether congeners in juvenile American kestrels (Falco sparverius).* Environ Toxicol Chem, 2007. **26**(2): p. 313-24.
12. Huwe, J.K., et al., *Comparative absorption and bioaccumulation of polybrominated diphenyl ethers following ingestion via dust and oil in male rats.* Environ Sci Technol, 2008. **42**(7): p. 2694-700.
13. Kelly, B.C., et al., *Bioaccumulation behaviour of polybrominated diphenyl ethers (PBDEs) in a Canadian Arctic marine food web.* Sci Total Environ, 2008. **401**(1-3): p. 60-72.

14. Shaw, S.D., et al., *Bioaccumulation of polybrominated diphenyl ethers in harbor seals from the northwest Atlantic.* Chemosphere, 2008. **73**(11): p. 1773-80.
15. Hardy, M.L., M. Banasik, and T. Stedeford, *Toxicology and human health assessment of decabromodiphenyl ether.* Crit Rev Toxicol, 2009. **39 Suppl 3**: p. 1-44.
16. Chen, D., et al., *Polybrominated diphenyl ethers in peregrine falcon (Falco peregrinus) eggs from the northeastern U.S.* Environ Sci Technol, 2008. **42**(20): p. 7594-600.
17. Chen, D., et al., *Polybrominated diphenyl ethers in birds of prey from Northern China.* Environ Sci Technol, 2007. **41**(6): p. 1828-33.
18. Law, R.J., et al., *Levels and trends of brominated flame retardants in the European environment.* Chemosphere, 2006. **64**(2): p. 187-208.
19. Harrad, S., et al., *Polybrominated diphenyl ethers in domestic indoor dust from Canada, New Zealand, United Kingdom and United States.* Environ Int, 2008. **34**(2): p. 232-8.
20. Thomsen, C., V.H. Liane, and G. Becher, *Automated solid-phase extraction for the determination of polybrominated diphenyl ethers and polychlorinated biphenyls in serum--application on archived Norwegian samples from 1977 to 2003.* J Chromatogr B Analyt Technol Biomed Life Sci, 2007. **846**(1-2): p. 252-63.
21. Schecter, A., et al., *Polybrominated diphenyl ether flame retardants in the U.S. population: current levels, temporal trends, and comparison with dioxins, dibenzofurans, and polychlorinated biphenyls.* J Occup Environ Med, 2005. **47**(3): p. 199-211.
22. Inoue, K., et al., *Levels and concentration ratios of polychlorinated biphenyls and polybrominated diphenyl ethers in serum and breast milk in Japanese mothers.* Environ Health Perspect, 2006. **114**(8): p. 1179-85.
23. Kawashiro, Y., et al., *Perinatal exposure to brominated flame retardants and polychlorinated biphenyls in Japan.* Endocr J, 2008. **55**(6): p. 1071-84.
24. Jin, J., et al., *Polybrominated diphenyl ethers in the serum and breast milk of the resident population from production area, China.* Environ Int, 2009. **35**(7): p. 1048-52.
25. Toms, L.M., et al., *Serum polybrominated diphenyl ether (PBDE) levels are higher in children (2-5 years of age) than in infants and adults.* Environ Health Perspect, 2009. **117**(9): p. 1461-5.
26. Jones-Otazo, H.A., et al., *Is house dust the missing exposure pathway for PBDEs? An analysis of the urban fate and human exposure to PBDEs.* Environ Sci Technol, 2005. **39**(14): p. 5121-30.
27. Sjodin, A., et al., *Concentration of polybrominated diphenyl ethers (PBDEs) in household dust from various countries.* Chemosphere, 2008. **73**(1 Suppl): p. S131-6.
28. Stapleton, H.M., et al., *Polybrominated diphenyl ethers in house dust and clothes dryer lint.* Environ Sci Technol, 2005. **39**(4): p. 925-31.
29. EPA, *Toxicological Review of Decabromodiphenylether (BDE-209) CAS No. 1163-19-5). In Support of Summary Information on the Integrated Risk Information System (IRIS).* in *EPA/635/R-07/008F*. 2008.
30. Van der Ven, L.T., et al., *A 28-day oral dose toxicity study in Wistar rats enhanced to detect endocrine effects of decabromodiphenyl ether (decaBDE).* Toxicol Lett, 2008. **179**(1): p. 6-14.