Measurements of PBDEs in Cat Serum and Cat Food: Is There a Relationship With Feline Hyperthyroidism?

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Introduction.
Polybrominated diphenyl ethers (PBDEs) are an important group of flame retardants. They are used worldwide in a variety of consumer goods, including household products. Over the last 20 years, the concentrations of PBDEs have rapidly increased in the environment (Hites, 2004; Zhu and Hites, 2004; Zhu and Hites, 2005) and in humans (Birnbaum et al., 2004; Mazdai et al., 2003). Experimental evidence in rodents suggests that PBDE exposure may perturb thyroid homeostasis (Birnbaum and Staskal, 2004). Over this same time period, the incidence of feline hyperthyroidism has substantially increased (Scarlett et al., 1988). Since many pet cats spend the majority of their lives indoors grooming themselves, and since household dust often contains relatively high levels of PBDEs (Stapleton et al., 2005), we hypothesized that development of feline hyperthyroidism could, in some manner, be related to increasing exposure to PBDEs. Furthermore, as carnivores, cats consume a variety of protein-based food products, again similar to their owners. Thus, cats may be useful sentinels for studying potential endocrine health outcomes related to chronic low-level PBDE exposure.

In this preliminary study, we attempted to verify this hypothesis by measuring PBDEs in serum from pet cats. Because feline hyperthyroidism is largely a disease of middle-aged to older cats, we compared the levels obtained in hyperthyroid cats to that of young cats (< 6 year of age), as well as to that of middle-aged cats with non-thyroidal illnesses. Commercial cat food samples were also analyzed to evaluate the importance of diet as a source of these brominated flame retardants.

Materials and Methods.
Cat serum samples were obtained from veterinary teaching hospitals in North Carolina, Massachusetts, and Georgia. These serum samples were grouped into three categories: hyperthyroid cats (HT), sick, non-hyperthyroid cats (SC), and young cats (YC). Cat food samples were purchased at grocery stores and pet specialty shops in Bloomington, Indiana. These cat food samples were selected to be representative of a broad range of flavors (chicken, salmon, etc.) and of preparation types (canned and dry).

Serum samples were extracted using a slightly modified version of a previously described method (Mazdai et al., 2003). Food samples were Soxhlet extracted for 24 hrs with 50% hexane in acetone. Lipids were removed with \(\text{H}_2\text{SO}_4\), and the extracts cleaned on alumina columns. Forty-one PBDE congeners were analyzed using gas chromatographic mass spectrometry as described elsewhere (Hoh and Hites, 2005).
**Results and Discussion.**

The mean (± standard error) cat serum concentration of total PBDEs was 9.8 ± 2.1 ng/g wet weight (N = 23). An analysis of variance performed on the HT, SC, and YC sample groups revealed no statistically significant difference among them. A box and whisker plot of these pooled concentrations is shown in the leftmost panel of Figure 1.

The relationship between total PBDE concentrations and the cats’ age was explored. As shown in Figure 2, there is a small but statistically significant correlation between the two parameters (p < 0.05). This indicates that PBDEs accumulate in the exposed cats throughout their lives.

The average concentration of total PBDEs was 1.8 ± 0.3 ng/g wet weight for dry cat food samples (N = 12, 4 flavors) and 0.66 ± 0.11 ng/g wet weight for canned food samples (N = 24, 12 flavors). The overall mean total PBDE concentration for all food samples, with no distinction of type, was 0.94 ± 0.14 ng/g wet weight. A box and whisker plot of these pooled concentrations is shown in Figure 1 in the second panel from the left.

The two sets of data (serum and food) were pooled together, and the congener-specific data were analyzed by principle component analysis. Based on these results, we defined a characteristic ratio as the sum of the concentrations of the less brominated congeners (47, 99, 100, 126, 153, and 154) divided by the total PBDE concentration. Values of this ratio close to 1 indicate no or little presence of hepta to deca brominated congeners, and values close to 0 indicate a relatively high abundance of these higher brominated congeners.

Serum samples were categorized on the basis of the cats’ eating habits. There were three such categories: dry, canned, and mixed. Figure 3 shows a bar plot of our characteristic ratio for all of the cat serum and food samples sequenced by decreasing ratio. Canned food and canned food eaters (see the red bars) showed the highest ratios, generally greater than 0.5. The smallest values (see the green bars) were found for dry food and dry food eaters, generally less than 0.3, indicating relatively high concentrations of the decabrominated conger (BDE-209) in these samples. As expected, those cats that ate a mixture of dry and canned food (see the yellow bars) spanned across the ratios. Given that the cat serum samples cluster with the type of food that the cats eat, food may represent an important source of PBDEs for pet cats.

PBDE concentrations measured in this study were compared with available data in the literature (see the two rightmost panels in Figure 1). Only results reported on a wet weight basis were used, and no geographical distinctions were made. For humans, only serum and whole blood data were included. Because of the great variability among the different studies in terms of the congeners analyzed, only the most common ones (47, 99, 100, 153, and 154) were used here. Because of the variability of the congeners covered by the various studies, one should be cautious in comparing these results. Nevertheless, these data indicate that, in sharing the same household environment with humans, cats seem to accumulate higher amounts of PBDEs; in fact, PBDE concentrations in cats are well over a factor of 10 higher that those in humans, on average. Owing to feline grooming behavior, it is likely that cats ingest any volatilized PBDE material or dust that comes in contact with their fur. When compared to other biota, cats showed PBDE levels lower than those in birds and marine mammals but similar to those in fishes. It is interesting to note that, on average, cat food has somewhat higher levels of PBDEs than human food.
Clearly, PBDEs are persistent and bioaccumulative compounds that are present in both feline and human food products.

All of the cats we studied had readily detectable serum PBDE levels. Our data suggest that the overall PBDE levels, as well as the specific congener profiles that accumulate in cats, are likely the result of the combined influence of diet and indoor exposure to PBDE-containing consumer products. As such, the levels of PBDEs in the serum of these pet cats should be carefully considered, given that they share the same home environment as their owners. Future studies, including prospective studies with larger numbers of cats, are needed to define how PBDE exposure modulates thyroid hormone homeostasis in cats, and to better confirm or rule out an association between increased brominated flame retardant body burden and risk of developing feline hyperthyroidism. (This abstract does not reflect U.S. EPA policy).

References.

Figure 1. Box and whisker plots of the sum of 5 selected congeners (47, 99, 100, 153, 154) discussed in the text. Dashed lines represent mean values.
Figure 2. Relationship between total PBDE concentration (ng/g wet wgt) and cat age (years). Color codes: cyan YC, blue SC, red, HT.

Figure 3. Ratio between the total concentrations of the less brominated congeners to the total concentration of all PBDE congeners in cat food and serum samples. Patterned bars refer to serum samples and plain bars to food.