Deca-BDE: Old Myths, New Realities

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Introduction

Production of the commercial flame retardant mixture, deca-BDE, has doubled over the last decade to 125 M lbs/yr, making it the largest PBDE (75%) and second largest BFR (30%) in the world and the major (70%) PBDE produced in North America[1]. It is used as an additive at high levels (15% by weight)[2] in high-impact polystyrene plastics found in a variety of consumer products, including small appliances (hair dryers, toasters, curling irons, coffee makers, TVs); computer towers, printers, and fax machines; and lighting fixtures and smoke detectors. Deca is also added to backing in textiles for draperies, furniture, and rugs, and to some polyurethane foams. Because of this use in consumer products, deca is likely a major indoor and urban contaminant. Its presence at significant levels in house dust[3,4], office air[5], and the film coating the insides of windows[6] supports this assertion.

Based upon production figures for the last decade, nearly a billion lbs of deca have been added to consumer products in our homes, offices, and transport vehicles. An additional large quantity of deca has already been dispersed into the environment.

Although deca has long been known to be photolytically labile, undergoing debromination to lower BDEs[7, 8], it has been characterized as an environmentally stable and inert product[9]. According to this paradigm, deca is not degraded in the environment, not dispersed (locked in to products or sediment forever), not taken up by biota, not metabolized, not toxic and, therefore, not a problem. However, data from recent studies provide a different picture, of a deca that is photo-labile, mobile, and toxic. These studies indicate that deca breaks down in the environment[10], is dispersed to remote locations[11,12], is bioavailable[13,14] in wildlife[15,16,17] and humans[18,19,20,21,22,23,], breaks down in wildlife to banned PBDEs[24], and causes neurodevelopmental toxicity[14].

Deca is additionally cause for concern because of exposures that would harm the fetus. The placenta is no barrier to the lower brominated PBDEs (PBDE 47, 99, 100, 153)[25],[26], For these chemicals and, likely, the similar breakdown products from deca, the maternal "body burden"= fetal "body burden "

Discussion

Myth #1: Deca is Non-Dispersive. Deca is widely dispersed in the indoor and outdoor environment. Indoors, high levels of deca were found in house dust in Germany (mean=1 ppm; max 19 ppm; deca comprised 77% of PBDEs)[3] and the US (1-30 ppm; 5-50% of PBDEs)[4]. In films on windows, deca comprised 50% of PBDEs, with inside

film>outside (1.5-20X), and indoor air >outdoor air (10X)[6]. Outdoors, deca was found attached to particles in air/rain collected on a remote island in the Baltic, comprising 75% of PBDEs[11]; in sediment cores collected from a completely isolated, Canadian lake[12]; and in sludge from Switzerland (1100 ng/g dw, 5X ↑in 10 yrs)[27] and the US (1470 ng/g dw)[28]. Thus, deca is dispersed.

Myth #2: Deca is Immortal (not broken down in the environment). Three studies show deca or other PBDEs with fully brominated rings are extremely photolabile in sunlight, one shows hepta-hexa BDEs break down to tetra-penta BDEs, and two studies show PBDEs 47, 99, 100 are stable.

a. In a fourteen-day indoor sunlight photolysis study by Hermann, et al.,[29] deca in toluene solutions in glass jars on indoor window ledges was extremely photolabile, breaking down rapidly (↓70% in 2 days). In contrast, PBDE 47 was photolytically stable in glass jars in indoor sunlight for the 14 days, and the hepta-hexa and lower brominated BDEs had only minor changes.

b. In a four-day outdoor sunlight photolysis study of deca placed on sand or sediment by Soderstrom, et al.,[10] deca was extremely photolabile, debrominating rapidly (↓70% in 3 days), with BDE-183 and nona- and octa-BDEs as major products. Only minor amounts of lower PBDEs were reported, although these may have been lost to analysis over the 4-day study period via volatilization in the hot afternoon sun.

c. In a two-minute, two-hour outdoor sunlight photolysis study by Peterman, et al.[30], 39 mono-hepta BDEs (plus hepta 183) were put in a synthetic fat (triolein) closed system. The four PBDEs with fully brominated rings ("pseudo-decas") were extremely photolabile (↓60-70% in 2 minutes), the other hepta- and hexa-BDEs were very photolabile (↓70% in 2 hrs), while the lower PBDEs (47, 99, 100) were photolytically stable over the 2-hour period. The latter three increased in mass (15-30%), indicating they were debromination products from the hepta and hexa BDEs.

Myth #3: Deca is Not Bioavailable. Deca is bioavailable. It is taken up by rats (10%; 20% absorbed from gut)[13], mice (5-10 permillage into brain)[14], is now being found in wildlife, including peregrine falcon eggs (mean=100-130 ppb; R=20-430 ppb; 15X controls)[17], and fish (bream, pike)[15]. Deca is found in humans in the blood of rubber workers (mean=30 ppb; high of 300 ppb; 15-30X controls)[18], electronic recyclers (5 ppb=BDE 47)[20], and computer technicians (1.6 ppb = 5X controls)[19]. Deca is found in breast milk in 3 recent studies: Lunder et al., found deca in 80% of samples (mean=0.2 ppb; high=1.2 ppb; N=20)[21]; She et al., found deca in 55% of samples (mean=0.2 ppb; high=1.5 ppb; N=18)[23]; and Schecter et al., found deca in 20% of samples (mean=1 ppb; high=8 ppb; N=23)[22]. Clearly, deca is bioavailable. The lower brominated breakdown products of deca are more bioavailable than deca, and bioaccumulate to a greater degree.

Myth #4: Deca is Not Metabolized. In lab studies, deca is metabolized to lower brominated PBDEs by carp (7 penta – octa BDEs including BDE 154 = 0.4% of deca)[31], trout (13 hexa – nona BDEs, including BDE 154)[32], and rat (octa-nona HO-BDEs)[13]. Octa and nona HO – and CH_3O – BDEs are reported in carp from the Detroit River, which suggest debromination of deca[16].

Myth #5: Deca is Not Toxic. Irreversible motor and behavioral effects that worsen with age are caused when male neonatal mice are exposed during the period of rapid brain growth (post-natal day 10) to one of the banned PBDEs (BDE 47, 99, and 100)[33,34] or PCBs (ortho 28, 52, 153; coplanar 77, 126, 169)[35]. The same effects are produced by deca when administered on post-natal day 3, not day 10. However, radiolabelling studies administered [U-^{14}C]-deca on day 3 at the same molar effective doses as the lower PBDEs. Radiolabelled deca or metabolites are taken up into the brain through PND-10[14].

Conclusion

1. Three studies[10,29,30] find deca or "pseudo-deca" (PBDEs with fully brominated rings) are extremely photolabile in indoor or outdoor sunlight[10,29]. Two studies show PBDEs 47, 99, 100 are extremely stable under the same conditions[29,30]. Thus, the environmental conversion of deca and higher brominated PBDEs to PBDE 47, 99, and 100 is quite plausible.
2. Results from the study of window films by Butt et al.,[6] suggest that deca in the outside film is debrominating to lower PBDEs which, in turn, are volatilized from the film by sunlight. This "cracking/distillation" by sunlight preferentially removes lower brominated PBDEs from exterior surfaces, leaving the remaining deca to wash off with rain into storm drains and finally into sediment. Urban centers are prime real estate for deca degradation, with large expanses of glass and with building exteriors 10-100X the land surface area.
2. An interesting study would be to put deca in sunlight for 14 days using a Peterman-style closed system[30] that would retain any lower brominated products.
3. Any additional neurodevelopmental study of deca should administer the deca as "aged in outdoor sunlight" using the Peterman protocol[30].
4. Deca is a cause for concern. Because it is present as an additive at high levels in a great variety of consumer products, an enormous (0.5 billion lb) reservoir of deca is available to the indoor environment, in which humans spend >80% of their time. Deca binds to particles, and is likely present at significant levels in dust and window films in homes, offices, bars, restaurants, public buildings, halls, meeting places, and transportation vehicles (cars, buses, subways, trains, and planes). Deca is much more photolabile than the lower brominated PBDEs found in the "penta" and "octa" commercial mixtures, and quickly degrades in sunlight to lower brominated forms which fin sunlight into some of these lower brominated congeners, deca is present in the environment "disguised" as these congeners. Where analyzed, deca has been found to be a world-wide contaminant in the environment, wildlife, and humans. Deca, or its metabolite(s), is toxic, causing neurodevelopmental damage in mice.

*The opinions given by the authors are not necessarily those of the DTSC or Cal-EPA. Mention of any products or organization does not constitute an endorsement by DTSC or Cal-EPA.

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