Exposure of Polybrominated Diphenyl Ethers, Polychlorinated Biphenyls, and Pesticides in the Anniston Community Health Survey Follow-up

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Introduction

Anniston, Alabama contained a former Monsanto Chemical Company facility, where production of polychlorinated biphenyls (PCBs) occurred between the 1930s and 1970s. All commercial and experimental PCB mixtures containing various congeners sold to over 3000 customers were produced at the facility. Elevated PCB exposure has been found in people and the environment [1,2]. We have previously reported on PCB exposure among Anniston residents in the Anniston Community Health Survey (ACHS 2005-7) [3].

Polybrominated diphenyl ethers (PBDEs) and chlorinated pesticides were not commercially produced in Anniston. However, PBDEs were used ubiquitously as a flame retardant since the 1970s [4,5] while chlorinated pesticides were used as early as the 1940s [6]. In the follow-up of ACHS (ACHS II), we continued to measure PCBs and pesticides, while also adding PBDEs to the exposure profile. PBDEs are similar to PCBs in chemical structure and in some human health effects, which may include disruption of thyroid homeostasis, neurodevelopmental deficits, and reproductive changes [7]. The similarity between PBDEs and PCBs contributed to the former being measured in ACHS II in addition to pesticides and PCBs. Pesticides have been shown to increase the risk of contracting various health conditions such as diabetes and prostate cancer [6].

We found significant associations between ACHS PCBs and various health outcomes such as diabetes and hypertension [8,9]. With the links between the chemicals and health consequences shown in previous literature, it is important to conduct in-depth exposure analyses and compare the exposure patterns of all the chemicals measured. We present the comparisons of PBDE, PCB, and pesticide concentrations found in ACHS II participants with the general U.S. population of the National Health and Nutrition Examination Survey (NHANES 2007/08).

Materials and Methods

Study Design and Population

Methods for the ACHS and ACHS II are described elsewhere in detail [10,11]. All surviving participants from ACHS I with PCB measurements were eligible to participate in the follow up. We recorded 69 participants to have moved away to outside the study area and attained the mortality status of 114 participants. Among the 438 participants we were able to contact, 359 were enrolled in ACHS II (82%). We had 338 participants left for

statistical analyses after limiting the group to individuals with sufficient amount of sera and available covariate information. Demographics, self-reported health behaviors and health conditions, medical, family, and occupational history, and individual medications were recorded. In addition to ortho-PCBs and pesticides measured in ACHS, participants in the follow-up were also tested for flame retardants, dioxins, furans, and dioxin-like PCBs. The study was reviewed and approved by the appropriate Institutional Review Boards.

Laboratory and Statistical Analyses

Fasting blood samples were collected from each individual at the office/home visit by a study nurse. After centrifuging, two mL of serum from each participant was stored on dry ice at -20°C until shipment. Once the samples were shipped to the laboratory, they were stored at -70°C until analyzed. 11 PBDEs (17, 28, 47, 66, 85, 99, 100, 153, 154, 183, 209), 9 pesticides (HCB, β-HCCH, γ-HCCH, Oxychlordane, *trans*-Nonachlor, *p,p'*-DDE, *o,p'*-DDT, *p,p'*-DDT, Mirex), and 35 ortho-PCBs (previously reported congeners [1]) were measured in the sera by the Centers for Disease Control and Prevention's National Center for Environmental Health laboratory. The analytes were measured using high-resolution gas chromatography/isotope-dilution high-resolution mass spectrometry as described previously [11]. Triglycerides and total cholesterol measurements were used in the enzymatic "summation" method to calculate serum total lipids [12].

In this report, arithmetic means and their associated 95% confidence intervals are presented for most highly detected PBDEs (47, 99, and 153), PCBs (153) and pesticides (p,p'-DDE) of ACHS II. Weighted arithmetic means and their 95% confidence intervals were calculated for the same chemicals in NHANES 2007/08 using statistical methods described elsewhere in detail [13].

Results and Discussion

Table 1 shows the demographics of ACHS II participants, stratified by race. Whites on average are were about 3 years older than African Americans (64 vs. 61 years old, respectively). The majority of the participants were female (72%) and were obese (59%). None of the covariates differed significantly between the race groups.

Table 1. Demographics of participants of ACHS II.

Demographics	**African Americans (n=172)**	**Whites (n=166)**	**p-value**
Age Categories (years)			0.17[a]
20-39 years	8 (4.7%)	11 (6.6%)	
40-59 years	68 (39.5%)	50 (30.1%)	
≥60 years	96 (55.8%)	105 (63.3%)	
BMI Categories (kg/m^2)			0.17[a]
Normal Weight (<25 kg/m^2)	30 (17.4%)	38 (22.9%)	
Overweight (25-29.99 kg/m^2)	45 (26.2%)	51 (30.7%)	
Obese (≥30 kg/m^2)	97 (56.4%)	77 (46.4%)	
Females	132 (76.7%)	113 (68.1%)	0.07[a]
Smoking Status	37 (21.6%)	34 (20.5%)	0.82[a]

Total lipid (mg/dL)	612.2 ± 12.3	634.0 ± 11.5	0.20[b]
Girth (inches)	42.1 ± 0.47	41.6 ± 0.49	0.48[b]

[a]p-value from chi-square analyses; [b]p-value from two-tailed t-test analyses.

Table 2. Chemical Arithmetic Means and 95% Confidence Intervals by Age Group

Chemical/Study	n	20-39 Years	n	40-59 Years	n	≥60 Years
PBDE 47						
ACHS II	19	16.0 (9.6, 22.5)*	116	31.5 (19.2, 43.7)	200	28.8 (21.9, 35.7)
NHANES 2007/8	72	31.0 (23.8, 38.2)	71	27.9 (19.6 (36.1)	79	39.9 (29.4, 50.5)
PBDE 99						
ACHS II	19	2.9 (1.8, 4.1)*	116	7.3 (3.6, 10.9)	200	6.3 (4.5, 8.1)
NHANES 2007/8	72	6.7 (4.6, 8.8)	71	6.5 (4.7, 8.4)	79	8.7 (6.0, 11.4)
PBDE 153						
ACHS II	19	12.9 (5.5, 20.2)	118	15.2 (8.1, 22.2)	201	14.0 (11.0, 17.0)
NHANES 2007/8	72	14.0 (11.3, 16.7)	71	11.4 (8.7, 14.1)	79	13.3 (10.1, 16.6)
PCB 153						
ACHS II	19	16.8 (6.4, 27.2)	118	120.5 (94.2, 146.7)*	201	233.0 (197.9, 268.1)*
NHANES 2007/8	72	10.3 (8.7, 11.9)	71	29.3 (26.6, 32.0)	79	60.8 (54.6, 67.0)
***p,p'*-DDE**						
ACHS II	19	70.0 (46.5, 93.2)*	118	313.0 (242.9, 383.2)	200	785.9 (654.2, 917.7)
NHANES 2007/8	72	253.8 (165.9, 341.7)	71	335.0 (215.6, 454.3)	79	758.0 (468.5, 1047.7)

*Non-overlapping 95% Confidence Intervals between ACHS II and NHANES 2007/8

We compared the arithmetic means of ACHS II and NHANES 2007/8 of PBDEs 47, 99, and 153, PCB 153, and *p,p'*-DDE. In all groups, PCB 153 and *p,p'*-DDE exposure increase with age while PBDEs do not appear to clearly follow this trend. As reported previously for ACHS I, PCB 153 also showed significantly elevated levels in ACHS II, especially in older age groups (3-4 times higher in ACHS II than in the same age groups of NHANES 2007/8). The 20-39 year age group showed a much smaller increase with inter-lapping confidence intervals. The timing of the sample collection for the two surveys differs by about 8 years which is in range a half-life for number of PCB congeners. More recent NHANES results (e.g. 2011/12; not released yet at the time of abstract preparation) may provide better estimates of exposure differences. While PCB concentration is declining both in NHANES and Anniston, the ratio remains around 3 times higher in Anniston [14]. Continued presence of the elevated PCB concentrations in older age groups is most likely due to historical exposure of the participants to PCBs.

In contrast, p,p'-DDE concentrations in Anniston and NHANES 2007/8 are very similar for the two older age groups, and about three times lower in the 20-39 age group in Anniston. All the other pesticides we measured (not shown in Table 2), including oxychlordane and mirex, follow the same trend of lower concentrations in the younger Anniston age group as *p,p'*-DDE. These results further suggest that pesticide concentrations are in line with background exposures.

PBDEs congeners have not been previously measured in Anniston cohort. In general, the range of the concentration for the three presented congeners (47, 99, and 153) is similar to NHANES 2007/8. PBDEs 47 and 99 are lower in the 20-39 year old age group of ACHS II than in NHANES. This may reflect about 8 year difference between

sampling for NHANES and ACHS II. This Anniston 20-39 year age group is also substantially smaller (n=19) than other two groups (n=116 and n=200, respectively) and may have more variation due to sample size.

This cross-sectional study comparison also supports the assumption that PBDE exposure in ACHS II participants is primarily from background concentrations, but as emphasized above, more precise estimates would be gathered from more recent NHANES sampling. It should be stressed that intake of PBDEs in the U.S is higher through indoor dust and inhalation than from diet in contrast to PCBs [5]. Preliminary analyses do not suggest major differences in PBDEs exposure in ACHS II by race (data not shown). Those were reported previously for PCBs but not for dioxin/furan congeners.

Associations have been found between various PCB congeners and diabetes, hypertension, and thyroid health. PBDEs are similar in chemical structures to PCBs, which makes it important to study their potential biological or statistical interactions and health consequences in the future analyses of these data.

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