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Exposure of dioxin-like chemicals in participants of the Anniston community health survey follow-up

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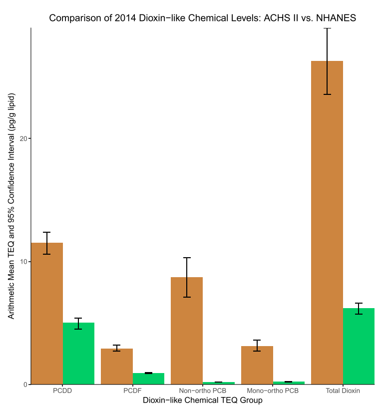
HIGHLIGHTS

- Anniston, Alabama residents have significantly higher dioxin-like chemical levels than the general United States population.
- In Anniston, Alabama, African Americans and women have higher dioxin-like chemical levels than Whites and men, respectively.
- Different groups of dioxin-like chemicals measured in Anniston, Alabama residents likely come from different sources.

GRAPHICAL ABSTRACT



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ABSTRACT

The 2014 follow-up of the Anniston Community Health Survey (ACHS II) consisted of 338 surviving participants from the 2005–2007 baseline study (ACHS) who had previous polychlorinated biphenyl (PCB) measurements, were not pregnant, and were not institutionalized. Questionnaires and blood samples provided the demographic, personal history, and chemical concentration data of the Anniston residents. Approximately 51% of participants were African American, 72% were female, and the mean age was 63 years old. The objectives of this study were to provide an exposure assessment of dioxin-like chemicals in the ACHS II participants and compare the measurements with the general United States (U.S.) population via the National Health and Nutrition Examination Survey (NHANES). Stratified analyses revealed significantly higher average total dioxin toxic equivalencies (TEQs) among African Americans compared to Whites (33.1 vs. 19.2 pg/g lipid), and in females compared to males (29.8 vs. 17.0 pg/g lipid). When adjusting for age, sex, and race in linear regression, we found ACHS II participants to have significantly higher total dioxin TEQ than the general 2014 U.S. population that we estimated for using half-life and NHANES 2003/04 data (most recent NHANES individual samples data), by 16.7 pg/g lipid. Principal component analyses showed that non-ortho and mono-ortho PCBs were separated from the other dioxin-like chemicals among the Anniston residents, whereas the chemicals were all clustered together for estimated

Abbreviations: PCB, polychlorinated biphenyls; PCDD, polychlorinated dibenzo-p-dioxins; PCDF, polychlorinated dibenzofurans; LOD, limit of detection; PCA, principal component analysis; ACHS II, Anniston Community Health Survey follow-up.

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NHANES 2014. The concentrations of dioxin-like chemicals, especially non-ortho and mono-ortho PCBs, in Anniston residents who resided near the former PCB production plant were higher than those in the general U.S. population. Although data strongly supported this difference, these inferences are limited because NHANES 2013/14 data were unavailable and we used estimated NHANES 2014 levels that we imputed from NHANES 2003/04 data in conjunction with half-life values estimated from Milbrath et al., 2009.

1. Introduction

Anniston, Alabama was the site of a production facility where approximately half of the total United States (U.S.) production of polychlorinated biphenyls (PCBs) occurred, from the 1930s to 1970s. Earlier ATSDR investigations detailing the extent of exposure to PCBs in Anniston communities found high concentrations of PCBs present in the environment and in local residents (ATSDR, 2000). We conducted the Anniston Community Health Survey (baseline ACHS 2005–2007) to investigate further PCB exposure and potential health effects in 765 participants (Pavuk et al., 2014a, 2014b). Several studies conducted in the ACHS cohort found positive associations between PCBs and diabetes, hypertension, and lipids (Silverstone et al., 2012; Goncharov et al., 2010; Aminov et al., 2013).

The follow-up of ACHS (ACHS II) was conducted in 2014 to expand on the chemical and health studies. Polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and non-ortho PCBs were added to ACHS II in addition to mono-ortho PCBs, which were also measured during ACHS, to provide a more extensive exposure profile. The inclusion of these dioxin-like chemicals was supported by the results of a small, nested pilot study (subset, $n = 65$) conducted within the ACHS baseline population. We found significantly higher concentrations of the non-ortho PCBs 126 and 169 when compared to NHANES 2001/02 (Pavuk et al., 2014c); this finding was the impetus for the current analyses of samples collected in 2014 for ACHS II. Another reason for including dioxin-like chemicals in ACHS II was that commercially produced PCBs have been shown to be contaminated with small amounts (10–1000 ng/g) of PCDFs. The heating or burning of PCBs is also known to produce PCDFs, small amounts of polychlorinated terphenyls, polychlorinated quaterphenyls, and traces of PCDDs (Kannan et al., 1987; Kodavanti et al., 2001). Today, uncontrolled burning of residential waste (outdoor/backyard trash burning) is considered to be the single largest source for releasing dioxin-like chemicals, such as PCB 169, in the U.S., in contrast to a larger contribution of historical releases by various industrial operations in the past (EPA, 2013; Brown et al., 1995; NIH, 2016).

The concentration of dioxin-like chemicals in the environment and humans has declined over time in most industrial countries (Lakind et al., 2009; Schecter and Gasiewicz, 2003; Consonni et al., 2012) because of improved environmental controls and reduction in emissions. Over the past three decades, exposure to dioxin-like chemicals has been assessed in various background adult populations across the world. Meta-analyses performed on the concentration levels revealed a significant decrease over time from 1985 to 2008 among PCDDs and PCDFs (Consonni et al., 2012). However, no significant decreases were found for non-ortho PCBs, while only a few mono-ortho PCB congeners exhibited clear, significant declines (Consonni et al., 2012). The National Health and Nutrition Examination Survey (NHANES) has also measured dioxin-like chemicals since 1999. NHANES found PCDDs, PCDFs, non-ortho PCBs, mono-ortho PCBs, and total dioxin toxic equivalencies (TEQs) to have decreased from 2001 to 2008 (Ferriby et al., 2007; Patterson Jr et al., 2009).

There is a strong need to continue studying and monitoring dioxin-like chemical concentrations (to prevent background exposure from reaching hazardous levels), especially in localities where environmental deposits of organochlorine chemicals may lead to bioaccumulation and associated health consequences. We present here the concentrations of individual dioxin-like chemicals and the TEQs of PCDD, PCDF, non-ortho PCB, and mono-ortho PCB groups measured from the human sera of ACHS II participants. We also compared ACHS II chemical concentrations to those of NHANES. The objectives of this study were to measure the concentrations of dioxin-like chemicals in the Anniston residents for providing internal comparisons and making external comparisons with the general U.S. population.

2. Methods

2.1. Data collection

ACHS II in 2014 accounted for the follow-up of the residential cohort of Anniston, Alabama from baseline ACHS in 2005–2007. The methods on how ACHS participants were followed over time are described by Birnbaum et al., 2016. All surviving participants with valid PCB results, who were neither pregnant nor incarcerated individuals were eligible to participate in the follow-up. From the initial 765 people, we attained the mortality status of 114 via the Social Security Index (Birnbaum et al., 2016). Another 69 participants were not re-contacted because they had moved to new locations outside the study area, which was confirmed through site visits and phone calls (Birnbaum et al., 2016). Out of 438 participants successfully reached, 359 were enrolled in ACHS II. Health questionnaires, medications, demographic information, lifestyle factors, and occupational and family medical history were collected to attain covariate data for regression analyses. We had 338 participants with available chemical concentration data and covariate information to study in ACHS II.

2.2. Laboratory analysis

The sera were isolated by centrifugation using red top vacutainer tubes from each participant and shipped on dry ice to the Division of Laboratory Sciences at the Centers for Disease Control and Prevention (CDC). Until measurements of persistent organic pollutants (POPs) were conducted on the samples, they were stored at −70 °C. The serum samples were measured first for ortho-substituted PCBs, persistent pesticides, and polybrominated diphenyl ethers (PBDEs) according to previously published methodology (Sjödin et al., 2004; Jones et al., 2012) using 2 g of serum (median 2.0 g; 1.0–2.0 g; 10th percentile was 2.0 g). The samples were then measured for PCDDs, PCDFs, and non-ortho PCBs based on published methodology (Turner et al., 1997) using 20 g of serum (median 20 g; 2.5–20.7 g; 10th percentile was 14.0 g). Each analytical batch for ortho-substituted PCBs, persistent pesticides, and PBDEs was defined as twenty-four unknowns, three quality controls, and three method blanks while in the case of PCDDs, PCDFs, and non-ortho PCBs, each analytical batch was defined as eight unknowns, two quality controls, and two method blanks. Measurements of target organohalogens were made by gas chromatography isotope dilution high-resolution mass spectrometry (GC/ID-HRMS). In HRMS, the accurate mass of a labeled or unlabeled compound is known and calculated. The limit of detection (LOD) was defined as the higher value calculated by two methods, (i) the lowest point of the calibration curve having a signal-to-noise ratio of >10:1 and (ii) three times the standard deviation of method blanks analyzed in parallel with the unknown