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Evaluation of Field Methods for Estimating Exposure of Children in Low-Income Families to Polycyclic Aromatic Hydrocarboı

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ABSTRACT

Children in low-income families may have higher exposures to polycyclic aromatic hydrocarbons (PAH) and related compounds than children in higher-income families. These higher exposures could result from the location of their homes, nearer to industrial sites and traffic; from poorer diet; from environmental tobacco smoke; or other causes. This study was designed to evaluate methods and estimate the range of total exposures of low-income children to PAH through various pathways. Nonsmoking participants with preschool children, incomes at or below the official US poverty level, and space heating in their homes were recruited. The PAH concentrations were measured in the household indoor and outdoor air, house dust, and yard soil, and in the diet of both an adult and a preschool child living in the home. An initial study in two homes and an additional study of nine homes, four urban and five rural, during the heating season were completed. The problems and successes encountered in the recruitment process and selected results of the heating season measurements are summarized in this paper.

INTRODUCTION

One of the many unanswered questions regarding exposure to polycyclic aromatic hydrocarbons (PAH) is whether persons living in low-income families have greater exposures to these compounds because of environmental factors such as living near industrial sites or heavy traffic, or lifestyle factors such as smoking, inadequate diet, or participation in activities that increase such exposures. Because preschool children may be more sensitive to these exposures, an investigation into the exposures of such children is especially important. Before a large-scale study to answer the above question can be designed, the field sampling and analysis methods must be developed and evaluated in real exposure situations.

In an initial study, recruitment, field sampling, and analytical methods were evaluated in two urban homes, one occupied by smokers and one by nonsmokers. Then, on the basis of the results of the two-home study, a more detailed methods evaluation study was carried out in nine homes, four urban and five rural, in and around Durham, North Carolina. In the latter study, participants were selected on the basis of their location, use of space heating, no resident smokers, at least one adult and one preschool, toilet-trained child who stayed at home, and family income at or below the U. S. poverty level. In each home, an adult and a preschool child participated. Polycyclic aromatic hydrocarbon concentrations were measured in the household indoor and outdoor air, soil and house dust, and in the individuals' diets. Twenty-four hour urine samples were also obtained for some of the participants, to evaluate the collection and analytical methods for selected urinary metabolites of PAH; however, these metabolite results are not discussed herein.

The aim of this study was threefold: to evaluate field methods for determining children's exposure to PAH for use in the design of a potential larger study, to estimate the ranges of these potential exposures through all environmental media, and to estimate the ranges of the subjects' total exposures. In this paper, we discuss the successes and failures of the participant recruitment process and summarize selected results of the heating season measurements.

METHODS

Questionnaires and other study materials were developed and tested first in two homes, as were several of the field methods. From the results from these two homes, we found it necessary to revise both the printed materials and the recruitment process. The two-home study and the lessons that we learned from it are summarized briefly below.

Two-Home Study

The initial recruitment process consisted of door-to-door counting and listing of homes in low-income neighborhoods, followed by contacting residents by telephone and in person, and administering a brief screening questionnaire. In addition to having an adult and a preschool, toilet-trained child living at home, the criteria included family income below the U. S. poverty level, as indicated by receipt of some sort of social services, such as Aid to Families with Dependent Children (AFDC) or food stamps, and use of unvented combustion space heating. After extensive effort, we were unable to locate households that met these criteria: 631 households were screened, and none met all the criteria. Even when the unvented space heating requirement was eliminated, only four households were identified and recruited.

The field sampling and analytical methods for the two homes were identical to those used in the nine-home study. They will be summarized in a later section of this paper.

Several lessons were learned from the two-home study. In addition to the severe problem of recruiting participants, we found that a significant education effort was required to assure the individuals that the sampling and sampling equipment would not cause them harm. Prior to the field effort, IRB approval of the study design and questionnaire was obtained from all three participating institutions. Both the adult participant and other adults or domestic partners living in the home had to be made aware of the intent and innocuousness of the study. Although informed consent was necessary only for the individual subjects, we found it prudent to have all the adult residents discuss the study with us and sign a consent form.

The participants had great difficulty understanding and carrying out instructions. Therefore, we had to simplify, and simplify again, our participant instruction booklets and activity diaries. Participants often did not keep their appointments, and occasionally moved away unexpectedly. Thus, to ensure success of a study with the type of criteria that we employed, it is necessary to select several backup homes and include them in all premonitoring activities.

A final seemingly small, but important, finding was that it is necessary, when using the duplicate plate dietary sample collection method in this type of study, to furnish a portion of the incentive payment ahead of time. This covers the cost of the extra food that must be prepared and supplied to the investigators for analysis.

Nine-Home Study

Following the above study, a study in nine homes was carried out, using the information and lessons learned from the two-home studies. The methods are summarized below.

Recruitment. Five methods were used to attempt to recruit participants. To recruit urban residents, telephone screening of homes located along those streets that bore heavy traffic, and similar telephone screening of homes located in a census tract known to have a large portion of low-income residents were tried. Neither of these was successful. To recruit rural residents, both mail contacts and telephone contacts were tried. These likewise were unsuccessful. However, with cooperation from the county social services offices, food stamp office, and health department, both urban and rural participants were enlisted successfully through a combination of flyers mailed to homes and posters in the various offices, which provided a short description of the study, mentioned a small financial inducement, and gave a telephone number which could be called for more information.

All homes that were selected for participation had a preschool, toilet-trained child at home and had no smokers in the household. Their family income was below the U. S. poverty level or the family received public assistance. In addition, the residents had lived there at least one year and did not plan to move in the next six months, and the home had only one story or was a ground-floor apartment. The urban homes were near heavy traffic, whereas the rural homes were far from heavy traffic. For each study home, there was at least one corresponding backup home, should sampling not be possible at the original home for some reason.

Premonitoring Activities. One month before sampling, staff visited each of the participants, including potential participants in the backup homes. At these visits, staff explained the study in detail, answered any questions, and obtained informed consent from the participating adult and domestic partner, if any. A premonitoring questionnaire was administered. Additionally, a new doormat for collection of entryway soil was placed just outside the entrance.

One week before sampling, staff visited the participants again. At that time any additional questions were answered, the participant information booklet was explained in detail, the child and adult activity diaries were also explained, and instructions for food and urine sample collection were given. A partial incentive payment was given to the participants, to cover the cost of extra food that they would furnish for the dietary sample collection.

Field Monitoring. The field monitoring took place in the winter of 1994-1995. Each home was sampled for 24 hr. Both indoor and outdoor air were sampled, using an integrated quartz fiber filter and XAD-2 resin sorbent cartridge in a sampler operating at a flow rate of approximately 15 L/min. Real-time fine particle-associated PAH were monitored indoors and out (EcoChem PAS 1002i, EcoChem Technologies, West Hills, CA), and air exchange was monitored with a PFT tracer. House dust was collected with an HVS3 house dust sampler [Cascade Stack Sampling Systems (CS3) Inc., Bend, OR], using an ASTM method.[1] Yard and entryway soil were also collected; the yard soil by scraping a 2-in deep sample in the middle of the yard, and the entryway by turning the doormat, which we had placed a month previously, upside down on aluminum foil and banging it vigorously. Food samples were collected by the duplicate plate method.[2-4] Total 24-hr urine samples were collected by the participant, using a bonnet that fit under the toilet seat; the bonnet contents were emptied into a collection jar for each individual after each use. In addition, temperature, relative humidity, wind speed, and wind direction data were collected by means of a meteorological tower that was erected in the back yard of the home.

To protect the outdoor sampling equipment from the elements, the susceptible pumps and electronic devices were placed in an unoccupied dog house, which was purchased new for the study. To protect the indoor sampling equipment from inquisitive investigation by the preschool occupants of the homes, the equipment was placed in a playpen, which likewise was purchased for the study.

Analysis. Air filter/sorbent cartridges were extracted with dichloromethane (DCM), and the extracts were analyzed by gas chromatography/mass spectrometry (GC/MS) using selected ion monitoring. Dust and soil samples were sieved into coarse (>150 μm) and fine fractions; the fine fractions were then extracted with hexane and analyzed similarly. Food samples were refluxed with KOH, extracted with hexane, treated with KOH, HCl, and water, fractionated with silica gel, and analyzed by GC/MS. Urine samples were extracted with acidified DCM, methylated, fractionated with silica gel; the hexane/DCM fraction was then analyzed by GC/MS. An aliquot of the original urine samples was sent for creatinine analysis (SmithKline Beecham Clinical Laboratories, Dallas, TX). Details of these analyses are provided elsewhere.[5]

The target PAH were: naphthalene, quinoline, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, cyclopenta[*c,d*]pyrene, benzo[*e*]pyrene, benz[*a*]anthracene, chrysene, benzofluoranthenes (three isomers), benzo[*a*]pyrene, indeno[1,2,3-*c,d*]pyrene, dibenzo[*a*]anthracene, and benzo[*g,h,i*]perylene. The latter nine compounds are classified as probable human carcinogens[6] and as B-2 carcinogens.[7]

RESULTS

PAH Concentrations

The sum of the 21 target PAH concentrations in indoor air averaged 4670 ng/m^3 in the rural homes and 1890 ng/m^3 in the urban homes. Outdoors, this sum averaged 218 ng/m^3 at the rural homes and 277 ng/m^3 at the urban homes. Thus, indoor concentrations were higher than those outdoors in both urban and rural settings. Outdoor concentrations were similar in both types of location, but indoor concer ations in the rural homes were much higher than those in the urban homes tested. The sum of the B-2 PAH averaged 2.14 ng/m^3 indoors and 2.01 ng/m^3 outdoors at the rural homes, essentially equi nt. However, the sum of the B-2 PAH at the urban homes was substantially higher indoors than out : 9.22 ng/m^3 indoors and 5.93 ng/m^3 outdoors.

food, the sum of 21 target PAH concentrations averaged 18.7 ppb for the adults and 14.5 ppb for ildren. The B-2 PAH averaged 0.359 ppb for the adults and 0.129 ppb for the children. Al the total PAH in the children's diets appeared similar to that in adults' diets, the adult diets had hi els . the B-2 PAH.

il concentrations of PAH were highest in the house dust, somewhat lower in the entryway soil, ar t in the yard soil. House dust concentrations of the 21 PAH averaged 3.96 ppm, and those of th AH averaged 1.57 ppm.

Pc l Dose Estimates

he total potential daily dose (the maximum dose) of PAH received by an individual can be est d from the following equations:

$$)_1 = A \times V/1000 \qquad (1)$$

w is the inhalation dose, A is the air concentration in ng/m^3, and V is the ventilation volume per da

$$_2 = F \times M \qquad (2)$$

w is the dietary ingestion dose, F is the diet concentration in µg/kg, and M is the mass of food ea g/day,

$$_3 = D \times Q \qquad (3)$$

wl s the nondietary ingestion dose, D is the dust concentration in µg/g, and Q is the mass of dust ing g/day, and the total dose is given by the sum of the doses through the environmental media

$$= D_1 + D_2 + D_3 \qquad (4)$$

wh e total potential dose T is in µg/day. We assumed that the inhalation volume of an adult is 20 m nd that of a child is 15 m^3/day;[8] that the mass of dust/soil ingested by an adult is 0.06 g/day, and th child is 0.1 g/day;[9] and that no routes of exposure other than inhalation and ingestion are si it.

sing Equations (1) through (3) the calculated adult doses of total PAH ranged from 0.1 to 0. y in dust, 10 to 65 µg/day in food, and 20 to 185 µg/day in air. For most adult subjects, inh was the most prevalent route of intake of total PAH. The adult doses of B-2 PAH ranged from 0.0 .35 µg/day in dust, 0.22 to 1.43 µg/day in food, and 0.02 to 0.31 µg/day in air. For all but two of ult sub ects, dietary ingestion was the most mportant route of intake of B-2 PAH. Even for the), the dose through the inhalation route was only slightly higher than that through diet.

he calculated doses of total PAH for children ranged from 1 to 3 µg/day from dust, 8 to 58 µg y from food, and 12 to 145 µg/day from air. Thus, with one exception, total PAH exposure of these children was predominantly through the inhalation pathway, just as it was for the adults. However, a different picture emerges for the children's exposure to B-2 PAH, as illustrated in Figure 1. The children's doses of B-2 PAH ranged from 0.06 to 0.31 µg/day from dust, 0.03 to 0.33 µg/day from food, and 0.02 to 0.32 µg/day from air. For all but two children, ingestion was a more important route of exposure to B-2 PAH than inhalation, and nondietary and dietary ingestion were of the same magnitude.

The total exposures to PAH, calculated using Equation (4) for the adult subjects, indicated that approximately 64% of their exposure, which is heavily influenced by the high concentrations of naphthalene in air, comes from inhalation, and 36% comes from food. Likewise, for the child subjects, approximately 72% of their exposure comes from inhalation, and 28% comes from food. However, for both adults and children, most of the exposure to B-2 carcinogenic PAH in this study derived from ingestion, and for children, about half of this ingestion was nondietary. This is illustrated in Figure 2.

CONCLUSIONS

For this sample of low-income, nonsmoking adults and children, inhalation is the most important pathway for total exposure to polycyclic aromatic hydrocarbons. However, ingestion is the most important pathway for total exposure to the carcinogenic PAH. And for young children, nondietary ingestion is as important as ingestion of food for exposure to the carcinogenic PAH.

Additionally, recruitment of participants to studies of this type is difficult. An effective means of recruitment is to work through the various social service agencies, using flyers and posters and inviting interested persons to initiate contact.

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This paper has been reviewed in accordance with the United States Environmental Protection Agency's peer and administrative review policies and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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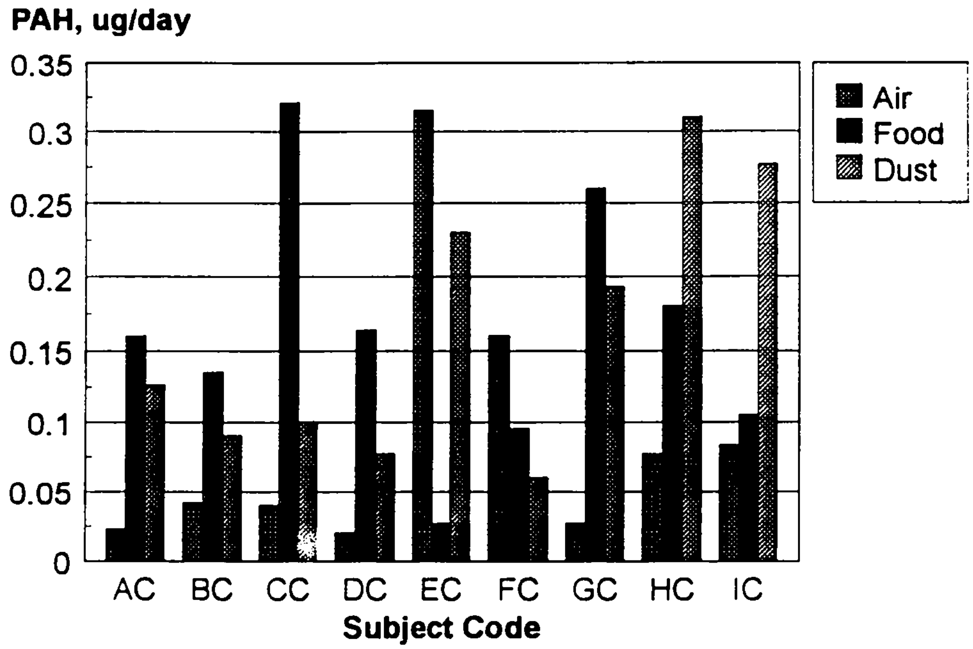

Figure 1. Children's exposure to B-2 carcinogenic polycylic aromatic hydrocarbons through three routes (environmental media): inhalation (air), dietary ingestion (food), and nondietary ingestion (dust/soil).

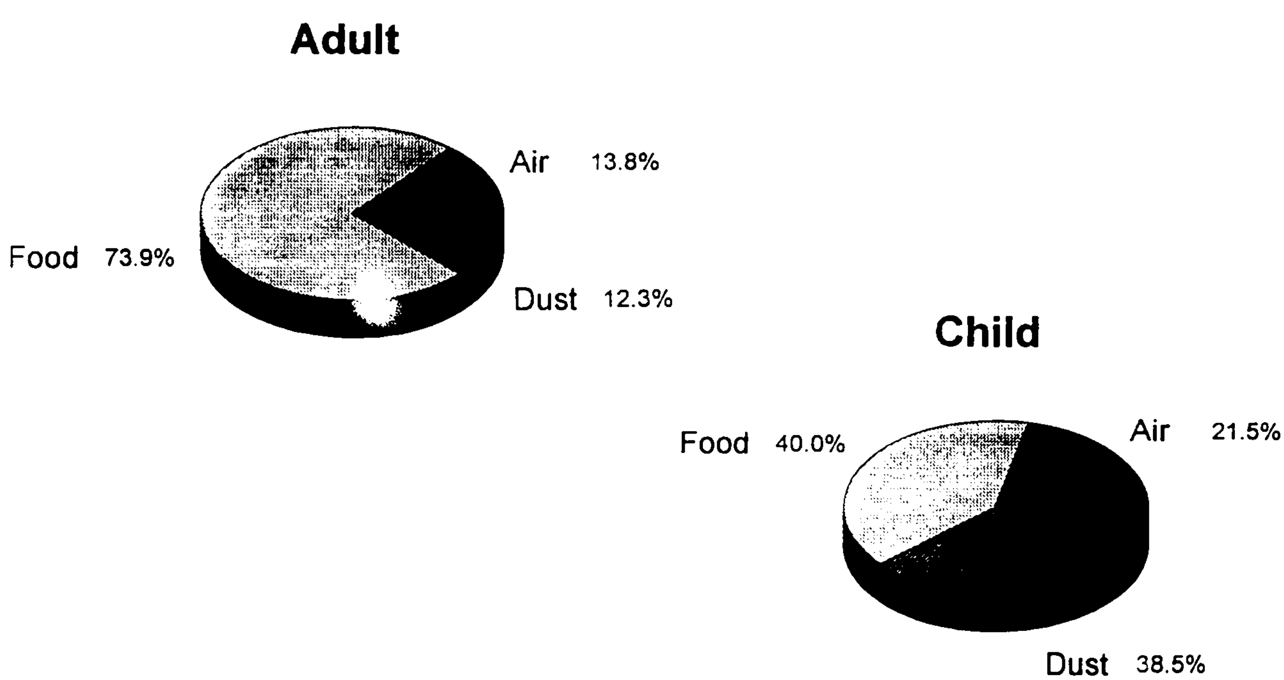

Figure 2. Comparative total exposure of adults and children to B-2 carcinogenic polycyclic aromatic hydrocarbons from three environmental media: air, food, and dust/soil.

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16. ABSTRACT

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