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Short communication

Are cockroaches reliable bioindicators of persistent organic pollutant contamination of indoor environments?

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ABSTRACT

We measured the concentrations of selected persistent organic pollutants (POPs) such as parent and halogenated polycyclic aromatic hydrocarbons (PAHs and HPAHs) and polybrominated diphenyl ethers (PBDEs) in indoor dust (ID) and indoor cockroach samples collected from Shenzhen, South China. Biota-dust accumulation factors (BDAFs) were computed and utilized to quantify targeted pollutant bioaccumulation in ID and cockroaches. Generally, halogenated compounds have higher BDAFs when compared to non-halogenated compounds. There are significant differences ($p < 0.05$) between the BDAFs of non-halogenated POPs (PAHs) and halogenated POPs (HPAHs and PBDEs). Correlation analysis of target pollutants' levels in ID and cockroaches were also conducted. The correlation coefficients for PAHs are less than 0.2 ($p > 0.5$) suggesting no significant relationship exists for PAHs between ID and cockroaches. In contrast, significant correlations exist for halogenated POPs (HPAH and PBDE) between ID and cockroaches (correlation coefficients >0.94, $p < 0.0001$). Based on this, the potential of cockroaches to be used as reliable bioindicators of POPs contamination of indoor environments was preliminarily evaluated. Our results indicate that indoor cockroaches may be useful bioindicator of indoor pollution for HPAHs and PBDEs contaminations.

1. Introduction

Cockroaches belong to insects of the order Blattaria or Blattodea living in a wide range of environments around the world. There are four species of cockroaches which are well known as pests, including *Periplaneta americana*, *Blattella germanica*, *Blattella asahinai*, and *Blatta orientalis*. They can serve as secondary sources of microbes and pollutants for human beings and are potential health risks. Most studies have hitherto focused on indoor cockroaches for their potentials to carry viral, bacterial and parasitic infections (Jeffery et al., 2012; Olmedo et al., 2011; Tungtrongchitr et al., 2004). However, no work has examined so far the possibility of indoor cockroaches being used as bioindicators of indoor pollution.

Indoor dust serves as a convenient medium to integrate historical and recent emissions of various pollutants from indoor spaces over long periods of time (Abdallah and Covaci, 2014; Baesteros-Gomez et al., 2014; Jiang et al., 2014). Therefore, ID can be regarded as a reliable sink to accumulate and mirror the occurrence of organic contaminants in indoor environments (Abdallah and Covaci, 2014; Baesteros-Gomez et al., 2014; Gevao et al., 2007; Jiang et al., 2014; Król et al., 2011; Ren et al., 2006). However, considering the fact that indoor cockroaches have nearly constant or intimate contact with ID, the bodily organic pollutants concentrations of cockroaches may indicate indoor pollution. In this present study, indoor cockroaches (*P. americana* (PA) and *B. germanica* (BG)) and ID samples were collected to determine the occurrences of parent and halogenated polycyclic aromatic hydrocarbons (PAHs and HPAHs) including polybrominated diphenyl ethers (PBDEs) in them. Based on this study, the potential of cockroaches to be used as reliable bioindicators of persistent organic pollutants loadings of indoor environments was preliminarily evaluated.

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2. Materials and methods

2.1. Chemicals

A standard solution of the 16 US EPA priority PAHs of the highest purity available was purchased from Chem Service, Inc. (West Chester, PA), including naphthalene (Nap), acenaphthylene (Acy), acenaphthene (Ace), fluorene (Fle), phenanthrene (Phe), anthracene (Ant), fluoranthene (Flu), pyrene (Pyr), chrysene (Chr), benzo[*a*]anthracene (BaA), benzo[*b*]fluoranthene (BbF), benzo[*k*]fluoranthene (BkF), benzo[*a*]pyrene (BaP), indeno[1,2,3-*c*,*d*]pyrene (IcdP), dibenzo[*a*,*h*]anthracene (DahA), and benzo[*g*,*h*,*i*] perylene (BghiP). 9-Chlorophenanthrene (9-ClPhe), 2-chloroanthracene (2-ClAnt), and 9,10-dichloroanthracene (9,10-Cl_2Ant) were purchased from Aldrich (St. Louis, MO). 1-Bromopyrene (1-BrPyr), 2-bromofluorene (2-BrFlu), 9-bromophenanthrene (9-BrPhe), 9-bromoanthracene (9-BrAnt), and 9,10-dibromoanthracene (9,10-Br_2Ant) were obtained from Acros Organics (Geel, Belgium). 7-Bromobenz (a) anthracene (7-BrBaA) was purchased from Tokyo Kasei Kogyo Co., Ltd. (Tokyo, Japan). Internal standards (2-fluorobiphenyl and p-terpheny-d_{14}) and surrogate standards (naphthalalene-d_8, acenaphthylene-d_{10}, phenathrene-d_{10}, chrysene-d_{12}, and perylene-d_{12}) for PAHs and HPAHs were purchased from Dr. Ehrenstorfer Gmbh (Augsbury, Germany). Fourteen PBDE congeners (BDE28, 47, 49, 85, 99, 100, 138, 153, 154, 183, 196, 206, 208, and 209) were selected for quantitative analysis. While ^{13}C-PCB208 was used as internal standards and ^{13}C-BDE15, ^{13}C-BDE77, and ^{13}C-BDE209 were used as surrogate standards for PBDE analysis. They were obtained from Cambridge Isotope Laboratories (Andover, MA).

2.2. Sample collection and preparation

Cockroaches were collected in two different ways: by using glue traps or swatting them in the selected buildings. Since the glues used in different cockroach glue traps are somewhat different, expectedly, appropriate cleaning agent should be chosen to separate the trapped cockroaches from the glue traps. In the present study, MELT-O-CLEAN (Henkel, Germany) was selected as cleaning agent. In addition, there is the possibility of swatted cockroaches losing target pollutants owing to loss of body parts; therefore only dead cockroaches with intact bodies were selected as final samples. Seventy American cockroaches (PA) and 1000 German cockroaches (BG) were collected from several contiguous buildings in September 2011 from Pingshancun (a village-in-city) in Nanshan District, Shenzhen, China. It was a

Table 1
Concentrations of PAHs, HPAHs, and PBDEs in cockroaches and indoor dust (ng/g).

	PA (n = 30)				BG (n = 29)				Dust (n = 23)		
	Mean	Min	Max	BDAF	Mean	Min	Max	BDAF	Mean	Min	Max
Acy	18.0	<RL	42.2	2.09	21.2	<RL	48.4	2.46	11.5	6.8	16.7
Ace	10.9	<RL	24.9	2.75	12.6	<RL	28.1	3.18	5.29	<RL	8.63
Fle	32.6	6.33	83.9	1.45	50.9	3.90	108	2.27	29.9	3.81	52.6
Phe	37.8	<RL	176	0.27	144	65.4	243	1.01	190	9.41	388
Ant	10.2	<RL	16.6	0.73	5.37	<RL	10.5	0.38	18.6	10.2	22.8
Flu	24.8	<RL	109	0.12	29.6	11.2	80.3	0.15	269	21.0	351
Pyr	95.0	43	345	0.70	30.2	7.62	52.3	0.22	182	86.5	235
BaA	4.38	<RL	21.0	0.31	1.81	<RL	19.0	0.13	18.9	9.27	32.4
Chr	4.46	<RL	39.6	0.03	3.82	<RL	25.3	0.03	200	8.05	274
BbF	8.38	<RL	27.6	0.09	4.30	<RL	21.5	0.05	119	2.73	159
BkF	1.35	<RL	12.9	0.07	0.49	<RL	5.65	0.03	25.7	11.5	128
BaP	2.34	<RL	16.5	0.15	1.27	<RL	12.4	0.08	20.6	4.37	33.4
IcdP	2.76	<RL	12.7	0.09	1.24	<RL	9.11	0.04	40.7	1.29	61.7
DahA	0.42	<RL	2.16	0.07	1.37	<RL	20.2	0.21	8.59	3.70	12.6
BghiP	5.87	<RL	19.2	0.13	3.79	<RL	11.1	0.08	60.3	29.6	73.3
Σ_{15}PAHs	624	238	1140		755	201	1438		1291	475	1642
2-BrFle	2.41	<RL	8.99	1.36	2.62	<RL	4.95	1.48	2.36	<RL	28.4
9-ClPhe	3.17	<RL	9.47	1.04	7.48	<RL	60.4	2.45	4.07	<RL	5.66
2-ClAnt	39.1	12.8	116	1.56	59.9	3.32	139	2.39	33.4	6.19	70.7
9-BrPhe	1.59	<RL	3.81	2.19	1.71	<RL	3.40	2.35	0.97	<RL	3.58
9-BrAnt	0.89	<RL	4.77	0.71	1.10	<RL	8.40	0.88	1.66	<RL	6.52
9,10-Cl_2Ant	0.37	<RL	1.08	1.90	0.32	<RL	1.39	1.64	0.26	<RL	0.48
9,10-Br_2Ant	0.16	<RL	0.43	1.52	0.23	<RL	0.78	2.19	0.14	<RL	0.35
1-BrPyr	0.70	<RL	2.75	2.83	0.72	<RL	1.78	2.91	0.33	<RL	0.84
7-BrBaA	1.13	<RL	4.13	3.96	0.86	<RL	2.55	3.02	0.38	<RL	1.26
Σ_9HPAHs	49.6	12.0	131		74.9	8	189		43.6	8.09	107
BDE28	0.14	0.02	1.30	0.15	0.03	<RL	0.20	0.03	1.22	0.09	20.8
BDE49	0.23	0.05	1.24	0.07	0.07	0.01	0.72	0.02	4.15	1.76	6.89
BDE47	0.60	0.06	4.70	0.10	0.13	0.03	0.21	0.02	7.80	0.29	67.7
BDE100	0.48	0.13	3.9	0.22	0.06	0.02	0.11	0.03	2.94	1.13	9.16
BDE99	1.73	0.19	15.6	0.23	0.12	0.03	0.21	0.02	9.83	0.55	43.0
BDE85	0.15	0.02	1.00	0.10	0.09	<RL	0.60	0.06	1.95	0.23	16.3
BDE154	0.64	0.08	2.53	0.46	0.08	0.03	0.16	0.06	1.84	0.24	7.53
BDE153	2.22	0.10	17.2	0.41	0.18	0.02	0.51	0.03	7.14	0.91	20.3
BDE138	0.30	0.06	1.47	0.15	0.07	0.02	0.17	0.04	2.64	0.30	36.4
BDE183	4.76	0.17	54.9	0.74	0.37	0.1	0.94	0.06	8.55	3.25	16.6
BDE196	6.63	0.67	58.4	0.18	1.17	0.49	4.13	0.03	49.2	8.59	485
BDE208	17.3	1.50	90.3	0.05	3.20	1.07	14.3	0.01	472	32.0	7722
BDE206	14.7	2.43	65.9	0.01	27.8	1.08	11.2	0.02	1563	40.9	30366
BDE209	115	0.98	577	0.04	117	4.89	41.9	0.03	4287	558	13598
Σ_{14}PBDEs	165	11.5	756		20.0	9.13	73.1		6419	654	52382

Max: maximum, Min: minimum, <RL: lower than the reporting limit, BDAF: the "biota-dust accumulation factor" of PAHs, HPAHs, and PBDEs in indoor cockroaches.