Original Article

Assessment of Exposure to Polybrominated Dipheny Ethers via Inhalation and Diet in China*

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Abstract

Objective This paper is to assess the current status of polybrominated diphenyl ethers (PBDEs) contamination in the environment in China and estimate the exposure to PBDEs in non-occupational populations.

Methods A total of 80 research papers published from January 2001 to October 2013 were selected. Geographic information system (GIS) was used in mapping PBDE concentrations and distributions in environmental media. Ni's model was applied to calculate ∑PBDE-intake via the intakes of contaminated food, water and air in the Pearl River Delta and Yangtze River Delta.

Results BDE-209 was found to be the major PBDE congener in the environmental media and food in China. PBDE concentrations varied among different areas, among which the contamination in Guangdong Province was most serious. Daily intake of ∑PBDEs was 225.1-446.0 ng/d for adults in the Pearl River Delta, which was higher than the intake for those living in the Yangtze River Delta (148.9-369.8 ng/d).

Conclusion PBDEs are ubiquitous in the environment of China. The estimated PBDEs daily dietary intake is comparable with that in European countries.

Key words: PBDEs; Exposure assessment; GIS; PBDE-distribution; Daily intake

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INTRODUCTION

Polybrominated diphenyl ethers (PBDEs) are a group of brominated flame retardants (BFRs) commonly used in consumer products such as electronics, textiles and polyurethane foams[1]. PBDEs have been marketed as three commercial mixtures: pentabromodiphenyl ether (penta-BDE), octabromodiphenyl ether (octa-BDE), and decabromodiphenyl ether (deca-BDE). The global demand for PBDEs was estimated to be 67,490 tons in 2001 (11%, 6%, and 83% were produced as penta-, octa-, and deca-BDE, respectively), of which 49% was used in North America, 37% in Asia, and 12% in Europe[2]. Among the PBDEs used in China, BDE-47, -99, -209 are the most common congeners. The multiple exposure sources and wide use of PBDE have aroused great concern on PBDE-exposure on people's health, especially the exposures to BDE-47, -99, -209, in China.

PBDEs have been shown to have toxicological effects, including developmental neurotoxicity and

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Biographical note of the first author: CHEN Li, female, born in 1987, master, with major in health-based risk assessment.

interference with thyroid hormone homeostasis, in laboratory animals[3-5]. Due to these effects, penta- and octa-BDE have been banned in the European Union since 2004, and were classified as persistent organic pollutants (POPs) due to their bioaccumulation, toxicity, and persistence, and have been banned under a Stockholm convention[6]. Since these compounds are continued to be found in the environment, reservoir sources may continue to contaminate air, water, soil, sediment, and biotic organisms[7-8], all of which are believed to contribute substantially to the human intake of these compounds. Hites[9] found that the PBDE concentrations in people had increased exponentially by a factor of approximately 100 during the last 30 years.

Although there is a wealth of data on PBDE distributions in environmental media, including surface water, air, soil, and sediment, and in the food chain, until now no nationwide systematic monitoring and tracking system for PBDE distribution has been established and no nationwide assessment of PBDE-exposure has been conducted in China. Given that dozens of papers on regional PBDE concentrations have been published, the assessment of non-occupational exposure to PBDEs in humans has become possible in this study.

Geographic information system (GIS) is a powerful tool in the exposure assessment of environmental contaminants, which is not only feasible but also can provide a visualization of contamination in the environment[10]. The combination of GIS use and statistical analysis allows for better understanding of the distribution of the contaminants in the environment of study population.

GIS was used to visualize the published data reviewed in this study in order to evaluate PBDE concentrations and distributions in environmental media. Ni's equations[11] were used to determine the major routes of PBDE-exposure, and to identify the geographical areas with high PBDE exposure levels. The results might facilitate further health-based risk assessments of PBDEs and might be helpful for the decision making on the management and control of PBDEs in China.

METHODS

Data Sources and Research Methods

A literature retrieval was carried out by using MEDLINE. The MeSH terms 'PBDEs', 'environmental exposure', 'air', 'water', 'soil', 'sediment', 'food', 'geographic information system', and 'China' were used. We also retrieved the references listed in the related published papers and reviews included in PubMed and China National Knowledge Infrastructures (CNKI). For this analysis, we selected papers which: a) were original ecological studies, b) were published in English or Chinese, c) defined all or subgroups of PBDEs as the target chemicals, and d) studied the environmental or human exposure status by using measured concentrations of PBDEs. Moreover, we retrieved conference proceedings in the ISI Web of Science for abstracts of other unpublished studies, using the same MeSH terms mentioned above, but we did not find any other related study.

A total of 184 papers were selected for this analysis, but only 80 papers qualified were used in this assessment. These papers were published from January 2001 to October 2013, and reported PBDE concentrations in environmental media and food in China.

GIS Mapping of the Data

For all the 80 studies, the sample sites could be indicated on the map precisely by using GOOGLE EARTH® via their longitudes and latitudes. By using the ArcView GIS 3.2 software, the sampling sites were geocoded. Boundaries of municipalities and provinces were obtained from the State Bureau of Surveying and Mapping. All the data were entered into ArcView GIS 3.2 operated on a PC workstation, and the data were incorporated into several maps to indicate the PBDE distributions in different sampling sites. PBDE concentration data in different environmental media were shown as separate map layers, with levels of PBDE concentrations being color coded.

Regional Exposure Assessment of PBDEs in China

Given the availability of the environmental and food concentrations of PBDEs in the Yangtze River Delta and Pearl River Delta, the exposure levels in these two regions can be estimated. According to Ni et al.[11], the daily intake levels of PBDEs in humans were estimated according to the collective environmental and food data by using the following formula: $I=\sum(C_i \times IR_i)$.

Where I is the total intake of PBDEs (ng/d); C_i is the concentration of PBDEs in the environmental medium and in various foods (ng/m^3 for air; ng/L for drinking water; ng/g for foods); and IR_i is the intake