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Health risk assessment of exposure to chlorpyrifos and dichlorvos in children at childcare facilities

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HIGHLIGHTS

- ► We examined pesticide exposure for children in 168 childcare facilities from 6 cities in South Korea
- ► Chlorpyrifos and dichlorvos were detected through major pathways at high frequencies.
- ► ECR was calculated for children at the facilities based on CPF and ADAF.
- ► Total cancer risk in the 50th percentile was noteworthy for inhalation in children at the facilities.
- ► Children in the facilities had the HQ score higher than the 95th percentile with a HQ of 1.9.

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ABSTRACT

The present study evaluated 168 childcare facilities from 6 cities in South Korea to assess exposure to organophosphorus pesticides (OPs) in children through 4 major pathways (indoor air, indoor dust, surface wipe of indoor objects, and hand wash water of children). The Excess Cancer Risk (ECR) was calculated based on the Cancer Potency Factor (CPF) and Age Dependent Adjustment Factor (ADAF) in adults. Dichlorvos residues were detected in the indoor air, indoor dust, surface wipes of indoor objects, and the hand wash water of children at frequencies of 47.4, 90, 100, and 100%, respectively. After revision based on the ADAF, total cancer risk in the 50th percentile was 3.99×10^{-3} for inhalation, oral intake, and dermal contact in children ages 3 to 4 and 4.63×10^{-4} in kindergarteners ages 5 to 6. Inhalation was the primary pathway of pesticide exposure in children in childcare facilities. Children ages 3 to 4 in daycare centers had a Hazard Quotient (HQ) of 0.5 for dichlorvos, which was 50% lower than the risk criterion level of 1 but was higher than the 95% percentile with a HQ of 1.9. This study postulates that children in childcare facilities may be exposed to specific OPs.

1. Introduction

The indoor environment is the most common site of pesticide exposure (Nigg et al., 1990; WHO, 1997). Individuals may be exposed to pesticides in indoor environments through multiple pathways, including inhalation of indoor air, oral intake of contaminated food, and dermal contact with pesticide residues (Brenda et al., 1999; Kang and Paik, 1999; Oh and Chung, 2001; Weichenthal et al., 2010). Many people living in urban environments have implicated pesticide exposure in indoor pollution and health complains (Petit et al., 2012). Studies have reported that indoor pesticide exposure can cause serious disease, such as brain tumor, leukemia and lymphoma, and testicular cancer (Blair et al., 1992; Blatter et al., 1997; Cockburn et al., 2011; Kristensen et al., 1996).

Many epidemiological studies have stated that pesticide exposure can have a greater impact in young children than adults (Eskenazi et al., 1999; Faustman et al., 2000; Lu et al., 2001; Sheets, 2000). These studies have proposed health concerns regarding chronic exposure to pesticides in young children in domestic environment (Grey et al., 2005). There have been specific health concerns regarding the exposure of young children to OPs and the potential health effects of accidental ingestion (Eskenazi et al., 1999; Faustman et al., 2000; Lu et al., 2001; Sheets, 2000). Researchers have reported that young children in childcare facilities with indoor contamination may be exposed to pesticides through multiple pathways, including indoor air and dust on indoor objects (Kawahara et al., 2005; Silver et al., 1994).

The application of biologically active substances in indoor environments has several risks (Petit et al., 2012). The most prevalent

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risks to occupants are indoor air pollutants by aromatics, aliphatics, and other volatile organic compounds (VOCs), pesticide residues on indoor objects, and the application of chemical substances used for cleaning (Mendell, 2007). A systematic investigation was performed at childcare facilities in various districts in South Korea to determine accurate indoor conditions of the facilities. The results provide a health risk assessment for exposure to some organophosphorus pesticides in young children and may assist in developing indoor management programs in childcare facilities.

2. Materials and methods

This investigation was performed according to previous studies (Kim et al., 2011a,b) and included selecting childcare facilities, collecting experimental materials, and observing and analyzing the target pesticide compounds. A total of 168 childcare facilities from 6 cities in South Korea were selected to observe indoor conditions and assess pesticide exposure. The childcare facilities consisted of 40 home daycares, 42 daycare centers, 44 kindergarten classrooms, and 42 indoor playgrounds. The 6 cities were included 2 large cities (Seoul and Busan), each with populations of more than 3 million, 2 small cities (Daejeon and Suwon) with the population ranging from 1 to 3 million, and 2 provincial cities (Yeosu, an industrial city and Asan, a farming city) with population of less than 1 million. The experiment was conducted during 2 seasonal observation periods. The first time period occurred from July 2007 to September 2007 when the air temperature was high (summer), and the second time period included January 2008 to February 2008 when air temperature was low (winter) (Tables 1, 2, and Fig. 1).

The study examined the following 4 pathways of pesticide exposure: indoor air, indoor dust, surface wipe of indoor objects, and hand wash water of children. Other pathways excluded in the present study because of even comparison for each facility. The indoor air samples were collected at all of the childcare facilities during both of the observation time periods. The samples for the other pathways were collected on a smaller scale in facilities in Seoul, Daejeon, Suwon, and Asan during the first time period. Indoor dust and hand wash water samples were collected at 30 childcare facilities. The 106 surface wipe samples were obtained from 28 home daycares, 28 daycare centers, 22 kindergarten classrooms, and 28 indoor playgrounds. According to a questionnaire, most facility managers regularly applied chemicals, including chlorpyrifos, dichlorvos, malathion, and parathion, to exterminate hygienic insects. This study evaluated the residues of these chemical substances (Table 3).

Table 1
General characteristics of the cities evaluated.

City	Location (° ′)		Population in 2010 (thousands)	Mean air temperature (°C)		Regional characteristics
	Latitude	Longitude		July	January	
Seoul	N 37 33	E 126 58	10,288	24.9	−2.4	Commercial district
Busan	N 35 06	E 129 03	3684	24.1	3.2	Commercial district
Daejeon	N 36 20	E 127 26	1451	25.0	−1.0	Commercial district
Suwon	N 37 17	E 127 01	1042	24.8	−2.9	Commercial district
Yeosu	N 34 57	E 127 28	293	24.2	2.4	Manufacturing district
Asan	N 36 48	E 127 09	570	24.7	−2.9	Agricultural district

Table 2
Description of different childcare facilities by regions.

Classification	Region	Childcare facility				
		Home daycare	Daycare center	Kindergarten classroom	Indoor playground	Total
First observation time period (summer)						
Large city	Seoul	7	7	7	7	28
	Busan	7	7	7	7	28
Small city	Daejeon	5	8	8	7	28
	Suwon	7	6	8	7	28
Industrial city	Yeosu	7	7	7	7	28
Farming city	Asan	7	7	7	7	28
Sub-total		40	42	44	42	168
Second observation time period (winter)						
Large city	Seoul	6	7	6	4	23
	Busan	6	7	6	5	24
Small city	Daejeon	5	8	3	7	23
	Suwon	6	5	8	7	26
Industrial city	Yeosu	7	7	7	6	27
Farming city	Asan	6	6	6	5	23
Sub-total		36	40	36	34	146
Total		76	82	80	76	314

Large city: population of more than 3 million.
Small city: population of 1 to 3 million.
Industrial and farming cities: population less than 1 million.

2.1. Pesticide residues at childcare facilities

2.1.1. Collection of experimental materials

To measure the pesticide residues in indoor air, a low volume vacuum pressure pump (GVAC, Gast, USA) absorbed 480 l of indoor air at a height of 1.5 m above the floor level at a flow rate of 16 l/m through a glass tube (ORBO-49P, Supelco, USA) filled with polyurethane granules (XAD-II, Supelco, USA). The granules were soaked in an extraction/desorbing (E/D) solution to extract the target compounds. The E/D solution consisted of 8 μl tributyl phosphate and 100 ml toluene.

A vacuum cleaner was modified by attaching 125-mm filter paper (no.1, Whatman, UK) at the filter holder to collect samples of indoor dust. The official US EPA A3051 analysis method was used to process the indoor dust samples. Approximately 0.05 g of the absorbed indoor dust was placed into a vial with 100 ml nitric acid for an hour extraction using an ultrasonic extractor. The extracted materials were placed into a new vial and rinsed with 20 ml nitric acid. The vial was heated to 160 °C in a microwave digestion system for 1 h and cooled at room temperature for 30 min. The contents was filtrated with 1.2 μm GF/C and diluted with distilled water.

A synthetic 100% continuous filament polyester 7.5 cm × 7.5 cm wipe (TX1009 cleanroom wipe, Alpha Wipe, USA) was rubbed twice back and forth over a 20 cm long to collect indoor dust samples on the surface of indoor objects, including floor mats, desks, chairs, and toys. Surface wipe samples were collected by hand wearing plastic gloves to prevent the contamination. Surface wipe samples from five locations that were thought to be in frequent contact with young children were collected and placed into a 40-ml glass vial. The samples were poured into a Teflon vessel with 20 ml 10% nitric acid. The samples were sealed with a cap and heated at 60 °C in a microwave digestion system for 1 h. After the extraction procedure, the vessel was cooled at room temperature for 30 min and the contents were filtered with 1.2-μm GF/C and diluted with distilled water to 50 ml.

To collect hand washing residue, all of the participating children first washed their hands with distilled water prior to spending more