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Indoor environmental pollutants and their association with sick house syndrome among adults and children in elementary school

Reiko Kishi[a,*], Rahel Mesfin Ketema[a,b], Yu Ait Bamai[a], Atsuko Araki[a], Toshio Kawai[c], Tazuru Tsuboi[c], Ikue Saito[d], Eiji Yoshioka[e], Takeshi Saito[b]

[a] Center for Environmental and Health Sciences, Hokkaido University, Sapporo, Japan
[b] Graduate School of Health Sciences, Hokkaido University, Sapporo, Japan
[c] Osaka Occupational Health Service Center, Japan Industrial Safety and Health Association, Osaka, Japan
[d] Department of Environmental Health and Toxicology, Division of Environment Health, Tokyo Metropolitan Institute of Public Health, Japan
[e] Asahikawa Medical University Department of Health Science, Asahikawa, Japan

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ABSTRACT

Sick house syndrome (SHS) derived from sick building syndrome (SBS) is used to describe symptoms that inhabitants experience due to indoor environment and personal factors, and children might be more susceptible to the effects of SHS than adults. However, there have been no comprehensive studies on effects of indoor pollutants exposure in relation to SHS. Thus, the aim of this study is to examine the association between indoor pollutants and SHS in children and adults who live in the same dwelling. This is a cross-sectional study on 184 elementary school children and 273 adults/adolescents in Sapporo, Japan. Indoor pollutants were measured in air and dust collected from 128 dwellings. Results showed children (20.6%) have higher prevalence of any symptoms than adults/adolescents (15.1%). Among SHS, mucosal symptoms were the most common in both children and adults/adolescents. Doctor diagnosed allergies, building age, dampness, and ventilation system showed significant association with prevalence of SHS. Formaldehyde, di(isobutyl) phthalate (DiBP), di(2-ethylhexyl) phthalate (DEHP), di(isononyl) phthalate (DiNP), endotoxin, and β-glucan were detected in all dwellings. Any symptoms and mucosal symptoms were significantly associated with the exposure to 2-ethyl-1-hexanol (2E1H). Floor dust DiNP, multi-surface dust Tris(2-butoxyethyl) phosphate with mucosal symptoms and endotoxin with dermal symptoms were inversely associated in adults/adolescent. Multi-surface dust DiBP also showed inverse association with mucosal symptoms in children. 2E1H emission increased with dampness in the dwellings thus, eliminating dampness in the dwellings may reduce the emissions of 2E1H and the risk of SHS in residents.

1. Introduction

Sick house syndrome (SHS) is originally derived from sick building syndrome (SBS) that describes the situations in which building occupants experience health problems such as a headache, fatigue, irritation of eyes, nose, and throat, and dry/itchy skin, when they spend time in indoor environment [1–3]. The severity of the symptoms tends to increase in the house and improve over time or even disappear after leaving the house [2]. These health impairments are often related to poor indoor air quality, caused by a variety of factors including indoor chemicals, microbial contaminants, building airtightness, and the dampness in the house [3–5]. Adverse public health effects including SHS have attracted attention to indoor environmental pollution in recent years [1,2,6].

Environmental pollutants in indoor air and dust samples have been detected worldwide include volatile organic compounds (VOCs) [6,7], semi-VOCs (SVOCs) [8–11] and microbial VOCs (MVOCs) [12,13]. In addition, studies reported that exposure to these pollutants increases the personal vulnerability risk of asthma, allergies and SHS in residents [9,14–18]. For instance, formaldehyde and MVOCs such as 1-octen-3-ol were associated with mucosal and atopic dermatitis symptoms [7,10,13,16] and semi-VOCs such as phthalates and tributyl phosphate (TBP) showed associations with mucosal symptoms [1]. Domestic exposure to β(1 → 3) D glucans also showed an increase in peak expiratory flow variability in school children [17].

Children and women are more susceptible to the effects of indoor environmental pollution because they spend more time in the home environment [19]. Children might particularly be vulnerable because of

* Corresponding author.
E-mail address: rkishi@med.hokudai.ac.jp (R. Kishi).

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their smaller, immature, and developing organs [6]. However, there have been no comprehensive studies on the effects of exposure to indoor pollutants in relation to SHS in children and adults who live in the same dwelling. Therefore, the objectives of this study are: (1) to analyse the levels of several indoor pollutants such as formaldehyde, VOCs, MVOCs, phthalates, phosphorus flame retardants (PFRs), and biological contaminants in indoor air and dust samples in dwellings, and (2) to investigate and compare the association of these indoor environmental pollutants with SHS in children and adults, who live in the same dwelling.

2. Materials and methods

2.1. Study design and population

This cross-sectional study solicits health and environmental information regarding elementary school children and their families in Sapporo, Japan. The study population consisted of two groups who live in the same dwelling, 184 elementary school children under 12 years old and their 283 family members (≥13 years old; father, mother, and siblings), which will be referred to as "adults/adolescent" hereafter. The detailed description of the study design was described elsewhere [8]. Briefly, in 2008, a total of 6393 baseline questionnaires were distributed to children in 12 elementary schools in Sapporo. Responses were obtained from 4408 students corresponding to a 68.9% response rate and the parents of 951 children in 832 dwellings agreed to a home visit. After excluding those respondents who sent back incomplete questionnaires, those who graduated from elementary school, or those for whom the home visit could not be arranged; participants from 128 dwellings with a completed home visit were included in this study. Home visits were conducted in October and November of 2009 and 2010 for the environmental exposure measurements along with the health surveys.

The study protocol was approved by the ethical board for epidemiological studies at Hokkaido University Graduate School of Medicine. All participants and parents of children under 12 years old provided their written informed consent before this study has started.

2.2. Questionnaires

All inhabitants received questionnaires that included questions about SHS, demographics, lifestyle, and household characteristics per dwelling. Parents were asked to respond to the questionnaires for participants ≤12 years old elementary school children, while participants over 13 years old (adults/adolescents) answered the questionnaires by themselves.

2.2.1. Sick house syndrome (SHS) questionnaires

We used the Japanese-translated standardized MM questionnaires designed for the epidemiologic assessment of SBS symptoms by the Department of Occupational and Environmental Medicine in Orebro, Sweden [20–22]. MM is an abbreviation of the Swedish word "Miljo Medicine" (Environmental Medicine). Separate MM questionnaires; MM 080 School for children and MM 040 EA for adults/adolescents were used to define SHS [20–22]. For children, the MM 080 School questionnaire includes ten sub-symptoms categorized as dermal symptoms (dry/or itching hands, dry facial skin, and itchy/or flaky scalp), mucosal symptoms (irritation of the eye, runny nose, and cough), and general symptoms (fatigue, headache, sleeping problems, and stomach ache). For adults, the MM 040 EA questionnaire includes 12 sub-symptoms categorized as dermal symptoms (dry/or itching hands, dry facial skin, and itchy/or flaking scalp), mucosal symptoms (irritation of the eyes, runny nose, cough, and dry throat), and general symptoms (fatigue, headache, sleeping problems, feeling heavy-headed, nausea and lack of concentration). Any symptoms is positive if at least one of the sub-symptoms are positive. Each question has three alternative answers: "Yes, every week", "Yes, sometimes", and "No, never" for the past three months. For this study, we only used the responses "Yes, every week" to define the robust cases. There was an additional question "if Yes, do you believe that it is due to the home environment?" Thus, SHS is defined as a symptom that occurs every week and that is attributed to the home environment by the respondents.

2.2.2. Household, demographics and lifestyle questionnaires

The household characteristics questionnaire includes questions on building structure (wood or concrete), building age, home renovation within 5 years, floor materials (PVC, compressed wood, wall-to-wall carpet and tatami/tiles/natural wood), wall materials (PVC or other), condensation (any window, wall, both or other) in the dwelling ever (Yes/No), mould odour (Yes/No), visible mould (Yes/No), water leakage (Yes/No), high humidity in the bathroom with slow drying wet towels (Yes/No), ETS (Environmental Tobacco Smoke) (Yes/No), furry pets (dog, cat, hamster) at home (Yes/No), mechanical ventilation in all rooms (Yes/No), weekly cleaning of the living room, and annual household income.

Data on demographics and lifestyle information such as gender, age, time spent at home, any doctor-diagnosed allergies ever (asthma, rhinoconjunctivitis, or atopic dermatitis), and parental history of allergies (both the mother or father of the child) were also collected.

2.3. Environmental exposure measurements

Indoor air and settled dust samples from 128 dwellings were collected for the exposure assessment. Analytical approach, and assessment of quality control and quality assurance (QA/QC) for the measurement of chemicals are described in previous papers [1,8,16] and appendix.

2.3.1. Air samples

Indoor air samples were collected over a period of 48 h in the living room. Samples were collected onto diffusive air samplers (DSD-DNPH for aldehydes and VOC-SD for VOCs and MVOCs, both from Sigma–Aldrich Co., St. Louis, MO, USA) at 150 cm above the floor level.

2.3.1.1. Aldehydes, VOCs, and MVOCs. Full details of the chemical analysis and schematic representations of the analytical procedures are described elsewhere [7,16,23]. The analysis of aldehydes, VOCs, and MVOCs were conducted at Osaka Occupational Health Service part of the Japan Industrial Safety and Health Association in Tokyo, Japan. The effect of individual VOCs has not yet been established. Hence, in this study, we used the sum of 34 targeted VOCs as a single indoor air pollutant, denoted hereafter as TVOC.

2.3.2. Dust samples

Dust samples were collected using a hand-held vacuum cleaner equipped with a paper dust bag. To avoid cross-contamination between the samples, vacuum nozzles were washed in an ultrasound bath and vacuum cleaners were wiped with ethanol after each sample was collected. Dust samples were collected from two areas of the living room, "floor dust" from the floor and any surface less than 35 cm above the floor level and "multi-surface dust" from any surface higher than 35 cm above the floor level such as shelves, mouldings, TV sets, and interior materials such as wallpaper and the ceiling. Full description of dust sampling and sample preparation has been described elsewhere [1,8].

2.3.2.1. Phthalates and phosphorus flame retardants. The analysis methods and quality assurance procedures have been given in details in our previous studies [1,8,11]. Gas chromatography/mass spectrometry (GC-MS) in selective ion mode (SIM) was used to analyse the concentrations of phthalates in the floor and multi-surface dust samples, and PFRs in multi-surface dust samples. The targeted compounds include phthalate esters, di(isobutyl) phthalate (DiBP), di