





Review

# Health Effects of Exposure to Indoor Semi-Volatile Organic Compounds in Chinese Building Environment: A Systematic Review

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**Abstract:** People spend a considerable portion of their lives indoors; thus, the quality of the indoor environment is crucial. Semi-volatile organic compounds (SVOCs) are among the primary indoor pollutants responsible for various health risks. This paper systematically reviews the impact of SVOC exposure on human health in Chinese built environments. Based on a set of criteria, we judged 12 publications as providing sufficient information on both SVOC exposure and health effects to inform the relationship. Out of six studies on polycyclic aromatic hydrocarbons (PAHs), three observed a positive association between PAH exposure and lung cancer. Out of six studies of phthalate exposure, two studies reported a significant positive association between DEP and DiBP and asthma, between DEP and DEHP and dry cough among children, and between DBP and rhinitis among younger adults. The results of this review suggest that there might be a link between phthalate exposure and asthma and allergies, as well as a link between PAH exposure and lung cancer. However, due to the limited number of studies conducted, more evidence is necessary to definitively guide the establishment of standards for SVOC control in China.



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**Keywords:** semi-volatile organic compounds (SVOCs); phthalate esters (PAEs); polycyclic aromatic (PAHs); health effects; building environment; China

## 1. Introduction

People's lives are affected by the indoor air quality, or IAQ, described as the air quality inside constructions and structures. IAQ is essential to provide healthy and comfortable conditions for residents in buildings [1,2]. Around 90% of people's time is spent inside buildings in today's modern societies [3]. Therefore, an increased attention to safety is observed in residential places [2,4–7]. Indoor air pollution can be considered a significant source of risk for some residents because of insufficient ventilation, along with low-quality construction materials, diffusing toxic or dangerous gases together with dust [8,9].

Thus, issues associated with human health make the environmental conditions of buildings extremely important [4]. One type of indoor pollutant associated with considerable health concerns is the group of semi-volatile organic compounds (SVOCs) [10,11], classified by the World Health Organization (WHO, Geneva, Switzerland) as indoor organic substances with boiling points ranging from 240/260 to 380/400 °C [12]. Different pathways contribute to the entrance of these pollutants into buildings, among which infiltrating outdoor air, indoor combustion, spray products, as well as material additives, can be mentioned. Due to the low vapor pressures of SVOCs at a temperature of 25 °C (77 °F) ( $10^{-9}$  to 10 Pa) in comparison with volatile organic compounds (VOCs) (10 to 104 Pa), the gas or condensed phases of these compounds can typically be observed, leading to their redistribution from the primary source to the buildings' interior and surfaces inside them, such as airborne particles, dust, and skin [11].

Reports have shown polycyclic aromatic hydrocarbons (PAHs), phthalate esters (PAEs), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs) in different studies as the main SVOC chemical classes found indoors [10,13–21]. When organic compounds are combusted or pyrolyzed incompletely, polycyclic aromatic hydrocarbons (PAHs) will be produced as pervasive environmental pollutants [22,23], resulting in public health concerns across the globe [24,25]. Environmental tobacco smoke (ETS) is recognized as the main source of PAHs in the indoor environment, with considerable emission factors related to smoking in industrialized countries. [26]. Heating and cooking with solid fuels, namely dung, agricultural remnants, wood, or coal, particularly in flueless or unvented stoves, is considered to be the main source of indoor air pollution in developing countries [27]. More than 70 percent of homes in China utilize solid fuels for cooking and heating [28].

According to the WHO, 2.7% of the annual global burden of disease is due to household air pollution that results from fuel combustion, one of the top ten global threats to public health [29,30]. Studies show that health risks due to exposure to byproducts of solid fuel combustion are of particular concern in developing countries, with an increased risk of lung cancer [31–33], particularly in Chinese and Indian women who are mostly nonsmokers [32,34,35]. Among households in developing countries, the concentrations of PAHs are of particular concern.

Polybrominated diphenyl ethers (PBDEs) are additive flame retardants frequently employed in a wide range of consumer goods, including textiles, automobiles, furniture, computers, and other electronic devices [36]. The environment and individuals are exposed to PBDEs as they dissipate from the items in which they are used [37]. PBDEs in placental tissue, cord blood, and human breast milk have been found [38], substances in which they have a tendency to bioaccumulate [39] and through which they even convey to the fetus [40,41]. Li and Fu observed that the main areas polluted with PBDEs in Beijing (China) were households and electronics shops [42]. The potential of PBDEs for long-range transport, bioaccumulation, endocrine disruption, and carcinogenic and mutagenic effects [42,43] has made it of particular concern for decades.

Polychlorinated biphenyls (PCBs) are typically added to capacitors and transformers as heat-transfer and insulation fluids [44]. PCBs still pose a problem since they are frequently found in the environment, even though China is not their primary source and has had restrictions on them for decades [45]. PCBs affect an organism's functions, including thyroid hormone levels, the immune system, and even cancer development [44]. In a Chinese cohort, it is significant to note that birth weight had an inverse relationship with placental PCB concentration; this relationship may be affected by placental disturbance [41].

Phthalates have become a constant in the modern lifestyle as developed countries begin to witness lifestyle changes in the form of new personal care products, cleaning products, furniture, building materials, paint, and more. All of these contain phthalates and are constantly present in our indoor environment. Humans are exposed to these materials through inhalation, ingestion, dermal absorption, or contact with medical tools [34–36]. This perpetual exposure to phthalates may be responsible for the increased numbers of asthma and allergies in industrialized nations over the last 60 years [46,47]. Between 1980 and 1996, the number of people who have asthma went from 6.5 million to 14.5 million in the United States [48]. China is currently the world's major consumer and producer of phthalates [49]. China produces around one-fourth of the entire amount of phthalates used worldwide [50,51]. In previous studies, Wang et al. found that the concentration of indoor phthalates in China was higher than in developed countries such as the USA, which indicates a more severe condition in Chinese building environments [50].

SVOCs (PAHs, PAEs, PBDEs, PCBs) are known as endocrine-disrupting chemicals (EDCs). EDCs have a wide range of influences on human health, and it is a universal concern at all stages of human life, from the embryonic development to the elderly, who are consistently exposed to low concentrations of these chemical compounds. It is our objective, therefore, to summarize the known health impacts of SVOCs in the Chinese built

environment as established by published literature. This information may be used for the establishment of Chinese standards on indoor SVOC exposure and for enlightening prospective studies.

## 2. Materials and Methods

### 2.1. Literature Searching

We searched all published literature on SVOC exposure and health effects in Chinese building environments between 1980 and 2017. The databases included China National Knowledge Infrastructure in Chinese (CNKI), WANFANG DATA (in Chinese), PubMed, and Web of Science. The search terms were categorized as:

Indoor pollutants: semi-volatile organic compounds, SVOCs, phthalic acid esters, phthalates, PAEs, polycyclic aromatic hydrocarbons, PAHs, benzopyrene, BaP.

Building type: university, college, school, classroom, institutes, office, home, house, dwelling, residence, apartment, kindergarten, daycares.

Health outcomes: Search terms were selected based on the World Health Organization (WHO) and the International Programme for Chemical Safety (IPCS) guidelines. They suggested 122 terms, including allergies, respiratory diseases, and cancer (see Supplementary Materials for more details).

The reference management program EndNote, version X8, Thomson Scientific, Stamford, CT, USA, was used to enter all of the retrieved papers and check for duplication.

### 2.2. Literature Screening

A total of 5477 papers were obtained in the literature search. Papers which provided information on indoor SVOC exposure and their impact on human health were selected; the rest were eliminated. Screening and evaluation of the papers occurred in two steps: First, we determined relevance based on the title and abstract of each article. Second, we read the full texts of the remaining papers. Papers were excluded if (1) studies had not been performed in China; (2) studies had been carried out on animals; (3) in vitro or in vivo studies had been performed on cells; (4) studies showed no data on health outcomes; (5) health risks were estimated with the use of models or equations; and (6) the studies investigated the health effects of pollutants on rivers, soil, vegetables, biomarkers, or ambient air. The screening process yielded 58 papers for further examination by the review panel. Prior to the workshop, the panel studied these 58 publications, and at the workshop, they discussed the papers and created a consensus statement based on the available evidence.

### 2.3. Literature Review

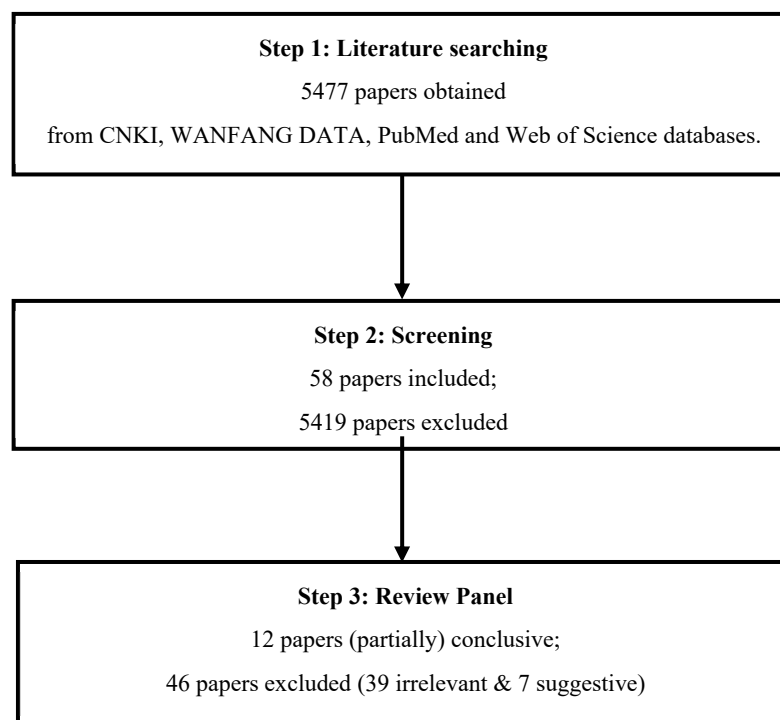
The review panel consisted of 5 people, with backgrounds in Environmental Science, Environmental Engineering, Public Health, and Built Environment. The full texts of the chosen papers were reviewed by two independent review panel members to avoid bias.

Reviewers retrieved data from each article, specifically the type of study, setting/location, investigated population, indoor pollution and health outcomes, potential sources of bias, research results, and conclusions. A primary reviewer verbally summarized each of the 58 papers during the workshop. A second reviewer provided further feedback. The review panel's broad discussion of each article resulted in its ultimate categorization into one of the following categories:

- Relevant and (partially) conclusive—giving sufficient information regarding exposure to indoor SVOCs and its health outcomes, and relationship between indoor SVOC exposure and its health outcomes.
- Relevant and suggestive (background)—although not conclusive, there is some suggestion that exposure to indoor SVOCs and health outcomes may be associated—or neither.
- Irrelevant—not addressing a topic covered by the review; lacking information on exposure to indoor SVOCs and its health outcomes.

### 3. Results and Discussion

As shown in Figure 1, out of the fifty-eight publications reviewed by the panel, thirty-nine were determined to be irrelevant and seven were deemed to be suggestive (see Supplementary Materials, Table S1), while twelve were deemed to be (partially) conclusive and were used to create the consensus statement.



**Figure 1.** Flowchart of the literature review.

These 12 studies were carried out in eight provinces/municipalities in China, namely, Beijing, Tianjin, Shanghai, Chongqing, Yunnan, Liaoning, Heilongjiang, and Hunan Province. Figure 2 illustrates the location of these investigated areas. None of these studies covered the northwest region of China.

The health effects of PAHs were examined in six papers, while six papers investigated the associations between phthalate exposure and health outcomes. Only one paper investigated the health effects of PBDEs, OCPs, and PCBs [52]. Nie et al. found, compared to healthy children, children diagnosed with asthma had considerably higher concentrations of PBDEs in their indoor fine particulate matter (PM<sub>2.5</sub>) (41.1 pg/m<sup>3</sup> v.s. 23.8 pg/m<sup>3</sup>). Indoor exposure to PBDEs may be linked to a risk of developing asthma in children [52].

#### 3.1. Polycyclic Aromatic (PAHs) and Health Outcomes

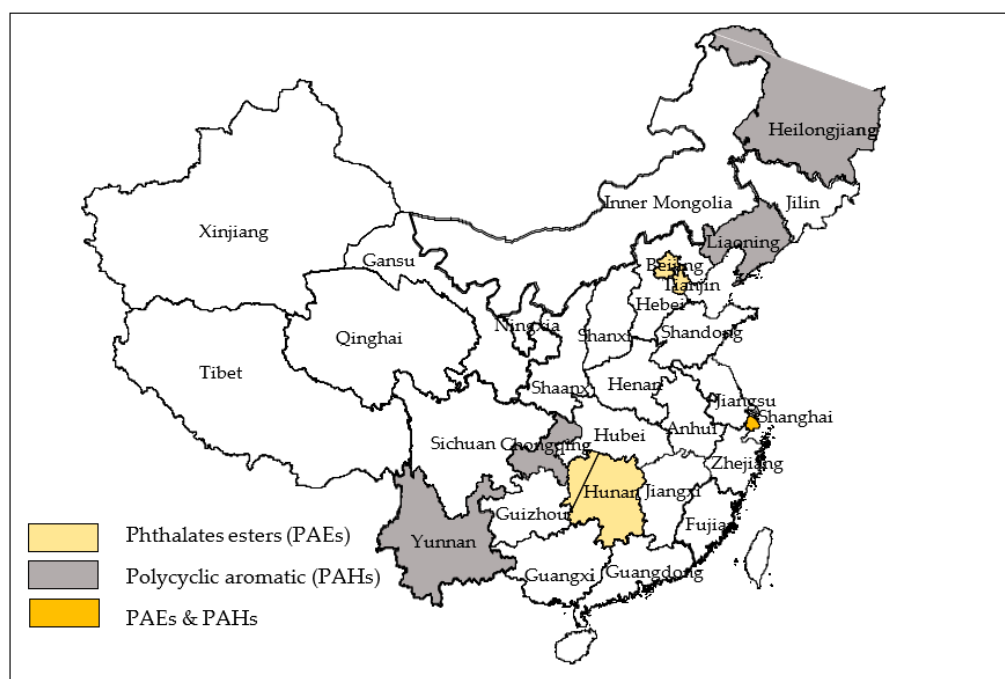
Table 1 presents the findings on PAH exposure and its associations with human health. Out of six studies, four studies focused on PAH exposure and lung cancer [53–56], one on asthma [52], and one on the ability of population learning and memory [57].

Based on the reviewed studies in Table 1, it can be concluded that higher PAH exposure is extremely likely to be risk factor for lung cancer [53–55].

Generally, PAHs are lipophilic substances that simply pass through cell membranes after inhalation via passive diffusion. Following entrance into the lung, PAHs activate phase I metabolic enzymes through both aryl hydrocarbon (AhR)-dependent and -independent routes. The transformation of PAHs into their carcinogenic metabolites is a factor in the etiology of cancer [58]. B[a]P is typically utilized as a marker for overall exposure to carcinogenic PAHs [59]. The average B[a]P content in indoor air in our reviewed studies ranged from 0.01 µg/m<sup>3</sup> to 6.29 µg/m<sup>3</sup>, which exceeded both the WHO's and China's

indoor air quality standards [60–63] (i.e.,  $0.001 \mu\text{g}/\text{m}^3$  for B[a]P (24 h average)), especially in Xuanwei, where the rate of people with lung cancer was higher than in other cities in China. This could be explained by the continued use of solid fuels [55] for heating and cooking [28] by many of the residents. Exposure to indoor smoky coal combustion has been linked to an increased risk of lung cancer [64,65]. Coal is often used in rural places due to its abundance and low cost [66]. Although developing countries like China face more lung cancer caused by fossil fuels, a small number of studies have investigated this issue in developed countries. In Los Angeles, CA, a sample of Caucasian women, who were at risk of developing cancer reported previous exposure to coal/wood stoves and fireplaces at an early age [67]. A study conducted in eastern Europe and Britain demonstrated a 20–40% risk of developing lung cancer among those who used solid fuels in the kitchen, as opposed to those that used it only for heat [68].

Additionally, this review showed the influence of PAH exposure on other outcomes such as asthma and population learning. Nie et al. suggested that some common PAHs combined with indoor PM<sub>2.5</sub> might be linked to the risk of developing asthma in children [52]. This is consistent with a comparable study conducted in Moravia, Czech Republic, which linked elevated PAH exposure to intrauterine growth retardation, as well as to asthma [69].



**Figure 2.** The locations of all studies on health effects of SVOCs in China.

Evidence was also presented for the neuropsychological effects of PAHs following occupational exposure. He investigated coke oven workers in Chongqing, a municipality of China, with a series of neurobehavioral tests, along with urinary 1-hydroxypyrene (a metabolite of PAHs) tests and found that PAH exposure caused a decline in population learning and memory, with increased monoamine neurotransmitters among the workers [57]. A similar trend was observed in a Korean research study conducted by Cho et al., who found that PAH exposure was linked to a decline in memory function and verbal learning in healthy adults [70].

**Table 1.** Polycyclic aromatic (PAH) exposure and its associations with health outcomes.

References	Health Outcomes	Types of Study	Settings/Locations	Investigated Population	Indoor Pollutants	Findings
Wang and Dai (1989) [53]	Lung cancer	Case–control	Homes in Harbin, Heilongjiang Province	55 females with lung adenocarcinoma and 55 healthy females aged 30–69 ( $\pm 5$ ) years old	B[a]P	The highest risk variables for lung cancer were a high coal consumption index (odds ratio (OR): 10.59) and indoor smog pollution (OR: 15.19). The daily amounts of total suspended particulate (TSP) and B[a]P in residents' bedrooms were 4.4 and 26.7 times higher indoors than outdoors in the winter. The indoor daily average concentration of B[a]P was 0.0106–0.0598 $\mu\text{g}/\text{m}^3$ .
China Preventive Medical Center (1984) [54]	Lung cancer	Case–control	Homes in Xuanwei County, Yunnan Province	People in areas with high/low incidence of lung cancer	B[a]P	The indoor concentrations of B[a]P in lung cancer high-incidence areas (6.29 $\mu\text{g}/\text{m}^3$ ) were significantly higher (more than ten times) than in low-incidence areas (0.45 $\mu\text{g}/\text{m}^3$ ).
Lan et al. (2008) [55]	Lung cancer	Case–control	Homes in Xuanwei, Yunnan Province	498 farmers with lung cancer as a case group and 498 farmers as a control group	Smoky coal subtype as an indicator of BaP exposure	When compared to the use of smokeless coal or wood (OR = 7.7, 95% confidence interval (CI) = 4.5–13.3), the influence of smokey coal (with subtypes of Laibin and Longtan) on lung cancer was significantly stronger (24.8 (95% CI: 12.4–49.6)).
Hoshuyama et al. (2006) [56]	Lung cancer	Cohort	Iron and steel manufactories in Anshan, Liaoning Province	121,846 workers in iron and steel factories	PAHs	PAH exposure was a main risk factor for lung cancer in exposed workers with standardized rate ratios (SRR) of 159 (95% Confidence Interval: 115–219).
Nie et al. (2016) [52]	Asthma	Case–control	Homes in Shanghai	29 children (3–6 years old) with diagnosed asthma as case group and 31 healthy children as control group	PAHs	In comparison to the control group (0.0442 $\mu\text{g}/\text{m}^3$ ), the case group with asthma had considerably higher concentrations of PAHs in their indoor PM2.5 (0.0572 $\mu\text{g}/\text{m}^3$ ).
He (2010) [57]	Ability of population learning and memory	Cohort study	Factories in Chongqing	100 male workers in cock plant of a steel company and 100 male workers of oxygen installation	B[a]P	The occupational exposure of B[a]P for coke oven workers was 0.27–2.47 $\mu\text{g}/\text{m}^3$ , and it was significantly higher than that for oxygen installation workers (0.025 $\mu\text{g}/\text{m}^3$ ). Tension–Anxiety(T) and Fatigue–Inertia(F) of the Profile of Mood States (POMS) in coke oven employees were substantially greater than in controls ( $p < 0.05$ ). Compared to the coke oven workers, the scores of the oxygen installation workers were higher in the total digital span, average simple reaction time, the forward digital span, first right dotting, digit symbol, mean right dotting, and mean total dotting, and the differences were statistically significant ( $p < 0.05$ ).



This review showed the primary source of PAHs was solid fuel combustion [53–55], such as with coal. Therefore, the health effects of indoor PAH exposure can be decreased by limiting the sources, replacing them with clean, alternative energy, and by providing adequate ventilation. The role of ventilation in decreasing PAH exposure was highlighted in a study that showed that women between the ages of 20 and 40 years old, who did not use the fume hood at all, had a 2.47 times higher likelihood of developing cervical cancer than those who used it all the time [71].

### 3.2. Phthalates and Health Outcomes

Table 2 presents the findings on PAE exposure and its associations with human health. All six existing studies focused on asthma and allergy health outcomes [4,6,72–75].

The data in Table 2 show that most studies focused on the primary constituents of phthalates in homes such as DEHP, DBP, DEP, and DiBP, which were supposed to be associated with allergies, asthma, and other respiratory diseases. Two studies in Tianjin reported significant positive associations between DEP and DiBP and asthma, DEP and DEHP and dry cough among children, and DBP and rhinitis among younger adults. In the studies conducted in Shanghai, Beijing, and Hunan Province, there was no clear association between phthalate exposure and asthma and allergy. It is possible these studies were limited by their sample size and design (around ten samples in the Beijing study [4], twelve in Shanghai [6] and ten in Hunan [74]). Whether or not these sample sizes have an influence on these studies, the findings do highlight the necessity for improved documentation of phthalate measurements and research design in future investigations of indoor environments and health.

The prevalence of allergies and asthma has increased in developed countries, such as Western Europe, Australia, the USA, and New Zealand [76]. As developing regions, such as China, progress, the prevalence of asthma and allergies has also increased [77]. Over the past 30 years, there has been a significant change in the pollutants released indoors due to the increased use of plastics, synthetic wood products, wall coverings, polymeric floors, and cleaning agents [78]. The trend is apparent, as the standard of living is improving, as is the exposure to phthalates and the burden of diseases. This is consistent with comparable studies conducted in Sweden, which linked elevated eczema and rhinitis rates with BBzP and established the association between asthma and DEHP among children [79], which was subsequently confirmed by Bulgaria's ALLHOMES study [80]. Bamai et al. also found an association between phthalate and asthma and allergies among Japanese children and adults [81]. The link between phthalate exposure and nasal, airway, ocular, and dermal allergy outcomes was supported by a review study by Bølling et al. [82]. These epidemiological studies from our review and other countries offer evidence of the relationship between asthma and allergy and phthalate exposure.

### 3.3. Research Gaps and Future Considerations

Although China is vast, research on phthalates and their health effects has mostly been conducted on children in Central, South, North, and Eastern China, where the majority of China's big cities are situated [83]. Most studies related to PAHs and their health outcomes were conducted predominantly on adults who live in Southwest, East, and Northeast China. However, semi-volatile organic compounds affect people (children, adults, and the elderly) all across the country, depending on their living conditions, making nation-wide assessments necessary. Furthermore, despite the fact that this has been extensively studied outside of China, no study in our review sought to investigate the connection between SVOC exposure and the emergence of disorders in pregnant women and their offspring. Overall, our review shows that the number of studies is too limited to definitively link SVOC dosage to health outcomes.

**Table 2.** Phthalate ester (PAE) exposure and its associations with health outcomes.

References	Health Outcomes	Types of Study	Settings/Locations	Investigated Population	Indoor Pollutants	Findings
Hu (2017) [74]	Allergic diseases	Case–control	10 homes in Changsha, Hunan Province	10 children aged 10–12 years old	DEHP and DBP	<p>The concentrations of DEHP (891 <math>\mu\text{g/g}</math> dust) and DBP (263 <math>\mu\text{g/g}</math>) in allergic children's homes were higher than those in homes with healthy children (DEHP: 755 <math>\mu\text{g/g}</math>, DBP 200 <math>\mu\text{g/g}</math>). However, the difference was not significant (<math>p &gt; 0.05</math>).</p> <p>The median concentrations of DEP, DiBP, BBzP, DnBP, DiNP, and DEHP were 0.31 <math>\mu\text{g/g}</math>, 16.38 <math>\mu\text{g/g}</math>, 0.11 <math>\mu\text{g/g}</math>, 42.6 <math>\mu\text{g/g}</math>, 0.28 <math>\mu\text{g/g}</math>, and 127.11 <math>\mu\text{g/g}</math>, respectively, in investigated homes.</p>
Zhang (2016) [73]	Asthma and allergy	A nested case–control	Home in Tianjin municipal and Cangzhou city	410 children aged 0–8 years old	DEP, DiBP, DnBP, DEHP, BBzP, DiNP	<p>The adjusted odds ratios (AOR) for children with diagnosed asthma were 2.08 and 2.48, respectively, when the concentrations of DEP and DiBP in dust in urban residential buildings were above 0.33 <math>\mu\text{g/g}</math> and 16.38 <math>\mu\text{g/g}</math>.</p> <p>Children's dry cough was linked to increased DEP and/or DEHP concentrations in rural areas.</p>
Fan et al., (2017) [4]	Respiratory and allergic symptoms	Case–control	Homes in Beijing	Six children (8–12 years old) diagnosed with allergic and respiratory symptoms as case group (group A) and four healthy children as control group (group B)	DEHP, DBP, DBA, DOA, and DEP	<p>The mean concentrations of SVOCs in living rooms and bedrooms of the control group (1590 <math>\mu\text{g/g}</math> and 2347.8 <math>\mu\text{g/g}</math>) were higher than the case group (1347.5 <math>\mu\text{g/g}</math> and 1754 <math>\mu\text{g/g}</math>) in winter. In summer, the mean concentrations of SVOCs in living rooms and bedrooms of the case group were higher than the control group (except one home, and two homes were detected with no SVOCs).</p>



Table 2. Cont.

References	Health Outcomes	Types of Study	Settings/Locations	Investigated Population	Indoor Pollutants	Findings
Zhang et al. (2016) [6]	Allergy	Case–control	Home in Shanghai	Seven children (9–10 years old) diagnosed with allergic symptoms as case group and five healthy children as control group	DEP, DBP, DEHP, BHT, DBA, DOA, TBP, TCEP, TPP	The concentrations of DEHP and DBP were not substantially different between healthy and allergic children.
Sun (2008) [72]	Allergies	A nested case–control	Dormitories at Tianjin University	209 students diagnosed with allergic symptoms as case group and 227 healthy students as control group	DEP, DiBP, DBP, BBzP, DEHP, and DiNP	The average indoor concentrations of DEP, DiBP, DBP, BBzP, DEHP, and DiNP were 21.38, 23.09, 24.90, 21.75, 48.54, and 31.95 µg/g. The adjusted odds ratio (AOR) for diagnosed rhinitis was 5.03 (1.32–19.14) in the dust of rooms with a concentration above 24.9 µg/g. The concentrations of DBP (43–60 µg/g), DCHP (119–155 µg/g), and DEHP (149–181 µg/g) in the dust of allergic students' dormitories were similar to those in healthy students' dormitories (DBP 20 µg/g, DCHP 126 µg/g, and DEHP 152 µg/g, respectively). The difference was not significant ( $p > 0.05$ ).
Zhang (2017) [75]	Eczema, allergic rhinitis	Case–control	146 Dormitories at Beijing University of Civil Engineering and Architecture. 74 were case rooms and 72 were control rooms	College students lived in these dorm rooms	DBP, DCHP, DiBP, and DEHP	

To our knowledge, this paper is one of the first systematic reviews on the health effects of exposure to SVOCs in Chinese buildings. We find that the number of published studies in China is very limited, even though SVOC exposure is an extremely important topic. There is a need to know more about SVOCs to plan for a healthy future. To start, comprehensive studies are needed throughout China to account for rapid urbanization, changes in lifestyle, new indoor building materials, and the burden of new diseases due to modern chemical compounds such as SVOCs. This can serve as a stepping stone for more extensive studies in the future. The authors' suggestion to the relevant stakeholders would be to develop a Chinese standardized IAQ protocol that assesses SVOC levels, along with other toxins, and put forward policies in line with national and international requirements.

#### 4. Conclusions

The objective of this review was to present a thorough summary of the available information on the impact of SVOC exposure on human health in Chinese built environments. In doing so, this review concluded that asthma and allergies may be linked to phthalate exposure, and lung cancer may be linked to PAH exposure. In order to improve indoor environments, along with safeguarding human health, SVOC levels have to be drastically reduced.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/ijerph20010678/s1>, Literature Searching Items for Health Outcomes; Table S1: Summary of Suggestive Studies on the Exposure to Phthalate esters (PAEs) and Polycyclic aromatic (PAHs) and health outcomes. References [5,28,71,84–87] are cited in the Supplementary Materials.

**Author Contributions:** Y.A.: writing—original draft preparation, formal analysis. Y.S.: methodology, supervision, review and editing. W.L.: investigation, data curation. A.S.E. and H.D.: investigation. U.M.A.: writing and editing. All authors have read and agreed to the published version of the manuscript.

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**Data Availability Statement:** The data are available from the corresponding authors upon reasonable request.

**Conflicts of Interest:** The authors declare no conflict of interest.

#### Abbreviations

AOR: adjusted odds ratios; B[a]P: benzo[a]pyrene; BBzP: Butyl benzyl phthalate; BHT: butylated hydroxytoluene; CI: confidence interval; DBA: dibutyl adipate; DBP: Dibutyl phthalate; DCHP: Dicyclohexyl phthalate; DEP: Diethyl phthalate; DEHP: Di (2-ethylhexyl) phthalate; DiBP: Diisobutyl phthalate; DiNP: Diisononyl phthalate; DOA: di(2-ethylhexyl) adipate; OCPs: Organochlorine Pesticides; OR: odds ratios; PAHs: Polycyclic aromatic hydrocarbons; PAEs; Phthalate esters; PBDEs: Polybrominated diphenyl ethers; PCBs: Polychlorinated biophenyls; SRRs: standardized rate ratios; SVOCs: semi-volatile organic compounds; TBP: tributyl phosphate; TCEP: tris(2-chloroethyl) phosphate; TPP: triphenyl phosphate; TSP: total suspended particulate.

#### References

1. US EPA. Introduction to Indoor Air Quality. 2014. Available online: <https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality> (accessed on 7 December 2017).

2. Lucattini, L.; Poma, G.; Covaci, A.; de Boer, J.; Lamoree, M.H.; Leonards, P.E. A review of semi-volatile organic compounds (SVOCs) in the indoor environment: Occurrence in consumer products, indoor air and dust. *Chemosphere* **2018**, *201*, 466–482. [[CrossRef](#)] [[PubMed](#)]
3. Klepeis, N.E.; Nelson, W.C.; Ott, W.R.; Robinson, J.P.; Tsang, A.M.; Switzer, P.; Behar, J.V.; Hern, S.C.; Engelmann, W.H. The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants. *J. Expo. Sci. Environ. Epidemiol.* **2001**, *11*, 231–252. [[CrossRef](#)] [[PubMed](#)]
4. Fan, G.; Xie, J.; Yoshino, H.; Yanagi, U.; Hasegawa, K.; Kagi, N.; Liu, J. Environmental conditions in homes with healthy and unhealthy schoolchildren in Beijing, China. *Build. Environ.* **2017**, *112*, 270–284. [[CrossRef](#)]
5. Hu, J.; Li, N.; Lv, Y.; Liu, J.; Xie, J.; Zhang, H. Investigation on indoor air pollution and childhood allergies in households in six Chinese cities by subjective survey and field measurements. *Int. J. Environ. Res. Public Health* **2017**, *14*, 979. [[CrossRef](#)]
6. Zhang, H.; Xie, J.; Yoshino, H.; Yanagi, U.; Hasegawa, K.; Kagi, N.; Lian, Z. Thermal and environmental conditions in Shanghai households: Risk factors for childhood health. *Build. Environ.* **2016**, *104*, 35–46. [[CrossRef](#)]
7. D'Hollander, W.; Roosens, L.; Covaci, A.; Cornelis, C.; Reynders, H.; Van Campenhout, K.; de Voogt, P.; Bervoets, L. Brominated flame retardants and perfluorinated compounds in indoor dust from homes and offices in Flanders, Belgium. *Chemosphere* **2010**, *81*, 478–487. [[CrossRef](#)] [[PubMed](#)]
8. Hu, J.; Li, N.; Yoshino, H.; Yanagi, U.; Hasegawa, K.; Kagi, N.; He, Y.; Wei, X. Field study on indoor health risk factors in households with schoolchildren in south-central China. *Build. Environ.* **2017**, *117*, 260–273. [[CrossRef](#)]
9. Waked, M.; Salameh, P. Risk factors for asthma and allergic diseases in school children across Lebanon. *J. Asthma Allergy* **2009**, *2*, 1. [[CrossRef](#)]
10. Fan, G.; Xie, J.; Yoshino, H.; Zhang, H.; Li, Z.; Li, N.; Liu, J.; Lv, Y.; Zhu, S.; Yanagi, U. Common SVOCs in house dust from urban dwellings with schoolchildren in six typical cities of China and associated non-dietary exposure and health risk assessment. *Environ. Int.* **2018**, *120*, 431–442. [[CrossRef](#)]
11. Xu, Y.; Zhang, J. Understanding SVOCs. *ASHRAE J.* **2011**, *53*, 121–125.
12. World Health Organization. Indoor Air Quality: Organic Pollutants. In Proceedings of the Report on a WHO Meeting, Berlin, Germany, 23–27 August 1987; EURO Reports and Studies 111. World Health Organization Regional Office for Europe: Copenhagen, Denmark, 1989.
13. Blanchard, O.; Glorennec, P.; Mercier, F.; Bonvallot, N.; Chevrier, C.; Ramalho, O.; Mandin, C.; Bot, B.L. Semivolatile organic compounds in indoor air and settled dust in 30 French dwellings. *Environ. Sci. Technol.* **2014**, *48*, 3959–3969. [[CrossRef](#)] [[PubMed](#)]
14. Król, S.; Namieśnik, J.; Zabiegała, B. Occurrence and levels of polybrominated diphenyl ethers (PBDEs) in house dust and hair samples from Northern Poland; an assessment of human exposure. *Chemosphere* **2014**, *110*, 91–96. [[CrossRef](#)] [[PubMed](#)]
15. Langer, S.; Weschler, C.J.; Fischer, A.; Bekö, G.; Toftum, J.; Clausen, G. Phthalate and PAH concentrations in dust collected from Danish homes and daycare centers. *Atmos. Environ.* **2010**, *44*, 2294–2301. [[CrossRef](#)]
16. Pei, X.; Song, M.; Guo, M.; Mo, F.; Shen, X. Concentration and risk assessment of phthalates present in indoor air from newly decorated apartments. *Atmos. Environ.* **2013**, *68*, 17–23. [[CrossRef](#)]
17. Rudel, R.A.; Camann, D.E.; Spengler, J.D.; Korn, L.R.; Brody, J.G. Phthalates, alkylphenols, pesticides, polybrominated diphenyl ethers, and other endocrine-disrupting compounds in indoor air and dust. *Environ. Sci. Technol.* **2003**, *37*, 4543–4553. [[CrossRef](#)]
18. Wang, B.-L.; Pang, S.-T.; Sun, J.-P.; Zhang, X.-L.; Li, X.-L.; Sun, Y.-G.; Lu, X.-M.; Zhang, Q. Levels of polychlorinated biphenyls in settled house dust from urban dwellings in China and their neurodevelopmental effects on preschool-aged children. *Sci. Total Environ.* **2015**, *505*, 402–408. [[CrossRef](#)] [[PubMed](#)]
19. Yu, Y.-J.; Lin, B.-G.; Liang, W.-B.; Li, L.-Z.; Chen, X.-C.; Xu, X.-Y.; Xiang, M.-d.; Huang, S. Associations between PBDEs exposure from house dust and human semen quality at an e-waste areas in South China—A pilot study. *Chemosphere* **2018**, *198*, 266–273. [[CrossRef](#)]
20. Yu, Y.-X.; Pang, Y.-P.; Li, C.; Li, J.-L.; Zhang, X.-Y.; Yu, Z.-Q.; Feng, J.-L.; Wu, M.-H.; Sheng, G.-Y.; Fu, J.-M. Concentrations and seasonal variations of polybrominated diphenyl ethers (PBDEs) in in- and out-house dust and human daily intake via dust ingestion corrected with bioaccessibility of PBDEs. *Environ. Int.* **2012**, *42*, 124–131. [[CrossRef](#)]
21. Zhang, Q.; Lu, X.-M.; Zhang, X.-L.; Sun, Y.-G.; Zhu, D.-M.; Wang, B.-L.; Zhao, R.-Z.; Zhang, Z.-D. Levels of phthalate esters in settled house dust from urban dwellings with young children in Nanjing, China. *Atmos. Environ.* **2013**, *69*, 258–264. [[CrossRef](#)]
22. Boström, C.-E.; Gerde, P.; Hanberg, A.; Jernström, B.; Johansson, C.; Kyrklund, T.; Rannug, A.; Törnqvist, M.; Victorin, K.; Westerholm, R. Cancer risk assessment, indicators, and guidelines for polycyclic aromatic hydrocarbons in the ambient air. *Environ. Health Perspect.* **2002**, *110*, 451–488.
23. Guo, Y.; Huo, X.; Wu, K.; Liu, J.; Zhang, Y.; Xu, X. Carcinogenic polycyclic aromatic hydrocarbons in umbilical cord blood of human neonates from Guiyu, China. *Sci. Total Environ.* **2012**, *427*, 35–40. [[CrossRef](#)] [[PubMed](#)]
24. Bu, Z.; Xu, X.; Xu, Q.; Mmereki, D.; Wang, J.; Cheng, Z.; Li, K.; Dong, C. Indoor polybrominated diphenyl ethers in urban China: An exposure and risk assessment based on settled dust from selected urban regions. *Sci. Total Environ.* **2020**, *714*, 136808. [[CrossRef](#)] [[PubMed](#)]
25. Huang, X.; Zhou, Y.; Cui, X.; Wu, X.; Yuan, J.; Xie, J.; Chen, W. Urinary polycyclic aromatic hydrocarbon metabolites and adult asthma: A case-control study. *Sci. Rep.* **2018**, *8*, 7658. [[CrossRef](#)] [[PubMed](#)]
26. Chuang, J.C.; Mack, G.A.; Kuhlman, M.R.; Wilson, N.K. Polycyclic aromatic hydrocarbons and their derivatives in indoor and outdoor air in an eight-home study. *Atmospheric Environment. Part B. Urban Atmos.* **1991**, *25*, 369–380. [[CrossRef](#)]

27. World Health Organization. *The World Health Report 2002: Reducing Risks, Promoting Healthy Life*; World Health Organization: Geneva, Switzerland, 2002; pp. 1–248.
28. Li, Z.; Zhang, L.; Ye, R.; Pei, L.; Liu, J.; Zheng, X.; Ren, A. Indoor air pollution from coal combustion and the risk of neural tube defects in a rural population in Shanxi Province, China. *Am. J. Epidemiol.* **2011**, *174*, 451–458. [\[CrossRef\]](#)
29. Khalequzzaman, M.; Kamijima, M.; Sakai, K.; Hoque, B.A.; Nakajima, T. Indoor air pollution and the health of children in biomass-and fossil-fuel users of Bangladesh: Situation in two different seasons. *Environ. Health Prev. Med.* **2010**, *15*, 236–243. [\[CrossRef\]](#)
30. Ahmed, F.; Hossain, S.; Hossain, S.; Fakhruddin, A.N.M.; Abdullah, A.T.M.; Chowdhury, M.A.Z.; Gan, S.H. Impact of household air pollution on human health: Source identification and systematic management approach. *SN Appl. Sci.* **2019**, *1*, 418. [\[CrossRef\]](#)
31. Sobue, T. Association of indoor air pollution and lifestyle with lung cancer in Osaka, Japan. *Int. J. Epidemiol.* **1990**, *19*, S62–S66. [\[CrossRef\]](#)
32. Behera, D.; Balamugesh, T. Indoor air pollution as a risk factor for lung cancer in women. *JAPI* **2005**, *53*, 190–192.
33. Ezzati, M. Indoor air pollution and health in developing countries. *Lancet* **2005**, *366*, 104–106. [\[CrossRef\]](#)
34. Ko, Y.-C.; Lee, C.-H.; Chen, M.-J.; Huang, C.-C.; Chang, W.-Y.; Lin, H.-J.; Wang, H.-Z.; Chang, P.-Y. Risk factors for primary lung cancer among non-smoking women in Taiwan. *Int. J. Epidemiol.* **1997**, *26*, 24–31. [\[CrossRef\]](#)
35. Zhong, L.; Goldberg, M.S.; Parent, M.-É.; Hanley, J.A. Risk of developing lung cancer in relation to exposure to fumes from Chinese-style cooking. *Scand. J. Work Environ. Health* **1999**, *25*, 309–316. [\[CrossRef\]](#) [\[PubMed\]](#)
36. Duan, Y.-P.; Meng, X.-Z.; Yang, C.; Pan, Z.-Y.; Chen, L.; Yu, R.; Li, F.-T. Polybrominated diphenyl ethers in background surface soils from the Yangtze River Delta (YRD), China: Occurrence, sources, and inventory. *Environ. Sci. Pollut. Res.* **2010**, *17*, 948–956. [\[CrossRef\]](#) [\[PubMed\]](#)
37. Hites, R.A. Polybrominated diphenyl ethers in the environment and in people: A meta-analysis of concentrations. *Environ. Sci. Technol.* **2004**, *38*, 945–956. [\[CrossRef\]](#) [\[PubMed\]](#)
38. Tang, J.; Zhai, J.X. Distribution of polybrominated diphenyl ethers in breast milk, cord blood and placentas: A systematic review. *Environ. Sci. Pollut. Res.* **2017**, *24*, 21548–21573. [\[CrossRef\]](#)
39. Leonetti, C.; Butt, C.M.; Hoffman, K.; Miranda, M.L.; Stapleton, H.M. Concentrations of polybrominated diphenyl ethers (PBDEs) and 2, 4, 6-tribromophenol in human placental tissues. *Environ. Int.* **2016**, *88*, 23–29. [\[CrossRef\]](#)
40. Zhao, Y.; Ruan, X.; Li, Y.; Yan, M.; Qin, Z. Polybrominated diphenyl ethers (PBDEs) in aborted human fetuses and placental transfer during the first trimester of pregnancy. *Environ. Sci. Technol.* **2013**, *47*, 5939–5946. [\[CrossRef\]](#)
41. Gingrich, J.; Ticiani, E.; Veiga-Lopez, A. Placenta disrupted: Endocrine disrupting chemicals and pregnancy. *Trends Endocrinol. Metab.* **2020**, *31*, 508–524. [\[CrossRef\]](#)
42. Li, K.; Fu, S. Polybrominated diphenyl ethers (PBDEs) in house dust in Beijing, China. *Bull. Environ. Contam. Toxicol.* **2013**, *91*, 382–385. [\[CrossRef\]](#)
43. Knoth, W.; Mann, W.; Meyer, R.; Nebhuth, J. Polybrominated diphenyl ether in sewage sludge in Germany. *Chemosphere* **2007**, *67*, 1831–1837. [\[CrossRef\]](#)
44. Lin, C.; Zeng, Z.; Xu, R.; Liang, W.; Guo, Y.; Huo, X. Risk assessment of PBDEs and PCBs in dust from an e-waste recycling area of China. *Sci. Total Environ.* **2022**, *803*, 150016. [\[CrossRef\]](#)
45. Zhao, S.; Breivik, K.; Jones, K.C.; Sweetman, A.J. Modeling the time-variant dietary exposure of PCBs in China over the period 1930 to 2100. *Environ. Sci. Technol.* **2018**, *52*, 7371–7379. [\[CrossRef\]](#)
46. Mallol, J.; Crane, J.; von Mutius, E.; Odhiambo, J.; Keil, U.; Stewart, A. The International Study of Asthma and Allergies in Childhood (ISAAC) Phase Three: A global synthesis. *Allergol. Immunopathol.* **2013**, *41*, 73–85. [\[CrossRef\]](#)
47. Braman, S.S. The global burden of asthma. *Chest* **2006**, *130*, 4S–12S. [\[CrossRef\]](#)
48. Redd, S.C. Asthma in the United States: Burden and current theories. *Environ. Health Perspect.* **2002**, *110*, 557–560. [\[CrossRef\]](#)
49. Zhu, C.; Sun, Y.; Zhao, Y.; Hou, J.; Zhang, Q.; Wang, P. Associations between Children’s asthma and allergic symptoms and phthalates in dust in metropolitan Tianjin, China. *Chemosphere* **2022**, *302*, 134786. [\[CrossRef\]](#)
50. Wang, L.; Zhao, B.; Liu, C.; Lin, H.; Yang, X.; Zhang, Y. Indoor SVOC pollution in China: A review. *Chin. Sci. Bull.* **2010**, *55*, 1469–1478. [\[CrossRef\]](#)
51. Wang, X.; Tao, W.; Xu, Y.; Feng, J.; Wang, F. Indoor phthalate concentration and exposure in residential and office buildings in Xi’an, China. *Atmos. Environ.* **2014**, *87*, 146–152. [\[CrossRef\]](#)
52. Nie, Z.; Meng, G.; Xiaomeng, W.; Yan, F.; Yong, Y.; Yan, W. Association between POPs in indoor PM2.5 and pediatric asthma. *Acta Sci. Circumstantiae* **2016**, *36*, 1849–1858. (In Chinese)
53. Wang, F.L.; Dai, X.D. Risk factor analysis of female lung cancer in Harbin—Indoor air pollution. *Chin. J. Prev. Med.* **1989**, *23*, 270–273. (In Chinese)
54. China Preventive Medical Center. Determination of air pollutants in areas with high and low incidence of lung cancer in Xuanwei County. *Health Res.* **1984**, *2*, 22–27. (In Chinese)
55. Lan, Q.; He, X.; Shen, M.; Tian, L.; Liu, L.Z.; Lai, H.; Chen, W.; Berndt, S.I.; Hosgood, H.D.; Lee, K.M. Variation in lung cancer risk by smoky coal subtype in Xuanwei, China. *Int. J. Cancer* **2008**, *123*, 2164–2169. [\[CrossRef\]](#)
56. Hoshuyama, T.; Pan, G.; Tanaka, C.; Feng, Y.; Liu, T.; Liu, L.; Hanaoka, T.; Takahashi, K. Mortality of iron-steel workers in Anshanl China: A retrospective cohort study. *Int. J. Occup. Environ. Health* **2006**, *12*, 193–202. [\[CrossRef\]](#)

57. He, L. The Effect and Mechanism of Polycyclic Aromatic Hydrocarbons Exposure on the Capability of Learning and Memory in Crowd. Master's Thesis, Chongqing Medical University, Chongqing, China, 2010. (In Chinese).
58. Moorthy, B.; Chu, C.; Carlin, D.J. Polycyclic aromatic hydrocarbons: From metabolism to lung cancer. *Toxicol. Sci.* **2015**, *145*, 5–15. [\[CrossRef\]](#)
59. World Health Organization, Regional Office for Europe. *WHO Guidelines for Indoor Air Quality: Selected Pollutants*; World Health Organization, Regional Office for Europe: Copenhagen, Denmark, 2010; pp. 1–454.
60. Tian, L.; Lan, Q.; Yang, D.; He, X.; Ignatius, T.; Hammond, S.K. Effect of chimneys on indoor air concentrations of PM10 and benzo [a] pyrene in Xuan Wei, China. *Atmos. Environ.* **2009**, *43*, 3352–3355. [\[CrossRef\]](#)
61. Bai, Z.; Wang, Z.; Zhu, T.; Zhang, J.J. Developing indoor air quality related standards in China. *J. Asian Archit. Build. Eng.* **2003**, *2*, 55–60. [\[CrossRef\]](#)
62. Verma, R.; Patel, K.S.; Verma, S.K. Indoor polycyclic aromatic hydrocarbon concentration in central India. *Polycycl. Aromat. Compd.* **2016**, *36*, 152–168. [\[CrossRef\]](#)
63. World Health Organization, Regional Office for Europe. *Air Quality Guidelines for Europe*; WHO Regional Office for Europe: Copenhagen, Denmark, 1987; pp. 1–426.
64. Hosgood, H.; Chapman, R.; Shen, M.; Blair, A.; Chen, E.; Zheng, T.; Lee, K.; He, X.; Lan, Q. Portable stove use is associated with lower lung cancer mortality risk in lifetime smoky coal users. *Br. J. Cancer* **2008**, *99*, 1934–1939. [\[CrossRef\]](#)
65. Lee, K.; Chapman, R.; Shen, M.; Lubin, J.; Silverman, D.; He, X.; Hosgood, H.; Chen, B.; Rajaraman, P.; Caporaso, N. Differential effects of smoking on lung cancer mortality before and after household stove improvement in Xuanwei, China. *Br. J. Cancer* **2010**, *103*, 727–729. [\[CrossRef\]](#)
66. Shen, G.; Lin, W.; Chen, Y.; Yue, D.; Liu, Z.; Yang, C. Factors influencing the adoption and sustainable use of clean fuels and cookstoves in China—a Chinese literature review. *Renew. Sustain. Energy Rev.* **2015**, *51*, 741–750. [\[CrossRef\]](#)
67. Wu, A.H.; Henderson, B.E.; Pike, M.C.; Yu, M.C. Smoking and other risk factors for lung cancer in women. *J. Natl. Cancer Inst.* **1985**, *74*, 747–751.
68. Lissowska, J.; Bardin-Mikolajczak, A.; Fletcher, T.; Zaridze, D.; Szeszenia-Dabrowska, N.; Rudnai, P.; Fabianova, E.; Cassidy, A.; Mates, D.; Holcatova, I. Lung cancer and indoor pollution from heating and cooking with solid fuels: The IARC international multicentre case-control study in Eastern/Central Europe and the United Kingdom. *Am. J. Epidemiol.* **2005**, *162*, 326–333. [\[CrossRef\]](#) [\[PubMed\]](#)
69. Sram, R.J.; Binkova, B.; Dostal, M.; Merkerova-Dostalova, M.; Libalova, H.; Milcova, A.; Rossner Jr, P.; Rossnerova, A.; Schmuczerova, J.; Svecova, V. Health impact of air pollution to children. *Int. J. Hyg. Environ. Health* **2013**, *216*, 533–540. [\[CrossRef\]](#) [\[PubMed\]](#)
70. Cho, J.; Sohn, J.; Noh, J.; Jang, H.; Kim, W.; Cho, S.-K.; Seo, H.; Seo, G.; Lee, S.-K.; Noh, Y. Association between exposure to polycyclic aromatic hydrocarbons and brain cortical thinning: The Environmental Pollution-Induced Neurological Effects (EPINEF) study. *Sci. Total Environ.* **2020**, *737*, 140097. [\[CrossRef\]](#)
71. Wu, M.-T.; Lee, L.-H.; Ho, C.-K.; Wu, S.-C.; Lin, L.-Y.; Cheng, B.-H.; Liu, C.-L.; Yang, C.-Y.; Tsai, H.-T.; Wu, T.-N. Environmental exposure to cooking oil fumes and cervical intraepithelial neoplasm. *Environ. Res.* **2004**, *94*, 25–32. [\[CrossRef\]](#)
72. Sun, Y. Research on the Association between Dorm Environmental Factors and Allergies among College Students. Ph.D. Thesis, Tianjin University, Tianjin, China, 2008. (In Chinese).
73. Zhang, Q. Study on Phthalates Exposure in Residential Buildings and its Health Effects. Master's Thesis, Tianjin University, Tianjin, China, 2016. (In Chinese).
74. Hu, J. Research on the Influence of Indoor Environment on Children's Health Risk in Urban Buildings. Ph.D. Thesis, Hunan University, Hunan, China, 2017. (In Chinese).
75. Zhang, W. Study on Exposure of Phthalates in Typical Indoor Environment of Campus. Master's Thesis, Beijing University of Civil Engineering and Architecture, Beijing, China, 2017. (In Chinese).
76. ISAAC Steering Committee. Worldwide variations in the prevalence of asthma symptoms: The international study of asthma and allergies in childhood (ISSAC). *Eur. Respir. J.* **1998**, *12*, 315–335. [\[CrossRef\]](#)
77. Sun, Y.; Hou, J.; Sheng, Y.; Kong, X.; Weschler, L.B.; Sundell, J. Modern life makes children allergic. A cross-sectional study: Associations of home environment and lifestyles with asthma and allergy among children in Tianjin region, China. *Int. Arch. Occup. Environ. Health* **2019**, *92*, 587–598. [\[CrossRef\]](#)
78. Zhang, Y.; Mo, J.; Weschler, C.J. Reducing health risks from indoor exposures in rapidly developing urban China. *Environ. Health Perspect.* **2013**, *121*, 751–755. [\[CrossRef\]](#)
79. Bornehag, C.-G.; Sundell, J.; Weschler, C.J.; Sigsgaard, T.; Lundgren, B.; Hasselgren, M.; Hägerhed-Engman, L. The association between asthma and allergic symptoms in children and phthalates in house dust: A nested case-control study. *Environ. Health Perspect.* **2004**, *112*, 1393–1397. [\[CrossRef\]](#)
80. Kolarik, B.; Naydenov, K.; Larsson, M.; Bornehag, C.-G.; Sundell, J. The association between phthalates in dust and allergic diseases among Bulgarian children. *Environ. Health Perspect.* **2008**, *116*, 98–103. [\[CrossRef\]](#)
81. Bamai, Y.A.; Shibata, E.; Saito, I.; Araki, A.; Kanazawa, A.; Morimoto, K.; Nakayama, K.; Tanaka, M.; Takigawa, T.; Yoshimura, T. Exposure to house dust phthalates in relation to asthma and allergies in both children and adults. *Sci. Total Environ.* **2014**, *485*, 153–163. [\[CrossRef\]](#) [\[PubMed\]](#)



82. Bølling, A.K.; Sripada, K.; Becher, R.; Bekö, G. Phthalate exposure and allergic diseases: Review of epidemiological and experimental evidence. *Environ. Int.* **2020**, *139*, 105706. [[CrossRef](#)] [[PubMed](#)]
83. Zhu, Q.; Jia, J.; Zhang, K.; Zhang, H.; Liao, C.; Jiang, G. Phthalate esters in indoor dust from several regions, China and their implications for human exposure. *Sci. Total Environ.* **2019**, *652*, 1187–1194. [[CrossRef](#)] [[PubMed](#)]
84. Kim, C.; Chapman, R.S.; Hu, W.; He, X.; Hosgood, H.D.; Liu, L.Z.; Lai, H.; Chen, W.; Silverman, D.T.; Vermeulen, R. Smoky coal, tobacco smoking, and lung cancer risk in Xuanwei, China. *Lung Cancer* **2014**, *84*, 31–35. [[CrossRef](#)] [[PubMed](#)]
85. Chuang, J.; Cao, S.; Xian, Y.; Harris, D.; Mumford, J. Chemical characterization of indoor air of homes from communes in Xuan Wei, China, with high lung cancer mortality rate. *Atmospheric Environment. Part A. Gen. Top.* **1992**, *26*, 2193–2201. [[CrossRef](#)]
86. Lan, Q.; Chen, W.; Chen, H.; He, X. Risk factors for lung cancer in non-smokers in Xuanwei County of China. *Biomed. Environ. Sci. BES* **1993**, *6*, 112.
87. Wei, C.-F.; Chen, M.-H.; Lin, C.-C.; Guo, Y.L.; Lin, S.-J.; Hsieh, W.-S.; Chen, P.-C. Household incense burning and infant gross motor development: Results from the Taiwan Birth Cohort Study. *Environ. Int.* **2018**, *115*, 110–116. [[CrossRef](#)]

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