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Comparison of Household Environmental Factors among Children with Reported Asthma and Controls

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Abstract

The present research was part of a cross-sectional project involving children aged 8 to 10 years in Porto, Portugal. The project involved a first research part at primary schools where the health tests and a questionnaire were performed and a second research part concerning environmental conditions. Two groups emerged from the health questionnaire answers: one group that reported "asthma diagnosed by a doctor" and/or "wheezing or whistling in the chest during last 12 months" and another that answered negatively to both questions. After performing the health questionnaire based on ISAAC, the children responsible were invited to participate in the environmental part of the study. The outdoor and indoor potential risk factors were extensively evaluated in children's homes. This research aimed to compare housing characteristics and indoor behaviours as environmental risk factors in the two children group and investigate whether the risks found are common. The results indicate that windows open during cleaning, standard window frame material, animals at present, dog presence, cat presence, sweep, and vacuumed floor cleaning were associated with both groups. This demonstrates that home characteristics influence some risks and may be exacerbated by certain occupants' behaviours.

Keywords
Housing characteristics; Indoor behaviours; Risk factors

1. Introduction

In recent years, several research studies have revealed associations between housing environmental factors and respiratory illness [1-10]. Despite the progress done so far concerning the evolution of populations' quality of life - by improving individuals' condition in the environment in which they live - the prevalence of illnesses, such as asthma, is increasing countries' financial burden [11, 12]. Environmental conditions represent a potential risk factor, particularly for vulnerable groups. Thus, approximately 90% of the population's time is spent indoors [13-15]. According to Heseltine et al. [16], children are considered a particularly vulnerable group due to the amount of time they spend in indoor environments either at school or home. Children's vulnerability to environmental exposure results from biological factors - not so developed respiratory system - and a high metabolic rate making them more susceptible to environmental risks [17-20]. Many studies have been conducted to assess children-related living environments and potential health outcomes such as respiratory and birth outcomes, stunting, allergies, sleep quality, and neonatal mortality, among others [20-23]. Respiratory effects, including asthma, allergies, lung function and development, are commonly associated with indoor air pollutants exposure [20]. However, the exposure of children to air pollution is complex to assess. Thus, the indoor environment of a building involves several variables which may affect occupants' health and comfort - cooking fuel and cookstoves, indoor ventilation, geographical and meteorological conditions, and exposure time [20]. In addition to outdoor risk factors, poor indoor air environments may be caused by cumulative hazardous substances - chemical, physical and biological pollutants - emitted from buildings construction materials, indoor equipment and human indoor activities [16]. Akar-Ghibril and Phipatanakul [10] refer that children are exposed to multiple triggers such as building location, socioeconomic status, and housing type. Race, income, housing type, and the presence of smokers, pets, pests, and mould/moisture-related problems, are considered predictors of high allergen burden. According to Lu et al. [21], exposure to classical air pollutants contributes to childhood allergy in developing countries. Early-life exposure to indoor mold/dampness significantly increases children's allergy risk. Associations between indoor dampness and allergies and asthma have been found in several studies [22-27].

Often indoor dampness is associated with housing-related risk factors. A systematic review, consisting of an exploratory analysis of housing-related risk factors associated with respiratory disease, concluded that inadequate ventilation was the most influential risk factor [28]. When studying the prevalence of dampness indicators in children's bedrooms, CO_2 levels were significantly higher in bedrooms with visible mould growth. Also, older buildings were a predictor for dampness and condensation on windows was a dampness indicator associated with parents with lower school levels [29]. Despite the mechanisms by which microbial growth affects health are not still known, biological agents may potentiate the risk of the development of respiratory illness, particularly in children [5, 30]. Studies have been performed to assess the effect of biological agents in children-related living environments. Fungi concentration was associated with several home characteristics, specifically, with the type of ceiling and floor material, visible mould growth, floor cleaning and the type of rug [31]. Floor material was also associated with biological concentrations at primary schools or children's homes [32]. Endotoxins concentration was positively associated with noticeable mould odour, heating system and cushion/pillow and rug in the children's bedroom [31].

Different research works concerning different geographical areas, study designs, and exposure assessment report children's allergy risk. However, more studies are needed to help to clarify household potential risk factors. In Portugal, not many investigations have been conducted to assess children's housing characteristics as well as their occupant behavioral risk factors. The obtained results are believed to help to identify some risk factors which may be helpful in the design of future standards and guidelines.

2. Methodology

This research is part of a cross-sectional project involving two major parts. The first part addressed the health component and included the performance of medical tests in 20 public primary school children aged between 8 to 10 years in Porto, Portugal. The study was conducted according to the guidelines in the Declaration of Helsinki and was approved by the Ethics Committee of the University of Porto (22/CEUP/2011). Written informed consent was obtained from the parents/legal guardians of the children.

In addition, the first part of the cross-sectional project involved a questionnaire based on the International Study of Asthma and Allergies in Childhood (ISAAC). 916 ISAAC-based questionnaires were distributed to the respondents (431 males and 427 females). A paper-based questionnaire was completed by parents or other legal guardians voluntarily. It included questions about the respiratory health of the child - allergy, wheezing, cough, family history of asthma, parental asthma, and parental allergy, current symptoms/diagnosis (during the past 3 months), and socioeconomic characteristics, building characteristics of the home, in particular the child's bedroom, and environmental tobacco smoke (ETS) exposure. From the health questionnaire, one group reported "asthma diagnosed by a doctor" and/or "wheezing or whistling in the chest during last 12 months" was established. The other group reported negatively on both questions.

After the first research part, 667 children's responsible - parents or other legal guardians - were invited to participate in the second part of the study that addressed the environmental component in a voluntary basis process. From this sample, 76 were accepted to participate in the environmental assessment part. The second questionnaire/checklist was performed at 76 homes.

The environmental component involved *in situ* chemical, physical and biological measurements at the children's home. In addition, the field study included a walkthrough inspection and the filling of a standardized paper checklist by a trained researcher. Some questions that assessed environmental risk factors (smoking indoors, building characteristics and others) were common to both questionnaires. This paper is focused on the second questionnaire answers.

The environmental part involved the monitoring of a total of 76 homes. It was conducted in the Porto metropolitan area, the second largest in Portugal, located north of the country at the seashore (41° N, 8° W). The location of the investigated homes is represented in Figure 1. The exclusion criteria included homes with refurbishments performed 6 months before the inspection and home address changes.

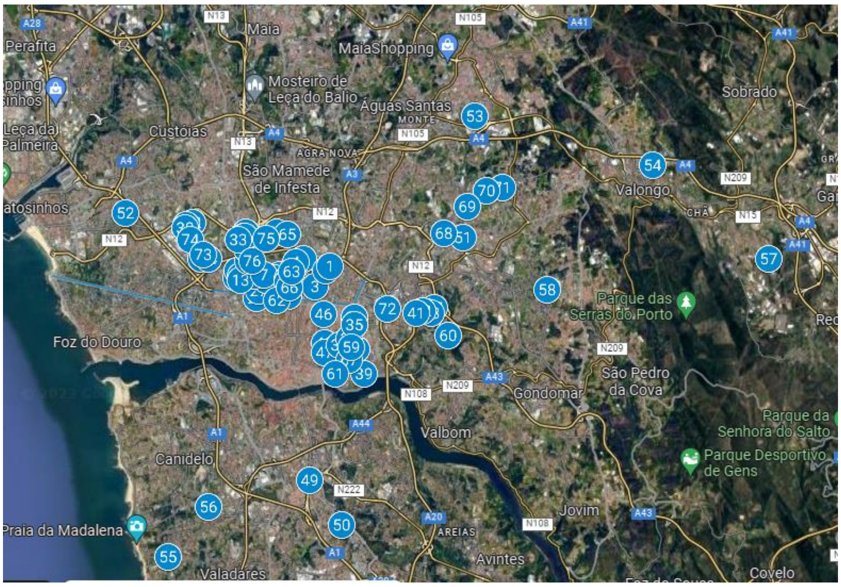

Figure 1 Location of the investigated homes. Source: From the author using Google software.

The larger majority of the inspected homes were located in Porto city. However, inspected homes were also located in other cities of the Porto metropolitan area, namely, in Vila Nova de Gaia (41°08′ N 8°37′ O), Matosinhos (41°11′ N 8°41′ O), Gondomar (41°09' N 8°32' O) and Valongo (41°11′ N 8°30″ O). As most of the inspected buildings were located in the city center, most air pollution from outdoor sources was related to car traffic. As demonstrated in Figure 1, there is a concentration of inspected homes in the north-central area of the city, close to a highway and/or national routes traffic infrastructure. In addition, inspected homes were also exposed to heavy traffic on busy streets and avenues. Figure 2 captures the proximity of some inspected buildings to highway traffic infrastructure (A20). Figure 3 represents some of Porto's most relevant traffic infrastructures, particularly two major traffic infrastructures, A20 (VCI) and N12.

Figure 2 View from an inspected sleeping local to A20 (VCI).

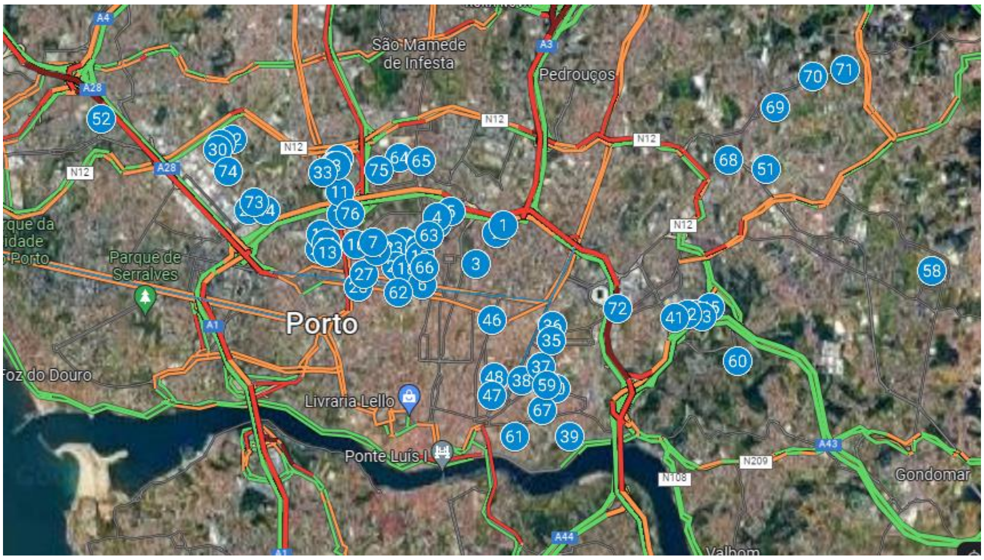

Figure 3 Traffic Risk Factor Zones. Source: From the author using Google software.

Traffic high concentration is represented with red and orange during critical hours (morning period between 8:00 and 9:30) when people are commuting to their jobs. Infrastructures with low traffic concentration are represented in green.

Before the local inspection, the location and outdoor pollution sources in the building's surrounding area was identified on Google Earth software. The building location was systematically classified according to the following categories: Industrial area; Mixed industrial/residential area; Commercial area; Mixed commercial/residential area; City center; Densely packed housing; Town, with no or small gardens; Suburban, with larger gardens and Village in a rural area.

In addition, the outdoor air pollution sources were systematically classified into a group of 14 categories: Car parking, garage, direct access from a basement or roof car park, busy road, highway, building a power plant, gasoline dispensing facilities; industry within 1 km distance, cooling towers, built on landfill site, waste management site, agricultural within 1 km distance, other. Within the type of traffic infrastructure, six categories were systematically classified: Street, Highway, Road, Crossing, Avenue and Plus than one of the previous categories.

During the visit to the home, the previous outdoor pollution sources information was verified, and additional information to complete the checklist was collected. The checklist addressed the building's surroundings and location identifying the nearby potential pollution sources, the physical characterization of the building and collecting information about indoor risk factors, such as interior pesticide use, smoking inside, animals' presence, and cleaning procedures. These are described in Table S1 (Supplementary Material).

The inspection carried out, included the description of the home layout, area measurements, identification of building pathologies, photographic records, and collection of information from the occupants, particularly, in issues regarding their habits and indoor procedures including the use of consumer products, the use and type of cleaning products, type of furniture, use of heating devices and other considered relevant for indoor air quality purposes. A general characterization of the bedroom was done considering the floor area, ceiling height, windows area, the number of permanent occupants and the characterization of surface materials (floor, walls and ceilings) as well as dampness presence indoors and other pathologies.

The SPSS® statistical package software v20.0 (IBM, USA) was used to analyze the data. The Shapiro-Wilk test was used to check the distribution of quantitative variables. Mann-Whitney test was used to compare quantitative variables and the Chi-square test was used to compare qualitative variables. Spearman's correlation was used to investigate the correlation between qualitative variables. The level of statistical significance was set at $p = 0.05$. The study does not aim to assess individual associations between the variables and the occurrence of asthma but to evaluate if environmental factors were common for the two groups.

3. Results

Home and children´s sleeping local characteristics as well as indoor behaviors in the investigated environments can be found in Table S1 (Supplementary File). In general, there is a similarity in the obtained results between the two groups concerning both building characteristics and occupant behaviors. The results demonstrate some homogeneity within the sample of inspected buildings, particularly in the location ($p = 0.283$), main outdoor pollution sources ($p = 0.279$) and housing type ($p = 0.081$). However, with concern to indoor dampness and cleaning procedures, significant differences were expected to be found for the two groups. Visible exposure to dampness ($p = 0.066$) and cleaning procedures using chemical detergents ($p = 0.147$) were not expected to be represented in the homes of children that reported asthma. However, the obtained results are not according to the expected.

The building's outdoor pollution sources were expected to be similar, thus most of the homes were inner-city located ($p = 0.283$), and most were exposed to traffic pollution sources ($p = 0.095$), ($p = 0.600$). Also, the constructive characteristics of the inspected sleeping locals were very homogenous – except for the standard window frame material type ($p = 0.018$) and the standard type of glazing ($p = 0.121$). Regarding indoor behaviors, homogeneity in the results found persists. Thus, the predominant behaviours were not risky and most homes had at least one pet present indoors/outdoors ($p = 0.028$). However, diversity was found regarding some of the cleaning procedures asked.

The majority of the inspected homes were located in a very limited geographic area – mostly in the city center (57.9%) ($p = 0.283$) with at least two pollution sources in the surrounding area (77.6%) ($p = 0.279$). According to Figure 3, most inspected homes were located near high-traffic zones, and about 86% of the inspected sleeping locals were near a busy road or a highway pollution source ($p = 0.095$). From the group that reported allergy, wheezing, cough, family history of asthma, parental asthma, and parental allergy, current symptoms/diagnosis, about 64% of the children sleeping locals were near a busy road or highway ($p = 0.600$). Associations for the housing outdoor risk factors between the group that declared "asthma diagnosed by a doctor" and/or "wheezing or whistling in the chest during last 12 months" and the group that did not declare are represented in Table 1. No associations were found, possibly, because the building's outdoor pollution sources were very similar for both groups as previously referred.

Table 1 Results for housing outdoor.

		Not declared	**Declared**	***p-value***
Building Location	Industrial area	0 (0)	0 (0)	0.283
	Mixed industrial/residential area	1 (25)	3 (75)	
	Commercial area	0 (0)	0 (0)	
	Mixed commercial/residential area	4 (57.1)	3 (42.9)	
	City center, densely packed housing	30 (68.2)	14 (31.8)	
	Town, with no or small gardens	6 (54.5)	5 (45.5)	
	Suburban, with larger gardens	4 (40)	6 (60)	
	Village in a rural area	0 (0)	0 (0)	
	Rural area with no or few other homes nearby	0 (0)	0 (0)	
Surrounding air pollution sources	One pollution source	12 (70.6)	5 (29.4)	0.279
	More than one pollution source	33 (55.9)	26 (44.1)	
Child sleep local proximity to a busy road or highway	Yes	4 (36.4)	7 (63.6)	0.095
	No	41 (63.1)	24 (36.9)	
Type of traffic infrastructure	Street	13 (65)	7 (35)	0.600
	Highway	2 (40)	3 (60)	
	Road	9 (64.3)	5 (35.7)	
	Crossing	2 (100)	0 (0)	
	Avenue	3 (50)	3 (50)	
	Plus than one	6 (46.2)	7 (53.8)	

Within the building type (p = 0.081), most of the inspected homes corresponded to apartments (73.7%). The surface area of the investigated homes was mostly within the range of 50-100 m^2 representing about 69% of the homes (p = 0.909). A large majority (74.4%) of the inspected houses had done any retrofitting action (p = 0.696), from which about 37% were in the previous year of the inspection. Most of these were painting-related and minor retrofitting actions concerning aesthetics and conservation.

When focusing on children's sleeping locals, these were mostly shared or single bedrooms, but other sleeping locals such as living rooms were also considered (p = 0.813). In about 38% of the sleeping locals, it was observed at least one sign of the indoor presence of water which included visible mould growth (p = 0.142), noticeable mold odor (p = 0.298), visible damp spots on walls, ceiling or floor (p = 0.849) and the tendency for the formation of condensation on windows (p = 0.063). A minority of the sleeping locals - about 8% - had leaking or flooding (p = 0.699). The two most common traces of indoor dampness in the sleeping local were the tendency for the formation of condensations on windows (40.8%) (p = 0.063) and visible damp spots (38.2%) (p = 0.849). From the total sample (76 houses and bedrooms) more than half, 48 sleeping locals had single glass windows (*p* = 0.121). This explains the tendency to form condensations as the major indicator of indoor water presence.

Considering the total sample of inspected sleeping locals, 43 had wood as the main type of floor surface (*p* = 0.895), about 99% of the walls were covered with water-based paint (*p* = 0.403) and about 96% of the surface ceiling was painted (*p* = 0.638). Other surface materials were also identified, namely gypsum or plaster, concrete, gypsum and wood and pasteboard, but these materials were a minority. Most sleeping locals had no heating system (60%) (*p* = 0.206). According to Table 2, the standard window frame material (*p* = 0.018) was the only housing characteristic positively associated ($p < 0.05$) in housing/sleeping local. A possible reason may be connected not to the frame itself but to the type of glaze associated, which in most situations is a simple glass pane that increases the tendency to form condensations.

Table 2 Results for housing/sleeping local.

		Not declared	**Declared**	***p-value***
Building Type		1 (100)	0 (0)	0.081
	Semi-detached house	15 (78.9)	4 (21.1)	
	Apartment	29 (51.8)	27 (48.2)	
	Other Type	0 (0)	0 (0)	
Total Area_m^2	Until 50 m^2	7 (63.6)	4 (36.4)	0.909
	50-75 m^2	12 (54.5)	10 (45.5)	
	76-100 m^2	15 (65.2)	8 (34.8)	
	101-150 m^2	5 (71.4)	2 (28.6)	
	151-200 m^2	1 (50)	1 (50)	
Modifications	No	12 (66.7)	6 (33.3)	0.696
	Yes, ever	16 (59.3)	11 (40.7)	
	Yes, in the last 12 months	14 (53.8)	12 (46.2)	
Child sleeping local	Bedroom	40 (58)	29 (42)	0.813
	Sister room	1 (100)	0 (0)	
	Mother room	1 (50)	1 (50)	
	Grandmother room	1 (50)	1 (50)	
	Parents	1 (100)	0 (0)	
	Living room	1 (100)	0 (0)	
Standard window frame material type	Metal	3 (60)	2 (40)	**0.018**
	Aluminum	22 (50)	22 (50)	
	Wood	12 (92.3)	1 (7.7)	
	PVC	7 (77.8)	2 (2.22)	
Standard type of glazing	Single glazing	28 (58.3)	20 (41.7)	0.121
	Double glazing	16 (69.6)	7 (30.4)	
Standard solar shading devices	External	33 (60)	22 (40)	0.150
	Internal	11 (68.8)	5 (31.3)	
Standard main ceiling surface material	Paint	43 (58.9)	30 (41.1)	0.638
	Laminated wood	2 (66.7)	1 (33.3)	

Standard main wall covering material	Paint	44 (58.7)	31 (41.3)	0.403
	Wallpaper	1 (100)	0 (0)	
	Wood	0 (0)	1 (100)	
Standard main floor covering material	Wood – Parquet	19 (59.4)	13 (40.6)	0.895
	Acoustic flooring	13 (59.1)	9 (40.9)	
	Stone or ceramic tiles	7 (63.6)	4 (36.4)	
	Wood – Lathes	5 (62.5)	3 (37.5)	
	Synthetic smooth	1 (50)	1 (50)	
Furniture	Wood	10 (55.6)	8 (44.4)	0.509
	Wood veneer	5 (50)	5 (50)	
	Plywood	0 (0)	1 (100)	
	Plus than one	30 (59.2)	31 (40.8)	
Child sleep on	Bed with mattress	44 (59.5)	30 (40.5)	0.343
	Mattress	0 (0)	1 (100)	
	Sofa bed	1 (100)	0 (0)	
Type blankets	Cotton	7 (38.9)	11 (61.1)	0.236
	Synthetic	17 (65.4)	9 (34.6)	
	Wool	1 (50)	1 (50)	
	Unknown	20 (66.7)	10 (33.3)	
Type bedcover	Cotton	20 (52.6)	18 (47.4)	0.469
	Synthetic	22 (62.9)	13 (37.1)	
	Wool	1 (100)	0 (0)	
Pillow cover	Cotton	25 (59.5)	17 (40.5)	0.321
	Synthetic	10 (71.5)	4 (28.6)	
Presence of cushion/pillow	No	11 (61.1)	7 (38.9)	0.538
	Yes	34 (58.6)	24 (41.4)	
Presence of rug	No	21 (65.6)	11 (34.4)	0.232
	Yes	24 (54.5)	20 (45.5)	
Visible dust	No	38 (56.7)	29 (43.3)	0.093
	Yes	7 (87.5)	1 (12.5)	
Stuffed toys	No	14 (63.6)	8 (36.4)	0.406
	Yes	31 (57.4)	23 (42.6)	
Bedroom with heating system	No	25 (73.3)	20 (44.4)	0.294
	Yes	20 (64.5)	11 (35.5)	
Heating system	None	18 (48.6)	19 (51.4)	0.206
	DHW	0 (0)	2 (100)	
	Hot water radiators	1 (100)	0 (0)	
	Electrical radiators	11 (68.8)	5 (31.3)	
	Warm air flow	1 (100)	0 (0)	
	Closed fireplace	1 (100)	0 (0)	
	Plus than one heating system	9 (75)	3 (25)	
Leaking or flooding	No	41 (58.9)	29 (41.4)	0.699
	Yes	4 (66.7)	2 (33.3)	

Moisture	No	24 (51.1)	23 (48.9)	0.066
	Yes	21 (72.4)	8 (27.6)	
Visible mold growth in room	No	26 (53.1)	23 (46.4)	0.142
	Yes	19 (70.4)	8 (29.6)	
Noticeable mold odour	No	42 (60.9)	27 (39.1)	0.298
	Yes	3 (42.9)	4 (57.1)	
Visible damp spots on walls, ceiling or floor	No	27 (60)	18 (40)	0.849
	Yes	15 (57.7)	19 (42.3)	
Tendency for formation of condensation on windows	No	21 (52.5)	19 (47.5)	0.063
	Yes	22 (73.3)	8 (26.7)	

Regarding indoor behaviors at the inspected homes, the majority of occupants had no risk behaviors such as using pesticides (63.2%) (p = 0.492) or smoking indoors (72.4%) (p = 0.821) and had the procedure of opening the windows during the cleaning (92%) (p = 0.029). In most homes, about 66%, there was at least one pet at home (permanently indoors, outdoors or in both environments) (p = 0.028). In the asthma-reported group, despite some extra careful cleaning procedures such as no bleach use, detergent for floor cleaning was reported to be regularly used (p = 0.147). These children's houses and/or sleeping locals were also expected to be predominantly vacuumed. However, the results indicate that some houses had no vacuuming procedures (11 houses did not vacuum and 18 had vacuumed procedures) (p = 0.041).

The results indicate that the presence of visible damp spots on walls, ceilings or floors (p = 0.849) in sleeping locals was slightly high among the children that reported asthma. Concerning indoor smoking (p = 0.821), in most of the inspected houses, it was not allowed to smoke indoors and most of the smoking parents did it outside the home. However, there were some reported situations of indoor smoking which represents a risky behavior.

When comparing both housing characteristics and behavioral factors, most characteristics were positively associated with behavioral factors (Table 3), namely: animals at the present time (p = 0.028), dog presence (p = 0.014), cat presence (p = 0.035), sweep (p = 0.011) and vacuumed (p = 0.041) floor cleaning and windows open during cleaning (p = 0.029).

Table 3 Results for behavioural factors.

		Not declared	**Declared**	***p-value***
Interior pesticide use	Yes	18 (64.3)	10 (35.7)	0.492
	No	27 (56.3)	21 (43.8)	
Smoke inside allowed	Yes	12 (57.1)	9 (42.9)	0.821
	No	33 (60)	22 (40)	
Animals at present time	No	11 (42.3)	15 (57.7)	**0.028**
	Yes	34 (68)	16 (32)	
Dog presence	No	32 (52.5)	29 (47.5)	**0.014**
	Yes	13 (86.7)	2 (13.3)	
Cat presence	No	28 (51.9)	26 (48.1)	**0.035**

	Yes	17 (77.3)	5 (22.7)	
Fish or turtle presence	No	39 (60.9)	25 (39.1)	0.346
	Yes	6 (50)	6 (50)	
Birds presence	No	38 (59.4)	26 (40.6)	0.594
	Yes	7 (58.3)	5 (41.7)	
Rodents presence	No	43 (58.9)	30 (41.1)	0.638
	Yes	2 (66.7)	1 (33.3)	
Child contact with animals	No	11 (42.3)	15 (57.7)	**0.028**
	Yes	34 (68)	16 (32)	
Windows open during cleaning	Yes	43 (62.3)	26 (37.7)	**0.029**
	No	1 (16.7)	5 (83.3)	
Floor cleaning with detergent	No	1 (20)	4 (80)	0.147
	With bleach	3 (100)	0 (0)	
	With detergent	37 (60.7)	24 (39.3)	
	With bleach and detergent	42 (59.2)	29 (40.2)	
Floor cleaning - polish	No	41 (59.4)	28 (40.6)	0.654
	Yes	1 (50)	1 (50)	
Floor cleaning - sweep	No	36 (67.9)	17 (32.1)	**0.011**
	Yes	6 (33.3)	12 (66.7)	
Floor cleaning - vacuumed	No	7 (38.9)	11 (61.1)	**0.041**
	Yes	35 (66)	18 (34)	
Wall cleaning	No	35 (58.3)	25 (41.7)	0.810
	With bleach	4 (57.1)	3 (42.9)	
	Detergent without bleach	3 (75)	1 (25)	
Wall cleaning - polish	No	42 (60)	28 (40)	0.408
	Yes	0 (0)	1 (100)	
Window cleaning	No	2 (40)	3 (60)	0.183
	Detergent with ammonia	27 (67.5)	13 (32.5)	
	Detergent without ammonia	7 (41.2)	10 (58.8)	
	Detergent with and without ammonia	1 (100)	0 (0)	
Furniture cleaning - detergent	No	23 (63.9)	13 (36.1)	0.293
	Yes	18 (54.5)	15 (45.5)	
Furniture cleaning - polish	No	20 (54.1)	17 (45.9)	0.233
	Yes	21 (65.6)	11 (34.4)	

Associations to occupant behaviors were expected thus the outdoor environment was very similar for the two groups. Some of the associations found, particularly those related to animals' presence (p = 0.028), were also expected, due to the number of inspected homes with pets. However, other positive association, particularly standard window frame material (p = 0.018), was not expected. Possibly this is an indirect association with indoor dampness traces, particularly with the tendency for the formation of condensation on windows.

4. Discussion

Most associations were related to indoor behaviors, particularly regarding cleaning procedures and animals' presence. Other associations, particularly with indoor dampness were expected to be found. Although no associations concerning indoor dampness were directly found, a positive association was found for standard window frame material (p = 0.018). In 44 of the investigated sleeping locals the standard window frame material type was aluminum and the type of glazing was mostly single. These characteristics are frequently related to indoor condensations, visualized in about 41% of the inspected sleeping locals. Another possible reason for the non-significant associations with moisture could be a low-statistical power due to a small sample size.

Mould/damp exposure and the increased risk for childhood asthma burden were reported by several studies [33-36]. Seo et al. [2] found associations between mould and water leakage and allergic rhinitis, atopic dermatitis and asthma in Korea. Also, Fisk et al. [37] concluded that building dampness and mould was associated with an approximately 30-50% increase in asthma-related outcomes. The study performed by Reponen et al. [5] identified environmental relative mouldiness index (ERMI) exposure at home associated with increased asthma risk. The association between moisture damage and asthma through home inspections in clinically determined cases of asthma and controls was studied by Pekkanen et al. [38]. This study’s conclusions indicate that the risk increased with the severity of moisture damage and the presence of visible mould in the main living areas, which suggests that childhood development of asthma is associated with moisture damage and mould growth. The study performed by Chinratanapisit et al. [39] examined the changes in asthma morbidity in children due to home remediation which aimed to root the causes of moisture presence. These combined with medical and behavioral interventions reduced symptom days and health care for asthmatic children living in these conditions. Moreover, Taskinen et al. [40] performed a study on 622 schoolchildren to evaluate whether exposure to moisture and mold sensitization was associated with respiratory symptoms. Evidence was found of an association between moisture and mould problems in the school and respiratory infections such as repeated wheezing and prolonged cough in children. Also, a study conducted by Emenius et al. [4], in 4089 children in Stockholm to assess the impact of building characteristics on recurrent wheezing in infants, found statistical associations for living in homes with absolute indoor humidity >5.8 g/kg and in homes where windowpane condensation was consistently and recurrent wheezing.

In addition to building dampness and mould, other factors such as smoke indoors may be associated with a risk increase. In the study performed by Spengler et al. [41] on 9 Russian cities, parents answered a questionnaire on children's respiratory health, home environment, and housing characteristics. Associations between respiratory allergies and dry cough increased with the home being adjacent to traffic. Positive associations were observed between some health conditions and maternal smoking during pregnancy. Many health conditions were associated with tobacco smoke (ETS), and almost all were associated with water damage and molds in the home. In the study by Seo et al. [2] statistical associations were found between water presence and asthma. Other associations were found with housing and behavioral factors, such as indoor smoking, although smoke indoors was reported in a minority of the inspected homes. Nevertheless, the obtained results may be due to the very low incidence of indoor smoke habits in the investigated environments or due to the low statistical power of the sample. Most children's parents and relatives were sensitized to risks and avoided smoking indoors for both children groups.

In addition to the previous factors, also cleaning product exposure represents a potential risk. Some studies consider there is growing evidence that cleaners increase the risk of respiratory disorders [42, 43]. The study performed by Zock et al. [44] summarises the recent literature on cleaning exposures and respiratory health, particularly asthma, including reviews, epidemiological surveys, surveillance programs and exposure studies. Exposure to cleaning sprays, chlorine bleach and other disinfectants may be particularly relevant. A review summarizing 21 studies on indoor residential chemical emissions and respiratory health or allergies in infants or children found significant associations with cleaning [45]. These results corroborate this study's results that indicated sweep (p = 0.011) and vacuumed (p = 0.041) floor cleaning represents a possible risk factor. In this study sweep and vacuumed floor cleaning (p < 0.05) were positively associated, despite, most houses' flooring cleaning procedures involving both vacuuming and using detergent, which may be a particularly relevant factor.

According to this research obtained results, having animals at present (p = 0.028), particularly cat presence (p = 0.035) and dog presence (p = 0.014) were risk factors (p < 0.05). These results are similar to other studies conclusions. In the study performed by Apelberg et al. [46], a systematic review was performed to synthesize the evidence of the effect of exposure to pets at home and the risk of asthma and asthma-related symptoms, concluded that exposure to pets appears to increase the risk of asthma and to wheeze in older children. The observed lower risk among exposed than among unexposed younger children is consistent with a protective effect in this age group but could also be explained by selection bias. This is corroborated by the results of Svendsen et al. [47] that concluded that pet dogs' presence increased monotonically with increasing asthma severity. Current cat exposure was a significant factor associated with allergic rhinitis in the study performed by Chinratanapisit et al. [39]. Also, the study performed by Brunekreef et al. [48] concluded that exposure to pets, including cats and dogs, was found to lead to respiratory complications in the early stages of life, including asthma symptoms, rhinoconjunctivitis, and eczema. Pets were found to be significant risk factors for respiratory and asthma symptoms by Cincinelli et al. [36]. However, Chen et al. [49] found evidence that the effects of pet keeping on the subsequent development of asthma or allergic diseases were not considered overwhelmingly strong. Carlsen et al. [50] study examined the associations between pet keeping in early childhood and asthma and allergies in children aged 6–10 years and concluded that pet ownership in early life did not appear to either increase or reduce the risk of asthma or allergic rhinitis symptoms in children aged 6–10. Also, the study performed by Medjo et al. [51] reached similar conclusions: that keeping a cat or a dog does not increase the risk for asthma. The research of Hage-hamsten [52], studied concentrations of cat (Fel d 1) and dog (Can f 1) allergens in settled dust and airborne cat allergen in day-care centers about pet ownership among children and staff, ventilation and general cleaning. No relation was found between levels of cat or dog allergen and the amount of general cleaning, but it was believed that appropriate ventilation seemed to reduce Fel d 1 in the air in day-care centers. The difference between the obtained results studies about this matter, corroborate Svendsen et al. [47] conclusions which support that the effects of cat and dog exposure on allergy risk are contradictory. These contradictory results may indicate that further studies are needed to assess the relationship between pet-keeping, asthma and sensitization.

This research found a significant association with windows opening during cleaning (p = 0.029). Parents were sensitized to this issue in most of the dwellings, and 69 in 75 dwellings declared to frequently open windows during cleaning. Opening windows during cleaning may be a simple mitigation strategy to ensure a sufficient air exchange rate to reduce indoor pollutants [29]. However, about 86% of sleeping locals were located near a busy road or a highway pollution source, considered a risk factor for childhood allergic and respiratory symptoms and diseases by Spengler et al. [41] and Liu et al. [53].

In this study, associations were found for the standard window frame material ($p = 0.018$) but no significant associations were found for the standard type of glazing. Ibargoyen-Roteta et al. [54] found that children with either a single-glazed window or a second level of glazing had a higher risk for current rhino conjunctivitis and that a single-glazed window could represent a risk factor for severe eczema. In citation to Silny et al. [55] the referred study suggests that the fit of the window frame may be rather important than the thickness of the glass panes, keeping out allergens such as grass and pollen. This explanation may also be applicable to this study and the fit of the window frame may be more relevant than the frame material itself. In the performed study the most usual materials of window frames were aluminum, followed by wood and other materials with less significance. In general, wood window frames are less airtight than aluminum ones, which may explain the obtained results.

If on the one hand opening windows during cleaning may be a simple mitigation strategy to assure a sufficient air exchange and remove indoor pollutants, it is necessary to consider that outdoor pollutants and allergens such as grass and pollen may infiltrate indoors. On another side, airtight and low-ventilated spaces may tend to accumulate pollutants that potentially originate health hazards. Bornehag et al. [56] studied whether the low ventilation rate in homes is associated with asthma and allergic symptoms among children in Sweden, but the results were not inconclusive. Ventilation is a remediation strategy for removing pollutants, but perhaps more relevant than the ventilation rate is to achieve a difficult equilibrium of controlling both outdoor and indoor pollutant sources.

5. Study Strangeness and Limitations

The inspection and checklist filling-in were *in situ* observation exercises concerning housing characteristics and behaviors. Meanwhile, it is important to recognize that the evaluation of some characteristics, i.e., moisture problems were restricted to the cataloging of the checklist. The small sample size is possibly the most relevant reason for some non-significant associations observed, particularly concerning moisture and indoor water traces. A low-statistical power may be behind some of the achieved. However, as the main strength, the present study was developed in a field campaign, assessing different built realities to collect data about the investigated homes done by trained experts.

6. Conclusion

This study's results found homogeneity and similarity for both groups concerning outdoor and indoor pollution sources, particularly building characteristics and occupant behavior. However, differences and diversity regarding cleaning procedures were reported.

For the considered housing characteristics, significant associations were found for windows open during cleaning ($p = 0.029$), standard window frame material ($p = 0.018$), animals at the present time ($p = 0.028$), dog presence ($p = 0.014$), cat presence ($p = 0.035$), sweep ($p = 0.011$) and vacuumed floor cleaning ($p = 0.041$). Most of the associations found were related to behaviors, particularly concerning floor cleaning and pet keeping. Nevertheless, particularly regarding pet keeping, more studies are necessary thus no consensus exists. Despite the similarity of environmental exposure factors between the two groups, housing characteristics related to occupant behaviors represent a controllable risk factor of which some parents are still unaware. Despite in most of the houses, no behavior risks were observed, some such as smoking indoors are still observed without any restriction.

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Author Contributions

The paper was entirely developed by the author with data provided by INEGI - Conceptualization, Methodology, Statistical treatment, Validation and Writing

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Competing Interests

The author declares that have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Additional Material

The following additional materials are uploaded at the page of this paper.

1. Table S1: Characteristics of the investigated homes and children's bedrooms (n = 76).

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