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Association between housing characteristics and population health

Housing and health: A correlational study

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Abstract
Aim: Human health can be significantly influenced by both the internal and external environment of housing. The aim of the study is to measure the association between housing characteristics and some clinical manifestations in the population living in the city of Agadir, Morocco.
Material and Methods: This is a correlational study, which covered 26 streets divided into three sectors in five districts of Agadir city in southern Morocco. All persons in the study area who agreed to complete the questionnaire were recruited, excluding the foreign population and healthcare workers. The sample size was 73 houses occupied by 420 people. We have designed a questionnaire for data collection based on characteristics of the housing, outdoor environment, clinical manifestations, and general maintenance and equipment. Four samples of household dust were analyzed using a Scanning Electron Microscope.
Results: The most important clinical manifestations experienced by the population were of a nervous, respiratory, ophthalmic and rhinolaryngological natures. They are explained principally by age, the number of hours spent in the house, the occupied floor, allergies and medical consultations. Living in sector C appears to be a risk factor (RR = 1.21 [CI95% 1.06 - 1.38], $p < 0.05$). There is a statistically significant association between the presence of dust in the home and clinical manifestations (RR = 1.20 [CI95% 1.05 - 1.37], $p < 0.05$). These disorders are also linked to the orientation of houses towards the Northeast (RR = 1.45 [CI95% 1.33 - 1.66], $p < 0.05$), dust extraction and ventilation. The composition of the household dust samples indicates a probable continental and marine source.
Discussion: These results suggest that the risk of developing health disorders is related to both the indoor and outdoor environment of the housing.

Keywords
Indoor pollution; Outdoor pollution; Health; Housing

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Introduction

Housing quality can influence both behavior and lifestyles, and, subsequently the health of its occupants [1]. Several studies have shown statistical correlations that are not necessarily causal between public health and some housing characteristics [2-4].

The indoor and outdoor environment of housing can influence the health of the occupants [5]. Indeed, respiratory, cardiovascular and metabolic diseases are linked to living in houses near heavy road traffic [6, 7]. The risk of respiratory infections can be reduced by reducing humidity [8]. Globally, 1 in 4 of all deaths are due to an insalubrious environment (available at: https://www.who.int/phe/news/e-News-82.pdf?ua=1).

According to WHO estimates in 2018, indoor and ambient air pollution is responsible for more than six million deaths each year (available at: https://apps.who.int/gb/ebwha/pdf_files/WHA71/A71_10Add1-fr.pdf). This pollution is a risk factor for morbidity and mortality, as it is associated with several diseases such as stroke, heart attack, lung cancer and broncho pneumopathy. The estimated cost of air pollution for global health and well-being is very significant (available at: https://openknowledge.worldbank.org/handle/10986/25013). Some of the measures to reduce the number of deaths include action on housing [9].

In Morocco, in 2017, indoor air pollution can be held responsible for about 1,350 deaths, nearly 90% of which are caused by ischemic heart disease, stroke or acute lower respiratory tract infections, with the youngest (under 5 years) and oldest (over 75 years) groups are most affected by indoor air pollution [10]. This estimate is based on the global burden of disease [10] and the proportion of deaths due to air pollution calculated using the concentration-response functions [11]. The cost of indoor air pollution amounts to 0.26% of Gross Domestic Product [12]. In Morocco, 92.4% of urban residents live in buildings that are considered old. These families occupy houses with 1-2 rooms (35.7%), 3-4 rooms (49.4%) and 5 rooms and more (14.9%) [10]. Documentation on health and housing in Morocco is scarce. Our objective was therefore to study the correlation between habitat characteristics and health of the population of the Agadir region (available at: https://www.hcp.ma/file/205145/).

Material and Methods

Type of study and population

A cross-sectional observational study was conducted, from March to May 2019, in 26 districts divided into three sectors, covering five districts in the Agadir prefecture. A non-probability sampling method was adopted, with houses selected using an accidental sampling technique. The study involved 73 houses hosting 420 people.

Procedure

The people were informed about the objective of the study and its procedure. A questionnaire was designed for data collection based on characteristics of the housing, outdoor environment, clinical manifestations and general maintenance and equipment.

The typology of clinical manifestations has been simplified to provide information on people's health disorders.

Measurement of clinical manifestations

These manifestations were classified according nervous, respiratory, ophthalmic and rhinolaryngological disorders.

Household dust sampling and analysis

Four samples of household dust were collected from houses located at the four cardinal points. They were analyzed using a Scanning Electron Microscope (SEM) at Ibn Zohr University in Agadir city.

Statistical analyses

The data were analyzed using Epi InfoTM version 7.2 software (available at: https://www.cdc.gov/epiinfo/index.html) and R version 3.5.2 software (available at: https://www.r-project.org/). We studied the association between the development of clinical manifestations and exposure to a few habitat factors. Statistical significance was established by a $p < 0.05$ value. Yates' Chi^2 test (x^2) was used for the comparison between the categorical variables, in addition to the exact Fisher test if the expected value is < 5. The relative risk values (RR) and 95% confidence intervals (CI95%) were estimated with multi-variate analyses to investigate risk factors leading to clinical manifestations in residents. Global model significance was tested by Fischer (F). Measures of Durbin-Watson (dw), tolerance (T) and variance inflation factor (VIP) were adopted to test the predictor's multicollinearity.

Results

The results of the study are presented according to the characteristics of 73 houses hosting 420 people, and the association between clinical manifestations with exposure factors. The processing of the questionnaire data is carried out by Epi InfoTM version 7.2.

Characteristics of the houses

The 73 houses studied were distributed in three sectors, covering five districts of the Agadir Ida Outanane prefecture. The number of individuals living in these houses was 420, giving an average of 6 people per house. The houses host a single family (72.6%), two families (19.2%) or more families (8.2%).

The proportion of houses with only one side was 60.3%, that of two sides was 31.5%, that of 3 and 4 sides was 8.2%. It should be noted that about half (49.3%) of the houses did not have a courtyard. A proportion of 59.5% of the courtyards had a roof and their surface was less than 9 m². Only 7 houses had a garden with a surface area of no more than 10 m².

About half of the houses (47.9%) were built with two floors, with an average of 3 rooms per floor. The mean age of the dwellings was about 20 years. The average number of windows per house was 6. The mean size of the windows was 1.1 m².

Characteristics of the housing environment

The exterior cladding was made of cement (83.6%) or bare ground (15.1%). During the period of the study, development work was observed in 15.1% of the dwellings.

The traffic lanes in the surrounding area accounted for 30.1% of noisy cases. The proportion of houses with a heavy-traffic parking was 39.7%. Houses built near agricultural sites represented 26.0%, those near a polluting source 21.9%, the latter were mainly carpentry, marble and a wastewater treatment plant.

Homes with an open interior space represented only 15.1%, these spaces were generally located on the ground floor (36.3%), on the first floor (18.2%) or on the second floor (45.5%)

Population profiles

During the study period, 420 people in the houses with a mean age of 28 years (95% CI = [26.774 - 29.950]). The age distribution was dispersed around the mean value (standard deviation = 16.552, range = 85 years, Min = 1, Max = 86), a quarter of the population was under 17 years, the median age was 24 years, and the ¾ of the population was under 40 years of age. This distribution was asymmetric on the right (Pearson's asymmetry coefficient = 0.6)

Association between clinical manifestations and some exposure factors and association between clinical manifestations and some characteristics of the housing

People with clinical manifestations represent 66.43%. Living in sector C appeared to be a risk factor (RR=1.21 [CI95% 1.06 - 1.38], p < 0.05). The results of the multi-varied analysis (Table 1) show that these clinical manifestations are associated with some housing characteristics such as the age of construction, the number of families living in the same house, the number of sides, the size of the windows and the presence of a yard.

Indeed, these disorders are most common among people living in houses built more than 30 years ago (RR = 1.08 [95% CI 0.87 - 1.34]). Also, for people who live with multiple family members (RR = 1.18 [CI95% 0.97 - 1.43]), for people who live in four-sided houses (RR = 1.52 [CI95% 1.42 - 1.63), for people living in houses with windows less than 1 m² (RR = 1.12 [CI95% 0.83 - 1.51]) and for people living in houses without courtyards (RR = 1.02[CI95% 0.89 - 1.16)

Association between clinical manifestations and some characteristics of the outdoor environment

The multi-varied analysis in Table 1 shows that clinical manifestations can also be explained by a few factors related to the outdoor environment of the home. Indeed, people who live near heavy road traffic are more exposed (RR = 1.10 [CI95% 0.96 - 1.27]).

The presence of a car park with heavy traffic had little effect ((RR = 1.00[CI95% 0.87 - 1.15]). On the other hand, habitat near an agricultural site appears to be a protective factor (RR = 0.64 [95% CI 0.45 - 0.91]).

Approximately one-quarter of the inhabitants lived near a polluting company (23.57%) (No exposure effect); there is a significant association between the vicinity of a marbling facility and clinical manifestations (RR = 1.40 [CI95% 1.23 - 1.59]).

The presence of a construction site inside the house is a risk factor (RR = 1.25[CI95% 0.83 - 1.45], p < 0.05). For exterior siding, bare flooring is a risk factor (RR = 1.23[CI95% 0.98 - 1.55]), also a grass siding (RR = 1.52 [CI95% 1.41 - 1.63])

Association between clinical manifestations and some characteristics of the occupants

People over 20 years of age and older are more exposed; the highest risk was observed in the age groups 70-75 (RR = 1.51 [CI95% 1.41 - 1.62]), 50 - 55 (RR = 1.33[CI95% 1.12 - 1.59]) and 55 - 60 (RR = 1.32 [CI95% 1.07 - 1.63]). The time spent indoors seems to be a risk factor, as the highest risks are observed for occupancy times of 16 to 20 hours (RR = 1.07 [CI95% 0.90 - 1.28]).

Table 1. Multivariate analysis: clinical manifestations and some indoor and outdoor housing exposure factors, n = 420

Variable	Total frequency [d]	RR (CI 95%) [e]	X^2 corrected by Yates	bilateral p-value [f]
Indoor housing exposure factors				
Sector			13.0287	0.0046
Sector A[a]	112 (26.67)	0.9927 (0.8505 – 1.1586)	0.0000	1.0000
Sector B[b]	138 (32.86)	0.7789 (0.6600 – 0.9193)	9.7190	0.0018
Sector C[c]	144 (34.29)	1.2105 (1.0608 – 1.3814)	6.6461	0.0099
Another sector	26 (6.19)	1.1702 (0.9370 – 1.4615)	0.9131	0.3393
Age of building in years			0.6475	0.6487
< 10	79 (18.81)	1.0123 (0.8523 – 1.2023)	0.0000	0.9955
10 - 20	153 (36.43)	0.9155 (0.7906 – 1.0601)	1.2160	0.2702
20 - 30	150 (35.71)	1.0534 (0.9168 – 1.2103)	0.3796	0.5378
>= 30	38 (09.05)	1.0771 (0.8684 – 1.3359)	0.2050	0.6507
Type of housing			0.9711	0.3732
Single family	299 (71.19)	0.9556 (0.8259 – 1.1057)	0.2343	0.6284
Bifamily	86 (20.48)	0.9753 (0.8210 – 1.1586)	0.0259	0.8721
Multifamily	35 (8.33)	1.1786 (0.9704 – 1.4315)	1.4763	0.2244
Number of sides			8.4843	0.0370
A front side	246 (58.57)	0.8714 (0.7621 – 0.9965)	3.4963	0.0615
Two sides	135 (32.14)	1.0386 (0.9005 – 1.1979)	0.1624	0.6870
Three sides	32 (7.62)	1.2460 (1.0391 – 1.4942)	2.7306	0.0984
Four sides	7 (1.67)	1.5184 (1.4165 – 1.6276)	2.2296	0.1354
Window size in m²			0.5987	0.7413
< 1	390 (92.86)	1.1154 (0.8260 – 1.5062)	0.3285	0.5665
1 - 2	10 (2.38)	0.9011 (0.5407 – 1.5016)	0.0094	0.9229
>= 2	20 (4.76)	0.8989 (0.6243 – 1.2942)	0.1453	0.7030
Outdoor housing exposure factors				
Heavy traffic road				
Yes	131 (31.19)	1.1031 (0.9598 – 1.2676)	1.4931	0.2217
No	289 (68.81)	0.9066 (0.7889 – 1.0419)	1.4931	0.2217
Parking with heavy road traffic				
Yes	242 (57.62)	1.0036 (0.8745 – 1.1517)	0.0000	1.0000
No	178 (42.38)	0.9964 (0.863 – 1.1435)	0.0000	1.0000
Near an agricultural site				
Yes	121 (28.81)	0.6398 (0.4511 – 0.9075)	6.4386	0.0112
No	299 (71.19)	1.5629 (1.1019 – 2.2168)	6.4386	0.0112
Near a polluting company				
Yes	99 (23.57)	0.7331 (0.5109 – 1.0519)	2.6888	0.1011
No	321 (76.43)	1.3641 (0.9507 – 1.9574)	2.6888	0.1011
Polluting company (n = 99)			14.2520	0.0141
Sewage treatment plants	51 (51.52)	0.8669 (0.6849 – 10.971)	0.9263	0.3358
Carpentry	7 (7.07)	0.5633 (0.2376 – 1.3352)	2.1917	0.1388
Marblework	8 (15.15)	1.4000 (1.2294 – 1.5943)	1.8000	0.1797
Manufactory (unspecified)	33 (33.33)	1.1739 (0.9362 – 1.4719)	1.1019	0.2939
Work site in the building				
Yes	61 (14.52)	1.2538 (0.8310 – 1.4514)	5.4746	0.0193
No	359 (85.48)	0.7976 (0.6890 – 0.9233)	5.4746	0.0193

[a]: Sectors of Essalam, Elhouda & Bensargaou; [b]: Sectors of Erac, Dakhla & Hay Mohamadi; [c]: Sectors of Tikiouine & Drarga; [d]: Results presented as headcount and percentage. The percentages are 100% complementary per category; [e]: Confidence interval for risk ratio at 95%; [f]: The value of p represents the statistical significance of clinical manifestations according to the presence or absence of exposure to some factors.

It can be noticed that people living on the ground floor or fourth floor are more exposed (RR = 1.06 [CI95% 0.89 - 1.25] and RR = 1.16 [CI95% 0.86 - 1.58], respectively) (Table 2)

Allergies to acarids, pesticides and dust are significant risk factors for the development of clinical manifestations.

Table 2. Multivariate analysis: clinical manifestations according to certain exposure factors related to the characteristics of the inhabitants, n = 420

Variable	Total frequency [a]	RR (CI 95%) [b]	X^2 corrected by Yates	bilateral p-value [c]
Age			14.5141	0.0023
0 – 5	24 (5.71)	0.8064 (0.5546 – 1.1726)	1.1825	0.2768
5 – 10	25 (5.95)	0.7722 (0.5266 – 1.1323)	1.8412	0.1748
5 – 15	54 (12.86)	0.7262 (0.5513 – 0.9565)	6.6780	0.0098
15 – 20	47 (11.19)	0.7130 (0.5282 – 0.9625)	6.4049	0.0114
20 – 25	87 (20.71)	10045 (0.8499 – 1.1872)	0.0000	1.0000
25 – 30	48 (11.43)	1.2594 (1.0781 – 1.4711)	4.6143	0.0317
30 – 35	30 (7.14)	1.0581 (0.8284 – 1.3516)	0.0526	0.8187
35 – 40	21 (5.00)	1.0038 (0.7359 – 1.3691)	0.0000	1.0000
40 – 45	24 (5.71)	1.1379 (0.8937 – 1.4489)	0.4505	0.4882
45 – 50	25 (5.95)	1.0252 (0.7764 – 1.3537)	0.0000	1.0000
50 – 55	23 (5.48)	1.3329 (1.1202 – 1.5859)	3.6756	0.0552
55 – 60	15 (3.57)	1.3195 (1.0690 – 1.6289)	1.9933	0.1580
60 – 65	13 (3.10)	1.0436 (0.7216 – 1.5093)	0.0000	1.0000
65 – 70	6 (1.43)	1.2591 (0.8746 – 1.8270)	0.2005	0.6543
70 – 75	2 (0.48)	1.5090 (1.4093 – 1.6158)	0.0662	0.7970
>= 75	-	-	-	-
Occupancy time			1.5976	0.6599
< 8	25 (5.95)	1.0897 (0.8448 – 1.4054)	0.1520	0.6966
8 – 16	236 (56.19)	0.9198 (0.8034 – 1.0530)	1.2052	0.2723
16 – 20	61 (14.52)	1.0723 (0.8968 – 1.2821)	0.3367	0.5618
>= 20	98 (23.33)	1.0384 (0.8884 – 1.2137)	0.1170	0.7323
Floor occupied			2.0365	0.7290
Ground floor	72 (17.14)	1.0553 (0.8895 – 1.2520)	0.2100	0.6468
First Floor	191 (45.48)	0.9874 (0.8611 – 1.1321)	0.0062	0.9374
Second Floor	116 (27.62)	0.9990 (0.8580 – 1.1632)	0.0000	1.0000
Third floor	28 (6.67)	0.8517 (0.6134 – 1.1826)	0.7567	0.3844
Fourth floor	13 (3.10)	1.1639 (0.8572 – 1.5801)	0.2659	0.6061
Allergies			33.8013	<0.0001
Dust mites	6 (1.43)	1.5165 (1.1451 – 1.6252)	1.7386	0.1873
Pesticides	54 (12.86)	1.4084 (1.22459 – 1.5920)	12.8855	< 0.0001
Dust	83 (19.76)	1.2832 (1.1230 – 1.4662)	8.6956	0.0032
No one	277 (65.95)	0.6471 (0.5956 – 0.7630)	30.9337	< 0.0001

[a]: Results presented as headcount and percentage. The percentages are 100% complementary per category; [b]: Confidence interval for risk ratio at 95%; [c]: The value of p represents the statistical significance of clinical manifestations according to the presence or absence of exposure to some factors.

Association between clinical manifestations and some features of housekeeping

A high accumulation of dust was reported in 43.6% of house occupants. This dust accumulates essentially on windows (42.4%), furniture (32.5%), walls (11.9%), roofs (8.6%), and other surfaces (4.6%), its texture is essentially fine (78.1%).

There was a statistically significant association between the presence of dust in the home and clinical manifestations (RR = 1.20 [CI95% 1.05 - 1.37], $p < 0.05$). These manifestations were more observed if these dusts are finer (RR = 1.16 [CI95% 0.96 - 1.40])

The high dust condensation seasons are autumn (44.3%) and summer (41.4%). The windows of the dwellings were oriented on average according to 144.7° (between SE and S), the houses with a single façade (60.3%) were oriented on average according to 129.9° (between E and SE)

Table 3. Multivariate analysis: clinical manifestations according to certain exposure factors related to the characteristics of general home maintenance

Variable	Total frequency [a]	RR (CI at 95%) [b]	X^2 corrected by Yates	bilateral p-value [c]
Dust				
Yes	183 (43.57)	1.1968 (1.0467 – 1.3685)	6.1862	0.0129
No	237 (56.43)	0.8355 (0.7307 – 0.9553)	6.1862	0.0129
Texture			5.9747	0.0504
Fine	327 (77.86)	1.1583 (0.9634 – 1.3926)	2.4413	0.1182
Medium	89 (21.19)	0.8319 (0.6856 – 1.0094)	3.7135	0.0598
Coarse	4 (0.95)	1.5127 (1.4121 – 1.6205)	0.8040	0.3699
Dust condensation season			1.9414	0.7465
Autumn	186 (44.29)	1.0664 (0.9312 – 1.2213)	0.6727	0.4121
Summer	174 (41.43)	0.9482 (0.8243 – 1.0907)	0.4189	0.5175
Springtime	31 (7.38)	1.0742 (0.8482 – 1.3603)	0.1285	0.7110
Winter	9 (2.14)	0.8333 (0.4627 – 1.5008)	0.1166	0.7327
All year long	20 (4.76)	0.8989 (0.6243 – 1.2942)	0.1453	0.7030
Orientation			22.8990	0.0018
North	48 (11.43)	0.7628 (0.5765 – 1.0093)	4.3009	0.3810
North-East	24 (5.71)	1.4524 (1.3270 – 1.6560)	8.5202	0.0035
East	80 (19.05)	0.9507 (0.7931 – 1.1396)	0.1869	0.6655
South-East	86 (20.48)	1.0415 (0.8853 – 1.2253)	0.2333	0.7255
South	49 (11.67)	1.1576 (0.9709 – 1.3803)	1.6164	0.2036
South-West	38 (9.05)	1.1661 (0.9628 – 1.4123)	1.3764	0.2407
West	46 (10.95)	0.9796 (0.7838 – 1.2242)	0.0004	0.9849
North-West	49 (11.67)	0.7452 (0.5616 – 0.9889)	5.1491	0.0233
Ventilation system				
Yes	346 (82.38)	0.8911 (0.7603 – 1.0444)	1.3873	0.2389
No	74 (17.62)	1.1222 (0.9574 – 1.3152)	1.3873	0.2389
Manually vacuum cleaner				
Yes	407 (96.90)	0.9582 (0.6626 – 1.3858)	0.0000	1.0000
No	13 (3.10)	1.0436 (0.7216 – 1.5093)	0.0000	1.0000
Frequency of dust removal				
Once a week	268 (63.81)	1.1343 (0.9768 – 1.3173)	2.5808	0.1082
Once a day	152 (36.19)	0.8816 (0.7592 – 1.0237)	2.5808	0.1082
Central vacuum cleaner				
Yes	397 (5.48)	0.9523 (0.7202 – 1.2591)	0.0101	0.9199
No	23 (5.48)	1.0501 (0.7942 – 1.3884)	0.0101	0.9199
Cooker hood				
Yes	383 (91.19)	1.4008 (0.9990 – 1.9642)	4.9105	0.02669
No	37 (8.81)	0.7139 (0.5091 – 1.0010)	4.9105	0.02669
Bathroom mechanical ventilation				
Yes	380 (90.48)	1.2932 (0.9554 – 1.7505)	3.1867	0.0742
No	40 (9.52)	0.7733 (0.5713 – 1.0467)	3.1867	0.0742
Monthly frequency of general cleaning				
Once	177 (42.14)	1.0361 (0.9038 – 1.1878)	0.1617	0.6876
Twice	73 (17.38)	1.0633 (0.8982 – 1.2587)	0.2995	0.5842
Three times	42 (10.00)	0.8086 (0.6090 – 1.0737)	2.2966	0.1297
Four times	128 (30.48)	0.9995 (0.8622 – 1.1587)	0.0000	1.0000

[a]: Results presented as headcount and percentage. The percentages are 100% complementary per category; [b]: Confidence interval for risk ratio at 95%; [c]: The value of p represents the statistical significance of clinical manifestations according to the presence or absence of exposure to some factors.

Multivariate analysis in Table 3 shows that clinical manifestations were most commonly perceived in autumn (RR = 1.07 [CI95% 0.93 - 1.22]) and spring (RR = 1.07 [CI95% 0.89 - 1.36]). These disorders are also linked to the Northeast orientation of the houses (RR = 1.45 [CI95% 1.33 - 1.66], p >

0.05), the lack of ventilation (RR = 1.12 [IC95% 0.96 - 1.32]), or hand vacuum (RR = 1.04[IC95% 0.72- 1,51]) or a central vacuum cleaner (RR = 1.05[IC95% 0.79- 1.39]), or kitchen hood (RR = 1.40[IC95% 1.00 - 1.97]), or mechanical ventilation in the bathroom (RR = 1.29 [IC95% 0.96 - 1.75])

Clinical manifestations are low if dust is removed daily (RR = 0.88 [CI95% 0.76 - 1.02]), and if the frequency of house cleaning exceeds three times per month (RR = 0.81 [CI95% 0.61 - 1.07])

Factor analysis of clinical manifestations

Figure 1 summarizes the most important clinical manifestations perceived by the population. We noticed disorders of the following types: eye, nose or throat irritation, weariness, wheeze and headache.

Clinical manifestations are principally explained by the following variables: age, number of hours spent in the home, occupied floor, allergies and medical consultations (significant model: $F < 0.05$, $R = 0.536$, $t > t$ (sig), $0 < T < 1$, dw = 1.194 and VIF < 4)

Analysis of the correlation matrix between the group of variables from the clinical manifestations (headaches, nausea, sneezing, shortness of breath, irritation of the eyes, nose or throat, blurred vision, coughing and wheezing) showed a strong positive correlation (r = 0.597 to 0.987). The variable " Weariness " and " Respiratory disorders " were positively correlated and the correlation was significant (r = 0.839).

Principal component analysis indicates that ten types of clinical manifestations can be represented by two factors, which explain 93.1% of the variance. This representation is of better quality since the extraction index is between 0.818 and 0.989, the model thus designed was significant in its globality (Fischer's F test = 749,169 with a significance rate < 5%), this model explains 99% of the variance (R^2 adjusted = 0.990). The ten explicative variables contributed well to explaining the model (Student's t-test > t of significance).

There was also a missing multi-collinearity between 8 variables (T < 1 and VIP < 4), two variables were in collinearity; these are "Irritation of the eyes, nose or throat" and "Blurred vision".

There was a negative correlation between clinical manifestations and the number of windows that can be opened (r = -0.275), the correlation was significant at the 5% level. Clinical manifestations were inversely proportional to the number of windows that can be opened, they can be explained by factors related to the internal characteristics of the home, i.e., the external environment had little influence on these clinical manifestations.

However, there is a link between clinical manifestations and 4 other variables "the number of windows that can be opened, the age of construction, the frequency of house cleaning and the size of the windows". Indeed, the correlation was significantly positive (r from 0.599 to 0.869 and F < 0.05). The clinical manifestations can be explained by these four variables, the model thus designed is significant as a whole (F = 43.578 with a significance rate less than 5%), this model explains 70% of the variance (adjusted R^2 = 0.7).

Three explanatory variables: "the age of construction, the frequency of house cleaning and the size of the windows" contribute well to explain the model (Student's test t > t of significance).

On the contrary, the variable "the number of windows that can be opened" does not contribute to explain the model (since the Student's t-test < t of significance) (significantly negative correlation). We also note that there was no multi-collinearity between the 4 explanatory variables (dw = 2,280, T < 1 and VIP < 10).

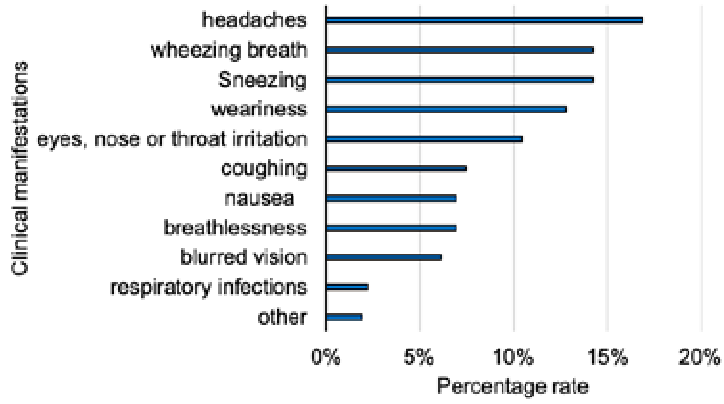

Figure 1. Distribution of clinical manifestations by type, Agadir, March 1 to mid-May 2019

Results of household dust analysis by SEM

The composition of the four household dust samples shows that this dust is dominated by carbonates followed by silicates (evaporation phenomenon) indicating a probable double source: continental (Calcium) and marine (Potassium); result in accordance with the characterization of external dusts. The analysis also shows the presence of elements associated with rock constituents (Iron, Calcium, Potassium, Sulphur, Aluminium, Sodium and Silicon) and elements resulting from evaporation: Sodium, Magnesium, Phosphorus (phosphates), Sulphur (sulphates) and Potassium. However, the analysis detected traces of Phosphorus: a result that requires further research.

Discussion

The most important clinical manifestations reported by the population are nervous, respiratory, ophthalmic and rhinolaryngological. In our study, we were able to identify several risk factors for these manifestations in the Agadir population attributable to housing. First, some exposure factors related to housing properties such as location, age of housing, number of families living in the same house, number of sides, size of windows and presence of a yard. In a similar way, Turunen et al. (2017) showed that respiratory infection risk is related to the quality of housing [13]. Also, the results a study by Habib et al. (2009) showed a significant positive association between housing conditions and chronic illness [14].

We also demonstrate that the outdoor environment is a risk according to Dong et al. (2008) [15] and Weitzman et al. (2013) [16]; living near heavy traffic, or near a polluting manufacturing plant, the construction site inside the house and the nature of the exterior siding.

Furthermore, the highest risk is observed in elderly subjects, which can be explained by the length of time spent in the house. Similarly, people who live on the ground floor or fourth floor, or who have allergies to dust mites, pesticides and dust are more exposed.

Our study also suggests the possibility of a positive association with characteristics of general housekeeping, such as the presence of dust inside the house and the fine texture of this dust. Furthermore, the study results of Herrin et al. (2013) show that the combustion of biomass for cooking is the most important adverse health effect [17]. Condensation of this dust is more frequent in autumn and summer when road traffic is intense combined with climatic conditions such as high relative humidity, temperature and wind direction.

Clinical manifestations are more frequent in autumn and spring, according to a study by Fielder (1991) [18], that seems to be essentially due to climatic conditions, air pollution both outside and inside the home and the presence of allergens in the atmosphere.

Our study also showed a positive association with the orientation of the houses towards the northeast, ventilation and dust extraction, in accordance with Mesa-Frias et al. (2014) who showed that poor ventilation rates were associated with respiratory-related morbidities [19].The occurrence of clinical manifestations is low if dust is removed daily, and if the total monthly frequency of cleaning in the house exceeds three times.

Our study has some limitations. By its very nature, we note the problem of the temporality of the association. Information bias is possible regarding the accuracy of information on clinical manifestations observed in the population at the time of the study.

In the absence of other similar studies in Morocco, it is considered that our results may be in concordance with other countries even if there is a difference in context.

However, other research proposals are suggested to develop our study further, including the characterization of indoor pollution and prospective studies to study the impact of indoor pollution on health.

Conclusion

The results of this study show that the association between the development of health disorders and the properties of the housing is significant. Exposure to contaminants from both the outdoor and indoor environment has an impact on the health of the population.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

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