



IMPACT OF ARCHITECTURAL DESIGN ON INDOOR POLLUTION

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Abstract:

Indoor air quality represents a major public health concern. This study aimed to assess the impact of housing architectural design on indoor pollution by analyzing particulate matter load, microbiological contamination, and health effects on occupants. A prospective study was conducted from January to December 2022 at three sites: a control administrative office, an old residence in El Khroub, and a modern residence in Ali Mendjeli. Air sampling was performed using a Sigma Millivac pump, and an epidemiological survey was carried out through questionnaires administered to residents.

Results showed that the average PM₁₀ concentration was higher at the modern residence (124 µg/m³) compared to the old residence (75 µg/m³) and the control site (22 µg/m³), with peak values recorded in July and August. Microbiological analysis revealed a high prevalence of molds, particularly *Aspergillus versicolor* (76%) and *Aspergillus flavus* (60%). From an epidemiological perspective, the most frequently reported respiratory symptoms were rhinitis (38%), morning cough (20%), and breathing difficulties (19%).

These findings suggest that certain architectural features, when combined with inadequate ventilation, may increase indoor pollutant levels and pose greater health risks to residents. Improving ventilation systems and selecting low-emission building materials are important strategies to mitigate this exposure.

Keywords : Indoor pollution, Air quality, PM₁₀ particles, Molds

Introduction:

Indoor air quality has become a major public health concern. It is estimated that people spend approximately 80% of their time indoors, where they inhale an average of 15 m³ of air per day. Contrary to common belief, indoor air can be more polluted than outdoor air due to the presence of numerous potential sources of contamination within enclosed environments. Several indoor pollutants are particularly worrisome due to their frequency and associated health risks. These include aldehydes, which can reach concentrations up to nine times higher indoors; hydrocarbons, often present at twice the outdoor levels; as well as phthalates, pesticides, radon, and fine particulate matter, whose concentrations may be up to 2.5 times higher than those found outdoors [1].

Air pollution is currently the leading environmental health risk faced by humans. Globally, nearly one-third of the burden of cardiovascular diseases is attributable to indoor and outdoor air pollution (17% and 13%, respectively), secondhand tobacco smoke (3%), and lead exposure (2%). Worldwide, 29% of deaths from chronic obstructive pulmonary disease (COPD) are linked to indoor air pollution, 8% to outdoor air pollution, and 11% to occupational exposure. According to a report by the World Health Organization (WHO) [2], air pollution causes 8 million deaths annually across the globe. Of these, 4.3 million are due to household air pollution and 3.7 million to ambient (outdoor) air pollution.

According to the Global Burden of Disease report, household air pollution is the leading cause of disability-adjusted life years (DALYs) in Southeast Asia and the third leading cause of DALYs worldwide. In this context, it is essential to identify the factors that influence indoor pollution, particularly the architectural design of dwellings, in order to better prevent the associated health risks.

Problematic :

To what extent does architectural design influence the type and concentration of pollutants present in indoor air, and consequently affect the quality of the home environment and the health of its occupants?

Materials and methods:

A prospective study was conducted from January to December 2022 to evaluate indoor air quality according to the architectural design of dwellings. Three sampling sites were selected: an administrative office serving as a control (S1), an old construction residence located in El Khroub (S2) (Figure 1), and a recently built residence in the new town (S3) (Figure 2). All dwellings included in the study are of type F4 and are located on the fourth floor, with an area ranging from 75 to 85 m².

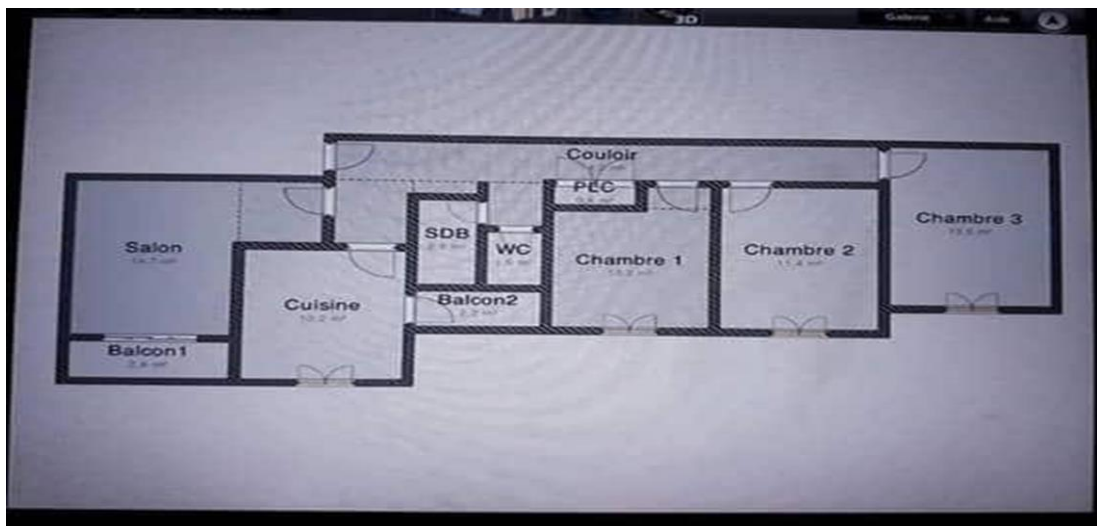


Fig 1. Residence located in El Khroub – Old construction

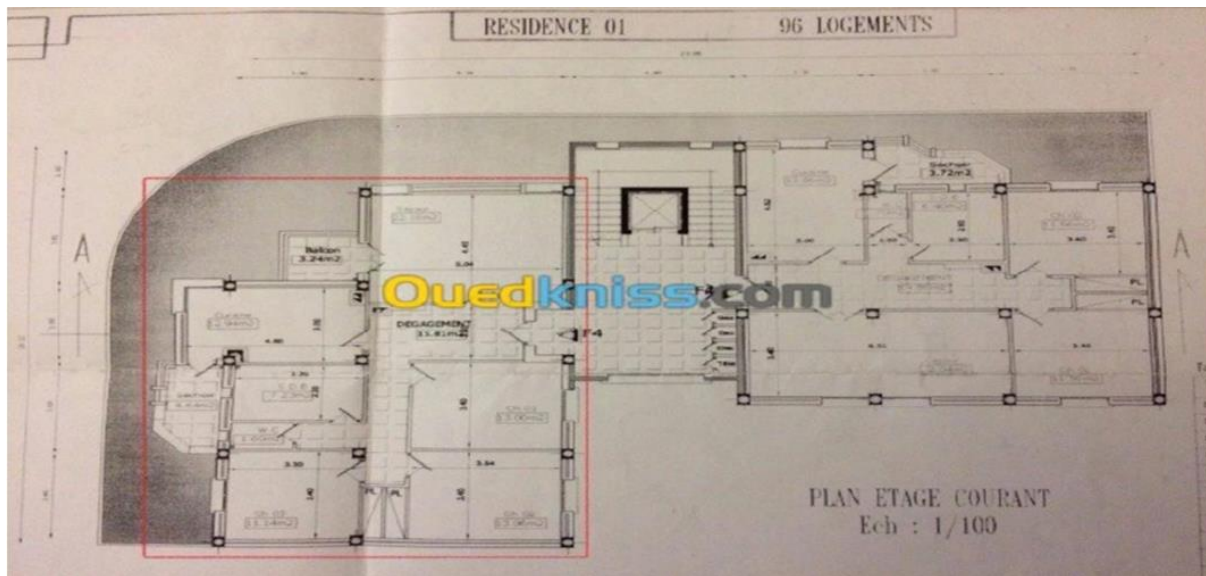


Fig 2. Residence located in the new town – Recent construction

Parameters Studied

The analysis focused on:

- Contaminants: particles and microorganisms.
- Comfort parameters: temperature and humidity.
- Dust concentrations.

Key factors considered based on a questionnaire:

- Information collected for each dwelling:
 - Type and year of construction.
 - Possible sources of pollution.
 - Number of floors in the building.
 - Type of sanitary ventilation.
 - Interior layout (presence of curtains, furniture, bedding, etc.).
- Household data:
 - Number of occupants living in the dwelling.
 - Length of residence.
 - Health indicators of the occupants.
 - Activities potentially influencing air quality (smoking, use of household products, presence of pets, cooking methods).

Sampling Protocol

Samples were collected approximately every 10 days per month (about one-third of the month), with each sampling session lasting 4 hours. Air was drawn using a Sigma Millivac-type pump equipped with PTFE HJ.656 filters, at a flow rate of 1.2 to 1.5 m³/day (Figure 3). The sampling device was installed two meters above the floor, representing an average height between standing (1.5 m) and lying down (0.5 m) occupants [3,4].

Particle concentrations were expressed in micrograms per cubic meter (µg/m³), calculated as follows:

$$C (\mu\text{g}/\text{m}^3) = \text{Mass collected} / \text{Volume of air sampled.}$$

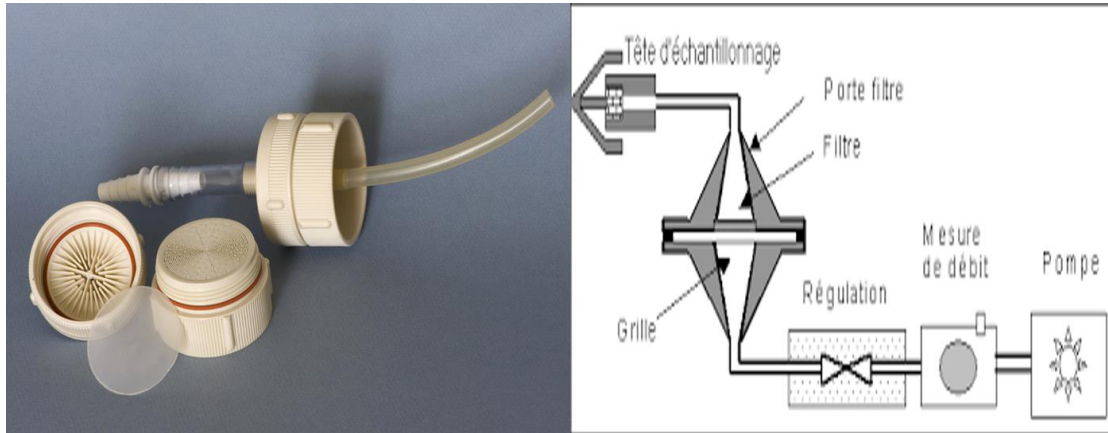


Fig. 3. Sigma Millivac pump used for air sampling with PTFE HJ.656 filters

Epidemiological Study

A questionnaire was distributed to the tenants of the different sites to collect epidemiological data. The distribution of apartments and individuals is as follows:

- Site S2: 8 apartments with a total of 33 individuals.
- Site S3: 12 apartments with a total of 40 individuals.

Results and discussions:

1. Comparison of Particle Levels Between the Two Sites

The analysis of particle levels between the two sites revealed interesting results. Contrary to expectations, higher particle concentrations were observed in the apartments located in the new town site (S3), compared to the old construction site (S2). These concentration peaks were particularly notable during July and August for both sites, corresponding to a period when climatic conditions, such as heat, may promote the suspension of particles in the air [5].

Figure 4 illustrates this variation in particle levels between the two sites, highlighting the peaks observed during the summer.

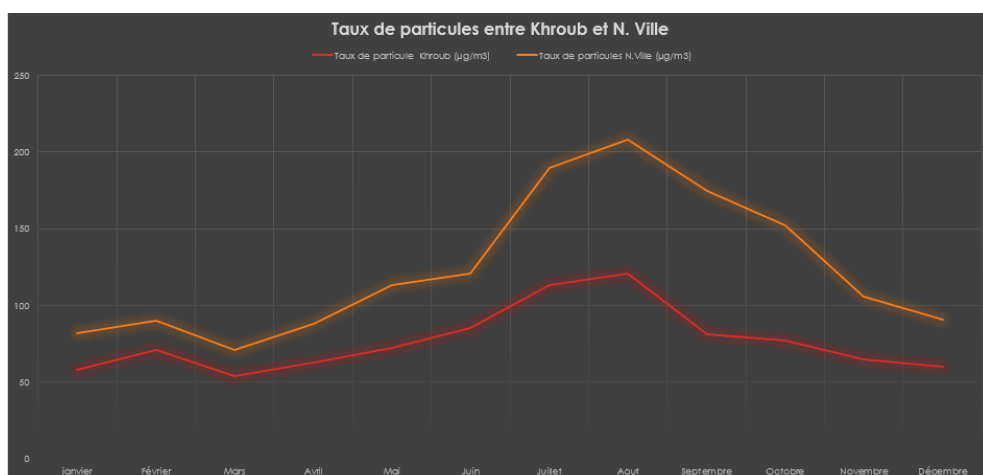


Fig. 4. Particle levels measured between sites S2 (old construction) and S3 (new town).

PM₁₀ Particle Levels Between Sites

PM₁₀ particle concentrations were measured at the different study sites, with the following results:

Table 1. PM₁₀ Particle Concentrations Measured at Different Sites

Site	Minimum Concentration ($\mu\text{g}/\text{m}^3$)	Maximum Concentration ($\mu\text{g}/\text{m}^3$)	Average ($\mu\text{g}/\text{m}^3$)
Control	11	42	22
El-Khroub (S2)	54	121	75
New Town-Ali Mendjeli (S3)	71	208	124

Particle levels in the studied homes ranged from 54 to 208 $\mu\text{g}/\text{m}^3$. By comparison, the WHO recommends an average concentration of 24 $\mu\text{g}/\text{m}^3$ for PM₁₀, with values fluctuating between 10 and 50 $\mu\text{g}/\text{m}^3$. These measured values are therefore significantly higher than the WHO recommendations, particularly for the new town site.

Regarding PM_{2.5}, the criteria from the Indoor Air Quality Observatory (OQAI) indicate a factor between 0.6 and 0.7 to estimate PM_{2.5} concentrations relative to PM₁₀. Thus, the measured concentrations at the sites vary between 48.75 and 80.6 $\mu\text{g}/\text{m}^3$, with international standards setting reference values as follows:

- Norway: 20 $\mu\text{g}/\text{m}^3$
- Canada: 40 $\mu\text{g}/\text{m}^3$
- USA: 60 $\mu\text{g}/\text{m}^3$
- France: 12–37 $\mu\text{g}/\text{m}^3$

Domestic air pollution has considerable health impacts. Each year, 4.3 million people die due to indoor air pollution, with 60% of these deaths attributed to cardiovascular diseases and 40% to pulmonary diseases. It has been shown that an increase of 10 $\mu\text{g}/\text{m}^3$ in indoor PM₁₀ levels can increase cardiovascular mortality by 0.36% and respiratory mortality by 0.42% [6].

2. Microbiological Study

Among the 20 apartments studied, 50% did not have a ventilation system in the wet rooms. This lack of ventilation promotes the accumulation of biological pollutants, particularly molds. Mainly originating from the outdoor environment, these molds inevitably enter buildings, interact with household dust, and thus form a permanent contamination reservoir indoors.

Analyses performed on samples taken from two sites and processed at the parasitology laboratory of the university hospital (CHU) revealed a significant presence of certain fungal species. *Aspergillus versicolor* was identified in more than 76% of the homes, while *Aspergillus flavus* was present in over 60% of the samples. Microscopic observation using a Zeiss microscope showed a high density of *A. flavus* (40 colonies observed across 10 examined fields) (Figure 5).

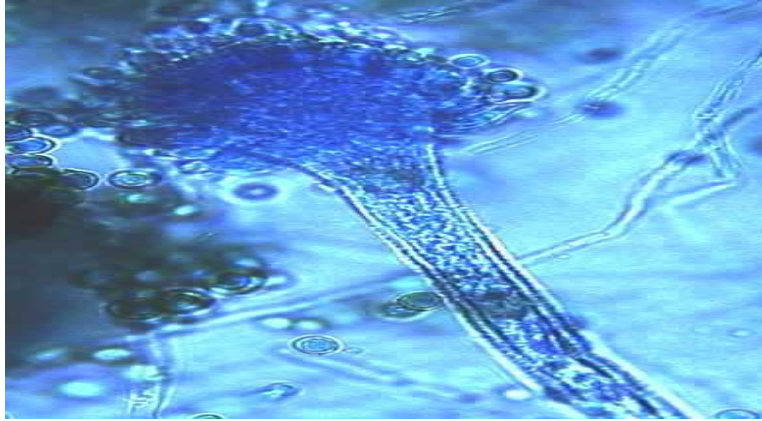


Fig 5. Microscopic observation of *Aspergillus flavus* using a Zeiss microscope

It is worth noting that some species, such as *A. versicolor*, are xerophilic, meaning they can develop with very little available water. In contrast, other species, such as *Aspergillus fumigatus*, isolated notably in kitchens (Figure 6), require an environment with a high water activity (a_w), above 0.90. Water activity is a fundamental parameter in microbiology, indicating the fraction of free water available for microbial growth.



Fig. 6. Isolation of *Aspergillus fumigatus* in kitchens

These results highlight the importance of humidity and ventilation in controlling fungal contamination in indoor environments.

3. Epidemiological study:

In this study, the demographic distribution of participants shows a female predominance, with 59% women and 41% men. Regarding age groups, the majority of participants are between 15 and 30 years old (30%), followed by 31–45 years (32%), 46–60 years (25%), and finally, individuals over 60 years old represent 13% of respondents (Figure 7).

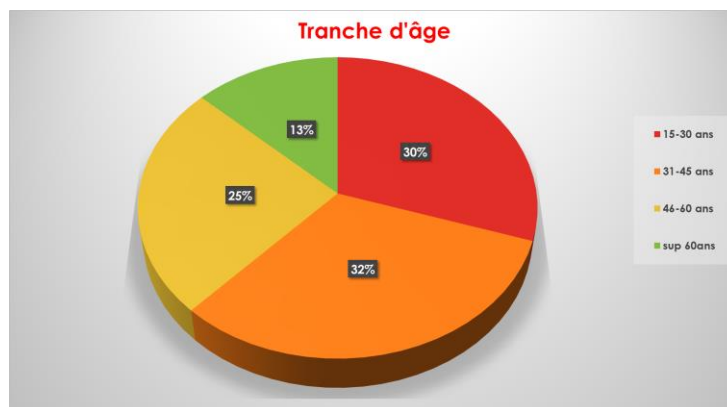


Fig. 7. Distribution of participants by age group.

Regarding tobacco exposure, 32% of participants smoke more than one pack per day, 30% smoke less than one pack, and 38% are non-smokers (Figure 8).

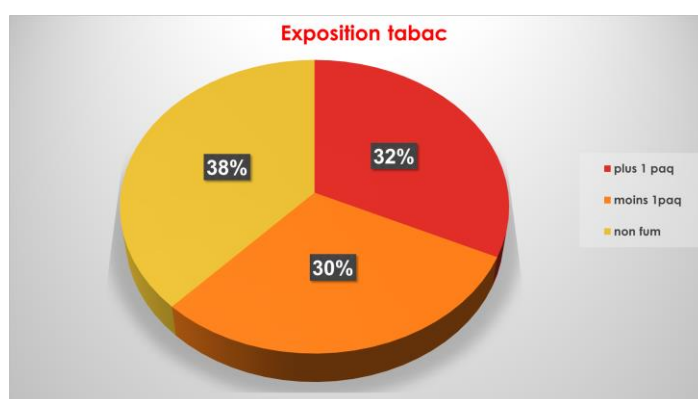


Fig 8. Distribution of participants according to their tobacco exposure.

Among the 4.3 million people who die each year due to indoor air pollution, 60% die from cardiovascular diseases and 40% from pulmonary diseases.

Respiratory symptoms reported by participants include rhinitis (38%), wheezing (15%), morning cough (20%), sputum production (8%), and respiratory problems (19%) (Figure 9). A respiratory health survey conducted in 2019 by the health department showed that respiratory diseases rank:

- 2nd among causes of morbidity (14.35%)
- 1st among reasons for medical consultation (35.62%)
- Asthma ranks 3rd among chronic diseases after hypertension and diabetes.

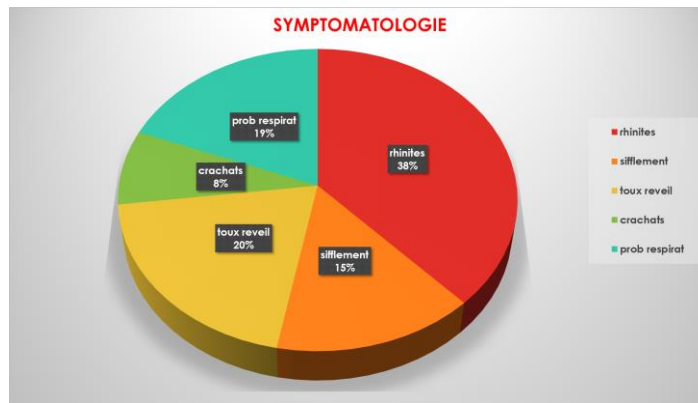


Fig 9. Distribution of respiratory symptoms among the participants.

It should be noted that multiple pollutants could cause a pathology or symptom associated with pollution; therefore, attributing causality to a single pollutant appears to be the exception. However, the single-pollutant model in epidemiological studies remains relevant, even when pollutants are correlated, with the pollutant considered as an indicator.

Conclusion:

This study highlighted the impact of architectural design on indoor air quality. The results show that particulate pollution levels are higher in recent constructions, which could be due to the numerous construction sites in the new town, with peaks observed during the summer months. From a microbiological perspective, the frequent presence of molds, particularly *Aspergillus versicolor* and *Aspergillus flavus*, underscores the role of confinement and lack of ventilation. The epidemiological study also reveals a notable prevalence of respiratory symptoms among the exposed residents. These findings confirm the importance of designing housing that promotes better ventilation and raising public awareness about the risks associated with indoor pollution.

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