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INDOOR ENVIRONMENTAL FACTORS SHAPING FUNGAL CONTAMINATION IN RESIDENTIAL SETTINGS

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ABSTRACT

A hygienic assessment of residential indoor environments in the urban context of Tashkent was carried out with a focus on factors potentially influencing moisture accumulation and fungal contamination. The study included 150 apartments and 305 residents from 10 administrative districts of the city. Particular attention was given to the characteristics of interior finishing materials and their role in shaping indoor environmental conditions. The results showed that moisture-resistant materials are predominantly used in sanitary areas, whereas materials with moderate moisture resistance and hygroscopic properties are more common in living rooms and balconies. Under certain operating conditions, such materials may contribute to the accumulation of moisture on indoor surfaces. The analysis of fungal contamination levels revealed higher microbial loads in premises with increased humidity, while living rooms were characterized by predominantly moderate levels and balconies by relatively low contamination. These findings indicate that indoor environmental conditions are closely associated with the functional use of premises and material characteristics. The obtained results suggest that interior finishing materials should be considered as factors influencing indoor environmental quality and contributing to conditions favorable for fungal contamination. The study highlights the need for further investigation of microclimatic parameters and ventilation as key determinants of moisture balance and indoor air hygiene

KEYWORDS: indoor environment, fungal contamination, interior finishing materials, moisture resistance, microclimate

1. INTRODUCTION

Modern processes of societal development are accompanied by significant changes in environmental factors affecting human habitats, including transformations in the biological composition of the air. At present, microscopic fungi are considered a permanent component of the human environment [1, 6]. Under conditions of anthropogenically altered environments, an increase in the proportion of micromycetes in bioaerosols has been observed, which enhances their hygienic significance [9].

Particular attention is given to the quality of indoor air in residential buildings, as modern urban populations spend up to 70–80% of their time in enclosed spaces [6, 7]. It has been established that indoor environments develop a specific mycobiota that differs from outdoor aeromycota but remains closely interconnected with it [10]. [10]. The accumulation of micromycetes in enclosed spaces is determined both by external sources and by the characteristics of the premises themselves, including structural and operational features of buildings [5].

Microscopic fungi represent an important risk factor for human health, as their effects are mediated not only through infectious mechanisms, but also through the toxic action of their metabolites and the immunological sensitization of the organism [2, 8]. Unlike obligate pathogenic microorganisms, opportunistic micromycetes can produce adverse effects by virtue of their biological foreignness alone, which broadens the understanding of the potential hazards associated with indoor aeromycota. Individuals with impaired immune function, particularly at the level of cellular immunity, are considered the most vulnerable [11, 13].

An additional factor of concern is the ability of micromycetes to actively disperse in the air through the production of large numbers of spores and mycelial fragments characterized by high volatility and resistance to environmental factors [5, 12]. It has also been shown that fine fungal particles can exert significant biological effects, including at concentrations that are not detected by standard monitoring methods [3, 4].

An important aspect is the influence of structural and operational characteristics of buildings on the formation of microclimatic conditions that determine the potential for growth and accumulation of micromycetes. The materials of building envelopes, features of interior finishing, as well as the condition of ventilation and waterproofing systems significantly affect the temperature–humidity regime of indoor environments, creating conditions conducive to moisture condensation and mold growth [5]. Violations of these parameters are considered one of the key factors contributing to the development of the "sick building syndrome" [5].

From a hygienic perspective, the determination of acceptable levels of fungal spores in indoor air is of fundamental importance. At present, there are no unified regulatory criteria for permissible concentrations of mold spores in residential indoor environments, nor standardized methodological approaches for assessing fungal contamination. In this context, a hygienic assessment of the structural characteristics of residential buildings, with regard to their potential role in moisture accumulation and the development of fungal contamination, remains highly relevant.

General Objective. The aim of this study was to provide a hygienic assessment of residential indoor environments in Tashkent, focusing on the characteristics of interior finishing materials as factors potentially influencing moisture accumulation and the formation of conditions conducive to fungal contamination.

2. METHODOLOGY

2.1. General Description of the Study Area

Tashkent is a large urbanized center with a well-developed residential and public infrastructure. Administratively, the city is divided into 12 districts, which differ in terms of building processes, population density, and characteristics of the housing stock. The climate of Tashkent is sharply continental, with hot, dry summers and relatively cool winters, which significantly influences the operation of residential buildings, ventilation practices, and the indoor moisture balance. Under traditionally arid climatic conditions, fungal contamination of residential premises has not long been considered a priority issue from a hygienic perspective. However, at present, changes in building operation, increased airtightness of building envelopes, and specific patterns of indoor space use have led to a growing importance of factors contributing to moisture accumulation and the formation of conditions favorable for fungal contamination.

The present study covered residential premises located in 10 administrative districts of the city, ensuring the representativeness of the sample and allowing consideration of diverse urban planning and operational conditions. The study included 150 apartments with different building types and structural characteristics, as well as 305 respondents.

Residential buildings were mainly represented by multi-apartment housing constructed during

different periods of urban development, which accounts for the variability in building envelope materials, layout solutions, and engineering systems. Significant differences in the characteristics of residential premises, including interior finishing materials, operating conditions, and microclimatic parameters, determine the features of indoor environmental formation and may influence the level of fungal contamination in indoor air.

2.2. Methods

The study was conducted in May–June 2025 and included two sequential stages.

At the first stage, data on the structural and hygienic characteristics of residential premises were collected and analyzed. Information was obtained using specially designed survey forms that ensured standardized data collection. The assessment included an analysis of interior wall finishing materials, followed by their classification according to moisture resistance.

At the second stage, air sampling in residential premises was carried out using the sedimentation method. To determine the total microbial count (CFU/m³), air samples were cultured on Sabouraud agar. Incubation was performed at a temperature of 27.0±1.0°C for up to 7 days, followed by the registration of grown micromycete colonies.

Statistical analysis included the calculation of relative indicators, mean values, and standard error (M±m). Data processing and analysis were performed using Microsoft Excel software.

3. RESULTS

The analysis of the territorial distribution of the surveyed apartments and respondents demonstrated a statistically consistent sample structure with a relatively uniform coverage of the administrative districts of Tashkent. The highest proportions of both apartments (18.1%) and respondents (19.0%) were recorded in the Yashnabad District, reflecting its largest contribution to the overall sample.

A substantial share was also observed in the Yunusabad (12.9% and 13.1%) and Shaykhantakhur districts (11.6% and 11.8%), indicating adequate representation of these areas. The lowest values were identified in the Mirabad (6.5% and 5.9%) and Yakkasaray districts (6.5% and 6.9%); however, their proportions remain comparable to those of other districts, which excludes any pronounced imbalance in the sample (Fig. 1).

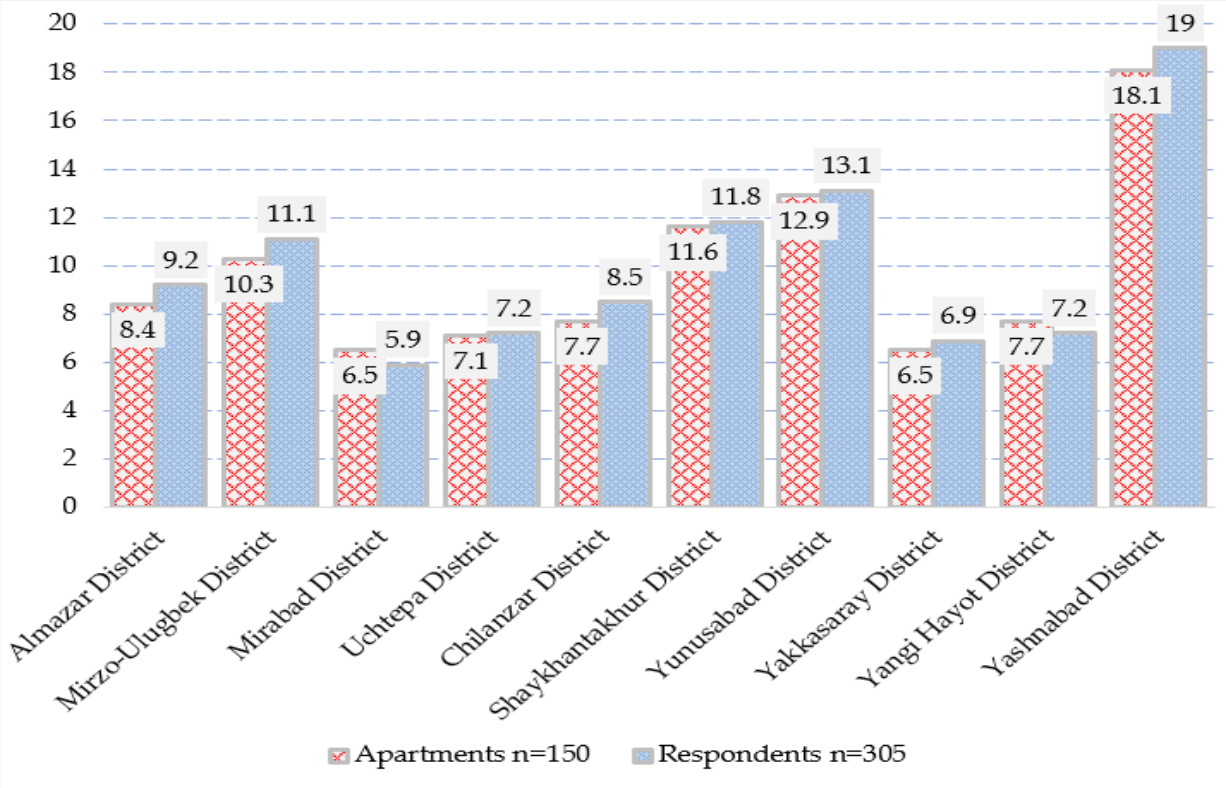

Figure 1: Distribution of surveyed apartments and respondents across the administrative districts of Tashkent

A comparative analysis of the distribution of apartments and respondents demonstrated a high degree of consistency across all administrative districts, with differences between proportions not

exceeding 1.0–1.2%, which were not statistically significant (p>0.05) and indicate the absence of systematic sampling bias.

Thus, the formed sample is territorially balanced and can be considered representative for assessing hygienic factors of residential premises in the urban environment of Tashkent. The analysis of interior wall finishing materials, grouped according to moisture resistance (Table 1), revealed pronounced differences depending on the functional purpose of the premises.

Table 1: Hygienic characteristics of interior finishing materials of walls, floors, and ceilings in residential premises according to moisture resistance (M±m, %)

Degree of moisture resistance		Material	Bathroom (n=150)	Balcony (n=150)	Bedroom (n=150)
Walls	Moisture-resistant	Ceramic tiles	71,6±3,54	4,6±1,39	0,0±0,00
		Plastic panels	4,5±1,37	7,9±1,96	2,6±0,83
	Moderately moisture-resistant	Paint	11,9±2,45	44,6±3,93	43,8±3,93
	Hygroscopic	Wallpaper	2,0±1,14	27,4±3,50	43,6±3,92
Floors	Moisture-resistant	Ceramic tiles	86,2±2,63	10,8±2,33	-
	Moderately moisture-resistant	Laminate	1,9±0,49	16,0±2,83	21,5±3,20
		Linoleum	-	54,1±3,94	57,9±3,91
	Hygroscopic	Wood	2,5±0,81	4,9±1,44	11,3±2,39
Ceilings	Moisture-resistant	Stretch ceiling	7,8±1,94	4,5±1,37	13,8±2,63
		Plastic panels	21,3±3,19	19,0±3,04	-
	Hygroscopic	Whitewash	56,4±3,92	53,1±3,95	56,0±3,93
		Gypsum board	5,2±1,51	8,5±2,05	20,9±3,17

It was established that bathrooms are characterized by the highest proportion of moisture-resistant finishing materials, particularly for walls (ceramic tiles – 71.6±3.54%) and floors (86.2±2.63%), reflecting the adaptation of finishing solutions to conditions of persistently elevated humidity. At the same time, the share of hygroscopic and moderately moisture-resistant materials in this area is minimal, indicating partial compliance with hygienic principles in the selection of finishing materials.

In contrast, living rooms are characterized by the predominance of materials with lower moisture resistance. In wall finishing, paint (43.8±3.93%) and wallpaper (43.6±3.92%) are used in nearly equal proportions. A similar pattern is observed for flooring, where linoleum predominates (57.9±3.91%), along with a notable share of wooden покрытия (11.3±2.39%). Balconies occupy an intermediate position; however, in terms of overall characteristics, they are closer to living rooms than to санитарные помещения. Moderately moisture-resistant and hygroscopic materials dominate in these areas (paint – 44.6±3.93%, wallpaper – 27.4±3.50%, linoleum – 54.1±3.94%), while the proportion of moisture-resistant materials remains low. Given the exposure of balconies to temperature fluctuations, this creates conditions conducive to moisture condensation.

The analysis of fungal contamination levels in indoor air revealed pronounced differences depending on the functional purpose of the premises. In bathrooms, moderate levels of contamination predominate, with 42.0±4.03% and 36.7±3.93% falling within the ranges of 101–200 CFU/m³ and 201–300 CFU/m³, respectively, while high levels (>300 CFU/m³) account for 20.7±3.31%. Low levels (below 100 CFU/m³) were observed only sporadically (0.7±0.66%), indicating consistently elevated fungal load under conditions of increased humidity (Table 2).

Table 2: Distribution of fungal contamination levels in indoor air by functional type of premises, CFU/m³, %

Air contamination level (CFU/m³)	Bathroom (n=150)		Balcony (n=150)		Bedroom (n=150)	
	n	M±m,%	n	M±m,%	n	M±m,%
up to 100	1	0,7±0,66	0	0,0	5	3,3±1,47
101-200	63	42,0±4,03	5	3,3±1,47	71	47,3±4,08
201-300	55	36,7±3,93	5	3,3±1,47	33	22,0±3,38
>300	31	20,7±3,31	10	6,7±2,04	23	15,3±2,94
total	150	100,0	20	13,3±2,78	132	88,0±2,65

Balconies are characterized by significantly lower levels of fungal contamination: the proportion of values below 200 CFU/m³ is limited (3.3±1.47% for each category), while even at higher contamination levels (>300 CFU/m³), the proportion does not exceed 6.7±2.04%. This indicates less favorable conditions for the accumulation of micromycetes, likely due to better aeration and a less pronounced humidity regime.

In bedrooms, moderate levels of contamination predominate, with the highest proportion observed in the range of 101–200 CFU/m³ (47.3±4.08%), while

higher levels are less frequently encountered (201–300 CFU/m³ — 22.0±3.38% and >300 CFU/m³ — 15.3±2.94%). Low levels (3.3±1.47%) are less common, indicating the formation of a relatively stable, though not optimal, microbiological background.

4. CONCLUSION

The conducted study has shown that the formation of indoor environmental conditions in residential premises is largely determined by the characteristics of interior finishing materials and the functional purpose of rooms. It was established that moisture-resistant materials are predominantly used in sanitary facilities, while in living rooms and balconies materials with moderate moisture resistance and hygroscopic properties prevail. Under certain эксплуатационных условий such materials may contribute to moisture accumulation on enclosing surfaces.

The analysis of fungal contamination of indoor air demonstrated that the highest levels are associated with premises characterized by increased humidity, whereas living rooms are mainly characterized by moderate levels, and balconies by relatively low contamination. These differences reflect the role of indoor environmental conditions in the formation of microbial load.

The obtained results allow considering the characteristics of interior finishing as a significant factor influencing the quality of the indoor environment and creating prerequisites for fungal contamination. At the same time, the findings indicate the need for further in-depth study of microclimatic parameters and ventilation conditions as key determinants of moisture balance and biological contamination of indoor air.

AUTHOR CONTRIBUTIONS:

Conceptualization, Ataniyazova R. and Isakova L.; methodology, Ataniyazova R.; software, Kamilov J., Barakaev F. and Kallieva T.; validation, Sadullayeva Kh.; formal analysis, Ataniyazova R., Atakhanova D. and Sadullayeva Kh.; investigation, Barakaev F., Kusbergenova Kh. and Kallieva T.; data curation, Kusbergenova Kh.; writing—original draft preparation, Ataniyazova R..; writing—review and editing Isakova L., Sadullayeva Kh., Atakhanova D. and Kamilov J.; visualization, Kamilov J. and Barakaev F.; supervision, Ataniyazova R.; funding acquisition, all authors. All authors have read and agreed to the published version of the manuscript.

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