UDC 614.71:551.510.42
DOI https://doi.org/10.32782/health-2026.1.7

RELATIVE HUMIDITY AS A FACTOR IN MICROCLIMATE AND PUBLIC HEALTH: A COMPARATIVE ANALYSIS OF UKRAINE AND ITALY

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Air humidity is one of the leading environmental factors determining the quality of the indoor environment and the health of the population. The aim of the study was to highlight and conduct a comparative analysis of the impact of different levels of indoor air humidity on the health of the population in Ukraine and Italy. A search, systematic review and meta-analysis of publications was conducted using the MEDLINE, Scopus®, ResearchGate, PubMed and Google Scholar scientific literature databases.

The study summarises current scientific data on the impact of humidity on the functional state of the respiratory system, the spread of infectious agents and the formation of a safe microclimate in residential and public premises. It shows that deviations in relative humidity from the optimal range have a two-sided negative effect. A decrease in indicators below 30–40% during the heating season is associated with dehydration of the mucous membranes, impaired mucociliary clearance, decreased local immune defence, and an increased risk of transmission of respiratory viral infections. At the same time, increased humidity above 60–70% contributes to moisture condensation, mould growth and microbiological contamination of the air, which is associated with allergic reactions, exacerbation of chronic respiratory diseases and deterioration of the technical condition of building structures.

It has been proven that the climatic characteristics of a region determine the nature of risks: in Ukraine, excessive dryness of the air during the heating season is a pressing problem, while countries with a Mediterranean climate more often experience chronically high humidity. A relative humidity range of 40–60% is considered optimal for maintaining human health. Maintaining this level requires systematic monitoring and the use of engineering and technical measures to regulate the microclimate.

Humidity control should be considered an important component of the prevention of infectious and non-infectious respiratory diseases and a component of public health strategies.

Key words: *relative humidity, absolute humidity, indoor air humidity, mould, risk factors, prevention, Ukraine, Italy.*

Олена Григорян, Ігор Завгородній. Відносна вологість як чинник мікроклімату та громадського здоров'я: порівняльний аналіз України та Італії

Вологість повітря є одним із провідних екологічних чинників, що визначає якість внутрішнього середовища та стан здоров'я населення. Метою роботи було висвітлити та зробити порівняльний аналіз впливу різного рівня вологості повітря в приміщенні на здоров'я населення в Україні та Італії. Проведений пошук, систематичний огляд і метааналіз публікацій за допомогою баз даних наукової літератури MEDLINE, Scopus®, ResearchGate, PubMed та Google Scholar.

У роботі узагальнено сучасні наукові дані щодо впливу вологості на функціональний стан респіраторної системи, поширення інфекційних агентів і формування безпечного мікроклімату житлових і громадських приміщень. Показано, що відхилення відносної вологості від оптимального діапазону мають двобічний негативний ефект. Зниження показників нижче 30–40% у період опалення асоціюється з дегідратацією слизових оболонок, порушенням мукоциліарного кліренсу, зниженням місцевого імунного захисту та підвищенням ризику передачі респіраторних вірусних інфекцій. Водночас підвищена вологість понад 60–70% сприяє конденсації вологи, розвитку плісняви та мікробіологічній контамінації повітря, що пов'язано з алергічними реакціями, загостренням хронічних респіраторних захворювань і погіршенням технічного стану будівельних конструкцій.

Обґрунтовано, що кліматичні особливості регіону визначають характер ризиків: в умовах України актуальною проблемою є надмірна сухість повітря в опалювальний період, тоді як у країнах із середземноморським кліматом частіше спостерігається хронічно підвищена вологість. Оптимальним для підтримання здоров'я

людини вважається діапазон 40–60% відносної вологості. Підтримання цього рівня потребує системного моніторингу та застосування інженерно-технічних заходів регулювання мікроклімату.

Контроль вологості слід розглядати як важливий компонент профілактики інфекційних і неінфекційних респіраторних захворювань та складову стратегій громадського здоров'я.

Ключові слова: *відносна вологість, абсолютна вологість, вологість повітря в приміщенні, цвіль, фактори ризику, профілактика, Україна, Італія.*

Introduction. Research on the relationship between environmental factors and human health has intensified, particularly in the context of climate change and urbanization. Ambient humidity is a significant environmental determinant influencing human health and indoor environmental quality. As a key meteorological parameter, air humidity reflects the water vapor content in the atmosphere and affects microclimate conditions, pathogen transmission, and overall well-being. Although humans inhale outdoor air, they spend most of their time indoors, where air quality can be modified and controlled [1].

Absolute humidity is defined as the mass of water vapor per cubic meter of air (g/m³). Relative humidity (RH) represents the ratio of current absolute humidity to the maximum possible humidity at a given temperature, expressed as a percentage, or the ratio of actual vapor pressure to saturated vapor pressure.

The recommended indoor RH is 45–60% in winter and 40–55% in summer, with an optimal range of 40–60%. Values outside this range may cause discomfort and increase disease risk.

Evidence indicates that humidity significantly affects respiratory health, particularly infectious diseases. Indoor RH is widely used in modeling respiratory virus transmission. Elevated RH has been negatively associated with lung function and increased risk of obstructive lung diseases, whereas moderate RH levels reduce the risk of chronic cough and sputum production [2;3]. Korean studies demonstrated that low (30–40%) or high (70%) humidity at low daily temperatures (0–5°C) significantly increases influenza risk [4]. Additional studies identified associations between RH and transmission and outcomes of COVID-19 [5;6].

The impact of humidity on airway function has been extensively investigated [7–10]. In patients with chronic obstructive pulmonary disease (COPD), high humidity – particularly in hot and humid or cold and dry environments – is associated with poorer well-being, reduced physical activity, and increased exacerbation frequency [7].

The purpose of the study to analyse the impact of different levels of indoor air humidity on the health of the population in Ukraine and Italy based on a meta-analysis of literature sources and the results of multicentre studies.

Materials and methods. The search, systematic review and meta-analysis of publications were performed in three stages in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines:

1. Identification stage: the main automatic search is performed using the MEDLINE, Scopus®, ResearchGate, PubMed and Google Scholar scientific literature databases. Relative humidity, absolute humidity, indoor air humidity, mould, risk factors, prevention, and Ukraine and Italy were the keywords that described the hidden paradigms.

2. The selection stage involved checking whether the titles and abstracts of the publications found met the inclusion or exclusion criteria.

3. Eligibility stage: full-text publications are checked for compliance with the study criteria.

Results of the study and their discussion. Relative humidity is an underrecognized environmental factor that significantly influences respiratory health in both outdoor and indoor settings. Values outside the optimal range may enhance infectious transmission and aggravate chronic respiratory diseases. This review aims to summarize the health consequences of non-optimal RH and outline strategies to mitigate its adverse effects. RH directly affects the rheological properties of mucus by altering its osmolarity and mucociliary clearance efficiency. The mucus layer, together with tight junctions, constitutes a critical physical barrier against pathogens and irritants. Control of RH is considered a potential preventive strategy against viral and bacterial transmission; however, its isolated contribution is difficult to determine due to concurrent exposure to other environmental risk factors. Nevertheless, RH imbalance may exert synergistic negative effects, and its normalization can promote a healthier environment [11].

Humidity patterns are influenced by atmospheric circulation, temperature variations, and precipitation. Since the early twentieth century, persistent changes in temperature–humidity regimes have been documented in association with global climate processes [12].

During the cold season, indoor heating frequently reduces RH to <30%, adversely affecting health and work performance. Drying of the mucous

membranes of the upper respiratory tract, eyes, and skin increases susceptibility to infections and contributes to inflammatory conditions such as rhinitis and laryngitis, as well as exacerbation of allergic responses, particularly in children. Subjective symptoms include ocular dryness, discomfort, and fatigue [11].

Epidemiological and experimental studies show that low RH increases the stability and airborne spread of viruses, while reducing the effectiveness of mucociliary clearance. Increasing indoor RH by humidifying the air is considered an effective non-pharmaceutical measure that reduces symptoms of dryness, improves subjective perception of the microclimate, and limits the viability of viruses in aerosols [13–15].

Conversely, high RH (>60%) also has negative consequences. It promotes the growth of mould, microscopic fungi, and dust mites, particularly in areas of condensation. Aerosolization of fungal spores increases the risk of allergic reactions, bronchial asthma, hypersensitivity pneumonitis, and other respiratory diseases. Additionally, excessive humidity contributes to thermal discomfort and reduced well-being [16; 17].

Elevated RH also affects thermoregulation. Reduced evaporative heat loss under high humidity conditions impairs convective and radiative heat dissipation, leading to redistribution of blood flow and increased thermal strain [18; 19]. Clinically, this manifests as early fatigue, decreased physical and cognitive performance, and, with prolonged exposure, an increased risk of heat exhaustion or hyperthermia [16; 19].

Overall, clinical studies confirm that maintaining an optimal RH reduces acute ocular and respiratory symptoms and lowers the risk of viral transmission, whereas excessively low or high RH is associated with increased respiratory morbidity [20].

Hygrothermal modelling of buildings with ground contact in a humid subtropical climate demonstrated consistently high indoor RH levels (75–90%) throughout the year, which contributed to seasonal mould growth (May–November) and condensation on windows (October–April). The heat capacity of the soil further influenced the temperature regime and moisture accumulation in building envelopes [21].

However, a multicenter European study (7,127 households) found no statistically significant association between outdoor RH and indoor dampness or mould. At the same time, higher air temperature, precipitation, and older building age were associated with a greater prevalence of dampness and fungal contamination. In addition, consistency between objective and self-reported data was observed, along with socioeconomic differences in the prevalence of mould and moisture problems [22].

According to an analysis of publications indexed in PubMed and reports from leading public health institutions, current guidelines (since 2017) confirm a causal relationship between building dampness, exposure to mould and the development of both pulmonary and extrapulmonary diseases. The introduction of new methods for assessing the toxicity of airborne fungal components has expanded the evidence base. Pathogens such as *Aspergillus fumigatus* are considered a significant risk factor for public health. This makes it impossible to underestimate their medical and socio-economic consequences [23].

Numerical modelling of respiratory events demonstrates that at 50% RH, the persistence time of small droplets (10 μm) increases significantly compared to the classical model of William F. Wells, and at 90% RH – up to 150 times, which increases the potential for airborne transmission of infections above 2 m/s. A turbulent moist breathing cloud promotes prolonged aerosol suspension, which has implications for ventilation strategies and humidity control during pandemics [24].

The climate of Ukraine is predominantly temperate continental, with seasonal fluctuations in humidity; summers are often dry with high evaporation rates. However, during the heating season, which typically lasts from late October to late March, indoor RH decreases significantly due to central heating or radiator operation. Humidity drops markedly when cold winter air is heated to room temperature, even if the outdoor air is humid. Without additional humidification measures, indoor RH after heating may fall below 20% (sometimes 10–20%) under typical winter conditions with freezing temperatures.

This is primarily an indoor microclimate issue rather than a feature of the outdoor climate. It results from the thermodynamics of air during heating and the operation of heating systems. When cold outdoor air is heated, its moisture-holding capacity increases substantially. However, if additional moisture is not introduced, RH decreases as a normal physical consequence. Operating radiators and central heating systems further dry the air, as warm air accelerates evaporation from indoor surfaces. For this reason, it is often said that humidifiers are necessary in winter to maintain mucous membrane health and immunity [25–27].

Italy has a highly diverse climate, ranging from humid subtropical conditions in the north (e.g.,

Lombardy and Milan) to a Mediterranean climate with relatively high humidity in central and southern regions. Summers and winters in Italy are generally warm and humid. For example, RH in Rome averages approximately 73% annually, with higher levels in winter and lower levels in summer.

Moisture condensation problems are exacerbated by certain architectural features of Italian buildings, such as the absence of effective vapor barriers behind wallpaper, particularly in older brick buildings. Condensation formation and elevated indoor humidity contribute to damp conditions, especially in northern valleys (e.g., the Po Valley). This promotes fungal and mould growth, particularly on walls, in corners, and in poorly ventilated buildings. Studies investigating the microclimate of historic buildings confirm the association between humidity and the risk of surface biodegradation [28].

Other studies conducted in Italy during the 2020 pandemic examined how weather changes affected the daily number of new cases, hospitalizations, and deaths. The findings indicate that humidity in Italy had a negligible impact on COVID-19 incidence and severity during both waves of the pandemic [29–31].

Thus, excessive indoor air dryness during the winter season is more characteristic of Ukraine, whereas Italy more commonly faces chronically elevated humidity levels and an associated risk of fungal contamination. Controlling indoor RH in accordance with regional climatic characteristics is an important component of the prevention of both infectious and non-infectious diseases.

Conclusions. Air humidity is a key microclimatic parameter that determines both the sanitary and hygienic safety of the indoor environment and the functional state of the human respiratory system. A synthesis of contemporary experimental, clinical, and epidemiological data confirms that deviations of relative humidity from the optimal range have a bidirectional adverse effect – both when decreased and when excessively increased.

Low RH (<30–40%) during the heating season leads to dehydration of the mucous membranes, impairment of the epithelial barrier function, and reduced efficiency of mucociliary clearance, thereby creating conditions for increased viral stability in aerosols and enhanced transmission of respiratory infections. At the same time, excessive humidity (>60%) promotes condensation, mould growth, and microbiological contamination of indoor air, which is associated with allergic reactions, exacerbations of bronchial asthma and other chronic respiratory diseases, as well as deterioration of building structures.

Regional climatic characteristics determine the prevailing types of risk. In Ukraine, despite relatively high outdoor humidity levels in winter, centrally heated buildings often develop a markedly dry indoor microclimate that requires correction. In contrast, countries with a Mediterranean climate, particularly Italy, more commonly face chronically elevated humidity levels and related problems of condensation and fungal contamination of surfaces.

Maintaining relative humidity within the range of 40–60% should be considered an evidence-based benchmark for ensuring optimal indoor environmental conditions. Achieving this level is possible only through a systematic approach that includes monitoring of microclimatic parameters, the use of humidification or dehumidification technologies as needed, effective ventilation, and proper thermal insulation of building envelopes.

Thus, regulating indoor air humidity is an important component of the prevention of infectious and non-infectious respiratory diseases, preservation of the functional integrity of the airways, and improvement of overall public health. Integrating microclimate management measures into public health strategies and building standards is both appropriate and scientifically justified.

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Дата першого надходження статті до видання: 23.02.2026

Дата прийняття статті до друку після рецензування: 02.04.2026

Дата публікації (оприлюднення) статті: 29.05.2026