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RESEARCH ARTICLE

The Relationship Between Indoor Air Quality and the Incidence of Respiratory Health Problems in Wetland Areas

Agita Diora Fitri[1], Novrikasari[2], Amin Rejo[3], Tan Malaka[4], Mariana[5]
Universitas Sriwijaya[1,2,3,4,5]
*Corresponding Author: agitadioraf@gmail.com

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ABSTRACT

Indoor air quality (IAQ) is a key determinant of respiratory health. In wetland areas, high humidity fosters fungal growth that may increase the risk of acute respiratory infections (ARI). WHO (2021) highlights dampness and mould as major health determinants, while EPA (2023) emphasizes that poor ventilation, biological pollutants, and indoor smoking exacerbate IAQ problems. In Indonesia, the Ministry of Health Regulation No. 2/2023 sets environmental health standards, including indoor biological and physical parameters. However, scientific evidence on the association between indoor fungi and respiratory problems in wetland settlements remains limited.

INTRODUCTION

Indoor air quality (IAQ) is a crucial determinant of public health, particularly in environmentally sensitive areas such as wetlands. The WHO (2021) emphasizes that exposure to biological pollutants, including fungi, significantly impacts the incidence of respiratory diseases, particularly in vulnerable groups such as children, the elderly, and individuals with chronic lung disease. Fungi in indoor air can produce spores and secondary metabolites that act as allergens and toxins, increasing the risk of asthma, acute respiratory infections (ARI), and chronic respiratory diseases (Kumar et al., 2021).

Globally, systematic studies have shown that indoor air pollution, both in the form of biological particles (fungi, bacteria) and non-biological particles (PM, VOCs), is strongly correlated with decreased lung function, chronic bronchitis, and asthma exacerbations (Maung et al., 2022; Tran et al., 2023). Climatic and environmental factors, including high humidity, warm temperatures, and housing conditions in wet areas such as wetlands, trigger faster and more widespread mold growth (Ofremu et al., 2025). Studies in daycare centers have also shown that indoor air quality with biological contaminants worsens respiratory symptoms in children (Najib et al., 2024).

The Indonesian context, particularly wetland areas in South Sumatra, has high relative humidity (>70%) and is susceptible to exposure to airborne mold. Recent local research has found a significant association between residential environmental conditions and the incidence of respiratory infections (ARI), including coughing, shortness of breath, and asthma, in residents of urban wetland areas (Pratiningsih et al., 2025). This aligns with an EPA report (2023), which confirms that mold growth in homes is influenced by humidity and poor ventilation, and is directly linked to increased cases of allergies and respiratory disorders.

Minister of Health Regulation No. 2 of 2023 concerning Environmental Health Quality Standards (SBMKL) also emphasizes that indoor air quality, including biological parameters such as mold, must be controlled to prevent health risks. This standard regulates the monitoring of environmental factors such as lighting, humidity, temperature, CO_2, PM10, and PM2.5 as part of environmental-based disease prevention efforts.

In the era of climate change, the increasing trend of respiratory diseases caused by environmental factors is increasingly worrying. Longitudinal studies have shown a significant increase in the incidence of respiratory allergies in children with climate change and humidity fluctuations (G'ofurjonov, 2025; Holden et al., 2023). Therefore, research focusing on the role of indoor airborne molds as a determinant of respiratory health problems is crucial, particularly in wetland areas with unique ecological characteristics.

Based on the description, this study was conducted to analyze the relationship between indoor airborne mold and the incidence of respiratory health problems in communities in wetland areas, using the Acute Respiratory Infection (ARI) questionnaire with four main symptoms (asthma, cough, phlegm, shortness of breath).

METHODOLOGY

Fungi in indoor air were conducted using an impactor ns 1000 air sampler with culture media (agar plate) that had been given Sabouraud Dextrose Agar (SDA). Sampling point: center of the room, at least 1 meter from walls, windows, doors, and floors. Tool height: approximately 1.2–1.5 meters from the floor (human breathing zone). Sampling was carried out when: Normal occupant activity and ventilation were in normal conditions. Indoor air quality was taken through an air quality sampler to detect PM10, PM2.5, CO2, Humidity and Temperature while lighting was taken using a Lux meter. Research data were analyzed using PSPP.

RESULTS

Home ventilation was shown to have a significant association with respiratory health problems (OR = 2; p = 0.022). Respondents living in homes with inadequate ventilation experienced more respiratory problems (50.9%) than those living in homes with adequate ventilation (33.9%). This indicates that poor ventilation has the potential to increase the accumulation of indoor air pollutants, including mold, thereby increasing

the risk of respiratory problems. Floor type and roof type did not show a significant association with respiratory health problems ($p > 0.05$). The proportion of respiratory problems in homes with wooden floors (45.2%) was almost comparable to that in homes with cement/marble floors (51.2%). Similarly, roof tile (49.2%) and zinc (45.1%) roof types did not show significant differences in relation to respiratory problems.

House material showed a trend (OR = 1.6; $p = 0.164$), although it was not significant. Brick houses showed a higher prevalence of respiratory problems (55.3%) compared to wooden houses (44%). This is likely related to moisture being more easily trapped in brick walls, although this finding did not reach statistical significance. Household sewage drainage did not show a significant association ($p = 0.508$). Both houses with drainage (44.7%) and without drainage (49.4%) had relatively similar proportions of respiratory problems.

In contrast, the number of occupants in a home was strongly associated with respiratory problems (OR = 9.3; $p = 0.010$). Homes with ≥5 occupants had a higher prevalence of respiratory problems (53.1%) compared to homes with <5 occupants (10.8%). Residential density clearly contributes to an increased risk of respiratory infection transmission and worsens indoor air quality. Smoking habits inside the home were also significantly associated with respiratory health problems (OR = 6.5; $p = 0.025$). Respondents exposed to cigarette smoke inside the home experienced respiratory problems more frequently (81.1%) than those in homes without cigarette smoke exposure (39.6%). This is consistent with the literature stating that cigarette smoke is a major risk factor for acute and chronic respiratory diseases.

Finally, house cleaning habits also had a significant impact (OR = 5.8; $p = 0.027$). Respondents who rarely cleaned their homes had a higher prevalence of respiratory problems (71%) compared to those who cleaned regularly (29.4%). This can be explained by the close relationship between home cleanliness and the accumulation of dust, allergens, and mold growth, which can potentially trigger respiratory tract disorders. (Table 1).

Table 1.The Relationship Between Respiratory Health Problems and Research Home Characteristics

Characteristics of the House	**Respiratory Health Problems**		**OR**	**P**
	Yes n(%)	No n(%)		
Ventilation			2	0.022a
Inadequate	85(50.9%)	82(49.1%)		
Adequate	21(33.9%)	41(66.1%)		
Floor Type			1.7	0.485a
Wood	85(45.2%)	103(54.8%)		
Cement/marble	21(51.2%)	20(48.8%)		
Roof Types			1.2	0.574a
Roof tiles	32(49.2%)	33(50.8%)		
Zinc	74(45.1%)	90(54.9%)		
Home Materials			1.6	0.164a
Wood	80(44%)	102(56%)		
Brick	26(55.3%)	21(44.7%)		
Sewer			1.8	0.508a

There is	68(44.7%)	84(55.3%)		
There isn't any	38(49.4%)	39(50.6%)		
Number of Residents in the House			9.3	0.010b
≥5	102(53.1%)	90(46.9%)		
<5	4(10.8%)	33(89.2%)		
Smoking in the House			6.5	0.025a
Yes	30(81.1%)	7(18.9%)		
No	76(39.6%)	116(60.4%)		
House Cleaning Habits			5.8	0.027a
No	66(71%)	27(29%)		
Yes	40(29.4%)	96(70.6%)		

a) Chi Square test; b) Fisher exact test, p is significant if p <0.05

Total indoor airborne mold levels differed significantly between groups with and without respiratory health problems (p = 0.002). The median number of mold colonies in homes with occupants experiencing respiratory problems was higher (11,000 CFU/m^3; range 1,300–21,000) than in homes without (4,900 CFU/m^3; range 1,050–13,400). This indicates that higher exposure to airborne molds increases the risk of respiratory problems.

Room temperature was also significantly associated (OR = 4.3; p = 0.023). Respondents living in homes with uncomfortable temperatures (>30°C or <18°C) experienced higher rates of respiratory problems (88.4%) compared to those living in homes with comfortable temperatures (63.6%). Extreme temperatures are thought to worsen humidity and accelerate the growth of fungal spores, thereby increasing the risk of respiratory problems.

Indoor lighting showed a significant association (OR = 7.2; p = 0.025). Respondents living in homes with insufficient lighting (<120 Lux) were more likely to report respiratory problems (84.5%) compared to those with adequate lighting (42.9%). Poor lighting can create a humid environment that supports mold growth.

Air humidity (RH) was the strongest factor in this study (OR = 14; p = 0.001). Respiratory health problems were more common in respondents living in homes with high humidity (>70%), at 88.9%, compared to only 36.4% in those with normal humidity (40–70%). High humidity increases the risk of fungal colonization and microbial growth indoors.

Indoor CO_2 levels were also significantly associated (OR = 12.2; p < 0.001). Respondents living in homes with CO_2 concentrations >1,000 ppm experienced respiratory problems more frequently (90.2%) compared to those living in homes with CO_2 ≤1,000 ppm (42.9%). High CO_2 levels are an indicator of inadequate ventilation, which can worsen indoor air quality.

Overall, these findings indicate that indoor microenvironmental factors, particularly airborne mold counts, temperature, lighting, humidity, and CO_2 levels, are closely related to the incidence of respiratory health problems in communities living in wetland areas. Humidity and CO_2 appear to be the most dominant factors, followed by lighting, temperature, and airborne mold counts. (Table 2).

Table 2 The Relationship Between Indoor Air Quality and Respiratory Health Problems

Variables	Respiratory Health Problems		OR	p
	Yes	No		
Total Fungi (CFU)	11000(1300-21000)	4900(1050-13400)	-	0.002
Temperature (oC)			4.3	0.023
Uncomfortable	38(88.4%)	5(11.6%)		
Comfortable (18-30 oC)	14(63.6%)	8(36.4%)		
Lighting (Lux)			7.2	0.025
Less (<120 Lux)	49(84.5%)	9(15.5%)		
Sufficient (120-250 Lux)	3(42.9%)	4(57.1%)		
Humidity (RH)			14	0.001
High (>70%)	48(88.9%)	6(1.1%)		
Normal (40-70%)	4(36.4%)	7(63.6%)		
CO2 (ppm)			12.2	0,000
>1000 ppm	46(90.2%)	5(9.8%)		
≤1000 ppm	6(42.9%)	8(57.1%)		

This study found that indoor air quality in wetland areas is closely linked to the incidence of respiratory health problems. The most dominant factors are high humidity (>70%) and CO_2 levels above 1,000 ppm, which increase the risk of respiratory problems more than tenfold. Furthermore, airborne mold, uncomfortable indoor temperatures, inadequate lighting, indoor smoking, and poor housekeeping also significantly contribute to the increase in respiratory health problems.

To reduce the burden of this disease, household-based interventions and public policies are needed. Key recommendations include: monitoring airborne mold (CFU/m^3), controlling humidity through ventilation and home improvements, increasing lighting and natural/mechanical ventilation, as well as campaigns to ban smoking indoors and educate about residential hygiene. Implementation of Minister of Health Regulation No. 2 of 2023 (SBMKL) needs to be strengthened in wetland areas as a preventative measure to reduce the risk of environmentally-related respiratory diseases. (Table 3)

Table 3 Research Findings, Implications, and Policy Recommendations

Research Findings (Evidence)	Policy Implications & Recommendations
Airborne mold was higher in homes with respiratory complaints (p = 0.002)	Monitoring of fungal counts (CFU/m^3) and education about the health risks of fungi.
Uncomfortable temperature is associated with respiratory problems (p = 0.023)	Maintain room temperature in the range of 18–30°C.
Low lighting <120 Lux increases the risk (p = 0.025)	Improve natural/artificial lighting to a minimum of 120 Lux.

Humidity >70% high risk (OR = 14; p = 0.001)	Control the humidity in your home (improve ventilation, dehumidifier, repair the roof/walls).
CO_2 levels >1000 ppm were significant (OR = 12.2; p < 0.001)	Increase natural/mechanical ventilation to reduce CO_2 and improve air circulation.
Smoking habits & home hygiene are related to respiratory problems	Implement a smoking ban inside the home & regular residential hygiene education.

Discussion

This study showed that several household characteristics, particularly inadequate ventilation, a population density of ≥5 people, indoor smoking, and poor housekeeping practices, were significantly associated with increased respiratory health problems (ARI symptoms: asthma, cough, phlegm, and shortness of breath). In contrast, floor type, roof type, house materials, and drainage did not show significant associations.

Home ventilation has been shown to be a crucial factor. These results support WHO findings (2021), which confirm that humidity and mold are key determinants of indoor air quality, contributing to respiratory problems. WHO guidelines recommend humidity control and improved ventilation as preventative strategies (WHO 2021). Other studies have also shown that high humidity and poor ventilation increase the accumulation of mold spores and the risk of respiratory problems in children (Holden et al. 2023).

Furthermore, this study found a strong association between residential density and respiratory problems. Respondents living in homes with more than five occupants experienced more respiratory problems. This finding aligns with epidemiological reports that overcrowding increases the risk of acute respiratory infections (Najib et al. 2024; Pratiningsih et al. 2025). This factor is associated with reduced effective ventilation and increased exposure to indoor pollutants (Mannan & Al-Ghamdi 2021).

Another significant finding concerns indoor secondhand smoke exposure. This study found that indoor smoking is associated with a higher prevalence of respiratory disorders. The EPA (2023) confirms that secondhand smoke is a major indoor pollutant, along with mold and humidity. These pollutants are known to trigger asthma exacerbations, bronchitis, and chronic respiratory disorders (Kumar et al. 2021; Maung et al. 2022).

Another important finding concerns the role of home hygiene. Respondents who rarely clean their homes experience a higher prevalence of respiratory problems than those who regularly clean their homes. This may be explained by the accumulation of dust, allergens, and fungal spores in unclean environments (Kumar et al. 2021; Ofremu et al. 2025). Recent review studies also emphasize that biological contaminants (fungi, bacteria, mycotoxins) are a significant component of indoor air pollution impacting respiratory health (Tran et al. 2023).

Meanwhile, the variables of floor type, roof type, house material, and drainage were not significant in this study. This difference from previous studies is likely due to the unique

conditions of wetland areas. In wetland ecosystems, humidity and ventilation are more dominant determinants of fungal growth than variations in building materials (Pratiningsih et al. 2025).

In the context of climate change, these findings are even more relevant. Ofremu et al. (2025) reported that climate-related increases in temperature and humidity worsen indoor air quality and promote mold growth, thereby increasing the burden of respiratory diseases. This is in line with a report by G'ofurjonov (2025) which showed an increase in allergic respiratory diseases in children during climate change.

From a policy perspective, these findings reinforce the urgency of implementing Minister of Health Regulation No. 2 of 2023 concerning Environmental Health Quality Standards. This regulation mandates control of environmental parameters such as CO_2, PM10, PM2.5, temperature, humidity, and lighting. The results of this study indicate that humidity control, improved ventilation, and indoor smoking bans align with national standards and international recommendations (Ministry of Health of the Republic of Indonesia 2023; EPA 2023; WHO 2021).

Overall, this study is consistent with recent literature that both biological and non-biological indoor pollutants contribute to respiratory health problems. The interaction between structural, behavioral, and environmental factors—such as ventilation, home hygiene, density, and smoking habits—needs to be considered in health risk management strategies in wetland areas (Mannan & Al-Ghamdi 2021; Tran et al. 2023).

This study found that indoor airborne mold counts were significantly higher in homes with occupants experiencing respiratory health problems compared to those without. This is consistent with a review by Kumar et al. (2021) which confirmed that mold spores are a major biological pollutant in indoor air, acting as both allergens and toxins, and contributing to respiratory disorders. The WHO (2021) also emphasized that humidity and mold growth in dwellings are important determinants of indoor air quality, which impacts health.

The analysis also showed that indoor temperature is associated with respiratory health problems. Uncomfortable temperatures, particularly above 30°C, increase the prevalence of respiratory symptoms. A study by Tran et al. (2023) highlighted that climate change, with increasing temperatures, worsens air quality and accelerates the growth of microorganisms, including fungi, which can potentially exacerbate respiratory symptoms. This condition is even more relevant in wetland areas with their high temperatures and humidity.

Lighting has been shown to be associated with respiratory health. Homes with lighting levels below 120 Lux have a higher risk of respiratory disorders. This aligns with the findings of Pratiningsih et al. (2025), who reported that inadequate lighting contributes to high humidity in homes, which triggers mold growth. Minister of Health Regulation No. 2 of 2023 also includes lighting as a parameter in the Environmental Health Quality Standards (SBMKL) that must be monitored to maintain occupant health (Ministry of Health of the Republic of Indonesia 2023).

Air humidity (RH) was found to be the most dominant factor with the highest odds ratio (OR = 14). Respondents in homes with RH >70% experienced significantly more respiratory problems than those with normal RH (40–70%). This finding is consistent

with the literature stating that high humidity is a major factor in the growth of mold, bacteria, and other allergens indoors (Mannan & Al-Ghamdi 2021; Holden et al. 2023). The WHO (2021) emphasizes that humidity must be controlled to prevent mold growth and its impact on respiratory health.

Furthermore, indoor CO_2 levels are also significantly associated with respiratory health problems. High CO_2 (>1,000 ppm) is an indicator of inadequate ventilation (EPA 2023). A study by Najib et al. (2024) in daycare centers showed that high CO_2 levels were associated with decreased air quality and increased respiratory symptoms in children. Thus, CO_2 levels not only reflect the accumulation of occupant metabolism but also indicate poor air exchange, allowing mold spores and other pollutants to persist longer indoors.

The findings of this study reinforce the view that multifactorial interactions (airborne mold, humidity, temperature, lighting, and ventilation/CO_2) simultaneously affect the respiratory health of home occupants. This is consistent with a systematic review by Maung et al. (2022) which emphasized the importance of controlling various indoor pollutants, both biological and non-biological, to protect vulnerable groups. From a policy perspective, these results support the implementation of SBMKL (Minister of Health Regulation No. 2 of 2023) as a national guideline, while also aligning with WHO and EPA recommendations regarding humidity control, improved ventilation, and indoor lighting and temperature regulation (WHO 2021; EPA 2023).

CONCLUSION

This study shows that indoor environmental factors—specifically the amount of airborne mold, temperature, lighting, humidity, and CO_2 levels—are significantly associated with respiratory health problems in wetland communities. High humidity (>70%) and CO_2 levels above 1,000 ppm are the most dominant determinants, followed by insufficient lighting, uncomfortable temperatures, and high numbers of airborne mold colonies.

These findings strengthen evidence that home microenvironmental conditions play a significant role in increasing the risk of respiratory disorders. Therefore, efforts to control indoor air quality are crucial, especially in wetland areas with high humidity.

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