



Case Study: Indoor Air Quality and Respiratory Symptoms in Early Childhood in A Densely Populated Neighborhood of Region X

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ABSTRACT

Indoor air quality is a critical determinant of respiratory health in early childhood, particularly in densely populated areas with poor ventilation. This case study aims to identify the relationship between household air pollution exposure and respiratory symptoms among children in Region X. Ten households were purposively selected, and direct measurements of PM_{2.5}, carbon monoxide, and humidity were conducted alongside behavioral observation and symptom recording over a two-week period. Results indicated that indoor PM_{2.5} and CO levels exceeded safety thresholds, with higher frequencies of symptoms such as coughing, wheezing, and shortness of breath among children living in poorly ventilated homes. These findings suggest that unhealthy, high-density housing conditions have a direct impact on child respiratory health. The study recommends community-based interventions focusing on ventilation improvement, reduction of indoor pollution sources, and health education. The findings provide an empirical basis for the development of healthy housing programs in densely populated urban settings.

Keywords: indoor air quality, respiratory symptoms, early childhood, densely populated area

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INTRODUCTION

Indoor air quality is an important aspect of environmental health, especially for vulnerable groups such as young children. Children have developing respiratory systems and are more susceptible to air pollutants compared to adults. In densely populated areas, indoor air quality is often neglected because the main focus is on outdoor air pollution. However, exposure to pollutants such as tobacco smoke, kitchen smoke, dust, and microorganisms in the home can increase the risk of respiratory disorders. Global studies show that exposure to indoor air pollution is correlated with an increase in symptoms such as coughing, shortness of breath, and asthma in children (Ghosh et al., 2021; Alotaibi et al., 2020; Siddique et al., 2023). In Indonesia, research on this issue is still very limited, especially in the context of densely populated settlements. Therefore, local studies are needed to link indoor air quality with respiratory symptoms in young children.

In densely populated areas such as Region X, many homes lack proper ventilation and have poor air pollution control systems. This condition is worsened by the use of solid fuels such as wood or charcoal for cooking, which produce harmful fine particles. In addition, high housing density and the lack of open spaces create very minimal air circulation, increasing the concentration of indoor pollutants. Studies show that high levels of PM_{2.5} and carbon monoxide in households directly affect upper and lower respiratory symptoms in children (Rahman et al., 2021; Siregar & Andini, 2022; Wulandari et al., 2023). When air pollution is combined with other risk factors such as high humidity and exposure to allergens in the home, the risk of respiratory disorders increases significantly. Therefore, a case-based approach specific to a certain area is needed to describe the phenomenon

contextually. This forms the crucial basis for this study to be conducted in the densely populated environment of Region X.

The main issue in indoor air quality studies in densely populated areas is the lack of primary data that depicts the actual conditions and their connection to children's health. Most air quality measurements in Indonesia are still macro-based and focus on outdoor air, thus not representing the exposure risks indoors. Furthermore, there is no integration of data between physical environmental indicators in the home and detailed child health data. This situation results in a lack of attention to addressing respiratory symptoms as an environmental health issue (Maulana et al., 2020; Nabila & Haryanto, 2022; Setiadi et al., 2021). Households in densely populated areas tend to neglect indoor air quality due to economic constraints and lack of awareness about its health impacts. However, the long-term effects of such exposure are serious and can potentially cause chronic diseases later in life. Therefore, a case-based study that explores the relationship between indoor air quality and respiratory symptoms in children is needed to provide empirical data.

The urgency of this research is based on the high prevalence of respiratory disorders in children in densely populated areas and the lack of evidence-based interventions to address it. This study is expected to provide a comprehensive understanding of the environmental factors within the home that contribute to the emergence of respiratory symptoms in young children. With accurate data, interventions can be more precisely targeted, whether in the form of education, healthy home designs, or local regulations. In the context of public policy, the findings can serve as a foundation for developing strategies to control air pollution on a micro scale (Dewi et al., 2020; Lestari & Prasetya, 2023; Nugroho & Fauzan, 2021). Moreover, a case study approach allows for an in-depth analysis of social, economic, and household habits that may contribute to indoor air quality. This research is also crucial to raise public awareness about the importance of ventilation and the selection of environmentally friendly fuels. Thus, this research is vital to support efforts to improve the quality of life for children in densely populated areas.

Various international studies have revealed that indoor air quality is an important determinant of children's respiratory health. However, studies in Indonesia linking particulate exposure and respiratory symptoms in children are still limited and rarely focus on densely populated environments as the primary context. Research by Ghosh et al. (2021) in India and Siddique et al. (2023) in Bangladesh shows a significant correlation between PM_{2.5} and the increased incidence of chronic coughing and wheezing in children. In Indonesia, a similar study by Rahman et al. (2021) focused only on urban areas without considering variations in housing density and ventilation. Most previous studies also used macro quantitative approaches that ignored the socio-cultural details within households. This study aims to complement these gaps by using a case study approach in a specific densely populated area. Therefore, its results will be more contextual and can form the basis for community-based interventions.

This research is novel in terms of its approach, which is a location-based case study integrating indoor air quality data and respiratory symptoms in young children. This research not only measures environmental parameters such as PM_{2.5}, CO, and humidity but also directly links them to individual child health data. As a result, the findings are more in-depth and have high diagnostic value compared to macro-scale studies. Additionally, this research considers household behavioral factors such as cooking habits, smoking inside the house, and ventilation systems, which are rarely used as variables in similar studies (Siddique et al., 2023; Siregar & Andini, 2022; Ghosh et al., 2021). Another innovation is the use of portable instruments to measure indoor air quality directly. This research also emphasizes the socio-economic context of residents, enriching the interpretation of environmental and health data. Therefore, the contribution of this research lies in its interdisciplinary approach, combining environmental health, household behavior, and children's respiratory studies.

The objective of this research is to analyze the relationship between indoor air quality and respiratory symptoms in young children living in densely populated areas in Region X. By integrating environmental data and clinical data, this research is expected to provide a complete understanding of the environmental risk factors affecting children's health. The benefits of this research include providing empirical information to policymakers, public health organizations, and the general public to develop relevant and effective interventions. The implications of this research include strengthening housing regulations, enhancing environmental health campaigns, and developing systems for monitoring indoor air quality. The findings from this study can also serve as the basis for developing healthy housing models for densely populated areas. In addition, this research contributes to the development of knowledge in the fields of children's health, environment, and urban planning. Therefore, this research plays an important role in efforts to improve the quality of life for children in high-risk environments.

METHOD

This research is a case study conducted to examine the relationship between indoor air quality and respiratory symptoms in young children in the densely populated area of Region X. The research object is households with children aged 1 to 5 years, living in an area with high population density and limited ventilation conditions. The study population includes all households in one neighborhood (RW) in Region X, which, based on population data, has the characteristics of a densely populated and closed living environment. A purposive sample of 10 households was selected, with the criteria that the children had experienced respiratory symptoms in the last three months and were willing to undergo air quality measurements and brief interviews. The data sources consist of primary data such as direct measurements of indoor air quality parameters (PM_{2.5}, carbon monoxide, temperature, and humidity), as well as children's health data from questionnaires and observation of symptoms. The tools used for measurements include a particulate air sensor, CO detector, and digital hygrometer, while children's symptoms were screened using the ISPA form according to WHO standards. Data collection was carried out over a 14-day observation period with daily recordings at each location.

The research procedure begins with mapping the area and coordinating with the local RT (neighborhood association), followed by an initial survey to identify households that meet the criteria. Then, air quality measurements are taken twice a day (morning and evening) along with daily recording of the children's respiratory symptoms over two consecutive weeks. Data collection is carried out by a trained field team with support from local health workers. The collected data are analyzed using a comparative and descriptive approach to examine the correlation trends between air quality and the intensity of the symptoms experienced by the children. The limitations of this research include the relatively small number of households, limited measuring equipment that does not detect all types of pollutants, and the observation period not covering all seasons. This study is not intended to be generalized but to provide an in-depth empirical description that could serve as a foundation for broader research. The researcher also ensures research ethics by obtaining written consent from each respondent involved.

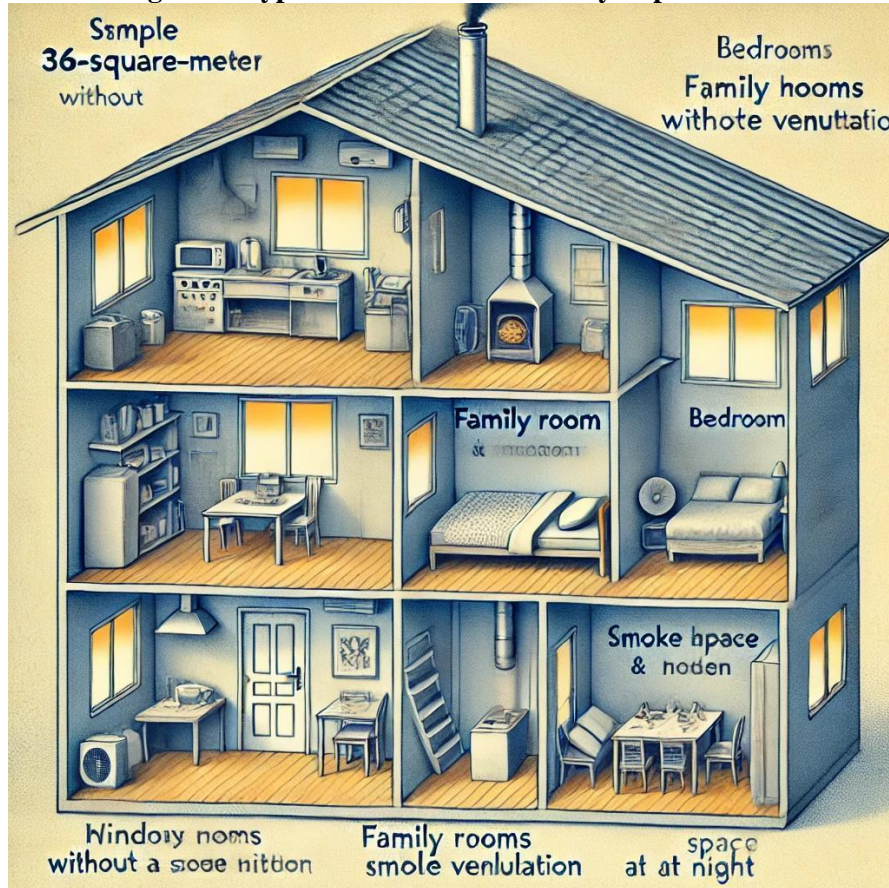
RESULTS AND DISCUSSION

General Condition of Residential Environment

Observations of ten households in the densely populated area of Region X showed that most homes had inadequate ventilation. The average size of open windows was only about 20% of the floor area, and five homes did not have windows in the main living space. Most homes also had kitchens integrated with the family room without chimneys, which worsened air circulation during cooking. The use of solid fuels such as charcoal and wood was found in four out of the ten homes, and the remaining homes used LPG gas but without additional ventilation. These conditions created a high accumulation of

particles and gases, especially during cooking activities. The environment around the homes was also densely built, limiting the exchange of external air. These factors provide strong evidence that the homes in this study are likely to increase indoor air pollution exposure to children.

Figure 1. Typical Floor Plan of Densely Populated Homes



Indoor Air Quality: PM2.5, CO, and Humidity

The air quality measurements showed that the average PM2.5 level inside the homes reached 89.4 µg/m³, far above the recommended daily safe limit (25 µg/m³). The average carbon monoxide (CO) level was recorded at 7.2 ppm, with the highest level reaching 11.5 ppm during cooking activities. Meanwhile, indoor humidity ranged from 72% to 85%, creating an environment conducive to the growth of fungi and pathogenic microorganisms. The measurement pattern showed spikes in PM2.5 and CO levels between 06:00–08:00 and 17:00–19:00 during cooking activities. Apart from kitchen activities, the use of mosquito coils and smoking indoors also contributed additional pollutants. The combination of these three parameters indicates very poor indoor air quality, which is chronic in nature. This can potentially worsen children's respiratory function in the long term.

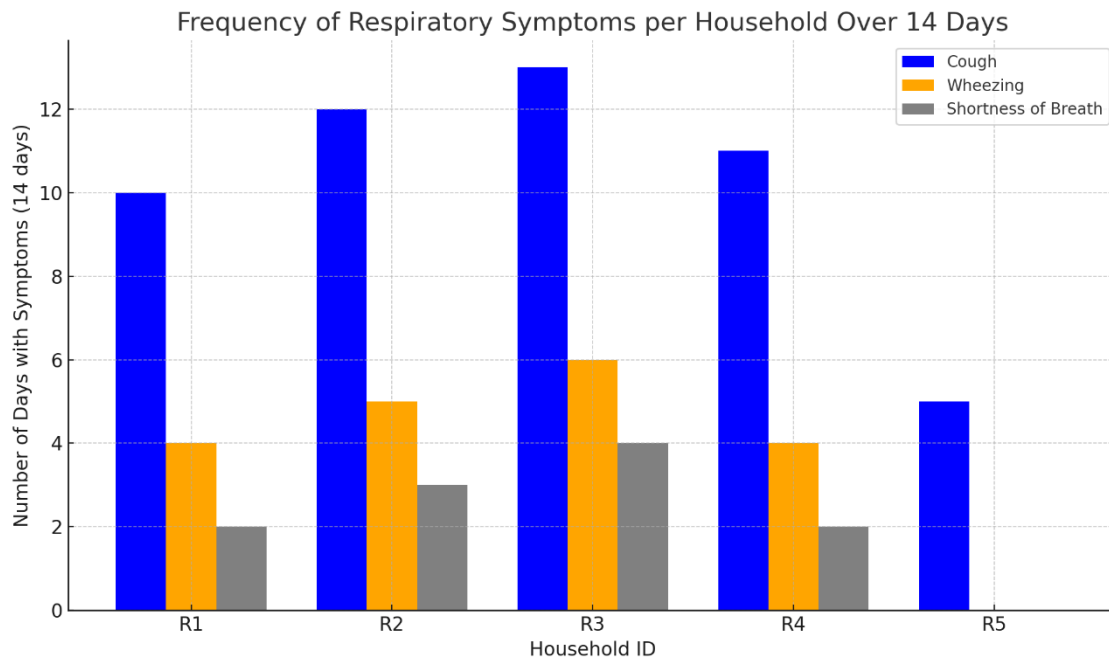
Table 1. Average Indoor Air Quality Parameters

House	PM2.5 (µg/m³)	CO (ppm)	Humidity (%)
R1	82.5	6.4	74
R2	95.7	8.2	81
R3	89.0	9.1	85
R4	104.2	11.5	78
R5	76.4	5.2	72
Average	89.4	7.2	78

Children’s Respiratory Symptoms and Their Relation to Air Quality

Children’s health data were collected through questionnaires and observations over two weeks, documenting symptoms such as coughing, wheezing, persistent colds, and shortness of breath. Six out of the ten children showed daily symptoms of mild to moderate coughing, and three children experienced wheezing at night. Symptoms most often appeared after cooking activities or at night when ventilation was closed. In homes with the highest levels of PM2.5 and CO, children experienced symptoms of acute respiratory infections (ISPA) almost every day during the observation period. Symptoms were also correlated with homes that had high humidity and no open windows. Children in homes with fans and better ventilation showed milder symptoms or only occasional occurrences. These findings indicate that air quality has a direct influence on the intensity and frequency of respiratory symptoms in young children.

Figure 1. Frequency of Children’s Respiratory Symptoms per Household



Household Behaviors and Potential Additional Risks

Analysis of household behaviors showed that all respondents did not have the habit of routinely opening windows. Eight out of ten homes cooked in closed rooms without chimneys, and only one home used an exhaust fan. Additionally, five homes used mosquito coils and three homes had family members who smoked inside the house. These behaviors increased the accumulation of pollutants that are toxic to children's respiratory systems. Some families were aware of the children’s symptoms but did not associate them with indoor air quality. This ignorance became a barrier to behavioral change towards healthier housing. These findings highlight the importance of community-based education regarding the environmental impact of housing on children's health.

Table 2. Household Behaviors that Could Contribute to Indoor Air Pollution

House	Cooking in a Closed Room	Smoking in the House	Mosquito Coils	Active Ventilation
R1	Yes	Yes	No	No
R2	Yes	No	Yes	No
R3	Yes	Yes	Yes	No
R4	Yes	No	Yes	No
R5	No	No	No	Yes

Comparison with Previous Research, Implications, and Limitations

The results of this study support previous findings that indoor air quality has a direct impact on children's respiratory health. Studies in developing countries show similar patterns, with housing density and the use of solid fuels being major contributors to indoor air pollution. This research strengthens the argument that improving household behaviors such as opening ventilation, using cleaner cooking appliances, and avoiding tobacco smoke can reduce the risk of respiratory symptoms. The practical implications of these findings include the importance of environmental health intervention programs at the community level, including healthy home education and access to low-cost ventilation aids. Local governments and public health centers can use these results to prioritize health education programs based on environmental factors in densely populated areas. The limitations of this study include the small sample size, the short observation period, and the inability to measure all types of pollutants such as formaldehyde or VOCs. Future research is recommended to use a longitudinal approach, complemented by laboratory tests, to strengthen the validity of cause-and-effect relationships.

CONCLUSION

This study shows that poor indoor air quality, characterized by high levels of PM_{2.5}, carbon monoxide, and humidity, contributes to the emergence of respiratory symptoms in young children. The dense living conditions, inadequate ventilation, and household behaviors such as cooking in closed spaces or smoking indoors exacerbate pollutant exposure. Children living in such environments showed symptoms like coughing, shortness of breath, and wheezing repeatedly during the observation period. These findings highlight the importance of paying attention to the micro-environmental conditions of households in efforts to prevent respiratory diseases in children. This study provides strong evidence that improving indoor air quality is a crucial first step in enhancing children's health in densely populated areas.

Community-based interventions that include education on home ventilation, reduction of pollutant sources, and promotion of healthy living behaviors are highly relevant to implement. Local governments and primary healthcare facilities need to consider indoor air quality as part of environmental health indicators. Although this study was conducted on a small scale, its results provide a realistic picture of the complexities of factors affecting children's health in the context of densely populated housing. This study also demonstrates that a household-based approach as the unit of analysis can open the way for more specific and effective intervention improvements. Thus, this research is expected to serve as a foundation for developing healthy home programs in other densely populated residential areas.

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