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Exposure to Indoor Air Pollution, Symptoms, and The Level of Control of Bronchial Asthma: A Literature Review

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ABSTRACT

Bronchial asthma is a chronic inflammatory disease of the airways that represents a global health burden, affecting approximately 300 million people worldwide. One environmental factor that contributes to the worsening of symptoms and reduced asthma control is exposure to indoor air pollution, given that most people spend 80–90% of their time indoors. Indoor air pollution can stem from cigarette smoke, combustion products, volatile organic compounds, humidity, mold, and biological allergens. Exposure to these pollutants can be assessed objectively using sensors or subjectively through self-assessment questionnaires. This literature review aims to summarize the scientific evidence regarding the definition, epidemiology, classification, pathogenesis, risk factors, symptoms, and assessment tools for asthma control, as well as the relationship between exposure to indoor air pollution and symptoms and the level of bronchial asthma control. A narrative literature review was conducted by searching primary and secondary literature across databases including PubMed, Scopus, and Google scholar up to 2026 using relevant keywords related to indoor air pollution, asthma, and control levels. The results of the review indicate that self-assessment using questionnaires is a practical, inexpensive method capable of capturing individuals' perceptions of their home air quality, although its limitations lie in subjectivity and the lack of standardized instruments, particularly in Indonesia. Evidence from various studies shows that increased exposure to indoor pollutants is associated with an increased frequency of symptoms.

Keywords: indoor air pollution; bronchial asthma; self-assessment questionnaire; asthma control level; sustainable environmental health

INTRODUCTION

Bronchial asthma is a chronic respiratory disease characterized by airway inflammation, bronchial hyperresponsiveness, and reversible airway obstruction [1]. This disease can affect people of all ages and is a significant public health problem worldwide. According to the Global Burden of Disease study, there are an estimated 300 million cases of asthma worldwide, with more than 460,000 deaths each year [2]. Uncontrolled asthma can reduce quality of life, increase the risk of exacerbation, and place an additional burden on the healthcare system [3].

One environmental factor that contributes to the worsening of asthma is indoor home environment conditions. Studies estimate that people spend about 90% of their time indoors [4], so air quality in these environments plays a crucial role in respiratory health. Long-term exposure to indoor pollution can worsen asthma symptoms and reduce the level of bronchial asthma control [5]. However, the characteristics of the home environment and its sources of pollution vary greatly across regions due to differences in social, economic, and cultural factors, as well as lifestyle, making it necessary to develop assessment methods capable of identifying these exposures on an individual basis.

Various approaches have been developed to assess indoor pollution exposure, ranging from the use of sensor technology to questionnaire-based self-assessment methods. Research on monitoring environmental conditions and asthma patient treatment adherence using technology has successfully identified personal asthma triggers [6], while monitoring exposure to nitrogen dioxide and ozone using real-time sensors has been shown to help patients avoid exposure that triggers exacerbations [7]. Although advanced technology provides accurate and objective data, its limitations lie in high costs, limited availability, and the need for specialized expertise in its operation. Therefore, self-assessment using questionnaires serves as a practical and efficient alternative for identifying household environmental risk factors, although a systematic review indicates that most existing questionnaires do not adequately describe their validation methods and have not been extensively studied in Indonesia [8].

This literature review was conducted to summarize the scientific evidence regarding the basic concepts of bronchial asthma, its risk factors and triggers, instruments for assessing asthma control, the characteristics of indoor air pollution, methods for assessing it, and the relationship between such exposure and asthma symptoms and control levels. It is hoped that this discussion will serve as a conceptual foundation for research and clinical practice in asthma management based on household environmental factors, while also supporting efforts to achieve the Sustainable Development Goals in the areas of health (SDG 3 – Good Health and Well-being) and sustainable cities and communities (SDG 11 – Sustainable Cities and Communities).

MATERIALS AND METHODS

Search Strategy and Information Sources

This literature review was conducted by searching primary and secondary literature across several electronic databases, including PubMed, Scopus, ScienceDirect, Web of Science, and Google Scholar, as well as official guidelines from international and national health organizations (World Health Organization [WHO] and Global Initiative for Asthma [GINA]). The literature search included studies published up to 2026. The search strategy utilized combinations of Medical Subject Headings (MeSH) terms and relevant free-text keywords joined by Boolean operators (AND, OR):

- ("indoor air pollution" OR "indoor air quality" OR "household exposure" OR "indoor pollutants")
AND ("bronchial asthma" OR "asthma control" OR "asthma symptoms")
AND ("self-assessment questionnaire" OR "ACT" OR "ACQ" OR "environmental assessment").

Eligibility Criteria

Studies were selected based on predefined inclusion and exclusion criteria:

- *Inclusion Criteria*

1. Peer-reviewed original research articles, systematic reviews, scoping reviews, and clinical practice guidelines.
2. Studies evaluating indoor air pollution sources (e.g., environmental tobacco smoke, combustion byproducts, volatile organic compounds, mold, humidity, biological allergens).
3. Studies investigating clinical symptoms of bronchial asthma, assessment tools for asthma control (e.g., ACT, ACQ), or self-assessment questionnaires.
4. Articles published in English or Indonesian with full-text availability.

- *Exclusion Criteria*

1. Studies focusing exclusively on outdoor/ ambient air pollution without assessing indoor home environments.
2. Articles lacking clear methodological descriptions.
3. Conference abstracts without full text, letters to the editor, or non-peer-reviewed commentaries.

Study Selection and Data Extraction

The selection process involved initial screening of titles and abstracts to remove duplicates and non-relevant articles, followed by a full-text assessment of eligible studies. Data were extracted systematically using a standardized extraction framework, capturing key information including author(s), publication year, study design, geographical setting, indoor exposure evaluation tools (objective sensors vs. subjective self-report questionnaires), asthma control outcome measures, and main clinical findings.

Data Synthesis

Given the heterogeneity of the included studies regarding exposure parameters, measurement tools, and study designs, a thematic narrative synthesis was performed. Extracted findings were categorized into key thematic domains:

1. Definition, epidemiology, classification, and pathogenesis of bronchial asthma.
2. Triggers and symptoms of asthma.
3. Assessment of tools for asthma control.
4. Indoor air pollution exposure assessment methods.
5. The relationship between indoor environmental exposure and asthma control levels.

Definition and Epidemiology of Asthma

The term "asthma" comes from the Greek word "asthma," which means "difficulty breathing." The World Health Organization (WHO) defines asthma as a chronic lung disease that can affect people of all ages due to inflammation and narrowing of the airways [9]. The Ministry of Health of the Republic of Indonesia defines asthma as a chronic inflammatory disorder of the airways that causes bronchial hyperresponsiveness to various stimuli, characterized by recurrent episodic symptoms such as wheezing, coughing, shortness of breath, and a tightness in the chest, especially at night, which are generally reversible with or without treatment [10]
As one of the noncommunicable diseases with a significant impact on global health, asthma is estimated to account for 21.6 million disability-adjusted life years (DALYs) worldwide [2].

The prevalence of asthma varies considerably among countries; high-income countries such as the United States, the United Kingdom, and Australia have higher prevalence rates than low-income countries, partly due to the high proportion of undiagnosed cases, particularly among adolescents, resulting from limited access to health care [11]. In South Asia, the number of people with asthma in India is estimated at 39 million, accounting for approximately 13% of the total global asthma burden, with a relatively high mortality rate [12].

Environmental factors also influence the epidemiology of asthma, particularly levels of exposure to both outdoor and indoor air pollution. Countries with the highest levels of air pollution, such as Bangladesh, Pakistan, and India, have a high burden of asthma [13]. Exposure to nitrogen dioxide in urban areas is even estimated to contribute to 13% of new asthma cases in children globally, with the highest burden in major cities such as Delhi and Dhaka [14]. Conversely, countries with good air quality, such as New Zealand, Finland, and Canada, tend to have more stable asthma prevalence and better-controlled exacerbation rates. In developing countries, indoor air pollution also plays a major role due to the use of solid fuels for cooking and inadequate home ventilation.

Classification and Pathogenesis of Asthma

Asthma can be classified based on phenotype, severity, and etiology. Based on phenotype, asthma is divided into atopic (extrinsic) asthma, which has clear external causes and is closely associated with a history of allergies and the production of specific immunoglobulin E (IgE), and non-atopic (intrinsic) asthma, which is not related to allergies but can be triggered by respiratory tract infections, stress, obesity, or other environmental factors [15]. Based on severity, the Global Initiative for Asthma (GINA) guidelines classify asthma into the categories of intermittent, mild persistent, moderate persistent, and severe persistent asthma, distinguished by the frequency of daytime and nighttime symptoms, impairment of daily activities, and lung function values (FEV1) [16]. Based on its etiology, asthma is classified into IgE-mediated allergic asthma, triggered by environmental allergens such as dust mites, pollen, and animal dander, and non-allergic asthma, which typically develops in adulthood and is triggered by infections, environmental irritants, or emotional stress [15]. In addition, there is also occupational asthma, which is caused by exposure to be sensitizing agents in the workplace, such as industrial chemicals, organic dust, metal fumes, or latex, and is characterized by symptoms that improve when not working and worsen during work hours [17].

Pathogenetically, asthma involves a complex interaction between genetic and environmental factors that trigger an inflammatory response in the airways. This process involves interactions between the airway epithelium, the innate immune system, and the adaptive immune system, with eosinophils and mast cells playing a primary role, accompanied by the involvement of neutrophils and T lymphocytes. Inhalation of antigens activates mast cells and type 2 T helper cells in the airways, triggering the release of inflammatory mediators such as histamine, leukotrienes, and cytokines (IL-4 and IL-5), which subsequently cause the differentiation and migration of eosinophils to the lung tissue, thereby leading to the clinical manifestations of asthma [18].

Risk Factors and Triggers of Asthma

Genetic factors include genetic predisposition, atopy, airway hyperresponsiveness, gender, and race/ethnicity. Environmental factors that influence the development of asthma in individuals with a specific predisposition include indoor allergens (house dust mites, animal dander, mold), outdoor allergens (pollen), substances in the workplace, secondhand smoke, air pollution, parasitic infections, socioeconomic status, diet, medications, and obesity. In addition, there are environmental factors that act as triggers for exacerbations or contribute to persistent symptoms, such as indoor and outdoor allergens and pollution, physical activity, weather changes, certain foods, excessive emotional expression, and exposure to irritants. Some specific triggers of airway hyperresponsiveness in people with asthma include viral and bacterial infections, indoor substances (dust mites, house dust, cockroaches), outdoor substances (pollen, mold), foods containing certain preservatives, medications such as aspirin and beta-blockers, irritants such as perfume, excessive emotional expression, cigarette smoke, indoor and outdoor air pollution, physical activity (exercise-induced asthma), and changes in weather [19].

Signs, Symptoms, and Assessment Tools for Asthma Control

Asthma attacks are generally characterized by coughing, wheezing, and shortness of breath (dyspnea) [9]. The cough associated with asthma tends to be dry and persistent, often occurring at night or in the early morning, while wheezing is an additional breathing sound caused by airway narrowing that is more clearly audible during exhalation. Shortness of breath in people with asthma is episodic and tends to worsen at night, especially after exposure to allergens, cold air, physical activity, or upper respiratory tract infections [9]. Other symptoms that may arise include the use of accessory breathing muscles as the body's compensatory response to increased respiratory effort caused by airway obstruction during an acute attack [20]. Effective symptom management is considered crucial for preventing relapses and limiting long-term airway damage [21].

Assessing asthma control status is a key component in evaluating the success of asthma management; it is typically done by asking about asthma-related symptoms over the past four weeks. The two instruments most frequently used in clinical and scientific settings are the Asthma Control Test (ACT) and the Asthma Control Questionnaire (ACQ), both of which have been internationally validated. The ACT was developed by Nathan et al. as a self-assessment questionnaire that evaluates asthma control over the past four weeks; it consists of five questions scored on a scale of 1 (worst) to 5 (best), resulting in a total score ranging from 5 to 25, with scores of 20–25 interpreted as controlled asthma, 16–19 as partially controlled asthma, and ≤15 as uncontrolled asthma [22]. The ACQ was developed by Juniper et al. as a quantitative instrument consisting of seven questions, although the six-question version without spirometry is more commonly used in practice due to its ease of implementation [23]. The ACQ score is calculated as the average of all items answered on a scale of 0–6, with scores of ≤0.75 interpreted as controlled asthma, 0.75–1.49 as partially controlled asthma, and ≥1.5 as uncontrolled asthma [23].

Exposure to Air Pollution and Its Impact on Asthma
Air pollution is the contamination of the atmosphere by a mixture of gases, solid particles, and liquid aerosols that are harmful to human health, with the main components being fine particulate matter (PM10 and PM2.5), ozone, sulfur dioxide, carbon monoxide, and nitrogen dioxide. Studies show that air pollution can reduce global average life expectancy by up to three years, making it one of the world's greatest health risk factors [24]. Both outdoor and indoor air pollution play a role in the onset and exacerbation of asthma. Outdoor pollution from motor vehicle emissions, the burning of fossil fuels, and wildfires produces fine particulate matter, ozone, and nitrogen dioxide, which are associated with an increased risk of asthma development in children, particularly in urban areas with poor air quality [25].

Indoor air pollution frequently receives less attention than outdoor air pollution, even though its effects are estimated to be two to ten times more harmful, given that most people spend 80–90% of their time indoors, whether at home, in the office, or in other public places [26]. Sources of indoor air pollution can include pollutants generated inside buildings, such as cleaning products, pesticides, and cigarette smoke; outdoor pollution that enters indoor spaces; building materials such as adhesives, fiberglass, asbestos, and formaldehyde; microbial contamination such as mold and bacteria; and insufficient air exchange due to inadequate ventilation. A systematic review identified various types of indoor environmental exposures relevant to asthma patients, including the use of air-quality equipment (air conditioners, air purifiers, humidifiers), environmental tobacco smoke, indoor combustion byproducts, volatile organic compounds, biological exposures from pets and dust mites, ventilation conditions, temperature, humidity, frequency of house cleaning, building characteristics, and occupancy density [8].

Methods for Assessing Indoor Air Pollution Exposure

Assessments of indoor air pollution exposure can be conducted using both objective and subjective approaches. The objective approach utilizes portable sensors that enable real-time monitoring of fine particulate matter and gaseous pollutants such as nitrogen dioxide and can provide location- and time-based information to identify daily exposure patterns, although their accuracy is still limited compared to reference monitoring instruments owned by environmental agencies [27]. The use of commercial air quality monitoring devices has also demonstrated the ability to measure parameters such as fine particulate matter, volatile organic compounds, temperature, and humidity, although their accuracy does not yet match that of professional measuring instruments [28].

The subjective approach is generally conducted through self-assessment questionnaires designed to identify the presence of pollution sources and home environmental conditions, including questions regarding the presence of cigarette smoke, mold, excessive humidity, the use of solid fuels, and home ventilation conditions, typically using a binary question format [8]. Comparisons between self-assessment methods and the use of objective measurement tools have been a topic of research in the context of asthma management. Studies have found that individuals' perceptions of air quality in their home environment can have a significant impact on respiratory health status, even more so than the results of objective air pollution measurements [29]. These findings suggest that subjective approaches hold significant value in assessing levels of indoor air pollution exposure, although their validity still needs to be thoroughly tested before they can be widely applied in clinical practice and research [8].

Questionnaires as Self-Assessment Tools

A questionnaire is a data collection tool consisting of a series of written questions designed to systematically and objectively obtain specific information from respondents, thereby enabling the measurement of research variables and simplifying the process of collecting large amounts of data. Based on the format of the questions, questionnaires are generally categorized into closed-ended questionnaires, which limit respondents' answers to available options and are thus easy to analyze statistically; open-ended questionnaires, which allow for narrative responses but are difficult to analyze quantitatively; and mixed questionnaires, which combine both formats. Questionnaires offer advantages such as efficient data collection, ease of analysis, and the potential to maintain respondent anonymity; however, they also have limitations, such as the inability to elicit in-depth information and the risk of respondent misunderstanding of questions that cannot be immediately clarified.

In the context of assessing exposure to indoor air pollution, self-assessment questionnaires are used to measure individual exposure levels based on respondents' perceptions or experiences regarding environmental risk factors. These questionnaires typically consist of binary questions covering sources of indoor pollution (cigarette smoke, solid fuels, gas stoves, candles), home environmental conditions (mold, humidity, ventilation), occupant behaviors (household cleaning habits, use of cleaning products, frequency of cooking in enclosed spaces), and home characteristics (room size and number of occupants) [8].

In both clinical practice and epidemiological research, such questionnaires serve as initial screening tools to identify households at high risk of exposure to indoor air pollution, thereby supporting more personalized strategies for asthma prevention and management.

The Relationship Between Indoor Air Pollution Exposure and Asthma Symptoms and Control Levels
Exposure to indoor air pollution is significantly associated with the worsening and onset of asthma symptoms. Indoor environments with poor ventilation tend to accumulate various irritant and allergenic pollutants, such as fine particulate matter, volatile organic compounds, formaldehyde, and biological allergens (molds, dust mites, cockroaches, pet dander), which can cause airway inflammation, increase bronchial hyperresponsiveness, and trigger oxidative stress. A systematic review indicates that exposure to excessive humidity, mold, and indoor chemical compounds is strongly associated with respiratory disorders and an increase in asthma symptoms [30]. Similar findings suggest that exposure to volatile organic compounds can significantly increase the risk of asthma and exacerbate symptoms in patients who have already been diagnosed [31]. Another study in children showed that exposure to high levels of formaldehyde is associated with a greater risk of asthma symptoms compared to children living in environments with low formaldehyde levels [32]. Overall, these findings confirm that poor indoor air quality is strongly correlated with increased asthma symptoms and severity.

The degree of asthma control is also influenced by indoor air quality, particularly in individuals with high sensitivity to irritants or allergens. Indoor pollutants can cause chronic inflammation of the airways and increase bronchial hyperresponsiveness, leading to worsening symptoms and reduced treatment effectiveness, which results in clinically uncontrolled asthma. Studies show that patients with high levels of exposure to household allergens, such as mold and dust mites, are more likely to experience uncontrolled asthma even after undergoing standard pharmacological therapy [33]. Conversely, interventions aimed at reducing exposure to indoor air pollution, such as using HEPA air filters, improving ventilation, and providing environmental education to families of asthma patients, have been shown to significantly improve asthma control [34]. These findings underscore the importance of assessing indoor environmental exposure, through both objective and subjective questionnaire-based approaches, as part of a comprehensive and sustainable asthma management strategy.

Synthesis and Conceptual Framework

Based on the above review, bronchial asthma is influenced by the interaction between genetic and environmental factors, with indoor environmental factors having a greater impact than outdoor environmental factors due to the fact that people spend the majority of their time indoors. Sources of indoor exposure, such as air quality equipment, cigarette smoke, combustion products, volatile organic compounds, biological exposures, ventilation, temperature, humidity, cleaning frequency, and occupancy density, can be assessed both objectively using sensors and subjectively through self-assessment questionnaires. These measured exposure levels can then be linked to clinical asthma symptoms such as shortness of breath, coughing, wheezing, and chest tightness, which ultimately influence the degree of asthma control, a factor that can be assessed using validated instruments such as the Asthma Control Test. Repeated and prolonged exposure to indoor pollution has the potential to exacerbate symptoms and reduce the level of asthma control; therefore, early assessment of the home environment is crucial as a basis for preventive interventions, both at the individual level and in terms of residential environmental health policies.

CONCLUSION

Bronchial asthma is a chronic inflammatory disease of the airways with a significant global health burden, influenced by complex interactions between genetic and environmental factors. Indoor air pollution is one of the environmental determinants that significantly contributes to the worsening of symptoms and a decline in asthma control, given that people spend most of their time indoors. Exposure assessment can be conducted objectively using sensors or subjectively through self-assessment questionnaires, with each method having its own advantages and limitations. Self-assessment questionnaires offer a practical, cost-effective approach capable of capturing individuals' perceptions of their home environment, although instruments specifically validated for the Indonesian context remain very limited. Existing scientific evidence consistently shows a link between high exposure to indoor pollutants and an increase in asthma symptoms and a decrease in asthma control; therefore, the development and validation of self-assessment questionnaires tailored to the local context are an urgent need to support early detection, preventive interventions, and the achievement of health and sustainable housing goals.

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