

REVIEW ARTICLE

Ventilation in school and students' health after outbreak of COVID-19: A systematic literature review

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Anita Dewi Moelyaningrum^{1*}, Soedjajadi Keman², Soenarnatalina Melaniani² and Corie Indria Prasasti²

Doctoral Degree Program of Public Health, Faculty of Public Health, Universitas Airlangga, Surabaya 60115, Indonesia¹; Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia²

***For Correspondence:** Email: Soedja_keman@fkm.unair.ac.id; Phone: +628121729908

Abstract

Ventilation is one of the factors that support the health of students needed to support the goals of education. The objective of this study is to analyze how ventilation at school impacts the health of students. Scopus and Web of Science were used to retrieve published articles on ventilation at school and students' health. The search method used the keywords "ventilation" OR "Indoor air pollution" OR "Indoor environment quality" AND "School" AND "Student" OR "Children" AND "Health", from 2019- May 2023. The ventilation in schools researched were ventilation methods, insufficient or lack of ventilation, and the frequency of opening windows. The air quality parameters studied in classrooms were Nitrogen Dioxide (NO₂); Particulate matter 10 (PM₁₀); Particulate matter 2,5 (PM_{2.5}); Particulate matter (PM₁); Ozone (O₃), benzene (C₆H₆), and carbon dioxide (CO₂). The results showed that the diseases identified in students as a result of poor ventilation were tiredness, bronchitis, symptoms of asthma, risk of infection, rhinitis, etc. We conclude that as ventilation reduces indoor air pollutants, thus related to student health, it should be prioritized to fulfil the requirements for the health of students. (*Afr J Reprod Health* 2024; 28 [10s]: 449-459).

Keywords: Ventilation, School health, Students, health, COVID-19 outbreak

Résumé

La ventilation est l'un des facteurs qui soutiennent la santé des élèves et sont nécessaires pour soutenir les objectifs de l'éducation. L'objectif de cette étude est d'analyser l'impact de la ventilation à l'école sur la santé des élèves. Scopus et Web of Science ont été utilisés pour récupérer des articles publiés sur la ventilation à l'école et la santé des élèves. La méthode de recherche a utilisé les mots-clés « ventilation » OU « Pollution de l'air intérieur » OU « Qualité de l'environnement intérieur » ET « École » ET « Étudiant » OU « Enfants » ET « Santé », de 2019 à mai 2023. La ventilation dans les écoles étudiées était les méthodes de ventilation, l'insuffisance ou le manque de ventilation et la fréquence d'ouverture des fenêtres. Les paramètres de qualité de l'air étudiés dans les salles de classe étaient le dioxyde d'azote (NO₂) ; les particules 10 (PM₁₀) ; Particules 2,5 (PM_{2,5}) ; Particules (PM₁) ; L'ozone (O₃), le benzène (C₆H₆) et le dioxyde de carbone (CO₂). Les résultats ont montré que les maladies identifiées chez les étudiants en raison d'une mauvaise ventilation étaient la fatigue, la bronchite, les symptômes d'asthme, le risque d'infection, la rhinite, etc. Nous concluons que dans la mesure où la ventilation réduit les polluants de l'air intérieur, donc liés à la santé des étudiants, elle devrait être une priorité pour répondre aux exigences en matière de santé des étudiants. (*Afr J Reprod Health* 2024; 28 [10s]: 449-459).

Mots-clés: Ventilation, Santé scolaire, Élèves, santé, Éclosion de COVID-19

Introduction

The COVID-19 pandemic has posed considerable threat to the general population¹ Available evidence indicate that children can get COVID-19 when exposed to risky areas² such as schools and public places. The value of ventilation was emphasized during the COVID-19 epidemic³, which led to new ventilation protocols being introduced in school buildings across the globe. An educational building,

like a school, is a place where teaching activities have enormous impact on students' health, well-being, and educational achievement. A vital component of a student's academic success and overall well-being is the learning environment which includes the use of sanitizers to promote skin and eye health and reduces throat irritation⁴. An educational building is also one of the places that have the potentials to attract contagious diseases. The pandemic of COVID-19 teaches us to be concerned

about air quality in schools because of the ease with which the virus can be transmitted in crowded schools among students, teachers, and staff⁵⁻⁷

School sanitation is an essential part of school health⁸, including classroom ventilation. Students spend more time in unfavourable indoor environments, but require a higher indoor air quality than adults. As a result of a variety of reasons, including their continual growth and the fact that they breathe more air, consume more food, and drink more water relative to their weight, children are more susceptible to environmental dangers than adults⁹. Children are in developmental age, they are sensitive people, and should be protected from poor environmental quality. They spend an extensive amount of time in the classroom at school, and the air quality in the classroom should be of concern.

Indoor air pollution levels can differ from outdoor levels in terms of both quantity and concentration. Students should receive protection that ensures that environmental conditions in classrooms are good so that they do not acquire or transmit diseases, both acute and chronic diseases. Evidence indicates that environmental quality in classrooms in several countries is often inadequate¹⁰⁻¹⁶. There are 8000 school buildings in the Mediterranean area that do not adhere to standard environmental quality criteria¹⁷. There are many ways to maintain quality in the classroom, one of which is the use of ventilation. Ventilation designs in schools should be carried out at the beginning of the construction of the school buildings

because it is often made based on many considerations¹⁸. Many ventilations often do not function properly¹⁹, and have problems such as errors in sizing, reduced performance due to lack of maintenance, and lack of operator knowledge²⁰. The space with poor ventilation has an increased risk of contamination like bacteria²¹. Ventilation has vital functions. It can decrease pollutants in the room like CO₂²².

Several investigations have been carried out on ventilation in schools and indoor air qualification²³⁻²⁵ but analysis on the health effects of poor ventilation effect on the health of students rarely had been conducted. The objective of this study is to determine the extent to which ventilation in the classroom correlates with students' health. We believe the results of the study will be relevant to design approaches for improving ventilation and the quality of air circulating in schools within the context of infectious pandemics such as COVID-19.

Conceptual framework

The conceptual framework of this research can be detailed with several variables, such as independent variables (Ventilation in school), dependent variables (Student Health), moderator variables (Indoor Quality) and media variables (Temperature, Moisture, Lighting, Disinfection etc). The objective of this research is focus in analysis about the existing ventilation in school impact the student health, not in the moderator variable and media variables although it cant avoided. (Figure1).

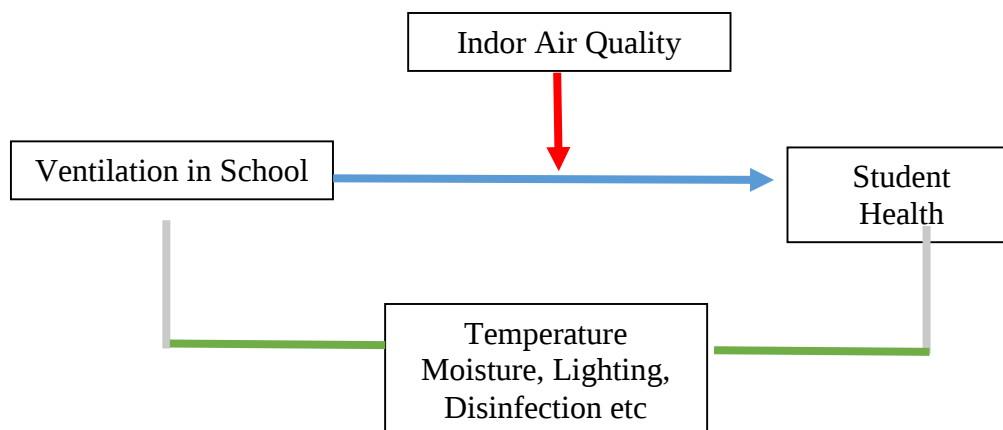


Figure 1: A conceptual framework for the ventilation, indoor air qualification, and health effects of students

Methods

The study was primarily based on a literature review. PRISMA guidelines were used to retrieve papers²⁶ (Figure 1). Data were found from search engines Scopus and the Web of Science. The Boolean technique was used to define the keywords. The database used for the search were: "Ventilation" OR "indoor air pollution" OR "Indoor environment quality" AND "School" AND "Students" OR "Children" AND "Health". The literature review was done for the period ranging from 2019 to May 2023. The articles were in full text and English language, and the articles which not full text were excluded. Search data was conducted in May 2023. Six articles met pre-defined criteria. Only studies reporting measurements in primary, middle, and secondary schools). (Figure 2).

Results

The objective of the research is to analyse how ventilation affected student health, but searching the articles from 2019 till May 2023 informed that some papers just analysed the school's ventilation and indoor air quality in school without continuing how it affects student health. The research only analysed the ventilation and indoor air quality in classrooms, not continuing to how it affects students' health^{23,25-34}. The others analyse the ventilation and the health effects³⁵⁻³⁹ and non-health effects^{32,40-44}, and also the research about indoor air quality and health students⁴⁵ (Figure 3).

Ventilation has many functions like keeping the air fresh in the rooms. According to the article published in 2019 till May 2023 showed that many types of ventilation are used in the classroom in schools. Some schools only use natural ventilation in classrooms or only use mechanical ventilation, but others use both (hybrid ventilation). The publication papers showed that the researcher analysed aperture ventilation, the frequency of opening windows, lack of ventilation, number of windows, etc., which is associated with indoor air quality in school or student health. Otherwise, the most parameter which was researched is Nitrogen Dioxide (NO₂), Particulate matter 10 (PM₁₀), Particulate matter 2.5 (PM_{2.5}), Particulate matter 1 (PM₁), Carbon Dioxide (CO₂), Benzen (C₆H₆), Ozone (O₃), etc.

The presence of pollution such as Nitrogen Dioxide (NO₂), Particulate matter (PM 1; PM 2.5; PM 10), and Carbon Dioxide (CO₂), Benzen can reduce the air quality in the classroom, which in turn can affect students' health and other conveniences⁴⁶⁻⁴⁸. Nitrogen Dioxide (NO₂) is the most important parameter that analysed indoor air quality attributed to ventilation at schools. NO₂ is a dangerous gas. It can be harmful to health. Nitrogen Dioxide (NO₂) was associated with adverse health effects influenza, asthma cases, paediatric asthma, lung cancer, mortality⁴⁹⁻⁵⁵, and instability superoxide enzyme and malondialdehyde serum⁵⁶.

Particulate matter is one of the air pollutants in the classrooms in schools as found in several publications. It is dangerous for human health^{57,58}, and increases morbidity and mortality⁵⁹. Particulate Matter can affect respiratory mortality⁶⁰, cardiovascular disease⁵¹, adverse effects on renal health⁶¹, Cardiovascular disease⁶¹, incident diabetes⁶²; respiratory, cancer, cardiovascular mortality⁶³, respiratory infection⁶¹, lung injury⁶⁴, stroke⁵⁷. Carbon dioxide (CO₂) has fatal effects. Carbon Dioxide reduces haemoglobin affinity for O₂⁶⁵, irritation, fatigue, anxiety, headaches, and poor cognitive performance⁶⁶, emotional responses of fear and panic⁶⁷, mortality⁶⁸, and headache⁶⁹. Ozone (O₃) is a secondary pollutant with strong oxidizing properties⁷⁰. Ozone (O₃) increased mortality⁷¹, and short-term ozone exposure increased the risk of chronic obstructive pulmonary disease⁷². This increases the risk of mortality from respiratory disease, cardiovascular disease (CVD), ischemic heart disease (IHD), and stroke⁷³. Long-term exposure to ozone (O₃) can increase cardiovascular mortality⁷⁴. Sulphur dioxide (SO₂) is also the toxic air pollution. SO₂ can cause respiratory mortality⁷⁵, and ischemic heart disease (IHD)⁷⁶. Exposure to benzene increases the risk of cancer⁷⁷. Associated with abnormalities in hematologic, hepatic, respiratory, and pulmonary functions in children⁷⁸, hepatotoxicity⁷⁹. These parameters are parameters that are often used as a measure of indoor air qualification which further often affect health. The results of research publications in 2019 - May 2023 show several health complaints experienced by students related to school ventilation and the state of indoor air quality in schools, including tiredness, bronchitis, asthma, tuberculosis, etc.

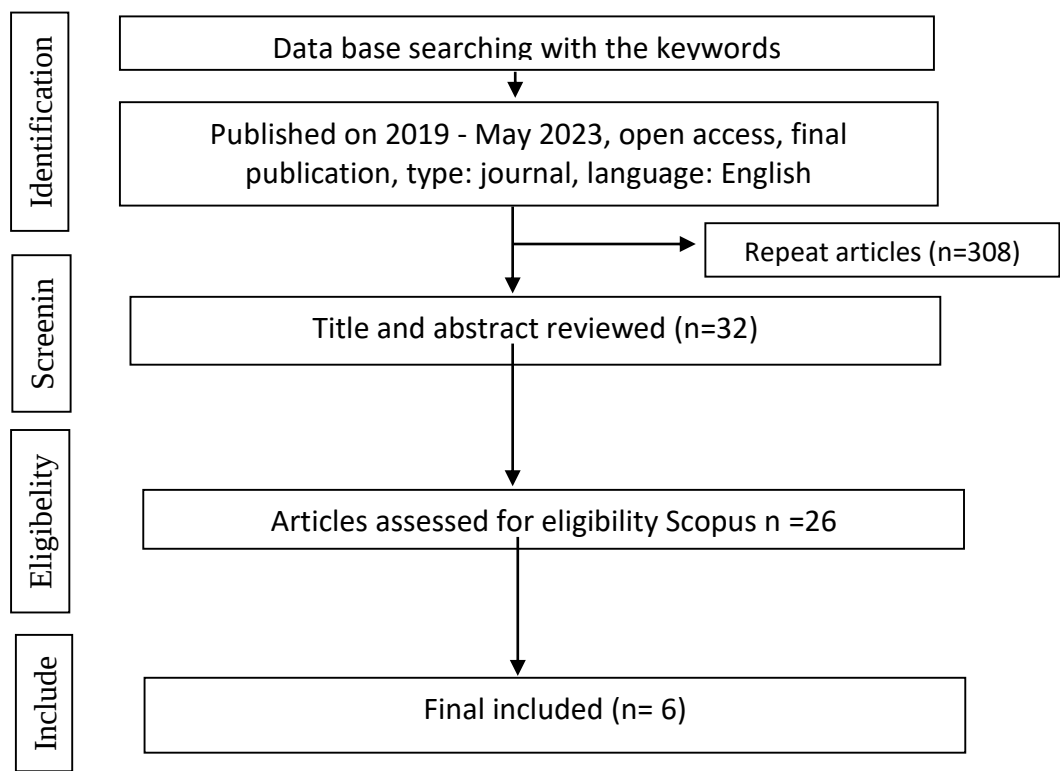


Figure 2: Process of selection papers based on PRISMA

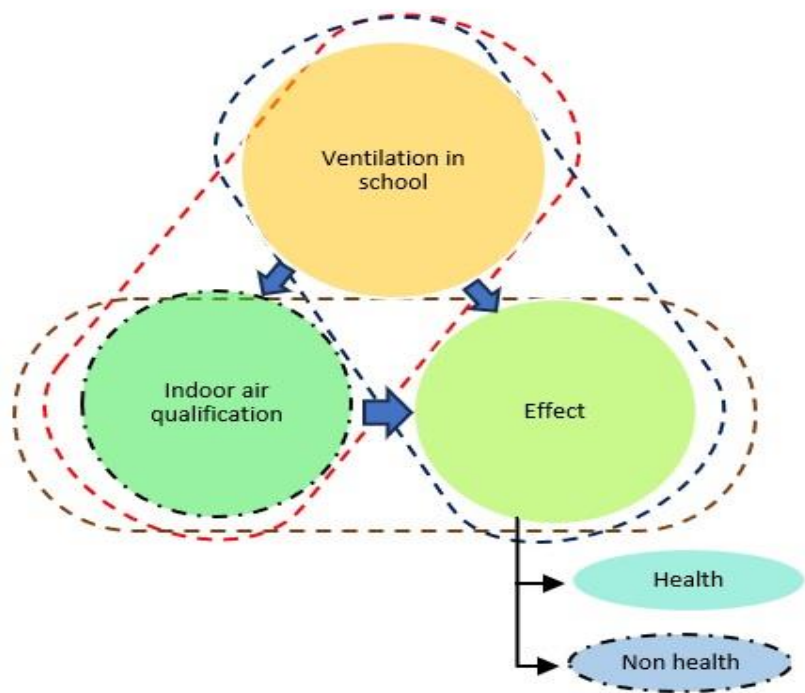


Figure 3: The publications that was founded and analyzed

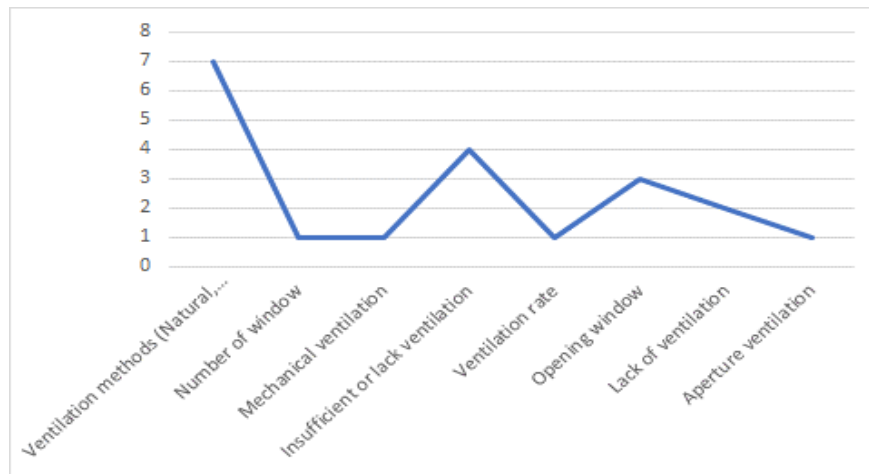


Figure 4: The variation of ventilation in classrooms variation

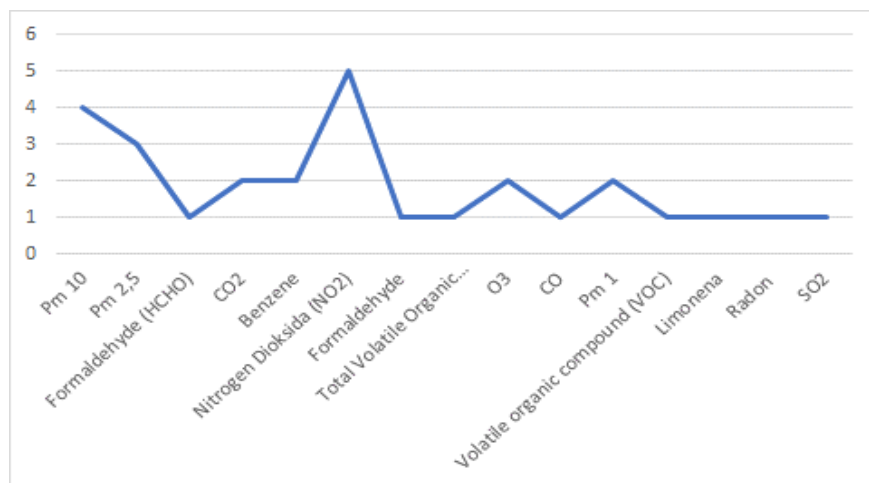


Figure 5: The parameters of classroom Air quality in school

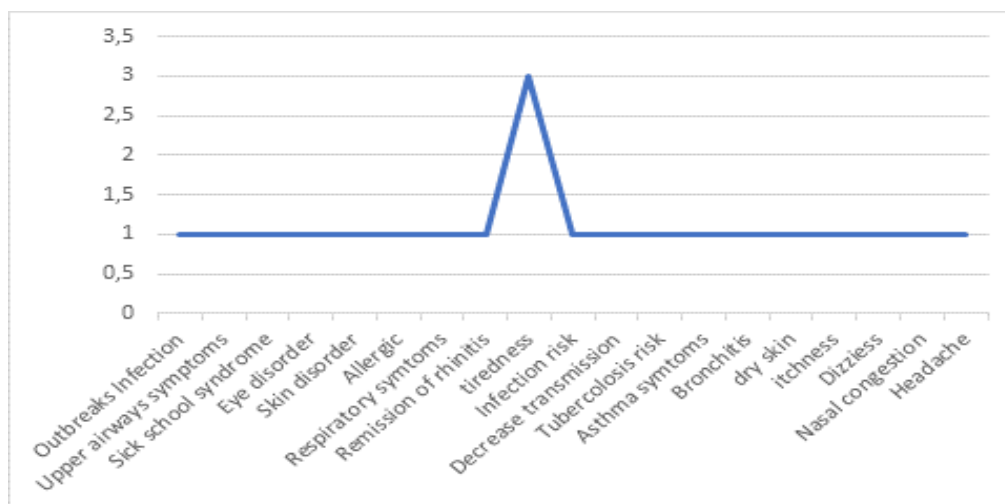


Figure 6: The health effects of ventilation on student health

Table 1: The effect of ventilation and students' health

No.	Author	Population	Location	Ventilation	Health effect
1.	Callies M. et al. 2023	Pupils and staff 43 primary and 38 secondary	Primary and secondary schools in Belgium	Ventilation	Increasing infection
2.	Gorgels, 2022	three primary school	Netherlands	Insufficient ventilation	School outbreak
3.	Cordery, 2022	Eight schools	London, UK in	Lack of ventilation	Increase transmission
4.	Sahin, 2022	Five schools	Sanliurfa, Turkey,	Natural Ventilation	Asthma symptoms, Bronchitis
5.	Baloch, 2020	115 schools, 5175 schoolchildren	54 European cities from 23 countries	Ventilation rate	Eye, skin disorder, upper airway symptoms, sick school syndrome
6.	Aguera, 2019	42 classrooms from 8 school buildings	Andalusia, Spanish	Opening window	Dizziness, dry skin, itchiness and nasal congestion dry skin, headache and tiredness

Discussion

This study focuses on the objective of analysing the relationship between ventilation in schools and student health. Finally, six articles analysed ventilation and health effects on students (Table 1). The poorer ventilation in schools was significant with a higher prevalence of SARS CoV-2 antibodies among pupils (RR: 0.96, 95% CI: 0.76 - 1.22)³⁵. In the same way, an American study found that the danger of face-to-face instruction decreased when ventilation measures were implemented (Lessler, Grabowski, Grantz, & Badillo-Goicoechea, 2021). Insufficient ventilation causes the primary school outbreaks SAR CoV 2 Alpha variant at primary school which has no mechanical ventilation and increased ventilation by opening windows and doors³⁶. Similar to other research, The frequency of COVID-19 in schools decreased by 37–48% as a result of improved classroom ventilation^{81,82}. Ventilation in schools is very important in the cases of SARS Cov 2 because of the various ways that SARS-CoV-2 might spread, such as contact, droplet, aerosol, fomite, faecal-oral, bloodborne-, mother-to-child, and animal-to-human⁸³. The airborne disease is very dependent on air quality conditions, when air quality is not good, the potential for transmission will be higher, this is where the role of ventilation becomes very important. Ventilation is the act or process of allowing fresh air to get into a room or building. Ventilation also correlates with SARSCOV 2 in bus⁸⁴. When ventilation works well,

the air quality will be better which will reduce the risk of transmission of airborne disease

The other research which was implemented at eight schools in the UK London showed that lack of ventilation increased transmission of disease, whereas low levels of environmental contamination in schools were consistent ventilation in schools during the period of a study conducted³⁷. The research which analysed 25 classrooms in five schools using only natural ventilation like opening windows and doors, showed that ventilation contributed to indoor air quality (PM_{2.5} and PM₁₀) thus health students with asthma symptoms and bronchitis³⁸. Acute bronchitis is a clinical diagnosis characterized by cough⁸⁵. Asthma is a chronic non-communicable disease, nonetheless, asthmatic patients should avoid respiratory viral infections (such as colds and influenza) as these can induce problems. In contrast to bronchitis, an infection is typically spread by microscopic, airborne droplets that are released by speaking, sneezing, or coughing and contain a germ. Additionally, it can spread through handshakes and other physical interactions with an infected individual. Asthma and bronchitis correlate with indoor air quality⁸⁶.

The ventilation in schools can cause school syndromes like eye, and skin disorders, upper airway symptoms, and sickness³⁹. Their research involved 7089 children, aged 7–14 years from 115 schools in 54 cities of 23 European countries. Their research analysed natural dan mechanical ventilation and Volatile Organic Compounds (VOCs), PM_{2.5}, CO

(ppm), ozone, and radon, further identifying the health. The ventilation rate had an apparent protective effect over eye and skin-related disorders and airway symptoms.

About 917 students (11–17 years of age) were surveyed on symptoms and effects on their health like dizziness, dry skin, headache, and tiredness because of the lack of ventilation facilities in Andalusia³³. The lack of ventilation facilities correlates with CO₂ in the 42 classrooms in 8 school buildings. Nearly 1878 parts per million is the average CO₂ concentration, and 42% of the case studies show values exceeding 2000 parts per million when the windows are closed. The symptoms that occurred when windows were closed were itchiness and nasal congestion in over 30%. When the windows are open the respondents report dry skin and headache.

The low ventilation rate causes the prevalence of rhinitis in schools⁸⁷. The poor indoor air quality in school potentially leads to allergic diseases or asthma⁸⁸. Analysis of 1325 students in eight junior schools, showed that PM₁₀, CO₂, and NO₂ at school can increase the onset of rhinitis⁴⁵. In classrooms, efficient mechanical and natural ventilation systems lower infection risks by over 80%. The information about the ventilation in classroom affected the student health, may help policy makers to make stricter regulations regarding the type, amount, and condition of ventilation in the classroom to control the disease transmission, however they are still few studies about it. (Table 1)

Conclusion

The ventilation in schools affected the student's health. Previous studies analysis the natural ventilation, aperture ventilation, mechanical and hybrid ventilation, lack of ventilation, number of windows, etc, and the parameters of air quality in the classroom are NO₂, particulate matter, benzene, CO₂, etc. The ventilation should be designed at the beginning of school construction to maximize its function in ensuring students' health.

Author contribution

Anita D. Moelyaningrum: conceptualized and searching data, writing manuscript draft
Soedjajadi Keman: review empirical study and analysed data

Soenarnatalina Melaniani: designed the methodology and edited the paper.

Corie I. Prasasti: searching data and edited paper.

Data availability

Data was openly available in a public repository

Conflict of interest

The authors declare no competing interest.

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