GeoScienceEd *5(4) (2024)*

Jurnal Pendidikan, Sains, Geologi, dan Geofisika

http://jpfis.unram.ac.id/index.php/GeoScienceEdu/index

Formaldehyde Measurements: A Bibliometric Analysis and Systematic Literature Review

Satya Cantika Agustinur[1], Riski Ramadani[2*]

[1,2]Department of Physics, Faculty of Mathematics and Natural Sciences, State University of Surabaya, Surabaya, Indonesian.

DOI: https://doi.org/10.29303/geoscienceed.v5i4.633

Article Info
Received: 23 July 2024
Revised: 16 September 2024
Accepted: 18 September 2024

Correspondence:
Phone: +6282151306251

Abstract: Formaldehyde is a dangerous air pollutant with severe health impacts. It can cause respiratory issues such as coughing, shortness of breath, and chest pain. In extreme cases, it can even lead to fluid buildup in the lungs, a condition that can be life-threatening. Formaldehyde can be measured using various chemical analysis methods, ranging from classical methods to modern instrument-based techniques, such as specific chemical reagents that react with formaldehyde, spectroscopy, chromatography, and electronic-based sensor techniques. This research aims to provide a comprehensive overview of the evolution of research related to formaldehyde measurements, especially relative humidity. This type of research is a systematic literature review (SLR) using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method. The database used was Scopus, covering the years 2014 to 2023, and obtained 3,489 documents. The literature review results show a significant influence between relative humidity (RH) and formaldehyde emissions from various building materials, such as paint, wood panels, and furniture materials. The consistency of these findings suggests that relative humidity influences the amount of formaldehyde released into indoor air.

Keywords: Measurement of Formaldehyde; Relative Humidity; Pollution; Room

Citation: Agustinus, S. C., Ramadani, R. (2024). Formaldehyde Measurements: A Bibliometric Analysis and Systematic Literature Review. *Jurnal Pendidikan, Sains, Geologi dan Geofisika (GeoScienceEd Journal), 5(4), 674-683.* doi: https://doi.org/10.29303/geoscienceed.v5i4.366

Introduction

Formaldehyde is a dangerous air pollutant with detrimental health impacts (Liu et al., 2022). Increased exposure to formaldehyde gas can pose serious health risks (Alimin & Wahyuni, 2021; U.S. EPA, 2007). Massive exposure can even cause blindness (ATSDR, 2014). Exposure to formaldehyde in the nose and lungs can irritate the respiratory tract, causing symptoms such as coughing, shortness of breath, and chest pain, and in extreme cases, can cause fluid to build up in the lungs (Liana et al., 2021; NJ Health, 2016). If swallowed, this gas can cause pain, vomiting, diarrhea, and potentially cause other diseases (Jailer et al., 2015). As a precaution, people need to measure formaldehyde gas before dangerous diseases occur.

Formaldehyde measurements are carried out using various chemical analysis methods, ranging from classical to modern instrument-based techniques (Salamah, 2016; Salthammer, 2019). These methods include using specific chemical reagents that react with formaldehyde, spectroscopy, chromatography, and electronics-based sensor techniques (Su & He, 2017). The importance of formaldehyde measurement lies in controlling air quality in industrial environments, checking product safety, and assessing the risk of formaldehyde exposure to human health (Qu et al., 2017). Various regulatory bodies and international organizations have established formaldehyde

Email: riski.20056@mhs.unesa.ac.id

measurement standards to ensure the safety and quality of the environment and products used by society (ANSES, 2019; CSRE, 2019). The Occupational Safety and Health Administration (OSHA) states that the permissible exposure limit is 0.75 ppm for 8 hours, and the short-term exposure limit for 15 minutes is two ppm. The National Institute for Occupational Safety and Health (NIOSH) states that the 8-hour time-weighted average is 0.016 ppm, and the short-term exposure limit is 0.1 ppm. Meanwhile, the threshold limit values set by the American Conference of Governmental Industrial Hygienists (ACGIH) include a time-weighted average of 0.1 ppm and a 15-minute short-term exposure limit of 0.3 ppm (Baldelli et al., 2020; Golden, 2011).

Research related to formaldehyde measurement was carried out by Wongsakoonkan et al. (2022) by creating a color testing device to detect formaldehyde levels in indoor air. The device has a high accuracy, selectivity, low cost, and is easy to use. Tests using various parameters, such as reaction time, accuracy, precision, stability, selectivity, and shelf life, show color changes according to the formaldehyde concentration with varying intensities. The test equipment can detect formaldehyde at concentrations as low as 0.01 ppm with an accuracy of ±25% and a bias of ≤10% (Wongsakoonkan et al., 2022). Another study was conducted by Meshalkina et al. (2018), which aimed to measure formaldehyde emissions from furniture materials investigated using a photometric method with acetylacetone reagent. The research results state that the smaller the density of indoor furniture, the less formaldehyde emissions there will be, with the resulting formaldehyde levels not exceeding 0.01 mg/m3 (Meshalkina et al., 2018). Some studies related to formaldehyde measurements do not include research suggestions that examine the causes of formaldehyde. Therefore, research on formaldehyde measurement is fundamental because it helps anticipate negative impacts on human health and the environment (Koç, 2019).

This research will review the literature by examining "formaldehyde measurement" from 2014 to 2023. This analysis is intended to provide a comprehensive picture of the evolution of research related to formaldehyde measurement and identify the most dominant patterns and techniques, especially relative humidity. Understanding research trends in this context is hoped to encourage improvements and innovations in formaldehyde measurement methods, which are more precise, efficient, and widely adopted. This research will also provide researchers with insight into advances in formaldehyde measurement and possible innovations that can be explored.

Method

This research is a meticulous type of descriptive research, employing thorough systematic literature review (SLR) methods and bibliometric analysis (Agustinur et al., 2023; Trisnanti et al., 2023). The literature review study adheres to the rigorous Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method, which involves review, evaluation, classification, and structure, all based on previously obtained data (Fitriyani, 2021). The source of this research is the esteemed Scopus database, chosen for its internationally recognized quality and reputation among research institutions. This ensures that the Scopus database source provides accurate data in scientific publications (Putro et al., 2022).

The data collection process, conducted on March 31, 2024, was comprehensive. The search was carried out using the keyword "formaldehyde measurement" to retrieve all relevant scientific publications from 2014 to 2023, with the specifications "Article, Abstract, Keywords". This yielded a substantial 3,489 documents. These documents, obtained based on the specified keywords, were exported in RIS form, which includes citation information and abstract & keywords. The downloaded files were then processed in VOSviewer.

VOSviewer is done by creating a map based on text data data (Jatmiko et al., 2021). The next step is to enter the RIS file from Scopus that has been downloaded and select the Title and abstract files fields (Krisnaningsih et al., 2021). Then, select the binary counting specifications, minimum number of occurrences of terms: 10, and number of terms to be selected: 1116. After that, verify the selected terms and click finish. This application can display network, overlay, and density visualization (Deta et al., 2024).

The obtained visualization is then reviewed. The review results refer to relative humidity. Then, search for articles using criteria in the form of articles and proceedings with the keyword relative humidity formaldehyde. The data that has been obtained is then analyzed using the narrative method. The narrative method is used to describe the effect of relative humidity on formaldehyde (Pahleviannur et al., 2022). The research stages can be described in Figure 1 and 2.

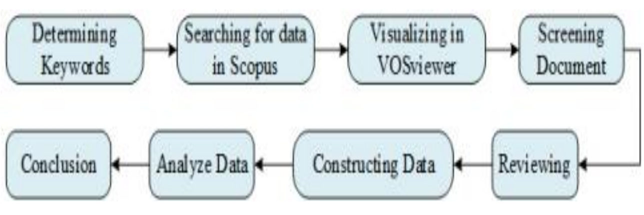

Figure 1. Research Stages

The research flow in Scopus and VOSviewer can be seen in Figure 2.

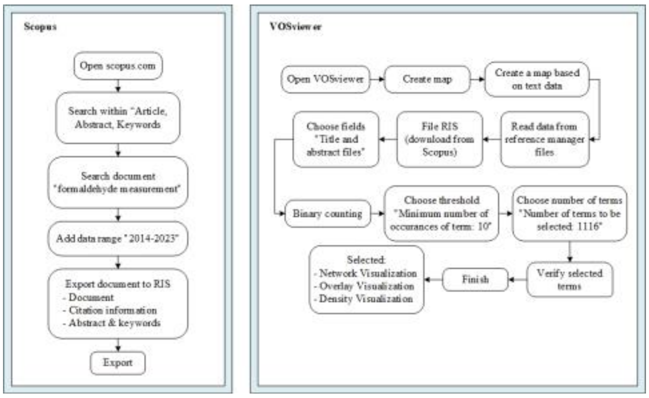

Figure 2. Research flow in Scopus and VOSviewer

Result and Discussion

Results should be clear and concise. The discussion should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature. The "formaldehyde measurement" keyword on the Scopus website yielded a substantial 3,489 documents from 2014 to 2023. This analysis, based on article title, abstract, and keywords, presents the annual development of research publications on formaldehyde measurements (Zakiyyah et al., 2022). The data from Scopus reveals that research on this topic has a long history, dating back to 1913, but it truly gained momentum in the 1990s, underscoring its enduring importance and relevance.

Figure 3. Graph of the Number of Formaldehyde Measurement Documents in 2014-2023

Figure 3 shows that research will fluctuate from 2014 to 2023. The highest document publication occurred in 2022, with 399 documents. The following analysis is based on source type. According to Figure 4, the journal type dominates with 3,130 documents, 298 documents in the form of conference proceedings, book series totaling 45 documents, 14 books, and trade journals totaling two documents.

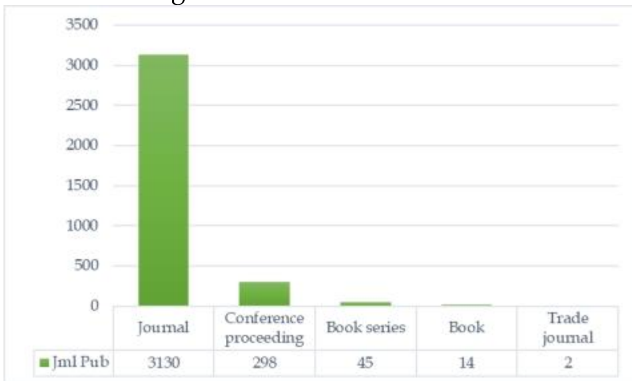

Figure 4. Graph of the number of documents based on source type

The analysis of this research is based on the top five countries with the highest number of publications, which can be seen in Figure 5.

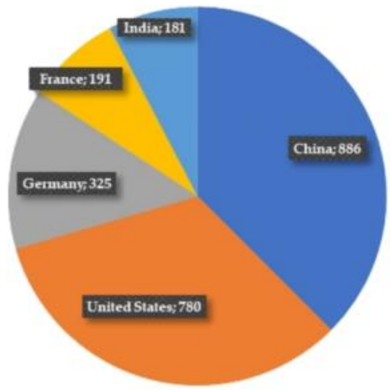

Figure 5. Graph of the Number of Documents based on the Top Five Countries

Figure 5 illustrates that China leads the world in publications discussing "formaldehyde measurement." As the top formaldehyde-producing country, particularly in its cities, China's production practices have a profound global impact (Mahdi et al., 2023; Tang et al., 2009). This is especially significant as goods from China often contain higher levels of formaldehyde than those from other countries, sparking a surge of research interest in formaldehyde measurements.

The document is visualized using the VOSviewer application, which provides a comprehensive overview of the research clusters. The thickness of the connecting lines indicates the strength of the connection between topic areas or critical pairs. The size of the circles represents the significance of the entity in the network (Putra et al., 2024; Yantidewi et al., 2023). Figure 6 reveals five distinct clusters associated with the keyword "formaldehyde measurement": red (cluster 1) with a total of 336 items; green (cluster 2) with

263 items; blue (cluster 3) with 259 items; yellow with 166 items; and purple with 92 items for cluster 5.

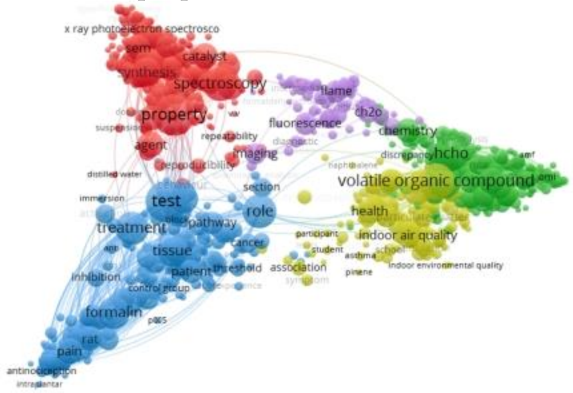

Figure 6. Network Visualization of Formaldehyde Measurements

Formaldehyde, known chemically as CH2O or HCHO and commercially as formalin, is represented in our network visualization (Isbilir et al., 2023). The term 'hcho' is depicted in green, 'formalin' in blue, and 'ch2o' in purple. While the term 'formaldehyde' itself may not be prominently displayed in a large circle, it is distributed across the five clusters, with the most significant distribution found in cluster 1, comprising 13 items. This distribution is further supported by the data in Table 1, which provides a visual representation of the distribution of formaldehyde-related keywords.

Table 1. Division of Clusters with the Keyword "formaldehyde"

Cluster 1 (Red)	Cluster 2 (Blue)	Cluster 3 (Blue)	Cluster 4 (Yellow)	Cluster 5 (Purple)
Formal-dehyde detection	Atmosp-heric formal-dehyde	Formaldehyde solution	Formaldehyde exposure	Formal-dehyde molecule
Formal-dehyde gas	Formal-dehyde production	**	formaldehyde levels	Formal-dehyde planar laser
Formal-dehyde sensing	**	**	indoor formaldehyde	**
Formal-dehyde free	**	**	indoor formaldehyde concentration	**
melamine formal-dehyde	**	**	**	**
melamine formal-dehyde resin	**	**	**	**
melamine urea Formal-dehyde	**	**	**	**
phenol Formal-dehyde	**	**	**	**
phenol Formal-dehyde resin	**	**	**	**
resorcinoformaldehyde	**	**	**	**
resort-cinolformaldehyde	**	**	**	**
urea formaldehyde	**	**	**	**
urea formaldehyde resin	**	**	**	**

**Not Discussed

In the red keyword cluster, "formaldehyde measurement" does not show a dominant circle, so the word formaldehyde has not become a popular topic. Meanwhile, the green cluster for the word hcho has a vast network because it shows attachment to all clusters (Figure 7).

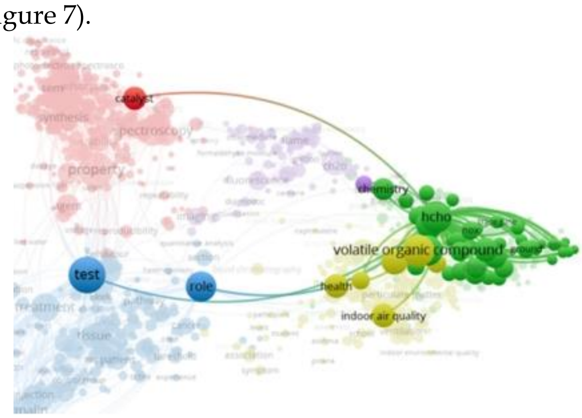

Figure 7. Green Cluster Network (Zoom Out)

The word formalin (blue cluster) has only an attachment to most of the blue circles and one red circle, according to Figure 8.

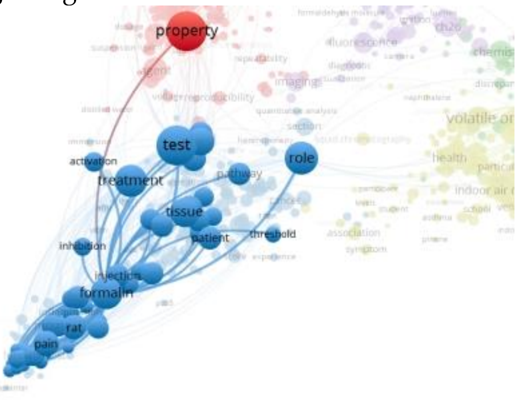

Figure 8. Blue Cluster Network

Meanwhile, ch2o in the purple cluster has a network of purple circles and one green circle (Figure 9). Thus, the word hcho is the dominant topic with the most popular research trends.

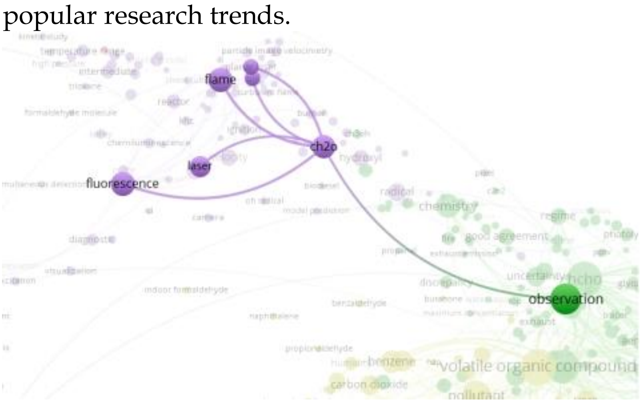

Figure 9. Purple Cluster Network

According to Figure 7, circle hcho is most frequently associated with the yellow cluster: volatile organic compounds (VOCs), pollutants, health, indoor air quality, and relative humidity, which can be observed more clearly in Figure 10.

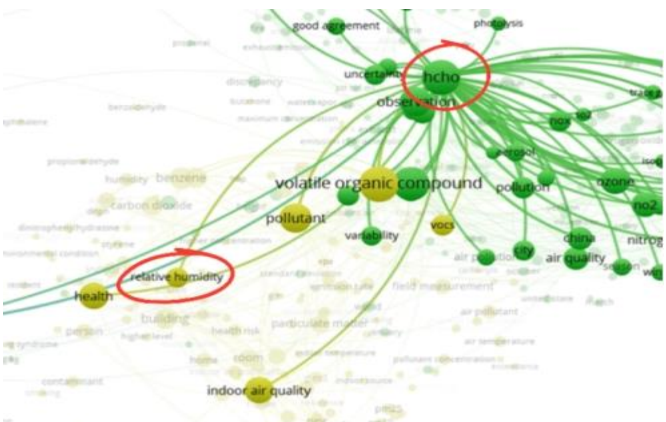

Figure 10. Green Cluster Network (Zoom In)

According to the literature from Parthasarathy et al., volatile organic compounds, pollutants, VOCs, health, indoor air quality, and relative humidity are related to HCHO. Parthasarathy et al. (2011) stated that formaldehyde (HCHO) is a type of volatile organic compound (volatile organic compounds or VOCs). As an air pollutant, exposure to HCHO can hurt human health. Various factors, including relative humidity, can affect HCHO levels in indoor air. Therefore, maintaining proper indoor relative humidity is essential to control the levels of HCHO and VOCs, as well as improve indoor air quality and the health of occupants (Wang et al., 2023).

However, research regarding relative humidity as a cause of HCHO still needs to be discussed. According to Figure 10, the yellow circle is from the words relative humidity compared to the circle from a volatile organic compound, pollutant, VOCs, health, and indoor air quality. This is supported by overlay visualization. Overlay visualization functions to visualize changes or evolution in data over time (Trisnanti et al., 2023). This visualization can see patterns or relationships between entities in the dataset changing from one time period to the next (Dewi & Jauhariyah, 2021). Purple to yellow colors use specific color schemes to represent certain periods in bibliometric analysis. The purple color is used to represent entities or data from earlier years, while the yellow color is used to represent entities or data from more recent years (Yantidewi et al., 2023).

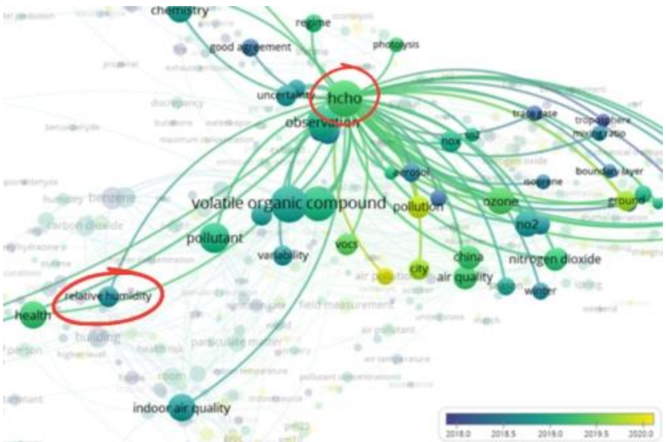

Figure 11. Overlay Visualization on The Keyword "hcho" (Zoom In)

Figure 11 shows that formaldehyde measurement research was updated between 2018 and 2020. Purple shows old research at the beginning of 2018, green shows research conducted in the middle of the year, and yellow shows the latest research published in 2020. The word relative humidity has a turquoise green color, indicating between 2018 and 2019. Therefore, this topic requires updates because publications have been rare, even for almost five years. Moreover, relative humidity, apart from being a factor causing the presence of HCHO, can also indicate whether the environment is healthy or unhealthy.

Relative humidity can affect formaldehyde measurements and can be observed in building materials. Formaldehyde is a chemical that can be released from various building materials, such as paint, floor coverings, and wood panels. Long-term exposure to formaldehyde can irritate the eyes, nose, and throat and contribute to respiratory problems and allergies. Formaldehyde and moisture measurements help ensure that building materials meet applicable regulatory requirements.

Research on formaldehyde and relative humidity in building materials was carried out by Huang et al. (2015). This research aims to study the impact of relative humidity (RH) on the initial emittable concentration (Cm,0) of formaldehyde emissions from building materials in the RH range of 20-85% and obtain a correlation between the emission rate and RH based on a theoretical approach. Data from the research was collected using the ventilated C-history method, which consists of two physical processes. The first process is emission under airtight conditions, where the tested building materials are placed in an airtight chamber until they reach equilibrium. The second process is emissions under ventilated conditions. Formaldehyde concentration data in the room was measured during these two emission processes. The research results showed that the initial concentration of formaldehyde increased ten times when the relative humidity increased from 20% to 85% so that there was a linear relationship between ln (initial concentration of formaldehyde) and relative humidity (Huang et al., 2015).

Shan Zhou et al. (2019) also measured formaldehyde by assessing relative humidity. The research method involved adjusting the relative humidity, temperature, and frequency of air exchange on wood-based panels and then measuring the concentration of formaldehyde released. The results showed that relative humidity and temperature influenced the concentration of formaldehyde released from wood-based panels. The higher the relative humidity, the more formaldehyde is released (Zhou et al., 2019).

Mostafa Ebrahimi et al. (2017) conducted similar research. The objective of this article is to examine the effect of relative humidity and temperature on formaldehyde emissions from Medium-Density Fiberboard (MDF) under load. Based on research results, there is a positive relationship between formaldehyde and relative humidity, where formaldehyde emissions increase as relative humidity increases (Ebrahimi et al., 2017).

Apart from building materials, research related to measuring formaldehyde in rooms by reviewing relative humidity is fundamental because formaldehyde is a chemical compound that can be dangerous to human health if exposed to high levels. Research by Pengpeng Yang et al. (2020) in a typical teaching machine room of Guangxi Normal University from March 2016 to February 2018. The research results show that formaldehyde changes as temperature and humidity change. Formaldehyde concentrations were higher in summer and autumn, while formaldehyde concentrations were lower in winter and spring. Further analysis shows that there is a strong positive correlation ($R2 > 0.85$) between formaldehyde concentration and relative humidity (Yang et al., 2020).

Measurement of formaldehyde and humidity in rooms was studied by Srinandini Parthasarathy et al. (2011). This study aimed to understand the effect of temperature and humidity on formaldehyde emissions in temporary shelter units provided by the US Federal Emergency Management Administration (FEMA). Composite wood was chosen to analyze the influence of temperature and humidity on formaldehyde emissions. Samples were examined via high-performance liquid chromatography. The results showed that increasing temperature or humidity caused an increase in the formaldehyde emission factor. The linear regression model shows a significant relationship between temperature, humidity, and formaldehyde emission factors (Parthasarathy et al., 2011).

Another study was conducted by Jung et al. (2022), who identified the relationship between VOC emissions and changes in temperature/humidity in 23 housing units in five different residential towers in Ajman, United Arab Emirates. At relative humidity, the results show that formaldehyde (HCHO) and VOCs such as benzene ($C6H6$), toluene ($C7H8$), ethylbenzene ($C8H10$), xylene ($C8H10$), and styrene ($C8H8$) has a consistent humidity dependence in the range of 15–60% of relative humidity (RH). However, there is an emission limit point where the generation of indoor air pollutants deviates from a linear relationship at RH 40–50% (Jung et al., 2022).

Based on the research discussed, relative humidity can affect formaldehyde measurements. Long-term exposure to formaldehyde can irritate the eyes, nose, and throat, as well as respiratory problems and allergies. Some studies highlight the relationship between relative humidity and formaldehyde emissions from various building materials such as paint, floor coverings, wood panels, and Medium-Density

Fiberboard (MDF). Results show that formaldehyde concentrations tend to increase as relative humidity increases, with some studies showing a linear relationship between the two. The analysis also highlighted changes in indoor formaldehyde concentrations and humidity changes, demonstrating the importance of formaldehyde and humidity measurements in ensuring compliance with health and safety regulations applicable to indoor environments.

Thus, the presence of formaldehyde gas can be influenced by relative humidity. The relative humidity in the room can be measured to determine the effect of formaldehyde levels further. It is hoped that research regarding the correlation of formaldehyde levels and relative humidity will become a reference for researchers.

Relative humidity can affect formaldehyde measurements and can be observed in building materials. Formaldehyde is a chemical that can be released from various building materials, such as paint, floor coverings, and wood panels. Long-term exposure to formaldehyde can irritate the eyes, nose, and throat and contribute to respiratory problems and allergies. Formaldehyde and moisture measurements help ensure that building materials meet applicable regulatory requirements.

Research on formaldehyde and relative humidity in building materials was carried out by Huang et al. (2015). This research aims to study the impact of relative humidity (RH) on the initial emittable concentration (Cm,0) of formaldehyde emissions from building materials in the RH range of 20-85% and obtain a correlation between the emission rate and RH based on a theoretical approach. Data from the research was collected using the ventilated C-history method, which consists of two physical processes. The first process is emission under airtight conditions, where the tested building materials are placed in an airtight chamber until they reach equilibrium. The second process is emissions under ventilated conditions. Formaldehyde concentration data in the room was measured during these two emission processes. The research results showed that the initial concentration of formaldehyde increased ten times when the relative humidity increased from 20% to 85% so that there was a linear relationship between ln (initial concentration of formaldehyde) and relative humidity (Huang et al., 2015).

Shan Zhou et al. (2019) also measured formaldehyde by assessing relative humidity. The research method involved adjusting the relative humidity, temperature, and frequency of air exchange on wood-based panels and then measuring the concentration of formaldehyde released. The results showed that relative humidity and temperature influenced the concentration of formaldehyde released from wood-based panels. The higher the relative humidity, the more formaldehyde is released (Zhou et al., 2019).

Mostafa Ebrahimi et al. (2017) conducted similar research. The objective of this article is to examine the effect of relative humidity and temperature on formaldehyde emissions from Medium-Density Fiberboard (MDF) under load. Based on research results, there is a positive relationship between formaldehyde and relative humidity, where formaldehyde emissions increase as relative humidity increases (Ebrahimi et al., 2017).

Apart from building materials, research related to measuring formaldehyde in rooms by reviewing relative humidity is fundamental because formaldehyde is a chemical compound that can be dangerous to human health if exposed to high levels. Research by Pengpeng Yang et al. (2020) in a typical teaching machine room of Guangxi Normal University from March 2016 to February 2018. The research results show that formaldehyde changes as temperature and humidity change. Formaldehyde concentrations were higher in summer and autumn, while formaldehyde concentrations were lower in winter and spring. Further analysis shows that there is a strong positive correlation (R2 > 0.85) between formaldehyde concentration and relative humidity (Yang et al., 2020).

Measurement of formaldehyde and humidity in rooms was studied by Srinandini Parthasarathy et al. (2011). This study aimed to understand the effect of temperature and humidity on formaldehyde emissions in temporary shelter units provided by the US Federal Emergency Management Administration (FEMA). Composite wood was chosen to analyze the influence of temperature and humidity on formaldehyde emissions. Samples were examined via high-performance liquid chromatography. The results showed that increasing temperature or humidity caused an increase in the formaldehyde emission factor. The linear regression model shows a significant relationship between temperature, humidity, and formaldehyde emission factors (Parthasarathy et al., 2011).

Another study was conducted by Jung et al. (2022), who identified the relationship between VOC emissions and changes in temperature/humidity in 23 housing units in five different residential towers in Ajman, United Arab Emirates. At relative humidity, the results show that formaldehyde (HCHO) and VOCs such as benzene (C6H6), toluene (C7H8), ethylbenzene (C8H10), xylene (C8H10), and styrene (C8H8) has a consistent humidity dependence in the range of 15–60% of relative humidity (RH). However, there is an emission limit point where the generation of indoor air pollutants deviates from a linear relationship at RH 40–50% (Jung et al., 2022).

Based on the research discussed, relative humidity can affect formaldehyde measurements. Long-term exposure to formaldehyde can irritate the eyes, nose, and throat, as well as respiratory problems and allergies. Some studies highlight the relationship between relative humidity and formaldehyde emissions from various building materials such as paint, floor coverings, wood panels, and Medium-Density Fiberboard (MDF). Results show that formaldehyde concentrations tend to increase as relative humidity increases, with some studies showing a linear relationship between the two. The analysis also highlighted changes in indoor formaldehyde concentrations and humidity changes, demonstrating the importance of formaldehyde and humidity measurements in ensuring compliance with health and safety regulations applicable to indoor environments.

Thus, the presence of formaldehyde gas can be influenced by relative humidity. The relative humidity in the room can be measured to determine the effect of formaldehyde levels further. It is hoped that research regarding the correlation of formaldehyde levels and relative humidity will become a reference for researchers.

Conclusion

Based on bibliometric analysis on the Scopus website with the keywords "formaldehyde measurement" from 2014 to 2023, visualized using the VOSviewer application, there were 3,489 documents. According to a literature review study, several studies have shown a significant influence between relative humidity and formaldehyde emissions from various building materials, such as paint, wood panels, and furniture. The consistency of these findings suggests that relative humidity influences the amount of formaldehyde released into indoor air. This bibliometric and SLR analysis helps establish a comprehensive research framework. It facilitates further exploration by future researchers to focus on aspects rarely explored, especially regarding formaldehyde measurement. In addition, this research also opens up space to explore the factors that cause formaldehyde, including the impact of relative humidity. Thus, topics not received much attention can become innovation points worthy of further development, perhaps resulting in significant discoveries..

References

Agustinur, S. C., Khalifa, K. I., Yantidewi, M., & Deta, U. A. (2023). Literature Review: Air Oxygen Level Monitoring System. *International Journal of Research and Community Empowerment*, 1(2), 62–70. doi: https://doi.org/10.58706/ijorce.v1n2.p62-70

Alimin, S. A., & Wahyuni, N. (2021). Kualitas Udara dalam Ruangan Sekolah (PM2.5, PM10, CO2, dan HCHO) dan Risiko Kesehatan pada Siswa di Kota Serang. *Jurnal JOUBAHS*, 1(2), 141–155. doi: https://doi.org/10.47080/joubahs.v1i02.1486

ANSES. (2019). Substance Evaluation Conclusion as required by Reach Article 48 and Evaluation Report for Formaldehyde EC No 200-001-8 CAS No 50-00-0 (Issue 200). French Agency for Food, Environmental and Occupational Health Safety (ANSES) on behalf French Ministry of Environment. Retrieved from http://echa.europa.eu/web/guest/information-on-chemicals/registered-substances

ATSDR. (2014). Formaldehyde (HCHO) CAS 50-00-0 ; UN 1198 , UN 2209 (formalin). Agency for Toxic Substances and Disease Registry. Retrieved from https://wwwn.cdc.gov/TSP/MMG/MMGDetails.aspx?mmgid=216&toxid=39

Baldelli, A., Jeronimo, M., Tinney, M., & Bartlett, K. (2020). Real-time measurements of formaldehyde emissions in a gross anatomy laboratory. *SN Applied Sciences*, 2(4). doi:https://doi.org/10.1007/s42452-020-2569-7

CSRE. (2019). *Benchmarks For Managing Indoor Air Quality Formaldehyde*. Haut Conseil de la santé publique.

Deta, U. A., Prahani, B. K., Suprapto, N., & Diani, R. (2024). Research Trends of Physics Local Wisdom in Scopus Database in Ten Years (2013-2022): A Bibliometric Analysis. *E3S Web of Conferences 482*, 482, 03008. doi:https://doi.org/10.1051/e3sconf/202448203008

Dewi, I. S., & Jauhariyah, M. N. R. (2021). Analisis Bibliometrik Implementasi Pembelajaran Fisika Berbasis STEM pada Tahun 2011-2021. *Jurnal Ilmiah Pendidikan Fisika*, 5(3), 368. doi:https://doi.org/10.20527/jipf.v5i3.3904

Fitriyani, N. I. (2021). Metode PRISMA untuk memprediksi penyakit kanker payudara. JII : *Jurnal Inovasi Informatika Universitas Pradita*, 6(2), 13–18. Retrieved from https://jurnal.pradita.ac.id/index.php/jii/article/download/187/82/642

Golden, R. (2011). Identifying an indoor air exposure limit for formaldehyde considering both irritation and cancer hazards. *Critical Reviews in Toxicology*, 41(8), 672–721. doi:https://doi.org/10.3109/10408444.2011.573467

Huang, S., Xiong, J., & Zhang, Y. (2015). The Impact of Relative Humidity on the Emission Behaviour of Formaldehyde in Building Materials. *Procedia Engineering*, 121, 59–66. doi:https://doi.org/10.1016/j.proeng.2015.08.1019

Isbilir, F., Akkoc, C. G. O., & Arıcan, I. (2023). Morphometric examination of hind limb and foot bones and fibre type composition of crus region muscles in quail and pigeon. *Journal of Veterinary Medicine Series C: Anatomia Histologia Embryologia*, 52(4), 560–570. doi:https://doi.org/10.1111/ahe.12912

Jailer, T., Lara-Meloy, M., & Robbin, M. (2015). Worker's Guide to Health and Safety. Hesperian Foundation. Retrieved from https://hesperian.org/wp-content/uploads/pdf/id_misc/id_electronics_workers.pdf

Jatmiko, B., Prahani, B. K., Suprapto, N., Admoko, S., Deta, U. A., Lestari, N. A., Jauhariyah, M. N. R., Yantidewi, M., & Muliyati, D. (2021). Bibliometric analysis on online physics learning during COVID-19 Pandemic: Contribution to physics education undergraduate program. *Journal of Physics: Conference Series*, 2110(1). doi:https://doi.org/10.1088/1742-6596/2110/1/012018

Jung, C., Mahmoud, N. S. A., & Alqassimi, N. (2022). Identifying the relationship between VOCs emission and temperature/humidity changes in new apartments in the hot desert climate. *Frontiers in Built Environment*, 8. doi:https://doi.org/10.3389/fbuil.2022.1018395

Koç, K. (2019). Formaldehyde Emissions and Effects on Health During Arrival of Furniture to Ultimate Consumer. *Wood Industry and Engineering*, 1(1), 14–19. Retrieved from https://dergipark.org.tr/en/pub/wie/issue/50853/652749

Krisnaningsih, E., Nurdiana Putri, M. A., Irba, T., Supapto, N., Deta, U. A., & Hariyono, E. (2021). Bibliometric Analysis of Multi Representation Based on Problem-Solving Skills Using VOSviewer. *Berkala Ilmiah Pendidikan Fisika*, 9(3), 274. doi:https://doi.org/10.20527/bipf.v9i3.11329

Liana, Y. R., Fianti, F., & Nurbaiti, U. (2021). Study of Sun Protection Factor (SPF) Batik Textile Fabric on Solar Radiation in Pekalongan. *Jurnal Penelitian Fisika Dan Aplikasinya (JPFA)*, 11(1), 39–49. doi:https://doi.org/10.26740/jpfa.v11n1.p39-49

Liu, N., Bu, Z., Liu, W., Kan, H., Zhao, Z., Deng, F., Huang, C., Zhao, B., Zeng, X., Sun, Y., Qian, H., Mo, J., Sun, C., Guo, J., Zheng, X., Weschler, L. B., & Zhang, Y. (2022). Health Effects of Exposure to Indoor Volatile Organic Compounds from 1980 to 2017: A Systematic Review and Meta-Analysis. *Indoor Air*, 32(5). doi:https://doi.org/10.1111/ina.13038

Mahdi, H. I., Ramlee, N. N., Santos, D. H. da S., Giannakoudakis, D. A., Oliveira, L. H. de, Selvasembian, R., Azelee, N. I. W., Bazargan, A., & Meili, L. (2023). Formaldehyde production using methanol and heterogeneous solid catalysts: A comprehensive review. *Molecular Catalysis*, 537, 112944. doi: https://doi.org/10.1016/j.mcat.2023.112944

Meshalkina, M., Sushnikov, V., & Kryzhova, N. (2018). The Estimation of Formaldehyde Concentration in Indoor Air. *MATEC Web of Conferences*, 245. doi:https://doi.org/10.1051/matecconf/201824503003

NJ Health. (2016). Right to Know Hazardous Substance Fact Sheet Common "Formaldehyde." *NJ Health*,. doi:https://doi.org/10.1097/00152193-199711000-00013

Putra, H. T., Haj, F. S., Rizaldi, D. F., Shinta, C. El, & Deta, U. A. (2024). Implementation of Independent Curriculum Differentiation Learning in Physics Learning in High School Completed with Literature Review and Bibliometric Analysis. *Indonesian Journal of Teaching in Science*, 4(1), 109–120. Retrieved from https://ejournal.upi.edu/index.php/IJoTis/article/view/68767

Putro, P. A., Hardhienata, H., Isnaeni, I., Ahmad, F., Khaerudini, D. S., Prasetyo, A. P., & Maddu, A. (2022). A Bibliometric Analysis of Carbon Dots in Sensors Application. *Jurnal Penelitian Fisika Dan Aplikasinya (JPFA)*, 12(2), 138–155. doi:https://doi.org/10.26740/jpfa.v12n2.p138-155

Qu, M., Lu, J., & He, R. (2017). Formaldehyde from Environment. *Formaldehyde and Cognition*, 1–18. doi:https://doi.org/10.1007/978-94-024-1177-5

Salamah, U. (2016). Rancang Bangun Pulse Oximetry Menggunakan Arduino Sebagai Deteksi Kejenuhan Oksigen Dalam Darah Pulse Oximetry Building Design By Using Arduino As an Oxygenic Saturation Detection in Blood. *Jurnal Penelitian Fisika Dan Aplikasinya (JPFA)*, 06(02). Retrieved from http://journal.unesa.ac.id/index.php/jpfa

Salthammer, T. (2019). Formaldehyde sources, formaldehyde concentrations and air exchange rates in European housings. In Building and environment. *Elsevier*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0360132318307960

Su, T., & He, R. (2017). Methods in Determination of Formaldehyde. *Formaldehyde and Cognition*, 271–295. doi:https://doi.org/10.1007/978-94-024-1177-5

Tang, X., Bai, Y., Duong, A., Smith, M. T., Li, L., & Zhang, L. (2009). Formaldehyde in China: Production, consumption, exposure levels, and health effects. *Environment International*, 35(8), 1210–1224. doi: https://doi.org/10.1016/j.envint.2009.06.002

Trisnanti, S. P., Yantidewi, M., & Alan Deta, U. (2023). Analisis Bibliometrik Pengukuran Kadar Karbon Monoksida (CO) Menggunakan Drone pada Rentang Tahun 2011-2021 Analisis Bibliometrik Pengukuran Kadar Karbon Monoksida (CO) Menggunakan Drone pada Rentang Tahun. *Jurnal Kolaboratif Sains (JKS)*, 6(7), 895–906. Retrieved from https://jurnal.unismuhpalu.ac.id/index.php/JKS

U.S. EPA. (2007). Formaldehyde Chemical Assessment Summary. Integrated Risk Information System (IRIS). Retrieved from https://archive.epa.gov/region5/teach/web/pdf/formaldehyde_summary.pdf

Wang, H., Guo, D., Zhang, W., Zhang, R., Gao, Y., Zhang, X., Liu, W., Wu, W., Sun, L., Yu, X., Zhao, J., Xiong, J., Huang, S., Wolfson, J. M., & Koutrakis, P. (2023). Observation, prediction, and risk assessment of volatile organic compounds in a vehicle cabin environment. *Cell Reports Physical Science*, 4(4). doi:https://doi.org/10.1016/j.xcrp.2023.101375

Wongsakoonkan, W., Pengpumkiat, S., Boonyayothin, V., Tangtong, C., Laohaudomchok, W., & Phanprasit, W. (2022). Colorimetric Pad for Low-Concentration Formaldehyde Monitoring in Indoor Air. *Journal of Health Research, 36(4)*, 781–790. doi:https://doi.org/10.1108/JHR-09-2020-0428

Yang, P., Meng, M., Gao, D., Lin, Z., Ding, H., Tian, M., Chen, C., Zhou, Z., Huang, S., & Kang, C. (2020). Study on the Characteristics of Formaldehyde Pollution in Typical Teaching Machine Room. *E3S Web of Conferences*, 143(02001). doi:https://doi.org/10.1051/e3sconf/202014302001

Yantidewi, M., Wati, J. N., & Deta, U. A. (2023). Bibliometric Analysis: Research Trends of Raspberry Pi-Based Egg Incubators in the Last Ten Years (2013-2022). *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, 11(2), 307. doi:https://doi.org/10.33394/j-ps.v11i2.7119

Zhou, S., Liu, H., Ding, Y., & Wu, Y. (2019). The effects of temperature and humidity on the VOC emission rate from dry building materials. *IOP Conference Series: Materials Science and Engineering*, 609(4). doi:https://doi.org/10.1088/1757-899X/609/4/042001