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Comparative Analysis of CCS811 Sensor Usage in Wearable Studies for Cigarette Smoke Detection: Literature Review

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ABSTRACT

The CCS811 sensor is a metal oxide semiconductor (MOX)-based gas sensor that is widely used in wearable systems to monitor air quality personally, especially in detecting volatile organic compounds (VOCs) contained in cigarette smoke. This study aims to conduct a systematic review of various studies that implement the CCS811 sensor in wearable devices for cigarette smoke detection, focusing on aspects of accuracy, sensitivity, detection time, and the effect of room size. The method used is a systematic literature review of 19 scientific articles published in the last ten years. The results of the review show that the CCS811 has several advantages, such as low power consumption, compact sensor size, real-time VOC detection capability, and easy integration with the Internet of Things (IoT) system. Quantitatively, this sensor is able to detect TVOC concentrations in the range of 20–1158 ppb, with a response time of less than 20 seconds in a small space. However, limitations are still found in terms of selectivity to certain types of compounds and the lack of studies evaluating the effect of room characteristics on detection performance. This study recommends further testing in various real-world conditions as well as the application of machine learning algorithms to improve the accuracy and adaptability of the CCS811-based wearable system in effectively detecting cigarette smoke

1. INTRODUCTION (STYLE TEMPLATE *HEADING 1*)

The issue that is the focus of the various journals reviewed in this paper is the increasing concern about the negative impacts of exposure to cigarette smoke, both for active and passive smokers. Tobacco exposure is a major modern epidemic that has claimed more than eight million lives worldwide each year due to direct tobacco use and indirect exposure to cigarette smoke. These statistics show the extent of people affected by smoking and the need to lead effective measures to combat smoke pollution (Tai et al., 2020). This risk is increased when exposure occurs in closed spaces such as bedrooms, vehicles, or workspaces, where air circulation is limited and smoke particles can remain in the air for longer periods. According to research conducted, smoking activity can cause the concentration of hazardous compounds such as VOCs and PM2.5 indoors to increase significantly, even in a relatively short time (Al-Absi et al., 2021). In addition, research conducted found that indoor air quality greatly affects a person's respiratory health, especially for those who live or work in environments that do not have adequate ventilation (Seneviratne et al., 2017). Consequently, monitoring indoor air quality is essential to detect cigarette smoke and protect the occupants of the room.

Various smart devices that have the ability to monitor air quality in real time have emerged as a result of the advancement of Internet of Things (IoT) technology. The metal-oxide (MOX) based digital gas sensor called CCS811 is one of the technologies widely used in air monitoring systems because it is able to detect volatile organic compounds (VOCs) and equivalent carbon dioxide (eCO2). This sensor has also proven to be effective for use in indoor environments and can be incorporated into low-power systems (Al-Okby et al., 2024). In addition, the inclusion of this sensor into the Internet of Things system allows for effective monitoring of environmental conditions. As previously stated in the study, the CCS811 sensor is very suitable for wearable devices, such as watches, because of its small size and low power consumption (Al-Absi et al., 2021). In addition, the trend of using wearable sensors in environmental and health monitoring has increased in recent years.

Many studies have investigated the ability of the CCS811 sensor to monitor air quality and detect air pollutants through the use of wearable devices (Al-Absi et al., 2021). (Al-Okby et al., 2024)However, most of these studies have focused only on sensor accuracy and the development of the overall monitoring system. Few studies have specifically investigated how room size affects cigarette smoke detection time, especially in the case of wearable applications such as watches . However, room size greatly affects the speed at which smoke particles and VOCs spread in the air. By understanding the relationship between room size and detection time, wearable-based detection systems can be better tailored to the user's environment. Therefore, this study is essential to fill this gap and help develop more responsive and adaptive cigarette smoke monitoring systems.

Based on the background and results of initial studies on various studies, it can be concluded that there are still limitations in understanding the performance of the CCS811 sensor in detecting cigarette smoke. Therefore, the formulation of the problem raised in this study is: how is the performance of the CCS811 sensor in detecting cigarette smoke in various studies using a wearable approach and air quality monitoring? What technical factors affect the accuracy and efficiency of this sensor in real implementation?

The purpose of this article is to conduct a comprehensive analysis of the literature discussing the use of CCS811 sensors in wearable devices to detect air pollution, especially cigarette smoke. The evaluation focuses on aspects of accuracy, sensitivity, response time, and the challenges of implementing this sensor in various indoor environmental conditions.

2. LITERATURE REVIEW AND DISCUSSION

2.1. 2.1Previous Relevant Studies

Research on cigarette smoke detection via wearable devices continues to grow as a result of advances in sensor technology and the need to monitor air quality personally. Studies have shown that the use of inertial motion sensors and smart lighters is very effective in identifying smoking habits (Senyurek et al., 2019). However, environmental factors such as room size have not been taken into account in these studies. On the other hand, other studies have presented a systematic review of various wearable sensors to identify smoking habits in free-living conditions (Imtiaz et al., 2019). Although the CCS811 as a gas detection sensor has not been the main focus, this study describes various sensors that are commonly used. Research has also been carried out by developing a wearable sweat band to detect nicotine from the user's sweat, providing an alternative detection route other than air (Tai et al., 2020). However, this approach focuses more on body biomarkers than on environmental air quality. Several studies have concentrated on the development of a personal air quality monitoring system based on wearable devices and wireless VOC sensor nodes (Kuncoro et al., 2022)

(Salamone et al., 2021). However, these studies do not address the effect of room size on detection performance, although the approach is relevant for the use of the CCS811 or similar sensors.

If we discuss more deeply about cigarette smoke detection sensors, it has also been discussed in previous studies which show that specifically using the CCS811 sensor to detect VOC-based air quality in indoor environments (Al-Okby et al., 2024). This study shows that the CCS811 has quite good sensitivity in detecting changes in VOC levels due to human activity in closed spaces, so it is very relevant to be used as a basis for cigarette smoke detection studies in various room sizes. In addition, one study showed that user activity and environmental conditions such as room size and ventilation level affect indoor air quality (Urbina-Garcia et al., 2024). The direct measurement method was used in various spaces with different activities, and the results showed that small spaces with limited ventilation experienced faster accumulation of pollutants. This study provides an important basis for evaluating the performance of gas sensors such as the CCS811 in various environmental conditions. The study also used the CCS811 to detect VOC-based air quality in indoor spaces, and showed that this sensor has quite good sensitivity in detecting changes in VOC levels due to human activity, so it is very relevant to be used as a basis for cigarette smoke detection studies.

In addition, several other studies have enriched the understanding of smoke detection and air quality. One study developed an Internet of Things-based indoor air quality monitoring system using Raspberry Pi 4 as a data processing center. This system is designed to monitor air parameters such as CO_2 and VOCs in real-time and can be accessed via a local network, although it is not yet wearable (Faiazuddin et al., 2020). Another study utilized a machine learning approach to calibrate the CCS811 sensor and improve the accuracy of indoor gas detection, but has not been explicitly linked to cigarette smoke detection (Yu et al., 2023). One study proposed a wearable-based e-nose system specifically designed to detect the presence of cigarette smoke in indoor environments. This system combines several chemical sensors to efficiently identify smoke traces (Erdem et al., 2019). In the context of ventilation, there is a study that investigates the effect of ventilation rate on the concentration of volatile organic compounds (VOCs) in closed spaces, and emphasizes the importance of the physical conditions of the space on the distribution of pollutants (Yeoman et al., 2020). A different approach is shown by another study that developed an EMG (electromyography)-based wearable device to recognize hand gestures when smoking. Although it does not use gas sensors, this approach provides an important perspective in detecting smoking behavior (E. Sazonov, 2018). While not using gas sensors, the EMG-based wearable approach in the study offers a behavioral perspective that complements air quality-based detection systems. By combining physical monitoring of smoking activity with chemical detection of pollutants, future wearable systems have the potential to be more comprehensive and responsive to a variety of environmental conditions.

2.2. Comparison of Methods, Results, and Findings

This study was conducted using a systematic literature review approach to examine various studies that use CCS811 sensors in wearable systems to detect cigarette smoke. Articles were systematically collected through two main sources, namely Google Scholar and IEEE Xplore, using keywords such as "CCS811", "wearable sensor", "VOC detection", and "cigarette smoke". Inclusion criteria included publications published in the last ten years, explicitly mentioning the use of CCS811 sensors, and relevant to the context of cigarette smoke detection, air quality monitoring, or IoT-based wearable applications. Articles that only discussed the sensor in general, did not mention CCS811 technically, or were not relevant to the study objectives were eliminated from the review process. Based on these criteria, 18 scientific articles were obtained which were then analyzed quantitatively in this review.

In reviewing the methods used by various studies, there are differences in approach between laboratory experiments, environmental simulations, and systematic review studies. Several of these previous studies have demonstrated the use of experimental methods to track sensor responses to smoking activity or biomarkers through direct testing on individuals or wearable devices (Tai et al., 2020), (Senyurek et al., 2019). On the other hand, several systematic studies have been conducted to identify trends in the use of wearable sensors in health and environmental monitoring (Imtiaz et al., 2019), (Salamone et al., 2021b). These studies discuss further developments in sensor technology, including evaluation of accuracy, reliability, and potential integration with Internet of Things (IoT) systems. Several studies focused on the development and testing of VOC sensor-based monitoring systems, including the CCS811 (Al-Okby et al., 2024), (Kuncoro et al., 2022). The systems developed showed effectiveness in detecting changes in air quality in real time, although with different scopes—one focused on a wireless system, while the other specifically used the CCS811 sensor in an indoor simulation.

To demonstrate the use of the CCS811 sensor in a wearable system, an air quality monitoring prototype was built in a study (Imtiaz et al., 2019). The system uses the CCS811 sensor to identify volatile organic compounds (VOCs) and equivalent carbon dioxide (eCO2), which are then sent to an Android device via the HC-05 Bluetooth module. In this procedure, the Arduino Nano microcontroller is used as the main data processor. The block diagram of the system is shown in Figure 1. Due to its small size and low power consumption, the CCS811 sensor is a perfect choice for wearable devices. This structure shows that this sensor can be well integrated into a portable monitoring system.

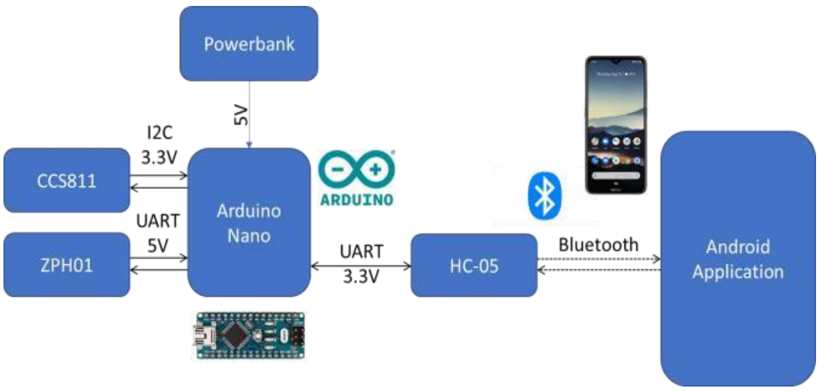

Figure 1. Block diagram of a wearable system based on CCS811 sensor, Arduino, and Bluetooth HC-05 for personal air quality monitoring. (Source: Géczy et al., 2022)

Figure 1 illustrates the structure of a wearable system that efficiently integrates the CCS811 sensor in personal air quality monitoring. This integration capability strengthens the relevance of the sensor in various environmental conditions.

One study adds an important dimension to the influence of room size and human activity on indoor pollutant concentrations (Urbina-Garcia et al., 2024). The direct measurement methodology used across a range of room sizes provides a useful empirical picture for understanding how physical environmental parameters affect the detection performance of gas sensors. In general, studies have shown that sensor type, wearing position, pollutant type, and ambient environmental conditions influence how well wearable devices detect pollutants. However, only a small number of studies have explicitly tested the relationship between room size and smoke detection time, which is an important issue that needs to be addressed in future studies.

Therefore, it is important to more systematically evaluate how the room design can affect the performance of gas sensors in wearable devices as early detection systems for cigarette smoke. One study developed and tested a wearable device based on the CCS811 sensor worn directly by the user (Imtiaz et al., 2019). This device allows real-time personal air quality monitoring in both laboratory and public environments. Figure 2 shows the implementation of the system in the form of a device worn on the user's arm. These findings support the potential use of the CCS811 sensor in the form of a smartwatch or similar wearable device to monitor cigarette smoke exposure in closed spaces.

Figure 2. Wearable device based on CCS811 sensor worn on the user's arm for personal air quality monitoring. (Source: Géczy et al., 2022)

As shown in Figure 2, the CCS811-based wearable device can be effectively used and is feasible for further development in the field of personal air quality monitoring.

The study that has been conducted (Alhadawiah et al., 2025) specifically describes to test the performance of the CCS811 sensor in identifying the total VOC (TVOC) concentration from the exhaled air of smokers and non-smokers. The results show that the CCS811 is able to distinguish between the two with an average reading of 78 ppb for smokers, 39 ppb for non-smokers, and 4 ppb for clean air, and the identification accuracy reaches >90%. The VOC measurement range in smoker samples ranges from 61–96 ppb, indicating consistent detection below 100 ppb in the context of real cigarette smoke. As a comparison, the study (Rudavskyi et al., 2024) used the CCS811 in an indoor experiment and reported VOC detection from 20 to 140 ppb, especially after activities such as spraying perfume, with a daily calibration method. Both studies show that the CCS811 has quite high accuracy in detecting changes in VOC levels in real environments and in wearable applications. However, the effectiveness of sensor accuracy is still influenced by the type of dominant VOC compound and the calibration technique applied.

The CCS811 sensor shows a high level of sensitivity to volatile compounds contained in cigarette smoke, especially formaldehyde (CH_2O) and ethanol (C_2H_5OH). Based on research (Alhadawiah et al., 2025), CCS811 provides a reading response to ethanol of 0–1022 ppb and to formaldehyde of 3–1158 ppb, with an average reading on CH_2O reaching 1156 ppb and a relative error rate of <50%. This shows that CCS811 is very sensitive to the main VOC compounds in cigarette smoke. As a comparison, (Yurko et al., 2019) evaluating the sensitivity of CCS811 to BTEX compounds and finding that CCS811 has the highest sensitivity to benzene, with a slope of 0.8959, much greater than the SGP30 (0.2668) and BME680 (−0.0211) sensors, although its sensitivity decreases to other compounds such as toluene. In the study (Yurko et al., 2019), the sensitivity of the CCS811 sensor to benzene was expressed in the form of a calibration slope of 0.8959, which indicates the change in sensor output to an increase in gas concentration in ppb units. Although not explicitly presenting data in the form of ppb ranges as in the study (Alhadawiah et al., 2025), the slope value mathematically represents the level of sensor response to each increase in ppb units of benzene compound, so it remains relevant as a measure of sensitivity based on gas concentration. Thus, the CCS811 is proven to be sensitive enough for cigarette smoke detection applications containing VOC compounds such as formaldehyde, ethanol, and benzene, provided that it is used with adequate calibration and under controlled environmental conditions.

Table 1. Analysis of CCS811 Sensor Experimental Study Based on Accuracy, Sensitivity, Detection Time, and Space Size

No	Article	Focus	Quantitative Data	Key Findings
1	Alhadawiah et al. (2025)	Accuracy, Sensitivity, Detection Time	- Average TVOC smoker: 78 ppb - Non-smoker: 39 ppb, clean air: 4 ppb - Response to ethanol: 0–1022 ppb, formaldehyde: 3–1158 ppb - Maximum detection time of VOC: <20 seconds	- CCS811 distinguishes smokers and non-smokers with >90% accuracy - Highly sensitive to CH_2O and C_2H_5OH - Suitable for small spaces and rapid detection
2	Rudavskyi et al. (2024)	Accuracy, Space Size, Detection Time	- VOC increases from 20 to 140 ppb post activity - Increase time: 3–5 minutes depending on space	- CCS811 is responsive to human activity indoors - Effectiveness depends on ventilation and room size
3	Yurko et al. (2019)	Sensitivity to Benzene	- Response slope of CCS811 to benzene: 0.8959 (vs SGP30: 0.2668, BME680: −0.0211)	- CCS811 has the highest sensitivity to benzene - Slope comes from the regression relationship against ppb, valid as a sensitivity parameter
4	Urbina-Garcia et al. (2024)	Room Size	- Small room: 12 m², VOC increases rapidly in 3–5 minutes - Large room: 30–40 m², slower increase	- Small space allows higher VOC accumulation in a short time - Relevant for testing CCS811 in confined spaces

Next is the detection time of the CCS811 sensor which is very influential in the context of wearables because it shows how quickly the system responds to the presence of pollutants such as cigarette smoke. The study (Alhadawiah et al., 2025) showed that the CCS811 provided an initial response to ethanol compounds in <20 seconds, with a maximum reading of 1022 ppb reached at the 20th second of the total test for 100 seconds. For formaldehyde, the maximum response occurred even faster, namely in the range of 10-15 seconds. These results indicate that the CCS811 has a fast detection time for volatile compounds in cigarette smoke. As a comparison, the study (Rudavskyi et al., 2024) also showed a VOC detection response by the CCS811 that appeared within minutes after activities such as the use of perfume in a closed room, with measured concentrations increasing from 20 ppb to more than 100 ppb within 3-5 minutes, depending on the room ventilation. This comparison shows that in controlled scenarios such as closed chambers or wearables that detect breath directly, the CCS811 can provide very fast detection in seconds, while in open spaces the detection time tends to be longer due to the influence of particle spread and ventilation. Therefore, the CCS811 is suitable for use in wearable systems that require real-time or near real-time cigarette smoke detection.

The dispersion of smoke particles and VOC compounds is also affected by the size of the room, which has a direct impact on the time and accuracy of gas sensors such as the CCS811. The study (Urbina-Garcia et al., 2024) measured air quality in rooms of 12 m2 and 30–40 m2 with various activities and different types of ventilation. The results showed that small rooms with limited ventilation experienced a significant increase in VOC concentrations within 3 to 5 minutes, while large rooms took longer to reach the same concentration level. This suggests that the rate of VOC accumulation is affected by the size of the room, which in turn affects the detection time of the sensor. Although this study did not use the CCS811 in the form of clothing, the results are still relevant because of the sensitivity of the CCS811 to variations in TVOC between 20 and 140 ppb. For comparison, the study (Alhadawiah et al.,

2025) used a small, closed acrylic room to simulate the room when measuring the exhaled air of a smoker. In this study, the CCS811 sensor showed a fast response (in less than 20 seconds) to changes in VOC levels, especially ethanol and formaldehyde, with readings up to 1158 ppb. The combination of these two studies shows that the CCS811 works best in small or enclosed spaces where concentrations are low. Therefore, when using wearable sensors to detect cigarette smoke, it is important to consider the physical features of the room such as area and ventilation.

To strengthen the quantitative analysis of the performance of the CCS811 sensor in detecting VOC compounds, especially in the context of cigarette smoke, the author conducted a literature study by comparing several previous studies. The following table presents a summary of the comparison of the four main articles used as references, to show the consistency of data and the validity of the use of the CCS811 sensor in wearable applications for real-time cigarette smoke monitoring.

2.3. Current Research Trends Analysis

Research trends in the field of sensor-based air quality monitoring show a growing trend towards the integration of miniaturization, energy efficiency, and real-time data connectivity. Wearable devices with gas sensors such as the CCS811 are becoming increasingly popular due to their compact size, low power consumption, and ability to measure volatile organic compounds that are closely related to cigarette smoke pollution. Several recent studies have also begun to highlight the importance of device adaptation to specific environments, such as rooms with limited ventilation or high activity levels that affect pollutant accumulation. However, despite the increasing trend of wearable sensors, very few studies have linked room characteristics, especially room size, to the response time or detection accuracy of gas sensors. This suggests important opportunities for further research in this field.

On the other hand, the integration of technologies such as the Internet of Things (IoT), machine learning, and edge computing is becoming mainstream in the development of sensor-based air quality monitoring systems. By implementing algorithms that are able to learn detection patterns in different room conditions, wearable systems can be enhanced to be more adaptive and responsive to real-world environmental conditions. Increasing advances in the field of sensor-based air quality monitoring indicate that miniaturization, energy efficiency, and real-time data connectivity are the way forward. Due to their small size, low power consumption, and ability to measure volatile organic compounds that are closely related to cigarette smoke pollution, wearable devices with gas sensors such as the CCS811 are gaining popularity.

Adaptation of devices to specific environments, such as rooms with limited ventilation or high activity levels that cause pollutant accumulation, has received greater attention in recent studies. Despite the increasing trend of wearable sensors, there are few studies that link room characteristics, especially room size, to response time or gas detection accuracy. This suggests that there is significant scope for further research in this area. In contrast, the development of sensor-based air quality monitoring systems has focused on technologies such as the Internet of Things (IoT), machine learning, and edge computing. By using algorithms that can learn detection patterns in various room conditions, wearable systems can become more responsive and adaptive to real-world environmental conditions. Table 1 below summarizes previous studies on the use of wearable gas sensor-based devices to detect cigarette smoke. This summary shows that despite various approaches, there are few studies that explicitly evaluate the effect of room size on smoke detection time.

Table 2 provides a summary of the methods, focus, strengths, and limitations of each of the studies analyzed. This summary shows that most studies still focus on the technical aspects of sensor and clothing prototype construction, while environmental variables such as room size and ventilation rate have not been fully considered. This suggests that there are still gaps in research that can be improved, especially if spatial factors are included in wearable-based air quality monitoring systems. Furthermore, despite the various approaches and sensors used, creating a more accurate and responsive system is still a challenge. The system must be able to adapt to the dynamics of the enclosed space.

Table 2. Table 2 Summary of Studies Related to Cigarette Smoke Detection and Wearable Sensors

Writer	Method	Research Focus	Excess	Limitations
Şenyürek et al. (2019)	Wearable experiment + lighter	Detect smoking habits	High accuracy	No discussion of room size
Imtiaz et al. (2019)	Systematic review	Wearable sensor for smoking	Wide coverage	Not focused on CCS811
Su et al. (2020)	Wearable sweat sensor experiment	Nicotine detection from sweat	Innovative biomarkers	No direct smoke detection
Kuncoro et al. (2022)	Development of wireless VOC sensors	Indoor air quality monitoring	Suitable for wearable	No discussion of room size
Frampton et al. (2021)	Systematic review	Wearable for environmental monitoring	Comprehensive review	Not specific to cigarette smoke
Al-Okby et al. (2019)	CCS811 sensor experiment	Indoor VOC detection	CCS811 Specification	Not tested with varying room sizes
Urbina-Garcia et al. (2024)	Direct measurement of various spaces	The influence of room size and ventilation	Empirical and applicable	No wearable sensor test
Géczy et al. (2022)	CCS811 wearable prototype	Personal air quality monitoring	Visual implementation of wearable	Not tested in different rooms
Tai et al. (2020)	Meta-analysis	Cigarette smoke exposure of non-smokers	Strong epidemiological basis	Does not discuss technical aspects of sensors
Al-Absi et al. (2021)	Systematic review	Wearable for environmental monitoring	Technology trends overview	Not specific to cigarette smoke
Sazonov et al. (2018)	Wearable EMG experiment	Hand movement detection while smoking	Specific behavior detection	Do not use gas sensor
Mannino et al. (2019)	Wearable experiment + e-nose sensor	Cigarette smoke detection with e-nose	Combined chemical sensors	No CCS811 test
Zhou et al. (2021)	IoT Prototype + CCS811	Indoor air quality monitoring with IoT	Real-time data logging	Not wearable
Lee et al. (2020)	Experiment on the effect of ventilation	Effect of ventilation on VOC concentration	Relevant for room size	Do not use wearable sensors
Chen et al. (2023)	AI + CCS811 Development	CCS811 sensor calibration with machine learning	Improved accuracy	Not focused on cigarette smoke detection
Applied Sciences (2024)	CCS811 indoor experiment	CCS811 response to daily activities (perfume, diffuser)	Real-world evaluation with daily calibration	Don't compare with other sensors
Chemosensors (2019)	CCS811 lab experiment	Evaluation of CCS811 sensitivity to BTEX	Quantitative data & comparison between sensors	Low selectivity towards some VOCs
Alhadawiah et al. (2025)	CCS811 e-nose experiment	Respiratory air profiles of smokers and non-smokers	Accurate data in ppb, accuracy >90%	The size of the room is not explicitly stated.
Rudavskyi et al. (2024)	CCS811 indoor experiment	CCS811 response to human activity	VOC data variation (20–140 ppb), real response	No wearable or direct smoker test

Yurko et al. (2019)	Gas sensor comparison experiment	Evaluation of CCS811 sensitivity to benzene	Slope value 0.8959, high sensitivity	Does not provide direct ppb reading range

3. CONCLUSION AND RECOMMENDATIONS

Based on the review of nineteen relevant studies, including quantitative analysis of accuracy, sensitivity, detection time, and the effect of room size, it can be concluded that the CCS811 sensor has high potential in the development of wearable systems for detecting cigarette smoke through monitoring volatile organic compounds (VOCs). This sensor is not only efficient in terms of power consumption and physical size, but also shows promising performance in terms of real-time detection of air pollutant fluctuations in indoor environments.

In terms of accuracy, the CCS811 has been proven to be able to distinguish between smokers' and non-smokers' respiratory air samples well. A study by Alhadawiah et al. (2025) showed that this sensor produced an average reading of 78 ppb in smoker samples and 39 ppb in non-smokers, with a classification accuracy of >90%. This value is supported by the findings of Rudavskyi et al. (2024) who reported a reading range of 20–140 ppb in human activity scenarios, indicating consistency of values in real environments.

In terms of sensitivity, CCS811 provides a significant response to major compounds in cigarette smoke, such as formaldehyde (CH_2O) and ethanol (C_2H_5OH), with maximum readings of 1158 ppb and 1022 ppb, respectively, and a fast response time of under 20 seconds. In addition, CCS811 shows high sensitivity to benzene with a slope value of 0.8959, superior to other sensors such as SGP30 and BME680, although the sensitivity to toluene and xylene is relatively low.

In terms of detection time, CCS811 shows a fast response in small or confined spaces, as demonstrated in both closed chamber-based studies and wearable experiments. The maximum response to VOC exposure can be achieved within 10–20 seconds, making it ideal for real-time monitoring systems. However, detection time tends to increase in large or well-ventilated spaces.

For the effect of room size, a combination of studies by Urbina-Garcia et al. (2024) and Rudavskyi et al. (2024) showed that small rooms (±12 m²) tend to accelerate VOC accumulation, resulting in higher readings and faster detection compared to large rooms (30–40 m²). While Alhadawiah et al. (2025) tested the CCS811 in a closed chamber, these conditions practically represent a small and limited environment, which supports the effectiveness of the sensor in detecting cigarette smoke exposure quickly.

Although the performance of this sensor is promising, several limitations are still found. The sensor's selectivity to certain types of VOCs is still limited, which can lead to biased results when used in environments with many non-smoking VOC sources. In addition, the accuracy of CCS811 readings is highly dependent on external calibration processes or the application of machine learning algorithms to reduce errors. The lack of studies that explicitly test CCS811 in various room sizes also hinders the validation of sensor performance in more complex real environments. Considering these advantages and disadvantages, it is recommended that further research focus on conducting systematic testing of the CCS811 sensor in various indoor room sizes to detect cigarette smoke, to determine how quickly the sensor responds to exposure in the context of active and passive smokers, developing an automatic calibration system and implementing machine learning based on VOC data from cigarette smoke, to improve the accuracy of readings against variations in smoke types and intensities, cross-validating the CCS811 sensor with other gas sensors or laboratory reference instruments in the context of direct cigarette smoke measurement, to strengthen accuracy and sensitivity, and finally designing and testing a CCS811-based wearable prototype worn on the wrist in a real smoky room, such as a cafe, home, or smoking room, to measure the reliability of detection in real scenarios.

A more comprehensive and standardized evaluation will strengthen the position of the CCS811 as the main sensor in a wearable cigarette smoke detection system, thus supporting efforts to prevent smoke exposure for passive smokers as well as a tool to modify the behavior of active smokers.

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